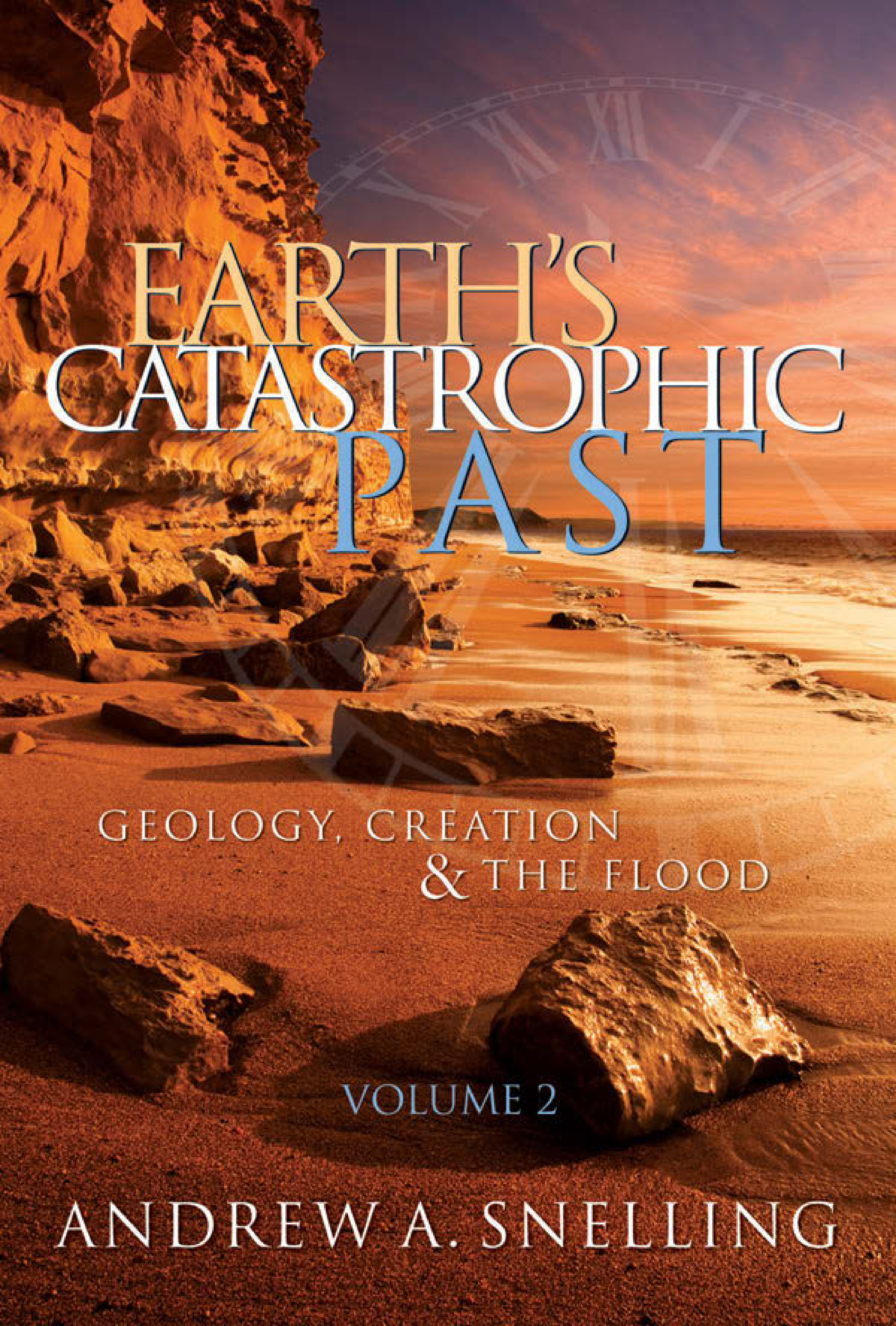

EARTH'S CATASTROPHIC PAST
GEOLOGY, CREATION & THE FLOOD
VOLUME 2
ANDREW A. SNELLING

EARTH'S CATASTROPHIC PAST

GEOLOGY, CREATION & THE FLOOD

VOLUME 2

EARTH'S CATASTROPHIC PAST

GEOLOGY, CREATION & THE FLOOD

VOLUME 2

ANDREW A. SNELLING

Master Books®
A Division of New Leaf Publishing Group
www.masterbooks.net

answersingenesis

EARTH'S CATASTROPHIC PAST
GEOLOGY, CREATION & THE FLOOD
VOLUME 2

by Andrew A. Snelling

Third printing: October 2014

Master Books®, P.O. Box 726, Green Forest, AR 72638

Master Books® is a division of the New Leaf Publishing Group, Inc.

Answers In Genesis, 2800 Bullittsburg Church Rd., Petersburg, KY 41080

ISBN: 978-0-89051-873-1
Library of Congress Catalog Number: 2009922120

Please consider requesting that a copy of this volume be purchased by your local library system.

Printed in the United States of America

CONTENTS

Volume 2. Geological Implications of the Biblical Record for a Biblical Geologic Model for Earth History

Section VI. Geological Implications of the Biblical Geologic Model for Earth History

SECTION VII. A BIBLICAL GEOLOGIC MODEL OF EARTH HISTORY

Section VIII. Problems in Biblical Geology Solved —Radioactive Dating and Geochronology

Section IX. Contradictions in Geochronology—Support for Biblical Geology

Section X. Problems For Biblical Geology Solved—Formations Implying Slow Deposition

Concluding Challenges

Section VI

Geological Implications of the Biblical Geologic Model for Earth History

61

Geological Implications of the Biblical record

The task before us now is to construct a biblical geologic model of earth history, taking the data of the geologic record and placing them within the scriptural framework for earth history. To achieve this goal, extreme care must be taken not to either force scientific details from the Scriptures or to manipulate the geological data to achieve agreement between the geologic and biblical records. The Bible was not written in scientific language and terminology from the standpoint of modern scientific endeavor to provide a science textbook. Instead, it was written under God's direction as His communication to common people, revealing in an understandable manner His provision for and dealings with man. Of course, this in no way implies that the early chapters of Genesis are couched in sub-scientific, conceptual language for the benefit of supposedly primitive people. Instead, the record indicates that Adam and his descendants were anything but primitive, with an ability and capacity to understand God's works in creation, and to apply that knowledge and understanding technologically. God's communication through the Scriptures was also not just intended for the children of Israel at the time of Moses and the immediate centuries that followed. It was intended to be timeless, communicating the truth to all people throughout history, including those of our modern scientific age. Furthermore, because God is all-knowing and infallible, His communication by and through the Scriptures, though not exhaustive in the details provided, must nonetheless be accurate and trustworthy when it touches on matters of science and history.

It should also be stressed that due care must be exercised in the levels of certainty and dogmatism attached to our understandings of the scientific information and implications that we might derive from the Scriptures. Thus, where the text of the Scriptures is clear and unambiguous in providing scientific and historical details, we have every reason to be dogmatic and assertive in applying those details in the construction of a biblical geologic model. We should not therefore be surprised when the geologic data are readily consistent with those details of the scriptural framework. However, it is abundantly clear that the Scriptures are far from exhaustive in the scientific and historical details provided, so there is always the temptation to fill in the "gaps" with inferences and suppositions. While this may be regarded as a legitimate process, such inferences and suppositions are to be held more tentatively and less dogmatically, and be subjected to more critical appraisal, particularly when applying them to the geologic data. There are definitely details and statements provided in the Scriptures that have clear implications of a scientific nature, and where that is the case we can usually be confident. However, a measure of caution is nonetheless warranted lest we read additional information into the text. Finally, in other places we endeavor to draw scientific inferences and suppositions from the text that may seem warranted to us, but are nonetheless speculative and open to challenge.

With these considerations and caveats in mind, attention is now directed to the stated task. First, it is important to highlight the geological implications that can be drawn from the biblical record and to confirm that the geologic data are consistent with them. Then, it is important to survey the available evidence that the geologic data, rightly understood, are in fact more consistent with the scriptural framework of earth history than the uniformitarian framework of the modern geological synthesis. Having satisfied ourselves, and thus established the superior explanation and consistency of the geologic data within the biblical framework of earth history, we are then well-positioned to construct a truly biblical geologic model and to elaborate upon how the geologic data, and the patterns and trends found in the geologic column, fit into this biblical geologic model of earth history.

Some geological implications have already been drawn from the biblical text in our earlier considerations of the relevant passages of Scripture, but it is instructive to gather them together here, along with other geological implications, so that their collective import may be established. Thus, the following geological implications would appear to be legitimately inferred from the biblical record of creation and the Flood.

The Uniqueness of the Creation Week

The Bible repeatedly emphasizes that, during this first week of the earth's history, God's supernatural acts of creation were responsible for bringing into existence the earth and all its basic features, such as the land and the oceans, all forms of life upon the earth, the rest of the solar system, and the stars and galaxies in outer space beyond. This would not have meant the total suspension of the rule of so-called natural laws. Those laws were also instituted by God during His supernatural creative acts for the ongoing operation and maintenance of what He had created, so it could be argued that any distinction may be somewhat arbitrary. Nevertheless, a fundamental difference between supernatural and so-called natural processes is the rates at which they occur, though this should not be misconstrued to infer that supernatural processes are only natural processes that operated at almost infinitely rapid rates. What is clear from the biblical record is that the perception of a human observer on the earth during the Creation Week would have been that countless millions of years of earth history at uniformitarian rates had been compressed into six days of normal human existence.

Furthermore, while the implication is that a different regime of geological processes was operating on the earth during those supernatural acts of creation, there was nevertheless continuity in the operation of those geological processes between what could be termed supernatural and natural rates. An example, by way of illustration, will help to avoid any misunderstanding or misconception.

When we read that, on the third day of the Creation Week, God commanded the dry land to appear, the implication is that earth movements occurred rapidly and the waters also rapidly drained from off the emerging land surface, thus undoubtedly causing extremely rapid erosion. However, that erosion did not simply cease when the process of formation of the dry land had occurred. Instead, erosion rates decreased rapidly to rates that would be considered normal under today's conditions. Thus, while a different regime was in operation while the dry land was rapidly being formed, there was nonetheless continuity between the erosion processes then operating, and those operating subsequently. It could almost be argued that to a human observer the erosion rates during this supernatural formation of the land were *catastrophic*. Nevertheless, because the Creation Week was a unique period in the earth's history, we should expect that some of the features and strata of the rock record produced in that period should likewise be unique, distinctive from features and strata of the subsequent rock record.

Enormous Geological Work Accomplished During the Creation Week

The implication in the biblical record is that by the end of the Creation Week there was one interconnected supercontinental landmass, fully vegetated and populated with animals and man, surrounded by seas. We are specifically told that, in the initial act of creation on Day One, the earth was created covered in water, and by inference there was a rocky earth underneath the waters, presumably already with its internal structure developed or developing. Whatever was then happening underneath the waters through the remainder of Day One and through Day Two, we are next told that on the third day of the Creation Week, God made the dry land to appear from under the globe-encircling waters. This implies an enormous amount of geological work was then accomplished as the waters were pushed aside by great earth movements that buckled the earlier-formed crust and uplifted its rock strata above the waters. As the uplift of this great orogeny occurred, the waters being pushed aside would have to drain off the newly emerging land surface, so this process was inevitably accompanied by a great amount of catastrophic erosion, transport of sediments, and then deposition of sediments as the waters flowed down into the new ocean basins.

Since these geological processes occurred at unprecedented rates with such profound results in such a brief period of time, the rock strata produced by these geological processes cannot be understood in terms of presently observed rates for these processes. Thus, not only would the features and strata of the rock record produced during this unique event defy explanation within the uniformitarian philosophical framework, they would not have their counterparts in the modern world, because the geological processes that produced them are no longer operating at the scale and intensity at which they operated during Creation Week.

It is also an implication from the biblical record that once the dry land surface was established, it stabilized sufficiently to be vegetated. Furthermore, once the major erosion that had shaped the land surface was completed, it tapered off rapidly to minimal levels. This would not have precluded continued geologic activity in the ocean basins, although even there a measure of stability would have been achieved by Day Five, when the ocean waters were populated with all manner of living creatures requiring a stable environment in which to live. Thus, it is likely that geological processes subsided rapidly in the latter part of the Creation Week to levels and rates more typical of geological processes as they occur today.

A Stable Pre-Flood World

The pre-Flood world was, by implication from the text of Scripture, tectonically quiet and geologically stable, living conditions being ideal for the animals and man on the land surface, and for the fish and other sea creatures in the ocean basins. However, the implication from 2 Peter 3:6-7 is that the pre-Flood world, "the world that then was," in contrast to "the heavens and the earth which are now," was different from the world that exists today. Thus, we could expect that the features and strata of the pre-Flood rock record are different from the rock record produced by the Flood, with features even different from what is being produced by geological processes operating today. It is even unclear whether uniformitarian rates of geological processes, or even exactly the same geological processes, were operating during the pre-Flood period as those operating today. Indeed, judging from the large numbers of plants and animals that have become extinct, there was obviously a far greater biodiversity in the pre-Flood world. Conditions then must have been more conducive for those plants and animals, perhaps even with environments that are no longer inhabited today in the same way as they were in the pre-Flood world.

Tremendous Erosion from the Rainfall During the Early Stage of the Flood

Speaking metaphorically to make the description more graphic, the Scriptures report that at the beginning of the Flood the "windows (or floodgates) were opened." In other words, great quantities of water poured down onto the earth from the skies, not in the form of gentle drizzle, but as a torrential global downpour that continued without ceasing for forty days and nights. The impact on the earth's surface of this intense pounding rain would first be prodigious rock and soil erosion, easily visualized from the effects of localized torrential downpours experienced in today's world. Falling raindrops, observed in today's torrential downpours, are a very significant factor in the initiation of erosion, as soil and rock particles are dislodged from the ground surface. As the raindrops then coalesce on the ground surface and the water begins to flow from higher to lower elevations, the loosened soil and rock particles are carried with the water. This sedimentary load, already contained in these surface run-off waters, then aids the further erosive action of the run-off by the mechanisms of turbulence and attrition as it flows *en masse* across the ground surface, or is channelized to form rivulets. The water then runs finally to the nearest stream, but in the process deepens the channels it flows through by further erosion. Thus, great gullies are carved out, often to great depths, even in a single storm today. However, the intensity of this unique, global, torrential downpour in the first forty days and nights of the Flood has to be visualized as somewhat analogous to the effects of the most intense localized torrential downpour today multiplied on a global scale. Under such conditions, the combined processes of raindrop impact, sheet erosion, and gully erosion would have catastrophically excavated and transported prodigious quantities of earth and rock, even if no other agencies had been available for sediment transport.

Clouds Not the Major Source of the Flood Rainfall and Waters

Intense, global, torrential rainfall continuing for forty days, as described in the biblical record, would have required a completely different mechanism, and an additional water source, for its production than is available for the localized intense storms experienced today. This is evident from the fact that if all the water in our present atmosphere were to be precipitated *en masse*, it would barely suffice to cover the ground to an average depth of less than 2 inches (5 centimeters). Furthermore, the normal process of evaporation could not have been effective during this intense, global, torrential rainfall at the beginning of the Flood, because the atmosphere immediately above the earth's surface would have been already at saturation level. Thus, the normal hydrologic cycle would not have been capable of supplying the tremendous amounts of water required to maintain this intense, global, torrential rainfall. The implication, therefore, is that there had to be an additional source of water, and a transfer mechanism to the atmosphere of an entirely different type and order of magnitude than now exists.

Some have suggested that the climatology and meteorology of the pre-Flood world were much different from today's world.[1] This is based on the contention that some form of water vapor canopy existed above the atmosphere in the pre-Flood world, because we are told in the biblical record that on the second day of the Creation Week some of the primeval ocean waters of Day One were placed above the firmament, also created on that day. Thus, it is argued, these "waters above" could have been the major source of the torrential, global rainfall for the first forty days and nights of the Flood, the expression "the windows of heaven" referring to the

1 J. C. Whitcomb and H. M. Morris, 1961, *The Genesis Flood: The Biblical Record and its Scientific Implications,* Philadelphia, PA: The Presbyterian and Reformed Publishing Company.

catastrophic collapse of this water vapor canopy, which precipitated as sustained, heavy rainfall. However, the Hebrew words for the "windows [or sluice-gates] of heaven" do not seem to imply anything about the source of the water for the rainfall. Furthermore, given that the firmament or "stretched-out thinness" more likely refers to interstellar space than to the earth's atmosphere, the "waters above" referred to in Genesis 1:7 would have been far removed from the earth at that point. If so, these "waters above" would not be referring to a water vapor canopy immediately above the earth's atmosphere. Apart from the issue of the identity and location of the "waters above," scientific considerations place severe restrictions on the amount of water vapor that could have been maintained in position above the atmosphere according to known physical laws. One consideration is that much more than a few inches of liquid water equivalent in a vapor canopy appears to lead to a runaway greenhouse effect.[2] A second is that the amount of latent heat released from the condensation of water vapor limits the amount of condensation that can occur during the Flood without boiling the oceans and killing all the life on earth because of the high temperatures required to radiate the latent heat to space at a sufficient rate. These considerations imply that even if a water vapor canopy did exist above the atmosphere, it could not have contained sufficient water vapor to have sustained forty days and nights of intense, global, torrential rainfall.[2]

There is, however, another source for the Flood waters described in the biblical record. Genesis 7:11 states that "all the fountains of the great deep [were] broken up" at the initiation of the Flood. The primary meaning of the Hebrew words translated "great deep" is undoubtedly the waters of the ocean depths, so these fountains would have primarily been springs on the pre-Flood ocean floor. Thus, the breaking up of them would have been the rupturing of the ocean floor in a vast upheaval. However, because a secondary meaning of the expression is simply "subterranean waters," water stored deep in the supercontinental crustal landmass of the pre-Flood world could possibly also be included. Thus, the breaking up at the commencement of the Flood might also refer to the rupturing of this supercontinental landmass to release these subterranean waters.

We are not told what triggered this upheaval that broke up all these fountains on the ocean floor and possibly also on land. It is conceivable that pressure built up inside the earth due to internal heat, so once the first fountain had cracked open, the water surging through would immediately weaken the adjacent crust, whether continental or oceanic crust, resulting in a rapid worldwide chain reaction that cleaved open "all the fountains of the great deep" right around the globe. If heat was involved as the driving force, then it is likely that much of the water was released as steam. This would have burst from this global network of cleaved fountains as jets, catapulting it high into the atmosphere, where it condensed and

2 D. E. Rush and L. Vardiman, 1990, Pre-Flood vapor canopy radiative temperature profiles, *Proceedings of the Second International Conference on Creationism*, ed. R.E. Walsh and C.L. Brooks, Pittsburgh, PA, 231-245.

fell as rain. Indeed, whereas the intense, global, torrential rainfall is described in the text as falling for forty days and nights, the fountains of the great deep were open for 150 days. Thus, the implication is that these fountains of the great deep were the major source of water not only for the Flood rainfall, but for the Flood event itself.

Enlarged Ocean Basins as a Result of the Flood?

Given the duration of the intense, global, torrential rainfall at the beginning of the Flood, the mass of waters that fell to the earth's surface could hardly have been elevated back up into the atmosphere after the Flood, because that quantity of water is simply not there in the atmosphere today. Similarly, if a large volume of subterranean waters actually were released through the fountains of the great deep during the first 150 days of the Flood, these also could not all be returned to the inside of the earth at the end of the Flood. Only a small portion of these waters became trapped in the sediments, and thus in the strata of the earth's crust, formed during the Flood.

Thus, the overall result of the Flood was that most of the Flood waters remained on the earth. Whether or not the volume of the ocean basins was greater after the Flood than before depends on the amount of new water added to the earth's surface. If some of the water that emerged from the fountains of the great deep was simply water from the pre-Flood ocean that flashed to superheated steam as it came into contact with molten rock rising to fill the gap as ocean plates pulled apart at mid-ocean ridges and emerged as supersonic steam jets, which in turn entrained more liquid water from the ocean to produce the forty days and nights of heavy rainfall, then perhaps little new subterranean water from the earth's interior was actually added to the earth's surface during the Flood. In this case, most of the water of the Flood was water that had been present in the pre-Flood ocean basin. On the other hand, it is likely that at least some new water was added to the earth's surface, and this implies that at least some of the waters of our present oceans entered at the time of the Flood. This, in turn, implies three possibilities: either the proportion of land area to water area was larger before the Flood; the ocean basins were shallower before the Flood, in contrast to their depth today; or there was a combination of more land area and shallower ocean basins. In any case, there is much evidence now that today's ocean basins are much younger features on the earth's surface than the continents, with only a relatively thin veneer of sediments on the ocean floors. This is consistent with great tectonic movements and isostatic adjustments having taken place toward the end of the Flood, in order for land to appear again from under the Flood waters and to form ocean basins sufficient to contain them.

This seems to be implied in the poetic reflection about the Flood in Psalm 104:5-9, where we read: "Who laid the foundations of the earth, that it should not be removed for ever. Thou coveredst it with the deep as with a garment: the waters stood above the mountains. At thy rebuke they fled; at the voice of thy thunder they hasted away. They go up by the mountains: they go down by the valleys unto the place where thou hast founded them. Thou hast set a bound that they may not pass over; that they turn not again to cover the earth." This passage of Scripture refers to the Flood, rather than to the events of Days One to Three of the Creation Week, because the last verse refers to God's promise that a globe-covering Flood would never again occur on the earth (Genesis 9:11). Also, to underline the implication of these verses to the tectonics of the Flood, a literal translation of Psalm 104:8 would be "the mountains rose, the valleys sank down." Thus, the biblical record makes it abundantly plain that the processes responsible for the Flood, and associated with it, were of immense geologic potency, and therefore caused profound geological changes.

Volcanic and Seismic Upheavals During the Flood

The statement in Genesis 7:11, that "all the fountains of the great deep [were] broken up," appears to suggest that the cleaving open of the earth not only involved the release of water and steam, but also the release of magmas (molten rock) through great volcanic explosions and eruptions. These would have been triggered by the cleaving open of the earth's crust, and undoubtedly would have also contributed to the initiation of that process. Not only would some water have been released from solution in the magmas themselves, but where the molten rock came in contact with cold ocean water, vast quantities of supercritical steam would be generated. The energy of this steam, given the temperature of the molten rock and pressure at the ocean bottom, is sufficient to accelerate it to supersonic velocity as it rises toward the ocean surface. It also has sufficient energy to entrain vast amounts of liquid water and carry it into the stratosphere, where it falls to produce the intense, global, torrential rainfall. Similarly, where cleaving of the earth's crust occurred on land, there would also have been volcanic eruptions accompanied by vast outpourings of lavas. Furthermore, it is entirely reasonable to make comparisons with the phenomena associated with volcanism today, and therefore to expect that there must have also been great earthquakes and tsunamis (popularly known as tidal waves) generated by this explosive volcanic activity around the globe during the Flood. The intensity and global scale of these eruptions, earthquakes, and tsunamis would have been catastrophic, wreaking havoc and thus accomplishing great amounts of geologic work directly, as well as augmenting the destructive effects of the Flood waters themselves.

Unprecedented Sedimentary Activity Again During the Flood

The biblical record of the Flood clearly implies that enormous quantities of earth and rock must have been excavated by the Flood waters to produce vast quantities of sediments, that were then transported and deposited in thick sequences of sedimentary strata. Unprecedented sedimentary activity, compared to the slow and gradual sedimentation observed today, had occurred already on Day Three of the Creation Week due to the catastrophic erosion caused by the retreating ocean waters as earth movements uplifted the earth's crust to form the dry land. The same factors that had operated during Creation Week, catastrophic erosion and sedimentation, would have been also operating during the Flood. However, many additional factors would have contributed during the Flood to the devastation and reshaping of the earth's surface and the catastrophic deposition of new sedimentary strata—in particular, the driving rains and the raging streams resulting from them, the volcanic eruptions, and accompanying earthquakes and powerful tsunamis, resulting from the cleaving open of the earth's crust. Furthermore, later in the Flood there would have been waves and other currents generated by tectonic processes again uplifting land surfaces and deepening the ocean basins.

Additionally, there would have perhaps been many other factors and their effects in operation during this unique catastrophic event that we cannot now know or study, because in today's slow and gradual regime of geological processes we cannot study the catastrophic geological processes that would have been uniquely in operation on a global scale during the Flood. Apart from the profoundly catastrophic geologic activity and shaping of the earth and its surface during the early part of Creation Week, there could never have been such extensive erosion of soil and rock strata on a global scale as during the Flood. The materials that were eroded would, of course, have formed prodigious quantities of sediments that eventually had to be re-deposited as new sedimentary rock strata in thick sequences on a vast scale. This is exactly what we find everywhere today in huge sedimentary basins that blanket the earth's surface.

Ideal Conditions for the Formation of Fossils During the Flood

It would seem that biodiversity in the pre-Flood world was much richer and more varied than in our present world. This can be inferred from the great numbers and varieties of flora and fauna found fossilized in the geologic record that have become extinct. This inference is supported by evidences that the pre-Flood climate was very different and more conducive globally to such a rich and varied biodiversity. Indeed, the fossil record provides evidence of what were probably whole ecosystems that are no longer found in today's world. (There will be more discussion of these details later.)

In any case, the stated purpose of the Flood was to destroy all life on the earth, that is, at least on the dry land ("And all flesh died that moved upon the earth… All in whose nostrils was the breath of life, of all that was in the dry land, died," Genesis 7:21-22), except, of course, the passengers on the Ark. Thus, an incredible number of living creatures, as well as plants, were likely swept away by the Flood waters, and then trapped and eventually buried in the huge, moving masses of sediments under conditions that were eminently conducive to fossilization. Indeed, never before or since could there have been such favorable conditions for the formation of fossiliferous strata. The uplift of the dry land and its catastrophic erosion on Day Three of the Creation Week occurred before the plants had been created to vegetate that dry land, and well before the creation of the land animals and man on Day Six. Therefore, even though the devastating erosion on Day Three of the Creation Week had produced catastrophic sedimentation conducive to fossilization, no mass destruction and fossilization of life occurred then. This implication of the biblical record will be utilized later in a biblical geologic model of earth history consistent with what is found in the geologic record.

Uniformitarianism Also Undermined by the Flood

In view of the global nature of the Flood catastrophe and the magnitude of the tectonic, volcanic, geophysical, erosion, and sedimentation phenomena accompanying it, the Flood constituted a profound discontinuity in the normal operation of all geological processes. Any deposits formed before the Flood, even the rocks and strata formed catastrophically during the Creation Week, would almost certainly have been changed, or even severely altered, by the catastrophic hydrodynamic and tectonic forces unleashed during the Flood period. The fundamental conceptual principle that the conventional geological community uses to build its reconstruction of earth history is uniformitarianism, encapsulated in the maxim "the present is the key to the past." However valid it may be for the study of rocks and strata formed since the Flood, the implication of the biblical record is that it cannot be legitimately applied before that time, that is, to the Flood and Creation Week periods. The catastrophism of the Flood period is especially important when considering the so-called absolute geological chronometers which the conventional geologic community uses to interpret observational and geochemical data to assign vast ages to the various strata and to the earth itself.

62

The Renewed Recognition of Catastrophism

All these geological implications of the biblical record of the Flood are generally supported by, and are consistent with, the actual details preserved in the rock record. Almost all of the sedimentary rocks, which are the strata containing fossils and from which the conventional interpretation of the earth's history has been largely deduced, were laid down by moving water. This is obvious and universally accepted. Sedimentary rocks by definition are those that were originally deposited as layers of sediments, which are defined as "solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice, or that accumulates by other natural agents, such as chemical precipitation from solution or secretion by organisms, and that form in layers on the earth's surface at ordinary temperatures in a loose unconsolidated form; for example, sand, gravel, silt, mud, till, loess, alluvium. Strictly speaking, solid material that has settled down from a state of suspension in a liquid…material held in suspension in water or recently deposited from suspension."[1] Thus, the great masses of sediments that now make up the earth's sedimentary rocks must first have been eroded from previous locations, transported, and then deposited (perhaps even more than once). This is exactly what would be expected to occur in any flood, and would obviously have occurred on a uniquely grand scale during the Genesis Flood.

As noted earlier, by the end of the 17th century and throughout the 18th century it was generally accepted, almost without question, by scientists in the western world that not only had the biblical Flood been global, but it was the key element in the biblical framework of earth history, having been responsible for the major geologic formations of the earth. However, during the 19th century a complete revolution occurred, the catastrophic geology of the biblical Flood being abandoned for the slow and gradual geological processes of the uniformitarian philosophy for interpreting the formation of rock strata through the earth's history.

1 R. L. Bates and J. A. Jackson, ed., 1980, *Glossary of Geology*, second edition, Falls Church, VA: American Geological Institute, 566.

It was Scottish geologist James Hutton who is often regarded as the founder of modern geology. His work paved the way for the revolution in geological thinking that followed. In 1785 he communicated to the Royal Society of Edinburgh his *Theory of the Earth*, presenting what was regarded as "an irrefutable body of evidence to prove that the hills and mountains of the present day are far from being everlasting, but have themselves been sculptured by slow processes of erosion such as those now in operation."[2] Hutton also showed that the alluvial sediment continually being removed from the land by rivers is eventually deposited as sand and mud on the sea floor. He observed that the sedimentary rocks of the earth's crust bear all the hallmarks of having accumulated exactly like those now being deposited, so he insisted that the vast thicknesses of these older sedimentary rocks implied the operation of erosion and sedimentation throughout a period of time that could only be described as inconceivably long. Thus, he declared that "the present is the key to the past," that "the past history of our globe must be explained by what can be seen to be happening now."[3] Hutton expressed his faith in the orderliness of nature when he wrote, "No powers are to be employed that are not natural to the globe, no action to be admitted except those of which we know the principle."[4] He insisted that the ways and means of nature could be explained only by observation, and that the same processes and natural laws prevailed in the past as those we can now observe or infer from observations. So Hutton did not exclude temporary and local natural catastrophes, such as earthquakes or volcanic eruptions. This interpretative principle became known as uniformitarianism, or actualism to those who did not like that term, and was based on a rejection of the supernatural global catastrophism of the Genesis Flood. In his book, also entitled *Theory of the Earth* and published in 1795, Hutton recorded that however far we penetrate back into the past in our study of the earth's rocks, we can find "no vestige of a beginning."

Far from being welcomed, Hutton's theory was regarded by most of his contemporaries with righteous horror, because it was in direct and open conflict with the prevailing and entrenched views of Flood geology and a young earth. Nevertheless, Hutton's assault was continued after his death by John Playfair, whose *Illustrations of the Huttonian Theory of the Earth* was published in 1802. However, it was not until the publication of the famous textbook *Principles of Geology* (subtitled *Modern Changes of the Earth and its Inhabitants Considered as Illustrative of Geology*) in 1830-1833 that the tide of the debate began to turn in favor of Hutton's uniformitarianism. The author was a young English attorney, turned geologist, Charles Lyell, who enthusiastically accepted and vigorously promoted Hutton's doctrine of gradual geological changes. It was in fact Lyell who introduced the term uniformitarianism, championing not only the uniformity of natural law, but also the uniformity of the rates of geological

---

2 A. Holmes, 1965, *Principles of Physical Geology*, second edition, London: Thomas Nelson and Sons, 43.

3 Holmes, 1965, 142.

4 Holmes, 1965, 44.

processes. Indeed, Lyell went further than his predecessors in his insistence that all geologic processes had been very gradual in the past, and in his utter abhorrence of anything suggestive of sudden catastrophes:

> [T]he earlier geologists had not only a scanty acquaintance with existing changes, but were singularly unconscious of the amount of their ignorance. With the presumption naturally inspired by this unconsciousness, they had no hesitation in deciding at once that time could never enable the existing powers of nature to work out changes of great magnitude, still less such important revolutions as those which are brought to light by Geology.…never was there a dogma more calculated to foster indolence, and to blunt the keen edge of curiosity, than this assumption of the discordance between the ancient and existing causes of change. It produced a state of mind unfavourable in the highest degree to the candid reception of the evidence of those minute but insistent alterations which every part of the earth's surface is undergoing…for this reason all theories are rejected which involve the assumption of sudden and violent catastrophes and revolutions of the whole earth, and its inhabitants—theories which are restrained by no reference to existing analogies, and in which a desire is manifested to cut, rather than patiently to untie, the Gordian Knot.[5]

Lyell was thus intent on removing any trace of the catastrophic biblical Flood from the study of geology, which was one of the main reasons why uniformitarianism was so quickly adopted by those intent on being freed from all biblical constraints. Furthermore, as a disciple of Lyell, Darwin built his theory of organic evolution upon the uniformitarian foundation which Lyell had laid. In *The Origin of Species,* Darwin acknowledged his debt of gratitude to Lyell when he referred to "Sir Charles Lyell's groundwork on the *Principles of Geology*, which the future historian will recognize has having produced a revolution in natural science."[6]

It is beyond dispute that Lyell's uniformitarianism has provided the interpretative framework for the geological study of earth history for almost 200 years. Nevertheless, recognition of catastrophism in the geologic record was not completely extinguished by Lyell's rigid insistence on the uniformity of the rates of geological processes. Indeed, in the last forty years there has been a renewed acceptance of the role of catastrophes in generating the rock record, although geologists still strictly adhere to accepting natural causes operating over the same recognized geological timescale for earth history. This change has been bolstered by the recognition that uniformitarianism has historically been a dual concept—substantive uniformitarianism (a testable theory of geologic change postulating

5 C. Lyell, 1872, *Principles of Geology,* eleventh edition, vol. 1, London: John Murray, 317-318.

6 C. Darwin, 1979, *The Origin of Species by means of Natural Selection*, reprinted first ed., New York: Avenel Books, 293.

uniformity of rates or material conditions), and methodological uniformitarianism (a procedural principle asserting spatial and temporal invariance of natural laws).[7] Thus, Stephen Jay Gould maintained that substantive uniformitarianism, which denies catastrophism, is an incorrect theory and should be abandoned. Furthermore, while methodological uniformitarianism enabled Lyell to exclude the miraculous from geologic explanation, "its invocation today is anachronistic, since the question of divine intervention is no longer an issue in science," so it is a superfluous term that is best confined to the past history of geology! Other geologists have also questioned uniformitarianism, calling it an "ambiguous principle,"[8] a "dangerous doctrine,"[9] a principle that is "vaguely formulated,"[10] a doctrine that is "largely superfluous,"[11] and a term that "should be abandoned when describing formal assumptions used in modern geological enquiry."[12]

So what has brought about these reactions and the shift within the modern geological synthesis to accept catastrophism within the range of geological processes that have shaped the earth and left their record in the geologic column? Albritton wrote:

> Those who oppose substantive uniformity [that is, the belief in the uniformity of the rates of geological processes] tirelessly point out that the present condition of the earth, with its high-standing continents and remnants of vast continental glaciers, must be quite atypical of average conditions through geologic time, so that the present cannot be a very reliable key to the past. These opponents have no difficulty in classifying substantive uniformity; it is a discredited scientific hypothesis, an *a priori* assumption, or an anti-historical dogma.[13]

As Austin also wrote, "if the term [uniformitarianism] is understood to require temporal uniformity of rates or conditions, it is refuted by geological data, and is therefore false."[14] And Shea has written:

> Contrary to all these historical modern examples, contemporary

---

7 S. J. Gould, 1965, Is uniformitarianism necessary? *American Journal of Science*, 263: 223-228.

8 C. C. Albritton, 1967, Uniformity, the ambiguous principle, in *Uniformity and Simplicity, a Symposium on the Principle on the Uniformity of Nature*, C. C. Albritton, Jr, ed., Geological Society of America Special Paper 89: 1-2.

9 P. D. Crynine, 1956, Uniformitarianism is a dangerous doctrine, *Journal of Palaeotology,* 30: 1003-1004.

10 M. K. Hubbert, 1967, Critique of the principle of uniformity, in *Uniformity and Simplicity, a Symposium on the Principle of the Uniformity of Nature,* C. C. Albritton, Jr, ed., Geological Society of America Special Paper 89: 3-33.

11 H. B. Baker, 1938, Uniformitarianism and inductive logic, *Pan-American Geologist*, 69: 161-165.

12 S. A. Austin, 1979, Uniformitarianism—a doctrine that needs rethinking, *Compass*, 56: 29-45.

13 Albritton, 1967, 1.

14 Austin, 1979, 42.

> uniformitarianism (or actualism) does not require that past processes or conditions be duplicated today. We now realize that Earth *has evolved* and that at least some past conditions and processes were quite different from those of today. However, this does not stop us from proposing reasonable, though unobserved, processes to explain geologic features, such as astroblemes, whose natural formation has not been observed.… The modern concept of uniformitarianism says nothing about the rate of processes but leaves such substantive matters to be determined by the evidence in the rock record.…Fortunately, modern geology has long since outgrown any tendency to reject natural catastrophes out of hand (see, for example, Cloud, 1961, p. 156), and many examples can be cited of scientific, reasonable (that is, uniformitarian) geologic catastrophes whose occurrence is almost universally accepted (for example, the Spokane Flood, the refilling of the Mediterranean Basin after desiccation, numerous astroblemes, the formation of extensive ignimbrites, the extrusion of flood basalts, the 1929 Grand Banks turbidity current). Furthermore, if one follows the usual procedure of consulting authoritative recent sources, one finds that "gradualism" is simply not a part of modern uniformitarianism. Goodman (1967), for example, referred to this fallacy as a "blatant lie"….The definitive modern works reject the substantive idea of constancy of conditions. In addition to being physically impossible (Hubbert, 1967, p. 29), this approach involves assuming what we want to find out, namely the condition of Earth at various times in the past. Furthermore, the geological literature offers numerous examples where a uniformitarian interpretation of empirical evidence suggests that past conditions were radically different from those of today….[15]

Elsewhere, Shea has also written:

> Unfortunately, we have overreacted…and have adopted an excessively gradualist view of earth history, refusing in many cases to consider catastrophic events…even when the evidence clearly suggests that sudden, violent, cataclysmic events have occurred. This attitude is changing, however, and we need to free ourselves completely from the artificial constraints of the fallacious dogma that would preclude any possibility of natural catastrophes having occurred, even if the postulated catastrophes are perfectly rational and supported by strong evidence.… In short, the time has surely come for sedimentologists to free themselves of all remaining traces of constraining dogmas of uniformitarianism and

15 J. H. Shea, 1982, Twelve fallacies of uniformitarianism, *Geology*, 10: 455-460. The references he cites are: E. Cloud, Jr, 1961, Paleobiogeography of the marine realm, *Report of the American Association for the Advancement of Science*, 151-200; N. Goodman, 1967, Uniformity and simplicity, in *Uniformity and Simplicity,* C.C. Albritton, Jr, ed., Geological Society of America Special Paper 89: 93-99; Hubbert, 1967.

> to become true scientists free to go where observation, experimentation, and reasonable theory take us.[16]

As a consequence, catastrophes, initially unrivalled in modern geological processes, have now become an acceptable and necessary part of the modern geological synthesis:

> This process brings with it visions of random violence to the Earth on a scale never before contemplated: meteorite or comet impacts scar the lithosphere and generate towering tsunamis; exceptional impacts trigger magmatism, or shroud the globe in darkness and cold, poisoning life on land and in the sea or igniting wildfires that incinerate the world's flora to ash.…Once the full implications of bolide impact are clearly understood, geologists will realize that this violent force carries with it a far more revolutionary departure from classical geology than did plate tectonics. The idea of instantaneous change triggered by projectiles from space runs counter to every tenet of uniformitarianism. To be sure, the ubiquity of impact scars on planets and satellites throughout the Solar System may seem to demonstrate a uniformity of process that brings bolide impact into conformity with the principle of uniformitarianism. But to regard the cataclysmic geologic effects of bolide impacts as uniformitarian is an exercise in "new speak," whereby we would impose a 1980s usage on an 1830s term, which since the time it was coined, has donated the exact opposite of cataclysmic. Impact-generated craters, eruptions, wildfires, and extinctions, whether they are sporadic or periodic, have a place in the serene uniformitarian world of Hutton and Lyell, the world that has been envisioned by the geological community for the past two centuries. Rather than to invert the definition of the venerable word, it is time to recognize that bolide impact is a geologic process of major importance, which by its very nature demolishes uniformitarianism itself as the basic principle of geology.[17]
>
> Both William Whewell and C. S. Peirce criticized Lyell's induction on grounds that he sought facts to support his theory of a uniformitarian Earth. They believed, instead, that nature's facts should be the only guide to scientific inference. For example, if the geomorphic facts or results observed in the Scablands of Washington State imply a floodwaters of magnitude greater than any ever observed in the present, we should trust what nature tells us. Assuming only that the fundamental principles of hydraulics have been uniform in kind through time, we can infer the

16 J. H. Shea, 1982, Editorial: Uniformitarianism and sedimentology, *Journal of Sedimentary Petrology*, 52: 701-702.

17 U. B. Marvin, 1990, Impact and its revolutionary implications for geology, in *Global Catastrophes in Earth History: an Interdisciplinary Conference on Impacts, Volcanism and Mass Mortality*, V. L. Sharpton and D. Ward, ed., Geological Society of America Special Paper 247: 147-154.

> nature of such an unwitnessed historical event—even quantitatively! This process of reasoning, whereby we observe historical effects and then infer past causes or past conditions, Peirce termed *retroduction*, in contradistinction to *induction*. Whereas Lyell's induction sought facts to support his theory, retroduction uses facts to seek a theory. The difference is profound, even if subtle. It allows us to accept unwitnessed cataclysmic events, and believe that Earth was bombarded by countless bolides in the past.…Finally, it even means that catastrophism, in the sense of not straining the intensities of processes, was a better premise than Lyell's uniformitarianism (Baker, 1998)![18]

Perhaps the data of the rock record that have been most influential in bringing catastrophism back into respectable contention and acceptance as the explanation for those data were the observations and careful recording of the first and last appearances of animal and plant families in the strata sequences of the geologic column. This data led to the recognition of mass extinctions and then catastrophic causes for them.[19] This development has led to a plethora of articles and books on the subject of catastrophes as the explanation for the mass extinctions recognized as being preserved in the rock record.[20]

This revolution in invoking catastrophism to explain features found in the rock sequences of the geologic column has not just been confined to fossils, but to the rock strata themselves. Recall the account of how the hundreds of graded beds in the Ventura Basin of California were originally interpreted as requiring several years to deposit each layer in shallow water. However, when the phenomenon of turbidity currents was discovered and understood, then it was realized that these graded beds had each been deposited within minutes in deeper water.[21] Indeed,

18 R. H. Dott, Jr, 1998, What is unique about geological reasoning?, *GSA Today*, 8 (10): 15-18. The reference he cites is: V. R. Baker, 1998, Catastrophism and uniformitarianism: Logical roots and current relevance in geology, in *Lyell: the Past is the Key to the Present*, A. C. Scott and D. Blundell, ed., Geological Society of London Special Publication 143.

19 N. D. Newell, 1963, Crises in the history of life, *Scientific American*, 208: 77-92; N. D. Newell, 1967, Revolutions in the history of life, in *Uniformity and Simplicity, A Symposium on the Principle of Uniformity of Nature*, C. C. Albritton, Jr, ed., Geological Society of America Special Paper 89: 63-91.

20 Some examples are M. Allaby and J. Lovelock, 1983, *The Great Extinction*, London: Secker and Warburgh; D. M. Raup, 1986, *The Nemesis Affair*, New York and London: Norton; C. C. Albritton, Jr, 1989, *Catastrophic Episodes in Earth History,* London: Chapman and Hall; S. K. Donovan, ed., 1989, *Mass Extinctions—Processes and Evidence,* London: Bellhaven Press; V. L. Sharpton and D. Ward, ed., 1990, *Global Catastrophes in Earth History*, Geological Society of America Special Paper 247; W. Glen, ed., 1994, *The Mass Extinction Debates*, Stanford, CA: Stanford University Press; D. H. Erwin, 1995, *The Great Paleozoic Crisis—Life and Death in the Permian,* New York: Columbia University Press; G. R. McGhee, 1996, *The Late Devonian Mass Extinction—The Frasnian-Famennian Crisis,* New York: Columbia University Press; A. Hallam and B. Wignall, 1997, *Mass Extinctions and their Aftermath,* Oxford: Oxford University Press; Palmer, 1999, *Controversy, Catastrophism and Evolution: The Ongoing Debate,* New York: Kluwer Academic/Plenum Publishers.

21 J. E. Eaten, 1929, The by-passing and discontinuous deposition of sedimentary materials, *American Association of Petroleum Geologists Bulletin* 13: 713-761; H. Kuenen and C. I. Migliorini, 1950, Turbidity currents as a cause of graded bedding, *Journal of Geology,* 58: 91-127; M. L. Natland and H. Kuenen,

turbidity current deposition represents a catastrophic event, in that each graded bed represents a single depositional episode.[22] A turbidity current can deposit one of these turbidite layers, that is more than a meter thick, as an enormous lobe of sediment covering thousands of square kilometers, but the length of time required for this deposition might be only a few minutes.

The first direct measurement of a turbidity current speed was facilitated by an earthquake on November 18, 1929, on the continental slope southwest of the Grand Banks, off the south coast of Newfoundland. The earthquake triggered a sudden slump of the sediments on the continental slope, which became a slide, and then as the sediments were thrown into suspension, a turbidity current. That turbidity current flowed rapidly downslope, causing breaks in the trans-Atlantic communication cables on the continental slope, and then further down the continental rise onto the abyssal plain. The times at which communications were interrupted by the sequence of different cables breaking enabled measurement of the turbidity current speed at an average of between 45 and 60 kilometers per hour.[23] It is also estimated that the quantity of sediment carried by this turbidity current and deposited as a turbidite unit on the abyssal plain amounted to a volume of 200 cubic kilometers.[24]

Another, more recently discovered, turbidite bed has been found on the deep abyssal plain floor of the western Mediterranean Sea.[25] What is exceptional about this turbidite unit is its scale. It is 8 to 10 meters thick and covers an area of some 60,000 square kilometers, with an estimated volume of 500 cubic kilometers. However, the evidence of episodic catastrophic sedimentation on a large scale is not just confined to finer sediments, since debris of immense sizes are now known to be capable of being transported in submarine debris flows. For example, giant submarine landslide deposits have been recognized off Hawaii, in which blocks of rock up to 10 kilometers long have been transported more than 50 kilometers.[26] Some of these landslides have flowed over 200 kilometers, and some have debris volumes exceeding 5,000 cubic kilometers. Another well-known set of submarine landslides is that known as the Storegga ("Great Edge") suite. These slides have an immense headwall, nearly 300 kilometers long, which runs roughly along the

---

1951, Sedimentary history of the Ventura Basin, California, and the action of turbidity currents, *Society of Economic Paleontologists and Mineralogists Special Publication* 2: 76-107.

22 J. Davidson, W. E. Reed, and M. Davis, 1997, *Exploring Earth: An Introduction to Physical Geology*, Upper Saddle River, NJ: Prentice Hall, 349.

23 C. R. Longwell, R. F. Flint, and J. Sanders, 1969, *Physical Geology,* New York: John Wiley and Sons, Inc., 360-364; Holmes, 1965, 864-870; Davidson, Reed, and Davis, 1997, 349.

24 E. G. Nisbet and D. J. W. Piper, 1998, Giant submarine landslides, *Nature*, 392: 329-330.

25 R. G. Rothwell, J. Thomson, and G. Kähler, 1998, Low-sea-level emplacement of a very large Late Pleistocene "megaturbidite" in the western Mediterranean Sea, *Nature*, 392: 377-380.

26 J. G. Moore et al, 1989, Prodigious submarine landslides on the Hawaiian ridge, *Journal of Geophysical Research*, 94: 17,465-17,484; J. G. Moore, W. R. Normark and R. T. Holcomb, 1994, Giant Hawaiian underwater landslides, *Science*, 264: 46-47.

edge of the continental shelf of Norway.[27] Debris, up to 450 meters thick, is spread over a distance of 800 kilometers out to the abyssal plain floor. Why are there so few large landslide deposits similar to those described here recognized in the geologic record? It has been suggested that perhaps geologists have misinterpreted the evidence.[28]

In his ground-breaking book *The Nature of the Stratigraphical Record*, the late Derek Ager, Professor at the University College of Swansea, Wales, presented his field observations from many parts of the world that compelled him to conclude that the rocks recorded a somewhat catastrophic picture of earth history, challenging some of the assumptions of uniformitarian stratigraphy at that time.[29] His discussion of abundant field data in each chapter is drawn together in concluding statements that summarize the thrust of the book:

> At certain times in earth history, particular types of sedimentary environment were prevalent over vast areas of the earth's surface. This may be called the *Phenomenon of the Persistence of Facies*.
>
> Palaeontologists cannot live by uniformitarianism alone. This may be termed the *Phenomenon of the Fallibility of the Fossil Record*.
>
> The sedimentary pile at any one place on the earth's surface is nothing more than a tiny and fragmentary record of vast periods of earth history. This may be called the *Phenomenon of the Gap Being More Important than the Record*.

In a subsequent book, Ager again emphasizes the importance of violent catastrophic events in building the geologic record:[30]

> The sedimentation in the past has often been very rapid indeed and very spasmodic. This may be called the *Phenomenon of the Catastrophic Nature of much of the Stratigraphical Record*.
>
> The periodic catastrophic event may have more effect than vast periods of gradual evolution. This may be called the *Phenomenon of Quantum Sedimentation*.
>
> Most sedimentation in the continental areas is lateral rather than vertical

27 Nisbet and Piper, 1998.

28 N. H. Woodcock, 1979, Size of submarine slides and their significance, *Journal of Structural Geology*, 1: 137-142.

29 D. V. Ager, 1973, *The Nature of the Stratigraphical Record*, London: MacMillan.

30 D. V. Ager, 1993, *The New Catastrophism: The Importance of the Rare Event in Geological History*, Cambridge: Cambridge University Press.

> and is not necessarily directly connected with subsidence. This may be called the *Principle of the Relative Independence of Sedimentation and Subsidence*.

In conclusion, Ager made the oft-quoted statement that "the history of any part of the earth, like the life of a solider, consists of long periods of boredom and short reigns of terror."[31] Of course, he still maintains that earth history has spanned countless millions of years. Nevertheless, Ager concludes:

> [I]t is obvious to me that the whole history of the earth is one of short, sudden happenings with nothing much in particular in between. I have often been quoted for my comparison of earth history with the traditional life of a soldier, that is "long periods of boredom separated by short periods of terror."[32]

Indeed, Ager reinforces this claim with copious examples of fossils and geological deposits that could not have formed by any other means than by sudden catastrophes or disasters that occurred in fleeting moments of time. However, he claims that these "episodic catastrophes" were separated by immense eons, when virtually no geological deposits and contained fossils were being formed, suggesting that there are "more gaps than record." Or to put it another way, the bulk of geological time occurred during the gaps in the record! "It may be said that Earth history is not a record of what actually happened," but "is a record of what happens to have been preserved."[33] Of course, this merely begs the question as to how Ager and the conventional geological community know that the gaps in the record represent vast eons of time. If neither the gaps nor the eons of geological time claimed to be associated with them are in the rock record, then one is left only with a record of brief catastrophic geologic processes!

31 Ager, 1973, 13, 26, 34, 42, 50, 59, 100.

32 Ager, 1993, 197-198.

33 Ager, 1993, 14.

63

Evidences of Catastrophism in the Geologic Column—Rate of Sediment Accumulation and Widespread Rapidly-Deposited Strata

Rate of Sediment Accumulation

The average thickness of the sediments on all of the continents is approximately 1,500 meters, although in some places the sedimentary rock sequences can be up to 10,000 meters or more thick. How long did it take to deposit the sediments that now make up these sedimentary rocks? Observations of present-day sedimentation rates have only been made for a relatively short time, but in conventional geology present observed rates of sedimentation are extrapolated into the past. Of course, variations in the rate of sedimentation and catastrophic events are now recognized as having happened in the past, but it is claimed that over the allegedly billions of years of earth history, the average rate of sedimentation has been more or less the same. On the other hand, it is quite obvious that in any biblical geologic model of earth history, sedimentation rates would have to have been cataclysmic during part of Day Three of the Creation Week and during the year-long Flood event. Do the sedimentary rocks themselves, therefore, provide any evidence of past sedimentation rates that would be definitive in favoring the scriptural timeframe of earth history compared to that of the modern geological synthesis?

Sediments are known to be deposited much faster today than they have supposedly accumulated in the geologic record according to conventional geologic reasoning.[1] Sedimentation rates were measured and estimated in meters of sediment per thousand years over different timespans and are plotted in Figure 39 (page 1079). Of course, the sedimentation rate measured over a one-minute period during a flash flood is extremely high; indeed, it can be more than a staggering 1 million meters per thousand years. In other words, if a flash flood continued steadily at its peak flow rate for 1,000 years, it would deposit sediment one million meters thick! On the other hand, if the measurements were averaged over a few hours, the rate would probably be lower, because flood water does not flow continuously

1 M. Sadler, 1981, Sediment accumulation rates and the completeness of stratigraphic sections, *Journal of Geology,* 89: 569-584.

at peak rates. Thus, a rate measured over a month is significantly lower, because a local flood occurs for only part of that time. Furthermore, the most realistic measurement to obtain for an average sedimentation rate at the present time would be to probably take a measurement over several years, because that would then reflect the changes in sedimentation through the seasons, and would average that for several yearly cycles. Of course, such rates actually can and have been measured today.

Needless to say, sedimentation rates over significantly longer timespans must be determined in a different way, such as by measuring the thickness of sediment between two radioisotopically dated layers. If it is assumed that the radioisotopic dates are correct (these are, of course, also based on assumptions and will be discussed later), then the amount of time for the measured thickness of sediments, and thus a rate in meters per thousand years, can be calculated. It is not surprising that calculated sedimentation rates for sedimentary strata in the rock record that are dependent on the radioisotopic dating methods are extremely low compared to measured modern sedimentation rates.

Figure 39, where the data are plotted on a log/log scale, indicates that the longer the timespan over which sedimentation rates are calculated, the slower are those sedimentation rates. The same data when plotted on a log/linear scale in Figure 40 (page 1079) more clearly reveal that sedimentation rates today are extremely rapid in comparison with ancient sedimentation rates calculated from sedimentary rock strata. From these data it is logical to conclude that:

1. Sedimentation occurred at a much slower rate in the past; or
2. Much of the ancient sediments originally deposited has not been preserved in the geologic record; or
3. The geological timescale is not correct, being a gross overestimate of the elapsed time of earth history.

If the present is indeed the key to understanding the past, then option 1 is not only an unlikely hypothesis, but is untenable by definition. Calculated sedimentation rates over a timespan of one million years average about 0.01 meters per thousand years, whereas the average sedimentation rate actually measured today over a period of one year is approximately 100 meters per thousand years. Thus, as recognized by Ager (cited earlier), the time over which the rock record has accumulated is only a small fraction of the claimed available time of the geological timescale. Indeed, even with all the possible claimed breaks in strata sequences, the accumulation of the rock record would still only have required less than ten percent of the claimed available time of the geological timescale. The universality, and especially the magnitude, of this shortfall are both startling and staggering (for the conventional geological community). Thus, option 2 is all too readily appealed to, with the claim that many cycles of sedimentation have occurred, erosion of most of those sediments having taken place before the next cycle of sedimentation began, so most of the ancient sediments originally deposited have not been preserved in the rock record. However, the field evidence for those proposed erosional breaks generally is not detectable (to be further discussed). Nevertheless, the startling shortage of sediments still remains after the detectable erosional breaks are accounted for, so option 2 is likewise untenable and inconsistent with the data.

Even if we assumed modern sedimentation rates (the present is the key to the past) had produced the Phanerozoic strata sequences in one or even ten percent of the geological time usually assigned to those rocks, it would still have taken between 5.45 and 54.5 million years. However, modern sedimentation rates fall drastically short of the sedimentation that would have been occurring during the global cataclysmic Flood. Therefore, the following conditions are assumed to have applied during the global cataclysmic Flood event, to demonstrate both the feasibility and compatibility of a biblical geologic model with the observational data:

1. Almost all deposited sediments have been preserved in the geologic record as extensive cycles of deposition, and erosion did not occur (discussed further below).
2. All Paleozoic and Mesozoic strata sequences were deposited during the Flood, while the Cenozoic strata were deposited post-Flood (this is only a first approximation for the sake of the argument).
3. These Flood strata sequences (Paleozoic and Mesozoic) average a thickness of about 700 meters on the continents.
4. During the Flood, the volume and speed of the flowing water were sufficient to sustain, on average, the same sedimentation rate as an average modern flash flood.

The modern geological synthesis allocates 480 million years for the accumulation of these Paleozoic and Mesozoic strata sequences, so the time required at modern depositional rates for those sedimentary rock sequences would be only 4.8 to 48 million years (that is, one to ten percent of the claimed time, assuming the claimed erosional breaks in the geologic record represent the passage of millions of years during which no sediment was preserved). However, the average deposition rate in a modern flash flood, measured over one hour (see Figure 39), is one million meters of sediment per thousand years, or 1,000 meters per year. Consequently, if the waters of the Flood only equaled a modern flash flood continuously covering all the earth, it would only have taken 8.4 months to deposit all the Paleozoic and Mesozoic strata sequences. Of course, in some places the sedimentary rock layers are much more than 700 meters thick.

For example, in northern Arizona and southern Utah the Paleozoic and Mesozoic strata sequences are approximately 2,925 meters thick.[2] To deposit all these

2 S. S. Beus and M. Morales, ed., 2003, *Grand Canyon Geology,* 2nd ed., New York: Oxford University Press.

sedimentary rock layers in just one year would require the waters of the Flood to be flowing on average only 1.7 times faster than the rate used in the previous calculation, as the sediment-carrying capacity of flowing water varies as the square of its flow rate. However, the required flow rate would not need to be that much faster if the Flood waters were deeper. In any case, this flow rate is still below the maximum flow rate for modern flash floods (Figure 39). Of course, the assumptions used in these calculations are only rough approximations, but they do suggest the possibility that the waters of the Flood could have deposited the thickness of sedimentary rock strata found in the geologic record. It is also realistic to assume that the waters of the Flood were deeper than those of any modern flash flood, and like a modern flash flood the waters would not necessarily have been flowing at a constant rate all the time. This not only demonstrates that realistic sedimentation rates could feasibly have produced the sedimentary rock record left behind by the Flood year, but more than adequately responds to those who have claimed otherwise.[3]

Widespread, Rapidly Water-Deposited Strata

If a rate of sedimentation equivalent to that in a modern flash flood, with the sediment-carrying capacity of deeper water, is capable of depositing the rock sequences preserved in the geologic record of the Flood within the scriptural time framework of the Flood year, then there should be evidence in the strata themselves of their rapid deposition by water on a widespread scale. In other words, if the biblical account and description of a cataclysmic global flood are both true and relevant to our understanding of the geologic record, then the strata in that record should show evidence of cataclysmic water deposition on a global scale.

The required evidence is not only observed in the strata sequences of the rock record, but it has already been recognized in the conventional geologic community. For example, note again the comments made by Derek Ager that catastrophic deposition has had more effect than any vast periods of gradual evolution, that particular types of sediments are prevalent over vast areas of the earth's surface, and that most sedimentation in the continental areas is lateral rather than vertical.[4] Ager provides numerous examples of globally extensive, unique strata at various levels in the geologic record. Most noteworthy are the examples of very thin units that persist over fantastically large areas in particular sedimentary basins, such as rock units with thicknesses of 30 meters or less in the Permian strata sequences of western Canada that persist over areas up to 470,000 square kilometers, and the thin layer only about one meter thick that can be found all around the Alpine chain of Europe.[5] In the United States, the Dakota Formation of the western

3 For example, A. N. Strahler, 1987, *Science and Earth History—The Evolution/Creation Controversy*, Buffalo, NY: Prometheus Books, and I. R. Plimer, 1994, *Telling Lies for God—Reason vs Creationism*, Sydney: Random House.

4 Ager, 1973, 1-13, 43-50, and 51-59.

5 Ager, 1973, 13.

United States (a sandstone), with an average thickness of 30 meters, covers an area of some 815,000 square kilometers.[6] Even more remarkable is the Brockman Iron Formation in the Paleoproterozoic rock sequences of the Hamersley Basin of Western Australia in which there are bands about 2 centimeters thick that are able to be correlated over an area of almost 52,000 square kilometers. Even microscopic "varves" within those bands can be traced laterally over almost 300 kilometers.[7]

There are also numerous examples of discontinuous, but yet spectacular, distributions of similar, or even identical, synchronous deposits. Perhaps the most distinctive are the familiar white chalk beds in the upper Cretaceous strata sequences of northwest Europe, with their layers of black flint nodules and characteristic fossils. The most familiar images of these chalk beds are the white cliffs along the channel coast of England. However, these beds extend from the Antrim area of Northern Ireland, via England and northern France, through the Low Countries, northern Germany and southern Scandinavia to Poland, Bulgaria, and eventually to Georgia in the south of the Commonwealth of Independent States. There are also records of these same white chalk beds on the Black Sea coast of Turkey, and at the other extreme end of the belt, in southwest Ireland, and also covering extensive areas of the sea floor south of Ireland. However, identical chalk beds are also found in Egypt and Israel, but more remarkably, they are also found on the other side of the Atlantic in Texas, as well as in Arkansas, Mississippi, and Alabama. Even more surprising are identical chalk beds, complete with the same black flint nodules and the same familiar fossils, on the coast of Western Australia just north of Perth, overlying glauconitic sands, as in northwest Europe.[8] This global distribution of such uniform beds with the same characteristics and fossils is astounding, given that the chalk is an extremely pure coccolith-bearing limestone that is unique to this level in the geologic record.

Two other examples will suffice here. The strata sequences making up the three-fold division of the Triassic geologic record in Germany are so distinctive that they can also be readily recognized in the English Midlands, in eastern Spain, and north of Sofia and elsewhere in Bulgaria at the other end of Europe.[9] Furthermore, the sedimentary strata of the Newark Group of the eastern seaboard of the United States are exactly like the Triassic strata of northwest Europe, even to the extent that the brown sandstone near Birmingham, England, is remarkably like the brown sandstone of New York. Similarly, the distinctive red and green marls of these German Triassic strata sequences may also be instantly recognized in

6 A. A. Roth, 1998, *Origins: Linking Science and Scripture,* Hagerstown, MD: Review and Herald Publishing Association, 218.

7 Ager, 1973, 13; A. F. Trendall, 1968, Three great basins of Precambrian banded iron formation deposition: a systematic comparison, *Bulletin of the Geological Society of America* 79: 1527-1544.

8 Ager, 1973, 1-2.

9 Ager, 1973, 4-6.

southern Spain, and in the southwestern United States, where the red and green marls and thin sandstones with layers of gypsum of the Moenkopi and associated formations of northern Arizona are identical to the Triassic strata exposed along the banks of the River Severn in England.

Yet another distinctive and unique example is the remarkable similarity of the upper Carboniferous (Pennsylvanian) Coal Measures on both sides of the Atlantic Ocean, in North America and in Europe. The plant fossils of the British Coal Measures are just as easy to identify in the diverse fossil flora of the coal beds in the Illinois Basin.[10] Certainly there are some differences, such as more sedimentary strata containing marine fossils in the American Pennsylvanian, but just as with the plant fossils, the non-marine bivalve fossils of the coal measures in the American Mid-West are very much like those found in the coal measures that extend from Ireland to Russia. Whatever the vertical and lateral changes in the upper Carboniferous strata sequences of the coal measures, the rock types, their features, and their contained fossils are essentially the same all the way from Texas to the Donetz Coal Basin, north of the Caspian Sea in the former USSR, an extent amounting to some 170° of longitude.

However, it is not just the widespread extent of the same strata and strata types that is consistent with global sedimentation patterns during the biblical Flood (and earlier at the end of the Creation Week in the case of the Hamersley Basin of Western Australia), but evidence of widespread sedimentary strata deposited rapidly by water that is of most importance in our quest to demonstrate the biblical geologic model of earth history. It is therefore imperative that numerous examples of the deposition or formation of such strata of many different rock types be documented.

10 Ager, 1973, 6-7.

64

The Widespread, Rapidly Water-Deposited, Paleozoic Strata of the Grand Canyon, Arizona—Limestones

Of the many places on the earth's surface that have been well studied, the Grand Canyon area of northern Arizona probably ranks among the most intensively investigated. The Paleozoic strata exposed in the walls of the Canyon and in surrounding areas have been thoroughly documented, and are well-known as examples of the principal sedimentary rock types—limestones, sandstones, and shales. These rock units are also widespread, extending more than 300 kilometers from one end of the Canyon to the other and beyond to surrounding areas, usually in all four directions. The evidence within them for their rapid deposition has been thoroughly discussed and well-documented by Austin.[1]

The shallow-water lime muds accumulating in tropical oceans today are usually believed to provide an excellent example of how ancient lime mudstones (micritic limestones) such as those in Grand Canyon accumulated. Modern lime muds are formed mainly by mechanical breakdown of the carbonate-containing remains of sea creatures, and they accumulate at an estimated average rate of 0.33 meters thickness per thousand years. Thus, for example, it is insisted that simply comparing the texture of the cliff-forming Redwall Limestone of Grand Canyon with modern lime muds provides the convincing evidence that this and other Canyon limestone strata required millions of years to be deposited.[2]

However, modern, shallow-water lime muds are dominated by silt-sized crystals (approximately 20 microns in diameter) of aragonite (most contain 60-90 percent aragonite, and 0-10 percent calcite), derived from disaggregation or abrasion of skeletons of marine organisms.[3] On the other hand, the ancient lime mudstones (micritic limestones) abundant in Grand Canyon are dominated by clay-sized

1 S. A. Austin, 1994, Interpreting strata of Grand Canyon, in *Grand Canyon, Monument to Catastrophe*, S. A. Austin, ed., Santee, CA: Institute for Creation Research, 21-56.

2 D. E. Wonderly, 1977, *God's Time-Records in Ancient Sediments*, Flint, MI: Crystal Press, 138-145.

3 R. Steinen, 1978, On the diagenesis of lime mud: scanning electron microscopic observations of subsurface material from Barbados, W.I., *Journal of Sedimentary Petrology*, 48: 1140.

crystals (less than 4 microns in diameter) of calcite (nearly 100 percent calcite and/or dolomite), with sand-sized and larger skeletal fragments floating in the fine crystal matrix.[4] These textural, mineralogical, and chemical differences between modern lime muds and many ancient limestones have been emphasized: "Micritic limestones, composed essentially of calcite, have textures quite different from those of the aragonite-dominated modern lime muds that have long been regarded as their precursors."[5] "Modern carbonate sediments contrast sharply in their chemistry and mineralogy with ancient carbonate rocks."[6] Even the shapes of the grains in modern lime muds are very different from those in these ancient limestones: "Furthermore, the grain (crystal) size distribution and grain (crystal) shape characteristics of modern lime-mud sediment are very different from their lithified counterparts."[7]

Nevertheless, could recrystallization after deposition be responsible for transforming modern, coarser-textured, aragonite muds into the ancient, finer-textured, calcite limestones? No, the recrystallization process makes larger crystals from smaller crystals, so coarse-grained lime muds simply do not recrystallize into finer-grained limestones. It was once argued that the microcrystalline-calcite (micrite) of ancient limestones formed by direct precipitation from seawater,[8] and not from recrystallization or even extensive abrasion of skeletons of marine organisms, a process much different from the slow processes in modern oceans. Thus, the scientific evidence does not support the contention that ancient fine-grained limestones were derived from lime muds resembling those being deposited slowly in modern tropical seas. Indeed, as the compositions and textures of modern lime muds and fine-grained limestones have been thoroughly investigated, the "lime mud problem" has become more apparent and "the origin of micrite is far from clear."[9]

Whereas many modern lime muds do accumulate very slowly, there are some modern examples of rapid lime mud accumulation. For example, hurricanes in the Florida-Bahamas area have been observed to move and redeposit large quantities of fine, laminated, carbonate mud. Flats above normal high-tide level receive carpets of laminated mud after hurricanes, and offshore mud deposits have been observed to form rapidly.[10] Of particular interest are layers of creamy-white

---

4 E. D. McKee and R. G. Gutschick, 1969, History of the Redwall Limestone in northern Arizona, *Geological Society of America Memoir* 114: 103.

5 Z. Lasemi and A. Sandberg, 1984, Transformation of aragonite-dominated lime muds to microcrystalline limestones, *Geology*, 12: 420.

6 R. M. Garrels and F. T. MacKenzie, 1971, *Evolution of Sedimentary Rocks*, New York: W.W. Norton, 215.

7 Steinen, 1978, 1139.

8 R. L. Folk, 1959, Practical petrographic classification of limestones, *American Association of Petrologists Bulletin,* 43: 8.

9 F. J. Pettijohn, 1975, *Sedimentary Rocks*, third ed., New York: Harper and Row, 334.

10 M. M. Ball, E. A. Shinn and K. W. Stockman, 1967, The geologic effects of Hurricane Donna in south Florida, *Journal of Geology,* 75: 583-597; R. W. Perkins and Enos, 1968, Hurricane Betsy in the Florida-

mud with the consistency of toothpaste found in tidal channels between islands in the Bahamas. These are lime muds dominated by silt- and clay-sized needles of aragonite in beds 2.5-5 centimeters thick within a 1-meter-thick deposit described as "a high-energy bank margin environment not usually considered to be the site of mud-sized particle deposition."[11] Subsequent investigations have revealed that these lime mud layers associated with tidal channels formed by direct precipitation of aragonite during storms.[12]

These observations of lime mud deposits within environments of rapid accumulation would appear to be puzzling. After all, modern mud-sized particles are observed to settle very slowly, and only in quiet water, so how could fine mud particles settle quickly from turbulent, fast-flowing waters? The answer: microscopic examination of lime muds from the tidal channels in the Bahamas washed by a gentle stream of water revealed that the mud particles had aggravated into pelletoids.[13] Evidently, these pelletoids of flocculated aragonite particles exhibit the hydraulic characteristics of sand, allowing aggregates of particles to settle quickly. Thus, these new discoveries "mandate caution when using these features as indicators of shoreline or quiet water in ancient carbonate deposits."[14]

The rapid accumulation of fine-grained lime muds in modern sedimentary environments suggests that many fine-grained ancient limestones would similarly have accumulated rapidly. Probably the most significant limestones often claimed to have formed by extremely slow deposition are the so-called "lithographic limestones," which have an extremely fine texture and extraordinary fossil preservation. These limestones appear to have formed as animals were smothered in lime mud.[15] The most famous lithographic limestone is that found at Solnhofen in Germany, which includes fossils of the bird *Archaeopteryx*. Another fine-grained limestone containing the "world's most perfect fossils" is the Santana Formation of northeast Brazil, where the fossil fish in it have been described: "… lithification was instantaneous and fossilization may even have been the cause of death."[16] Yet

---

Bahamas area—geological effects and comparisons with Hurricane Donna, *Journal of Geology*, 76: 710-717; E. A. Shinn et al, 1993, Lime-mud layers in high-energy tidal channels: a record of hurricane deposition, *Geology*, 21: 603-606.

11 R. F. Dill and R. Steinen, 1988, Deposition of carbonate mud beds within high-energy subtidal sand dunes, Bahamas, *American Association of Petroleum Geologists Bulletin* 72: 178-179.

12 E. A. Shinn et al, 1989, a sedimentologic dilemma, *Journal of Sedimentary Petrology*, 59: 147-161; J. D. Milliman et al, 1993, Great Bahama Bank aragonitic muds: mostly inorganically precipitated, mostly exported, *Journal of Sedimentary Petrology*, 63: 589-595.

13 Dill and Steinen, 1988, 179; R. F. Dill, C. J. S. Kendall, and E. A. Shinn, 1989, Giant subtidal stromatolites and related sedimentary features, *American Geophysical Union, Field Trip Guidebook,* T373: 33.

14 Dill and Steinen, 1988, 179. See also Shinn et al, 1993, 605-606.

15 C. E. Brett and A. Seilacher, 1991, Fossil largerstätten, a taphonomic consequence of event sedimentation, in *Cycles and Events in Stratigraphy*, G. Einsele, W. Ricken and A. Seilacher, ed., New York: Springer-Verlag, 296.

16 D. M. Martill, 1989, The Medusa Effect: instanteous fossilization, *Geology Today*, 5: 201.

another excellent example of a lithographic limestone that must have accumulated rapidly as fine lime mud because of the extraordinarily preserved fossils in it is found in Mexico.[17] Clearly, catastrophic depositional processes are required to produce these fine-grained limestones.

Many abundantly fossiliferous limestones are claimed to be organically constructed limestone "reefs," which accumulated slowly in shallow ancient seas. It is alleged that it must have taken thousands of years to construct the huge, wave-resistant frameworks of these limestone "reefs," as innumerable generations of marine organisms chemically cemented themselves one on top of another. Thus, if there were large, organically-bound structures ("reefs") within the Grand Canyon limestones, they would seemingly be evidence that the lime muds making up these limestones must have accumulated slowly and *in situ* on the floors of ancient tranquil seas.

In the most extensive study of a Grand Canyon limestone, it was admitted: "Coral reefs are not known from the Redwall Limestone."[18] Concerning laminated algal structures (stromatolites) in the Redwall, which might have formed slowly in tidal flat environments, it was reported: "The general scarcity or near absence of bottom-building stromatolites suggests that places generally above low tide are not well represented."[19] Yet these cautious statements concerning algal structures in the Redwall Limestone have still been used to imply that the presence of some algal structures indeed represent *in situ* ocean floor.[20] However, the reported laminated algal structures typically show concentric structure (oncolites), and are best interpreted as algal masses that were transported by rolling. Thus, the claim that the Redwall Limestone represents an *in situ* ocean-floor deposit has not been proven by any empirical evidence.

In many modern reefs, sponges, as well as corals and algae, are responsible for building the rigid-growth frameworks, but sponge frameworks are not found in Grand Canyon limestones. Instead, small broken fragments of sponges have been described in the Redwall, but the largest sponges occur in the lower part of the Kaibab Limestone. Nevertheless, a recent report on the Kaibab admits: "Discrete organic build-ups, such as sponge patch reefs, have not been documented."[21] The absence of any coral or sponge-reef structures in all the limestones of the Grand Canyon strongly mitigates against any claim of slow *in situ* accumulation of these limestones on ancient ocean floors.

17 D. M. Martill, 1989, A new "Solnhofen" in Mexico, *Geology Today,* 5: 25-28.

18 McKee and Gutschick, 1969, 557.

19 McKee and Gutschick, 1969, 546.

20 D. E. Wonderly, 1987, *Neglect of geologic data: sedimentary strata compared with young-earth creationist writings,* Hatfield, PA: Interdisciplinary Biblical Research Institute, 17.

21 R. L. Hopkins, 1990, Kaibib Formation, in *Grand Canyon Geology*, S. S. Beus and M. Morales, ed., New York: Oxford University Press, and Flagstaff: Museum of Northern Arizona Press, 243.

However, there is a significant fossil deposit within the Redwall Limestone that provides relevant evidence of the mode of deposition of the limestone. Numerous, large orthocone nautiloids, marine mollusks in the class Cephalopoda, which includes the living octopuses, squids, and cuttlefishes, are found fossilized within a thin but extremely persistent bed in the basal member of the Redwall Limestone throughout the length of the Grand Canyon.[22] These are distinctive cigar-shaped fossils that are up to 0.6 meters in length and up to about 10 centimeters in diameter. Their chambered calcium carbonate shells are straight, unlike those of the modern coiled nautilus. Like its modern counterpart, the fossil nautiloid had a squid-like animal living in the last (largest) chamber of its shell, the other chambers being pressurized and used to compensate for buoyancy in a fashion similar to a submarine. This construction allowed the animals to swim freely, probably at great speed, through the deep ocean.

The two-meter-thick, coarse-grained, medium-gray dolomite bed in which these large fossil nautiloids are found is at the top of the Whitmore Wash Member within the Redwall Limestone. The fossil nautiloids are within this upper half of this bed, and always as a single layer. In the far eastern Grand Canyon the density is greater than one fossil nautiloid per four square meters, and similar nautiloid density is seen at outcrops in both the central Grand Canyon and in the type section at Whitmore Wash in the western Grand Canyon. This fossil-nautiloid-containing bed also extends into the Monte Cristo Limestone, which is equivalent and directly correlatable to the Redwall Limestone, as far as the Las Vegas area in southeastern Nevada. With such a fossil density laterally over a distance of more than 220 kilometers, the number of these fossil nautiloids is conservatively estimated at more than a billion. How then could so many of these free-swimming, deep-sea animals become buried and fossilized in fine-grained lime mud at this one particular horizon over such a large area?

The orientations or alignments of 160 of these fossil nautiloids have been measured and plotted on a rose diagram, which shows the compass-direction alignment of the long axes of the shells. The long axes of most of the fossilized nautiloids are aligned primarily in a northwest-southeast direction. Simple probability analysis indicates an extremely low chance that such an arrangement of shells could be generated by random falling of dead nautiloids over an extended period of time onto a motionless and static, deep ocean floor. On the other hand, it is known that long, cigar-shaped objects tend to align themselves in the direction of minimum resistance to flowing water, so it can be inferred that the long axes of these nautiloid shells in the Redwall Limestone were aligned in the direction of the prevailing current. However, any current able to induce orientation of large shells on the deep ocean floor would also be able to move and deposit fine-grained lime mud. Therefore, these fossil nautiloids indicate that the lime mud entombing them

22 S. A. Austin, A. A. Snelling and K. Wise, 1999, Canyon-length mass kill of orthocone nautiloids, Redwall Limestone (Mississippian), Grand Canyon, Arizona, *Geological Society of America Annual Meeting Abstracts*, Volume A: 421.

was moved and accumulated by the current catastrophically. Indeed, the sizes of the fossil nautiloids are log-normally distributed, indicating a life assemblage and therefore a mass-kill event involving a single species. Furthermore, shell implosion structures and the shell orientations are consistent with their bodies being present in many of the shells during the burial event. The chert directly overlying this bed is chemically distinctive, suggesting deposit-length toxic marine conditions as the cause of the mass-kill event. Mounds within the chert above, as well as the orientations of the fossil nautiloids, indicate a bi-directional current during rapid sedimentation and deposition of the fine-grained lime mud that entombed the nautiloids. Thus, a gigantic population of orthocone nautiloids was overcome by a catastrophic event that buried them in fine-grained lime mud over an area exceeding several thousand square kilometers.

What is also significant about this fossil nautiloid bed within the Redwall Limestone is that, except for the fossil nautiloids, it resembles many other limestone beds within the Redwall Limestone and other Grand Canyon limestones. Indeed, the fine-grained composition and bedded structure of the bed containing the fossil nautiloids is typical of the Redwall generally. Thus, it is reasonable to infer that many of the other fine-grained limestone layers were also rapidly accumulated, as lime muds were moved by water currents, and not by the slow and steady rain of fine lime debris in calm and placid seas.

However, not all Grand Canyon limestones are fine-grained. Some contain coarse, broken fossil debris, which appears to have been sorted by strong currents. The Redwall Limestone contains coarse, circular discs (columnals) from the stems of crinoids (sea-lilies). Vigorous current-washing to disaggregate these marine animals into fragments must have occurred, followed by winnowing away of the finer sediment to leave a "hash" of crinoid debris. Occasionally, the heads of crinoids are found embedded with the coarse, circular discs in the limestone. Sometimes these occur where the limestone is cross-bedded, which implies strong currents. Because modern crinoid heads in the ocean today are susceptible to rapid breakdown when these organisms die,[23] we can conclude that rapid burial was required to fossilize these crinoid heads.

Cross-bedded limestone layers sometimes reach great thicknesses. In the Redwall Limestone, cross-beds have been reported from several locations.[24] One set of cross-beds in the Redwall Limestone has a vertical thickness of almost ten meters. This implies that these beds represent the remnants of large (up to 20-meter-high) sand waves (underwater dunes) composed of coarser lime sediment, which were shaped by vigorous and sustained ocean currents moving at 1-1.5 meters per second. Thick cross-beds also occur within limestone members of the Esplanade

23 D. L. Meyer and K. B. Meyer, 1986, Biostratonomy of recent crinoids (Echinodermata) at Lizard Island, Great Barrier Reef, Australia, *Palaios*, 1: 294-302.

24 McKee and Gutschick, 1969, 111.

Sandstone in the western Grand Canyon.

Evidence of current transport of lime sediments is also provided by quartz sand grains, which are found embedded in the fine-grained matrix of many Grand Canyon limestones. These quartz sand grains are common in the Kaibab Limestone and limestones of the Supai Group. Because quartz sand grains cannot be precipitated from seawater, they must therefore have been transported from some other location. Any water current fast enough to move sand grains would also be able to move lime mud. Thus, these quartz sand grains are convincing evidence that the Kaibab Limestone and Supai Group limestones accumulated by deposition of sediments transported by moving water, and not simply by slow, steady, gravity settling of lime muds on the floors of calm and placid seas.

Thus, the evidence in the Grand Canyon limestones overwhelmingly points to the lime sediments of which they are composed having been deposited after rapid transport, and this implies that the limestones were derived from pre-existing sediments elsewhere. Rapid transportation would explain the broken fossil fragments that compose an important part of these limestones. Nevertheless, some of the lime muds were derived simply by precipitation of calcium carbonate from seawater, which explains some of the very fine micrite particles.

65

The Widespread, Rapidly Water-Deposited, Paleozoic Strata of the Grand Canyon, Arizona—Sandstones

If the sedimentary strata of the Grand Canyon were deposited by advancing and retreating seas through millions of years, as is claimed by the conventional geologic community, then clay-rich mud and quartz sand would have been deposited in these oceans by rivers. As rivers enter the ocean they typically form deltas, triangular-shaped (map view) sediment deposits that thin abruptly and become finer grained under the sea in the direction of deeper water. The clay, silt, and sand so deposited when buried and cemented would form strata of shale, siltstone, and sandstone, with distinctive geometry. The sediments deposited in a delta would be wedge-shaped in cross-section, and individual sandstone beds would represent either the distributary channels of the river on the delta or the sand bars at the front of the delta where the sand is deposited where the river enters the ocean.

If Grand Canyon sandstones had accumulated in river deltas, there ought to be evidence of these deltas, where "marine limestones" are interlayered with "terrestrial sandstones." In Grand Canyon, the most obvious candidate would be the Supai Group, repeating layers of sandstone, siltstone, shale, and limestone. Furthermore, these strata contain fossils of both marine and terrestrial animals, as might be expected in the sediments of ancient river deltas.[1] However, although the river-delta model for accumulation of the Supai Group strata has long been considered by the conventional geologic community, most geologists remain skeptical. McKee, who has published the most data relevant to the Supai Group, wrote an entire paper on these strata without using the word "delta."[2] Another geologist who has also extensively studied these strata has questioned the delta model:

Numerous previous workers have loosely assigned Supai deposition to a

1 W. J. Breed, V. Stefanic and G. H. Billingsley, 1986, *Geologic Guide to the Bright Angel Trail,* Grand Canyon, Arizona, American Association of Petroleum Geologists, Tulsa, Oklahoma, 20.

2 E. D. McKee, 1979, Characteristics of the Supai Group in Grand Canyon, Arizona, in *Carboniferous Stratigraphy in the Grand Canyon Country, Northern Arizona and Southern Nevada*, ed. S.S. Beus and R.R. Rawson, Falls Church, VA: American Geological Institute, 105-113.

> deltaic environment. Both stratigraphic and sedimentological data gathered in this study contradict these earlier findings. Vertical sequences typical of deltaic environments are not abundant and paleogeography and basin analysis do not support major deltaic episodes of deposition.…The sand was probably distributed, deposited, and reworked by shallow marine currents.[3]

The exceptionally extensive nature of the individual sandstone layers is perhaps the most obvious problem with the delta model.[4] In fact, the sandstone units within the Supai Group are remarkably thin, and some extend the whole length of the Grand Canyon. These units are not wedge-shaped, as are sand layers in modern deltas. Furthermore, channels that might represent rivers or distributary channels of river systems are unknown.

The failure of the delta model for the Supai Group sandstones has only heightened the prevailing controversy over their formation. An alternative depositional model is that these sandstones represent shallow marine sand deposits,[5] perhaps moved by intense tides, storms, or floods. Another suggestion is accumulation as terrestrial sand dunes in a desert.[6] Thus, no consensus has been reached, even within the conventional geologic community, about the deposition of these sandstone strata, though there is considerable doubt about river accumulation and the delta model. Instead, the controversy that rages is whether the Grand Canyon sandstones were deposited by water or by wind.

Within many of the large-scale horizontal sandstone beds are distinctly inclined cross-beds, most obvious in the Coconino Sandstone (Figure 41, page 1080), but also a dominant property of Supai Group sandstones. For many years these cross-beds have been compared with sand dunes in modern deserts, which are dominated by quartz sand and have inclined internal sand beds. It has been proposed that the Coconino Sandstone, for example, accumulated in an immense windy desert as a result of migrating sand dunes. The cross-beds supposedly accumulated over many thousands of years on the down-wind side of dunes as sand was deposited there. A large number of fossilized footprints, usually in sequences called trackways, are also found in the Coconino Sandstone, and these appear to have been made by four-footed vertebrates moving across the original inclined sand surfaces. Because these fossil-footprint trackways seem similar to

---

3 R. C. Blakey, 1979, Stratigraphy of the Supai Group (Pennsylvania-Permian), Mogollon Rim, Arizona, in *Carboniferous Stratigraphy in the Grand Canyon Country, Northern Arizona and Southern Nevada,* ed. S.S. Beus and R.R. Rawson, Falls Church, VA: American Geological Institute, 102-108.

4 E. D. McKee, 1982, *The Supai Group of Grand Canyon*, US Geological Survey Professional Paper 1173: 1-504.

5 McKee, 1982.

6 R. C. Blakey, 1990, Supai Group and Hermit Formation, in *Grand Canyon Geology*, ed. S.S. Beus and M. Morales, New York: Oxford University Press, and Flagstaff: Museum of Northern Arizona Press, 167-168.

the tracks made by reptiles on desert sand dunes,[7] it has been assumed that these fossilized footprints in the Coconino Sandstone must have been made in dry desert sands, which were then covered up by wind-blown sand and subsequently cemented. Additionally, the sand grains from modern desert dunes studied under a microscope often show pitted or frosted surfaces, so when similar grain-surface textures were observed in the very thick cross-bedded Coconino Sandstone, it strengthened the argument that the Coconino Sandstone was originally deposited slowly as dunes in a dry desert.

Above the Coconino Sandstone is the Toroweap Formation and below is the Hermit Formation (Figure 41), both of which consist of sediments that were clearly deposited in water.[8] How then could there have been a period of dry, desert conditions depositing the Coconino Sandstone between these water-deposited sediment layers, particularly if all these Grand Canyon strata were deposited during the Genesis Flood? This seeming problem is recognized by certain Christian geologists in the conventional geologic community who argue against the Flood depositing the Coconino Sandstone, and who instead argue for the desert dune interpretation:

> The Coconino Sandstone contains spectacular cross bedding, vertebrate track fossils, and pitted and frosted sand grain surfaces. All these features are consistent with the formation of the Coconino as desert sand dunes. The sandstone is composed almost entirely of quartz grains, and pure quartz sand does not form in floods…no flood of any size could have produced such deposits of sand.[9]

However, the fossilized footprint trackways in the Coconino Sandstone have been re-examined in the light of experimental studies.[10] Observations and measurements were performed on 236 trackways made by living amphibians and reptiles in experimental chambers. These tracks were formed on sand beneath water, on moist sand at the water's edge, and on dry sand. The sand surface was mostly sloping at an angle of 25°, although some observations were made on slopes of 15° and 20°, for comparison. Observations also were made of the underwater locomotion of five species of salamanders (amphibians) both in the laboratory and in their natural habitat, and measurements were again taken of their trackways.

---

7 E. D. McKee, 1947, Experiments on the development of tracks in fine cross-bedded sand, *Journal of Sedimentary Petrology*, 17: 23-28.

8 Blakey, 1990, 176-178; C. E. Turner, 1990, Toroweap Formation, in *Grand Canyon Geology,* ed. S.S. Beus and M. Morales, New York: Oxford University Press, and Flagstaff: Museum of Northern Arizona Press, 203-223.

9 D. A. Young, 1990, The Discovery of Terrestrial History, in H.J. Van Till et al, *Portraits of Creation*, Grand Rapids, MI: William B. Eerdmans, 72-73.

10 L. R. Brand, 1979, Field and laboratory studies on the Coconino Sandstone (Permian) vertebrate footprints and their paleoecological implications, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 28: 25-38.

Careful surveying and detailed measurements of 82 fossilized vertebrate trackways in the Coconino Sandstone were then made. A detailed statistical analysis of all these data led to the conclusion, with a high degree of probability, that the fossil footprints in the Coconino Sandstone must have been made underwater.

Furthermore, whereas the animals had produced footprints under all experimental conditions, both up and down the 25° slopes of the laboratory "dunes," all but one of the fossil trackways could have been only made by the animals in question climbing "uphill" underwater. Indeed, whereas fossilized footprints have generally distinct toe imprints, the dry-sand, uphill tracks made in the animal experiments were usually just depressions, with no details. Of added interest were the observations that living salamanders all spent the majority of their locomotion time by walking on the bottom, underwater, rather than by swimming.

When all these observations were put together, the overwhelming conclusion was that the configurations and characteristics of the animals' trackways made on the underwater sand surfaces most closely resembled the fossilized quadruped trackways in the Coconino Sandstone. Furthermore, the fossilized trackways are best understood as suggesting that the animals were entirely underwater (not swimming at the surface) and moving upslope (against the current), in an attempt to get out of the water. This evidence is thus consistent with water deposition of the Coconino Sandstone during the Flood, under conditions of water flow which overwhelmed even four-footed reptiles and amphibians that normally spend most of their time in water.

These initial studies were pursued with further research,[11] the results of which were so significant that brief reports of them were subsequently published elsewhere.[12] Careful analysis of even more fossilized trackways in the Coconino Sandstone again revealed that all but one had been made by animals moving up cross-bed slopes. Furthermore, these additional tracks often showed that the line of the trackway was in one direction, while the animals' feet and toes were pointing in a different direction, indicating that the animals had been walking in a current of water, not air. Other trackways started and stopped abruptly, with no sign that the animals' missing tracks were covered by some disturbance such as shifting sediments, consistent with these animals having simply swum away from the sediment.

Because many of the tracks have characteristics that are virtually impossible to explain unless the animals were moving underwater, it was suggested that newt-like animals made the tracks while walking underwater and being pushed by a current. To test these ideas, living newts were videotaped while walking through

11 L. R. Brand and T. Tang, 1991, Fossil vertebrate footprints in the Coconino Sandstone (Permian) of northern Arizona: evidence for underwater origin, *Geology*, 19:1201-1204.

12 R. Monastersky, 1992, Wading newts may explain enigmatic tracks, Science News, 141: 5; Anonymous, 1992, Wet tracks, *Geology Today*, 8: 78-79.

a laboratory tank with running water. All 238 trackways made by the newts had features similar to the fossilized trackways in the Coconino Sandstone, and their videotaped behavior, while making the trackways, thus indicated how the animals that made the fossilized trackways might have been moving. These additional studies confirmed the conclusions of the earlier research. Thus, it was concluded that all data suggest the fossil tracks are not evidence of desert-wind deposition of dry sand to form the Coconino Sandstone, but instead are conclusive evidence for underwater deposition.

The desert sand-dune model for the origin of the Coconino Sandstone has been challenged also by the observations that large storms, or amplified tides, today produce submarine sand dunes called "sand waves."[13] These modern sand waves on the sea floor contain large cross-beds composed of sand with very high quartz purity. The Coconino Sandstone has thus been interpreted as a submarine sand-wave deposit accumulated by water, not wind. Furthermore, the average angle of slope of the Coconino cross-beds is about 25° from the horizontal, less than the average angle of slope of sand beds on the down-wind side of most modern-desert sand dunes. Those sand beds usually slope at an angle of more than 25°, with some beds inclined as much as 30-34°—the angle of rest of dry sand. Thus, the lower average angle of the Coconino Sandstone cross-beds matches those of modern oceanic sand waves.

Other positive evidence for accumulation of the Coconino Sandstone in water is the feature within it known as "parting lineation," which is commonly formed on sand surfaces during brief erosional bursts beneath fast-flowing water.[14] In fact, parting lineation is not known from any desert sand dunes. Thus, this feature is evidence of vigorous water currents having accumulated the sand that now forms the Coconino Sandstone. Furthermore, the different grain sizes of sand within the sandstone are a reflection of the process that deposited the sand. Thus, when sand grain-size analyses of the Coconino Sandstone, desert sand dunes, and modern sand waves were performed, it was found that the Coconino Sandstone does not compare favorably to dune sands from modern deserts.[15] Instead, the bimodal character of the grain-size distribution in the Coconino Sandstone resembles the sand accumulated underwater as sand waves.

The pitting and frosting of sand grains, claimed to prove wind deposition, has also been investigated further. It now has been found that not only is the pitting

---

13 G. S. Visher, 1990, *Exploration Stratigraphy,* second edition, Tulsa, OK: Penn Well Publishing Co., 211-213.

14 J. R. L. Allen, 1984, *Sedimentary Structures: Their Character and Physical Basis,* second ed., New York: Elsevier Science Publishers, 259-266.

15 Visher, 1990, 213; W. E. Freeman and G. S. Visher, 1975, Stratigraphic analysis of the Navajo Sandstone, *Journal of Sedimentary Petrology*, 45: 651-668; G. S. Visher and J. D. Howard, 1974, Dynamic relationship between hydraulics and sedimentation in the Altamaha estuary, *Journal of Sedimentary Petrology*, 44: 502-521.

not diagnostic of the last process to have deposited the sand grains (pitting can, for example, form first by wind impacts, followed by redeposition by water), but pitting and frosting of sand grains can form outside a desert environment.[16] For example, it has been described how pitting on the surface of sand grains can form by chemical processes during the cementation of sand.

There is now considerable evidence that most of the Grand Canyon sandstones were deposited by the ocean. The Tapeats Sandstone, the Supai Group sandstones, the Toroweap sandstones, the sandstones within the Kaibab Limestone, and the Coconino Sandstone are all characterized by cross-bedding that was produced by transport and deposition of the sand in dune-like sand waves by ocean currents.[17] The water current moves over the sand surface, mounding up the sand into the dune-like sand waves (Figure 42, page 1080).[18] The current erodes sand from the back of the sand wave, and deposits it in the zone of reverse flow as the inclined layers of the cross-beds on the front of the sand waves. The current moves the sand waves forward, eroding sand from the backs and tops of the sand waves as the inclined layers continue to be deposited. Only the fronts of the sand waves are usually preserved as the cross-beds, and usually just the lower half of the original dune fronts. Thus, the heights of the cross-beds preserved are just a fraction of the original sand-wave heights. If the current and sediment supply continue, a second series of sand waves migrating over the area of sand already deposited produces a second layer of sand containing another set of cross-beds.

Sand waves have been observed forming under laboratory conditions in large flumes, and also on certain parts of the ocean floor and in rivers. Experimentally-produced sand waves have been used to demonstrate that sand-wave wave height is related to water depth.[19] As the water depth increases, so does the height of the sand wave which is produced. The empirically-derived relationship between sand-wave height and water depth is shown graphically in Figure 43 (page 1081), on the left side.[20] Sand-wave height is thus approximately one-fifth of the water depth. These laboratory studies have also helped delimit the hydrodynamic conditions under which sand waves and cross-beds form. As a water current flowing over sand reaches a critical velocity, small ripples form. As the water velocity increases, the ripples grow larger and become sand waves that form cross-beds. Observations of sand waves in San Francisco Bay have also been related to the sand waves made in flumes.[21] In Figure 43 the graph on the right side shows the stable bedforms

16 P. H. Kuenen and W. G. Perdok, 1962, Experimental abrasion—frosting and defrosting of quartz grains, *Journal of Geology*, 70: 648-658.

17 For a summary on sand waves, see C. L. Amos and E. L. King, 1984, Bedforms of the Canadian eastern seaboard: a comparison with global occurrences, *Marine Geology*, 57: 167-208.

18 Austin, 1994, 33, Figure 3.11.

19 J. R. L. Allen, 1970, Physical Processes of Sedimentation, London: George Allen and Unwin Ltd, 76-80.

20 Austin, 1994, 34, Figure 3.12.

21 D. M. Rubin and D. S. McCulloch, 1980, Single and superimposed bedforms: a synthesis of San

produced in fine sand at various water depths and water velocities. Cross-beds form within the stability field of sand waves.

Very thick cross-bed sets have been found in the fine-grained sandstone strata of Grand Canyon. Cross-beds sets in Supai sandstones are up to five meters thick,[22] while the quartz sandstone at the base of the Kaibab Limestone has individual cross-beds up to six meters thick.[23] Among the thickest sets of cross-beds are those in the Coconino Sandstone, where a thickness of nine meters has been reported.[24] Even coarse-grained lime sediments contain thick cross-bedding, the most extraordinary examples being in the Redwall Limestone, where nine-meter-thick cross-beds have been described.[25] These great thicknesses of individual cross-beds imply enormous heights of sand waves. Because erosion removed the sand from the tops of the sand waves during deposition, the true height of the sand waves could have been double the present cross-bed thickness. Thus, in the case of the sand waves that formed the cross-beds in the Supai and Kaibab sandstones, the sand-wave heights could have been ten meters, while those that deposited the Coconino Sandstone could easily have been eighteen meters high.

Using the sand-wave heights for the cross-beds in the Supai and Kaibab sandstones, the current velocity that deposited the sand in them can be estimated. For the sand-wave height of ten meters the water depth on the curve in Figure 43 (left side) is 54 meters. Then in Figure 43 (right side) the stability field of sand waves at a water depth of 54 meters is bounded by minimum and maximum water current velocities of 90 centimeters per second and 155 centimeters per second respectively. Thus, cross-beds five meters high were produced from sand waves ten meters high, which would require a water depth of 54 meters and a current velocity between 90 and 155 centimeters per second. Similarly, the nine-meter-thick cross-beds in the Coconino Sandstone were produced by sand waves eighteen meters high, in a water depth of between 90 and 95 meters by a water current velocity between 95 and 165 centimeters per second.[26]

The large-scale cross-beds in Grand Canyon sandstones thus indicate that high

---

Francisco Bay and flume observations, *Sedimentary Geology*, 26: 207-231. For a survey of flume studies of bed configuration, see J. B. Southard and L. A. Boguchwal, 1990, Bed configuration in steady unidirectional water flows. Part 2. Synthesis of flume data, *Journal of Sedimentary Petrology*, 60: 658-679.

22 McKee, 1979, 110, 112.

23 J. W. Brown, 1969, Stratigraphy and petrology of the Kaibab Formation between Desert View and Cameron, Northern Arizona, in *Geology and Natural History of the Grand Canyon Region, Four Corners Geological Society Guidebook*, Fifth field conference, 172.

24 S. S. Beus, 1979, Trail log—third day: South Kaibab trail, Grand Canyon, Arizona, in Carboniferous Stratigraphy in the Grand Canyon Country, Northern Arizona and Southern Nevada, ed. S. S. Beus and R. R. Rawson, Falls Church, VA: American Geological Institute, 16.

25 McKee and Gutschick, 1969, 111.

26 A. A. Snelling and S. A. Austin, 1992, Startling evidence for Noah's Flood! Footprints and sand "dunes" in a Grand Canyon sandstone, *Creation Ex Nihilo*, 15 (1): 46-51.

velocity water currents deposited them as enormous sand waves. Sustained, unidirectional currents of 90 to 155 centimeters per second occurred in deep water. Modern tides and normal ocean currents do not have these velocities in the open ocean, but deep-sea currents have been reported to attain velocities of 150 centimeters per second in the Norwegian Sea, more than 100 centimeters per second out of the Mediterranean Sea, and more than 50 centimeters per second out of the Red Sea.[27] On the bottom of San Francisco Bay at the Golden Gate, currents have been measured at over 250 centimeters per second.[28] However, these high velocities are caused by the flow of tides through restrictions of the ocean within straits, whereas the Grand Canyon strata provide no evidence of having been deposited where there were geographic restrictions. On the other hand, catastrophic events can also produce high-velocity ocean currents. For example, hurricanes are thought to make small sand waves, but hurricane-driven currents approaching 100 centimeters per second in water over 50 meters deep have not been measured. The most severe ocean currents known are generated during a tsunami ("tidal wave"). In shallow oceans, tsunami-induced currents can exceed 500 centimeters per second, and unidirectional currents have been sustained for hours.[29] Such an event would move large quantities of sand, and in its waning stages build huge sand waves in deep water. Thus, tsunamis could have formed the large-scale cross-beds in Grand Canyon sandstones.

From what source was the sand transported to be deposited as these Grand Canyon sandstones? As the quartz and feldspar grains that constitute most of the Grand Canyon sandstones could not have been precipitated from water, these grains had to be derived either by erosion of crystalline basement rocks such as granite, gneiss, or schist, or by reworking of earlier sandstones and sand deposits. The grains in the Tapeats Sandstone were derived from both sources. This sandstone rests directly, with an erosional contact, on both crystalline basement and beveled sandstones, and at its base in some places it contains boulders up to three and five meters in diameter that have been eroded and moved 500 meters from their source in the strata beneath.[30] Thus, this erosion and these boulders are evidence of catastrophic underwater debris flows.

The cross-beds in the Supai Group sandstones dip southeast, indicating that the current that moved the sand flowed southeast.[31] However, there is no acceptable source of quartz sand grains for these Supai strata to the northwest of Grand Canyon. Everywhere north and west, the Supai Group overlies the Redwall

27 P. Lonsdale and B. Malfait, 1974, Abyssal dunes of foraminiferal sand on the Carnegie Ridge, *Geological Society of America Bulletin*, 85: 1697-1712.

28 Rubin and McCulloch, 1980, 207.

29 P. J. Coleman, 1978, Tsunami sedimentation in *The Encyclopedia of Sedimentology*, R. W. Fairbridge and J. Bourgeois, ed., Stroudsburg, PA: Dowden, Hutchison and Ross, 828-831.

30 A. V. Chadwick, 1978, Megabreccias: evidence for catastrophism, *Origins*, 5: 39-46.

31 McKee, 1982, 218-242.

Limestone, which is an extraordinarily pure carbonate with extremely rare sand grains. Furthermore, the Supai sandstones laterally change northwestward, grading into limestone.[32] Therefore, there is no nearby source for quartz sand for the Supai Group sandstones to the west or north of the Canyon. This sand-source problem is recognized:

> Full interpretation of the Supai-Hermit sequence is thwarted by some puzzles. For example, throughout the Grand Canyon region the typically aqueous cross-bedding in the Supai consistently dips toward the south and southeast, indicating that this was the general direction of the depositing currents. Yet, it is difficult to find an adequate northern or northwestern source for such quantities of sand and mud; those that lie in the right direction seem either to have been underwater or composed predominantly of limestone at the appropriate time. [33]

This evidence clearly indicates that the Supai sand grains were transported a great distance by ocean currents, and not by a river. Northern Utah, and even Wyoming, have been postulated as the nearest sources for the Supai sand.[34] However, there is no evidence of a great, ancient river system that eroded and transported the Supai sand grains from Wyoming. Instead, the limestone deposits of an ocean are directly on the path from Wyoming to the Grand Canyon.

The Coconino Sandstone is part of a vast blanket of sandstone extending eastward from Arizona into New Mexico, Colorado, Kansas, Oklahoma, and Texas (Figure 44, page 1082).[35] The area covered by the Coconino and its correlating sandstones is about 520,000 square kilometers, and the sand volume in the sandstones is estimated at about 42,000 cubic kilometers. The cross-beds within the Coconino Sandstone (and the Glorieta Sandstone of New Mexico and Texas) dip toward the south, indicating that the sand came from the north. However, along its northern occurrence the Coconino rests directly on the Hermit Formation, which consists of silt and mud. Thus, it would not be an ample erosional source of sand grains for the Coconino. Therefore, the source of this colossal quantity of sand must be further northward beyond the underlying Hermit Formation and its lateral equivalent in southern Utah. Thus, there is no obvious, nearby source for the Coconino sand grains, and again, this means a very distant source must be postulated.

---

32 McKee, 1982, 335-359.

33 J. S. Shelton, 1966, *Geology Illustrated*, San Francisco, CA: W.H. Freeman, 280.

34 Blakey, 1979, 102.

35 R. C. Blakey and R. Knepp, 1989, Pennsylvanian and Permian geology of Arizona, in *Geologic Evolution of Arizona*, ed. J. Jennie and S. J. Reynolds, Arizona Geological Society Digest, 17: 313-347; D. L. Baars, 1962, Permian system of Colorado Plateau, *American Association of Petroleum Geologists Bulletin* 46: 200-201; J. M. Hills and F. E. Kottlowski, 1983, Correlation of Stratigraphic Units of North America—Southwest/Southwest Mid-continent Region, American Association of Petroleum Geologists, Tulsa, Oklahoma.

In conclusion, the combined evidence indicates that the colossal quantities of sand grains in Grand Canyon sandstones had to be transported and deposited by tsunami-generated ocean currents, which had to also erode and transport the sand over great distances from distant source areas. It is also abundantly obvious that uniformitarian models of desert dunes or river erosion, transport, and sedimentation are woefully inadequate as explanations for these sandstone strata. Instead, abundant evidence for catastrophic, inter-regional erosion, transport, and sedimentation is far more consistent with the biblical description of the Flood and its geological implications.

66

The Widespread, Rapidly Water-Deposited, Paleozoic Strata of the Grand Canyon, Arizona—Shales

Rather than always being rich in lime (calcium carbonate), many muds are dominated by microscopic particles of clay minerals. Rivers carry enormous amounts of clay, much of which comes from weathered materials on the continents. Indeed, clay-rich muds are distinctive of continents and shale is generally assumed to be their sedimentary-rock counterpart. The conventional geologic community favors the delta model for deposition of clay-rich shale, especially if the shale contains fossils of terrestrial plants and animals. However, the delta model for the deposition of Grand Canyon shales has proven inadequate, because of the tremendously extensive nature of these strata and the absence of the necessary sand-channel systems suggestive of rivers. Nevertheless, the belief persists that the Grand Canyon shales represent very slow accumulation of muds in quiet water. Three main lines of evidence are claimed to indicate very slow deposition of muds to form shales—thin laminae, burrows of organisms, and shrinkage cracks.

Laminae are defined as sedimentary layers less than one centimeter thick. They are frequently abundant in fine-grained, clay-rich rocks such as shales. The conventional geologic community often makes the assumption that great periods of time are required to deposit thinly laminated sediments. Usually, each lamina is regarded as representing a seasonal alternation of sedimentary conditions, a feature known in some modern lake sediments. Thus, a single lamina, or pair of laminae, is supposed to represent the alternation between summer and winter deposition over a one-year period. The boundary between successive laminae is claimed to represent a break in sedimentation, perhaps at times caused by a drought. Thousands of laminae, stacked one on top of each other as they are in many shales, are thus supposed to represent thousands or even millions of years of slow accumulation. Furthermore, the conventional geologic community maintains that catastrophic sedimentary action would homogenize fine clay-rich sediments, and thus would deposit massive, non-laminated strata.

The thinly laminated sediments of the Green River Formation of Colorado, Utah, and Wyoming are usually regarded as a classical example of thin laminae that represent yearly alternations in sedimentation (called varves):

> There are more than a million vertically superimposed varve pairs in some parts of the Green River Formation. These varve deposits are almost certainly fossil lake-bottom sediments. If so, each pair of sediment layers represents an annual deposit.…The total number of varve pairs indicates that the lakes existed for a few million years.[1]

This slow-and-gradual notion of laminae formation has consequently had a powerful impact on the interpretation of many sedimentary deposits.

However, a large body of experimental and observational data refutes this claim that laminae in shales generally formed slowly.[2] In fact, new evidence demonstrates just the opposite, that fine-grained laminated sediments can, and do, form by rapid sedimentation. Indeed, rapid deposition of laminae has been observed in some modern situations, and laboratory experiments have documented how extremely thin laminae form rapidly.

In 1960, Hurricane Donna created surging ocean waves that flooded inland up to eight kilometers for six hours along the coast of southern Florida.[3] The hurricane deposited a 15-centimeter-thick mud layer, with numerous thin laminae. In Colorado, a storm in June 1965 caused flooding of Bijou Creek, and fine lamination was produced in the resultant sediments.[4] The June 12, 1980, eruption of Mount St Helens produced a hurricane-velocity, surging flow of volcanic ash, which accumulated in less than five hours as a 7.6-meter-thick layer of laminated fine-grained volcanic ash.[5] A Swiss lake, which was thought to accumulate one pair of laminae each year, was shown to accumulate up to five laminae pairs per year by a rapid, turbid-water, underflow process.[6] Indeed, one layer within the Swiss lake that dates from the year 1811 was observed in 1971 (160 years later) to be buried beneath 300 to 360 varve-like silt laminae.

Laboratory experiments have also enabled researchers to observe this process. Horizontal laminae were produced in fine-grained sediment by a high-velocity

1 Young, 1990, 77.

2 For a summary of the literature, see S. A. Austin, 1984, *Catastrophes in Earth History*, El Cajon, CA: Institute for Creation Research.

3 Ball, Shinn and Stockman, 1967.

4 E. D. McKee, E. J. Crosby and H. L. Berryhil, Jr, 1967, Flood deposits, Bijou Creek Colorado, June 1965, *Journal of Sedimentary Petrology*, 37: 829-851.

5 S. A. Austin, 1986, Mount St Helens and Catastrophism, in *Proceedings of the First International Conference on Creationism*, vol. 1, Pittsburgh, PA: Creation Science Fellowship, 3-9.

6 A. Lambert and K. Hsu, 1979, Non-annual cycles of varve-like sedimentation in Walensee, Switzerland, *Sedimentology*, 26: 453-461.

current in a circular flume.[7] The high-velocity currents had sorted and deposited the sediment grains by weight, density, and shape. The grain segregation occurs as a turbidity current loses velocity, producing a succession of thin, parallel laminae. However, laboratory experiments have also shown that a current is not needed to form laminae. Both in water and air, rapidly deposited homogenized, heterogranular clay and silt is deposited *en masse*, but separates just after deposition to form very thin laminae.[8] Evidently, the laminae form rapidly just below the sediment-water or sediment-air interface by a grain-penetration process, the coarse silt particles penetrating downward a certain distance through the clay particles until they meet the resistance of more compacted clay. Similar, more recent experiments have confirmed that heterogranular mixtures spontaneously segregate in the absence of external perturbations into alternating laminae of smaller and larger grains, this spontaneous stratification being related to the occurrence of avalanches.[9]

This rapid grain-segregation has also been demonstrated to have potentially been responsible for forming laminae in some ancient rocks.[10] Two laminated sedimentary rocks were carefully disaggregated then rapidly redeposited in a laboratory sedimentation apparatus, where the laminae of the original rocks were reproduced without requiring long periods of time.

The claim that the laminae in shales formed by slow deposition has also been disputed as a result of field research on such rocks. Marine black shales in Scotland were found to intertongue with large boulders.[11] It was suggested that the boulders were moved during a submarine earthquake, and that an enormous tsunami rapidly deposited shallow marine organisms in clay-rich muds on top of the boulders. Similarly, large boulders have also been reported within the Bright Angel Shale of the Grand Canyon, and these would also appear to have required rapid accumulation of the shale. Rapid deposition of laminated shales and mudstones has been documented in Ireland, England, and Canada.[12] It was proposed that the laminae were deposited from high-velocity, dense suspensions of sediment and water that moved over the ocean floor. In Washington state, thin laminae in

7 P. H. Kuenen, 1966, Experimental turbidite lamination in a circular flume, *Journal of Geology*, 74: 523-545.

8 G. Berthault, 1986, Experiments on lamination of sediments resulting from a periodic graded-bedding subsequent to deposition—a contribution to the explanation of lamination of various sediments and sedimentary rocks, *Compte Rendus Académie des Sciences, Paris*, 303: 1569-1574; G. Berthault, 1988, Sedimentation of a heterogranular mixture: experimental lamination in still and running water, *Compte Rendus Académie des Sciences, Paris*, 306: 717-724.

9 H. A. Makse et al, 1997, Spontaneous stratification in granular mixtures, *Nature*, 386: 379-382; J. Fineberg, 1997, From Cinderella's dilemma to rock slides, *Nature*, 386: 323-324.

10 Berthault, 1986.

11 E. B. Bailey and J. Weir, 1932, Submarine faulting in Kimmeridgian times, East Sutherland, *Transactions of the Royal Society of Edinburgh*, 57: 429-454.

12 D. J. W. Piper, 1972, Turbidite origin of some laminated mudstones, *Geological Magazine*, 109: 115-126.

beds of clay, silt, and sand more than 90 meters thick called the Touchet beds were once supposed to have been deposited slowly by gradual water fluctuations in an ancient lake, but were later reinterpreted as slack-water sediments associated with the catastrophic floods that formed the famous Channeled Scabland of eastern Washington.[13]

The Green River Formation in Wyoming is dominated by oil shale containing very thin laminae. The popular opinion is that each pair of laminae represents a varve deposited during a one-year period. These very thick laminated oil shales are claimed to represent slow deposition on a lake bottom over millions of years. However, this varve interpretation fails a crucial test.[14] Near Kemmerer, Wyoming, the Green River Formation contains two tuff beds, each 2 to 3 centimeters thick, representing the synchronous deposits of two volcanic eruptions. The two tuff beds are separated by 8.3 to 22.6 centimeters of laminated oil shale. According to the varve interpretation, the number of years between the two tuff beds should be exactly the same over the wide area the tuff beds cover, so the number of varves between the tuff beds should be the same over the entire area. Furthermore, the average thickness and composition of the laminae should be nearly constant over this same wide area. However, the number of laminae counted between the two tuff beds varies from 1,160 to 1,568, with an overall increase of laminae number (up to 35 percent) and laminae thickness, from basin center to basin margin. The kerogen content of the oil shale also decreased from basin center to basin margin. Quite clearly, these observations are inconsistent with the varve model of deposition of the Green River Formation in a stagnant lake:

> The differences in laminae count, laminae thickness, unit thickness, and kerogen content can be accounted for by a model evoking more voluminous sedimentation and more frequent sedimentation "events" nearer the lake margins than center. The "varve" model is not adequate to explain these differences because it would predict the same number of laminae lake-wide as well as consistent unit thickness and kerogen content.[15]

More recent flume experiments have demonstrated that clay particles flocculate in larger "clumps" to be transported and deposited at flow velocities similar to sand.[16] The experimenters found that deposition-prone floccules formed over a wide

13 R. J. Carson, C. R. McKhann and M. H. Pizey, 1978, The Touchet beds of Walla Walla Valley, in *The Channeled Scabland*, ed. V. R. Baker and D. Nummedal, Washington, D.C.: National Aeronautics and Space Administration, 173-177.

14 H. Buchheim and R. Biaggi, 1988, Laminae counts within a synchronous oil shale unit: a challenge to the "varve" concept, *Geological Society of America Abstracts with Programs*, 20: A317.

15 Buchheim and Biaggi, 1988.

16 J. Schieber, J. Southard, and J. Thaisen, 2007, Accretion of mudstone beds from migrating floccule ripples, *Science*, 318: 1760-1763; J. H. S. Macquacker and K. M. Bohacs, 2007, On the accumulation of mud, *Science*, 318: 1734-1735.

range of experimental conditions, and floccule ripples developed into low-angle foresets so that the resulting mud beds appeared laminated after postdepositional compaction. It was concluded that laminated mudstones (and shales) can therefore be deposited under far more energetic conditions than conventionally assumed. Furthermore, since mudstones make up the majority of the sedimentary record (about two-thirds), a total reappraisal is required of the rate at which many sedimentary strata sequences accumulated.

Burrows are the tubes left by organisms that live within sediments. Many terrestrial and marine organisms occupy burrows and leave obvious evidence of their activity by disrupting layering, especially lamination in clay-rich muds. Modern marine and terrestrial organisms are "biological bulldozers," so thoroughly reworking and burrowing recent sediments that stratification is often completely homogenized. For example, the distinctive five-centimeter-thick, graded sand, silt, and mud layer deposited offshore of the central Texas coast by Hurricane Carla in 1961 had been so thoroughly burrowed by marine organisms that 20 years later it was unrecognizable.[17]

Therefore, if the burrowing in sediments on land and under the sea is so intense, how could any laminae be preserved in the strata record if sediments accumulated very slowly and were in contact with burrowing organisms for so long? It has been proposed that the deep-burrowing activity of organisms had not yet evolved when most Grand Canyon strata were deposited.[18] However, this view has been strongly challenged by deep-burrow structures found even in Cambrian strata.[19] On the other hand, the reason why major laminae have not been severely burrowed may be because the thick sequences of strata were deposited rapidly, not slowly. The sediments would only have been in contact with burrowing organisms for very short periods of time, ensuring the probability of burrowing was low.

While the evidences of rapid sedimentation in the Bright Angel Shale (Cambrian) of Grand Canyon are obvious, it is still claimed that some horizons where trackways and burrows occur represent long time periods.[20] Of course, burrows and trackways are regarded as features produced by normal life activities of organisms, with some burrows representing feeding, and others representing resting. Thus, burrows and trackways might indicate cessation of sedimentation,

17 R. H. Dott, Jr., 1983, Episodic sedimentation—How normal is average? How rare is rare? Does it matter?, *Journal of Sedimentary Petrology*, 53: 12.

18 C. W. Thayer, 1979, Biological bulldozers and the evolution of marine benthonic communities, *Science*, 203: 458-461.

19 M. F. Miller and C. W. Byers, 1984, Abundant and diverse early Paleozoic infauna indicated by the stratigraphical record, *Geology*, 12: 40-43; M. Sheehan and D. R. J. Schiefelbein, 1984, The trace fossil *Thalassinodes* from the Upper Ordovidician of the Eastern Great Basin: deep burrowing in the early Paleozoics, *Journal of Paleontology*, 58: 440-447.

20 D. K. Elliott and D. L. Martin, 1987, A new trace fossil from the Cambrian Bright Angel Shale, Grand Canyon, Arizona, *Journal of Paleontology*, 61: 641-648.

which is not consistent with a single flood forming great thicknesses of strata. However, trackways of trilobites on bedding surfaces in the Bright Angel Shale did not necessarily require long periods of time to form. Modern marine arthropods move rapidly across sediment surfaces and form short trackways in seconds. Both horizontally and vertically oriented burrows are in the Bright Angel Shale. Each of the three types of horizontal burrows (*Palaeophycus, Phycodes*, and *Teichichnus*) observed in the Bright Angel Shale are formed by marine organisms burrowing while entirely buried within the sediment. Thus, because these horizontal burrows had no connection with the overlying water column, the organisms that produced them did not require cessation of sedimentation, and their activity would not have been restricted by the overlying sedimentation, whether slow or fast.

On the other hand, the two types of vertically oriented burrows (*Dipolocraterion* and *Skolithos*) observed in the Bright Angel Shale have direct bearing on the rate of sedimentation question, because they connected vertically to the water column that overlaid the sediments. If these vertical burrows were the dwellings of the organisms, then they represent occupation levels upon which these marine burrowers lived and died. This would suggest long time periods elapsed at each burrowing level, an interpretation favored by the conventional geological community that would cast doubt on the sedimentation being due to catastrophic flooding. However, instead of representing occupation or dwelling-sites of organisms, these vertical burrows may have been excavated by organisms escaping vertically from rapid sediment burial. The modern worm-like organism *Phoronopsis viridis* constructs burrows that closely resemble *Skolithos*.[21] Laboratory experiments show that burial induces an escape response from the organism, which can produce either vertical or horizontal burrows.[22] *Dipolocraterion*, the commonest vertical burrow in the Bright Angel Shale, could have been made also by upward movement of an organism in response to rapid sedimentation. It has been admitted that "… *Dipolocraterion* cannot be dismissed as an escape trace."[23] If vertical burrows in shale are regarded as the traces of animals escaping from sediment that was rapidly burying them, then the long time periods needed for their formation disappears. Instead, they become evidence for rapid burial.

Shrinkage cracks are the third line of evidence claimed to indicate great periods of time within sedimentary layers. Clay-rich muds often shrink when they lose water and form cracks on the bedding surfaces. Many different strata surfaces within the Grand Canyon sedimentary sequence display irregular and polygonal cracks. These are especially abundant within the Hakatai Shale, Supai Group, and Hermit Formation. Interpreted as shrinkage cracks, they resemble those commonly seen in the beds of dry lakes and ponds, or on mud flats on modern deltas. Thus, it

21 Miller and Byers, 1984, 40.

22 T. E. Ronan, Jr, 1975, Structural and paleoecological aspects of a modern marine soft-sediment community: an experimental field study, Ph.D. dissertation, University of California, Davis.

23 Miller and Byers, 1984, 41.

has been proposed that these Grand Canyon shales were alternately wet and dry during deposition, like a modern delta or mud flat. When the surface was wet, water brought in clay-rich muds. Then, when drying of the mud began, shrinkage of mud occurred and a layer of cracks formed. This repeated wetting and drying formed the different layers of cracks in the Supai Group and Hermit Formation, the desiccation process claimed to require enormous amounts of time.[24] Thus, no single flood could be responsible for depositing these shales:

> Mudcracks commonly develop on tidal flats or the shores of lakes when mud dries out. As the mud dries, it shrinks and cracks into individual plates that curl up with increased drying. Obviously, mudcracks could not have formed during flood conditions, but only afterward. The Supai Group within the Grand Canyon contains numerous layers with abundant mudcracks, as do the Moenkopi, the Chinle, and the Morrison Formations. Each of these formations had to experience several episodes of wetting and extended drying out. They cannot be global flood deposits.[25]

However, a cross-sectional view of the shrinkage cracks in the Hermit Formation reveals that the cracks frequently occur in clay-rich shale where it contacts thinner silty or sandy layers. After the clay-rich layer contracted and cracked, silt or sandy material, which had not shrunk as much, filled in the cracks. The reason why these shrinkage cracks are apparent in the Hermit Formation is that the silty or sandy material that fills in the cracks is of a different color and resistant to erosion. The desiccation hypothesis for these shrinkage cracks requires that each clay-rich layer dried and cracked before the silt or sand layer was deposited on top of it. This requires that the infilling of the cracks was from above, and that the cracks only penetrate downward. However, the Hermit Formation shrinkage cracks are from above and from below. This downward and upward filling of cracks occurs where two clay-rich shale layers have been penetrated by a much thinner sandy layer which lies between them. Thus, logic requires that the lower and upper clay-rich layers shrank and cracked simultaneously. Furthermore, the principle of cross-cutting relationships requires that the thin sandy and upper clay-rich layers were on top of the lower clay-rich layer when the clay-rich layers cracked. Thus, no period of desiccation of the lower clay-rich layer would have been required to shrink and crack it before the sandy layer infilled it. This evidence, therefore, requires that the cracks in the Hermit Formation formed while the clay-rich layers were buried, and not while they were drying at the surface.

It is now widely recognized that shrinkage cracks can form in clay-rich sediments without desiccation.[26] Both modern subaqueous natural environments and

---

24 Wonderly, 1987, 6-10.

25 Young, 1990, 74.

26 W. A. White, 1961, Colloid phenomena in sedimentation of argillaceous rocks, *Journal of Sedimentary Petrology*, 31: 560-570; L. Dangeard et al, 1964, Triggers et structures observes au cours du passement des vases sous l'eau, *Compte Rendus Académie des Sciences, Paris*, 258: 5935-5938; J. F. Burst, 1965.

laboratory experiments have demonstrated that wet, clay-rich sediments commonly develop shrinkage cracks. That evidence documents the process of *syneresis*, a volume reduction that occurs as clay-rich sediments lose water in a subaqueous or subsurface environment. Numerous examples of such shrinkage cracks in shales that have been filled from above and below have been documented.[27] Indeed, the "from-above-and-below" filling is diagnostic of syneresis cracks. They are common in the geologic record and form in a substrata environment without the desiccation process. Such research, experiments, and field observations discount the long-age interpretation of the shrinkage cracks in the Hermit Formation shales. Thus, all claimed evidence for slow-and-gradual deposition of the shales in the Grand Canyon strata sequence has proved incorrect by both experimental and field observations. Instead, these data remain consistent with catastrophic flood deposition of these shales.

Subaqueously formed shrinkage cracks in clay, *Journal of Sedimentary Petrology*, 35: 348-353; P. H. Kuenen, 1965, Value of experiments in geology, *Geologie en Mijnbouw*, 44: 22-36; P. S. Plummer, 1978, The upper Brachina Subgroup: a late Precambrian intertidal deltaic and sandflat sequence in the Flinders Ranges, South Australia, Ph.D. dissertation, University of Adelaide, Adelaide, Australia.

27 P. S. Plummer and V. A. Gostin, 1981, Shrinkage cracks: desiccation or synaeresis?, *Journal of Sedimentary Petrology*, 51: 1147-1156.

67

Other Examples of Widespread, Rapidly Water-Deposited Strata

The detailed discussion of the Grand Canyon strata demonstrates in a conclusive manner that the evidence associated with these limestone, sandstone, and shale strata strongly favors their catastrophic deposition by water on a grand scale over a widespread area, contrary to the oft-repeated claims that these strata were deposited during long ages of slow-and-gradual deposition. Indeed, for such rapid sedimentation to have occurred on a widespread scale, the evidence points to the ocean having been over the continent, the sediments being transported very long distances after erosion in great quantities from source areas. The sum total of evidence in these strata is thus very compelling for their flood deposition. However, it also needs to be recognized that many of these same features found in these strata that are consistent with catastrophic flood deposition are also found in similar and other types of strata in many other parts of the world. Thus, it is important to describe other examples of widespread, rapidly water-deposited strata of other rock types from other parts of the world.

The Shinarump Conglomerate, Utah

The Shinarump Conglomerate has an average thickness of about 15 meters and covers more than 260,000 square kilometers in Utah and neighboring states. This formation is composed of sand and rounded pebbles, like those often found in many stream beds. Indeed, this conglomerate looks very much like a river deposit. The usual interpretation is that a network of braided streams flowed over this vast area, slowly and gradually depositing pebbles and sand over a long period of time. Of course, the stream beds of a braided system frequently change as the stream changes course, so it is argued that as these streams migrated they gradually covered this entire vast area with stream deposits.[1]

However, the Shinarump Conglomerate does not match any modern depositional environment, and especially does not compare to the modern analog of a braided

1 R. F. Dubiel, 1994, Triassic deposystems, Paleogeography and Paleoclimate of the western interior, in *Mesozoic Systems of the Rocky Mountain Region, USA*, M. V. Caputo, J. A. Peterson and K. J. Franczyk, ed., Denver, CO:Rocky Mountain Section, Society for Sedimentary Geology, 133-168.

stream system. Specifically, where is there any place in the world today where streams are depositing sand and conglomerate of such massive uniform thickness like this over such a vast area of 260,000 square kilometers, or even close to that? There is simply not one known. Streams make deposits that meander through a valley, but they don't create uniform deposits over tens of thousands of square kilometers. Thus, it is far more realistic to explain this conglomerate formation as deposited by a massive sheet of rapidly flowing water *en masse*, in what therefore had to be a catastrophic event over such a vast area in a very short time. Such conditions are totally consistent with Flood deposition.

The Uluru Arkose and Mt. Currie Conglomerate, Central Australia

Technically known as an inselberg, Uluru is an isolated rock-mass or monolith that rises steeply on all sides to a height of about 340 meters above the surrounding desert plain of central Australia. It is, in effect, an enormous outcrop of beds of arkose, a coarse sandstone consisting of poorly sorted, jagged grains of other rock types, and feldspar. The arkose occurs in multiple layers that together form a cohesive massive rock unit, and these beds dip at 80-85°. The cumulative thickness of the arkose through the entire length of Uluru is at least 2.5 kilometers, but from drilling below the surrounding desert sands, the total thickness of this arkose has been determined at almost 6,000 meters. Its full lateral extent is poorly known, due to paucity of other outcrops, but the Uluru Arkose is very conservatively estimated at covering an area of at least 30 square kilometers.[2]

Thirty kilometers west of Uluru is Kata Tjuta, a series of huge, rounded, rocky domes, the highest being Mt. Olga about 600 meters above the desert floor. These spectacular domed rock-masses cover an area of about 40 square kilometers (8 km x 5 km), and consist of layers of conglomerate dipping at 10-18° to the southwest, with a total cumulative thickness of 6,000 meters. This massive conglomerate unit, known as the Mt. Currie Conglomerate, extends under the desert sands to other outcrops over an area of more than 600 square kilometers. The conglomerate is poorly sorted and contains boulders up to 1.5 meters in diameter, as well as cobbles and pebbles, held together by a matrix of finer fragments and cemented sand, silt, and/or mud. The pebbles, cobbles, and boulders are generally rounded and consist mainly of granite and basalt, but also some sandstone, rhyolite, and several kinds of metamorphic rocks.

Though the outcrops of the Uluru Arkose and the Mt. Currie Conglomerate are isolated from one another, the available evidence clearly suggests that both rock units were formed at the same time and in the same way. Conventional geologic

2 D. J. Forman, 1965, *Ayers Rock, Northern Territory 1:250,000 geological map series plus explanatory notes*, Canberra, Australia: Bureau of Mineral Resources; A. T. Wells et al, 1970, Geology of the Armadeus Basin, Central Australia, *Bureau of Mineral Resources Bulletin 100*, Canberra, Australia; I. Sweet and I. H. Crick, 1992, Uluru and Kata Tjuta: a geological history, *Australian Geological Survey Organisation*, Canberra, Australia.

explanations for these rocks units, which are now regarded as uppermost (or terminal) Neoproterozoic, have changed. They were once regarded as having been deposited by massive glacial action during a claimed "late Precambrian ice age,"[3] but are now believed to be the products of rapid erosion and deposition in alluvial fans adjacent to mountains in an arid landscape. Occasional flash floods are believed to have scoured the mountain ranges and carried the rubble many tens of kilometers out onto the adjoining alluvial flats, where the two separate deposits of arkose and conglomerate are supposed to have progressively accumulated, slowly and gradually, with successive flash floods over many thousands, or perhaps even millions, of years. Of course, the streams had to be very swiftly flowing in order to carry boulders up to 1.5 meters across, and the stream channels needed to be large and form a vast network in order to deposit the conglomerate and arkose over such vast areas.

While large alluvial fans are known on the earth's surface today, none are forming over such vast areas with such massive thicknesses, or with the scale and intensity of the sheet flooding that would have been required to transport such enormous quantities of conglomerate and sand such long distances with a ferocity capable of carrying boulders up to 1.5 meters across. Furthermore, if deposition had been episodic over millions of years, there ought to be evidence of erosion (such as channels) and weathering surfaces between the layers within both the conglomerate and the arkose, while some compositional and fabric variations would be expected between successive layers. However, in the exposures at Uluru and Kata Tjuta, the arkose and conglomerate compositions, respectively, and their fabrics, are uniformly similar throughout the 2.5-kilometer thickness at Uluru and the 1.8-kilometer thickness exposed at Kata Tjuta, and the layering is extremely regular and parallel. In contrast, where there are large alluvial fans on the earth's surface today, deposition on them is only occurring at a greatly reduced rate and scale, and most of the water flow across them in flash floods erodes channels in the earlier deposits.

Furthermore, the ubiquitous fresh feldspar crystals in the Uluru arkose would never have survived the claimed millions of years of deposition, as feldspar deposited in sheets of sand only centimeters thick spread over many tens of square kilometers and exposed to the sun's heat, water, and air over countless years would decompose relatively quickly to clays. Additionally, sand grains that are moved over long distances and periodically swept further and further by water over vast time periods would lose their jagged edges to become smooth and rounded. Moving water would also produce sorting of the sands. Thus, fresh feldspar crystals and jagged, unsorted sand grains are more consistent with the Uluru Arkose having accumulated rapidly.

The implication of all this evidence is that the deposition of the arkose and the

3 Holmes, 1965, 737-740.

conglomerate concurrently as lateral equivalents required an amount and force of water sufficient to erode, transport, and deposit at least 4,000 cubic kilometers of boulders, pebbles, cobbles, and sand distances of at least tens of kilometers in successive continuous pulses, so as to stack the resultant layers to a thickness of 6,000 meters over at least 600 square kilometers, all probably in a matter of hours or days at the very most![4] This description is consistent with what we know of turbidity currents and submarine debris flows. However, the scale, intensity, and rapid repetition would not only have required cataclysmic flooding, but repetitive fault movements and earthquakes to trigger the currents and flows responsible for the rapid successive pulses of erosion, transport, and deposition.

Kingston Peak Formation, Southeastern California

Another graphic example of catastrophic deposition is the Kingston Peak Formation in the eastern Mojave Desert of southeastern California. In its type section in the northern Kingston Range, the Kingston Peak Formation is dominated by very coarse clastics, with clasts ranging from pebble size to enormous blocks greater than 1.5 kilometers wide.[5] More than twelve such megaclasts, with their main axes greater than 200 meters long, occur along a 17-kilometer exposed strike length within the Kingston Peak Formation. Each gigantic megaclast often consists of portions of the dolomite units that underlie the Kingston Peak Formation. Two of these megaclasts seem to have been rotated into place, while the other ten megaclasts occur at various levels with bedding concordant to the surrounding Kingston Peak Formation. Directly associated with the large megaclasts are lithology-matching, clast-supported megabreccias. Away from these gigantic megaclasts, the sizes of the clasts in these megabreccias, and their angularity, decreases, matrix/clast ratio increases, and clasts of other lithologies become more common. Several of the largest megaclasts sit directly on top of thick, massive, carbonate-rich, matrix-supported conglomerates, which are sometimes called "pudding stones," but which are often known as *diamictites*. These pudding stones have been interpreted as long-runout, matrix-supported submarine debris flows that carried sedimentary blocks (including the carbonates and many of the largest megaclasts) into a depositional basin. Multiple stratigraphic levels of megaclast emplacement, deformation of the upper part of the underlying rock unit in the basal section of the Kingston Peak Formation, and the breccia facies associations within the formation, all indicate a brief depositional period from the upper portion of the underlying rock unit through the entire Kingston Peak Formation.

The observational data support a catastrophic sedimentary-tectonic model for deposition, with gravitational collapse of a basin margin generating mass-flow

4 A. A. Snelling, 1984, The origin of Ayers Rocks, *Ex Nihilo*, 7 (1): 6-9; A. A. Snelling, 1998, Uluru and Kata Tjuta: testimony to the Flood, *Creation*, 20 (2): 36-40.

5 K. P. Wise and S. A. Austin, 1999, Gigantic megaclasts within the Kingston Peak Formation (upper Precambrian, Pahrump Group), south-eastern California: evidence for basin margin collapse, *Geological Society of America Abstracts with Programs 31*, A455-A456.

deposits, turbidites, high-energy currents, and enormous megaclasts. The sandy and limey debris flows that produced the pudding stones are estimated to have moved at a rate of 15-30 meters per second, after being instantly generated by the onset of massive local faulting.[6] A displacement of 950 meters or more in some areas along the giant fault scarp would have changed the gentle slope of the continental shelf depositional environment to a slope approaching 60°. This would have resulted in flows of fluidized rock masses cascading down this slope and flowing across the depositional basin below at 50-100 meters per second. Large-scale slumping would have occurred in deeper areas, as huge megaclasts or slabs hundreds of meters long slid downslope within a succession of high concentration turbidites.

The Kingston Peak Formation has traditionally been interpreted as a tillite, and therefore of glacial origin.[7] However, there is now abundant observational data that is far more consistent with this formation being a submarine landslide deposit, as described above. Paleomagnetic and fossil data, and the presence of carbonates, suggest a low-latitude, warm water, position for this area during deposition of the Kingston Peak Formation, which is an improbable glacial environment.[8] Furthermore, the faceted and striated boulders in the Kingston Peak Formation could have been produced during conditions of catastrophic mass movement, while pillow lavas and ripple marks throughout the formation are unequivocal evidence of subaqueous deposition. Indeed, dish structures, inverse to normal-graded beds, turbidites, flame structures, and convolute lamination all indicate not just subaqueous, but also rapid deposition, consistent with debris flows resulting from a submarine landslide. Thus, the Kingston Peak Formation would be better described as a diamictite.

The Kingston Peak Formation is only one of many upper Precambrian diamictites that are conventionally thought to be glacial deposits. In western North America, the Kingston Peak Formation apparently correlates with other similar formations from Mexico northward through the western United States and Canada up to at least Alaska.[9] Upper Proterozoic diamictites have also been recognized in at

6 R. Sigler and V. Wingerden, 1998, Submarine flow and slide deposits in the Kingston Peak Formation, Kingston Range, Mojave Desert, California: evidence for catastrophic initiation of Noah's Flood, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 487-502.

7 J. M. G. Miller, L. A. Wright and B. W. Troxel, 1981, The Late Precambrian Kingston Peak Formation, Death Valley Region, California, in *Earth's Pre-Pleistocene Glacial Record: International Geological Correlation Program Project 38: Pre-Pleisotocene Tillites*, M. J. Hanbrey and W. B. Harland, ed., Cambridge University Press, 745-748; J. M. G. Miller, 1985, Glacial and syntectonic sedimentation: the upper Proterozoic Kingston Peak Formation, southern Panamint Range, eastern California, *Geological Society of America Bulletin*, 96; 1537-1553.

8 S. A. Austin and K. P. Wise, 1994, The pre-Flood/Flood boundary: as defined in Grand Canyon, Arizona and eastern Mojave Desert, California, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 37-47.

9 J. H. Stewart, 1972, Initial deposits in the Cordilleran Geosyncline: evidence of a late Precambrian (<850m.y.) continental separation, *Geological Society of America Bulletin*, 83: 1345-1360.

least 100 other formations located in at least fifteen countries around the globe, including other parts of the United States, southern Australia, and southern Africa.[10] These correlated diamictites that dot the globe are commonly associated with low-latitude indicators, so these deposits may also have not been produced by glaciation.[11]

Essentially coarse conglomerates, diamictites are the product of substantial mechanical erosion and are commonly deposited during tectonic disturbances. The lithological character and gross dimensions of the Kingston Peak Formation and the upper Proterozoic diamictites are comparable to features in modern giant submarine landslide deposits. For example, off Hawaii, blocks of rock up to 10 kilometers long have been transported more than 50 kilometers, and off Norway, where an immense headwall nearly 300 kilometers long defines the source area, the debris is up to 450 meters thick and spread over a distance of 800 kilometers.[12] Thus, these submarine debris flows duplicate most, if not all, the features unique to these diamictites. Consequently, the major diamictites found not only in the upper Proterozoic, but at other levels in the geological record, all around the globe can be interpreted more consistently as having been produced by giant submarine landslides or debris flows.[13] Because the Kingston Peak Formation and all these other upper Proterozoic diamictites it correlates with globally at the same level in the geologic record are best understood as submarine debris flow/landslide deposits, there must have been a tectonic disturbance of catastrophic global dimensions.

Hawkesbury Sandstone, Sydney Basin, Australia

The Hawkesbury Sandstone dominates the landscape within a 100 km radius of the city center of Sydney. It is a flat-lying layer of sandstone with an areal extent of about 20,000 square km and a maximum thickness of 250 m.[14] Rather than consisting of just one sandstone bed encompassing its total thickness, the Hawkesbury Sandstone is made up of three principal rock types—sheet sandstone, massive sandstone, and relatively thin mudstone. Conventionally, this formation

10 W. B. Harland, 1983, The Proterozoic glacial record, in *Proterozoic Geology: Selected Papers from an International Proterozoic Symposium, Geological Society of America Memoir*, 161: 279-288.

11 L. J. G. Schermerhorn, 1974, Late Precambrian mixtites: glacial and/or nonglacial?, *American Journal of Science*, 274: 673-824.

12 J. G. Moore et al, 1989, Prodigious submarine landslides on the Hawaiian ridge, *Journal of Geophysical Research*, 94: 17,465-17,484; E. G. Nisbet and D. J. W. Piper, 1998, Giant submarine landslides, *Nature*, 392: 329-330.

13 M. J. Oard, 1994, Submarine mass flow deposition of pre-Pleistocene 'Ice Age' deposits, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 407-418; M. J. Oard, 1997, Ancient ice ages or gigantic submarine landslides?, *Creation Research Society Monograph 6*, Chino Valley, AZ: Creation Research Society Books.

14 P. J. Conaghan, 1980, The Hawkesbury Sandstone: gross characteristics and depositional environment, in *A Guide to the Sydney Basin*, C. Herbert and R. Helby, ed., Geological Survey of New South Wales, Bulletin 26, 188-253.

is designated as middle Triassic, and has variously been attributed to having been deposited in sedimentary environments ranging from shallow marine and littoral (intertidal) to estuarine, fluvial, and lacustrine, and even aeolian. Based on studies of present-day depositional environments and the depositional features within the Hawkesbury Sandstone, the current favored explanation for deposition of the Hawkesbury Sandstone is deposition by a low-sinuosity river such as the Brahmaputra River in Bangladesh.[15]

However, that view has been challenged, because key depositional features in the Hawkesbury Sandstone do not match those in the Brahmaputra River floodplain. For example, the frequent cross-bedding, generally 2-5 m high, but sometimes up to 8 m high,[16] has foresets dipping at between 20 and 30°, usually averaging about 25°, which contrasts with the maximum dip of 18° recorded for sand-wave cross-beds in the banks of the Brahmaputra River, where even lower average foreset dips of 3-7° are common.[17] Furthermore, the sand waves are distinct, in that they are two-dimensional forms with straight to sinuous crests, with no examples of lunate sand waves having been identified, for example, in the Brahmaputra River floodplain, regardless of channel size or discharge, whereas the sand waves responsible for generating the cross-bedding in the Hawkesbury Sandstone, as evident from the foresets in plan view, were straight-crested and lunate.

Even more significant is the fact that the Hawkesbury Sandstone is composed of well-sorted and rounded, generally fine to medium (massive sandstone) or medium to coarse (sheet sandstone) quartz sand. Rounding and sorting of this type is not known to occur in rivers today, unless derived from a source that is already a rounded and sorted sand.[18] For instance, the detritus of the Mississippi River at its delta end is generally more angular than near its source, after being transported thousands of kilometers down the river. In contrast, the only rounded quartz sands occur on the beaches and barrier bars offshore from the main Mississippi deltas. Indeed, such sediment is well known from studies in modern sediments, and is generally deposited in the barrier bar-tidal delta environment.[19] The sediments in such environments are well-sorted and rounded sands, containing little or no siltstone or mudstone supposedly derived from levies, back swamps, lakes, or bank or splay deposits found in normal river delta systems that feed from the land

15 P. J. Conaghan and J. G. Jones, 1975, The Hawkesbury Sandstone and the Brahmaputra: a depositional model for continental sheet sandstones, *Journal of the Geological Society of Australia*, 22 (3): 275-283; Conaghan, 1980.

16 J. C. Standard, 1969, Hawkesbury Sandstone, in The Geology of New South Wales, G. H. Packham, ed., *Journal of the Geological Society of Australia*, 16 (1): 407-417; B. G. Jones and B. R. Rust, 1983, Massive sandstone facies in the Hawkesbury Sandstone, a Triassic fluvial deposit near Sydney, Australia, *Journal of Sedimentary Petrology*, 53 (4): 1249-1259.

17 G. M. Ashley and I. J. Duncan, 1977, The Hawkesbury Sandstone: a critical review of proposed environmental models, *Journal of the Geological Society of Australia*, 24 (2): 117-119.

18 J. R. Conolly, 1969, Models for Triassic deposition in the Sydney Basin, *Special Publications of the Geological Society of Australia*, 2: 209-223.

19 J. R. L. Allen, 1970, *Physical Processes of Sedimentation*, London: Allen and Unwin.

and in braided river systems, even those of low sinuosity such as the Brahmaputra River. Thus, the general lack of silt and clay within the Hawkesbury Sandstone, and the excellent rounding and sorting of the quartz grains, would appear to be more consistent with a barrier bar-tidal delta depositional environment.[20]

The nature of the cross-bedding in the Hawkesbury Sandstone also provides important clues to the mode of deposition of what are enormous thick and wide blankets of very pure quartz sand. Each blanket or cross-bedded unit overrides the underlying unit by advancing of the foresets in a simple deltaic-like fashion. The units are generally trough-shaped in plan view, the troughs being commonly 90-360 m across. These are much larger than those found in point-bar sands in present-day braided river systems, but they are similar to those found in present-day tidal sand sheets behind barrier bars in shallow marine waters. Also characteristic of the Hawkesbury Sandstone are many erosion surfaces with reliefs of between three and six meters. These surfaces are continuous over distances of up to at least 0.8-1.5 km. These have been interpreted as channels that formed during ebb-flow through the interpreted tidal delta system. In present-day tidal-flat environments, most deposition occurs during flood tides when the sand sheet builds landward, whereas the strong ebb currents may cut channels but deposit little sand on the seaward side of the sand sheet. Thus, the barrier bar-tidal delta model envisages that it was in this manner the bulk of the Hawkesbury Sandstone was redeposited. Because cross-bedding measurements indicate a pattern of paleocurrents in the general northerly to northeasterly direction,[21] the blanket sands are interpreted as having formed by the coalescing of a series of interlocking tidal deltas that spread in a general northward to northeasterly direction away from the presumed sea. The degree of variation in the direction of the paleocurrents is remarkably small. This is not what would be expected from redeposition in either a braided or meandering river, whereas it is very consistent with unidirectional marine currents influenced by ocean swells.

However, it has been claimed that the "complete lack of marine fossils" is a problem for the barrier-bar tidal delta marine depositional model for the Hawkesbury Sandstone.[22] Nevertheless, while it is true there is an apparent lack of fossils, in general, in the massive and sheet sandstones of the formation, the siltstone/mudstone or shale lenses, that may be up to 35 m thick and up to several kilometers in extent, contain a mixture of diverse marine/estuarine and freshwater fossils.[23] Indeed, the abundance of fish fossils on single bedding planes in some of these shale lenses indicates mass mortality in what are known as fossil graveyards,

---

20 Conolly, 1969; J. R. Conolly and J. C. Ferm, 1971, Permo-Triassic sedimentation patterns, Sydney Basin, Australia, *Bulletin of the American Association of Petroleum Geologists,* 55: 2018-2032; Ashley and Duncan, 1977.

21 Standard, 1969; Conolly, 1969.

22 Ashley and Duncan, 1977.

23 C. Herbert, 1997, Sequence stratigraphic analysis of Early and Middle Triassic alluvial and estuarine facies in the Sydney Basin, Australia, *Australian Journal of Earth Sciences*, 44: 125-143.

some spectacular examples of which have been found in the Hawkesbury Sandstone. Many varieties of fish and even sharks are preserved in patterns consistent with their sudden burial under catastrophic conditions.[24] The list of fossils found in these mudstone/shale lenses includes more than twenty genera of fish (both freshwater and marine), a shark, insects, freshwater-marine arthropods, crustaceans, amphibians (for example, labyrinthodonts), bivalves, and gastropods, as well as amphibian footprints. These mudstone/shale lenses also contain abundant plant microfossils and plant debris, including horsetails (*Phyllotheca*), tree ferns, and seed ferns (*Dicroidium*).[25] Organic remains within the sheet and massive sandstones are scarce, but those that occur consist predominantly of fragments of fossil wood, commonly coalified.[26] All of these fossils, including the plant debris and wood fragments, and the mixture of both freshwater and marine creatures, are evidence for the rapid deposition of the Hawkesbury Sandstone, both the sheet and massive sandstones, and the mudstone/shale lenses.

Just how rapidly the water currents responsible for deposition of the Hawkesbury Sandstone were flowing can be quantified from the height of the cross-beds in the sandstones, as discussed earlier. It has been empirically demonstrated that the heights of the sand waves, of which the cross-beds are remnants, were originally double the cross-bed thickness, and the heights of the sand waves are directly related to the water depth and the velocities of the water currents moving the sand waves along (see Figure 43 again). The cross-beds in the Hawkesbury Sandstone are up to 8 m high, with average heights between 2 m and 5 m. The original sand-wave heights would thus have averaged 4 to 10 m, up to a maximum of 16 m, with the water depths between approximately 20 m and 54 m, up to as much as 90 m. Sand waves 10 m high would require water currents flowing at velocities of between 0.9 m per second and 1.55 m per second, while sand waves 16 m high would require water current velocities approaching 1.7 m per second to move the sand along. In context, we have to therefore envisage sustained, unidirectional currents of around 1 m per second occurring in deep water over some 20,000 square kilometers in order to deposit the flat-lying sandstone layers that together make up the Hawkesbury Sandstone.

We know of such high velocities occurring because of the flow of tides through restrictions of the ocean within straits, such as at the entrance to the Mediterranean Sea, so to generate such high velocity, sustained, unidirectional ocean currents over such a large area would require a mechanism of catastrophic proportions. The only modern analogue would be the severe currents generated during a tsunami, when unidirectional currents exceeding 1 m per second are

24 A. A. Snelling, 1988, An exciting Australian fossil fish discovery, *Creation*, 10 (3): 32-36.

25 Standard, 1969; R. J. Helby, 1969, Plant microfossils in the Hawkesbury Sandstone, in *The Geology of New South Wales*, G. H. Packham, ed., *Journal of the Geological Society of Australia*, 16 (1): 417; M. E. White, 1986, *The Greening of Gondwana*, Sydney: Reed Books, 135-155.

26 Conaghan, 1969; A. A. Snelling, 1999, Dating dilemma: fossil wood in ancient 'sandstone,' *Creation*, 21 (3): 39-41.

known to have been sustained for hours while moving large quantities of sand and building huge sand waves in deep water in its waning stages. The recent discovery of recumbent or overturned cross-beds within the Hawkesbury Sandstone has provided convincing evidence that a succession of catastrophic, massive flood waves, possibly as high as 20 m and up to 250 km wide, carried billions of tons of sand at enormous speed and dumped it to form the massive sandstone units.[27] This admission recognizes that the extent and volume of these massive sandstones have no equal or comparison among the sandy sediments deposited by rivers in the present world. The huge volumes and velocities necessary to explain the water and sediment flows to deposit these sandstone beds over these vast areas required catastrophic conditions in the past on a scale not experienced in the present world.

Megasequences of North America

The advent of the seismic reflection method to recognize and delineate strata sequences, and correlate them across and between sedimentary basins, has made it possible to analyze the sedimentation patterns on regional and continental scales. Thus, as a result of the extensive use of the seismic reflection method and the concurrent emphasis on sequence stratigraphy, various orders of strata sequence cycles in the geologic record have been recognized, including continent-wide, unconformity-bounded packages of sedimentary strata known as megasequences. Six such megasequences traceable across North America have been identified, and can be traced from the Cordilleran region in the west to the Appalachian Basin in the east.[28] Recognition of these megasequences is based on physical relationships among the rock units, each megasequence representing a major cycle of transgression and regression.

The first and lowermost of these North American megasequences has been called the Sauk Megasequence. A typical exposure of it occurs in the Grand Canyon, where it is known as the Tonto Group. The Cambrian strata compromising this group are, from the base of the sequence upwards, the Tapeats Sandstone, the Bright Angel Shale, and the Muav Limestone, which represents a fining upwards sequence produced by a transgression.[29] As the ocean waters from the southwest flooded northeastwards onto what had been land, they and their sediment load eroded that land surface as they surged over it. A prograding, fining-upwards sequence of sediments was deposited as the waters flooded further and further inland. The different strata units were deposited side-by-side laterally and stacked vertically at the same time. The result was deposition of the Tapeats Sandstone, Bright Angel Shale, and Muav Limestone contemporaneously to form the Tonto

27 J. Woodford, April 30, 1994, Rock doctor catches up with our prehistoric surf, *The Sydney Morning Herald*, 2.

28 L. L. Sloss, 1963, Sequences in the cratonic interior of North America, *Geological Society of American Bulletin*, 74: 93-114.

29 S. A. Austin, A creationist view of Grand Canyon strata, in Austin, 1994, 67-70. Note especially Figure 4.12 on 69.

Group over a vast area, separated from the underlying basement rocks by an angular unconformity.

At the base of the sequence where the surging waters were at their fastest, boulders with a diameter of up to 4.5 m and weighing up to 200 tons eroded from the basement strata were carried along by the advancing waters and then deposited at the unconformity.[30] Just above in the water column where the current was not quite as fast, sand was carried landwards to be deposited on top of the basal boulders of the Tapeats Sandstone as the waters transgressed further inland. In the relatively quieter waters oceanward, clay and lime muds were deposited to form the Bright Angel Shale, and Muav Limestone, respectively. The Tapeats Sandstone varies in thickness between 38 and 99 meters, the Bright Angel Shale is between 106 and 122 meters thick, while the Muav Limestone thickens westwards from 106 meters to 305 meters.[31] The majority of the Tapeats Sandstone consists of beds typically less than 1 meter thick, with planar and trough cross-stratification and crudely developed horizontal stratification, features comparable to storm-generated sand beds. Similarly, horizontal laminations, small- to large-scale planar, tabular, and trough cross-stratification, and wavy and lenticular bedding, in the Bright Angel Shale have been described as suggesting "deposition by storm-enhanced currents."[32]

The vertical sequence consisting of the Great Unconformity, Tapeats Sandstone, Bright Angel Shale, and Muav Limestone has enormous horizontal extent, which can be measured in terms of many hundreds of kilometers. However, the Sauk Megasequence, which consists of these Tonto Group strata in the Grand Canyon region, has been traced right across the North American continent, because strata units similar to those which make up the Tonto Group can be correlated with one another over such an enormous lateral extent. Indeed, it is possible to map the occurrence of all the sandstone strata that correlate with the Tapeats Sandstone, which together are known as the basal sandstone lithosome of the Sauk Megasequence. Distribution of this basal sandstone lithosome appears to form a single sandstone body that blankets a major portion of North America, extending along the Mexico border from southern California to Texas northwards across Montana and much of North Dakota through to Canada, and from southern California and Nevada right across to the Mid-West and the New England including Maine (Figure 45, page 1082). As such, this enormous blanket of sandstone right across North America represents a major flooding of the land, the evidence in the Tapeats Sandstone implying that it was a rapid, storm-driven inundation, such as that which occurred at the initiation of the cataclysmic Flood event.

30 Austin, 1994, 46, Figure 3.23.

31 L. T. Middleton and D. K. Elliott, 2003, Tonto Group, in *Grand Canyon Geology*, 2nd ed., S.S. Beus and M. Morales, ed., New York: Oxford University Press, 90-106.

32 Middleton and Elliot, 2003.

68

Fossilization

Although it cannot be categorically said that no fossils are now being formed in currently accumulating sediments, it is nevertheless emphatically true that there are no modern parallels for the formation of the fossil assemblages found in great numbers in various parts of the geologic record. Actually, the formation and preservation of fossils is rare, and requires special conditions:

> All kinds of agents may destroy or damage organisms beyond recognition, before they can become fossils or while they are fossils. After death the soft parts of organisms may rot or be eaten, and any hard parts may be dissolved by water, or broken or crushed and scattered by scavengers, or by storms, flood, wind, and frost. Remains must be buried to become part of the rock, but the very process of burial may cause cracking and crushing. After burial, groundwater seeping through the sediment may dissolve bones and shells. Earth movements may smear or crush the fossil beyond recognition or may heat them too much. Even if a fossil survives and is eventually exposed at the earth's surface, it is very unlikely to be found and collected before it is destroyed by weathering and erosion.[1]

> [M]any marine organisms secrete shells of calcium carbonate, and many marine and terrestrial animals secrete skeletons of calcium phosphate…. Despite the relative resistance of these shells and bones to bacterial decay and their lack of appeal to predators and scavengers, only a small proportion of such hard parts formed by organisms are entombed in sediments to become part of the fossil record….In order for hard parts to enter the permanent record, they must be protected from these destructive processes by being covered rapidly with sediment. This cycling of both soft and hard parts is the normal condition in most environments; removal of the remains from the recycling agents, enabling them to be preserved in the fossil record, is an exceptional event.[2]

---

1 R. Cowen, 1990, *History of Life*, Boston, MA: Blackwell Scientific Publications, 33.

2 C. W. Stearn and R. L Carroll, 1989, P*aleontology: The Record of Life*, New York: John Wiley and Sons, Inc., 6-7.

The full significance of the fossils preserved in the geologic record can only be fully appreciated when it is understood how these fossils have been preserved and the conditions responsible. There are numerous ways in which animal and plant remains may be preserved as fossils.[3]

Preservation of Unaltered Remains

Few organisms are entombed and persist to the present day essentially complete, with little change of form or composition. Mammoths found frozen in the tundra of North America and Siberia are so little changed that their flesh has been reported still palatable to wild animals, and their last meals remained undigested in their stomachs. Estimates of the remains buried all along the coastline of northern Siberia and into Alaska are as high as 5 million mammoths.[4] The great number of bones interred with them in the same sediments cannot be explained easily apart from a widespread catastrophic event. Among other examples are a rhinoceros preserved intact in a Polish oil seep, because petroleum penetrating the flesh retarded bacterial decay, while similar preservation has occurred of numerous animals in the La Brea tar pits of Los Angeles. Another spectacular example of the exquisite preservation of unaltered tissues are the insects and other organisms preserved in unsurpassed detail in amber (tree resin), the most famous deposits of which are found around the Baltic Sea area and in the Dominican Republic, though other deposits are found in New Jersey.[5] These examples are all exceptionally rare, and are not representative of normal conditions of preservation.

Of particular interest are certain details about the insects that have been preserved in amber, such as in the Baltic Sea area:

> In the pieces of amber, which may reach a size of 5 kilos or more, especially insects and parts of flowers are preserved, even the most fragile structures. The insects are of modern types and their geographical distribution can be ascertained. It is then quite astounding to find that they belong to all regions of the earth, not only to the Palaeoarctic region, as was to be expected.…The geological and palaeobiological facts concerning the layers of amber are impossible to understand unless the explanation is accepted that they are the final result of an allochthonous process, including the whole earth.[6]

3 Stearn and Carroll, 1989, 7-11.

4 H. H. Hopworth, 1887, *Mammoth and the Flood—An Attempt to Confront the Theory of Uniformity with the Facts of Recent Geology*, London: Sampson Lowe, Marston Searle and Risington, provides a very detailed description of these deposits. Other estimates of fossil numbers and the references to them are provided in M. J. Oard, 2000, The extinction of the woolly mammoth, was it a quick freeze?, *Creation Ex Nihilo Technical Journal*, 14 (3): 24-34.

5 A. Henwood, 1993, Still life in amber, *New Scientist*, 137 (1859): 31-34; D. A. Grimaldi, 1996, Captured in amber, *Scientific American*, 274 (4): 70-77.

6 N. Heribert-Nilsson, 1953, *Synthethische Artbildung*, Sweden: Verlag C.W.E. Gleerup, Lund, 1194-1195.

> An allochthonous process is one which transports materials from a source area (or areas) and finally deposits them elsewhere, more often than not by the agency of flowing waters. Though at most amber shows signs that it was moved by water before it settled into the sediment in which it now lies.[7]

Just as astounding is the claim that large segments of DNA were recovered and sequenced from a termite fossilized in Dominican amber claimed to be 25 million years old.[8] Subsequent research challenged this claim by demonstrating that when an organism dies the DNA rapidly breaks down.[9] Then painstaking and exhaustive experiments to replicate the original DNA results failed completely.[10]

After the soft parts decay, the hard parts of many organisms can still be preserved essentially unaltered in sedimentary rocks. For example, the shells of many marine organisms, once they have been entombed in sediments, are relatively stable. Thus, some fossil shells claimed to have been formed millions of years ago cannot be distinguished from modern shells. An example of this phenomenon occurs near Wootton Bassett, near Swindon in Wiltshire, England, where oozing mud springs are bringing to the surface "pristine fossils" from Jurassic strata about 13 meters below.[11] Among these fossils, claimed to be 165 million years old, are specimens of the ammonite *Rhactorhynchia inconstans*—many still with "shimmering mother-of-pearl shells," their iridescence retained because "their original shells of aragonite" have been retained—and "the shells of bivalves which still have their original organic ligaments."[12]

Preservation by Permineralization

The most common type of fossil found, especially bones and shells, is where only the hard parts of the organisms have been preserved. Most shells and bones are not solid, but contain canals and pores. The bones of land animals, for example, are generally highly porous, particularly in their central regions where marrow fills the voids when the animals are alive. When organisms die, if they are buried in sediments the soft parts decay, but the pores in the bones and shells are filled with water that often contains dissolved minerals. Such ground waters may then

---

7 Henwood, 1993, 32.

8 R. DeSalle, J. Gatesy, W. Wheeler and D. Grimaldi, 1992, DNA sequences from a fossil termite in Oligo-Miocene amber and their phylogenetic implications, *Science*, 257: 1933-1936.

9 Lindahl, 1993, Instability and decay of the primary structure of DNA, *Nature*, 362: 709-715.

10 J. J. Austin et al, 1997, Problems of reproducibility—does geologically ancient DNA survive in amber–preserved insects?, *Proceedings of the Royal Society of London, B*, 264: 467-474.

11 A. A. Snelling, 1997, A "165 million year" surprise, *Creation*, 19 (2): 14-15, and references contained therein.

12 Dr. Neville Hollingworth, paleontologist with the Natural Environment Research Council, as quoted in N. Nuttall, May 2, 1996, Mud springs a surprise after 165 million years, *The Times*, London, 7; Anonymous, 1995, Irridescent fossils rise up from volcano, *New Scientist*, 148 (1998): 10.

precipitate calcium carbonate or silica in the pores of the shells or bones, reinforcing and solidifying them. The fossilized remains of many organisms, including almost all fossils in sedimentary strata deemed to be old, are subject to this process, which is called permineralization, but is sometimes called petrification or petrifaction. For example, coniferous logs in the Petrified Forest of Arizona have been preserved through the infiltration of silica into the original cellular structure of the wood, with so little disturbance that the microstructure appears to be that of a living tree.

Preservation by Recrystallization

After a shell, for example, has been covered with sediment and possibly also infiltrated with mineral matter via the process of permineralization, the crystals that were secreted to form the shell originally may be changed in form and size, without changing in composition. In calcium carbonate shells, the original minute crystals often increase in size until the texture of the shell is instead a coarse calcite mosaic. Forms of the shells may remain faithfully defined, but the microstructure secreted by the organisms has been destroyed. Such fossils are said to be recrystallized.

Preservation by Replacement

The ground water seeping through sedimentary rocks that contain fossil bones and shells may dissolve some of the hard parts, and at the same time replace them with the minerals it carries in solution. The effect is to substitute another material for the original hard parts without changing the form of the shells or bones. "Paleontologists cannot duplicate these processes, nor do they fully understand them, but the fossil record leaves no doubt that they occur."[13] Commonly, the replacing mineral is silica in its fine, crystalline form known as chalcedony. Delicate spines and fine structures on silicified shells have been revealed by dissolving the limestone that encases them in dilute hydrochloric or acetic acid. Many other minerals can also replace fossils. In shales, for example, shells are commonly replaced by the iron sulfide mineral, pyrite. Thus, delicate structures of organisms may be replaced by pyrite and preserved, as in the Hunsrück Slate in western Germany. The iron oxide, hematite, may also replace fossils, and under rare conditions, both the soft and hard parts of animals may be replaced by calcium phosphates. In all, about twenty different minerals are known to have replaced fossils.

Preservation of Only the Original Forms in Casts and Molds

Instead of replacing fossil shells, ground water passing through sediments may dissolve them completely. If the sediments packed around the shells have been consolidated into rocks before the shells are dissolved, voids will be formed. The

13 Stearn and Carroll, 1989, 7.

walls of the voids may preserve impressions of the faces of the shells, which can be examined when the voids are broken open. These impressions are called molds. Their relief is opposite to that of the shells themselves: knobs on the shells are represented by depressions and vice versa. If conditions change and the ground water deposits minerals into the voids where the shells have been dissolved, the molds may be filled. The resultant mineral deposits will take from the molds the external forms of these fossils they have inherited, but will have none of their internal structures. Thus, this is not a replacement of the shells, but casts that duplicate the shells after the originals have been destroyed. The casts are replicas of the dissolved fossils. The molds are negative impressions of their surfaces.

Preservation of Carbon Only (Carbonization)

Plants are commonly fossilized by being preserved as thin forms of carbon pressed between the bedding planes of sandstones and shales. When plants die and are covered with sediments, the volatile constituents of the various carbohydrates of which they are composed (for example, hydrogen and oxygen) largely disappear by being dispersed, leaving behind a residue of coal-like carbon, a black film that preserves forms of the original leaves, stems, or even fruits. Similarly, the soft parts of marine animals have also been preserved in the fossil record. Such preservation of soft parts rarely takes place, but when it does, it has to have been due to burial where bacterial decay was inhibited by lack of oxygen. An excellent example of where this has occurred are the black shales that are so prevalent in the geologic record.

Preservation of the Tracks and Trails

Animals crossing the surfaces of sediments may leave behind footprints or impressions of parts of their bodies. These are then preserved when the sediment hardens to rock. Similarly, animals living or feeding within sediments leave behind burrows and tunnel systems that may then be preserved, for example, by infilling with other material at the time of burial, or by minerals that have crystallized in the voids from percolating ground waters after burial. These types of fossils are called *ichnofossils*, or trace fossils.

Related to animal tracks and traces that have been thus preserved are the many instances of the preservation of ripple marks produced by water flowing across sediment surfaces, or of raindrop impressions. That such ephemeral markings have been preserved in great numbers, particularly ripple marks, and in such perfection, is truly remarkable, all the more so because there appears to be no modern parallel phenomenon. Indeed, our observations in today's world overwhelmingly indicate that impressions like this in soft mud or sand are very quickly obliterated. It would seem, therefore, that the only way raindrop impressions could be preserved as fossils is by rapid lithification of the sediments (which would have to be by the rapid reaction to harden a chemical cement), followed by rapid burial of the sediment surface and the now fossilized prints. Such rapid burial would necessitate rapid sediment transport and deposition by fast moving water.

While there are the following seven ways in which fossils are preserved—unaltered, permineralized, recrystallized, replaced, carbonized, as molds and casts, and as ichnofossils—each requires specialized conditions. The frequent occurrence of fossils, especially in large accumulations called fossil graveyards, suggests specialized conditions repeatedly on large scales. However, it is virtually impossible to find specific present-day depositional areas where fossils are forming that are analogous to the fossil deposits found in the rock record. Land animals, amphibians or fish, whole bodies or just their bones, may occasionally be trapped in sediments and buried, but this is not a normal or frequent occurrence, even where mass destruction and mortality occurs in some localized catastrophe. Usually, the bones remain in land or sediment surfaces until they gradually disintegrate.

69

Fossil Graveyards

Great "graveyards" of organisms buried together undergoing fossilization and preservation are not found in the world today. However, this is exactly what must have happened in the past, because of the frequent fossil graveyard deposits found in many places around the world in the rock record. Many examples could be cited, but just a few examples, and details concerning them, will suffice.

The Cambrian Burgess Shale, British Columbia, Canada

More than 120 species of marine invertebrates have been preserved at various closely-spaced stratigraphic levels within this shale in the Canadian Rockies. Most of these were soft-bodied animals, but they have been preserved with soft parts intact, often with food still in their guts. Arthropods make up nearly 40 percent of the fossil species, including trilobites, while worms of various types make up more than 25 percent.[1] Other animals preserved in the shale include four species of coelenterates, at least four species of echinoderms, three species of mollusks, and eighteen species of sponges, plus five species of chordates and hemichordates, and species from ten or more previously unknown phyla. Many thousands of specimens of these fossils have been collected from small quarries in the shale since their discovery in 1909.

Usually found squashed flat into thin films, these animals were not fossilized in their normal life position, and though difficult to interpret, it is believed that more than 40 percent were mobile bottom dwellers and around 30 percent were fixed bottom dwellers, the remaining 30 percent representing free swimmers and burrowers. It is believed that the Burgess Shale animals lived on a quiet muddy sea floor. Submarine landslides swept the animals into a deeper basin where there was no oxygen, where they were killed instantly and buried immediately in fine

1 S. Conway Morris and H.B. Whittington, 1982, The animals of the Burgess Shale, in *The Fossil Record and Evolution*, Readings from *Scientific American*, San Francisco, CA: W. H. Freeman and Company, 70-80; Cowen, 1990, 90-93; S. J. Gould, 1991, *Wonderful Life, The Burgess Shale and the Nature of History*, London: Penguin Books; D. E. G. Briggs, D. H. Erwin and F. J. Collier, 1994, *The Fossils of the Burgess Shale*, Washington and London: Smithsonian Institution Press; S. Conway Morris, 1998, *The Crucible of Creation: The Burgess Shale and the Rise of Animals*, Oxford, England: Oxford University Press.

mud. Indeed, the turbulent flow is evidenced by the disposition of the fossils in the rock, the animals being dumped at a variety of angles to the bedding.[2] The Burgess Shale is, therefore, an enormous fossil graveyard, produced by countless animals living on the sea floor being catastrophically swept away in landslide-generated turbidity currents, and then buried almost instantly in the resultant massive turbidite layers, to be exquisitely preserved and fossilized.

The Ordovician Soom Shale, South Africa

The Soom Shale member of the Cedarberg Formation in the Table Mountain Group outcrops in the Cedarberg Mountains of the Cape Province of South Africa.[3] The Soom Shale is only 10 m thick and thinly laminated, the mud and silt laminae being normally less than 1 mm thick (rarely up to 10 mm) and laterally persistent and undisturbed by any penetrative bioturbation. This is consistent with rapid deposition and lithification, before burrowing organisms could obliterate the laminae. Thousands of exceptionally preserved fossils have been found throughout this shale unit at several locations hundreds of kilometers apart, which suggests that this shale unit is an incredibly large and widespread fossil graveyard. Among the identified fossils are brachiopods, straight-shelled nautiloids, various arthropods, worms, conodonts, chitinozoan chains, and a number of enigmatic organisms, including one represented only by scattered spines.

The most spectacular fossil specimens are those of arthropods called eurypterids. They not only display complete cuticular skeletons, but also show the sensory chelicerae and walking appendages that are normally lost to early decay after death. The preservation of some of the fibrous muscular masses that operated these appendages is particularly remarkable. A spiral food tract is also sometimes visible at the rear of the head, and there are well-preserved gill tracts and dendritic structures in the pre-abdomen. Trilobites are rare. Nautiloids are characteristic members of this fossil assemblage, several being found colonized by inarticulate brachiopods. Other inarticulate brachiopods are the most common isolated shells in the shale, some displaying exquisite preservation of the shell ornament. A few completely soft-bodied organisms, which are represented by carbon films or mineral replacements, are currently enigmatic.

Conodonts are extinct soft-bodied vertebrates, normally represented in the fossil record only by the scattered phosphatic elements of their feeding apparatuses, which are generally about 1 mm in length and microscopic. In the Soom Shale, however, the conodont elements in individual specimens are up to 20 mm long, so are easily visible on the bedding planes. Of great significance is the fact that most of the conodonts are represented not by scattered elements, but by complete

2 Cowen, 1990, 90; Briggs, Erwin and Collier, 1994, 27.

3 R. J. Aldridge, J. N. Theron and S. E. Gabbott, 1994, The Soom Shale: A Unique Ordovician Fossil Horizon in South Africa, *Geology Today*, 10 (6): 218-221.

feeding apparatuses. These show that the conodont animals must have been buried alive in the shale and become fossilized without any disturbance from water currents, scavengers, or burrowers. Even more important is the fact that several of these apparatuses are associated with traces of the soft tissues of the conodont animals, with the eyes, in particular, commonly well preserved. The evidence is clearly consistent with catastrophic burial of countless thousands of these organisms over thousands of square kilometers, which implies that the shale itself had to be catastrophically deposited and covered under more sediments before burrowing organisms could destroy the laminations.

The Devonian Thunder Bay Limestone, Michigan

Outcropping along the western shore of Lake Huron south of Alpena, Michigan, the Thunder Bay Limestone is at least 4 meters thick and stretches laterally for many hundreds of kilometers. It dips westward into the Michigan Basin, which covers many hundreds of square kilometers right across Michigan. Of particular interest are the fossilized corals and brachiopods that occur in profusion in the limey shale and crystalline limestone portions of this rock unit.[4] A full list of fossils found in this limestone include colonial corals, solitary corals, bryozoans, crinoids, stromatoporoids, brachiopods, blastoids, and conodonts.

Most of the fossil remains in this limestone are fragments and broken pieces of the hard parts of the original organisms, such as the disks or columnals of crinoids' stems or stalks, which were connected and stacked on top of one another in the living crinoids. After death, crinoids fall apart very quickly, so it is common to find abundant fossilized columnals from broken stalks scattered and jumbled indiscriminately through limestones such as this Thunder Bay Limestone. This limestone, like so many other limestones in the geologic record, is largely composed of the debris and broken remains of all these marine organisms. They were destroyed then transported by fast-moving water before being dumped and buried in what is an enormous fossil graveyard. Thus, the Thunder Bay Limestone contains countless billions of fossils that have been catastrophically buried over many hundreds of square kilometers across Michigan.[5]

The Carboniferous Montceau Shale, Central France

This shale, in the Montceau Basin of central France, is associated with coal seams, and so far has yielded the fossilized remains of nearly 300 species of plants and

4 R. C. Gutschick, 1987, Devonian shelf-basin, Michigan Basin, Alpena, Michigan, *Geological Society of America Centennial Field Guide—North-Central Section*, Boulder, CO: Geological Society of America, 297-302; D. M. Ehlers and R. V. Kesling, 1970, *Devonian Strata of Alpena and Presque Isle Counties, Michigan*, Guidebook prepared for the North-Central Section, Boulder, CO: Geological Society of America, and the Michigan Basin Geological Society, 1-130.

5 P. A. Catacosinos and P. A. Daniels, Jr, ed., 1991, *Early Sedimentary Evolution of the Michigan Basin, Special Paper* 256, Boulder, CO: Geological Society of America; A. A. Snelling, 1998, Thundering burial: a fossil graveyard in Michigan gives another example of Flood catastrophism, *Creation*, 20 (3): 38-41.

pollen, and 16 classes of animals representing about 30 genera.[6] These animals and plants are found flattened within the shale between layers of silt, or in nodules that are believed to have formed as a result of finer sediments accumulating around the organisms as they were buried and fossilized. Among the fossilized plants are giant seed ferns and conifers, the former represented by specimens that must have grown as tall as trees, judging by the trunks found fossilized. Fossilized leaves and thorns are plentiful.

Arthropods are by far the most numerous and well-preserved animals in this fossil graveyard, crustaceans alone representing about 33 percent of the fossil fauna. These include the shrimp-like syncarids, and ostracods and estherians, both minute crustaceans with bivalve shelves. Other aquatic arthropods included the euthycarcinoids (resembling millipedes with tails), and xiphosurans, believed to be related to the horseshoe crabs. Among the terrestrial arthropod fossils are millipedes, spiders, and scorpions, the latter in many cases being beautifully preserved, complete with their venomous vesicle and sting. Representatives of eight orders of insects, including cockroaches, are present, many of the insects being found as nymphal forms. Due to the exceptional preservation, even the soft tissues of polychaete annelids (segmented worms) have been fossilized, along with rare specimens of onychophores, animals that bear a superficial resemblance to large caterpillars. Other invertebrates include bivalve mollusks, which are found at Montceau in great abundance.

The vertebrates found belong to at least four classes—bony fishes, cartilaginous fishes, amphibians, and reptiles. Fish are the most numerous, including small sharks. The fossil amphibians resemble small salamanders, and dual-bearing larvae, similar to the tadpoles of extant amphibians, are also found fossilized here. While only fragments of larger skeletons have been preserved, numerous footprints of amphibians and reptiles have been found, complete with finger and claw marks, and sinuous lines made by tails trailing in the mud. Even raindrop imprints and ripple marks have been found preserved, signifying that burial and lithification must have been extremely rapid. Similarly, the preservation of the fragile hinges in the bivalve mollusk fossils suggests that these animals were not transported before burial, but were entombed abruptly by rapid deposition of sediment. As this fossil graveyard contains a mixture of freshwater, marine, and terrestrial animals and terrestrial plants, some rapid transport of organisms had to take place, along with the rapid sedimentation and burial. Such a mixture of organisms from vastly different habitats buried catastrophically together is consistent with conditions during the Genesis Flood.

The Carboniferous Francis Creek Shale, Mazon Creek Area, Illinois

A similar diverse array of organisms is found in the fossil graveyard in the Francis

6 B. Heyler and C. M. Poplin, 1998, The fossils of Montceau-Les-Mines, *Scientific American*, 259 (3): 70-76.

Creek Shale, associated with coal seams in the Mazon Creek area near Chicago. More than 100,000 fossil specimens representing more than 400 species have been recovered for study, and these belong to 14 phyla, more than 33 classes, and about 100 orders, including forms that are otherwise unknown outside of their modern counterparts.[7] These organisms are found spatially distributed in two overlapping groups—a terrestrial assemblage of ferns, insects, scorpions, and tetrapods, and an essentially marine assemblage dominated by jellyfish, but also consisting of abundant mollusks, crustaceans of various types, and fish.

Arthropods, and all of their major sub-phyla (except trilobites), are again particularly well represented by marine, freshwater, and terrestrial forms, the latter including spiders, scorpions, millipedes, centipedes, giant arthropleurids, and insects (some 150 species). The crustaceans include a host of shrimp-like forms, stromatopods, isopods, clam-like conchostracans, ostracods, and barnacles. Many varieties of worms are also present. The comparatively rare vertebrates are well represented by a variety of fish, including lampreys, hagfishes, sharks, and spiny jawed fish. At least four orders of amphibians are also present, including an extremely rare, tiny salamander-like fossil, preserved in such exquisite detail that it even shows partially digested food within its gut. Finally, some small, extraordinarily rare lizard-like reptiles are also found in the nodules.

The remains of all these organisms were evidently buried rapidly in the silty and muddy sediments, with the exquisite preservation of lightly skeletonized, and even soft, body parts in traces being paradoxically the result of their incipient decay. Bicarbonate produced as a by-product of their anaerobic decay led to the entombment of the organism remains as nuclei of the iron carbonate (siderite) concretions or nodules. Strikingly similar to the Montceau fossil graveyard, this Mazon Creek fossil graveyard also contains a mixture of terrestrial, freshwater, and marine organisms that show evidence of being rapidly buried in order for the exquisite preservation of even the soft part details of these fossils.

The Triassic Mont San Giorgio Basin, Italy-Switzerland

The shales of Mont San Giorgio are in a basin that is estimated to have been from 6 to 10 kilometers in diameter and only approximately 100 meters deep. Yet thousands of well-preserved fossils in a diverse assemblage of fish and reptiles have been found in these bituminous shales.[8] Once buried in the fine-grained muds, compression flattened the animal skeletons as they petrified. In some instances, the force of compression crushed the skeleton so severely that interpretation of fine anatomical detail is difficult, if not impossible. However, most of the fossils are well preserved, so that delicate bones and fine details, such as tiny spines and

7 C. W. Shabika and A. A. Hay, ed., 1997, *Richardson's Guide to the Fossil Fauna of Mazon Creek*, Chicago, IL: North-eastern Illinois University; C. E. Brett, 1998, Picture of an ancient world, *Science*, 279 (5358): 1868-1869.

8 T. Bürgin et al, 1989, The fossils of Monte San Giorgio, *Scientific American*, 260 (6): 50-57.

scales, are still distinctly visible. It is readily apparent that a wide variety of animal species were buried and preserved in this basin.

In terms of fish diversity alone, the fossil assemblage in these shales is analogous to a modern coral reef. Five species of sharks have been identified so far, four of them being small, yet robust in shape, with crushing teeth that suggest they ate shellfish. The San Giorgio specimens are represented mostly by teeth and occasional fin spines or backbones (sharks, unlike bony fish, have skeletons made of cartilage and deteriorate rapidly after death). Yet several almost complete shark specimens have been found, providing further testimony to the exceptional preservation in this fossil graveyard. A limited number of lobe-finned fish specimens tend to be complete, because their heavy, enamel-like scales have resisted decay. They fall into three distinct size categories. The largest ones measure about 70 cm in length, and in contrast, the smallest ones are only 20 cm long. More than 550 well-preserved specimens of ray-finned fishes (the group to which the majority of living fish belong) have been catalogued. The exquisite preservation of these San Giorgio fossils is exemplified by some of these ray-finned fishes, with fine details, such as the tail fins and elongate snout of the lizard fish *Saurichthys* being visible. Even more remarkable is the presence of two embryos inside the abdomen of a female, evidence that these fish gave birth to live young. Many of these fish are believed to have been ocean-dwelling, fast-swimming forms, based on comparison with their modern counterparts.

Most abundant and perhaps best studied of the reptile fossils are the amphibious nothosaurs. They are thought to have moved forward through water by lateral undulations of the trunk and tail. In addition to having elongate, flattened tails, most of these fossil reptiles have long, flexible necks. These nothosaurs vary in shape and size, from three meters in length to a dwarf lizard which averaged only about 30 cm in length. All together some 400 specimens, representing each stage of the life cycle from embryo to adult, have been documented. It has been possible to study the development of these animals, because, like all cold-blooded reptiles, they grew by adding new bone in the form of annual growth rings. Thus, thin cross-sections of their bones, about 50 microns thick, have been examined microscopically, and the number of growth rings counted, extensive analysis revealing the animals lived to a maximum of six years. The genera of placodonts, short, stout marine reptiles that had large, flattened teeth, are known from Monte San Giorgio, while a group of reptiles known as archosauromorphs are well represented. The most bizarre of these fossil reptiles is the 4.5 meter giraffe-necked saurian, *Tanystropheus*, which had an absurdly long neck more than twice the length of its trunk. Only one true archosaur (the group to which dinosaurs belong) has been found in this fossil graveyard. The animal, which was about 2.5 meters long, is believed to have been a ferocious terrestrial carnivore. Thalattosaurs, another enigmatic group of marine reptiles, are also represented in the San Giorgio shales by three genera, the largest specimen of which measures about 2.5 meters in length and has a long, narrow skull. Ichthyosaurs, a group of marine reptiles that were similar in size and shape to modern dolphins, having paddle-shaped limbs and distinct snouts, are also represented by three genera here. Some specimens have been found that contain the remains of unborn young, so it is surmised that the eggs must have developed within the mother's body, and that the young were born live.

As for how this great diversity of vertebrates came to be fossilized together, it is conventionally suggested:

> The bottom of the (San Giorgio) basin consisted of fine-grained mud, and when the animals that lived in the basin died they sank to the bottom. There conditions were anoxic (without oxygen), so their remains, which would normally be broken down by aerobic bacteria and other scavengers, were protected from decay, thus exquisitely preserving even fine details.[9]

However, fish, like so many other creatures, do not naturally become entombed like this, but are usually devoured by other fish or scavengers after dying. Furthermore, when most fish die their bodies float. In the fossil assemblage at Mont San Giorgio are some indisputable terrestrial reptiles among the marine reptiles and fishes. Thus, to fossilize all those fish with the large marine *and* terrestrial reptiles, so that they are all exquisitely preserved, would have required a catastrophic water flow to sweep all these animals together and bury them in fine-grained mud.

The Triassic Cow Branch Formation, Cascade, Virginia

The fossiliferous shales of the Cow Branch Formation in the Virginia-North Carolina border area contain an abundance of complete insects, and preserve even the soft-part anatomy of some vertebrates, along with an unusual diversity of flora.[10] The sediments of this formation are markedly cyclical and fossiliferous throughout, including plants and abundant plant fragments, together with ripple marks and what are interpreted as mudcracks. However, it is in the micro-laminated, organic-rich shales that the great diversity of fossilized insects has been found, together with the articulated remains of the tanystropheid reptile, *Tanytrachelos*, complete with impressions of soft tissue, and the best preserved plant remains. The matrix is an exceptionally fine-grained black shale that shows no evidence of bioturbation, and the insects are preserved as two-dimensional silvery images. Microscopic details are preserved with great fidelity, and the resolution of preserved detail is approximately 1 micron.

The most abundant fossilized insects are aquatic sucking bugs, two families being represented by numerous nymphal and adult specimens. The next most common

9 Bürgin et al, 1989, 52.

10 N. C. Fraser et al, 1996, A Triassic Lagerstätten from eastern North America, *Nature*, 380: 615-619.

order of insects in the fossil assemblages is leaf-hoppers, and at least six families of flies are also represented here. Single specimens of a thrip, a caddis-fly, and of a new family of the super-family of moths and sandflies, are also found in these shales. Finally, a single large specimen of an extinct family of beetles, specimens unquestionably belonging to a huge living family of beetles, and a representative of an undetermined family of cockroaches, complete the list of insect taxa found in this significant fossil deposit. Despite lacking cuticle (typically a diagnostic feature of fossil plants), the plant remains show a remarkable diversity. Ferns, cycadeoids, and conifers predominate, but also present are lycopods, scouring rushes, gingko, and cycad-like seed plants, as well as a number of seeds.

Many articulated specimens of the aquatic reptile *Tanytrachelos* have been described from these black shales. Many more specimens have been recovered in the latest excavations, including some spectacular individuals complete with ghosts of the muscles on the tails, and ligaments in the webbed hind feet. Fragmentary remains of two as-yet undescribed tetrapods have also been found. Also, numerous specimens of bony fishes, both ray-finned and lobe-finned, have been recovered from these black shales, along with an isolated shark tooth. It is this mixture of organisms (terrestrial, freshwater, and marine) buried together, fossilized and so well preserved, that again is consistent with very rapid deposition and burial, repeatedly during this cyclical sedimentation to produce this fossil graveyard. Insects do not simply die, fall into a body of water, and slowly sink to be gradually covered up by slowly accumulating sediments, even if anoxic conditions prevailed. There are still bacteria which operate under those conditions that would destroy the insects before they could be preserved in such exquisite detail.

The Cretaceous Santana Formation, Brazil

The Santana Formation of Brazil possibly represents the finest fossil locality in the world, due to the incredible preservation of fishes and other animals.[11] The strata hosting the fossils consists of lithographic limestones (compact, dense, homogeneous, exceedingly fine-grained), and shales with nodular calcium carbonate concretions. It is in these concretions that many of the fish have been so well preserved that it is often concluded fossilization must have been instantaneous (the so-called "Medusa effect"). The fossil assemblage is dominated by fishes, including numerous species of armored fishes and ray-finned bony fishes, with rare sharks, a skate, and two species of coelacanth. Associated with the fishes are rare crocodiles, frogs, turtles, dinosaurs, and pterosaurs, particularly pterodactyls with wingspans of over three meters. The invertebrate fauna includes shrimps (crustaceans), ostracodes, bivalves, gastropods, echinoderms, rare foraminifera, insects, and spiders. Fossil plants are also present.

The most spectacular of the fossil fishes are the three-dimensional specimens

11 D. M. Martill, 1989, The Medusa effect: instaneous fossilization, *Geology Today*, 5 (6): 201-205; P. G. Davis, 1992, Geological miracles, *Nature*, 355: 218.

that are found in the calcium carbonate nodules. Some display large patches of buff-colored calcium phosphate, which must have formed before the fishes were buried in the sediment, and before any decomposition could occur. Sometimes the calcium phosphate replaces the soft tissues of the fishes at the molecular level. Preservation has been so rapid, and so perfect, that structures such as muscle fibers with banding present, some displaying ultrastructure, fibrils, and even cell nuclei arranged in neat rows, have been fossilized. Underneath the scales, small pieces of skin are preserved and show thin sheets of muscle and connective tissue. In a female specimen the ovaries have been preserved with developing eggs inside, and one egg even had phosphatized yolk. Many specimens display the stomach wall with all its reticulations, and often with the last meal still in the stomach. One specimen has no fewer than 13 small fish in its alimentary tract, with a number of shrimps, that even had their compound eyes preserved with the lenses in place. But the most spectacular tissues found in these fish specimens are the gills, many having the arteries and veins of the gills preserved with the secondary lamellae intact.

These tissues are very useful for estimating the speed of the phosphatization process. After the death of a fish, blood pressure is reduced and the secondary lamellae collapse within one to three hours. In the Santana fossil fish, the secondary lamellae are intact, with very little sign of collapse, cells are inflated, but the ultrastructure is not preserved. It is clear, therefore, that the fossilization process took place moments after the fish had died, and was completed within only a few (probably less than five) hours. It is truly remarkable that if a phosphatized fish becomes the nucleus for a carbonate concretion, these phosphatized soft tissues remain in an uncrushed condition, and can be examined today as though they were from a fresh fish! However, the fishes are not the only animals whose remains have been phosphatized. For example, ostracodes are found phosphatized, with the tiny animal still inside with its hairy legs preserved. However, even more spectacular are the phosphatized wings of pterosaurs, which somewhat unusually are the most abundant reptiles in the Santana Formation. Preserved in an uncrushed condition, the bones can be extracted from the matrix and related to each other to work out how they functioned, including the aerodynamics of pterosaur flight. Even better still, the Santana Formation has yielded pterosaurs with phosphatized wing membrane, which has been cross-sectioned to reveal a highly complex organ consisting of a variety of tissue types, including skin, a vascular layer, and muscle tissue.

It is abundantly clear from examination of the incredible preservation of so many fossils in the Santana Formation that this fossil graveyard represents a spectacular catastrophic event, given that flying reptiles and terrestrial dinosaurs, plants, insects, and spiders are found buried together and exquisitely preserved as fossils with fish of many types, crocodiles, turtles, and various marine invertebrates. Burial had to be very rapid, because scavenging and water current activity did not disturb the carcasses, which had to be phosphatized rapidly between death and their very rapid burial. The carbonate concretions also had to form rapidly around the phosphatized carcasses, before overburden pressures squashed the carcasses flat. Obviously, to produce this fossil graveyard required a catastrophic mass-mortality event to virtually instantaneously kill and bury all these organisms together.

The Cretaceous Tepexi Limestone, Mexico

Fissile red limestone near the town of Tepexi southwest of, and close to, Mexico City contains a fossil graveyard with an assemblage of organisms not too dissimilar to the Santana fossil graveyard in Brazil.[12] Fishes are again the most prominently represented, with more than thirty new species. This fact, coupled with the exceptional preservation of the specimens, makes Tepexi a spectacular fossil fish site. For some species the site has yielded a complete developmental series from hatchling to adult. Numerous species of bony, ray-finned fishes are found fossilized with deep-bodied, armored fish with crushing dentitions that are thought to have inhabited coral reefs, while many more specimens remain to be satisfactorily identified. Several thin spines have also been found, indicating the presence of sharks. The fish fossils are probably more abundant here than at many famous fossil fish localities (estimated at about one fossil per cubic meter), although they do not cover entire bedding planes as they do in some other localities, such as the Eocene Green River Formation in Wyoming. Usually the fish are astonishingly well preserved in their entirety, fully articulated, with every bone, scale, and fin in place. Some specimens have been preserved with their last meals still in their guts, and these often include other fishes. The generally perfect preservation of the fish shows that no scavenging took place as the fish died.

Furthermore, the limestone hosting the fossils does not represent deposition on an inhabited sea floor, because the fossilized invertebrate fauna is dominated by free-swimming, pelagic forms, compared to benthic (bottom living) forms, which although present, are extremely rare. The invertebrate fauna is diverse, although somewhat sparse, and is dominated by mollusks. Several ammonites have been discovered, along with rarer bivalves and gastropods. Many new species of invertebrates have been revealed, including crabs. A number of other crustaceans have been found, as have the spines of regular echinoids, and small but complete brittle-stars. Even soft-bodied organisms have been found, among them anemones, some extremely rare sea-cucumbers, and a segmented, bristle-bearing worm. Fish are not the only vertebrates found in this fossil graveyard, as there are also extinct reptiles, including lizards, a turtle, a new type of crocodile, a pleurosaur, and a pterosaur (some isolated bones are attributed to pterodactyls, although no complete specimens have yet been found).

The most puzzling fossils are what have been called "assorted fronds," several

12 D. M. Martill, 1989, A new "Solenhofen" in Mexico, *Geology Today*, 5 (1), 25-28.

different types of which have been found. Some may merely be solution features or dendrites, but a number are certainly of organic origin. A segmented frond might be a gymnosperm, but it is only preserved as an impression or an external mold. Other frond-like structures, varying in size and degree of branching, might be organic-walled bryozoa (lace corals), hydroid coelenterates, or algae. Otherwise, trace fossils are relatively common, such as the impressions of ammonites where the shell hit the sediment surface, and feeding traces of worm-like animals. Coprolites, presumably from the fish, are also quite common, in some cases showing that the fish were eating foraminifera.

Most of the fossil-bearing horizons in the limestone are laminated micrites (carbonate mud with crystals less than 4 microns in diameter), often with slightly coarser bases. The width of the laminae is highly variable, with individual laminae often only 1 to 2 mm thick, but the rock usually splits in slabs 1 to 3 cm thick. Throughout the succession there are thin clay partings, which appear to represent volcanic ash falls. It has been suggested that the individual laminae may represent micro-turbidite sequences generated during storms. The direction of flow of the turbidites appears to be reflected in the various current-formed sedimentary structures that have been found, along with indicators of current movements preserved on some of the fossils, such as faint drag marks made by the trailing arms of a fossilized free-swimming crinoid. It is quite obvious that a catastrophic process was involved in transporting and depositing a diverse mixture of organisms, from flying and terrestrial reptiles, to fish and marine organisms. Turbidity currents carrying fine lime-mud were interspersed with falls of volcanic ash, so that the organisms were killed, squashed together, and rapidly buried so as to be well preserved in this fossil graveyard.

The Cretaceous Djadokhta Formation, Nemget Basin, Ukhaa Tolgod Area, Mongolia

In the Ukhaa Tolgod area of the Gobi Desert of Mongolia, an unmatched abundance of well-preserved vertebrate fossils are found in the Djadokhta Formation, including the highest concentration of mammalian skulls and skeletons from any Mesozoic site.[13] From an area of about four square kilometers, the recovered and uncollected articulated skeletons of theropod, ankylosaurian, and protoceratopian dinosaurs represent over 100 individuals. Specimens collected also include skulls, many with associated skeletons, of over 400 mammals and lizards, and include the first known skull of the bird *Mononykus*. Certain sites have been interpreted as nests, because fossilized eggs at these sites contain what are believed to be theropod dinosaur embryos. A distinctive feature of this Ukhaa Tolgod fossil graveyard is the marked diversity and abundance of small vertebrates. Also striking is the preservational quality of these delicate specimens. Many skulls are virtually complete with lower jaws still in articulation, and tympanic rings

13 D. Dashzeveg et al, 1995, Extraordinary preservation in a new vertebrate assemblage from the Late Cretaceous of Mongolia, *Nature*, 374: 446-449.

and ear ossicles well preserved. Postcranial skeletons associated with the mammal skulls provide evidence of anatomical regions that have not been preserved at comparable sites. Indeed, five well-preserved skeletons of a placental mammal species were found *in situ*, close together. Thus, this fossil graveyard represents an unprecedented aggregate of mammal skeletons in Mesozoic strata.

The excellent preservation of these vertebrate fossils at Ukhaa Tolgod prompts questions concerning the mode of their death, burial, and preservation. Given that the well-preserved fossils are all found in a distinctive sandstone layer, it is obvious that this fossil assemblage resulted from rapid post-mortem *in situ* burial in sand. Evidence for this is the abundant articulated skeletons, which suggest minimal post-mortem surface weathering and transport, positions of skeletons that suggest "death struggles," and monospecific death assemblages for certain dinosaurs such as *Protoceratops* and *Pinacosaurus*. Many of the small mammals may simply have been buried in their burrows. Above the fossiliferous sandstone layer is a moderately coarse conglomerate bed, which is indicative of high-energy water deposition. Furthermore, the structureless (non cross-bedded) sandstone in which all the vertebrate fossils are found contains pebbles and abundant coarse sand.[14] Because of the perfect articulation of the fossil skeletons entombed within the sandstone, its structureless nature is interpreted as being depositional, and not the result of bioturbation. Thus, to virtually bury alive such large animals as dinosaurs implies rapid water flow and catastrophic deposition of the sand. Interbedded with the fossil-bearing, structureless sand units are further sandstone layers with large-scale cross-bedding, which has resulted in these sandstone layers being interpreted as aeolian (produced by desert dunes). Enclave-up downfolds seen in vertical cross-section on the cross-bed surfaces in these sandstones have been interpreted as the tracks of large vertebrates. Although most of these tracks are represented by smooth folds, some show distinct toe and claw indentations. While it hasn't been possible to identify the makers of the tracks, on the basis of the fossils found in the structureless sandstone units, the tracks were probably made by larger dinosaurs such as ankylosaurs or *Protoceratops*. Invertebrate burrows are also present in great abundance.

There is, however, an alternative explanation for the cross-beds in these sandstone units, which is more consistent with what we know of present-day depositional environments and with the evidence in the fossil-bearing, structureless sandstone units. In a desert environment the cross-beds produced by sand dunes are at an angle of 30-34°, the angle of repose for sand. However, the cross-beds produced by underwater sand waves are consistently at an angle of 25°. Thus, the cross-beds in these sandstones being at an angle of 25° are more consistent with an underwater sand-wave origin, which is also consistent with the rapid transport of the sand that catastrophically buried the vertebrates in the associated, structureless sandstone units. Thus, all the evidence surrounding this Ukhaa Tolgod fossil

14 D. B. Loope et al, 1998, Life and death in a Late Cretaceous dune field, Nemegt Basin, Mongolia, *Geology*, 26 (1): 27-30.

vertebrate graveyard points to catastrophic burial under rapidly water-transported sand.

70

Coal Beds—Fossil Graveyards of Plants Transported and Deposited by Water

Coal is formed from the accumulation and compaction of dead plant material. It consists of nearly pure carbon, from carbon compounds that made up the plants.[1] Even though the oxygen and hydrogen largely disappear from the original plant remains leaving only the carbon, the original plant structures are usually beautifully preserved, so it is easy to identify coal as the end product of the metamorphism of enormous quantities of plant remains buried under sediments and transformed by temperature, pressure, and time. Thus, coal beds qualify as fossil graveyards, where huge masses of plants have become fossilized, their original constituents still often visible within the coal at macroscopic and microscopic scales. Many plant remains such as leaves, stems, and tree trunks are still visible macroscopically in the coal, while under the microscope, wood, leaves, spores, and other components of plants can be readily identified.

Coal beds are first found in the geologic record among Carboniferous strata, and are then found all through the strata sequences above, right up to among Miocene strata, close to the present. Coal beds are found in all parts of the world, on every continent, including Antarctica. In the United States alone, the coal reserves have been estimated by the U.S. Geological Survey to be 7.64 trillion tons,[2] but huge coal reserves occur in China, Canada, Australia, and South Africa. Many coalfields contain multiple coal seams interbedded with other sedimentary strata, each coal seam having a thickness that may vary from a few centimeters to more than a meter. Each meter of coal is thought to represent 4 to 6 meters of plant remains,[3] so the great thicknesses of coal seams testify to the former existence of

1 Davidson, Reed and Davis, 1997, 92, 422-424.

2 Davidson, Reed and Davis, 1997, 423.

3 E. Stach et al, 1982, *Stachs' Textbook of Coal Petrology*, third revised and enlarged edition, Berlin: Gebrüder Borntraeger, 17-18.

almost unimaginably massive accumulations of buried plants.

Theories of Origin

Historically, geologists have been divided into two camps: those favoring the autochthonous (growth-in-place) theory for the origin and formation of coal, and those favoring the allochthonous (transport and deposition) theory. However, because of the ascendancy of consistent uniformitarianism in geological reasoning over the last century or more, today it is almost universally accepted and taught that the coal-forming plants grew in swamps that slowly over thousands of years accumulated peat layers, which were subsequently buried by other sediments (sands, muds, etc.), to be compressed and biochemically transformed (coalified) to eventually form coal seams.[4] Modern peat-forming swamps, usually cited as examples of what the postulated ancient coal-forming swamps must have been like, include the Dismal Swamp near the coast in the Virginia-North Carolina border area, the swamps and marshes along the Gulf of Mexico coast associated with the Mississippi River delta, and the Okefenokee Swamp and the Everglades of Florida. The great thicknesses of coal seams in coal measure sequences are thus accounted for by assuming a continuous subsidence of the land, more or less at the same rate as the slow accumulation of plant remains in a swamp.

The sedimentary strata interbedded with the coal seams, some of which often contain fossils of marine organisms, are explained by alternating marine incursions over the swamps, and the resulting periods of sediment deposition. A wide variety of sedimentary strata have been found between coal seams, but these are typically explained in terms of cyclothems, recurring cycles of deposition of different sediments, corresponding to the various stages of marine transgressions and regressions. The "ideal" cyclothem is defined on the basis of ten different sedimentary units in sequence in the western part of the Illinois Basin,[5] but the exact cycle found at any one locality is always different from the cycle at any other locality:

> The concept of the ideal cyclothem was developed to represent the optimum succession of deposits during a complete sedimentary cycle. The ideal cyclothem has not been observed fully developed in any one locality.[6]

In fact, a typical cyclothem is usually missing one or more of the strata in the ideal sequence, and/or the order of strata may be reversed. Alternately, coal seams may be interrupted, or disappear laterally, being replaced by massive limestone or being marginally supplanted by shale. Thus, the coal seams appear to constitute a regular part of the deposition that has produced the sequences of sedimentary

4 Stach et al, 1982; C. F. K. Diessel, 1992, *Coal-bearing Depositional Systems*, Berlin: Springer-Verlag.

5 J. M. Weller, 1930, Cyclical sedimentation of the Pennyslvanian Period and its significance, *Journal of Geology*, 38: 97-135.

6 W. C. Krumbein and L. L. Sloss, 1963, *Stratigraphy and Sedimentation*, second edition, San Francisco, CA: W.H. Freeman and Company, 536-537.

strata. Indeed, the coal beds are commonly associated above and below with strata that clearly consist of transported sedimentary material.

In any one locality in a coal-bearing sedimentary basin, the cyclothems are commonly repeated tens of times, with each cycle of deposition having accumulated on the previous one. Thus, for example, there are fifty successive cycles in the Illinois Basin, and over one hundred in West Virginia. Although the coal seam in a typical cyclothem may be quite thin (commonly a few centimeters to a few meters thick) compared with the other sedimentary strata, the lateral extent of the coal is often incredible. For example, detailed stratigraphic research has found that the Broken Arrow coal seam of Oklahoma can be correlated with the Croweburgh Seam (Missouri), the Whitebreast Seam (Iowa), the Colchester No. 2 Seam (Illinois), the Coal IIIa Seam (Indiana), the Schultztown Seam (west Kentucky), the Princess No. 6 Seam (east Kentucky), and the Lower Kittanning Seam (Ohio and Pennsylvania).[7] Thus, these seams together form a single, vast bed of coal exceeding 260,000 square kilometers in area in the central and eastern United States. No modern swamp has an area even remotely similar to that of these Carboniferous coal seams.

If the autochthonous (growth-in-place) model for coal formation is correct, a very unusual sequence of circumstances must have occurred. An entire region, often encompassing tens to hundreds of square kilometers, had to be raised simultaneously relative to sea level in order to allow a vast swamp to develop and accumulate peat, and then lowered to permit the ocean to flood the area to deposit the successive sedimentary strata in the cyclothem sequence. If the land surface on which the swamp and its forest had developed was raised too far above sea level, the swamp and its antiseptic water necessary for peat accumulation would have been drained, thus destroying the swamp and the forest. On the other hand, if during peat accumulation the ocean invaded the swamp, then the marine conditions would have killed the plants, and other sediments would have been deposited instead of peat. Thus, according to this almost universally-held conventional model, the formation of a thick bed of coal would require the maintenance of an incredible balance, over many thousands of years, between the rate of peat accumulation, and the rising and falling of sea levels. One or two, or even three, coal seams formed by such alternate stages of swamp growth and peat accumulation, followed by marine transgression, and then subsequently regression, might be believable, but the insistence that this cycle was repeated scores of times on the same spot, and over an enormous area, over a period of perhaps millions of years, is not only most improbable and thus not easy to accept, but simply impossible, there being no modern parallel. Depending on

---

7 C. R. Wright, 1965, Environmental mapping of the beds of the Liverpool Cyclothem in the Illinois Basin and equivalent strata in the northern Mid-continent Region, unpublished Ph.D. thesis, University of Illinois; R. M. Kosanke, 1973, Palynological studies of the coals of the Princess Reserve District in north-eastern Kentucky, US Geological Survey, Professional Paper 839; S. E. Nevins, 1976, The origin of coal, Impact Series No. 41, Santee, CA: Institute for Creation Research.

the compaction ratio, each meter thickness of coal seam could represent five, six, or even twelve meters thickness of accumulated plant remains,[8] so seams of up to ten meters thickness would have supposedly required up to one hundred or more meters thickness of accumulated plant remains, and this cycle at many sites needed to be repeated up to one hundred or more times!

Though almost universally accepted and dogmatically championed, the autochthonous peat swamp model for coal formation utterly fails to explain even one coal seam, because the evidence associated with coal seams, when carefully examined, is utterly inconsistent with the model. Decades of concerted scientific research has not changed this assessment. One of the most respected authorities on coal geology in the 1940s said:

> Though a peat-bog may serve to demonstrate how vegetal matter accumulates in considerable quantities, it is no way comparable in extent to the great bodies of vegetation which must have given rise to our important coal seams.…There is sufficient peat in the temperate regions of the world today to form large amounts of coal, if it were concentrated into coal seams, but no single bog or marsh known would supply sufficient peat to make a large coal seam.[9]

More than fifty years later, a comparable scientific authority commented in the introduction to a major textbook:

> Development of actualistic models of peat formation has led to a rejection of the delta environment as the most likely birthplace of major coal deposits.…Yet most of today's peat deposits can be compared, in time and volume, only with the (often quite dirty) bottom portion of many economic coal seams. The origin of the up to 80-m-thick anthracite seam (Grande Couche) in the Hongai Coalfield of Vietnam's Tongking Basin (Dennemberg 1937), or the composite thickness of the 300 m of brown coal in a mere 800 m of coal measures in the Latrobe Valley of Victoria, Australia (George 1982), to mention only two of many examples, require conditions in time and space for which there are no current equivalents on Earth.[10]

The Dismal Swamp of coastal Virginia-North Carolina, perhaps one of the most frequently cited examples of a swamp producing a peat layer that could potentially become a coal seam, has formed only an average of just over two

8 R. A. Gastaldo, 1999, Debates on autochthonous and allochthonous origin of coal: empirical science versus the diluvialists, in *The Evolution-Creation Controversy II: Perspectives on Science, Religion, and Geological Education*, W.L. Manger, ed., The Palaeontological Society Papers, 5: 135-167.

9 E. S. Moore, 1940, *Coal: Its Properties, Analysis, Classification, Geology, Extraction, Uses and Distribution*, second edition, New York: Wiley, 146.

10 Diessel, 1992, 3-4.

meters of peat, hardly enough to make a single respectable coal seam if the compaction ratio requires 5 to 6 or up to 12 meters of peat to form a one-meter-thick coal seam. However, if the calorific values of equal volumes of coal and peat are compared, then the peat-to-coal compaction ratio would only be 2.3 to 1, while comparing the specific weight of these two, the ratio would come down to 2.2 to 1.[11] In other words, to produce a one-meter-thick coal seam would only require a 2.3-meter-thick layer of peat, which is comparable to the peat layer that has formed beneath the Dismal Swamp. Indeed, field evidence from the geometry of penecontemporaneous channel sandstones in contact with coal seams, and dinosaur tracks in the roofs of coal mines, show that peat-to-coal ratios of 1.2-2.2 to 1 are more realistic estimates of the magnitude of compaction.[12] Furthermore, these data also indicate that virtually all of the compaction occurs at the surface, or within the upper few meters of burial.

However, this evidence does not in itself give credence to the peat swamp model for coal formation, because there is so much evidence associated with coal seams that is far more consistent with the allochthonous (transport and deposition) model. Coal seams are an integral part of the sedimentary sequences in which they occur, and are commonly associated with, and enclosed by, sedimentary strata consisting of transported sediments. For example, sandstones may occupy as much as 80 percent of the total thickness of strata in coal measure sequences, the sand having been moved and deposited by water, as evidenced by cross-bedding. Conglomerates, even with large boulders and wood debris, are not uncommon. In the Newcastle Coal Measures of the Sydney Basin, eastern Australia, conglomerate beds make up 29 percent of the coal measure strata (sandstones make up another 23 percent), and some of these conglomerate beds are cross-bedded and directly overlie coal seams.[13] Even fine-grained siltstones and shales, usually even-bedded, often contain evidence of rapid deposition by water, such as aligned fossilized plant remains, flute casts, and the general absence of bioturbation. Often coal seams are abruptly overlain by sedimentary strata interpreted as distinctly marine, because of the marine fossils found in them. There is a complete lack of any intervening transitional brackish-water deposits, which would be expected with the gradual change in salinity if the ocean had gradually encroached upon the enormous freshwater swamps and bogs, in which the peat for the coal seams was supposedly formed.

Some coal seams when followed laterally are found to split into two seams, separated by strata consisting of transported marine sediments. This can only indicate that the deposition of the plant remains making up the coal and the

11 J. Scheven, 1981, Floating forests on firm grounds: advances in Carboniferous research, *Biblical Creation*, 3 (9): 36-43.

12 G. C. Nadon, 1998, Magnitude and timing of peat-to-coal compaction, *Geology*, 26 (8): 727-730.

13 C. F. K. Diessel, 1980, Newcastle and Tomago coal measures, in *A Guide to the Sydney Basin*, C. Herbert and R. Helby, ed., *Geological Survey of New South Wales Bulletin,* 26: 100-114; Diessel, 1992, 330-335, 361-374.

associated marine sediments had to be coeval. In the west European coalfields, coal seams not only coalesce or split over a distance of only a few kilometers, but cases are known where two separate well-defined seams are connected by a sloping third coal seam, producing what is termed a Z-connection. Coal seams themselves are usually bedded, with laminations marked by slight changes in color, and break apart on certain planes, like shale that is regarded as being of transported origin. Indeed, many coal seams, particularly thick coal seams, contain one or more shale or siltstone bands that are often consistent for tens of kilometers or more. Thus, the actual physical evidence associated with coal seams is very strongly consistent with the plant remains, which formed the peat precursor to the coal, having been transported and deposited by water flow, just as the sediments in the inter-seam strata have been water-deposited. Simplicity and consistency would both suggest that the plant remains were also water-borne and deposited.

The microscopic texture and structure of peat and coal have been investigated, as part of a comparative structural study between modern autochthonous (growth-in-place) mangrove peats, and a rare modern allochthonous (transported and deposited) beach peat from southern Florida.[14] It was found that most autochthonous peats had plant fragments showing random orientation within a dominant matrix of finer material, while the allochthonous peat showed current orientation of elongated axes of plant fragments generally parallel to the beach surface, with a characteristic lack of the finer matrix. Also, the poorly-sorted plant debris in the autochthonous peats had a massive structure, due to the intertwining mass of roots, while the allochthonous peat had characteristic micro-lamination, due to the absence of intergrown roots. It was concluded:

> A peculiar enigma which developed from study of the allochthonous peat was that vertical microtome sections of this material looked more like thin sections of Carboniferous coal than any of the autochthonous samples studied.[15]

It was also noted that the characteristics of this allochthonous peat (orientation of elongated fragments, sorted granular texture with general lack of finer matrix, micro-lamination with a lack of matted root structure) are also the general characteristics of Carboniferous coals, the world's major coal deposits in North America and Europe.

Not only are coal seams interbedded with sedimentary strata containing marine fossils, but marine fossils have also been found in the coal seams themselves:

> The small marine tubeworm, *Spirorbis*, is abundant in the fossil record.

14 A. D. Cohen, 1970, An allochthonous peat deposit from southern Florida, *Geological Society of America Bulletin*, 81: 2477-2482.

15 Cohen, 1970, 2480.

> No member of this genus is found in a fresh-water habitat. Since *Spirorbis* tubes are found as a constituent of Carboniferous coal, they are strong evidence for the allochthonous, or transported, origin of much of the coal.[16]

These marine tubeworms must have become attached to the drifting plants that now make up the coal, because they are commonly found attached to the plant remains in the Carboniferous coals of Europe and North America. Furthermore, it is not uncommon to find various marine fossils within what are known as "coal balls," which are rounded masses of matted and exceptionally well-preserved plant and animal fossils, cemented with mineral matter. The marine animals found fossilized in these coal balls include sponges, corals, crinoid stems, bryozoa (lace corals), brachiopods, mollusks, arthropods, conodonts, and even fish.[17] Furthermore, the mineral cement of these coal balls requires a salt-water environment for their formation.[18]

One of the most striking inorganic features of coal seams is the presence of boulders. These have been observed in coal beds all over the world, including Europe and North America, for well over one hundred years. In a survey of the many erratic boulders found in the Sewell Seam in West Virginia, the average weight of forty boulders collected was 5.44 kg, with the largest weighing just over 73 kg.[19] Many of the boulders were igneous and metamorphic rocks, unlike any rock outcrops in West Virginia. The nearest possible source for some of them was almost 100 km away. It has been suggested that the boulders must have been transported from their distant source areas as they were entwined in the roots of trees. Thus, the occurrence of these boulders in the coal seams would seem to favor the allochthonous model.

16 H. G. Coffin, 1968, A paleoecological misinterpretation, *Creation Research Society Quarterly*, 5: 85.

17 S. H. Mamay and E. L. Yokhelson, 1962, *Occurrence and significance of marine animal remains in American coal balls*, US Geological Survey Professional Paper, 354-I: 193-224.

18 L. R. Moore, 1968, Some sediments closely associated with coal seams, in *Coal and Coal-bearing Strata*, D. Murchison and T.S. Westoll, ed., New York: American Elsevier Publishing Company, 105-107.

19 P. H. Price, 1932, Erratic boulders in Sewell Coal of West Virginia, *Journal of Geology*, 40: 62-63.

71

Coal Beds—Fossil Graveyards of Plants That Grew Floating on Water

The types of fossil plants found in coal seams do not readily, or necessarily, support the autochthonous (growth-in-place) model for coal seam formation. The fossil plants in the North American and European Carboniferous coals are dominated by fossil lycopods trees (for example, *Lepidodendron* and *Sigillaria*), and giant ferns (especially *Psaronius*). While it is claimed these plants may have had some ecological tolerance to swampy conditions, other Carboniferous coal plants, such as the conifer *Cordaites*, the giant scouring rush *Calamites*, and the various extinct seed ferns, by their basic construction must have preferred well-drained soils, not swamps.

However, the anatomy of these plants needs to be carefully reconsidered. The huge, fossilized trunks of these Carboniferous trees, as exposed in outcrops and in coal mines, are not solid wood, but casts of hollow stems. Indeed, all the trees whose remains are either found in the Carboniferous coal seams, or associated with them, are either hollow or otherwise lightly-built structures.[1] The lycopods, *Lepidodendron*, *Sigillaria*, and related genera, giant relatives of the clubmosses, were supplied with mineral nutrients and water through a central cylinder, while a tough and ever-widening ring of bark rendered structural support. The space between the bark and the central cylinder was largely filled with aerenchyma (air tissue). In the fossil state, these tree trunks are found either flattened or, if buried erect, filled with sediment, which on occasion has been found to have entombed gastropods, worms, and even reptiles.[2] These tree-sized lycopods are known to have grown to heights of up to 45 meters,[3] their trunks rising above four cross-shaped, equally air-filled, main roots, which in turn were forked dichotomously, and extended away from the stem by as much as 20 meters horizontally. Apart from a spongy central cylinder, these structures were also essentially hollow, so like the trunks, they are also preserved either flat or as casts. The central cylinder usually became compressed after burial, which left a characteristic groove on the top sides of many of these roots resulting from this compression. These air-filled root axes, known as *Stigmaria*, were covered all around with radiating appendices, that is,

1 Scheven, 1981, 40-41; J. Scheven, 1990, Stasis in the fossil record as confirmation of the belief in Biblical Creation, in *Proceedings of the Second International Conference on Creationism*, volume 1, R. E. Walsh and C. L. Brooks, ed., Pittsburgh, PA: Creation Science Fellowship, 197-215.

2 J. W. Dawson, 1866, On conditions of the deposition of coal, more especially as illustrated by the coal formations of Nova Scotia and New Brunswick, *Quarterly Journal of the Geological Society*, 22: 95-104.

3 White, 1986, 75.

pencil-thick organs up to 0.5 m long, which again seem to have contained little but air. Frequently they are preserved in their original lamp-brush position, which is a growth pattern characteristic of plant organs submerged in water, whereas roots growing in soils are always predominantly geotropic. These *Stigmarian* axes thus formed a network of roots in water, over which the tall trunks of the lycopods could stand erect, the leaf tops of the trees probably being quite small. The fact that disused appendices of older *Stigmaria* fell off at tree-formed abscission layers, leaving behind the well-known circular scars seen on the bark of fossilized trunks, is further proof that the coal-forming lepidophytes never grew in soils on firm ground, but must have been floating adherently on water surfaces.

That the flora found fossilized in the Carboniferous coals was originally a floating vegetation ecosystem was first recognized more than a century ago.[4] The principal constituent of a Carboniferous coal seam appears to have been these criss-crossing, intertwined lycopod roots (*Stigmaria*), as determined through the study of coal balls. Furthermore, the remains of trunks have been found fossilized, buried in the upright living position, apparently rooted in the coal seams themselves, having grown in the peat that developed on the floor of this floating-forest vegetation, supported by the entangled *Stigmaria*. Nevertheless, the most common plant fossils found in the shales, which often overlie the coal seams, are the leaves of seed-bearing ferns, the stems of which grew several meters high. The roots of these seed ferns are never encountered in the so-called underclays, where lycopod roots are usually found in abundance. Instead, the roots of the seed ferns are found only in the coal seams themselves, and thus the seed ferns seem to have been rooted above the matted and interwoven *Stigmaria*-tangle in the thick-layered peat formed from leaf and other litter. The seed ferns, therefore, probably represented the undergrowth in the floating forest's decay system. Similarly, the roots of the conifer *Cordaites* are not found in the underclays among the *Stigmaria*, so it seems certain that the *Cordaites* trees also grew on the peat layer accumulating above the *Stigmaria* roots, rather than from the level of those roots that became buried in the underclays. Tree trunks of *Cordaites* enclosed a wide pith, which thus lessened their weight. Some Carboniferous coal-bearing strata contain a greater percentage of fossilized giant horsetails, commonly *Calamites*, whose stems were essentially hollow, greatly reducing their bulk weight. Cross-sections of the roots of *Calamites*, also sometimes found in coal balls within coal seams, reveal that they also consisted of large air spaces, which means that these roots can likewise be interpreted as submerged organs. Thus, the giant horsetails were probably also growing as part of this floating-forest ecosystem, perhaps sometimes growing by themselves.

The coal seams of the southern hemisphere continents plus India, that are said to have been joined together in a Gondwana supercontinent, are all Permian, in contrast to the North American and European coals, which are Carboniferous. These Gondwana coals also are made up of a different fossil flora, dominated by

4 O. Kuntze, 1895, *Geogenetische Beitrage. Sind Carbonkohlen autochthon, allochthon oder pelagochthon?*, Leibzig, Germany.

fossilized *Glossopteris* leaves. The common lack of underclays, or so-called fossil soils, beneath the Gondwana coal seams has in the past been convincing evidence that the plant remains were transported and deposited to form the coal seams:

> In the case of the Permo-Carboniferous of India, the Barakar Series and the Damuda Series, overlying the Talchir Boulder Bed, include numerous coal seams, some up to 100 feet thick, occurring in a well-developed and oft-repeated cycle of sandstone, shale, coal.... The vegetation is considered to be drift accumulation.[5]

However, such is the strength of the prevailing paradigm, shaped by the interpretation of the evidence associated with the Carboniferous coals, that the Permian Gondwana coals are nevertheless still almost universally regarded to have been produced by peat swamps that grew in place.[6] That assertion, though, depends heavily on the assumption that the *Glossopteris* flora found fossilized associated with, and in, the coal seams is of autochthonous origin. Yet the fossil *Glossopteris* flora is poorly understood, because what has been preserved is almost exclusively fossilized leaves.

The name *Glossopteris* refers to the tongue-shaped outline of these detached leaves, but the overall appearance of the plants has not yet been conclusively elucidated due to the lack of complete fossils, and in spite of claims to the contrary.[7] To identify *Glossopteris* leaves on a specific level is practically impossible, given the range of shapes and venations found in fossil specimens. Without a pronounced mid-rib such fossil leaves are referred to the genus *Gangamopteris*. There are, however, so many intermediates between this absence of a mid-rib through to the mid-rib in *Glossopteris* leaves, and an arrow-shaped *Glossopteris* leaf from India has an outline similar to the leaf of an arum lily.[8] Without the support of this mid-rib (which is actually only a concentration of parallel veins), these leaves may even have grown underwater. There are perhaps fewer than one dozen descriptions of fossil twigs with *Glossopteris* leaves connected to them.[9] It appears that the leaves grew in whorls, perhaps comparable to some conifers like *Araucaria*. The compressed reproductive organs have been given various names, and are so different from one another that their relationships are difficult to elucidate with

5 S. E. Hollingsworth, 1962, The climatic factor in the geological record, *Quarterly Journal of the Geological Society of London*, 118: 13.

6 For example, Diessel, 1992.

7 For example, White, 1986, 99-121.

8 J. Scheven, 1992, *Gleanings from Glossopteris*, Fifth European Creationist Congress, Biblical Creation Society and Creation Science Movement, England.

9 J. Etheridge, 1905, Sub-reniform-ovate leaves of *Glossopteris, Records of the Geological Survey of New South Wales*, Sydney; E. Dolianiti, 1954, *A Flora do Gondwana Inferior Em Santa Catarina IV*. Notas Preliminares e Estudos, Ministry of Agriculture, Rio de Janeiro; E. P. Plumstead, 1958, The habitat of growth of *Glossopteridae, Transactions of the Geological Society of South Africa*, 61: 81-96; D. D. Pant, 1977, The plant of *Glossopteris, The Journal of the Indian Botanical Society*, 56 (1): 1-23.

certainty.[10] The striking uniformity of leaf shapes may have been imposed by an environmental factor, or may be internally controlled. Its nearest replication is among numerous recent ferns.[11]

The only fossilized, stem-like structures found with *Glossopteris* leaves are flat ribbon-like impressions that are vaguely reminiscent of bones in the human vertebral column, so they have been given the name *Vertebraria*. Although usually much rarer, the fact that they occur in conjunction with *Glossopteris* leaves probably means that both are just different organs of the same type of plant. A number of reconstructions of *Vertebraria* postulate large serial air spaces along their axes, which would explain the invariably flattened appearance of the *Vertebraria*.[12] Thin threads, that are apparently genuine roots, are sometimes visible where they emerge from the main axes at the junction between neighboring air spaces. It also appears as if there are two modifications of *Vertebraria* axes—the thin and inflated horizontal rhizome-like structures, and the more solid, upright version, which would appear to have carried the foliage. The chambered axes with their air spaces clearly point to an aquatic mode of life, which would suggest only moderate growth, perhaps with a semi-herbaceous, water-borne habit.

Despite the almost total absence of fossilized *Glossopteris* leaves attached to fossilized branches and tree stumps, it has been claimed that the *Glossopterids* were woody plants, presumably of all sizes from shrubs to large trees.[13] However, the fossilized tree stumps and prone logs found associated with coal seams, and at various levels within the inter-seam sedimentary strata of the coal measures in the Sydney Basin, eastern Australia, have been assigned to the genus *Dadoxylon*, related to the conifers of the *Araucaria* because of their woody structure with many distinct growth rings.[14] It should, therefore, be obvious that these woody tree stumps and logs cannot be the same as, or even related to, these *Vertebraria* with their chambered air spaces that are undoubtedly related to the ubiquitous *Glossopteris* leaves found with them. The other fossil flora that accompanies *Glossopteris* in association with the Gondwana coals include some lycopods,

10 E. P. Plumstead, 1958, Further fructifications of the *Glossopteridae* and a provisional classification based on them, *Transactions of the Geological Society of South Africa*, 61: 51-79, M. E. White, 1978, Reproductive structures of the *Glossopteridales* in the plant fossil collection of the Australian Museum, *Records of the Australian Museum*, 31 (12): 473-505; M. E. White, 1986, 108-121.

11 Scheven, 1992.

12 J. M. Schopf, 1965, Anatomy of the axis in *Vertebraria*, in *Geology and Palaeontologies of the Antarctic*, Antarctic Research Series, 6: 217-228; R. B. Gould, 1975, A preliminary report on petrified axes of *Vertebraria* from the Permian of eastern Australia, in *Gondwana Geology*, K. S. W. Campbell, ed., Canberra: Australian National University Press, 109-115; Pant, 1977; White, 1986, 102-109; P. G. Neish, 1993, A. N. Drinnan and D. J. Cantrill, Structure and ontogeny of *Vertebraria* from silicified Permian sediments in east Antarctica, *Review of Palaeobotany and Palynology*, 79: 221-244.

13 Pant, 1977; White, 1986, 102-3, 108.

14 W. B. Clarke, 1884, Awaba fossil forest, *Annual Report of the Department of Mines, New South Wales*, 156-159; T. W. E. David, 1907, The geology of the Hunter River coal measures, New South Wales, *Geological Survey of New South Wales, Memoir 4*; Diessel, 1992.

horsetails, ferns, and seed-ferns. Thus, this fossil floral assemblage, ostensibly from mixed habitats, though dominated by water-borne varieties, is more consistent with an allochthonous origin for these Gondwana coals.

Because "the composite thickness of the 300 m of brown coal in a mere 800 m of coal measures in the Latrobe Valley of Victoria, Australia" required "conditions in time and space for which there are no current equivalents on Earth,"[15] it is important to also review the fossil flora found in these thick (up to 165 m) lignite seams. These seams are considered to be autochthonous in origin, requiring a coal-forming swamp that occupied an area of at least 50 x 25 km, in which there were a number of changing plant communities. These ranged from a swamp lake and moors, to swamp forests, supposedly similar to the vegetation claimed to be in the coal-forming swamps responsible for producing the Tertiary brown coals of the Lower Rhineland area of Germany.[16] Yet the list of trees whose wood is found in the Latrobe Valley coal seams includes the conifers *Agathis* (Kauri), *Araucaria* (Hoop Pine), *Dacrydium* (Huon Pine), *Phyllocladus* (Celery-top Pine), and *Podocarpus* (Totara), all in the families *Araucariaceae* and *Podocarpaceae*, and the angiosperms *Casuarina*, *Nothofagus*, and *Banksia*.[17] Other plant groups, including the *Ericales*, *Myrtaceae*, *Oleaceae*, and *Proteaceae*, are assumed to be present in the brown coal because of the occurrence of their pollen there.

It has been concluded that the forests from which the brown coal was formed were most purely coniferous, and hardwoods, although occasionally present, were somewhat accidental. Furthermore, the coal seams consist largely of tree trunks, some with their roots upright, there being a general absence of mineral matter. Nevertheless, it is insisted that all these conifers, and hardwoods, grew in a huge forest in a swamp. However, these trees today are known to only grow in rainforests.[18] Indeed, many of these trees cannot tolerate swampy conditions, as is evidenced by where their descendants grow today, namely, in soils on firm ground that is not swampy. Some grow in the same area today, but the Kauri and most of the other pines, for example, prefer more subtropical-tropical environments. Thus, it is evident that the brown coal formed as a result of transport and deposition of all this plant material, leaving prone logs and tree stumps with roots upright as unequivocal evidence.

15 Diessel, 1992, 4.

16 M. Teichmüller, 1958, Reconstruction of the various moor types in the mainland Coal Seam of the Lower Rhineland, *Fortschrieft Geologische Rhineland und Westfalen*, 2: 599-612; A. M. George, 1975, Brown coal lithotypes in the Latrobe Valley deposits, *State Electricity Commission of Victoria, Petrological Report*, 17: 32-35.

17 I. C. Cookson and S. L. Duigan, 1951, Tertiary Araucariacae from south-eastern Australia, with notes on living species, *Australian Journal of Scientific Research*, B (4): 415-449; R. T. Patton, 1958, Fossil wood from Victorian brown coal, *Proceedings of the Royal Society of Victoria*, 70 (2): 129-143; George, 1975.

18 Patton, 1958; I.R.K. Sluiter et al, 1995, Biogeographic, ecological and stratigraphic relationships of the Miocene brown coal floras, Latrobe Valley, Victoria, Australia, *International Journal of Coal Geology*, 28: 277-302.

Underclays—Fossil Soils?

Among the strongest evidences claimed for the autochthonous (growth *in situ*) model for coal formation is the widespread presence, under the Carboniferous coal seams of North America and Europe, of what are called underclays or seat-earths. These are regarded as the fossilized remains of the substrate or soil in which ancient vegetation once germinated and flourished in a swamp, and then died to accumulate the peat. The presence of *Stigmaria*, the fossilized roots of the lycopods found fossilized in association with the coal seams, projecting out from under the coal seams into these underclays, is claimed to be *prima facie* evidence that these lycopods grew *in situ* in these underclays in coal-forming swamps. However, the *Stigmarian* roots of the lycopods are the only plant organs commonly found in these underclays. Other roots, for example, of ferns, seed-ferns, horsetails, and the conifer *Cordaites*, which are well known within the coal seams, are completely absent in the underclays.[19] This is the principal difference between the *Stigmarian* roots of the lycopods and the roots of other constituents of the coal-forming vegetation. In contrast, in any modern plant community the member plants are rooted side-by-side in the substrate soil. Because this is not the case with the underclays, the obvious conclusion is that the plant communities of these Carboniferous coal-forming forests were not rooted in soils, and the underclays are thus not fossilized soils.

Additional confirmation of this is the hollow structure of the *Stigmarian* roots and of the trunks of the lycopods (as already elaborated above), which conclusively demonstrate that these trees (giant clubmosses) must have grown in water in a unique floating-forest ecosystem that is now extinct.[20] Thus, the presence of the fossilized *Stigmaria* in the underclays is because they became entombed in these clays as the peat layers they supported, by their intertwined network generated by the floating forests, were buried by the sediments being deposited on top of them. The evidence for these *Stigmaria* not being soil-penetrating roots but hollow structures for supporting the lycopod trees in water is irrefutable, because of the careful investigation of well-preserved *Stigmaria* in coal balls.[21] Indeed, the name "stigmaria" is derived from the presence of numerous scars spirally distributed all over the surface of the cylindrical roots where aging rootlets were shed, just like foliage discarded on branches, a procedure that does not occur in roots that grow in soils, but is consistent with their growth in water.

---

19 J. Scheven, 1996, The Carboniferous floating forest—an extinct pre-Flood ecosystem, *Creation Ex Nihilo Technical Journal,* 10 (1): 70-81.

20 K. P. Wise, 2003, The pre-Flood floating forest: a study in paleontological pattern recognition, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 371-381.

21 J. Frankenberg and D. A. Eggert, 1969, Petrified *Stigmaria* from North America: part 1. *Stigmaria ficoides*, the underground portions of lepidodendraceae, *Palaentographica Abt.*, B 128: 1-2, Stutgart; J. R. Jennings, 1973, The morphology of stigmaria stellata, *American Journal of Botany*, 60 (5): 414-425.

Much research has shown conclusively that these underclays are not fossilized soils. For example, the chemical and physiological nature of the underclays reveals no soil profile similar to that found in modern soils:

> The relationships between underclays and coals indicate that the underclays formed before the coals were deposited. Furthermore, lack of a soil profile similar to modern soils and similarity of the mineralogy of all rock types below the coals indicate that underclay materials were essentially as they were transported into the basin. … The underclays were probably deposited in a loose, hydrous flocculated state, and slickensides developed during compaction.[22]

Numerous other scientific papers reporting research on these underclays over five decades repeatedly conclude that the underclays are not the product of atmospheric weathering, show no soil profiles, and are in fact transported sediments.[23] Indeed, some of the minerals found in the underclays are not those that would be expected in a soil. Probably the most widespread type of underclay is a purplish-black mudstone, thickly permeated from flattened *Stigmaria* and their adhering appendices. Most common are underclays consisting of laminated siltstone or of pure sandstone. In some instances, it has been observed the lithology of an underclay may vary below a seam over some distance. Furthermore, an underclay may also consist of limestone. How could these underclays therefore be fossilized soils, as no living plant is known that would tolerate such a diversity of "soils," from nutrient rich to sterile, and from utterly acidic to utterly alkaline? The different lithologies around the lycopod roots are therefore simply the product of the deposition of different sediments, and no relationship exists between the uniform coal-forming vegetation and the varying compositions of these underclays that have been claimed to be fossil soils. In any case, many coal seams do not rest on underclays, even being found to overlie granite or schist where there is no evidence whatsoever of a former soil. Other coal seams, such as the Gondwana coals that rival the Carboniferous coals of North America and Europe, are rarely underlain by these underclays, with siltstones, sandstones, and even conglomerates and tuffs, being far more prevalent beneath the coal seams than shales or mudstones.[24]

Where underclays contain a component of sand or silt they are commonly laminated or stratified, due to the differential segregation of the different sized sediment particles during the settling process. Many typical underclays of the northwest European coal basins are between two and three meters thick, and are distinctly more coarse-grained toward their bases. In other examples there is

22 L. G. Schultz, 1958, Petrology of underclays, *Geological Society of America Bulletin*, 69 (4): 391-392.

23 Scheven, 1996, 72, Table 1.

24 For example, Diessel, 1992, 362-365, Figure 7.9, which is a detailed stratigraphic section of the Tomago and Newcastle Coal Measures in the Sydney Basin, eastern Australia.

evidence of clay flocculation. These are all simple sedimentary features that always form in water-accumulated layers. Furthermore, the laminations, stratification, and graded bedding have in no way been disturbed by the *Stigmaria* entombed in the underclays, in comparison to a true soil where growing roots will destroy any such original structures. Thus, the coal-forming vegetation did not take root on the surfaces of the underclays after the underclays formed, so the latter were not soils, but just sediments that buried the *Stigmaria*. Also relevant is the observation that, although the Carboniferous underclays are devoid of root organs other than the *Stigmarian* axes belonging to lycopods, there are numerous fine examples of fern pinnules and even parts of whole fronds found in some underclays, as well as lepidophyte bark and fossilized marine organisms. A fresh fern frond in soil will decompose within a very short time, yet these fern fronds are identical to those ordinarily found in the roof shales above the coal seams, so both must therefore have been buried in the same manner by sediment deposition. The persuasive clarity of all this evidence has convinced serious investigators for more than a century that these ubiquitous underclays beneath Carboniferous coal seams are not soils in which vegetation grew *in situ*, but are very clearly water-laid sediments.[25]

It was the *Stigmaria* in the underclays beneath the Carboniferous coal seams of Nova Scotia, studied by Charles Lyell and J. W. Dawson almost 160 years ago, that were considered to provide definitive proof that the coal-forming vegetation grew in place.[26] However, this same Nova Scotia coal sequence was restudied 125 years later, and four types of sedimentary evidence for the allochthonous origin of the *Stigmaria* in the underclays were documented.[27] The *Stigmaria* were found to be only fragments, and rarely attached to a lycopod tree trunk. The *Stigmaria* in each sampling location also showed a preferred orientation of their long axes, unequivocal evidence of current action during deposition. Furthermore, the *Stigmaria* were filled with sediment unlike the immediately surrounding sedimentary rock, and they were often found on multiple horizons in beds that were entirely penetrated by upright fossilized lycopod tree trunks. Thus, it was concluded that these *Stigmaria* studied, and their enclosing sedimentary strata, must have been transported by water and deposited in their present locations, rather than having grown in place. However, this is not the only coal measure sequence where these observations have been made, because the *Stigmarian* axes associated with coal seams in other places have occasionally been found to be in drift-aligned positions, while the surrounding appendices have been found compressed on split rock surfaces contrary to their natural arrangement of

---

25 W. S. Gresley, 1887, Notes on the formation of coals seams as suggested by evidence collected chiefly in the Leicestershire and South Derbyshire coalfields, *Quarterly Journal of the Geological Society of London*, 43: 671-674.

26 C. Lyell, 1844, On the upright fossil-trees found at different levels in the coal strata of Cumberland, Nova Scotia, *Annals and Magazine of Natural History, Companion: Botanical Magazine N.S.*, 17: 148-151.

27 N. A. Rupke, 1969, Sedimentary evidence for the allochthonous origin of Stigmaria, Carboniferous, Nova Scotia, *Geological Society of America Bulletin*, 80: 2109-2114.

growth.[28] All of these observations, taken together, plus the fact that underclays may also occur on top of coal seams, demonstrate conclusively that underclays were deposited in the normal sedimentary deposition cycle of the other strata in coal measure sequences, including the coal seams themselves.

Upright Fossilized Trees

One of the most fascinating types of fossils associated with coal seams are upright tree trunks, which often penetrate several to ten or more meters perpendicular to the stratification, such fossils being known as polystrate (many strata). These upright tree trunks are frequently encountered in strata associated with coal, often sitting directly on top of the coal seams, and on rare occasions are found in the coal itself. It was in the 1830s that the so-called fossil forest at Joggins, Nova Scotia, was first noticed, and following detailed mapping in the early 1840s, was frequently visited by Lyell and Dawson, who both regarded these fossilized upright lycopod tree trunks, along with the *Stigmaria* in the underclay, as conclusive proof of the autochthonous (growth-in-place) model for coal-seam formation.[29]

Among the important discoveries also made was the occurrence of vertebrate and invertebrate fauna within the erect tree stumps, the hollow insides of which had been infilled with sediments that had entombed these animals. Eleven vertebrate genera have so far been identified, including amphibians and reptiles (over 100 individuals), as well as snails, millipedes, worms, and even a may-fly.[30] In recent years, fauna previously found only in the fossilized tree trunks has been discovered external to them, including an amphibian skull, and a fully articulated reptile skeleton. "Many of the trunks are up to 5 m tall and 75 cm in diameter, and the nature of the sediments within the trunks suggest that at some periods the trunks may have been submerged in more than 5 m of water."[31] Sediments that fill the hollow lycopod trunks to make the cast of them are commonly unlike the immediately surrounding sedimentary strata, but there is also evidence that, after the hollow lycopod trunks were surrounded by sediment, the bark surviving long enough to keep the hollow inside unfilled, the sediment layer being washed in above slumped into the hollow trunks to infill them, taking with them the animals

28 Scheven, 1981, 39; Gastaldo, 1999, 151, Figure 4.1.

29 Lyell, 1844; C. Lyell and J. W. Dawson, 1853, On the remains of a reptile (*Dendrerpeton acadianum* Wyman and Owen), and of the land shell discovered in the area of an erect fossil tree in the coal measures of Nova Scotia, *Geological Society of London Quarterly Journal*, 9: 58-63; J. W. Dawson, 1866, On the conditions of the deposition of coal, more especially as illustrated by the coal formations of Nova Scotia and New Brunswick, *Quarterly Journal of the Geological Society*, 22: 95-104; J. W. Dawson, 1882, On the results of recent explorations of erect trees containing animal remains in the coal-formation of Nova Scotia, *Philosophical Transactions of the Royal Society of London*, 173 (II): 621-654.

30 M. R. Gibling, J. H. Calder and R. D. Naylor, 1992, Carboniferous coal basins of Nova Scotia, *Geological Association of Canada and Mineralogical Association of Canada, Joint Annual Meeting*, Wolfville '92, Field trip C-1, guidebook, 21-29; A. C. Scott and J. H. Calder, 1994, Carboniferous fossil forests, *Geology Today*, 10 (6): 213-217.

31 Scott and Calder, 1994, 215.

that had been trapped within those sediments due to the speed of the deposition.[32] Also confirming the rapid rate of transport and deposition of these sediments that buried and infilled these lycopod trunks is the presence of cross-bedding in the sandstones inside some of the casts of the fossilized lycopod trunks.[33]

The "fossil forest" of upright, polystrate tree trunks associated with the Carboniferous coal seams at Joggins, Nova Scotia, is not unique. Numerous other examples have been found in North America and Europe. Some examples include the "fossil forests" at Kupferdray near Essen in Germany,[34] at Weaklaw near North Berwick on the Scottish coast just east of Edinburgh, on the northeast corner of the island of Arran off the west coast of Scotland, at Table Head near Sydney on Cape Breton Island, at Mary Lee in the Warrior Basin of northwestern Alabama, [35] and along Sand Mountain in the Plateau coalfield of northeastern Alabama.[36] However, these "fossil forests" are not confined to Carboniferous coal measure sequences, but have also been found in Permian Gondwana coal measure sequences, such as in the Newcastle and Wittingham Coal Measures in the Sydney Basin of Australia's east coast.[37] Indeed, in the Newcastle Coal Measures there are repeated horizons with fossilized upright tree stumps and prone logs, but here the wood of the trees, which are usually *Dadoxylon* (probably belonging to the *Araucariaceae*), is either coalified or petrified. Some of these tree trunks are sitting on top of one coal seam penetrating the strata above and right up through the next coal seam (Figure 46, page 1083). Miners have reported such upright coalified logs being tens of meters long, and penetrating several coal seams and the strata between them.[38] Most of these fossilized logs and tree stumps have no roots, because they have been broken off (Figure 47, page 1084).

In each case, the sediments that make up the strata in which these fossilized trees are entombed must have amassed rapidly in a short time to cover the trees before they could rot and fall down:

> In 1959 Broadhurst and Magraw described a fossilized tree, in position

32 Scheven, 1996, 76-77, Figures 5-7; H. G. Coffin, 1969, Research on the classic Joggins petrified trees, *Creation Research Society Quarterly*, 6 (1): 35-44, 70.

33 Diessel, 1992, 390, Figure 7.30; Scheven, 1996, 77, Figure 7.

34 H. Klusemann and R. Teichmüller, 1954, Begrabene Wälder im Rurhkohlenbecken, *Natur und Volk*, 84: 373-382; Stach et al, 1982, 7, Figure 1.

35 R. A. Gastaldo, T. M. Demko, and Y. Liu, 1993, The application of sequence and genetic stratigraphic concepts to Carboniferous coal-bearing strata: an example from the Black Warrior Basin, USA, *Geologische Rundschau*, 82: 212-226; Scott and Calder, 1994; Gastaldo, 1999, 150, Figure 3.1.

36 R. A. Gastaldo, M. A. Gibson and T. B. Gray, 1989, An Appalachian-sourced deltaic sequence, northwestern Alabama, USA: biofacies-lithofacies relationships and interpreted community patterns, *International Journal of Coal Geology*, 12: 225-257.

37 David, 1907; I. G. Percival, 1985, *The Geological Heritage of New South Wales*, volume 1, New South Wales National Parks and Wildlife Service, Sydney, 2-3, 81-89; Diessel, 1992, 312-329, Figures 6.33, 6.41 and 6.42, 360-371, Figures 7.9 and 7.18, and 388-393, Figures 7.29, 7.31 and 7.32.

38 Personal communication from Bruce Clark in 1998 in reference to the West Wallsend Colliery.

> of growth, from the coal measures at Blackrod near Wigan in Lancashire. This tree was preserved as a cast, and the evidence available suggested that the cast was at least 38 feet (almost 12m) in height. The original tree must have been surrounded and buried by sediment which was compacted before the bulk of the tree decomposed so that the cavity vacated by the trunk could be occupied by new sediment which formed the cast. This implies a rapid rate of sedimentation around the original tree.[39]
>
> It is clear that trees in position of growth are far from being rare in Lancashire (Teichmüller, 1956, reaches the same conclusion for similar trees in the Rhein-Westfalen Coal Measures), and presumably in all cases there must have been a rapid rate of sedimentation.[40]

It is also noteworthy that even though many of these fossilized tree trunks may be six to nine meters high, the tops of the trees have never been found preserved also. In every case, the tops of the trees have been broken off, and often at the bottom as well, being devoid of both branches and roots. The fossilized tree trunks are not always found erect either, occurring in positions at all angles to the enclosing strata, and some even appear to be upside down, with their root end uppermost.[41] A striking example of an inclined fossilized trunk was found in a sandstone quarry near Edinburgh, Scotland, this fossilized log being 25 m long, leaning at an angle of about 40°, and intersecting ten or twelve different strata.[42] Other similar examples have been recorded, in one case with the comment: "In such examples, the drifted trees seem to have sunk with their heavy or root end touching the bottom and their upper end pointing upward in the direction of the current."[43] Just as noteworthy is where upright trees appear to be rooted in the growth position in one stratum, which is entirely penetrated by a second upright tree.[44]

Thus, in conclusion, the evidence unequivocally favors the contention that these polystrate tree fossils in the strata associated with coal seams were buried rapidly, and thus the sediments making up the strata enclosing them had to also be rapidly deposited. Of even further significance is that not only are the polystrate tree

39 F. M. Broadhurst and D. Macgraw, 1959, On a fossil tree found in an opencast coal sight near Wigam, *Lancashire, Liverpool and Manchester Geological Journal*, 2: 155-158; F. M. Broadhurst, 1964, Some aspects of the paleoecology of non-marine faunas and rates of sedimentation in the Lancashire coal measures, *American Journal of Science*, 262: 865.

40 R. Teichmüller, 1956, Die Entwicklung der Subvariscishen Vortiefe und der Werdegang des Ruhrkarbons, Z, *Dtsch Geol. Ges.*, 107: 55-65; Broadhurst, 1964, 866.

41 N. A. Rupke, 1966, Prolegomena to a study of cataclysmal sedimentation, *Creation Research Society Quarterly*, 3: 16-37.

42 W. E. Tayler, 1857, *Voices from the Rocks (or proving the existence of man during the Paleozoic or most ancient period of the earth): A Reply to the late Hugh Miller's Testimony of the Rocks*, London.

43 A. Geikie, 1903, *Textbook of Geology*, fourth edition, London: MacMillan, 655.

44 Rupke, 1966.

fossils found over wide areas in many places, but they occur over thick vertical strata successions, such as Joggins, Nova Scotia, where these erect fossilized tree trunks have been found at twenty horizons distributed at intervals through about 750 m of strata.[1] Thus, these polystrate tree trunks are also significant as evidence for rapid deposition of thick sequences of strata and the coal seams found in these coal measure sequences. Furthermore, the coal seams represent the fossil graveyards of countless billions of tons of plant remains.

1 C. O. Dunbar, 1960, *Geology*, second edition, New York: Wiley, 227.

72

Further Examples of Fossil Graveyards

The geologic record consists of many fossil graveyards and their enclosing strata sequences that show convincing evidence of rapid and catastrophic deposition of sediments on an enormous scale. Examples of fossil graveyards already described above, including the coal beds, are but a few of the many that could be cited. A few more examples, therefore, will suffice to underscore how prevalent fossil graveyards really are.

In the lower Devonian Hunsrück Slate of Germany, the non-biomineralized tissues of organisms with exceptional detail are preserved by replacement with pyrite, including trilobites, nautiloids, star-fishes, and other invertebrates.[2] It is considered even more remarkable that the finest details of arthropod trackways and other trace fossils are so well preserved, along with the pyritized soft-bodied fossils, in what are regarded as storm-induced, rapidly-deposited, fine-grained turbidites.[3]

Upper Devonian strata are also known for their abundant fish fossils, often found in mass mortality layers, such as that found near Canowindra in the central west of New South Wales, Australia—thousands of fossilized armored and lobe-finned fishes, the latter up to 1.5 m long, with head, skull, and gill regions superbly preserved in three dimensions.[4] Testimony to the immensity of this fossil fish graveyard is that the first discovered slab of sandstone, two meters by one meter, had 114 fossilized fish, most of them complete, beautifully preserved on its surface, and the thousands of fossilized fish specimens so far recovered have all come from a twenty meter section of this extensive sandstone layer.

An equally impressive upper Devonian fossil fish graveyard with three-dimensionally, perfectly preserved, armor-plated, jawed fishes is found in the

2 D. E. G. Briggs, R. Raiswell, S. H. Bottrell, D. Hatfield and C. Bartels, 1996, Controls on the pyritization of exceptionally preserved fossils: an analysis of the lower Devonian Hunsrück Slate of Germany, *American Journal of Science*, 296: 633-663; C. Bartels, D. E. G. Briggs and G. Brassel, 1998. *The Fossils of the Hunsrück Slate: Marine Life in the Devonian*, Cambridge, England: Cambridge University Press.

3 A. Seilacher et al, 1985, Sedimentological, ecological and temporal patterns of fossil Lagerstätten, *Royal Society of London Philosophical Transactions B*, 311 (1148): 5-23; O. E. Sutcliffe, D. E. G. Briggs and C. Bartels, 1999, Ichnological evidence for the environmental setting of the Fossil-Lagerstätten in the Devonian Hunsrück Slate, Germany, *Geology*, 27 (3): 275-278.

4 A. Ritchie, 1994, The Canowindra fish kill, *Australasian Science*, Summer Issue: 17-18; J. Cribb, 1996, A prize catch, Australian Geographic, 43: 100-115.

limestones of the Gogo Formation of northern Western Australia.[5] Also well preserved in the Gogo fossil fish graveyard are ray-finned fishes, lung-fishes, and megamouth-toothed, lobe-finned fishes.

Yet another Australian fossil fish graveyard is a shale lens in the Triassic Hawkesbury Sandstone at Somersby in the Sydney Basin, where in a volume of shale, measuring 100 meters by 60 meters to an average depth of 2 meters, it was estimated that over 1,200 well-preserved fossil fish were found, including more sharks and lung-fishes.[6] As many as six or seven fossilized fish were found per square meter of shale in morality zones, where the occurrence of associated sand and pebbles confirms the catastrophic death and burial of these fish.

Another spectacular fossil graveyard of incredible extent, somewhat comparable to coal seams, are the Cretaceous chalk beds that consist of the tiny calcium carbonate shells (or tests) of countless trillions of microscopic foraminifera and coccolithophores (calcareous algae). In southern England the chalk beds are estimated to be about 405 m thick, and from there they extend inland across England to the Antrim area of Northern Ireland, southwest Ireland, and to extensive areas of the sea floor south of Ireland. In the opposite direction they extend from northern France across northern Germany and southern Scandinavia, to Poland, Bulgaria, and eventually to Georgia in the south of the Commonwealth of Independent States.[7] However, identical chalk beds are also found in Egypt and Israel. On the other side of the Atlantic Ocean the same chalk beds are found in Texas, through to Alabama, Arkansas, Mississippi, and Tennessee, in Nebraska and adjoining states, and in Kansas. Incredibly, identical chalk beds, complete with the same black flint nodules and the same fossils, are found in the Perth basin of Western Australia. As well as the countless microfossils, this fossil graveyard of global distribution contains many macroscopic fossils, including barnacles, crustaceans, brachiopods, oysters, gastropods, pelecypods, cephalopods, ammonites, bryozoans, echinoids, corals, crinoids, and even fish, as well as abundant trace fossils, particularly burrows.[8] That catastrophic deposition rates were involved in forming these thick chalk beds is evident from the size of some of the ammonite fossils (which may be up to one meter in diameter), and the large *Mosasaurus* skull found near Maastricht (The Netherlands), as well as by the recognition of storm-deposited tempestite layers within the chalk.

Other famous fossil graveyards in Mesozoic strata include the upper Jurassic Solnhofen Limestone of Bavaria, Germany, which has yielded some of the world's

---

5 J. A. Long, 1988, Late Devonian fishes from the Gogo Formation, Western Australia, *National Geographic Research*, 4: 436-450.

6 F. Holmes, 1987, Somersby – Paradise for "Palaeofisherman," *The Fossil Collector*, 21: 23-28; Mann, 1987, Fossil find rewrites Australia's past, *Omega Science Digest*, January/February: 14-21.

7 D. V. Ager, 1973, *The Nature of the Stratigraphical Record*, London: MacMillan; A. A. Snelling, 1994, Can Flood geology explain thick chalk layers?, *Creation Ex Nihilo Technical Journal*, 8 (1): 11-15.

8 H. Zijlstra, 1995, *The Sedimentology of Chalk*, Berlin: Springer-Verlag.

most perfect fossils and some of its rarest, including those of the fossil bird *Archaeopteryx*. This limestone was deposited as a very fine lime-mud which was capable of preserving exceptional details, such as the impressions of feathers and skin, among the small dinosaurs, crocodiles, lizards, fish, crustaceans, and other fossils found in it.

Also of a spectacular nature are the fossil graveyards of dinosaur bones in the upper Jurassic Morrison Formation, which persists over an area of more than 1.5 million square kilometers in thirteen U.S. states and three Canadian provinces, stretching from Manitoba to Arizona, and Alberta to Texas.[9] In the United States alone, dinosaur bones have been found at 353 sites in the Morrison Formation, including 141 principal dinosaur bone sites and quarries.[10] Other dinosaur fossil graveyards are found in the upper Cretaceous Hell Creek and Lance Formations in Montana and Wyoming, and adjoining areas of southern Canada. One of these fossil graveyards consists of a bone-bed containing a transported assemblage of disarticulated bones in all size categories, ranging from small bone chips and ossified tendons to whole femora, all dinosaur remains from the genus *Edmontosaurus*.[11] With these dinosaur bones are fragments of turtle and fish bones, fish scales, and numerous teeth, not only those of *Edmontosaurus*, but also from several other species of dinosaurs (including *Triceratops*, *Tyrannosaurus*, *Troodon*), as well as those from crocodilians, fish, mammals, and other forms still under study. It is evident that this fossil graveyard is part of a high-energy debris accumulation, the extent of which is still being determined.

Tertiary strata also abound with fossil graveyards, such as that found in the Green River Formation of Wyoming, Utah, and Colorado. Some of the most perfect specimens of fossil fish and plants in the world are found there—palm leaves more than two meters long and about one meter wide, sycamore, maple, poplar, and other leaves, flowers, and pine fruit and needles, gar-pike up to two meters long, sunfish, deep-sea bass, chubs, pickerel, herring, and others—buried with birds up to the size of today's domestic chickens, some with feather impressions, alligators, turtles, mollusks, crustaceans, lizards, frogs, snakes, crocodiles, bats, and numerous mammals, and many varieties of insects, including beetles, flies, dragonflies, grasshoppers, moths, butterflies, wasps, ants, and others.[12] Numerous attempts have been made to explain the "uniform" process by which hundreds of

---

9 J. A. Peterson, 1972, Jurassic System, in *Geological Atlas of the Rocky Mountain Region*, Denver, CO: Hirschfeld Press.

10 C. E. Turner and F. Peterson, 1999, Biostratigraphy of dinosaurs in the upper Jurassic Morrision Formation of the Western Interior, USA, in *The Morrison Formatin Extinct Ecosystems Project, Final Report*, C.E. Turner and F. Peterson, eds., National Parks Service, United States Geological Survey Joint Project, unpublished report.

11 L. Spencer, L. E. Turner and A. V. Chadwick, 2001, A remarkable vertebrate assemblage from the Lance Formation, Niobrara County, Wyoming, *Geological Society of America Annual Meeting Abstracts with Program*.

12 L. Grande, 1984, Palaentology of the Green River Formation, with a review of the fish fauna, second edition, *Geological Survey of Wyoming, Bulletin*, 63.

thousands of modern and extinct fishes, birds, reptiles, mammals, insects, and plants could have been piled together, buried, and preserved in exquisite detail, as is often the case, but inevitably the only explanation consistent with the state of this fossil assemblage is catastrophic entombment.

Similar catastrophic burial also explains the myriad of a wide variety of insect fossils preserved in minute perfectional detail in shales with a volcanic component, near Florissant, Colorado:

> Although insect remains are by far the most numerous of the animal fossils preserved at Florissant, other groups are also represented. The shells of tiny freshwater mollusks are not difficult to find entombed in the rock and occasionally even the skeletons of fish and birds are seen. Several hundred species of plants have been identified from these shales, usually from leaves, but fruits (that is, nuts) and even blossoms have also been found.…Insect life around and above Lake Florissant must have been abundant, for it is not unusual to find on a single piece of shale from one of the richer fossiliferous layers several individuals within two to three inches of each other. This life was also extremely varied, with the total number of species running into the hundreds.[13]

In southern Alberta, Canada, a layer of silty mudstone only a few centimeters thick in the lower part of the Paskapoo Formation contains thousands of complete skeletons of fossil fishes, primarily species in the trout-perch family.[14] There is little disarticulation and no sign of scavenging, and the fishes occur in distinct size classes, tend to be clumped together on a scale of a few meters or less, and tend to lie with their heads facing one or perhaps preferred directions. All of these findings are consistent with this fossil graveyard representing a mass-death event with extremely rapid burial. Although the fishes occur without other kinds of fossils in this distinctive layer, other layers in the same outcrop have yielded abundant remains of plants, insects, mollusks, and mammals.

At Grube Messel, about 30 km southeast of Frankfurt in western Germany, articulated skeletons of various fish, salamanders, frogs, turtles, lizards, snakes, crocodiles, birds, and mammals, as well as several hundred insects and plant remains, have been found in an oil shale of the Messel Formation.[15] The quality of preservation is truly exceptional, for in many cases not only are the skeletons articulated, but the outlines of the entire bodies are preserved as black silhouettes, and sometimes even the contents of the digestive tracts are available for investigation.

---

13 R. D. Manwell, 1955, An insect Pompeii, *Scientific Monthly*, 80 (6): 357-358.

14 M. V. H. Wilson, 1996, Taphonomy of a mass-death layer of fishes in the Paleocene Paskapoo Formation at Joffre Bridge, Alberta, Canada, *Canadian Journal of Earth Sciences*, 33: 1487-1498.

15 J. L. Franzen, 1985, Exceptional preservation of Eocene vertebrates in the lake deposit of Grube Messel (West Germany), *Philosophical Transactions of the Royal Society of London B*, 311: 181-186.

Also in Germany, the lignite beds of Geiseltal are an incredible fossil graveyard:

> Here, too, there is a complete mixture of plants and insects from all climatic zones and all recognized regions of the geography of plants or animals. It is further astonishing that in certain cases the leaves have been deposited and preserved in a fully fresh condition. The chlorophyll is so well preserved that it has been possible to recognize the alpha and beta types.…An extravagant fact comparable to the preservation of the chlorophyll, was the occurrence of preserved soft parts of the insects: muscles, corium, epidermis, keratin, color stuffs as melamine and lipochrome, glands, and the contents of the intestines. Just as in the case of chlorophyll we are dealing with things that are easily destroyed, disintegrating in but a few days or hours. The incrustation must therefore have been very rapid.[16]

> More than 6000 remains of vertebrate animals and a great number of insects, mollusks, and plants were found in these deposits. The compressed remains of soft tissue of many of these animals show details of cellular structure and some of the specimens had undergone but little chemical modification.…Well-preserved bits of hair, feathers and scales probably are among the oldest known examples of essentially unmodified preservation of these structures. The stomach contents of beetles, amphibia, fishes, birds and mammals provide direct evidence about eating habits. Bacteria of two kinds were found in the excrement of crocodiles and another was found on the trachea of a beetle. Fungi were identified on leaves and the original plant pigments, chlorophyll and coproporphyrin, were found preserved in some of the leaves.[17]

It is inconceivable that fossil graveyards like this could be somehow due to normal, slow autochthonous processes, for even a putrid swamp has bacteria at work in it, and this would not also explain how bats and birds became similarly entombed with horses, mollusks, and palm trees. Instead, unusual transport and rapid burial mechanisms would have been required.

Finally, on the northwest coast of Tasmania, Australia's island state, is a headland called Fossil Bluff, due to the fossil graveyard in the calcareous sandstone layers exposed there. The lowermost sandstone layer is composed of coarse sand and broken shells, with rounded quartz pebbles. The number of fossil species decreases upwards as the grain size of the sandstones also decreases, with particular horizons containing distinctive bands of just the one fossil species.[18] Fossils found in

16 N. Heribert-Nilsson, 1953, *Synthetische Artbildung*, Lund, Sweden: Verlag CWK Gleerup, 1195-1196.

17 N. O. Newell, 1959, Adequacy of the fossil record, *Journal of Paleontology*, 33: 496.

18 R. Tate and J. Dennant, 1896, Correlation of the marine Tertiaries of Australia. Part III. South Australia

this graveyard include 267 species of mollusks (gastropods, cephalopods, and pelecypods), corals, bryozoans, brachiopods, barnacles, sea urchins, sharks' teeth, leaves, decomposed wood, brown coal fragments, and the skeletal remains of a toothed whale and a possum-like marsupial (mammal). The grading of the sediment and fossils, the stratification of the sandstone and some of the fossils, the broken shells, and the mixture of fossils, including the land-dwelling marsupial and the ocean-dwelling toothed whale, are all clear testimony to this fossil graveyard, which is exposed for more than one kilometer, having resulted from catastrophic water transport and sediment burial.

Mass Extinctions

The succession of fossils found in the sequences of rock strata making up the geologic record is primarily a record of death and the sequence in which the animal and plant remains were buried. Fossil graveyards found throughout the geologic record, in strata from the uppermost Precambrian upwards in many places around the globe, demonstrate the rapid and catastrophic processes that had to be operating to transport, bury, preserve, and fossilize such an abundance of animal and plant remains on a global scale. Such has been the scale of destruction recognized at various levels in the geologic record that even the conventional geological community has recognized what have been called mass extinctions. Eight such "mass extinctions" have been recognized in the Cambrian to Recent strata sequence (see Figure 25, page 357).[19] At these levels in the geologic record a great variety of organisms, those that would have been living in both marine and terrestrial environments, both stationery and swimming forms, carnivores and herbivores, protozoans and metazoans, were buried on a global scale, so the catastrophic processes involved transcended specific ecological, morphological, and taxonomic groupings of organisms simultaneously on the land and in the sea.

To explain these global mass destructions, the conventional geological community has accepted the possibility of global catastrophes, such as the earth being impacted by asteroids or comets.[20] Thus, while fossil graveyards are usually only of local to regional extent, though still requiring catastrophic and rapid transport and burial of sediments and organisms, the recognition of "mass extinction" on a

---

and Tasmania, *Transactions of the Royal Society of South Australia*, 20 (1): 118-148; N. R. Banks, 1957, The Stratigraphy of Tasmanian Limestones, in *Limestones in Tasmania*, vol. 10, T. D. Hughes, ed., Mineral Resources of Tasmania, 39-85; A. A. Snelling, 1985, Tasmania's Fossil Bluff, *Ex Nihilo*, 7 (3): 6-10.

19 S. M. Stanley, 1987, *Extinction*, New York: Scientific American Books, W.H. Freeman and Company; J. J. Sepkoski Jr, 1989, Periodicity in extinction and the problem of catastrophism in the history of life, *Journal of the Geological Society of London*, 146: 7-19; M. J. Benton, 1995, Diversification and extinction and the history of life, *Science*, 268: 52-58.

20 C. Stearn and R. Carroll, 1989, *Paleontology: The Record of Life*, New York: John Wiley and Sons, 368-371; D. J. McLaren and W. D. Goodfellow, 1990, Geological and biological consequences of giant impacts, *Annual Review of Earth and Planetary Sciences*, 18: 123-171; K. C. Condie, 1997, *Plate Tectonics and Crustal Evolution*, fourth edition, Oxford, England: Butterworth-Heinemann, 218-225.

global scale in the geologic record extends the evidence for catastrophic transport and deposition of sediments and organisms to a global scale. Asteroid or comet impacts, and/or catastrophic volcanic outpourings, as explanations for this global catastrophism have evidence to support them, and both are consistent with the global catastrophic Flood within the biblical framework for earth history.

73

The Rate of Fossilization

Once the plants and animals have been buried catastrophically, processes of fossilization need to be operative to ensure preservation of these animal and plant remains in the resultant sedimentary strata. The different fossilization processes have already been discussed earlier, but the mechanisms and rates of the fossilization processes are crucial, not only because of the exquisitely preserved details in so many fossils, as seen already in many of the fossil graveyards discussed above, but because of the limited timeframe for these processes to have occurred during the year of the Genesis Flood, and in the overall biblical framework for earth history.

Petrification by Silicification

Rapid petrification of wood has long been demonstrated and understood. For example, silica deposition rates into blocks of wood lowered into alkaline springs in Yellowstone National Park, Wyoming, have been reported at being between 0.1 and 4.0 mm/yr.[1] Petrification of wood is considered to take place in five stages:

1. Entry of silica in solution or as a colloid into the wood
2. Penetration of silica into the cell walls of the wood's structure
3. Progressive dissolving of the cell walls, which are at the same time replaced by silica, so that the wood's dimensional stability is maintained
4. Silica deposition within the voids within the cellular wall framework structure
5. Final hardening (lithification) by drying out[2]

This understanding of the petrification process is solidly based on experimental evidence. For example, small branches were partially silicified by placing them in concentrated solutions of sodium metasilicate for up to 24 hours,[3] while fresh wood was immersed alternately in water and saturated ethyl silicate solutions until the open spaces in the wood filled with mineral material, all within several months to a year.[4] As early as 1950 it had been shown that the sorption of silica by

---

1 A. C. Sigleo, 1978, Organic geochemistry of silicified wood, Petrified Forest National Park, Arizona, *Geochimica et Cosmochimica Acta*, 42: 1397-1405.

2 G. Scurfield and E. R. Segnit, 1984, Petrification of wood by silica minerals, *Sedimentary Geology*, 39: 149-167.

3 R. W. Drum, 1968, Silification of Betula woody tissue in vitrio, *Science*, 161: 175-176.

4 R. F. Leo and E. S. Barghoorn, 1976, *Silification of Wood*, Harvard University Botanical Museum Leaflets

wood fibers from solutions of sodium metasilicate, sodium silicate, and activated silica sols (a homogeneous suspension in water) at only 25°C (77°F) was as much as 12.5 moles of silica per gram of wood within 24 hours, the equivalent of partial silicification/petrification.[5] It has thus been concluded: "These observations indicate that silica nucleation and deposition can occur directly and rapidly on exposed cellulose [wood] surfaces."[6] Indeed, a patent has even been issued for the artificial petrification of wood.[7] More recent experiments, where pieces of wood were suspended in hot spring water in Japan, for up to seven years, showed complete silicification of wood was a rapid process under natural conditions requiring only years.[8]

However, perhaps these processes observed in experiments are not really applicable to conditions and processes in the natural world? To the contrary, there is much anecdotal evidence that petrification of wood can occur rapidly, even in soils:

> [F]rom Mrs McMurray [of Blackall, southwestern Queensland, Australia], I heard a story that rocked me and seem to explode many ideas about the age of petrified wood. Mrs McMurray has a piece of wood turned to stone which has clear axe marks on it. She says the tree this piece came from grew on a farm her father had at Euthella, out of Roma, and was chopped down by him about 70 years ago. It was partly buried until it was dug up again, petrified. Mrs McMurray capped this story by saying that a townsman has a piece of petrified fence post with the drilled holes for wire with a piece of the wire attached.[9]
>
> Piggott writes of petrified wood showing axe marks and also of a petrified fence post. This sort of thing is, of course, quite common. The Hughenden district, N.Q. [north Queensland], has…*Parkensonia* trees washed over near a Station [ranch] homestead and covered with silt by a flood in 1918 [which] had the silt washed off by a flood in 1950. Portions of the trunk had turned to stone of an attractive colour. However, much of the trunks and all the limbs had totally disappeared. On Zara Station [ranch], 30 miles [about 48 km] from Hughenden, I was renewing a fence. Where it was dipped into a hollow the bottom of the old posts had gone through black soil into shale. The Gidgee wood was still perfect in the black soil. It

---

No. 25, 1-47.

5 R. C. Merrill and R. W. Spencer, 1950, Sorption of sodium silicates and silicate sols by cellulose fibers, *Industrial Engineering Chemistry*, 42: 744-747.

6 Sigleo, 1978, 1404.

7 H. Hicks, 1984, Mineralized sodium silicate solutions for artificial petrification of wood, U.S. patent no. 4612050, filed October 12, 1984, and issued September 16, 1986.

8 H. Akahane, T. Furano, H. Miyajima, T. Yoshikawa and S. Yamamoto, 2004, Rapid wood silification in hot spring water: An explanation of silicification of wood during Earth's history, *Sedimentary Geology*, 169: 219-2287.

9 R. Piggott, 1970, Petrified wood, *The Australian Lapidary Magazine*, 6 (6): 9.

> then cut off as straight as if sawn, and the few inches of post in the shale was pure stone. Every axe mark was perfect and the colour still was the same as the day the post was cut.[10]

Wood is not the only material that has been observed to have rapidly petrified. Laboratory experiments have also demonstrated that unicellular bacteria can be readily silicified in silicate solutions.[11] However, *in situ* silicification of bacteria in natural hot spring waters has been also observed and studied.[12] Microbial mats were observed growing as hard, finely-laminated crusts on ledges within the outflow channel of the Strokkur Geyser in south Iceland, and samples examined by electron microscopy revealed that the filamentous bacteria making up the mat had undergone rapid silicification in the hot spring water. The silica mineralization association with the cells occurred both extra-cellularly, within and on the external sheaths of the bacteria, and intra-cellularly, within the cytoplasm. The exceptional preservation of the bacterial sheaths was found to be due to the presence of distinct mineral nucleation sites, which had resulted in the production of silica casts of the bacteria remarkably similar to microbial remains in microfossil assemblages preserved in the geologic record.[13] It was concluded that the observed silicification in a natural environment represents an important link between laboratory experiments of microbial silicification and observational studies of ancient microfossils assemblages. Furthermore, the observed rapid *in situ* silicification of the bacteria is regarded as a prerequisite to preservation of cell structure as a microfossil.

Fossilization by Phosphatization

In some fossil graveyards, some of the most remarkable fossils have preserved cellular details of soft tissues because of being replaced by calcium phosphate. This process had been assumed to require elevated concentrations of phosphate in sediment pore waters. However, in decay experiments, modern shrimps became partially mineralized in amorphous calcium phosphate, preserving cellular details of muscle tissue, particularly in a system closed to oxygen.[14] The source

10 R. C. Pearce, 1970, Petrified wood, *The Australian Lapidary Magazine*, 6 (11): 33.

11 J. H. Oehler and J. W. Schopf, 1971, Artificial microfossils: experimental studies of per-mineralisation of blue-green algae in silica, *Science*, 174: 1229-1231; F. G. Ferris, W. S. Fyfe and T. J. Beveridge, 1988, Metallic binding by *Bacillus subtilis:* implications for the fossilizations of microorganisms, *Geology*, 16: 149-152; M. M. Urrutia and T. J. Beveridge, 1993, Mechanism of silicate binding to the bacterial cell wall in *Bacillus subtilis*, *Journal of Bacteriology*, 175: 1936-1945.

12 S. Schultze-Lam, F. G. Ferris, K. O. Konhauser and R. G. Wiese, 1995, *In situ* silification of an Icelandic hot spring microbial mat: implications for microfossil formation, *Canadian Journal of Earth Sciences*, 32: 2021-2026.

13 E. S. Barghoorn and S. A. Tyler, 1965, Microorganisms from the Gunflint chert, *Science*, 147: 563-577; J. W. Schopf and B. M. Packer, 1987, Early Archean (3.3-billion to 3.5-billion-year-old) microfossils from the Warrawoona Group, Australia, *Science*, 237: 70-73; J. W. Schopf, 1993, Microfossils of the Early Archean Apex Chert: new evidence of the antiquity of life, *Science*, 260: 640-646.

14 D. E. G. Briggs and A. J. Kear, 1993, Fossilization of soft tissue in a laboratory, *Science*, 259: 1439-1442.

for the formation of the calcium phosphate fossilization was the shrimp itself. Mineralization commenced within two weeks, and increased in extent for at least four to eight weeks. The mechanism observed in the laboratory halts the normal loss of detail of soft-tissue morphology before fossilization. Thus, it was concluded that for the first time success had been achieved in phosphatizing soft tissue in laboratory experiments, which had demonstrated that the process occurs relatively rapidly, requiring only the phosphate present in the carcasses, although it was reasoned that elevated phosphate concentrations may be necessary to explain the more extensive phosphatization seen in fossils.

In these laboratory experiments it was also shown how bacteria can turn flesh into stone, in only a few weeks managing to mimic a mineralization process that supposedly takes millions of years "in nature."[15] The key was allowing the freshly killed shrimps to decay in closed experimental vessels of seawater. The researchers placed the carcasses in containers of artificial seawater, then inoculated the containers with water from the Firth of Tay in Scotland, a site characterized by the activity of both aerobic and anaerobic bacteria. Because the containers were airtight, an anoxic environment could be built up and the initial fall in acidity was slightly reversed. The result was that blocks of muscle tissue, individual muscle fibers, and eggs were replaced by calcium phosphate particles ("microspheres") less than one micron across.

The experiments were also designed to investigate the role of bacteria, which were expected to play a role in this extraordinary process of preservation of anatomical details found in certain fossils in some fossil graveyards. The role of bacteria in post-mortem decay is well known, and there is fossil evidence of bacteria themselves being preserved. The researchers had developed biochemical models, using our understanding of how it is possible for bacteria to concentrate, oxidize, and precipitate mineral ions on soft tissue surfaces. They found that the smaller the aggregations of calcium phosphate particles precipitated in their experiments, the greater the fidelity of morphological preservation, and the highest fidelity occurred where the bacteria themselves, present in the sealed containers in the experiments, are not replicated, even though the precipitation of the calcium phosphate had been bacterially induced. Furthermore, the soft tissue phosphatized in their laboratory experiments closely resembled the fossil phosphatized soft tissues in the remarkably preserved fossil fish from the fossil graveyard in the Santana Formation of Brazil, indicating that similar processes must have been involved in the fossilization of the fish. Indeed, in mineral composition, textures, and features, the laboratory phosphatized shrimps were very similar to the fossilized shrimps found in the stomachs of the fossil fish from the Santana Formation.

While the mineralization of soft tissue in the laboratory was not "instant," taking

15 D. E. G. Briggs, A. J. Kear, D. M. Martill and P. R. Wilby, 1993, Phosphatization of soft-tissue in experiments and fossils, *Journal of the Geological Society*, London, 150: 1035-1038; D. Palmer, 1994, How busy bacteria turn flesh into stone, *New Scientist*, 141 (1917): 17.

several weeks (it may even take months if decay is inhibited), the experiments did produce mineralized "fossils" without having to wait hundreds of millions of years. It was concluded that, while extensive phosphatization of larger carcasses may necessitate the build-up of phosphate concentrations in the sediment beforehand, this is not the case for phosphatization of small quantities of soft tissue, because the phosphate content of the carcass itself is adequate for starting the process. Of significance also was the determination in the experiments that the precipitation of associated calcium carbonate is controlled by shifts in pH in response to the decay process, thus showing how the precipitation of the calcium carbonate nodules, in which many of the Santana fossil fish are found, may have been initiated. In conclusion, these experiments have unmistakably demonstrated that the delicate fossilization of even soft tissues, as seen in many fossil graveyards, can be a rapid process that takes weeks, rather than millions of years.

Although limited phosphatization of soft tissues may be sourced from within the carcasses themselves, simple mass-balance calculations indicate that more phosphorus is present in extensively phosphatized fossils than would have originally been present in the living animal, so an external source of phosphorus would have been required. Microbial mats are one of the factors most widely invoked to explain exceptional fossil preservation, because they are believed to prevent carcasses from floating, and to protect them from scavengers and currents. Microbial mats have also been recorded in several fossil graveyards where phosphatized soft tissues have been preserved, including the Solnhofen Limestone of Germany, and the Santana Formation of Brazil. Nevertheless, the precise means by which microbial mats create a suitable chemical environment for the phosphatization of soft tissues had not been determined, until tested by chemical analyses of the Jurassic limestones of Cerin, France, where phosphatized soft tissues are also abundant, and are also associated with unequivocal microbial mats.[16] It was found from these analytical results that the sedimentary distribution of phosphorus, potassium, and iron following deposition of the limestone was controlled by the presence of the microbial mats, the phosphorus concentrations in the mats approaching 2.5 times those elsewhere in the sediments. Indeed, the highest phosphorus concentrations correlated precisely with the occurrence of phosphatized soft tissues in fossil fish and crustaceans. This analytical evidence thus demonstrates the fundamental geochemical role for microbial mats in localizing the mineralization that preserves the soft tissues during fossilization. The microbial mats may not only function to trap phosphate, but also control the pH, which laboratory experiments have shown is a critical factor in the soft-tissue phosphatization process.

Fossilization by Biofilms

Terrestrial leaf fossils often form through authigenic preservation, in which the

16 P. R. Wilby, D. E. G. Briggs, P. Bernier and C. Gaillard, 1996, Role of microbial mats in the fossilization of soft tissues, *Geology*, 24 (9): 787-790.

leaf surface is coated by a variety of minerals, especially iron oxides, such that leaf venation patterns, stomatal morphology, and even epidermal hairs are often well preserved. However, the hydrophobic, waxy cuticles covering the surfaces of most leaves results in leaf surfaces themselves not being able to readily bind metal ions as the direct mechanism involved in this authigenic fossilization process. Under normal circumstances, leaves and other plant detritus are colonized and decomposed by a variety of microorganisms and macro-invertebrates, but in aquatic environments, these and other objects are quickly colonized by bacteria that form surface-adherent biofilm communities. It has now been demonstrated that these diverse bacterial species, which rapidly colonize leaf surfaces and form biofilms within days of the leaves falling into water, enhance the fossilization of these leaves.[17]

Leaves, from living counterparts of plant genera commonly preserved as iron-encrusted impressions in the fossil record, were used in controlled experiments to show that mineralization does not form on leaves without biofilms, whereas leaves with biofilms rapidly adsorb metal ions such as Fe^{3+} onto the biofilm surface (which is anionic), where the ions form ferrihydrite. It was concluded that once such mineralized leaves are buried by sediment, they are more likely to be converted to fossils than non-mineralized leaves, because this early mineralization would ensure the integrity of the leaf is maintained during subsequent mineralization and fossilization, so that small-scale structures can be preserved. Furthermore, examination by scanning electron microscopy of some iron-encrusted fossil leaves, showing fine-scale surface details, showed bacteria-sized structures resembling those found in biofilms. Thus, it was concluded that these experimental data imply that bacterial colonization of leaves may be an essential prerequisite for authigenic preservation. Furthermore, because these bacterial biofilms and the early mineralization they adsorb form within a few days, it is evident that leaf fossilization can also be relatively rapid.

It is evident, therefore, that microbial mats play a major role in the formation of exceptionally preserved fossil deposits, by overgrowing and binding organic remains and sedimentary particles, which minimized hydrodynamic and biological disruption of dead organisms and sedimentary laminae. The microbial agent is usually prokaryotic cyanobacteria, the presence of which likely also assists in locally controlling the pH and the concentration of ions. It is equally significant that the exceptionally well-preserved macrofossils in the Florissant (Colorado) fossil graveyard are enveloped in matted aggregations of mucous-secreting, pinnate diatom frustules.[18] It has thus been suggested that the macrobiota became entrapped in mucous-secreting mats of surface water blooms of planktonic diatoms, and as the mats and the incorporated macrobiota were subsequently

17 K. A. Dunn, R. J. C. McLean, G. R. Upchurch and R. L. Folk, 1997, Enhancement of leaf fossilization potential by bacterial biofilms, *Geology*, 25 (12): 1119-1122.

18 I. C. Harding and L. S. Chant, 2000, Self-sedimented diatom mats as agents of exceptional fossil preservation in the Oligocene Florissant Lake beds, Colorado, United States, *Geology*, 28 (3): 195-198.

sedimented out of the water column, the mucosic mats and their associated bacterial communities arrested decay and promoted preservation of refractory tissues as organisms were fossilized. Thus, it would appear that, by a completely different mechanism, the diatom mats fulfilled the same preservational role as already demonstrated for cyanobacterial mats, and may be an important causative factor in the formation of some exceptionally preserved fossil biotas.

Fossilization by Pyritization

Whereas in animals the highest fidelity in fossil preservation of soft tissues is retained in calcium phosphate (apatite), and pyritized soft tissue is relatively rare, pyritization of plants is more common. However, the process has been poorly understood.[19] Where pyritization has occurred, it is unclear how the plant tissues became fossilized, whether pyritization is selective to specific biopolymers, or whether original organic constituents survive. Consequently, laboratory experiments have been used to replicate the fossilization process, by using both microbial and chemical approaches to pyritize plant debris. The experimental results demonstrated that initial pyritization can be an extremely rapid process (within 80 days), and is driven by anaerobic bacterial-mediated decay. The outcome was pyritization of the plant debris, very similar to that found in fossilized plants.

It would appear that, initially, pyrite precipitates on and within plant cell walls, and in the spaces between them. Further decay and infilling at all scales preserve broad cellular anatomy. Thus, pyritization does not seem to involve direct replacement of the original organic material, but precipitation on, and impregnation of, the cell walls, plus rapid filling of intracellular spaces, provide sufficient strength to preserve detailed plant morphology as burial proceeds. As microbial decomposition of organic material continues, even after burial, more space is made available within which pyrite crystallizes, to produce a cast of the original plant material. The decaying plant materials provides a locus for pyritization, because the enhanced nucleation of pyrite on organic substrates as the concentration of decomposable organic matter increases stimulates bacterial activity, and thus anoxia, sulfate reduction, and sulfide formation. These experimental results thus demonstrate that pyritized plant fossils can be produced rapidly in a matter of weeks, rather than requiring millions of years.

Coalification

When plant remains accumulate in great thicknesses to form peat, subsequent burial of it beneath layers of sediments causes it to be compacted due to the pressures, plus the heat at depth dries out the water and gases in the original plant

19 P. Kenrick and D. Edwards, 1988, Anatomy of the lower Devonian *Gosslingia breconensis* Heard based on pyritised axes with some comments on the permineralisation process, *Linnean Society Botanical Journal*, 97: 95-123; D. E. G. Briggs, R. Raiswell, S. H. Bottrell, D. Hatfield and C. Bartels, 1996, Controls on the pyritization of exceptionally preserved fossils: an analysis of the Lower Devonian Hunsrück Slate of Germany, *American Journal of Science*, 296: 633-663.

material in a manner that progressively enriches the peat with carbon, until it finally forms coal.[20] The rank (quality) of the resultant coal is a measure of carbon content, which depends on the amount of volatiles (mainly CO_2 and NH_3) and moisture that have been removed from the coal during this coalification process. The rank varies from lignite (or brown coal), which contains only about 30 percent carbon, to sub-bituminous to bituminous coal, the latter containing about 87 percent carbon, and then to anthracite, which contains about 94 percent carbon.

It is often claimed that rank increases with time and depth of burial, but there isn't always a systematic increase in the rank of coal with increasing age. Some blatant contradictions include lignites (low rank) in some of the oldest coal measure strata sequences, and anthracites (highest rank) occurring in some of the youngest coal measure strata. However, pressure likewise cannot be the major factor in metamorphosis of peat to coal, because the rank of coal does not increase in highly-deformed and folded strata. Furthermore, laboratory experiments have demonstrated that increasing pressure can actually retard the chemical alteration of peat to coal.[21] The most important factor in coal metamorphoses is now regarded as temperature. The effect of igneous intrusions on coal seams has confirmed that elevated temperatures can cause coalification. Nevertheless, these three factors, namely, time, pressure, and temperature, must work together to transform the plant debris of a peat into coal. Indeed, compaction of peat and its transformation to lignite have been observed to occur below depths of only six and eleven meters.[22]

Laboratory experiments have been quite successful in artificially producing coal-like materials relatively rapidly, under conditions designed to simulate those present in sedimentary basins where coal measure strata have accumulated. For example, artificial coal has been produced by rapidly applying vibrating pressures to wood.[23] In this experiment, the prolonged series of brief violent shocks (rather than the application of continuous pressure) altered the molecular arrangement of the organic matter so that it resembled coal, and this was produced within hours and days. In different experiments, a substance like anthracite was manufactured in just a few minutes by rapid application of intense heat, much of the heat involved being generated by the cellulosic material being altered.[24] While both of these studies used simulated conditions that are applicable to the coalification of buried peat layers in areas of tectonism and volcanism, other laboratory studies have wider application.

---

20 J. Davidson, W. E. Reed and P. M. Davis, 1997, *Exploring Earth: An Introduction to Physical Geology*, Upper Saddle River, NJ: Prentice-Hall, 422.

21 S. E. Nevins, 1976, The Origin of Coal, *Acts & Facts*, 5 (11): 41.

22 Nadon, 1998, 729.

23 J. Carlweil, 1965, Kolloquim Chemi und Physik dar Systinkhole, *Erdol und Kohle-Erdgas Petrochemie*, 18 (7): 565.

24 G. R. Hill, 1972, Some aspects of coal research, *Chemical Technology*, May: 292-297.

A research team at the Argonne National Laboratory in Illinois made insoluble material resembling coal macerals (components) by heating lignin with clay minerals at 150°C for 2 to 8 months in the absence of oxygen.[25] It was discovered that the longer heating times produced higher rank coal macerals, and the clays appeared to serve as catalysts that speed the coalification reactions, given that the lignin was fairly unreactive in their absence. The clay mineral montmorillonite was primarily used in the experiments, but using kaolinite or illite, independently or mixed with montmorillonite, produced similar results. It was also demonstrated that in the presence of clay minerals activated by acid, the reaction of lignin to form coal macerals was highly accelerated (four weeks instead of 2 to 4 months), even at only 150°C. Furthermore, loss of catalytic action of the clay minerals occurred when the reaction was carried out in the presence of air. The overall conclusion was that coal macerals can be produced directly from biological source material via clay-catalyzed thermal reactions in periods from only one to four months. It is relevant, therefore, that clay minerals often account for up to 80 percent of the total mineral matter associated with the plant debris that has formed the coal. Indeed, clay minerals are found in coal as fine inclusions, layers, and partial or complete fillings of plant cell cavities. Thus, with the presence of clay minerals obviously dispersed through the original peat, clay-catalyzed thermal reactions would easily be achieved after burial of the peat to induce rapid coalification. Other experiments have confirmed that clay mineral particles act as catalysts in what is a rapid coalification process.[26]

Pressure has always been considered crucial to the coalification process, given that once buried, peat layers are subject to overburden (or lithostatic) pressures. Thus, uniaxial pressure devices have routinely been used in artificial coalification experiments, which invariably are conducted at temperatures ranging from 100 to 400°C over periods of from one to eight days.[27] The result of such experiments on wood samples was the transformation of the wood into materials similar in microscopic appearance to the maceral components of naturally-formed coals. This was also confirmed by chemical analyses. However, temperatures above 200°C in the natural coalification process can be definitely discounted, because at temperatures of 220°C and above, clay minerals such as montmorillonite and kaolinite are metamorphosed to chlorite and pyrophyllite,[28] whereas the clay minerals montmorillonite and kaolinite are routinely found in coal seams and associated with them, rather than chlorite and pyrophyllite. These clay minerals, principally kaolinite, are found in tonstein layers that are important as marker

25 R. Hayatsu, R. L. McBeth, R. G. Scott, R. E. Botto and R. E. Winans, 1984, Artificial coalification study: preparations and characterization of synthetic macerals, *Organic Geochemistry*, 6: 463-471.

26 J. D. Saxby, P. Chatfield, G. H. Taylor, J. D. FitzGerald, I. R. Kaplan and S.-T. Lu, 1992, Effect of clay minerals on products from coal maturation, *Organic Geochemistry*, 18 (3): 373-383.

27 A. Davis and W. Spackman, 1964, The role of the cellulosic and lignitic components of wood in artificial coalification, *Fuel*, 43: 215-224.

28 Stach et al, 1982, 84-86.

horizons within coal seams, and for correlation of coal seams within and between coal basins, even over distances of several hundred kilometers, such as in the northern European coal belt.[1] These tonsteins are widely regarded as having originated as ash-fall tuffs.[2] Thus, the presence of clay minerals in these tonsteins intimately associated with coal seams indicates the temperatures involved in coalification must have been less than 200°C. More recent coalification experiments have tried to more closely simulate the natural geologic conditions, with temperatures of only 125°C in both lithostatic and fluid pressures equivalent to burial under 1,800 meters of wet sediments, yet maintained as a geologically open system which allowed by-products that may retard coalification to escape.[3] In that experiment, after only 75 days, the original peat and petrified wood had been transformed into coalified peat and coalified wood, comparable chemically and structurally to lignite and coalified wood from the same geographical region as the original peat and petrified wood samples.

It is thus certain that, because these artificial coalification experiments have demonstrated the process under simulated natural conditions, coalification is a quick process that does not require long periods of time to be achieved. Therefore, there is no reason to insist that coalification under natural conditions must take millions of years. Indeed, the many examples of dislocated fragments of mature coal being found enclosed in sandstones, which are nearly contemporaneous with the nearest coal seam above or below, emphatically demonstrate that not only is coalification extremely rapid, but neither deep burial nor elevated temperatures and pressures are required for coalification.[4] Similarly, rounded pebbles of mature coal are known to occur in a conglomerate bed less than half a meter vertically from the underlying coal seam (Figure 48, page 1084). Whatever then are the natural conditions under which coalification occurs, such evidence demands that the process is rapid in terms even of days at or close to the earth's surface.

1 Stach et al, 1982, 158-164.

2 N. B. Price and P.McL. D. Duff, 1969, Mineralogy and chemistry of tonsteins from Carboniferous sequences of Great Britain, *Sedimentology*, 13: 45-69; Stach, 1982, 158-164; Diessel, 1982, 140-149, 312-329.

3 W. H. Orem, S. G. Neuzil, H. E. Lerch and C. B. Cecil, 1996, Experimental early-stage coalification of a peat sample and a petrified wood sample from Indonesia, *Organic Geochemistry*, 24 (2): 111-125.

4 Scheven, 1981, 42.

74

Are There Long Ages Between the Strata?

Even though the conventional geological community now generally recognizes that some strata may have been catastrophically deposited, it is still argued that long periods of geologic time are accounted for by gaps between the strata in the geologic record. However, the magnitude of these time gaps between strata, required by the conventional geological community, become larger than the time supposedly represented by the strata themselves when modern sedimentation rates are taken into account. Calculated sedimentation rates over a timespan of 1 million years average about 0.01 meters per thousand years, whereas the average sedimentation rate actually measured today over a period of one year is approximately 100 meters per thousand years. Thus, the calculated and measured sedimentation rates data (see Figures 39 and 40)[5] indicate that the geologic record contains only a small fraction of the sedimentary strata that would be predicted as having been deposited over geological time based on modern sedimentation rates. Expressed another way, these data indicate that the time over which the rock record would have accumulated is only a small fraction of the claimed available time according to the geological timescale.

The proposed answer to this problem is that either the geologic record consists of brief periods of sedimentation separated by long periods of inactivity, or there may be long periods in which sediments are deposited, and then much or all of the sediments are eroded before the next sediments arrive.[6] Similarly, it has been claimed that the whole history of the earth has been one of short, sudden happenings with nothing much in particular in between, so that these "episodic catastrophes" were separated by immense eons when virtually no geologic deposits and contained fossils were being formed, suggesting that there are "more gaps than record," and that therefore the bulk of geological time occurred during the gaps in the record![7] The corollary to this is the claim that, therefore, earth history is not a record of what actually happened, but is a record of what happens to have been preserved.

However, if there are many gaps between different strata in the geologic record that represent more geologic time than the strata themselves, then there ought

5 P. M. Sadler, 1981, Sediment accumulation rates and the completeness of stratigraphic sections, *Journal of Geology*, 89: 569-584.

6 T. H. van Andel, 1981, Consider the incompleteness of the geological record, *Nature*, 294: 397-398.

7 D. V. Ager, 1993, *The New Catastrophism: The Importance of the Rare Event in Geological History*, Cambridge, MA: Cambridge University Press.

to be some record that can be detected of the events that occurred in these time gaps. In particular, there ought to be some evidence of erosion, soil formation, or burrowing by animals. However, there is generally a lack of such evidence, which is puzzling for the conventional geological community. After all, if the present is the key to the past, then in the present, land surfaces have been carved by erosion into an irregular topography, with upland areas being deeply eroded and the sediments deposited in lowland basins, principally by water. This is not to deny that there are erosion surfaces buried and preserved in the geologic record, but often it is claimed that there are time gaps between consecutive strata without any evidence of erosion, or any other events that might have occurred in the time represented by the gaps.

Two examples will graphically illustrate this problem. In Venezuela, two thin coal seams separated by 30 cm of gray clay were, respectively, assigned to the lower Paleocene and upper Eocene.[8] Even though the outcrops are excellent, very close inspection of them failed to identify the precise position of the claimed 15 million year time gap. In the central United States, the Pliocene Ogallala Formation, dated at 2 to 5 million years old, covers an area of 150,000 square kilometers and lies directly on top of the Triassic Trujillo Formation, regarded as 208 million years old.[9] If indeed 200 million years had passed before deposition of the Ogallala Formation on top of the Trujillo Formation, then there should surely have been erosion of valleys, gullies, or even canyons, as well as soil formation and plant growth. However, the contact between these two formations is very flat, with only slight evidence of erosion, even though there are soft layers in the Trujillo that should have eroded easily.

There are, of course, many significant erosion surfaces in the geologic record, and these are known as unconformities. These do show evidence of erosion and/or uplift of sedimentary layers before the next layers were deposited. A good example occurs in the Grand Canyon, where a prominent erosion surface called the Great Unconformity cuts across tilted upper Precambrian strata with some topography evident on that surface (for example, hills of the harder Shinumo Quartzite), which is covered by the flat-lying Cambrian Tapeats Sandstone and the Paleozoic rock sequence above it. The time gap involved is claimed to be perhaps 200 million years,[10] during which time gentle weathering and slow erosion is claimed to have occurred: "The observed features indicate that the Unconformity is an ancient land surface that experienced gentle weathering and erosion over a long period of time before being submerged beneath a gradually encroaching sea."[11]

---

8 Van Andel, 1981, 398.

9 A. A. Roth, 1988, Those gaps in the sedimentary layers, *Origins*, 15: 75-92.

10 T. D. Ford and C. M. Dehler, 2003, Grand Canyon Supergroup: Nankoweap Formation, Chuar Group, and Sixtymile Formation, in *Grand Canyon Geology*, second edition, S. S. Beus and M. Morales, eds., New York: Oxford University Press, 53-75.

11 D. A. Young, 1990, The discovery of terrestrial history, in *Portraits of Creation*, H. J. Van Till, R. E. Snow, J. H. Stek and D. A. Young, eds., Grand Rapids, MI: William B. Eerdmans, 68.

However, geologists have been divided on whether gentle weathering occurred at this Great Unconformity. Some have maintained that extensive chemical weathering occurred because of a prevailing humid climate, yet the very granular detritus at the boundary is structureless and not at all consistent with different chemical weathering zones expected in a residual soil.[12] Other geologists have disputed the claims of extensive chemical weathering, of either the bedrock or of the debris incorporated into the base of the Tapeats Sandstone.[13] Indeed, there are minerals in some areas of the bedrock that would be unstable during long exposure in a humid climate, and instead, there is evidence of considerable physical disintegration without chemical effects. Large boulders of Shinumo Quartzite and sand-filled great channels occur in places directly at the Great Unconformity, and these have been wrongly interpreted as "fossil soils."[14] However, boulder and sand beds that cover hills in the bedrock at the Unconformity are more consistent with catastrophic underwater debris flows, which were able to move boulders 20 meters in diameter more than half a kilometer.[15] Such processes unmistakably require conditions that would be very erosive to bedrock, so rather than there being evidence of "gentle weathering and erosion" at the Great Unconformity over many millions of years, the observed features are only consistent with significant erosion occurring catastrophically while the Great Unconformity was underwater, rather than being an exposed and elevated land surface.

So even where there are angular unconformities in the geologic record, catastrophic erosion rules out that these time gaps represent millions of years. However, the problem of the supposed time gaps in the geologic record is far more acute for the conventional geologic community, because after the evident unconformities have been accounted for, there is still a general lack of evidence for the many claimed erosional gaps that remain in the geologic record. For example, between the ten major Paleozoic formations that constitute the walls of the Grand Canyon are nine boundaries, five of which are claimed to represent time gaps. There is certainly some erosion at the top of the Cambrian Muav Limestone, because there are channels up to 120 meters wide and 30 meters deep in various parts of the eastern Grand Canyon, which are filled with the Devonian Temple Butte Formation.[16] However, such minor erosion with insignificant topographic relief could easily be catastrophically eroded, instead of supposedly taking the best part of 80 million years. There are also places in the Canyon where the overlying lower

12 R. Sharp, 1940, Ep-Archean and Ep-Algonkian erosion surfaces, Grand Canyon, Arizona, *Geological Society of America Bulletin*, 51: 1235-1270.

13 N. E. A. Hinds, 1935, *Ep-Archean and Ep-Algonkian Intervals in Western North America*, vol. 1, Carnegie Institution of Washington Publication, 463.

14 S. A. Austin, 1994, Interpreting strata of Grand Canyon, in *Grand Canyon: Monument to Catastrophe*, S. A. Austin, ed., Santee, CA: Institute for Creation Research, 46-47.

15 A. V. Chadwick, 1978, Megabreccias: evidence for catastrophism, *Origins*, 5: 39-46.

16 S. S. Beus, 2003, Temple Butte Formation, in *Grand Canyon Geology*, second edition, S. S. Beus and M. Morales, eds., New York: Oxford University Press, 107-114.

Carboniferous Redwall Limestone lies directly on the Cambrian Muav Limestone in an apparent conformable relationship, without any trace of significant erosion to represent the claimed time gap of more than 140 million years.

The upper surface of the Redwall Limestone has been identified as a disconformity, that is, where parallel strata occur above and below the boundary, but where discordance of bedding is still apparent. In places there is a slight degree of relief on top of the Redwall, and broad channels commonly 45 to 60 meters deep are filled with the Surprise Canyon Formation.[17] Elsewhere the uppermost strata of the Redwall Limestone are very level and continuous, being overlain by the thick limestone sequence of the Watahomigi Formation, which forms the base of the Supai Group. Of particular significance is the evidence of buried and infilled caves found in places at the top of the Redwall Limestone, which contain lenticular deposits resembling the overlying Supai lithology. These buried caves and associated solution deposits clearly formed as a result of chemical weathering and erosion producing a karst topography.

It is assumed by the conventional geological community that this chemical weathering and solution occurred in a time gap between deposition of the Redwall Limestone and the overlying Supai Group, that is, while the Redwall Limestone was an exposed land surface prior to inundation by the ocean that deposited the overlying Supai Group sediments.[18] However, there are hundreds of solution and collapse structures (breccia pipes) in strata above the Redwall Limestone, many having filled horizontally with radiating solution drainage channels in the uppermost Redwall, but containing fragments of formations overlying the Supai Group.[19] Many of these solution collapse structures, which have been mined for copper and uranium, contain breccia fragments of Coconino Sandstone and even Kaibab Limestone, conclusively demonstrating that the solution of the Redwall Limestone occurred after the rest of the Grand Canyon strata were deposited, and not in any claimed time gap between deposition of the Redwall Limestone and Supai Group sediments. Furthermore, in many other places it is difficult to locate the disconformity exactly and prove that it exists, especially where limestone overlies limestone. Thus, most solution and infilling features are localized, and appear to have formed after the deposition of the Grand Canyon strata sequence, so that the evidence for solution having occurred is not evidence for a time gap of millions of years at this strata boundary.

Siltstones and shales of the Hermit Formation overlie the Esplanade Sandstone,

17 S. S. Beus, 2003, Redwall Limestone and Surprise Canyon Formation, in *Grand Canyon Geology*, second edition, S. S. Beus and M. Morales, eds., New York: Oxford University Press, 115-135.

18 E. D. McKee and R. G. Gutschick, 1969, History of the Redwall Limestone in Northern Arizona, *Geological Society of America Memoir*, 114: 74-85.

19 K. J. Wenrich and P. W. Huntoon, 1989, Breccia pipes and associated mineralization in the Grand Canyon region, northern Arizona, in *Geology of Grand Canyon, Northern Arizona*, D. Elston, G. H. Billingsley and R. A. Young, eds., Washington D.C.: American Geophysical Union, 212-218.

the uppermost formation of the Supai Group, with a boundary claimed to be an unconformity of regional extent, representing an extended period of non-deposition due to uplift, weathering, and erosion.[20] However, abundant field evidence does not substantiate this claim. There is a general lack of conglomerate at the boundary, signifying the claimed time gap was so short that the Esplanade Sandstone did not become lithified prior to Hermit Formation deposition.[21] In many areas there is no obvious relief, on what is an even, flat contact. Furthermore:

> In a number of areas no evidence of a physical break has been detected, and at these places a boundary between formations can be established only by placing it arbitrarily where a lithologic change occurs. Thus, the significance of the surface as a record of regional erosion seems questionable.[22]

At many locations there is a definite transition with intertonguing of the two units, and where channels are found they are related to deposition of the Hermit Formation.[23] "A relatively sharp contact is between the two units in some areas, whereas gradation and probable intertonguing is observed elsewhere."[24] Thus, the evidence unequivocally shows that there is no claimed unconformity with a time gap between these two strata units. The intertonguing and transitional gradation between them resulted from continuous sedimentation.

There is an extraordinarily flat surface, free of any channel erosion, between the Hermit Formation and the overlying Coconino Sandstone. No soil or weathering profile is known at the top of the Hermit Formation, nor are pebbles of lithified Hermit siltstone known from the base of the Coconino. Instead, the uppermost Hermit Formation contains elongated cracks filled from above with Coconino Sandstone (clastic dikes). It would thus appear that the uppermost Hermit was not lithified when deposition of the Coconino began.[25] However, the discovery of the thick Schnebly Hill Formation between the Hermit Formation and the Coconino Sandstone in central and eastern Arizona has prompted the conventional geological community to insert a significant paraconformity between the Hermit and Coconino: "The sharp contact may be a major regional unconformity though sufficient paleontological evidence to confirm this hypothesis is not

20 L. F. Noble, 1923, A section of Paleozoic formations of the Grand Canyon at the Bass Trail, *U.S. Geological Survey Professional Paper*, 131-B: 63-64; E. D. McKee, 1982, The Supai Group of Grand Canyon, *U.S. Geological Survey Professional Paper*, 1173: 169-171; Young, 1990, 68-69.

21 McKee, 1982, 171.

22 McKee, 1982, 202.

23 R. C. Blakey, 2003, Supai Group and Hermit Formation, in *Grand Canyon Geology*, second edition, S. Beus and M. Morales, eds., New York: Oxford University Press, 136-162; Austin, 1994, Figure 3.26: 50.

24 R. C. Blakey, 1990, Stratigraphy and geologic history of Pennsylvanian and Permian rocks, Mogollon Rim region, central Arizona and vicinity, *Geological Society of America Bulletin*, 102: 1205.

25 Austin, 1994, 49.

yet available."[26] If "there is no evidence of prolonged weathering or extensive erosion" at this boundary,[27] then insertion of a time gap is neither necessary nor mandatory. Usually the sole reason for defining a paraconformity is different biostratigraphic (fossil) ages for the strata on either side of the contact, the absence of the appropriate fossils between the strata defining the time gap, even though no physical evidence of subaerial exposure or erosion is present to confirm the claimed millions of years between the strata. In this instance, if the Schnebly Hill Formation did not exist, then "sufficient paleontological evidence" would not be sought to define a time gap and a paraconformity. Thus, this supposed time gap at the Coconino-Hermit contact is an artifact of theory, and not based on the observable field evidence.

The fifth boundary in the Grand Canyon Paleozoic sequence where a time gap is postulated is the contact between the Toroweap and Kaibab Formations. Because the Toroweap Formation is absent from between the Kaibab Formation and Coconino Sandstone east of the Grand Canyon, and because at rare locations there are small channel-like "erosional structures" filled with broken clasts of Toroweap lithology at the contact with the Kaibab, it has long been conjectured that a significant paraconformity or disconformity exists at the Kaibab-Toroweap boundary.[28] Such was the confidence that a time break existed at this boundary, it was held up as a "textbook" example:

> The relative importance of a hiatus is immediately evident if the beds above and below bear fossils by which they can be assigned to their proper position in the geologic column. In most instances this is the final and the only criterion that gives quantitative results for the large unconformities. In the Grand Canyon walls, for example, where the Redwall limestone can be dated as lower Mississippian and the underlying Muav limestone as Middle Cambrian, we know that the paraconformity represents more than three geologic periods, yet the physical evidence for the break is less obvious than for that which separates the Toroweap and the Kaibab limestones, both of which are Middle Permian. Many large unconformities would never be suspected if it were not for such dating of the rocks above and below.[29]

The implication of this claimed regional unconformity is that, after marine deposition of the Toroweap limestone, the ocean responsible supposedly retreated, and an epoch of subaerial exposure followed, in which cementation occurred, followed by weathering and erosion of the lithified, uppermost surface of the

26 Blakey, 1990, 164.

27 J. S. Shelton, 1966, *Geology Illustrated*, San Francisco: W.H. Freeman, 283.

28 E. D. McKee, 1938, *The Environment and History of the Toroweap and Kaibab Formations of Northern Arizona and Southern Utah*, Washington: Carnegie Institute, Publication 492, 1-268.

29 C. O Dunbar and J. Rodgers, 1957, *Principles of Stratigraphy*, New York: John Wiley and Sons, 127.

Toroweap. Then this land surface had to subside, for the ocean to rise again to cover the region in order for the Kaibab limestone to be deposited. So is there really physical evidence for an epoch of subaerial erosion between the Kaibab and Toroweap? The Kaibab-Toroweap contact has now been declared as conformable, because no erosional channels have been found.[30] Furthermore, the channel erosion at the top of the Toroweap was found to be very localized and limited, while the broken clasts of Toroweap lithology at the top of the Toroweap and the associated "erosional channels" were found to have formed by underground solution and collapse of limestone, not by subaerial weathering and channel erosion.[31] So the Kaibab-Toroweap boundary is now regarded as conformable, or only locally disconformable, so no time gap of any significance can be inserted between these two formations.

Thus, it can be shown that there are real problems for the conventional geological community regarding these claimed time gaps between consecutive strata, as illustrated from the walls of the Grand Canyon. The physical evidence is absent or minimal at best, being more consistent with continual deposition of the strata. On a global scale this problem is greatly expanded, for if this phenomenon were rare, it might easily be passed over as an oddity not pertinent to explaining the geologic record in general. However, these gaps are characteristic of what is found frequently in the geologic record globally.[32] As has been stated:

> The difficulty with the extended passage of time proposed for various gaps in the sedimentary record is that we find neither deposition, nor is much erosion evident. If there is deposition, there is no gap, because sedimentation continues. If there is erosion, one would expect abundant channeling and the formation of deep gullies, canyons and valleys, yet the contacts (gaps), sometimes described as "continent-sized," are usually "near planar" (flat). It is difficult to conceive of little or nothing happening for millions of years on our planet's surface. Over time either deposition or erosion will occur.…The question of the assumed gaps in the sedimentary layers witness to a past that differed greatly from the present. We can easily reconcile that difference with catastrophic models such as the Genesis flood that propose rapid deposition of the layers with no extended time periods between them.[33]

To add visual impact to the significance of this problem, Figure 49 (page 1085)

30 Austin, 1994, 48, and references contained therein.

31 C. W. Cheevers and R. R. Rawson, 1979, Facies analysis of the Kaibab Formation in northern Arizona, southern Utah, and southern Nevada, in *Permianland Guide Book for the Ninth Field Conference Four Corners Geological Society*, Durango, CO, 105-113; R. L. Hopkins, 2003, Kaibab Formation, in *Grand Canyon Geology*, second edition, S. S. Beus and M. Morales, eds., New York: Oxford University Press, 196-211.

32 Roth, 1998.

33 Roth, 1998, 229.

compares the erosion that might be expected if long time periods had passed between sedimentary formations with the characteristic appearance of the geologic record, especially in the Paleozoic and Mesozoic, where there has been minimal erosion between formations. Some erosional channels are evident, as seen between some of the Grand Canyon strata, but the amount of relief is surprisingly small compared to modern topography produced by erosion with the passage of time.

Figure 50 (page 1086), a geological time cross-section through southeastern Utah, illustrates how common these gaps are in the geologic record in a well-studied area just to the north of the Grand Canyon. The presumed time gaps are shown in black, but of course, in reality, the formations lie on top of one another over large areas without significant erosion between them. They are relatively thin, widespread layers (the vertical exaggeration in the diagram is 16x), with some of them laterally correlating with one another. It is clearly evident that the claimed time gaps between these strata represent more geological time than that claimed for the deposition of these strata themselves (more than 60 percent of the Phanerozoic geologic record represented in this diagram is claimed time gaps). Yet there is little to virtually no erosion on the strata surfaces below the claimed time gaps, as has already been well documented for that part of this strata sequence that outcrops in the walls of the Grand Canyon.

Attempts to explain how the surfaces of these layers below each of the time gaps have remained uneroded during the claimed millions of years, when deposition was supposed to not be occurring, have not withstood critical analysis. Apparently, no modern analog exists for these very flat areas with little or no erosion.[34] However, some very arid areas of Australia, which are quite flat and featureless, are believed to represent areas that have been uneroded for millions of years. Perhaps the most extreme case would be Kangaroo Island, off the coast of South Australia, which is 140 x 60 kilometers in area, is extremely flat, and has a land surface believed to have been undisturbed for at least 200 million years.[35] However, the very arid condition of this and other parts of Australia today is not at all comparable to the apparent climatic conditions believed to have been operating during accumulation of the geologic record, including those parts containing the claimed time gaps, and even during the supposed 200 million years there at Kangaroo Island and other parts of Australia. Furthermore, these relatively flat land surfaces in arid areas of Australia are not characteristic of the expected results of normal geological processes, but are oddities which are "in some degree an embarrassment to all the commonly accepted models of landscape development."[36] On the other hand, the land surface of an area like Kangaroo Island is much more easily explained by a timespan for its existence of only thousands of years. After all, it stretches

34 Roth, 1998.

35 B. Daily, C. R. Twidale and A. R. Milnes, 1974, The age of the lateritized summit surface on Kangaroo Island and adjacent areas of South Australia, *Journal of the Geological Society of Australia*, 21 (4): 387-392.

36 C. R. Twidale, 1976, On the survival of paleoforms, *American Journal of Science*, 276 (1): 77-95 (81).

scientific credulity to suppose that a land surface was exposed for more than 200 million years without leaving any trace of any significant weathering and erosion.

The far simpler scientific explanation, that is elegantly consistent with the scientific evidence, is that the rocks beneath such land surfaces formed during the Genesis Flood, and that the land surfaces themselves were formed at the end of the Flood only thousands of years ago. This explains why there has been so little modification by weathering and erosion subsequently. Similarly, the catastrophic geological processes operating during the Genesis Flood offer a more scientifically reasonable explanation for these presumed time gaps in the geologic record. The timespans represented by the genuine gaps would vary from days to weeks if during the Flood, or to years or hundreds of years, at most, if generated subsequent to the Flood. Of course, the geologic record sometimes does contain evidence for erosion between some strata, as has already been described—in localized erosion channels within the Cambrian Muav Limestone, which are filled with Devonian Temple Butte Limestone at the boundary with the overlying lower Carboniferous Redwall Limestone. However, notwithstanding the geological ages assigned to these strata, the actual physical evidence at this and other boundaries between strata in the Grand Canyon sequence is far more consistent with the elapsed timespan for this erosion having been only hours or days during the catastrophic geological processes of the Genesis Flood, rather than the claimed 100 or more million years. Indeed, it is only to be expected that the global geological catastrophe represented by the Genesis Flood would have at times resulted in erosion of significant amounts of sediments, including erosion of strata already deposited during the catastrophe. Current geological processes on the present earth, even at their comparatively slow rates, cannot explain the small amounts of erosion at many strata boundaries in the geologic record in the presumed passing of extremely long periods of time, measured in millions of years.

Additionally, where there has been no erosion at strata boundaries, yet the geological ages assigned to the strata imply the absence of sedimentation and erosion for presumed millions of years, the physical evidence is really only consistent with deposition having been continuous. Thus, the presumed time gaps of millions of years are eliminated, and bringing into question the conventional geologic age dating. Instead, this evidence supports the role of the global Genesis Flood catastrophe in depositing the strata sequences.

Another related observation is that on top of some strata sequences are enormous, fairly flat erosion surfaces. An excellent example is the extensive, fairly flat erosion surface that occurs above most of the strata units found in the Grand Canyon, and forms the upper surface of many of the most prominent plateaus of northern Arizona. In the Grand Canyon area this erosion surface is most commonly seen as the upper surface of the Coconino and Kaibab Plateaus, and the Kaibab Limestone is the most prominent formation observed at this surface, which intersects the rim of the Canyon itself (see Figures 3 and 4, pages 441 and 312).

The Kaibab Limestone is the prominent formation at the Canyon rim and is the most prominent formation observed across the erosion surface at the top of the surrounding plateau country. That other formations were originally deposited on top of the Kaibab Limestone can be seen in two erosionally isolated remnants that consist of the overlying Moenkopi Formation and the Shinarump Conglomerate Member of the Chinle Formation. North of Grand Canyon the same erosion surface is just above the level of the Navajo Sandstone in the strata sequence above the Kaibab Limestone.

This physical evidence for extensive removal of most of the units in the strata column above the Kaibab Limestone is best explained as being the result of sheet erosion, by an enormous body of water that uniformly swept across the vast area. Furthermore, this enormous sheet of water would have been retreating from this area, and the strata eroded and removed must have been poorly consolidated after only having been recently deposited, that is, relative to the flooding of the area by this extensive sheet of water. This broad sheet-flood erosion of these elevated plateaus of northern Arizona stands in stark contrast to the channelized erosion that forms the present topographic profile within the Canyon, the latter erosion being more recent than the extensive sheet-flood erosion of the plateaus. There is really no modern counterpart to this catastrophic flooding, and movement of the resultant vast body of water responsible for such sheet erosion, to produce such extensive fairly-flat surfaces. This evidence is again consistent with the waters of the Genesis Flood when they retreated, being responsible for this sheet erosion across Arizona and elsewhere.

75

Soft-Sediment Deformation Features

Most sedimentary strata today, even when exposed at the earth's surface, are hard and brittle, because after deposition the sediment grains were cemented together, turning the soft sediment into hard rock. The processes are called diagenesis and lithification. In conventional geologic thinking, the layers of sedimentary strata in any given strata sequence, such as that exposed in the walls of the Grand Canyon, were deposited consecutively over millions of years, with the deposition of each conformable layer separated in time, perhaps also by millions of years. Diagenesis and lithification are also said to have perhaps taken millions of years, as chemicals in the water trapped between the sediment grains precipitate and crystallize to form the cement that binds the grains together. The strata sequence was then probably deformed, by being folded and faulted, probably millions of years after deposition finished and diagenesis and lithification had occurred, as has happened to the strata sequence in the Grand Canyon. Because in conventional geologic thinking deformation would thus have taken place after the sediment layers had already hardened into solid rocks, there should have been brittle failure of those rocks in response to the deformation.

It is known from experimental evidence that, under severe pressure and moderate temperature conditions, rocks can be made to deform and flow as if they were plastic, similar to modeling clay. However, when that happens, there is also evidence of the rocks being mineralogically and physically transformed, that is, metamorphosed. Nevertheless, many sedimentary strata sequences have not been so metamorphosed, and even though the strata are now brittle, they appear to have only suffered plastic deformation. The only way this could have occurred, without the tell-tale signs of metamorphism, is when the sediments were still soft after deposition, but prior to diagenesis and lithification. Yet even where the strata show compelling evidence of this having occurred, conventional geologic thinking discounts this evidence, because it automatically accepts the millions-of-years geologic timescale for the deposition of the sequences of sedimentary strata and their subsequent deformation.

On the other hand, this evidence of soft-sediment deformation is precisely what would be expected if the sedimentary sequences were rapidly deposited and then deformed in the year-long Genesis Flood, only thousands of years ago. Since the sediment layers at the base of strata sequences would generally have been deposited early in the Flood, then even if considerable thicknesses of other sediments were deposited on top of them, there would not have been the time or appropriate conditions for diagenesis and lithification to have fully occurred in the subsequent months of the Flood year, when deformation would have occurred while all the sedimentary strata were thus still soft and plastic.

This raises the question as to how long it takes for diagenesis and lithification of sediment layers to occur. Unfortunately, because there are a lot of variables involved, and each sediment layer experiences different conditions, there is no one specific answer. Important factors include the type of sediment, the amount of water in pore spaces, the type and amount of cement in solution, and the depth of burial (which determines the pressure and temperature conditions). If a sediment layer is buried deeply enough, then confining pressure will force the trapped water out of the pore spaces between the sediment grains, and the increased temperature will help precipitate the cement to bind the sediment grains together. Because conditions are unique to each sediment layer, in any particular strata sequence some sedimentary rock units are softer than others, while some may not have yet completely lithified, for one reason or another. Nevertheless, all sedimentary strata do become lithified, hard, and brittle, because under normal conditions sediments lithify relatively quickly, often in a matter of years, but at the most perhaps hundreds of years. Given ideal conditions, lithification can happen within days. The lithification process is somewhat analogous with a man-made mixture of gravel, sand, Portland cement, and water that lithifies to produce concrete, because the chemical present in the cement reacts with the water as the mixture dries. The process only takes hours to days.

A natural example of lithification illustrates how rapidly the process can occur. Following the explosive eruption of Mount St. Helens in Washington state on May 18, 1980, up to 600 feet (180 meters) of strata accumulated from the primary air blast, landslides, pyroclastic flows, mudflows and air falls.[1] The resultant strata, having been deposited catastrophically, appear essentially the same as other strata in the geologic record that are claimed to have been deposited over thousands and millions of years. After being deposited by the volcanic activity of Mount St. Helens, these sediment layers have subsequently not been subjected to optimum conditions for lithification, even suffering severe erosion as a result of a mudflow on March 19, 1982, eroding deeply into them to form a canyon system over 100 feet (30 meters) deep. Yet within five years of having been deposited, these sediment layers had been lithified sufficiently for them to support near-vertical cliffs in this canyon system. Thus, lithification can be a relatively rapid process, even at the earth's surface.

Thus, once sediment layers become lithified, the resultant sedimentary rocks are extremely difficult to bend and deform without being broken and shattered. The rocks are hard and brittle, which is in stark contrast to their soft and plastic, more pliable, condition soon after sediment deposition, and prior to lithification. If

1 S. A. Austin, 1986, Mount St Helens and catastrophism, *Proceedings of the First International Conference on Creationism*, vol I, 3-9, Pittsburgh, PA: Creation Science Fellowship.

deformation of a rock has occurred after its lithification, then the effects of the deformation on the mineral grains making up the rock can clearly be seen upon microscope examination. Many sedimentary strata sequences appear to have been deformed while the sediments were still soft and pliable, yet in conventional terms the sediments were deposited and supposedly lithified millions of years before deformation occurred. Thus, since lithification had occurred millions of years before deformation, the rocks were hardened when deformation occurred, and should have behaved in a brittle fashion. However, both at the macroscopic and microscopic scales, evidence implies plastic deformation has occurred when the sediments were still soft and pliable after deposition, thus challenging the claimed millions-of-years timeframe for the deposition of the sedimentary strata sequences and the subsequent deformation.

An excellent example of this soft-sediment deformation, which challenges the conventional timeframe for a sedimentary strata sequence, is found in the Grand Canyon area. The Grand Canyon itself has been carved through a 7,000-8,000 foot (2,150-3,450 meter) high plateau, and in the walls of the Canyon the sedimentary strata beneath the plateau are exposed. However, to the east, the same rock units that crop out at the rim of the Grand Canyon are found at a lower elevation. Indeed, some 250 miles (400 kilometers) to the east the same rock units are a mile or so (more than 1,600 meters) lower in elevation, so the plateau through which the Grand Canyon has been carved was uplifted to its current elevation by earth movements during tectonic adjustments of the earth's crust. In conventional terms, this is claimed to have occurred some 70 million years ago, during the Laramide Orogeny when the Rocky Mountains were also being formed. This pronounced elevation difference, due to uplift of what is known as the Kaibab Plateau, was achieved by upwarping in the eastern Grand Canyon, where the strata have been bent to form a fold structure called a monocline. The axis of the fold is called the East Kaibab Monocline, and its surface expression is a bending/folding of the Kaibab Limestone through an elevation difference of 3,000 feet (more than 900 meters). The fact that the Kaibab Limestone has been folded rather than altered indicates that it was still soft and pliable when the deformation occurred supposedly 70 million years ago. However, the Kaibab Limestone is supposed to be 250 million years old, more than enough time for it to have lithified in the claimed 180 million years since its deposition.

The other rock units in the sequence below the Kaibab Limestone have also been folded during this deformation event responsible for the Kaibab Upwarp, and the most extreme example is the Tapeats Sandstone at the base of the strata sequence. In the hinge zone of the monocline, the Tapeats Sandstone has been severely deformed, the internal layering being bent and twisted to be oriented almost vertically (Figure 51, page 1087). In conventional terms, the Tapeats Sandstone is claimed to be around 540 million years old, so that at least 470 million years had supposedly elapsed by the time of the Laramide Orogeny 70 million years ago. Since there was also at least 4,000 feet (1,200 meters) thickness of other sedimentary layers stacked on top of the Tapeats Sandstone for 180 million years (that is, after deposition of the Kaibab Limestone), there was ample time and sufficient confining overburden pressure to have resulted in the lithification of the Tapeats Sandstone by the time the deformation occurred. Thus, it would be expected that the lithified Tapeats Sandstone suffered brittle failure during deformation, if the millions of years are the correct time framework for these events.

However, the bending of the sandstone in the hinge area of the monocline does not show any sign of brittle failure (Figure 51), but instead the sandstone appears to have been in a soft, pliable condition when the bending occurred. Thus, lithification of the sandstone had not yet taken place, and therefore, there could not have been millions of years between deposition of the sandstone and the deformation event. Furthermore, close examination of the sandstone does not reveal any evidence of elongated sand grains, or of broken and recrystallized cement, both brittle deformation features that would be expected if the sandstone was fully lithified when the bending occurred. The Tapeats Sandstone obviously was thus still soft and pliable when the deformation occurred, even though the confining pressure of the overlying sediments must have compacted the sandy sediment, so the process of lithification had begun. There can't have been much time, therefore, between deposition of the Tapeats Sandstone, deposition of the overlying sediment layers, and then the deformation of the entire strata sequence.

It cannot be denied that if a rock is buried deeply, and thus experiences confining pressure from all directions surrounding it, then bending can occur in an otherwise brittle rock. Nevertheless, in a hard, lithified sandstone, such as the Tapeats Sandstone, such bending always results in elongated sand grains, and/or recrystallization of broken cement, neither of which has been found in the deformed Tapeats Sandstone in the Grand Canyon. There is a limit to how much strain (or deformation) a rock can endure under a given stress.[2] Deformation occurs when stress is applied to a rock, and if the stress is maintained at a constant level, the rock will continue to deform or "creep." If the rock experiences additional stress, it will suffer failure because it is brittle and will fracture. On the other hand, if a constant stress is maintained, at a value below that failure point, deformation will continue in most rocks, until a terminal value is reached where the rock will either become stable or will fracture. For most rocks there is a limit to the amount of creep that can occur over time, because they cannot undergo unlimited deformation, and will eventually rupture.

In the example of the Tapeats Sandstone in the Grand Canyon, in the hinge area of the East Kaibab Monocline where the folding is greatest, the sandstone is bent at an approximate 90° within a distance of about 100 feet (30 meters). In the folding process, the sandstone in the outer half of the fold would have been

2 R. E. Goodman, 1980, *Introduction to Rock Mechanics*, New York: John Wiley and Sons, 74.

under tension, while in the inside part of the fold the sandstone would have been under compression. Lithified rock is notoriously weak under tension, invariably failing by fracturing, yet at places within the hinge zone of the monocline, it can be seen that entire layers within the sandstone have thinned as they were stretched during bending. This is visible confirmation that the sandstone must have still been relatively soft and plastic under the stress of the deformation event, which must therefore have occurred soon after deposition of the sandstone, not 470 million years later. Lithified sandstone could otherwise have not withstood the amount of stretching involved in this folding, even under the confining pressures involved, because experimental work has demonstrated that lithified rock simply does not stretch and thin in the way observed in the Tapeats Sandstone. Thus, this observed soft-sediment deformation of the Tapeats Sandstone, in the hinge zone of the East Kaibab Monocline in the eastern Grand Canyon, is irrefutable testimony that the sequence of events, beginning with deposition of the Tapeats Sandstone and the overlying 1,200-meter-thick sedimentary strata sequence, followed by the deformation event that folded this strata sequence along this monocline during the uplift of the Kaibab Plateau, could not have occupied hundreds of millions of years, but rather an extremely short timeframe, which implies that deposition and deformation of this sedimentary strata sequence were catastrophic events.

Added powerful confirmation that this is the correct interpretation of the observed evidence is the faulting of the metamorphic rocks below the folded Tapeats Sandstone to Kaibab Limestone strata sequence along the East Kaibab Monocline. During the Kaibab Upwarp event, the same applied stress that stretched and thinned the Tapeats Sandstone as it was folded, caused fracturing and faulting of the schists and other metamorphic rocks in the basement complex directly underlying the Tapeats Sandstone. This implies that, by the time deposition of the Tapeats Sandstone-Kaibab Limestone sediments was occurring, these metamorphic rocks were hard and brittle, which in turn implies that sufficient time had previously elapsed for these rocks to have reached this condition. This is, therefore, consistent with their formation prior to the Genesis Flood, even dating back to the events of the Creation Week itself. Seismic studies have demonstrated that the fracturing of these brittle metamorphic rocks resulted in a vertical displacement of at least 5,000 feet (1,500 meters) along faults located underneath the East Kaibab Monocline. Thus, while the previously hardened brittle metamorphic rocks in the basement complex were faulted by the deformation produced by the Kaibab Upwarp, the Tapeats Sandstone-Kaibab Limestone sedimentary sequence catastrophically deposited on top of the basement complex during the Flood was only folded, because the strata were still soft and pliable due to the upwarp occurring so soon after deposition that lithification had not fully taken place. However, the subsequent faulting with much less displacement, for example, along the Bright Angel Fault, which fractured and faulted the entire Tapeats Sandstone-Kaibab Limestone strata sequence, implies that the lithification of these sediments was soon completed after the major deformation of the Kaibab Upwarp.

This dramatic example of soft-sediment deformation in the Grand Canyon is definitely not unique, because there are almost countless other examples in other places where strata have been deformed while still soft and pliable. In the United States alone, both the Appalachian Mountains and the Rocky Mountains are full of such occurrences. Several examples in the Rocky Mountains are associated with the Ute Pass Fault, west of Colorado Springs.[3] The Front Range of the Rocky Mountains in Colorado was formed by large reverse faults, with vertical displacements of as much as 21,000 feet (6,400 meters). The very abrupt margin of the Front Range, with Pikes Peak (more than 14,000 feet or 4,250 meters elevation) on the west and Colorado Springs (6,000 feet or 1,830 meters elevation) on the east, is caused by the Ute Pass Fault, a prominent north-trending reverse fault more than 40 miles (64 km) in length. On the west side of the fault is the upthrown Pikes Peak granite and associated Precambrian metamorphic rocks, all sedimentary strata overlying them having been removed by erosion. On the east side of the Ute Pass Fault there are about 12,000 feet (3,650 meters) of Phanerozoic sedimentary strata overlying the Precambrian basement, so the vertical displacement on the fault is about 20,000 feet (6,100 meters). The Ute Pass Fault truncates, or folds, Cambrian to Cretaceous strata, so it must therefore be Cretaceous or post-Cretaceous. Field relationships confirm that all of the very intense deformation associated with the Ute Pass Fault is thus assignable to the Laramide Orogeny, which was responsible for the formation of the Rocky Mountains and for the uplift of the Kaibab Plateau in the Grand Canyon area.

Characteristic of the Ute Pass Fault is the intensity of folding of the strata on its east side, where there is an eroded remnant of an enormous monocline involving about two miles (more than 3 km) of structural relief. Approaching the flank of the Front Range, within three miles (almost 5 km) of the exposure of the Precambrian basement on the other side of the fault, the 14,000 feet (more than 4,200 meters) of sedimentary strata are bent into nearly vertical orientation. The Ute Pass Fault appears to be concealed at depth in the Precambrian basement, but this thick overlying sedimentary rock cover did not fault, and so must not have then been fully lithified. Instead, these sedimentary strata were plastically deformed by vertical displacement on the Ute Pass Fault to form this spectacular monocline.

Further evidence of soft-sediment deformation are the tight drag folds very close to the Ute Pass Fault, such as the very strong folding of the Fountain Formation sandstone in contact with the fault near Manitou Springs. The sandstone dips at 35°NE just 80 feet (24 meters) northeast of the Ute Pass Fault, but at the fault it is overturned and dips about 60°NW. This folding was caused by drag of the strata against the upthrown west side of the fault. Field observations clearly reveal

3 S. A. Austin and J. D. Morris, 1986, Tight folds and clastic dikes as evidence for rapid deposition and deformation of two very thick stratigraphic sequences, *Proceedings of the First International Conference on Creationism*, vol II, 3-15, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship.

that the sandstone was not able to transmit stress away from the fault, so was not internally faulted as it was folded, which is consistent with the strata being ductile and not solidly cemented when deformed. However, this Fountain Formation sandstone is Pennsylvanian-Permian, so in conventional terms it is regarded as 300 million years old, whereas the Laramide Orogeny is supposed to have occurred less than 70 million years ago. Therefore, how could this sandstone have remained ductile for those claimed 230 million years? That ductile flow was the mechanism for the tight drag folds has long been recognized from field observations of several outcrops on the Ute Pass Fault:

> These examples demonstrate that the drag effect in Fountain arkoses can be very local. The drag is accomplished with few visible fractures. The shape of the beds is apparently altered by ductile flow, that is, by small translation and rotation of individual grains of the arkoses and conglomerates.[4]

Translation and rotation of individual grains could be easily accomplished if the sandstone was not yet cemented when deformed. If the sandstone was cemented and fully lithified when Ute Pass Fault was formed, significant modifications to the shapes of individual grains within the sandstone due to the stress of the folding should now be observed. Furthermore, there should also have been significant faulting due to brittle failure.

Other soft-sediment deformation features that are even more significant are the clastic dikes of quartz sandstone associated with the Ute Pass Fault and many other reverse faults of the Front Range.[5] More than 200 sandstone dikes were mapped in one study alone, the dikes varying from a fraction of an inch to miles in length, from a fraction of an inch to 300 feet (over 90 meters) in width, and penetrating up to 1,000 feet (305 meters) or more through the surrounding bedrock, which is usually Precambrian basement (Pikes Peak granite or associated metamorphic rocks). The dikes occur most frequently on the upthrown (hanging wall) side of the Ute Pass Fault, within one mile (1.6 km) west of the fault, having been injected downwards from sandstone overlying the Precambrian basement (now eroded away) along extension fractures in the hanging wall of the convex-upward reverse fault. Virtually all the dikes strike parallel to the strike of the main reverse fault, and because of their coincidence with, and relationship to, the structures generated by the Laramide Orogeny, it is only reasonable to conclude that they are Laramide dikes. These sandstone dikes are remarkably uniform in composition, with greater

4 J. C. Harms, 1965, Sandstone dikes and their relation to Laramide Faults and stress distribution in the southern Front Range, Colorado, *Geological Society of America Bulletin*, 76: 989.

5 W. Cross, 1894, Intrusive sandstone dikes in granite, *Geological Society of America Bulletin*, 5: 225-230; P. W. Vitanage, 1954, Sandstone dikes in the South Platte area, Colorado, *Journal of Geology*, 62: 493-500; G. R. Scott, 1963, Geology of the Kassler Quadrangle, *U.S. Geological Survey Professional Paper*, 421-B: 125pp; Harms, 1965, 981-1002; L. S. Kost, 1984, Paleomagnetic and petrographic study of sandstone dikes and the Cambrian Sawatch Sandstone, east flank of the southern Front Range, Colorado, University of Colorado, unpublished M.S. thesis, 173 pp.

than 90 percent quartz by volume, less than 5 percent feldspar, and less than 5 percent clay-size matrix. Xenoliths of granite from the wall-rock are common. Among investigators of these clastic dikes there is agreement that the Sawatch Sandstone (the Cambrian sandstone immediately overlying the basement) is the source. Not only is the Sawatch the closest sandstone to the dikes, but there is nearly identical compositional and textural similarity.

The evidence that the sand of the dikes was unconsolidated when injected has been widely recognized. There is little evidence of breakage of sand grains as if they were cemented before injection, and there is a lack of fine matrix, which would have formed from disaggregation of the sandstone had it been lithified. On the other hand, the long axes of granite xenoliths are oriented parallel to the dike walls, and the dikes themselves show laminated flow structures, with segregation of sand by size as if forcefully injected. Even dikes only a fraction of an inch wide are completely filled with sand, testimony to the great fluidity of the injected material.

Having agreed upon the source of the sand in these clastic dikes along the Ute Pass Fault, there is a divergence of opinion as to when their intrusion occurred. Of course, some investigators have recognized the fundamental impossibility of the Cambrian Sawatch Sandstone (supposedly 500 million years old) remaining unlithified while deeply buried for 430 million years until the Laramide Orogeny (assumed to be late Cretaceous about 70 million years ago or less). To avoid this obviously embarrassing problem, important field relationships are overlooked in order to suggest that the dikes were actually intruded in the Cambrian while the Sawatch Sandstone was unconsolidated. However, there is no evidence of tectonic movements in the Cambrian or Ordovician of a magnitude able to open up extension fractures hundreds of feet (tens of meters) wide along the Ute Pass Fault. Instead, the actual field data strongly support the Laramide intrusion of the dikes. The Laramide Orogeny was not only of sufficient magnitude to open up the large extension fractures, but the coincidence of the dikes along the Ute Pass Fault, a proven Laramide structure, cannot be accidental. Furthermore, one of these quartz sandstone bodies penetrates the Pennsylvanian-Permian Fountain Formation sandstone, so this dike cannot be Cambrian or Ordovician, but is related to the Laramide Ute Pass Fault.

In conclusion, it is abundantly clear that the total time required for deposition of the sequence of 14,000 feet (more than 4,200 meters) of sedimentary strata overlying the Precambrian basement, for regional flexing, for faulting, and for the development of the local deformation features, must have been less than the time it took for this entire thick sequence of soft sediments, complete with their contained water and mineral cement content, to lithify and completely harden to rock. This implies catastrophic deposition of these strata, and that tectonism immediately followed deposition before lithification of even the sand layer at the base of the 14,000-feet-(more than 4,200 meters) thick sequence of sediments. On the other hand, the conventional view is that this 14,000-feet-(more than 4,200 meters) thick sequence of strata along the Ute Pass Fault in Colorado accumulated from the Cambrian through to the Cretaceous, from supposedly 500 million years ago through to 70 million years ago, a total deposition time of some 430 or more million years. However, as amply demonstrated by the field observations of numerous investigators, there are numerous soft-sediment deformation features (monoclines, tight drag folds, and clastic dikes) among the strata along the fault which are associated with the Laramide Orogeny that supposedly occurred less than 70 million years ago, so how could this thick sequence of sediments escape lithification after deep burial through a duration of up to 430 million years? Without a doubt, the answer is that the evidence overwhelmingly supports the conclusion that the entire thick sequence of sediments was catastrophically deposited, and then immediately deformed, on a timescale consistent with the Genesis Flood, rather than the conventional view that claims deposition over 430 million years.

These two examples of soft-sediment deformation features that question the conventional claims of hundreds of millions of years for deposition of thick sequences of sedimentary strata should suffice. One or two such occurrences might be discounted as simply anomalies, but when there are numerous similar examples of soft-sediment deformation in many similarly deformed terrains all over the world, the overwhelming conclusion must be that the conventional timescale is wrong. The catastrophic deposition of these thick sequences of sedimentary strata was followed immediately by deformation before the sediments were lithified, on a timescale that must have been brief, because lithification can occur in only days or weeks. This is all consistent with the biblical account of the Genesis Flood.

76

Summary

This discussion and documentation of many detailed examples of distinctive features of the geologic record have been necessary to demonstrate the overwhelming evidences of catastrophic accumulation of the rock record and these distinctive features. Furthermore, it has been easily demonstrated that, even in the conventional geologic community, there has been renewed recognition of the evidence for catastrophism in the geologic record. These evidences for catastrophism in the geologic record include:

1. The rate of sediment accumulation

When actual sedimentation rates have been measured, they far exceed the sedimentation rates conventionally claimed for accumulation of the sedimentary strata of the geologic record, often by many orders of magnitude. Thus, it has been recognized that a single flash flood could deposit as much sediment in a few hours as that which is conventionally claimed to have been deposited over thousands, and even millions, of years. Thus, it was concluded that even if the waters of the Genesis Flood were like those of a modern flash flood, there would have been ample time in the biblical timescale for the Flood to have accumulated the sedimentary strata sequences we find worldwide in the geologic record. Therefore, realistic sedimentation rates would feasibly have produced the sedimentary rock record within the year of the Genesis Flood.

2. Widespread, rapidly water-deposited strata

Whereas today's sediments accumulate intermittently on a local scale, the numerous thick sediment strata with amazing horizontal continuity, even on a continental scale, are overwhelming testimony to catastrophic deposition of sediments on the continental scale that would be expected to result from the global inundation of the Genesis Flood. It has also been demonstrated that even for different sediment types, as diverse as limestones from sandstones and shales, the nature of these sediments as preserved, and the internal structures within them, can only be explained by catastrophic accumulation rates. Furthermore, the depths of water and the velocities of the water currents involved, and the catastrophic widespread deposition of the sedimentary strata of the geologic record, plus the regular occurrence of marine fossils in many strata now exposed on the continents, even at elevations thousands of meters above sea level, are testimony that the ocean waters in the past covered the continents, just as recorded in the Scriptures with respect to the Genesis Flood. The sediments in these thick widespread strata spanning all regions of continents, and even across continents, show no evidence of having been derived by erosion and transport of the materials immediately underlying them, which implies that the sources of such sediments were at some distances from the regions now blanketed by these strata. This thus implies enormous distances for transport of such sediments, even on a continental scale, evidence that is not consistent with conventional explanations, but instead with the catastrophic, inter-regional erosion, transport, and sedimentation clearly implied from the scriptural record of the Genesis Flood.

3. Fossil graveyards

The presence of so many fossils, often preserved in exquisite detail, throughout the geologic record on every continent, are testimony to the rapid burial of countless animals and plants during the catastrophic sedimentation of these strata. The detailed descriptions of some of the many spectacular fossil graveyards, found at all the various levels within the sedimentary rock record, serve to emphasize the catastrophic rates at which the sediments accumulated to bury such huge masses of animals and plants on a global scale. Indeed, the presence of many thick coal beds on every continent, with the types of plant fossils found in them, and the way these plant fossils have accumulated and been buried, is not consistent with the growth of countless plants *in situ* over millions of years, but instead with the catastrophic destruction and burial of forests with their accumulated peats on a global scale. It can also be demonstrated that the fossilization processes were extremely rapid, so as to preserve the exquisite details of fossils found in the fossil record, just as the conversion of plant material to coal has also been shown to occur in only a matter of weeks or months, a timescale consistent with the year of the Genesis Flood, only thousands of years ago.

4. Rapid erosion and/or time gaps

The conventional view—based as it is on timescales of millions of years for strata accumulation with contained fossils characteristic of each epoch, period, and era—is that in many instances there are significant time gaps between strata in the geologic record. This is not only where some erosion is clearly evident between strata, but even where strata boundaries are flat and featureless with knife-edge clarity, because stratigraphic and biostratigraphic dating dictate the time gaps. However, while there are many locations in the geologic record where significant erosion has occurred at unconformities, such erosion can be shown to have been catastrophically rapid, thus ruling out the necessity of long ages between these strata. Furthermore, in those places where there has been minor erosion at strata boundaries, the relief is miniscule, compared to that found on the present-day land surface, if the proposed millions of years for these time gaps really did occur. If both stratigraphic and biostratigraphic dating were ignored, then the scale of erosion at these boundaries, and where so many strata boundaries are flat, featureless and knife-edge, would indicate that the rapid accumulation of the sediments in these strata would merely have been continuous, as dictated by the field evidence. Thus, the millions of years for each of the many claimed time gaps between strata in the geologic record has not been documented, but instead, the continuous catastrophic deposition of the sediments is consistent with the Genesis Flood. Furthermore, where there are water-eroded surfaces still evident on the earth's surface today, these were produced by regional-scale sheet erosion, consistent with the retreating waters at the end of the Genesis Flood.

5. Soft-sediment deformation

Following the deposition of many thick sequences of sedimentary strata, the whole sequences were deformed by earth movements that uplifted the strata to form plateaus and mountains. Whereas this resulted in fracturing and faulting of strata, primarily in the older Precambrian basements, often the overlying sedimentary strata were bent into monoclines, and even tight folds, without evidence of the brittle fracture and failure that would be expected if the deformed sedimentary strata had already been lithified and hardened. Clastic dikes also intrude along tension fractures where faulting of strata has occurred. These soft-sediment deformation features are often found in sedimentary strata that were deposited hundreds of millions of years before the deformation events, according to conventional dating. Thus, the field evidence consistently implies that these sediment sequences thousands of meters thick had to be deposited and remain unlithified so as to subsequently deform while still soft and pliable, which automatically discounts the claimed hundreds of millions of years from the beginning of deposition to the deformation events. Thus, the timescale for accumulation of the sedimentary record is consistent with the timescale for the year-long Genesis Flood only thousands of years ago.

These summarized conclusions, based on field and laboratory evidence, give overwhelming testimony that the conventional view, which claims the geologic record required hundreds of millions, and even billions, of years to accumulate, is not only misleading, but in error because of the interpretative framework assumed and applied. Even conventional geologists are increasingly recognizing the evidences of catastrophism in the geologic record. Their uniformitarian assumptions, however, blind them to insisting that catastrophism was periodic, punctuating millions and millions of years of little to no geologic activity. This survey of the evidences for catastrophism in the geologic record, on the other hand, uninhibited by these uniformitarian assumptions, clearly demonstrates that most of the geologic record must have accumulated catastrophically, particularly that portion of the record containing fossils. All this evidence is exactly what one would expect to find in the geologic record based on the details given in the biblical record in Genesis of creation and the Flood. All that now remains to cement this demonstrated consistency between the biblical record of earth history and the geologic data is to systematize the latter within a biblical geologic model of earth history.

Section VII

A Biblical Geologic Model of Earth History

77

The Creation Week

In the scriptural account of earth history, there are four major time periods in which the geologic record accumulated. These in order are: the Creation Week era, the pre-Flood era, the Flood era, and the post-Flood era. The durations of these eras are markedly different, and the eras themselves can be readily subdivided.

The Creation Week involves but six days of God's creating a fully-functioning mature earth with a fully operational biosphere, hydrosphere, and atmosphere, followed by God's day of rest—referred to as the "Sabbath" day. In this short timespan, the earth was created and established, with an almost incomprehensible amount of geological work completed in order to produce as much as half or more of the geologic record. By contrast, the pre-Flood era that followed lasted for approximately1,656 years, and the pace of geological processes would have to have been much, much slower in order to ensure the earth was habitable for its biosphere that was teeming with all manner of life. On the other hand, during the year-long Flood era, catastrophic geological processes were responsible for the wholesale destruction, burial, and fossilization of the pre-Flood biosphere, so again a major portion of the geologic record was built in a relatively short period of time. Finally, the post-Flood era commenced at the close of the Flood about 4,500 years ago, and has continued to the present day. In the early years of the post-Flood era the residual effects of the Flood would have been significant enough to have left behind a detectable portion on the geologic record, in sharp contrast to the slow and gradual geological processes now operating that barely leave behind any geologic record at all.

Within this broad outline it is necessary to build a comprehensive geologic model of earth history that can account for the preserved geologic record we observe today, and that upholds the veracity and integrity of both the historical record in Scripture and all the geologic data. Each of these eras therefore needs to be extensively examined in light of the data supplied by both the biblical and geologic records.

The Creation Week Processes Unique

Reading the account of the Creation Week in Genesis 1-2, one immediately observes the specific sequence in which God performed His acts of creation of different entities that eventually joined together to make a completed and integrated whole. The description in Genesis is of unequivocal acts of fiat creation that, from a human perspective, would be observed as instantaneous, simply at God's command. Psalm 33:6, 9 declare: "By the word of the LORD were the heavens made; and all the host of them by the breath of his mouth....For he spake, and it was done; he commanded, and it stood fast." Nevertheless, the text of Genesis 1 not only refers to God's commands, but also His acts of creating and making, while Genesis 2:2 refers to God ending His work. Thus, it can be argued that God's acts of creating and making involved the unleashing and setting in motion of processes that accomplished what God had commanded. However, this does not imply that these processes were anything other than unique to the Creation Week era, when God was bringing matter into existence and then organizing, ordering, and energizing it to establish the universe, the earth, and life itself. It is abundantly clear in the Genesis record that the processes used by God in creation were utterly different from the processes that now operate in the universe. That the Creation Week era was unique, entirely incommensurate with this present world, is unmistakably emphasized by divine revelation, which concludes in Genesis 2:1-2 with the words: "Thus the heavens and the earth were finished, and all the host of them. And on the seventh day God ended his work which he had made; and he rested on the seventh day from all his work which he had made." In view of these strong and repeated assertions in God's Word, it is highly presumptuous for any scientist to imply that the origin and early history of the earth can be elucidated and studied in terms of present geological and other processes.

Yet herein lies the basic fallacy of modern conventional geological research and the model for earth history it has developed, based as they both are on the belief that geological processes have been uniform in scope and operation throughout the earth's history, and indeed during its origin. It may seem reasonable to use the principle of the uniformity of natural processes as a key to deciphering the geologic record that has been produced since the end of the Creation Week, except that the scale and intensity of present-day geological processes could not have been uniform throughout the earth's history because of their acceleration during the Flood year. Obviously, the geologic record does provide much valuable information concerning earth history subsequent to the close of the Creation Week, after God finished His work of creating the "heaven and earth, the sea, and all that in them is," as summarized in Exodus 20:11. However, it is not legitimate for the uniformity principle to be used, as it has been by the general scientific community, to attempt to establish a long history for the origin and development of the creation itself over billions of years. God has plainly said that the processes He used during the creation no longer operate, a fact that is thoroughly verified by the two universal laws of thermodynamics that are intrinsic to the creation as designed by God.

The Laws of Thermodynamics

The two most fundamental and certain of all laws of modern physics are the first two laws of thermodynamics. The well-known first law of thermodynamics is the law of energy conservation, confirming that although energy can be converted from one form to another, the total amount remains unchanged, because energy is neither being created out of nothing nor totally destroyed at the present time. Matter may be transformed into energy and energy into matter, but neither creation nor annihilation occurs. The second law states that, although the total amount of energy remains unchanged, there is always a tendency for it to become less available for useful work. In other words, in any closed system in which work is being accomplished through energy conversions, the "entropy" increases, where entropy is essentially a mathematical formulation of the non-availability of the energy of the system to it.

The importance of the universal application of these laws has never been in doubt:

> The two laws of thermodynamics are, I suppose, accepted by physicists as perhaps the most secure generalizations from experience that we have. A physicist does not hesitate to apply the laws to any concrete physical situation in the confidence that nature will not let him down.[1]

These two laws operate through the whole modern scientific enterprise, and the technology it has spawned. The operation of all geological processes, as well as all other physical and biological processes, is governed by these laws, without exception. In none of them is any energy or matter (matter being one form of energy) being created. However, during the six days of creation, both matter and energy were being created, so God's creative activity was entirely different from all current geological, physical, and biological processes.

Still more significantly, this newly-created matter and energy were being organized into increasingly complex and highly energized systems, emphatically the opposite to the universal tendency toward disorganization and de-energization experienced in all processes at the present time:

> Another way to explain the meaning of entropy is to compare it to the property of "randomness." This conclusion leads to the generalization that every system that is left to itself will, on the average, change toward a condition of maximum randomness. The implication of this statement that the entropy of a system increases spontaneously…when entropy

1 P. W. Bridgman, 1953, Reflections on thermodynamics, *American Scientist*, 41: 549.

> is thought of as randomness, it can be recognized in many natural phenomena.[2]
>
> [E]ntropy is the supreme law of nature and governs everything we do.[3]

Randomness, of course, is synonymous with disorder, disorganization, disintegration, and degeneration. Furthermore, this is an absolutely universal rule of nature at the present time, as demonstrated and verified by countless scientific observations.

However, in spite of this unequivocal recognition of the universality of the entropy principle in all natural processes operating today, as repeatedly tested by experiments and confirmed by every scientific observation, the conventional scientific community today presupposes that the universe, the earth, and all living things on it, have developed by means of the supposed universal principle of evolution (for example, stellar evolution, planetary evolution, biological evolution). Numerous attempts have been made to harmonize, and even to equate, entropy and evolution in order to overcome this profound dilemma. The standard "answer" provided by the conventional scientific community has long been the insistence that this conflict is resolved by the fact that the earth is an "open system," with the incoming energy from the sun able to sustain evolution throughout the geological ages, in spite of the natural tendency of all systems to deteriorate toward disorganization:

> The total of living material forms a very thin layer on the surface of the earth, the *biosphere*, which is continually being degraded and reconstituted out of the same mass of chemical constituents. The work involved in this reconstitution and those evolutionary changes that go on in the biosphere is supported by photosynthesis, the process through which a small fraction of the energy of sunlight is captured: thus the biosphere system is dependent upon energy exchange in the Sun-Earth system of which it is a part. The energy of sunlight received by the Earth is ultimately reradiated to space; consequently the Earth's temperature remains nearly constant. But the outgoing quanta are smaller in size and greater in number than the incoming, this representing a continuing increase in entropy of the Sun-Earth system. Since any increase in order within the biosphere must be very small compared to the increase of entropy in the Sun-Earth system there is no reason to think that evolution controverts the second law of thermodynamics, even though it may appear to do so if viewed as a thing apart.[4]

---

2 G. Faure, 1998, *Principles and Applications of Geochemistry*, second edition, Upper Saddle River, NJ: Prentice Hall, 162.

3 J. Rifkin, 1980, *Entropy*, New York: Bantam Books.

4 H. F. Blum, 1968, *Times Arrow and Evolution*, third edition, Princeton, NJ: Princeton University Press, 200-201.

This, of course, does not solve the problem of entropy at all, because it does not explain the origin of the machinery of photosynthesis that is able to increase the local order in an open system. Simply saying that the earth is open to the energy from the sun says nothing about how that raw solar heat is converted into increased complexity in any system, open or closed. The fact is that the best known, and most fundamental, equation of thermodynamics states that the influx of heat into an open system will increase the entropy of that system, not decrease it:

> Evolution produces temporary structures of subtle and beautifully ordered complexity, but the Second Law ensures that their net contribution will be a permanent increase in the entropy and disorder of the Universe.[5]

The above claim is made as if evolution is a fact, even though it naively ignores that no explanation, apart from creation by design, has yet been forthcoming to explain the complexity of the machinery of photosynthesis. Nevertheless, mainstream scientists still continue to defend what they think is the "natural processes' ability to increase complexity" by insisting that there is a "flaw" in "the arguments against evolution based on the second law of thermodynamics":

> Although the overall amount of disorder in a closed system cannot decrease, local order within a larger system can increase even without the actions of an intelligent agent.[6]

However, all known cases of decreased entropy (or increased organization) in open systems involve a guiding program of some sort, and one or more energy conversion mechanisms. Indeed, it is the origin of the complexity that permeates all living organisms that continues to confound all attempts at naturalistic explanations, for even in the building block of life, the cell, and its intricate biochemical workings, are many examples of "irreducible complexity" in the machinery and their operation.[7] Each of the claimed evolutionary processes, for which there is no general consensus in the scientific community, has neither a guiding program nor energy conversion mechanisms. Mutations are not "organizing" mechanisms, but disorganizing (in accordance with the second law of thermodynamics). They are commonly harmful, sometimes neutral, and never beneficial (at least as far as observed mutations are concerned). Furthermore, natural selection cannot generate order, but can only "sieve out" the disorganizing mutations presented to it, thereby conserving the existing order, but never generating new order. Natural selection can only work on the existing genetic and biochemical information in the cells of an organism—it cannot "create" new information. Thus, it is barely conceivable that evolution could even occur in open systems, in spite of the tendency of all systems to disintegrate sooner or later.

---

5 S. Adams, 1994, No way back!, *New Scientist*, 144 (1948), Inside Science 75: 4.

6 N. A. Johnson, 2000, Design flaw, *American Scientist*, 88 (3): 274.

7 M. J. Behe, 1996, *Darwin's Black Box: The Biochemical Challenge to Evolution*, New York: The Free Press.

Failing the advent of the "chaos theory," some evolutionists are now arguing that the apparent underlying order in chaotic systems, instead of complete randomness, may somehow generate a higher stage of evolution: "In far from equilibrium conditions, we may have transformation from disorder, from thermal chaos, into order."[8] The fact is, however, that except in the very weak sense, it has not been demonstrated that dissipation of energy in an open system produces order, because in the chaotic behavior of a system in which a very large energy dissipation is taking place, certain temporary structures (called "dissipative structures") form and then soon decay. They have never been shown, even mathematically, to reproduce themselves or to generate still higher degrees of order. It is very significant that all discussions, of how chaotic systems (which are of course still perfectly consistent with the laws of thermodynamics) supposedly generate a higher order required by evolutionary theory, have been purely philosophical and mathematical—not experimental. Such phenomena as these, which evolutionary theorists attempt to call evolution from chaos to order, may be manipulated on paper or on a computer screen, but not in real life.

Not even the first, absolutely critical, step in the evolutionary process, that of the self-organization of non-living molecules into self-replicating molecules, can be explained in this way:

> The problem of biological order involves the transition from the molecular activity to the supermolecular order of the cell. This problem is far from being solved.…However, we must admit that we remain far from any quantitative theory.[9]

Yet the naïve claim continues to be made that since life "appeared" on earth very early in geologic history, it must have been the result of spontaneous self-organization. This claim still awaits objective scientific demonstration, as opposed to circumstantial interpretation of the geologic record. "In short, chaos theory cannot explain complexity."[10]

Sadly though, in spite of the overwhelming objective scientific evidence of the serious implications of entropy for claimed biological evolution, most evolutionists continue to simply ignore the problem of entropy, or continue to blandly assert that the second law is refuted by the "fact of evolution." However, this second law of thermodynamics has always proved valid wherever it has been tested, and this law of increasing entropy continues to be, by any measure, one of the most universal best-proved laws of nature. It still applies, not only in physical and chemical systems, but also in biological and geological systems, without exception:

> No exception to the second law of thermodynamics has ever been found

8 I. Prigogine and I. Stengers, 1984, *Order out of Chaos*, New York: Bantam Books, 12.

9 Prigogine and Stengers, 1984, 175-176.

10 P. Bak, 1996, *How Nature Works: The Science of Self-Organized Criticality*, New York: Springer-Verlag, 31.

> —not even a tiny one. Like conservation of energy (the "first law"), the existence of a law so precise and so independent of details of models must have a logical foundation that is independent of the fact that matter is composed of interacting particles.[11]

This comment is, of course, referring primarily to physics, but it is stated that the second law is "independent of details of models." In any case, practically all evolutionary biologists insist that all biological processes are explicable in terms of physics and chemistry alone. Therefore, biological processes also must operate in accordance with the laws of thermodynamics, and practically all biologists acknowledge this. The same, of course, applies to geological processes.

The incredible enigma is that mainstream biologists (and geologists) are unable to see that this insurmountable impasse is not due to difficulties with the second law of thermodynamics, but is rather a consequence of their assumption of universal evolution, for which there has never yet been offered even a shred of any genuine, experimental, laboratory proof! The evidences for speciation, including mutations and natural selection, are irrelevant, because there is no experimental or observational justification for extrapolating these processes as somehow proof of the macro-evolutionary changes required between the entirely different body plans of different phyla. These natural processes are themselves subject to increasing entropy, as mutations result from new combinations of the existing genetic information that can lead to degeneration. Natural selection also acts only on what is already present. Neither of these processes, therefore, leads to the greater order and complexity required by macro-evolution in the opposite direction to the overwhelming, universally demonstrated, downward influence of the second law of thermodynamics. This basic and absolute disharmony between the evolutionary model and the real-world scientific laws governing all natural processes cannot be disposed of simply by pointing to small systems that temporarily receive external stimuli retarding, or apparently reversing, their normal tendency toward deterioration. Any claimed circumstantial evidence will never overcome the almost infinite accumulation of improbabilities in the biological evolution model, which is nothing less than an absolute denial of the second law of thermodynamics, despite the fact that the second law has been always verified by observation and experimentation wherever tested.

Let it be emphasized again, lest there is a misunderstanding on this point, that there is no dispute over the fact that natural processes operating today do cause biological changes, which are patently obvious from observations and experiments. However, it is the quality and direction of these changes, which only result in conservation or deterioration, that emphatically rule out the postulated changes required by biological evolution theory, which are supposed to be progressing toward increasing order and complexity.

11 E. H. Lieb and J. Yngvason, 2000, A fresh look at entropy and the second law of thermodynamics, *Physics Today*, 53 (4): 32.

The creation of all living things (or what mainstream biologists imply by "evolution") was actually accomplished by means of creative processes that, according to the first, or conservation, law of thermodynamics, no longer operate. Indeed, rather than creative processes, what we observe in the world around us are the deteriorative processes of increasing entropy implicit in the second law of thermodynamics. Every living organism eventually dies, at which point the highly developed order of organisms is reduced to random and disorderly collections of molecules. Yet despite this being the universal experience of every living creature, including man, demonstrated by observation and experimentation of relentless overall deterioration, contemporary biologists insist that their model of biological evolution is a fact, despite the complete absence of any experimental evidence supporting it. Indeed, they simply assume evolution as the universal overriding principle of change in nature, despite all the evidence from observation and experimentation demonstrating the very opposite, that is, disorganization and deterioration. Simply stated, they refuse to accept God's emphatic statement that the creation of the world and its living creatures was accomplished by processes no longer in operation. In man's quest to explain the origin and operation of everything around him in the cosmos in terms of what he can comprehend and quantify, man refuses to acknowledge that there is a Creator to whom he is accountable. Therefore, he has to find an explanation for his origins that does not require a Creator. He even builds this exclusion of God into his definition of science.

Just how did the "curse" in Eden affect these principles of science? Some have suggested that the universal domination of overall increasing entropy must have been established as part of God's "curse" on the earth and the whole of the cosmos as a result of the entrance of sin (Genesis 3:17) and represents the "bondage of decay" to which the entire creation has been "subjected" by God (Romans 8:20-22). Death did indeed begin as a result of sin and the Curse. This is a fundamental truth of Scripture. However, the second law of thermodynamics is also fundamental to the proper functioning of almost every physical process, and it is difficult to conceive that it was not included, in some form, in God's original design of this creation. The thermodynamics of all systems, the metabolism of our bodies, and even the movement of heat from warm regions to colder ones, depend critically on the second law. But how did this law operate on these systems during a state of absolute perfection in the environment and in Adam and Eve? There may be no direct statement in the text of Scripture of God altering the physical laws governing His creation when He pronounced the Curse. However, it is clear from Scripture that life in Eden was conserved in an absolutely perfect manner. Then when the Curse came, decay, loss, and death ruled over all of creation.

It is important to remember that the real understanding of origins requires the testimony of an eyewitness who was present at the time the earth and its living creatures came into existence, and this has been provided in the divine revelation of the Genesis record. God in His greatness has provided this revelation to satisfy the inquisitiveness that He created in us. Yet men refuse to believe it and insist this record must be wrong, which in effect implies that God is a liar. It is no wonder that in denying reality, contemporary scientists ultimately face contradictions and irreconcilables in their reasoning! We must therefore approach the study of the origin of the universe, the earth, and all life on it, strictly from the perspective of the God-given biblical revelation, and emphatically not by a projection of present natural processes back into the past, and particularly not into these six days of the Creation Week. It is precisely this sort of illegitimate presumptions by scientists and philosophers that led to the theories of biological and geological evolution that are now regarded as fact, and to the various theological devices that have been conceived for harmonizing these theories with the biblical revelation. However, since God's revealed Word describes the creation of the universe, the world, and all living things, as taking place in six literal days, and since there apparently is no contextual basis for understanding these days in any sort of symbolic sense, it is an act of both faith and reason grounded in the authority and truth of God's Word to accept them literally, as real days.

Furthermore, while rejecting the assumption that present geological processes can be extrapolated back to the origin of the earth to explain how the earth formed and the timescale it formed in, God's use of creation processes during the Creation Week would nevertheless have left behind details now preserved in the geologic record. Since the geologic record of the Creation Week and Scripture must be completely compatible with one another, because God is the originator of both, then it is legitimate to carefully study the details preserved in the early part of the geologic record, and guided by Scripture to use those details to unravel the earth's early history. Because there was a progression through the six days in God's creative activities, the geologic record should reflect this. While the geologic evidence will never explain the creation processes that God used (our finite minds would never be able to grasp the activity of the infinite), geologic evidence is the product of those creation processes. It is, then, with great caution in total submission to the scriptural record, that the geologic record can give us clues to the history of the earth during the Creation Week, somewhat similar to how the rest of the geologic record must accurately reflect the rest of the earth's history, through the pre-Flood, Flood, and post-Flood eras.

78

The First Two Days

The First Day

Whatever scientists and philosophers may speculate in their many theories regarding the origin of the universe, the sun, and the solar system, the opening sentences of God's infallible and authoritative revelation states that, at the beginning of this first day of the Creation Week, God created the matter of the earth in empty space, with the earth's surface empty and uninhabited, but covered in water (Genesis 1:1-2). This was a once-for-all event, never repeated and not observed by man. Our only real knowledge of the mode of origin of the universe and the earth must be therefore by means of this divine revelation. Although secondary processes are not precluded by Scripture here, the most obvious meaning of the text would be that God instantaneously, by divine omnipotence, called space ("the heaven") into existence and the earth as a discrete entity within it. Perhaps the earth was even placed at the center of what was to become the universe, because the earth from God's perspective was to be the focal point of His creative activities and of His dealings with man through history. Similarly, Psalm 33:6 declares: "By the word of the LORD were the heavens made; and all the hosts of them by the breath of his mouth." Not only is this the most obvious meaning of these passages, but there is nothing whatever in science (as opposed to philosophical and scientific speculations) or theology to prevent us from accepting this obvious meaning simply as written under the direction of God's Spirit. Nevertheless, if this initial creation involved secondary processes, they would still have to have been in the category of creative processes, that is, processes involving the actual creation of matter and energy as well as processes, that put order and complexity into what was created. These would not have been the same processes we observe in operation today, which conserve matter and energy and are accompanied by deterioration and disorganization as the available energy is less able to accomplish work.

While it is impossible to deduce from present processes and their rates the manner in which the earth was originally created, we can most certainly ascertain the make-up and condition of this newly-created primeval earth because of the present structure of the earth and the earliest details in the geologic record. The majority of conservative Christian Old Testament scholars maintain that the biblical text can be understood to imply that in its original state on this first day, the earth was already rocky, even though the earth was not yet completed as far as God's ultimate purposes were concerned.[1] Indeed, Hebrew scholars are comfortable that the biblical text allows the earth at creation to be differentiated into core, mantle, and crust, with a rocky surface covered in water. There are also good scientific reasons for postulating that God differentiated the earth into core, mantle, and crust, much as it is today, right at the outset of the Creation Week. First, under any known natural conditions, core/mantle differentiation would destroy all evidence of life on earth completely. The current earth has a core/mantle/crust division according to the successively lower density of its components. If this differentiation had occurred by any natural means, the gravitational potential energy released by the heavier elements relocating to the earth's interior would produce enough heat to melt the earth's crust and vaporize the earth's oceans. If differentiation of the earth's elements did occur with its associated natural release of energy, it is therefore reasoned that it most certainly had to have occurred before the creation of organisms, at the latest on Day Three of the Creation Week. Second, even though such differentiation could have been performed by God without the "natural" release of gravitational potential energy, the already-differentiated earth's interior has subsequently provided a natural driving mechanism for the rapid tectonics (earth movements) that primarily occurred on Day Three of the Creation Week, and then during the Flood (to be described below).[2]

Of course, it is entirely reasonable based on the biblical record to just say that the core and mantle were simply created at the outset in essentially their present form. Perhaps these are the "foundations of the earth" about which the Bible often speaks (e.g., Jeremiah 31:37; Isaiah 48:13). It is of course questionable whether man will ever be able to observe directly the nature of these "foundations" in the earth's deep interior, although in the last few decades great strides have been made in understanding the probable make-up of the earth's interior based on carefully considered inferences drawn from both direct and indirect investigations. For example, seismic tomography has enabled the earth's interior to be imaged using the characteristics of seismic waves generated by earthquakes as these waves propagate through the earth. Moreover, large numbers of rock samples and minerals from deep within the earth's mantle have now been recovered from lava flows and from materials erupted onto the earth's surface by volcanoes, and these have carefully been tested and analyzed. Furthermore, it is known that volcanic rocks on the sea floor and on ocean islands were produced from magmas forced

1 J. C. Whitcomb, Jr., 1986, *The Early Earth*, revised edition, Grand Rapids, MI: Baker Book House, 39, 149; Whitcomb and Morris, 1961, 219-221; E. J. Young, 1964, *Studies in Genesis 1*, Philadelphia, PA: Presbyterian and Reformed Publishing Company, 34, 35, 91.

2 S. A. Austin, J. R. Baumgardner, D. R. Humphreys, A. A. Snelling, L. Vardiman and K. P. Wise, 1994, Catastrophic plate tectonics: a global Flood model of earth history, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 609-621.

from different levels deep within the earth's mantle. Therefore, they represent an important direct chemical profile of the earth's mantle. Detailed analyses of these rocks, especially their trace element and radioisotopic compositions, have provided a wealth of insight concerning the composition and differentiation of the earth into its core, mantle, and crust. In particular, these data have revealed that the earth seems to be made from the same recipe of higher melting temperature elements as those observed in the sun and in most meteorites, presenting a strong case for the earth to have undergone significant chemical differentiation during its earliest history, when segregation of much of the iron to the center of the earth formed the core. Furthermore, these chemical data strongly suggest that the earth's continental crust has been extracted via partial melting processes from the silicate-mineral-based mantle that remained after the metallic core had segregated. These partial melting processes also appear to have extracted and concentrated into the continental crust a large fraction of the mantle's incompatible elements, elements that are excluded from the normal crystal lattice structures of the minerals found in the mantle due to their large ionic radii and high ionic charges, and these include the major heat-producing radioactive elements.[3]

So just how realistic and robust is the evidence that the earth's major chemical/structural divisions, that is, its crust, mantle, and core, are the result of chemical differentiation processes very early in the earth's history? There are two basic features of the geochemical data that would seem to argue forcefully that a significant amount of chemical differentiation has indeed occurred during the earth's early history. These are the complementary abundances of the incompatible elements between the continental crust, and the mantle below that is depleted in these same elements, and the complementary abundances of siderophile elements (those that are readily soluble in molten iron, that is, they are "iron-loving") between the core and the mantle. The implications are very real, because the extraction of the core from an initially undifferentiated earth is not a trivial process that occurs in a few hours time, according to the physical processes we currently observe. Likewise, the chemical segregation of the continental crust via partial melting of mantle rock, assisted by the presence of water, also seems to require much more than a few hours time in the framework of presently observed physical laws.

However, this is precisely what we would expect to have happened during this first day of the Creation Week, where the Scriptures clearly indicate that God employed special means to accomplish changes such as these, by methods outside the physics we observe today, that is, by creative processes. The scientific data upon which our understanding of the earth's internal chemistry and structure is based, and the conjectures regarding the chemical differentiation to form the core, mantle, and crust internal structure, are all based on present-day observations and

3 J. R. Baumgardner, 2000, Distribution of radioactive isotopes in the earth, in *Radioisotopes and the Age of the Earth: a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 49-94.

analyses of rock and mineral samples, and seismic data, so that the basic conclusions drawn are not dependent on any interpretations of a great age for the earth, or the extrapolation of any known present-day processes. Thus, as already conceded, it is possible that after the initial creative act of bringing the earth into existence covered by water, that God then used secondary creative processes to bring about the chemical differentiation of the earth's interior through the remainder of that first day. Whether this chemical differentiation process was completed by the end of the first day we have no way of knowing. We can also only speculate as to which part and how much of the actual geologic record corresponds to God's creative activities on this first day, particularly as it has proven very difficult to locate and identify the very earliest scant fragments in the geologic record that belonged to this earliest period of earth history, which the conventional geologic community has called the Hadean. Of course, given all the geologic work that was accomplished by God in the remainder of the Creation Week, and then the massive geologic upheavals of the Flood (soon to be discussed), the earliest part of the geologic record would have subsequently been reworked, perhaps several times, so that it is no longer in the pristine state in which it was created. Thus, we have no way of knowing now what the initially created rocky materials would have looked like.

The only other detail we are given in the Scriptures of this first day is God's command for light to shine on the earth, to dispel the darkness that enshrouded the earth when He first created it (Genesis 1:3-5). This light could not have been from the sun, because the sun was not created until the fourth day, so we have no way of knowing for sure the nature of this light, except that it was a special provision of God at this time and instituted the day-night cycle and the literal day, just as we know and continue to experience today. We do not need to speculate the source of this light, as God does not need a source to provide light apart from Himself if He so chooses. After all, we are told in Revelation 21:23 and 22:15 that in the holy city of the new heaven and new earth, there will be no need for either the sun or moon and there will be no night there, because God Himself will provide the light of His glory through His Son, the Creator Jesus Christ. Since light would be considered the most basic and all-pervasive form of energy, its introduction to the surface of the earth might well have been the physical manifestation of God energizing the primordial earth that He had just created, so as to bring about this internal reorganization through chemical differentiation. However, what we can be certain about is that, despite the presence of light shining on the waters covering the earth's surface, there was no life within those waters to utilize the light energy, because God had not yet created any form of life. This also applies to those rocks forming in the earth's earliest crust as a result of the initiation of this chemical differentiation process, if that's how God created the earth's basic internal chemical/structural divisions. Because there were no life forms of any type, there would also not have been any bacteria or other life forms that today we find are able to live within the rocks deep within the earth's surface. Thus, any strata now found in the earliest part of the geologic record that contain fossils, or any evidence of life, cannot have been produced during this first day of the Creation Week era.

The Second Day

On the second day of the Creation Week, the waters covering the earth's surface were divided into two great reservoirs, by God commanding into existence a firmament (or "expanse") "in the midst of the waters" (Genesis 1:6-8). As we have mentioned previously, various lines of evidence suggest that the Hebrew word *raqia* translated "firmament" or "expanse" refers almost certainly to what we today call interstellar space, where God on Day Four created the sun, moon, and stars. If so, this means that a large mass of water that earlier deeply enveloped the earth was now separated from it by this expanse, a region God calls "heaven" in Genesis 1:8. The water that remained on the earth became the seas on Day Three.

If God initiated on the first day the secondary creative processes of chemical differentiation inside the earth, to chemically and structurally divide it into the core, mantle, and crust, then such processes would appear to have not only required the cycling of a large fraction of the mantle's silicate rock, via rapid thermal convection to very near the earth's surface (where two stages of partial melting plus interaction with the water covering the earth's surface could take place), but also a significant amount of accompanying radioisotopic "decay." (The use of the term "decay" is somewhat misleading, as it unfortunately gives the impression of imperfection in God's "very good" creation. A better, less emotive, descriptive term would be "transmutation.") The amount of convective circulation in the mantle involved with the extraction of the continental crust implies a vast amount of heat extraction from the earth's interior. Furthermore, it is the elements whose radioisotopes undergo transmutation that are among those elements that are incompatible with the mantle silicate minerals, and so have been partitioned into the earth's crust, particularly the continental crust where the nuclear transmutations generate further heat. The convective circulation in the mantle, of course, also provides the means for removal of the heat from this nuclear transmutation. Quite obviously, the heat from both chemical differentiation and nuclear transmutation would, by convective circulation in the mantle, be transferred to the earth's surface, where it would have come in contact with the water covering the earth's surface. Thus, it is conceivable that this rapid application of tremendous amounts of heat on a global scale to this surface water would have caused intense boiling of the water at the crust/water interface and rapid weathering of the earth's surface rocks.

Regarding the formation of the earth's atmosphere, it is also likely that, in addition to the convective circulation in the mantle bringing heat to the earth's surface, it would also have brought gases to be released above it and accumulate as the atmosphere. Today gases are added to the atmosphere from the earth's deep interior, primarily due to volcanic activity, which is also believed to be largely due to convective transfer of heat in the mantle. However, if God used this secondary creative process to put the atmosphere in place, the speed at which the gases were expelled from the earth's interior to accumulate as the atmosphere would have been incredibly rapid, as the whole task was completed in the biblical timeframe before the end of the second day.

In what are regarded as the earliest rocks found in the geologic record, there is abundant evidence for high temperatures within the earth. It is important to reiterate that, if God was using secondary creative processes to generate the chemical/structural divisions within the earth, then convective circulation in the mantle, partial melting, and magma generation would have occurred at rates many orders of magnitude faster than the rates of similar processes observed today. This would also have applied to other processes in operation contemporaneously, such as magma cooling, sedimentation, metamorphism, and nuclear transmutation. What are perceived to be the earliest known mineral grains are zircons from metamorphosed sandstone in Western Australia, whose radioisotopic ratios have been interpreted as "dating" these grains as being around 4.2 billion years old.[4] This is graphic testimony that, at this early stage of the earth's history only thousands of years ago, the radioisotopic transmutation rates were incredibly rapid as a result of the creative processes God was using to form the earth's crust, beginning on the first day and continuing into the second day of the Creation Week. It is also significant that zircons are among the earliest mineral grains detected in the geologic record, and that they are in a sedimentary rock, because this means they were eroded from an earlier crystalline rock. Such would have likely been a granitic rock, from a suite of granitic rocks that are almost unique to the earliest part of the geologic record, the so-called tonalite-trondhjemite-granodiorite (TTG) suite, with their geochemistry suggesting that they were produced by partial melting of a wet, mafic crust. That would be the composition expected for the earliest crust forming by extraction from the mantle by chemical differentiation.

The other dominant rock types in this earliest section of the geologic record, known as the Archean, are basaltic lavas with a very high and unusual Mg content called komatiites. These are again almost unique to the Archean section at the base of the geologic record, and all the evidence points to these being derived at very high temperatures deep within the earth's mantle, after which they were extruded onto the earth's surface as lavas at very high temperatures, much higher than experienced when normal basaltic lavas are extruded today. This is exactly what would be expected to have been happening at this very earliest stage of earth history, as a result of this convective circulation in the mantle moving heat to the earth's surface and establishing the earth's earliest crust.

4 D. O Froude, T. R. Ireland, P. D. Kinny, I. S. Williams, W. Compston, I. R. Williams and J. S. Myers, 1983, Ion microprobe identification of 4100-4200 Myr-old terrestrial zircons, *Nature*, 304: 616-618; R. Maas, P. D. Kinny, I. S. Williams, D. O. Froude and W. Compston, 1992, The earth's oldest known crust: a geochronological and geochemical study of 3900-4200 Ma old detrital zircons from Mt. Narryer and Jack Hills, Western Australia, *Geochimica et Cosmochimica Acta*, 56: 1281-1300.

Once these granitic rocks were intruded to near the earth's surface and were cooling rapidly along with these komatiite lava flows that were beginning to form the earth's earliest crust, contact with the water covering the earth's surface would have induced rapid chemical weathering and erosion, so that sediments began forming sedimentary rocks. It is no surprise, therefore, that we find also in the Archean geologic record, interbedded with komatiite and basaltic lavas, a variety of different sediment types, particularly volcanic tuffs and breccias that have resulted from explosive eruptions of more felsic (granitic-like) magmas, chemical sediments such as cherts, carbonates, banded-iron formations, unusual shales, "immature" sandstones, and conglomerates. In those Archean terranes exposed today, such as in Western Australia and Canada, these sedimentary rocks are found in wide linear belts of strata dominated by komatiites and basalts known as greenstone belts that surround large circular exposures of these TTG granitic rocks.

As well as magmas being expelled onto the earth's surface and intruded into its rapidly forming crust, massive amounts of hot water must likewise have been expelled from the earth's deep interior, carrying with it dissolved chemicals such as silica, carbonate, and iron, that then precipitated as the expelled hot waters mixed with the waters God had created covering the earth's surface. In so doing, these chemical sediments would have been rapidly formed. The heat being released as these granitic magmas intruded into these sediments and volcanics, crystallized, and cooled, would have metamorphosed the strata in contact with them, and the hydrothermal fluids from the cooling granitic magmas would have rapidly carried the heat away, resulting in metamorphism on a regional scale. It must be emphasized, though, that these were potential outworkings of God using secondary creative processes that He had initiated on the first day, and that continued through this second day, building the earth's early crust by geological processes that unfolded at rates many orders of magnitude higher than any similar conceivable geological processes today. As can be seen, these details are consistent with what are regarded as the earth's earliest rocks in the geologic record. It is worth noting that even mainstream geologists recognize that many of these rocks, as described here, are unique to this Archean section of the geologic record, meaning that we know of no geological process occurring today at today's rates that would have been capable of producing these rocks. Furthermore, the fact that the radioisotopic ratios found in these rocks are able to be interpreted in terms of "ages" of 3.5 to 4.0 billion years indicates that extremely rapid nuclear transmutations must have occurred to give these rocks such extraordinarily old apparent "ages."

By the end of the second day, the work of forming the earth's earliest crust by convective circulation within the mantle, which was being formed distinct from the core by chemical differentiation, would almost have been complete. At no point was God not in control, as He was fashioning the earth by His creative activity to prepare it for the next stages of His plans.

79

The Third Day

God's secondary creative geological processes now reached their climax and culmination in the early part of the third day. God's command, "Let the dry land appear" (Genesis 1:9), is interpreted by most conservative Christian Old Testament scholars as an unveiling of previously created crustal rock, suggesting that a continent (or continents) were uplifted on this third day out of the water that had previously covered the whole, rocky earth.[1] "The waters, which were still covering everything under the heavens, were to be concentrated in one place, and, as a result, the solid matter hidden beneath them would be revealed in the remaining areas."[2] To make the "dry land" appear from under the waters, heretofore covering the earth's surface, must have required earth movements on the scale of global tectonics at an extremely rapid or catastrophic rate. The earth's buoyant continental crust would have been gathered together in some parts of the earth's surface, while the complementary areas would have been swept clean of this continental material, so that the surface waters could in turn be gathered together in ocean basins to allow a dry land surface on a continent (or continents) to be exposed. If God was continuing to use secondary creative processes, then based on what we know of the early geologic record in the Archean, plus what we can infer about the global tectonic processes resulting from both the chemical differentiation of the earth's internal structure and the convective circulation in the mantle, there would have to have been an early form of plate tectonics at work, catastrophically resulting in what could termed the first great "orogeny" or mountain-building episode.

The reason continents sit on the earth's surface above sea level today is because they are composed of continental crust of an overall felsic (granitic or sialic) composition, compared to the denser oceanic crust of mafic (basaltic) composition. The denser oceanic crust sinks relative to the less dense continental crust, thus forming the ocean basins.[3] Just how this distinct horizontal differentiation of the

1 Whitcomb and Morris, 1961, 229-232; Young, 1964, 91; Whitcomb, 1986, 39.

2 U. Cassuto, 1978, *From Adam to Noah*, Part One, Jerusalem: Magnes Press, 34; See also H. C. Leupold, 1942, *Exposition of Genesis*, Columbus: T. Wartburg Press, 63-66.

3 Austin et al, 1994, 609-621.

early earth's crust into oceanic and continental crust might have been achieved is unclear. However, one possibility is that, as the chemical differentiation and mantle convection processes began, the first-formed crust globally around the earth's surface was entirely mafic oceanic crust, and then, as these processes continued, partial melting took place to generate lighter felsic magmas, which intruded that early-formed oceanic crust in some places to produce the buoyant TTG granitic plutons. Because of their buoyancy, these plutons would tend to clump together above the zones of downwelling of the large-scale mantle convection pattern. The initial continental crust would have begun to thicken in those areas and to rise relative to other areas where only denser mafic oceanic crust was present. This process of sections of the earth's crust adjusting in surface height according to their densities is known by geologists as *isostasy*, meaning "equal weights." It is now a well-known basic process in global tectonics that has even been enunciated in the Scriptures as a process the Creator used and put into operation: "[God] hath measured the waters in the hollow of his hand and metered out heaven with the span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance" (Isaiah 40:12).

Hence, there was almost certainly a significant component of horizontal tectonics at work in order to bring together and concentrate all the less dense felsic rock materials into the continental crust, relative to the denser mafic oceanic crust. Given the convective circulation in the mantle, driven by the heat generated from the chemical differentiation and nuclear transmutations occurring there, it is highly likely that there would have been some catastrophic form of what is now known as plate tectonics. This directly follows from the convective upwelling of heat in the mantle, which would cause partial melting to produce new oceanic crust where the upwelling met the earth's surface. Therefore, there could have been horizontal spreading of oceanic crust, which then pushed together those areas where granitic magmas had intruded. Both horizontal and vertical tectonics would have resulted, therefore, in distortion and buckling to bring together and concentrate the felsic rock materials into a less dense crust, to form the continent or continents that God had commanded to rise from under the globe-encircling waters on this third day. Any subduction of oceanic crust under this newly forming continental crust, as a result of these horizontal tectonic movements, would only have caused further partial melting of that subducted oceanic crust to produce new magmas, which intruded into, and extruded onto, the newly-forming continent (or continents).

This uplift, through the waters that then parted as land surfaces became exposed, would have resulted in an enormous amount of catastrophic erosion, which would of course result in the widespread deposition of thick sequences of sedimentary strata. Furthermore, accompanying the upwelling of magmas into both the oceanic and continental crusts would have been large amounts of hydrothermal fluids, which would have carried in solution incredible amounts of different chemicals. Thus, as the hydrothermal fluids came in contact with the cooler surface waters, the dissolved chemical species would have precipitated to produce chemical sediments, such as chert, carbonates (dolomites and limestones), and banded-iron formations, as well as metal ore deposits from the other metals carried in the fluids. Where the hydrothermal fluids intruded into the continental crust there would also have been a change in temperature, which would have triggered precipitation of dissolved chemical species and metals, again leading to the formation of metal ore deposits that would later prove valuable for man's use. There would also have been accompanying explosive volcanic eruptions from water and gases being released from the earth's interior, and this would have contributed large volumes of volcanic fragmental materials to the sedimentary rocks being deposited.

This scenario is not simply speculative, because the details match what is found in the geologic record, particularly in the Archean section of that record. A crucial marker point in this rock record, as we attempt to align it with the scriptural account, would be the first, and therefore earliest, record of fossilized former living organisms. It was only on this third day, after God had commanded the dry land to appear from under the waters, which were now gathered together in "one place," that God created the first life. He commanded the earth to "bring forth grass, herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself" (Genesis 1:11-12). Thus, the earliest fossilized evidence of living organisms would have to be plants, or plant-related organisms (as opposed to animals), and such fossilized remains would have to date to the middle and later part of this third day of the Creation Week era. This would correspond in the geologic record to after the tectonic upheavals, magmatism, sedimentation, and metamorphism responsible for building the continental crust that became the first continent (or continents). There is still some dispute in the conventional geological community over the validity of several claims of the fossilized evidence for the earliest life,[4] but there is general agreement that the structures known as stromatolites, first found in chert conventionally dated at almost 3.5 billion years old in the Pilbara region of Western Australia, were built by *cyanobacteria*.[5] These cyanobacteria are a form of blue-green algae, and they evidently built the

4 S. J. Mojzsis, G. Arrhenius, K. D. McKeegan, T. M. Harrison, A. P. Nutman and C. R. L. Friend, 1996, Evidence for life on Earth before 3800 million years ago, *Nature*, 384: 55-59; J. M. Hayes, 1996, The earliest memories of life on Earth, *Nature*, 384: 21-22; Y. Sano, K. Terada, Y. Takahashi and A. P. Nutman, 1999, Origin of life from apatite dating?, *Nature*, 400: 127; S. J. Mojzsis, T. M. Harrison, G. Arrhenius, K. D. McKeegan and M. Grove, 1999, Origin of life from apatite dating?, *Nature*, 400: 127-128; S. M. Awramik, J. W. Schopf and M. R. Walter, 1983, Filamentous fossil bacteria from the Archean of Western Australia, *Precambrian Research*, 20: 357-374; R. Buick, 1984, Carbonaceous filaments from North Pole, Western Australia: Are they fossil bacteria in Archean stromatolites?, *Precambrian Research*, 24: 157-172; J. W. Schopf, 1993, Microfossils of the early Archean Apex Chert: new evidence of the antiquity of life, *Science*, 260: 640-646; M. D. Brasier, O. R. Green, A. P. Jephcoat, A. K. Kleppe, M. J. Van Kranendonk, J. F. Lindsay, A. Steele and N. V. Grassinean, 2002, Questioning the evidence for earth's oldest fossils, *Nature*, 416: 76-81.

5 B. R. Lowe, 1980, Stromatolites 3400-Myr old from the Archean of Western Australia, *Nature*, 284: 441-443; M. R. Walter, R. Buick and J. S. R. Dunlop, 1980, Stromatolites 3400-3500 Myr old from the North Pole area, Western Australia, *Nature*, 284: 443-445; H. J. Hofmann, K. Grey, A. H. Hickman and R. I. Thorpe, 1999, Origin of 3.45Ga coniform stromatolites in Warrawoona Group, Western Australia, *Geological Society of America Bulletin*, 111 (8): 1256-1262.

stromatolite structures as a result of their mat-like growth at the sediment-water interface. Other undisputed fossilized stromatolites are also found in the Archean rock record, so the presence of these fossils is thus consistent with this portion of the Archean rock record being a result of God's creative activities in the middle and latter part of this third day of the Creation Week.

Such a correlation between the geologic and scriptural records does, though, raise one very critical question, namely, if the scriptural account specifies grasses, herbs, and fruit trees as having been created by God on this third day, then why are not these plants found fossilized this early in the rock record instead of just bacteria and stromatolites? The answer lies in recognizing that the fossils found at any level in the rock record only represent those creatures that were in environments and locations where they could be buried and fossilized. Many other creatures and organisms would likely have been alive at the same time, but in other areas of the earth's surface where they were not prone to burial and fossilization. If this is the case at other levels in the rock record, then it is likely to be the same here in the Archean rock record. Indeed, all the available evidence indicates that the stromatolite-growing cyanobacteria lived in hypersaline waters fed by hydrothermal springs, where chemical sediments were being precipitated and where sulfide ores were accumulating due to the volcanic activity that was producing the hydrothermal fluids.[6] The stromatolites and their cyanobacteria-builders thus lived in an environment where they were automatically prone to fossilization, due to the chemical sedimentation continually going on around them. The fact that stromatolites and these bacteria are among the major fossils of the Precambrian rock record, and then are virtually absent in Phanerozoic rocks and are rare today, suggests that these stromatolites were a significant part of an important late Creation Week/pre-Flood hydrothermal biome.[7]

Fossils of the plants created on the third day, and the creatures created later in the Creation Week, are not found preserved in the rock record that probably dates back to the Creation Week and early pre-Flood eras. This suggests that conditions on the land surface exposed by the tectonic upheavals in the early part of the third day were quite stable, and free from catastrophic destruction, by the time God created the grasses, herbs, fruit trees, and other plants later that day, and that these conditions remained stable and conducive for life for the remainder of the Creation Week and on into the pre-Flood era. Of course, one could argue that many fossils of other plants and creatures, which might have formed after the Creation Week, were subsequently destroyed by catastrophic erosion during

6 G. P. Glasby, 1998, Earliest life in the Archean: rapid dispersal of CO_2-utilizing bacteria from submarine hydrothermal vents, *Episodes*, 21 (4): 252-256; B. Rasmussen, 2000, Filamentous microfossils in a 3235-million-year-old volcanogenic massive sulphide deposit, *Nature*, 405: 676-679; E. G. Nisbet and N. H. Sleep, 2001, The habitat and nature of early life, *Nature*, 409: 1083-1091; Y. Shen, R. Buick and D. E. Canfield, 2001, Isotopic evidence for microbial sulphate reduction in the early Archaean era, *Nature*, 410: 77-81.

7 K. P. Wise, 2003, Hydrothermal biome: a pre-Flood environment, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 359-370.

the Flood, but this argument from the absence of evidence would seem to be discounted by the enormous thicknesses of sedimentary strata in the Precambrian rock record. The deposition of these strata would easily have been conducive for the fossilization of plants and animals if there had been catastrophes across the earth's surface capable of their destruction and burial.

Thus, once the land surface was exposed, God established stable conditions on it before creating all the plants upon it. First, there was the catastrophic tectonic upheaval that built the continental crust, which then rose from under the waters. There is the distinct possibility that there was just one supercontinent formed as a result, because it can be argued that since God commanded all the waters to be gathered together into one place to form the seas, then the land may also have been in one place. However, it may otherwise be argued that this expression "one place" may simply refer to the waters being gathered into the newly-formed ocean basins whose geographical distribution has not been stipulated, just as today's ocean waters could be argued as being in the one place, namely, the ocean basins that are in any case interconnected with one another. With the retreating of the globe-encircling waters from the emerging land surface of the newly-formed continental crust, there would have been enormous catastrophic erosion, and this event could be given the name "the Great Regression." Once the land surface was exposed, further erosion and sedimentation would have been confined to the continental shelf and slope areas adjoining the exposed continental land surface, and on the floors of the ocean basins.

As the land surfaces would likely have been saturated with water, the subsequent intense drying out would have initiated deep chemical weathering, so that very thick soil soon blanketed the entire land surface. This is not to suggest that God was somehow dependent on the natural rate at which such a drying out process occurs today, because this was still part of His creative activity. Therefore, these secondary creative processes would have been occurring at supernatural rates, outside of the operation of the laws of physics as we know them today. Once this thick, nutrient-rich soil was ready, then God covered it in all types of grasses, herbs, fruit trees, and other trees and plants. This would also have included all types of bacteria, in all types of environments and ecological niches, including those that live deep within the rocks below the earth's surface, and those in the hydrothermal biome responsible for building stromatolites in the warm hypersaline waters in shallow marginal seas adjacent to the continent or continents, and perhaps even where hydrothermal springs may have occurred within continental areas. These hydrothermal springs may well have been "the fountains of waters" referred to in Revelation 14:7 in connection with God also making "heaven, and earth, and the sea." Since these springs would be gushing hot waters, they may likewise have been responsible for the "mist from the earth" that "watered the whole face of the ground" (Genesis 2:6).

Thus, by the end of the third day, the chemical differentiation process of internally structuring the earth into core, mantle, and crust would have been completed, and the convective circulation in the mantle would have slowed. All the heat having been generated by these processes and by nuclear transmutations would have largely been released from inside the earth and dissipated from the earth's surface, so that conditions were now ideal for life on both the exposed land surface and in the oceans. There would now also be a distinct horizontal differentiation between oceanic and continental crust, very much as there is today. As well as being sialic (essentially on average granitic) in composition, the continental crust would also have been stabilized into a craton or cratons that would suffer little deformation through subsequent earth history. Thus, it is suggested here, the remnants of this Creation Week continental crust are found in the cratonic Archean shield areas still exposed at the earth's surface today in the continental nuclei (Figure 52, page 1088). Since much Archean sialic material still survives today, its existence by the middle of the Creation Week would have meant that it was then available for erosion and sedimentation in the pre-Flood era and beyond.

The existence today of low-density, low-temperature "keels" beneath these Archean cratons implies that they have persisted more or less in their present form since their differentiation in these first three days of the Creation Week.[8] This also suggests that little or no mantle convection has disturbed the upper mantle beneath these cratons since their formation. Furthermore, if these Archean cratons were sialic and the adjoining oceanic crust was mafic, then the buoyancy forces due to the density differences would provide a natural means of supporting the cratons above sea level, with isostatic adjustments thus producing the dry land on the continents on this third day. That the oceanic crust has always been mafic (basaltic) is suggested by ophiolites (containing pillow basalts and presumed ocean sediments), which are thought to represent pieces of ocean floor that were subsequently thrust up and accreted onto the continents, found in the Archean rock record.[9] Additionally, if the oceanic crust were mafic in contrast to a sialic continental crust, then the denser oceanic crust would sink as the continental crust rose, thus providing natural basins for the ocean waters to drain into, so that sea level would be lower than the exposed continental crust land surface. At the end of the third day this process of cratonizing continental crust would have been completed, so that it became stabilized, and the Great Regression would have completed its erosive leveling of that land surface. Residual erosion and sedimentation would still occur, though around the marine margins of the continent or continents. After drying out and deep chemical weathering to form a thick soil, all manner of plants had been created to vegetate the entire land surface.

Just exactly what level in the rock record represents the end of this third day can

8 P. H. Jordon, 1978, Composition and development of the continental tectosphere, *Nature*, 274: 544-548; Austin et al, 1994, 611.

9 T. M. Cusky, J-H. Li and R. D. Tucker, 2001, The Archean Dongwanzi ophiolite complex, North China craton: 2.505-billion-year-old oceanic crust and mantle, *Science*, 292: 1142-1145.

only be speculated, given that very few specifics are given in the scriptural account. Any strata containing indisputable fossilized bacteria and related microorganisms, as well as the stromatolites built by cyanobacteria mats, have to post-date the creation of plants in the latter part of this third day. This would make the Hadean and early Archean section of the rock record remnants of the earliest continental crust produced by God's creative processes during the early part of the Creation Week, up until He created the plants in the middle or latter part of this third day. The first undisputed fossilized bacteria and stromatolites are in strata of the Pilbara region of Western Australia, that are conventionally "dated" at 3.5 billion years old, so if there is any systematic correlation between such "dates" and the scriptural record (to be discussed later), then this point in the rock record would have to be placed in the middle or latter part of the third day of the Creation Week era.

It is also highly likely that the ramifications of God's creative activities to form and uplift the continental crust and produce the dry land surface did not cease as a result of the Great Regression, as it is likely that catastrophic geologic activity continued on through the remainder of the third day, and even through the rest of the Creation Week into the pre-Flood era. While the geological processes occurring at supernatural rates would have climaxed with the uplifting of the continental crust, formation of the ocean basins, and the Great Regression, the tempo of that activity would perhaps have continued to gradually decline in intensity and scope from the latter part of this third day onwards. This may then account for the middle and late Archean rock record, and some of the overlying Proterozoic, and such rocks would have to have been formed in areas adjacent to, but away from, the exposed vegetated land surfaces. The rock record seems to support this pattern, because most of the early Archean cratons are surrounded by middle-late Archean rocks accreted to them, and subsequently cratonized (Figure 52). Furthermore, in many instances these Archean cratons are surrounded by adjoining Proterozoic sedimentary basins, whose strata unmistakably overlie these Archean cratons at their margins. An excellent example of this is the Proterozoic sedimentary basins that are marginal to, and surround, the Pilbara Archean craton of Western Australia (Figure 53, page 1089). The original nature of these rocks early in the geologic record has been transformed by metamorphism, and their original extent has been modified by subsequent erosion, so how extensive they originally were, and the relationship of these original Archean cratons to one another, has been destroyed, perhaps even as early as the Great Regression during the third day of the Creation Week.

This scenario is also consistent with the presence in the middle-late Archean and early Proterozoic rock sequences of further volcanic rocks and lava flows, chemical sedimentary rocks such as carbonates, cherts, and banded-iron formations, and sedimentary rocks composed of volcanic fragments and normal detritus derived from erosion of land surfaces. It is conceivable that there would have been continued volcanic activity in the shallow ocean basins adjoining the exposed continent or continents, and hydrothermal springs would have continued to precipitate chemical sediments that were then deposited in alternation with lava flows, volcanic fragmental sediments, and detritus washed from margins of the nearby land surfaces. The presence of fossilized bacteria and stromatolites in these sequences testifies to their deposition and formation in the latter part of the third day of the Creation Week, after the plants and the bacteria were created.

80

The Fourth Day to the End of the Creation Week

During the remainder of the Creation Week following the close of the third day, the Bible is silent with respect to any ongoing geological processes as part of God's creative activities. However, it is possible to make some reasonable, logical speculations which are consistent with the details preserved in the geologic record. It is possible that marginal continental areas were still rising and surfaces being eroded prior to stabilization, soil formation, and growth of vegetation. Further volcanic activity and hydrothermal springs on continental shelves, and in shallow marine areas adjoining the continents, would have continued to release heat from inside the earth and chemicals to precipitate chemical sediments, such as the extensive and enormous banded-iron formations and associated cherts, as well as the carbonates with fossilized stromatolites, and the interbedded volcanics and other fragmental sediments. Such a strata sequence is seen in the early Proterozoic (Paleoproterozoic) Hamersley Basin of Western Australia, which is marginal to and overlies the Pilbara Archean craton. Some tectonic adjustments could well have continued through this period, particularly away from the exposed and vegetated land surfaces where such would not disturb God's continuing creation of other life forms.

During the fourth day, the focus of God's creative work was on providing the sun, moon, and stars to rule the day and the night, and to be for signs and seasons (Genesis 1:14-19). The light that God had provided for daylight on the first three days was now replaced with light from the sun. This provides significant evidence that these days of the Creation Week were literal, approximately 24-hour days, because the plants created on Day Three would only have endured approximately twelve hours of darkness (night) before the light of this fourth day dawned, and the daylight was then provided by the sun. However, if these were only figurative "days" that were in fact millions of years long, as proposed by those who advocate the day-age, progressive creation, and theistic evolution views, then the plants would have somehow had to have survived millions of years of darkness (the figurative "night") before the fourth figurative "day" dawned. Of course, the reality is that these views simply propose these figurative "days" to represent millions of years in which there were countless regular days, so that the plants had the benefit of the regular, more or less normal length, day-night cycle for millions of years before the next stage of God's "progressive creation," or instead "theistic evolution," activity. However, this only leads to further inconsistencies and complications. For example, the insects (whether they are categorized as "winged fowl" or "creeping things") were not created ("evolved") until either the fifth or sixth figurative "day," so this begs the question as to how the plants could have survived through the intervening millions of years without the insects available to pollinate them.

The truth is that the order of God's creative activities as outlined in the biblical text can in no way be made to fit the order described by both the progressive creation and theistic evolution views, which blindly follow the claimed order of development of the universe, the earth, and all life upon it as insisted by the conventional scientific community. Their version of earth history is largely atheistic, because assigning any of this "development" to the work of God in the scientific literature is ruled as inadmissible by all, and heretical by some. After all, the conventional scientific world insists that the sun was formed billions of years after the universe began, and the earth developed subsequent to the sun. This in no way can be reconciled with the order in the biblical record, where it is clearly stated that the earth was created at the beginning at the same time as the universe, and then the sun and the stars were created four days later. Thus, the day-age, progressive creation, and theistic evolution attempts to unify the Scriptures and conventional science, by insisting the two are really telling us the same "story," are merely wishful thinking. Such attempts to marry the Scriptures and conventional science can only lead to compromises that do violence to the Scriptures or conventional science, or both, because how "can two walk together, except they be agreed?" (Amos 3:3). The tragedy is that when faced with being unable to reconcile the order in the Genesis record with the order insisted upon by the conventional scientific community of astronomers, geologists, and biologists, the proponents of these alternative views end up compromising by "trashing" the text of Scripture, bending or "reinterpreting" it to make it fit what the conventional scientific community insists is "fact." However, it is insisted here that the Genesis record is the infallible account of the early history of the earth and the universe provided by the Creator Himself, who was there at creation and who cannot lie. Therefore, the interpretations of the fallible, finite conventional scientists, who were not there, must be questioned if they conflict with the scriptural account. Furthermore, it is here maintained that the data, as opposed to conventional scientific interpretations, are not in conflict with the details given in the Scriptures.

Thus, substantial, wide-scale geologic activity could have continued at catastrophic supernatural rates right through this fourth day, marginal to the vegetated continent (or continents) on the surrounding continental shelves and in the shallow ocean basins. There would have been no problems engendered by the large areas where the marine environment was rendered hypersaline and/or toxic by the enormous quantities of chemicals issuing into them from the hydrothermal springs and volcanic activity that produced the interbedded chemical sediments, lavas, and volcanic fragmental sediments, because no marine creatures had yet been created. This is confirmed by the absence of fossilized marine creatures in these strata. Neither the heating locally of the ocean waters by the hydrothermal springs and volcanic activity, nor the turbulent water filled with choking sediments washed by erosion from the continental margins, would have killed off marine creatures or then have potentially buried and fossilized them.

However, these considerations imply that the scale of these secondary creative processes must have became greatly reduced by the dawn of the fifth day, when "God created great whales and every living creature that moveth, which the waters brought forth abundantly, after their kind" (Genesis 1:21). The fact that the text insists that there was no animal death and bloodshed prior to the Fall in God's very good creation clearly implies that no marine creatures were buried and fossilized by geologic activity during this fifth day and the remainder of the Creation Week. In contrast, in God's reckoning plants don't "die" in the same way as animals do, and the plants were created for food that was eaten prior to the Fall, so the fossilization of plants (bacteria and stromatolites) is allowed by Genesis during the Creation Week.

Also created on the fifth day was "every winged fowl after his kind" "that may fly above the earth in the open firmament of heaven" (Genesis 1:21, 20). Then on the sixth day, God created "the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind," followed by the creation of man in His image (Genesis 1:25, 27). Thus, during these fifth and sixth days, no geologic activity could have occurred to violently disturb the atmosphere or the land surface to kill and bury any birds or land creatures. Thus, for example, any violent volcanism and/or catastrophic flooding and erosion on the land surface are ruled out. As on the third and fourth days, on these fifth and sixth days, God declared both His creative activities and the products of them to be "good" (Genesis 1:10, 18, 21, 25, 31), clearly implying that nothing had occurred during these Creation Week days that was inconsistent with God's standards of perfection.

Just what portion of the geologic record corresponds to the Creation Week era is open to reasonable, logical speculation, based on the implications of the data of the rock record in accordance with the biblical account. The latter, though, does not provide the required specific geological details. Nevertheless, it is imperative to emphasize that just because continued secondary geological creative processes are not specifically mentioned in the Genesis account for the fourth through the sixth day, that does not mean that such were not occurring. Indeed, it is not until the end of the sixth day, and the dawning of the seventh day, that the biblical text stipulates God's declaration that "the heavens and the earth were finished," because God had "ended his work which he had made" so He "rested from all his work which God had created and made" (Genesis 2:1-3). Thus, if Scripture does not specifically discount the possibility of continued creative geological processes during the latter half of the Creation Week, then we may speculate that such secondary geological creative processes could have continued right through this period, but would have done so at supernaturally-directed and catastrophic rates. This means that the data of the geologic record corresponding to this second half of the Creation Week must not be viewed in terms of today's slow-and-gradual rates of geologic processes. Indeed, today's imperceptively slow geologic processes would conceivably have taken hundreds of millions, and even billions, of years to accomplish what God's secondary creative geologic processes would have achieved in just these few days of the Creation Week.

So just what can we glean from the data of the geologic record? First, it has already been noted (Figure 15, page 446) that the granitic rocks in the Archean belong to the tonalite-trondhjemite-granodiorite (TTG) suite, and these are significantly different geochemically and mineralogically from post-Archean TTGs, which are in contrast calc-alkaline and predominantly granite-granodiorite. Second, Archean greenstone belts are characterized by the presence of komatiites, and the volume of basalt plus komatiite exceeds that of intermediate plus felsic volcanics, whereas on the whole, Proterozoic greenstones have smaller proportions of basalt (and usually no komatiite), and range from 20 to 50 percent felsic volcanics plus andesite. Also of significance is the evidence that the lavas in Archean greenstone belts have been erupted chiefly as submarine flows in deep water, whereas a great proportion of post-Archean greenstone belt volcanics would seem to have been erupted in shallow water. These observations alone would suggest a fundamental change in the nature and style of the operating geologic processes, as well as significant changes on the earth's surface and in the mantle, perhaps related to a change in the convective circulation there. Because the first genuine fossilized stromatolites and bacteria are also found in these Archean strata sequences, it seems evident that the formation of these Archean cratons has to have been the work of the third day of the Creation Week, with the transition into the Proterozoic strata sequences marking the transition into the fourth day. At this point in the late Archean rock record, there is evidence of rapid growth of new continental crust, in conjunction with many intrusions of granitoids during the development, metamorphism, and cratonization of surrounding greenstone belts (Figure 13, page 445). This period also coincided with the formation of many volcanic-hosted metal sulfide ore deposits, gold/base metal veins, Kambalda-type nickel sulfide deposits, and massive gold and uranium-bearing conglomerates (see Figure 26, pages 452-453). There was also a pronounced rapid increase in the development of banded-iron formations, climaxing at the beginning of the Proterozoic with the formation of the giant, iron-rich, banded-iron formations of the Hamersley Basin of Western Australia, the Transvaal Group of South Africa, and in the Lake Superior region of the United States (see Figure 10, page 444). This reflects the coincidence of the generation of copious quantities of hydrothermal fluids that then deposited these enormous quantities of chemical sediments, with the peak in granitoid magmatism, volcanism, and the formation of volcanic-related metal ore deposits, plus the generation of new continental crust that continued to be eroded, exposed, and vegetated in the closing stages of the third day. Thus, the end of the third day and the beginning of the fourth day may arbitrarily be placed at the Archean/Proterozoic boundary in the geologic record, conventionally dated at around 2.5 billion years ago.

It is in the Proterozoic rock record that algal mats and their stromatolite structures are found fossilized in increased numbers and complexity (see Figure 20, page 349), which reflects the importance of this hydrothermal biome in conjunction with the hydrothermal springs that were producing copious quantities of chemical sediments in the shallow waters of the continental shelves, and in the marine basins adjoining the continent (or continents) that had been produced on the third day. During the fourth day there were still no creatures living with the plants anywhere on the earth's surface, in its atmosphere, or in the oceans, so vigorous volcanic, magmatic, hydrothermal, and sedimentation activity on the continental shelves and in the ocean basins could have continued through the fourth day. However, they would need to have come to an end by the fifth day, when God created the marine creatures. Figure 10 indicates that there was a dramatic decrease in the generation of banded-iron formations, and thus the hydrothermal activity responsible for them, in the latter part of the early Proterozoic (Paleoproterozoic) rock sequence, at a level conventionally "dated" at around 1.7-1.8 billion years ago. This level in turn corresponds to another peak in the generation and intrusion of granitoids into contemporaneously extruded volcanics and deposited sediments in further greenstone belts, that were consequently metamorphosed and cratonized as new continental crust (see Figure 13). However, the volume of activity and strata produced by these secondary creative geologic activities was not as large at the close of this fourth day as in the latter part of the third day. This is consistent with the inference from the biblical record that the third day was the climax in these secondary creative activities, which would then have begun to wane progressively during the second half of the Creation Week.

Even though there was a rapid decline in hydrothermal activity producing banded-iron formations, other volcanic activity at this time was still responsible for further development of volcanic-hosted metal sulfide ore deposits, while hydrothermal fluids began depositing metal sulfides in the thick sedimentary strata sequences that had resulted from the continued erosion and sedimentation adjacent to the continental margins. Thus, it may be possible to place the end of the fourth day at the level in the geologic record marked by the end of the Paleoproterozoic, perhaps even at the level conventionally dated at 1.6 billion years ago. Of course, it needs to be emphasized that these are not here regarded as "absolute ages," these quoted conventional figures having been produced by accelerated nuclear transmutations, coupled with inheritance from mantle sources and consequent contamination/mixing (to be discussed in detail later).

From this level upwards in the geologic record, there is a continued marked decrease in the formation of new continental crust, and in the generation and intrusion of granitoid magmas, compared with the volume produced at the closing stages of the third and fourth days (see Figure 13). There seems to have been almost a complete cessation of secondary creative geologic processes in the lower part of the middle Proterozoic (Mesoproterozoic) rock record, possibly coinciding with the commencement of the fifth day when marine and flying creatures were created. However, hydrothermal activity must have continued, with increasing fossilization of the algae and stromatolites of the hydrothermal biome in the carbonate sediments precipitated from the hydrothermal springs, while at depths within the crust the hydrothermal fluids precipitated uranium deposits, with or without gold and platinum group elements, and copper sulfides were precipitated with associated uranium, gold, and rare earth elements in an iron-oxide matrix within brecciated granitic rocks to form Olympic Dam-type ore deposits (see Figure 26). Circulating hydrothermal fluids also continued to precipitate metal sulfide ore deposits within the fragmental sediments being deposited. There had also been a change in the type of chemical sediments being deposited, with virtually no more precipitation of banded-iron formations, but manganese-rich sediments, which had begun to be deposited in Paleoproterozoic rock sequences, continued being deposited in the Mesoproterozoic strata record.

There seems to be no obvious feature (or features) in the subsequent Mesoproterozoic rock record that might indicate the boundary between the fifth and sixth days. However, this is not unreasonable, given that once set in motion, these secondary creative geologic processes would just have continued producing the rock record as they progressively waned during these closing days of the Creation Week. The focus of God's primary creative activity was on the creation of all manner of marine and flying creatures on the fifth day, and then all manner of land creatures and man on the sixth day. So long as these secondary creative geologic processes were not bringing death and destruction to the creatures God was creating and placing in the ocean waters, in the atmosphere, and on the land surfaces, they would have been allowed to continue their work of building and shaping the earth's crust, and furnishing it with the rock and mineral resources man would need to use in exercising the dominion over the earth that God was to give him. Perhaps it might be easier to identify the level in the rock record where the sixth day, and thus the Creation Week era, ends, because that is where all of God's creative activities ceased, and where supernaturally directed process rates operating outside of today's God-ordained physical laws also ceased. From this time onwards the pre-Flood era began, in which God's involvement in His creation was one of conservation, using the physical laws He had built into His creation. Thus, geological and other processes then simply continued according to those physical laws, more or less at today's "natural" process rates as recognizable today. Because the products of the Creation Week processes appear to be exactly comparable to the products of today's "natural" geologic processes, there would have been continuity across this Creation Week/pre-Flood boundary between these respective geologic processes. However, there could still be features in the rock record that would indicate at which level this Creation Week/pre-Flood boundary occurs.

The first clues are probably found in the fossil record. Figure 20 shows that fossilized stromatolites increased in numbers and complexity through the Paleoproterozoic and Mesoproterozoic, to reach their peak in relative diversity at the level in the geologic record that is conventionally "dated" at about 1.2 billion years ago, after which there was a rapid decrease in their fossilization in Neoproterozoic rock sequences. It is conceivable that because there were such prodigious volumes of hydrothermal fluids being discharged through springs onto the shallow continental shelves and ocean floors, with large quantities of carbonates being precipitated in the latter part of the Creation Week, these conditions were ideal for both the rapid growth and diversification of the stromatolite-building cyanobacterial and microbial mats, and for their rapid burial and fossilization. With the close of the Creation Week and the waning of the supernaturally-directed rate of discharge of these hydrothermal springs, and precipitation of carbonate sediments, into the God-ordained "natural" rate of these same processes, it is also conceivable that there was a decline in the growth, diversification, and fossilization of the stromatolites, and their cyanobacterial and microbial builders. These considerations would thus suggest that the level in the rock record that might represent the boundary between the strata of the Creation Week era and those formed during the pre-Flood era might coincide with where this distinct change in fossilized stromatolite abundance occurs, which is conventionally "dated" at approximately 1.2 billion years ago, near the end of the Mesoproterozoic geologic record. This is the same level above which fossils of multicellular algae begin appearing in the rock record (see Figure 21, page 350), but is still well below where worm-like megafossils, and subsequently the fossilized Ediacaran fauna, are found.

Another clue that is consistent with this choice for the Creation Week/pre-Flood boundary is that this level in the upper Mesoproterozoic rock record is where sedimentary phosphate rock units start appearing in strata sequences. This is a significant change that strongly suggests a change in geologic processes, and in ocean water chemistry due to the supply of nutrients to the ocean basins (see Figure 11, page 445). This might perhaps be explained by the life cycles of marine creatures becoming established, as they flourished in the pre-Flood seas, their deaths contributing their remains to the ocean waters and the sediments accumulating on the ocean floors. Otherwise, at this same level in the upper part of the Mesoproterozoic rock record, there is another, but much smaller, peak in the number of granitic magmas generated and intruded, but interestingly, this does not coincide with any major generation of new continental crust (Figure 13). This implies that these secondary creative geologic processes were rapidly diminishing and waning, which is exactly what would be expected at the close of the sixth day and the Creation Week. Thus, on balance, the end of the Creation Week might possibly coincide in the geologic record with the top of the Mesoproterozoic rock sequences, which have been conventionally "dated" at around 1 billion years ago.

81

Creation of "Appearance of Age"

This attempt at reconciling the details preserved in the geologic record with the scriptural account of the creation of the earth, the land, the vegetation, all the animals and man, during the six days of the Creation Week, is at best very sketchy and somewhat tentative. Despite the wealth of data now available on the large volume of rocks that make up the Archean and Proterozoic strata sequences, there are still a lot of unknowns and puzzles in deciphering what these strata sequences and rock units mean in terms of the earth's early history, with the relationships between strata and strata sequences often being determined by reliance on radioisotopic dating. On the other hand, we are given so few details in the Genesis record of the Creation Week that it is difficult to be any more than very tentative about these correlations with the early geologic record. All we have are some guidelines that constrain these tentative correlations, which will likely remain tentative, even as advances continue to be made in unraveling the geologic details of the Archean and Proterozoic rock record, and their apparent implications for the earth's early history.

However, there is one extremely important implication that remains very significant. The scriptural account of God's creative activities in the six days of the Creation Week unmistakably describes the results of God's creative work on each day as fully-functioning, complete, and pronounced "good" by God Himself. From a human perspective, even though there is a hint of progressive processes involved, at each stage God created what to us would be termed a mature creation, with an appearance of age in terms of our understanding and experience. This is a fundamental principle clearly implied in the Genesis record, which is of paramount importance in applying the scriptural account to the rock record. This principle is a direct consequence of God accomplishing by creation in an instant of time, as now measured in our human existence, what our experience today suggests would take years, decades, and even perhaps millions of years, to be accomplished by today's "natural" processes operating over such timescales. Expressed another way, the earth, the land, the vegetation, and all the animals and man, were created virtually instantly with the appearance of a long history, as we would perceive it, that did not occur over such human-measured timescales, and which in fact did not at all occur as such. As this concept may be difficult to grasp, or may seem far-fetched, and perhaps even straining the biblical text, some illustrations and elaborations will help.

In John 1:1-3, Jesus is identified as in very nature and essence both truly God and the Creator of all things. Even in human flesh He never ceased to be God (John 1:14), or the Creator. The miracles He performed testified to this. Indeed, His very first miracle, recorded in John 2:1-11, was the creation of wine from water at the marriage feast in Cana. Jesus told those serving at the feast to fill six "water pots of stone" with water, and then draw from them a sample of the created wine for the master of the feast to taste. The master's response was that it seemed to be the best quality wine that had been served during the whole of the feast, and he declared that to the bridegroom, without inquiring of the servants as to where the wine had come from. He, of course, assumed that because of the quality of this wine it was of natural origin, having come from grapes that had been grown on vines, nurtured by soil and water, and then crushed to extract the juice, which was then stored to ferment and mature, a process well known in human experience that required years for the best wines to be produced. However, only minutes before being served to the master of the feast this wine had been water, and Jesus the Creator had performed this transformation within a split second, without any hint of how He did it. Note that this had to be a miracle of creation, because whereas there were only water molecules to begin with, a split second later there were now more complex molecules, also containing carbon atoms when carbon atoms had not been present before. The product of Jesus' creative miracle was a wine with the "appearance of age," and of a history as measured in human terms. Note that there was no deception here, because the master of the feast, even though he didn't see the miracle take place, could have asked the attendants who served the wine to him as to where the wine came from, and they as the eyewitnesses of Jesus' miracle could readily have told him. There is no hint whatsoever of any deception on the part of Jesus, who quite openly instructed the attendants, who in obeying His instructions witnessed the water pots being filled with water, and then the serving of the wine minutes later to the master of the feast. In doing so, they witnessed the transformation.

The parallels to God's miracles of creation during the Creation Week as recorded in Genesis should now be obvious. For example, when God created the plants on the third day, certain absolutely necessary environmental components had to be put in place, so that once created the plants would continue to grow—soil, water, light, chemical nutrients, etc. Whereas the biblical text mentions the creation of water and light on the first day, no details are provided as to the provision of the soil and its contained chemical nutrients, so we can only surmise that the provision of soil is implied when God made the dry land appear, in readiness for the land surface to be vegetated, all on the third day. Yet in our human experience soil requires a long period of development before being able to support plant growth. However, here in the Genesis record, the creation of the soil on the newly exposed land surface must have been virtually instantaneous, yet from God's perspective this is not even significant enough to rate a specific mention! Whether God created the soil instantaneously, or used secondary creative processes of chemical weathering at supernaturally accelerated rates, we are not told, except that the end result was a land surface blanketed by thick, nutrient-rich soil with an appearance of being "old," when it was still just new. It was created with an "appearance" of age, without having gradually developed over centuries of chemical weathering of bedrocks, alluvial deposition, etc. Furthermore, there is no deception on God's part in creating new soil that from a human perspective looked "old," because as the eyewitness present when He created the soil, God has told us the timeframe in which the creation of this soil took place.

The same is also true with respect to the plants that were subsequently created on the third day. The biblical account states that after God issued the command, "the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind" (Genesis 1:12). The implication is that all these plants were created instantly. Furthermore, these plants included mature fruit trees already yielding fruit. Similarly, the fish and birds were created on the fifth day, and the land animals, insects, and man were created on the sixth day, each "full grown" and placed in environments already perfectly suited to them. This rapid, almost instantaneous, attainment of maturity is simply stated as implicit in the text of Scripture. Special emphasis and some more details are provided in the case of the first man, who is said to have been directly formed by God out of the same elements ("the dust") as are found in the earth (Genesis 2:7), but was then endued with the breath of life. Then the first woman was fashioned by God out of man's side (Genesis 2:21-22).

Without doubt, this clear implication of a "mature creation" with an "appearance of age" is a tremendously significant truth that cannot be overemphasized. Many details about how God created, and further descriptions of what was created, are not given to us in the Genesis record, because finite humans, locked into our space-time existence locally on the surface of planet earth, cannot possibly comprehend the infinite Creator God who exists in eternity outside of the entire universe that He created. However, God considers that He has revealed enough for us to accept, and know beyond any doubt, that at the end of these six days the creation of "heaven and earth, the sea, and all that in them is" was complete and perfect, being "very good" in God's assessment (Genesis 1:31). Everything was in harmony, with each of God's creatures fully grown and placed in environments perfectly suited to them, with interlocking relationships. Thus, for example, there had to be fully-grown grasses and fruit trees bearing fruit at the end of the third day, so that flying creatures created on the fifth day, and the land animals and man on the sixth day, would have food to eat. Furthermore, to emphasize that the first man, Adam, was fully mature and intelligent, rather than a baby who still had to grow and develop, we are told that after he was placed in the Garden of Eden, he "gave names to all cattle, and to the fowl of the air, and to every beast of the field" there within less than a few hours, before God created Eve from his side (Genesis

2:20). Adam was thus created with the full capacity to speak a language and to think, as well as to have dominion over the creation and maintain the Garden of Eden, right from the very time he was created on the sixth day.[1]

However, simple acceptance of genuine creation by the all-powerful, infinite Creator God of the Bible, as revealed in the person of His Son Jesus Christ, has not only become extremely difficult for modern man in general, but is anathema to the scientific intelligencia of our day. Of course, this is not just simply a rejection of genuine creation, but of the Creator Himself, who is deemed irrelevant and unnecessary, because modern science now claims to be able to explain the origin of the universe, the earth, and all life on it by so-called natural processes. Evolutionary theories are not just a phenomenon of the modern era, because even in ancient times, philosophers were continually devising varied and sundry schemes of evolution to explain how the world might have gradually developed from primeval chaos into its present state of high organization and complexity. Such evolutionary theories may perhaps reflect faintly the actual creation revelation recorded in the Scriptures, according to which God in six days did build up the universe from an initial formless state into a primeval order of high perfection. However, the great error made by scientists and philosophers in the last 200 to 300 years has been the refusal to recognize that this original creation was completed at the end of the sixth day of the Creation Week, and that modern natural processes are not the continuation of the processes God used in creation.

Modern man generally rebels at any suggestion of an original complete creation, desiring instead to push the divine Creator as far back in time as possible, so as to conceive Him as being as little concerned as possible with, and even irrelevant to, His creation. Any concept of a creation and a Creator, in any vital sense of the words, is assiduously avoided and vehemently opposed in all scientific literature, apart from very rare exceptions in some very recent scientific literature allowing the promotion of New Age, pantheistic "mother earth," or Gaia hypotheses. Geological evolution over billions of years is proclaimed as the explanation for the origin and formation of the earth, its rock strata, and its landscapes, while biological evolution is all but universally accepted today as the sufficient explanation for the origin and formation of all living organisms, including men, as well as the evolution of life itself from inorganic compounds. The most absurd improbabilities have been considered more probable than the alternative of real

1 These details, which are clearly explicit in the Genesis account of a mature creation with an appearance of age, have led to questions on non-consequential issues that we can merely speculate about when searching for answers. For example, some might ask whether because the trees were created fully mature and fruit-bearing on the third day, did they then have growth rings? Similarly, did Adam and Eve have navels? We are, of course, not told, so we are left to speculate. Logically the answer in both instances would likely be "no," because on the one hand the trees did not take years to grow (growth rings generally correlating with the seasons of the year), and on the other hand, Adam and Eve did not come into existence as babies birthed from a mother's womb, where they would have required umbilical cords. These answers would seem to be correct and logical implications of what we are given in the biblical text, and yet they are not specifically stated there. Thus, these are inconsequential issues where the answers are not really important, one way or the other.

creation. For example, a former professor of biology at Harvard University, when discussing the extreme complexity of even the simplest living organisms, and the almost infinite improbability that such systems could ever arise spontaneously from living systems, still confessed:

> One has only to contemplate the magnitude of this task to concede that the spontaneous generation of a living organism is impossible. Yet here we are—as a result, I believe, of spontaneous generation.[2]

This Harvard biology professor, only a few paragraphs before making the above quoted statement, had admitted that the only alternative to belief in spontaneous generation was "to believe in a single, primary act of supernatural creation," which he admitted most modern biologists are unwilling to accept. Yet, in spite of decades of research, in conjunction with many hopeful experiments, the impossible improbabilities remain:

> The chance that higher life forms might have emerged in this way is comparable with the chance that "a tornado sweeping through a junkyard might assemble a Boeing 747 from the materials therein."[3]

So how have biochemists and other scientists today, researching how life may have spontaneously evolved, overcome these probabilities? In summary, they have faith in the ability of inanimate molecules to generate life:

> Most researchers agree with Hoyle on this point (although on little else). The one belief almost everyone shares is that matter quickened through a succession of steps, none of which is widely improbable.[4]

Furthermore, their faith position has become essential, because even ingenious experiments have not demonstrated how life could have begun:

> The full details of how the RNA world, and life, emerged may not be revealed in the near future. Nevertheless, as chemists, biochemists and molecular biologists co-operate on ever more ingenious experiments, they are sure to fill in many missing parts of the puzzle.[5]

Such is the confidence of modern scientists in their own abilities, that they believe it is only a matter of time doing more experiments before they will then eventually be able to work out how life began, and so "create" themselves. As a consequence,

---

2 G. Wald, 1954, The origin of life, *Scientific American*, 191 (2): 47.

3 The late Sir Fred Hoyle, Professor of Astronomy at Cambridge University, England, as quoted in Hoyle on evolution, 1981, *Nature*, 294: 105.

4 J. Horgan, 1991, In the beginning…, *Scientific American*, 264 (2): 102.

5 L. E. Orgel, 1994, The origin of life on the earth, *Scientific American*, 271 (4): 61.

they proudly denounce those Christians who maintain that it was God who created life, and God alone who can create it:

> The debate about life's origins has deep resonance in our society. Those who work in this field frequently find their search challenged in assaults on empirical natural science. Judeo-Christian thought must accept convincing evidence from nature: denial is both destructive of faith and dangerous to science. To find the fragments of fact, and to attempt to understand them, is a powerful response to the creationist heresy. Not only fact and honest interpretation, but also orthodox theological argument reject creationism.[6]

The modern scientific intelligensia arrogantly asserts, and has convinced most in society, that nature "created" itself, all of which seems to be a sad but up-to-date commentary on a well-known biblical passage, describing man and his drift into polytheistic pantheism:

> For the invisible things of him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead; so that they are without excuse: Because that, when they knew God, they glorified him not as God, neither were thankful; but became vain in their imaginations, and their foolish heart was darkened. Professing themselves to be wise, they became fools, and changed the glory of the uncorruptible God into an image made like to corruptible man, and to birds, and fourfooted beasts, and creeping things. (Romans 1:20-23)

6 E. G. Nisbet and N. H. Sleep, 2001, The habitat and nature of early life, *Nature*, 409: 1090.

82

Cosmological Evolution and the "Big Bang"

The evolutionary philosophy does not only purport to explain the origin of life and the development of living organisms. The denial of true creation extends into the inorganic realm, encompassing the origin of stars and galaxies, and even eventually all the elements that make up the physical universe. In the last fifty years, there have been two competing cosmologies vying to successfully explain the origin of the universe and the matter in it—the so-called "steady-state" and "big bang" cosmologies.

The first of these, the steady-state cosmology, obtained a large following among scientists and philosophers when first proposed fifty years ago. Carrying the principle of uniformitarianism to its ultimate extreme, this theory was often called (really a misnomer) the "continuous creation" theory, because its key feature was the concept of the continual evolution (not creation in the real biblical sense) of matter out of nothing, at many places at the same time in the vast universe! The philosophy of this theory has been described in the following terms:

> This idea requires atoms to appear in the Universe continually instead of being created explosively at some definite time in the past. There is an important contrast here. An explosive creation of the Universe is not subject to analysis. It is something that must be impressed by an arbitrary fiat. In the case of the continuous origin of matter on the other hand the creation must obey a definite law, a law that has just the same sort of logical status as the laws of gravitation, of nuclear physics, of electricity and magnetism.[1]

The extreme uniformitarianism of this theory is even more evident in the statement:

> The old queries about the beginning and end of the universe are dealt with in a surprising manner—by saying that they are meaningless, for the reason that the Universe did not have a beginning and it will not

1 F. Hoyle, 1955, *Frontiers of Astronomy*, New York: Harper's, 317-318.

> have an end.[2]

It is obvious that the concept of a Creator God and a real creation have no place in this interpretation of the universe. It is also obvious that the basic reason for replacing the concept of creation with that of an eternal "steady-state" is not scientific at all, but purely the desire to conform all things in the universe to man's understanding in terms of present physical processes. This has been perceptively noted:

> So far as I can judge, the authors of this new cosmology are primarily concerned about the great difficulty that must face all systems that contemplate a changing universe—namely, how can we conceive it to have begun? They are not content to leave this question unanswered until further knowledge comes; all problems must be solved now. Nor, for some reason, are they content to suppose that at some period in the distance past something happened that does not continually happen now. It seems to them better to suppose that there was no beginning and will be no ending to the material universe, and therefore, tacitly assuming that the universe must conform to their tastes, they declare that this must have been the case.[3]

However, in the years that followed, an alternative theory became so prominent, that it was for a time presented as almost the only contender that explained the origin and history of the universe. For some years now, the big bang cosmology has been promoted by astronomers and cosmologists in the media as a virtual fact, so that most in our society now accept this theory as "the explanation" for the origin and history of the universe. This cosmology maintains that:

> Fifteen billion years ago, a Universe erupted out of nothing in a titanic explosion that we now call the big bang. Everything—all matter, energy, even space and time—came into being at that instant. Ever since, the stuff of the Universe has been expanding and cooling. In the earliest moments of the big bang, the Universe occupied a tiny volume and was unimaginably hot. It was a blistering fireball of radiation mixed with microscopic particles of matter, but eventually, the universe cooled enough for atoms to form. Gradually, these clumped together under gravity to make billions of galaxies, great islands of stars of which our own galaxy, the Milky Way, is but one.[4]

Enthusiastic support has been given to this big bang cosmology by some Christian astronomers, as if it were a confirmation of the biblical account of the origin

---

2 Hoyle, 1955, 321.

3 H. Dingle, 1954, Science and modern cosmology, *Science*, 120: 519.

4 M. Chown, 1994, Birth of the universe, Inside Science 69: 1, *New Scientist*, 141 (1914).

and history of the universe and the earth.[5] However, the reality is that this big bang cosmology is also purely evolutionary and naturalistic, because the initial state of the universe is not conceived in any way as a time of divine creation. Indeed, no allowance or mention of a divine Creator appears anywhere in the scientific literature discussing the origination of this big bang, and where the word "creation" is used, it in no way is meant to imply divine creation, but is a play on words, in all probability to appease man's religious consciousness. Rather than a beginning as such, other descriptions are used:

> If we run the expansion of the Universe backwards to the moment of creation itself, we find that the Universe was compressed into an impossibly small volume, was infinitely dense and infinitely hot. In mathematical jargon, the Universe was a singularity. Singularities are a disaster in any physical theory. They are a warning that we have gone terribly wrong with our description of nature. We need a better theory and that theory is a "quantum" theory of gravity. Quantum theories have been hugely successful in describing the other three forces of nature… so there is great confidence that they will be successful in describing gravity as well.…in any quantum theory, the idea of an exact position in space is jettisoned because of the Heisenberg uncertainty principle. The implication is that if the Universe were to be run backwards in time it would never quite reach the stage where all of creation is compressed into a single point. Something would happen to prevent the formation of a singularity.[6]

> By applying quantum mechanics to the universe as a whole, cosmologists hope to look beyond the very instant of creation.…So we arrive at a possible answer. According to the picture afforded by quantum cosmology, the universe appeared from a quantum fuzz, tunneling into existence and thereafter evolving classically. The most compelling aspect of this picture is that the assumptions necessary for the inflationary universe scenario may be compressed into a single, simple boundary condition for the wave

5 H. N. Ross, 1994, Cosmology's holy grail, *Christianity Today*, 38 (14): 24-27. In Ross's words: "And if the universe is 'exploding' there must have been a start and a Starter to that explosion. As Genesis reveals, the universe had a beginning—hence, an Initiator, one who existed before and outside of the universe, as the Bible uniquely declares." (p. 26) "The scientific underpinning for correlating the big bang with Jesus Christ lies in a set of mathematical equations, the equations of general relativity" (pp. 25-26). "How awesome to consider that God caused the big bang and all its components, including exotic matter and over 10 billion trillion stars..." (p. 27). What Ross fails to acknowledge is that the Genesis account of God creating the universe begins with God creating the earth "in the beginning" on the first day, with the sun and other stars, and the galaxies not being created until four literal days later, specific details given by God which are totally in conflict with the claims of the big bang cosmology, both in terms of the timescale and in the order in which creation took place. In order to maintain this compromised position, the Scriptures ultimately suffer, as the biblical text is reinterpreted to fit finite, fallible man's scientific ideas.

6 Chown, 1994, 4.

> function of the universe.[7]

Thus, there is no more room in the big bang cosmology for a genuine divine creation than there is in the steady-state cosmology.

What compromising Christian astronomers need to remember is that finite, fallible, science theories usually end up eventually being discarded, because new observations and data in conflict with those theories invariably accumulate. If the Bible has then been reinterpreted so as to accommodate finite, fallible man's theories, then when those theories are abandoned, the Scriptures are further discredited and are regarded increasingly as irrelevant. As a matter of fact, the once discredited and largely discarded steady-state cosmology is now making a comeback, as observations and data that conflict with the big bang cosmology have increasingly accumulated.

More than a decade ago it was stated:

> The relativistic…Big Bang model for the expanding Universe has yielded a set of interpretations and successful predictions that substantially outnumber the elements used in devising the theory, with no well-established empirical contradictions. It is reasonable to conclude that this standard cosmology has developed into a mature and believable physical model.[8]

Yet only seven years later there was a different assessment being made:

> The "Big Bang" model includes a few unknown numbers that determine the size, shape and future of the Universe. In the past few years our measurements of these three parameters have begun to rule out the old picture of the Universe dominated by cold dark matter. What will take its place?…Theoretical slack in the Big Bang model is being tightened all the time, and we should soon pin down the floating parameters with acceptable confidence. But perhaps none of the available family of models will fit all the new data.[9]

Indeed, even when the big bang cosmology was being trumpeted as being the best and virtually only viable theory, severe doubts about it were being raised:

> The above discussion clearly indicates that the present evidence does not warrant an implicit belief in the standard hot Big Bang picture….As a general scientific principle it is undesirable to depend crucially on what

7 J. J. Halliwell, 1991, Quantum cosmology and the creation of the universe, *Scientific American*, 265 (6): 28, 35.

8 P. J. E. Peebles, D. N. Schramm, E. L. Turner and R. G. Krom, 1991, The case for the relativistic hot Big Bang cosmology, *Nature*, 352: 769.

9 P. Coles, 1998, The end of the old model Universe, *Nature*, 393: 741, 744.

> is unobservable to explain what is observable, as happens frequently in Big Bang cosmology. Geology progressed variably from the time Hutton's principle of uniformity was adopted, according to which everything in geology is explained by observable ongoing processes. One can suspect that cosmology and cosmogony would profit similarly from the adoption of the same principle, as the view proposed here does.[10]

So what alternative cosmological theory is now being proposed? In fact, the steady-state cosmology has been revived:

> Note that in the steady-state theory the Universe expands because of the creation of matter within it. The space-time structure of each near creation unit makes room for itself by shouldering aside the products of previously existing units, a process that requires each creation unit to expand with just sufficient energy to fit itself into the general Hubble flow of the Universe…the conventional critic may argue that from the standpoint of economy of postulates the idea of "many" creation events is a lot worse than the notion of the single creation event (the Big Bang). We disagree. The "many" events in our alternative theory are potentially observable and satisfy the repeatability criterion of physical theories. The Big Bang satisfies neither of these requirements, and hence as a scientific hypothesis fails to compete with the alternative proposed here.[11]

Meanwhile, attempts are being made to adjust the big bang cosmology to overcome some of the recent conflicting observations:

> The evolution of inflationary theory has given rise to a completely new cosmological paradigm, which differs considerably from the old big bang theory and even from the first versions of the inflationary scenario. In it the universe appears to be both chaotic and homogeneous, expanding and stationary. Our cosmic home grows, fluctuates and eternally reproduces itself in all possible forms, as if adjusting itself for all possible types of life that it can support.[12]

There is neither room nor scope for the divine Creator in this cosmology, so how will compromising Christian astronomers reinterpret the biblical text of Genesis to accommodate the Scriptures to this cosmology? The end result is total capitulation that relegates the Genesis record to nothing more than an historically-based myth!

Furthermore, just how empirically verifiable and valid are the claims made by the

10 H. C. Arp, G. Burbidge, F. Hoyle, J. V. Narlikar and N. C. Wickramasinghe, 1990, The extragalactic Universe: an alternative view, *Nature*, 346: 810, 812.

11 Arp et al, 1990, 811-812.

12 A. Linde, 1994, The self-reproducing inflationary universe, *Scientific American*, 271 (5): 39.

scientists championing these cosmologies? Of course, it is sheer wishful thinking to suppose that observations made today can establish the conditions at the beginning, and the means by which the universe came into existence:

> How can one verify a law of initial conditions?…because it is so hard to verify quantum cosmology, we cannot conclusively determine whether the no-boundary or the tunneling proposals are the correct ones for the wave function of the universe. It could be a very long time before we can tell if either is an answer to the question, "Where did all this come from?"[13]

Moreover, when honest enough to admit it, even the scientists involved in constructing these cosmologies admit to the paucity of hard data available to construct their theories:

> Cosmology is unique in science in that it is a very large intellectual edifice based on very few facts. The strong tendency is to replace a need for more facts by conformity, which is accorded the dubious role of supplying the element of certainty in peoples' minds that properly should only belong to science with far more extensive observational support. When new facts do come along, as we believe to be the case with anomalous redshifts, it is a serious misprision to ignore what is new on the grounds that the data do not fit established conformity. Certainty in science cannot be forthcoming from minimal positions such as those which currently exist in cosmology.[14]

If this then is the true state of these cosmological theories, admitted to be based on only a few scarce real facts, it is totally illogical, out of order, and absurd to compromise the God-provided eyewitness account of His supernatural creation of the universe, the earth, and all life, by attempting to reinterpret the biblical text to accommodate finite, fallible man's woefully inadequate cosmological theories.

It should now be obvious, therefore, that when one decides to reject the concept of real creation, there is no scientific stopping-point short of totally rejecting any role for the divine Creator, in what then amounts to atheism, or increasingly, animistic pantheism. Not only various types of living creatures, but even life itself, and then everything in the physical universe from the simplest atom to the greatest galaxy, must be incorporated into the all-encompassing cosmic evolutionary hypothesis! One searches in vain for any acknowledgement of the Creator God of the Bible and His creative power in all these theories. Everything can be "scientifically" explained, so what need is there for a Creator?

---

13 Halliwell, 1991, 35.

14 Arp et al, 1990, 812.

However, the conviction of so many scientists in the mainstream scientific community (especially those quoted above), that evolution is the explanation of all things, must obviously arise from outside the domain of verifiable science, because the evidence for it is only circumstantial at best, and in the main highly speculative and conjectural. It thus has to be, in fact, much more of a faith or belief system than is creationism. It is a belief exercise, in spite of all the evidences of the most basic and best-validated scientific laws that are absolutely contrary to it. On the other hand, creation as a fact revealed by God both in the biblical text of Genesis and in the miracles performed by the Creator Himself, Jesus Christ, is at least very strongly supported by the law of cause and effect,[15] by the first and second laws of thermodynamics, and by other basic truths of demonstrable science.

Men complain, however, that God would be dishonest to create the universe, the earth, and all life on it with an appearance of age. If God is Truth, then how could He cause things to look as though they were old with a history, and had come into their present forms by long processes of growth and development, when actually they had just been created? To do this would be deceptive, and therefore this is impossible for God to do. After all, God would not lie, for in fact, He has specifically condemned lying (Exodus 20:16), as well as punishing those who have lied to Him (e.g., Acts 5:1-11).

This sort of reasoning, however, is entirely unworthy of reasonable men, especially scientists who pride themselves on their skepticism of any argument or claim that will not stand up to scrutiny unless supported by valid evidence and observable, reputable data. Such reasoning is essentially an affirmation of atheism, a denial of the possibility of a real creation. If God actually created anything at all, even the simplest atoms, then those atoms, or whatever it was He created, would necessarily have an immediate appearance of some age to us, as human observers bound by our finite understanding of the processes operating around us today. This is exactly how the master of the marriage feast in Cana saw the wine that our Creator Jesus Christ had just created from water. There could be no genuine creation of any kind without an initial appearance of age inherent in it. Of course, it would still be possible to interpret this newly-created matter in terms of some

---

15 The law of causality or cause and effect is very much a part of the empirical basis of the scientific method. It affirms that like causes produce like effects, and that every effect must have an adequate cause. No effect can be quantitatively greater than or qualitatively divergent from its cause. Thus, for example, if the personality of man is regarded as an effect, his intelligence requires a Cause possessed of intelligence, man's power of choice implies a Cause possessed of volition, and his moral consciousness must be explained in terms of a Cause possessed of morality. Similarly, the intelligibility of the physical universe implies an intelligent Designer, and so on. Thus, the law of causality, though admittedly not philosophically impregnable, is at least very strong circumstantial evidence of the existence of a great First Cause, a personal Creator-God. This has again, very recently, been powerfully argued in W. A. Dembski, 1998, *The Design Inference: Eliminating Chance through Small Probabilities*, Cambridge, UK: Cambridge University Press; W. A. Dembski, 1999, *Intelligent Design: The Bridge between Science and Theology*, Downers Grove, IL: InterVarsity Press; W. A. Dembski and J. M. Cushiner, eds., 2001, *Signs of Intelligence: Understanding Intelligent Design,* Grand Rapids, MI: Brazos Press, Baker Book House.

kind of previous evolutionary history. However, if God is able to create the simplest atoms with an appearance of age—in other words, if God exists—then there is no reason why He could not, in absolute conformity with His character as the Truth, instantaneously create a whole universe full-grown and fully functioning.

Obviously, if God did this, there would be no way by which any of His creatures could deduce the age or manner[16] of creation, by the study of the laws of maintenance of His creation that have operated since He completed His creation. This information could only be obtained, correctly, through God Himself revealing it! Furthermore, if God has revealed how and when He created the universe and its inhabitants, then to charge God with falsehood in creating His creation with "apparent age" is presumptuous and arrogant in the extreme—even blasphemous. It is not God who has lied, but rather those who have called Him a liar by rejection of His revelation of creation, as given in Genesis and verified by the Lord Jesus, the Creator Himself!

However, if we are willing to accept in faith the biblical account of creation as simple, literal truth, then we immediately have a powerful tool for understanding all the observations and data of geology in proper perspective. We can study the earth, starting with the concept that its internal constitution, the rocks and minerals of its crust, and the various necessary geologic entities, were all brought into existence by God during the six days of the Creation Week, using unique creative processes that resulted in the earth and its surface being eminently and perfectly suitable for man's habitation and dominion. Of course, the original form and appearance of the creation is now much masked, because of the subsequent entrance of sin, decay, and death into the creation, and very much altered by the subsequent upheavals associated with the Flood. Not only mankind, but also "the whole creation," has been delivered into the "bondage of decay," and has ever since been "groaning and travailing together in pain" (Romans 8:21, 22). Recognition of all these basic facts must ultimately lead to a far more satisfactory, scientific explanation of all the observed geologic field relationships than any evolutionary/uniformitarian synthesis can ever do.

16 F. A. Schaeffer, 1969, The universe and two chairs, in *Death in the City*, Chicago: Inter-Varsity Press, 110-127; A. E. Wilder-Smith, 1987, Materialism in the light of an analogy and of some practical examples, in *The Scientific Alternative to Neo-Darwinian Evolutionary Theory: Information Sources and Structures*, Costa Mesa, CA: TWFT Publishers, 109-129.

83

The Pre-Flood Era—The "Waters Above the Firmament"

The Fall and the Beginning of the Pre-Flood Era

The Genesis record does not state how long it was between man's creation and the Fall and the entry of death into the world. It may not have been all that long, though, between the end of the Creation Week and when Satan came to tempt Adam and Eve, because Eve did not become expectant of her firstborn son until after the Fall (Genesis 4:1). Indeed, it is unlikely Adam and Eve had been unresponsive to God's admonition to be fruitful and multiply (Genesis 1:28) before the Fall, in view of Adam's delight at God's provision of Eve and God ordaining the first marriage (Genesis 2:21-25).

Fossils are a notable aspect of the rock record. So an important issue in our comparison of the rock record with Scripture is the point in the record where animal fossils appear, since fossils of living creatures other than plants plainly record suffering, bloodshed, and death. Plants do not contain blood, and they do not suffer or experience "death" in the same way as living creatures. In any case, God provided them for food, including for man's consumption, even during the Creation Week when it was all declared by God to be "very good" (Genesis 1:29-31). Although the sentence of death was specifically pronounced only on man, and on the serpent used by Satan as the vehicle of his temptation, the most obvious implication is that this curse on the master of creation extended likewise to his dominion. This fact is also strongly implied by the New Testament expositions on the Fall. Paul says, "By man came death" (1 Corinthians 15:21); and in another place, "By one man, sin entered into the world, and death by sin" (Romans 5:12). Similarly, in Romans 8:20 we are told that "the creation was subject to vanity."

Most of the fossil deposits display evidence of the sudden burial of animals and plants of all kinds, and they therefore often indicate a watery catastrophe of some kind. The whole appearance of the rocks containing animal fossils seems completely out of harmony with the system of creation that God so many times pronounced as "good." Therefore, it would seem compelling to date all rock strata with contained fossils of once-living creatures as subsequent to Adam's Fall. This is certainly consistent with our analysis already of the content of the overall fossil record. As depicted in Figures 20 and 21, only algae and stromatolite fossils are found in Archean, Paleoproterozoic, and Mesoproterozoic strata, so it is possible to consign these to the Creation Week era, whereas worm-like megafossils and other animal fossils only begin appearing in Neoproterozoic and later strata, which should thus be consigned to the pre-Flood era subsequent to the Fall and beyond, for the reasons just given.

Furthermore, it seems likely that relatively few of these animal fossil-bearing strata, if any, should be dated to the period between Adam's Fall and the Flood, that is, to the 1,650 or more years of the pre-Flood era. This is primarily because geologic activity would seem to have been very mild during this period of time, because otherwise there would have been the capacity to produce fossil deposits of at least some animals in pre-Flood strata, for example, of marine invertebrates in shallow marginal marine environments, where they would normally be susceptible to burial by sediments eroded and transported from off the adjacent continental margins. Of course, it is also possible that any such fossil deposits that did form in the pre-Flood era would most likely have been reworked, or even destroyed, during the initial stages of the Flood. The conclusion that the pre-Flood era was probably one of relative inactivity, geologically, has traditionally been argued from the relevant Scripture passages,[1] so these arguments need to be examined.

The "Waters Above the Firmament"

It is beyond dispute that, on the second day of the Creation Week, God elevated some of the water covering the earth's surface, from when He created the earth on the first day, and placed a "firmament" (literally, a stretched out thinness) between these "waters above" and the waters left on the earth's surface. It has frequently been argued that this "firmament" was the atmosphere, because on the fifth day God made "fowl that may fly above the earth in the open firmament of heaven" (Genesis 1:20). However, it has recently been proposed that this "firmament" or "expanse" was instead interstellar space, which would then require that these "waters above the firmament" be cosmic in scale and represent an outer boundary for interstellar space.[2] If this interpretation is correct, then this would place these "waters above" well beyond any further consideration with respect to their involvement in the earth's atmosphere and climate system and in the Flood.

Otherwise, it has been suggested that these were waters that existed above the atmosphere, apparently in the form of a great vapor canopy around the earth of unknown (but possibly very great) extent. Of course, in the form of water vapor this canopy would have been quite invisible, but nevertheless it is claimed that it would have had a profound effect on the earth's climate and meteorological

1 Whitcomb and Morris, 1961, 240-243, 255-258.

2 D. R. Humphreys, 1994, A Biblical basis for Creationist cosmology, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 255-266.

processes.[3] However, before it is appropriate to discuss the climatic and meteorological effects of such a water vapor canopy, it is necessary to investigate the scientific feasibility of such an entity. Such a water vapor canopy would have been put in place supernaturally while natural physical laws were suspended during the Creation Week. Once in place, it would have to be maintained there subsequently, as well as operating, under the same natural physical laws that govern the earth's atmospheric processes today.

Dillow determined from his expository studies of the biblical text, and general physical reasoning, that these "waters above" were probably in vapor form, and had originally rested on top of the earth's atmosphere.[4] He preferred to use a two-layer model of the earth's atmosphere in his scientific analysis, with pure water vapor above resting on top of the air compressed below. Dillow also assumed that the amount of water vapor in the canopy was a column equivalent to 40 feet (about 12 meters) of liquid water. He obtained this estimate from an assumed rainfall rate of 0.5 inches (12.7mm) per hour over a period of forty days and nights during the initial stage of the Flood. Such a rainfall rate would be considered a heavy rainfall rate today, particularly if it occurred uniformly over a large area. The Bible indicates that the rainfall was heavy during the first forty days and nights of the Flood. If this quantity of water was in such a canopy, and was converted to rain over the entire earth during these forty days and nights at the beginning of the Flood, then the canopy would have produced 40 feet (about 12 meters) of water on the ground. Dillow also justified this figure of 40 feet (about 12 meters) of water, contained in his vapor canopy model, by recognizing that the weight of water vapor in this canopy would have increased the pressure of the atmosphere at the earth's surface. A column of water 34 feet (over 10 meters) high would produce one atmosphere of pressure (approximately 1,013 millibars) at the bottom of such a column, so 40 feet (just over 12 meters) of water in a vapor canopy on top of the air in the atmosphere would increase the total pressure (of the atmosphere plus the vapor canopy) at the earth's surface to a little more than two atmospheres (more than 2,026 millibars). He also found that another factor constraining the total pressure, and therefore the amount of water vapor that could have been in such a canopy, was that a pressure much greater than two atmospheres would have caused oxygen poisoning of human and animal life on the earth's surface.

Dillow realized that the major problem for his vapor canopy model was that there simply seemed to be no apparent mechanism by which the atmosphere, as it is presently constructed, could either hold within it, or support above it, anywhere near the required 40 feet (over 12 meters) of water as vapor. For example, it is easy to demonstrate that for a saturated atmosphere, with a sea-level temperature of 28°C (82.4°F) and in saturation-adiabatic equilibrium, the total

3 Whitcomb and Morris, 1961, 240-241, 255-258; J. C. Dillow, 1981, *The Waters Above: Earth's Pre-Flood Vapor Canopy*, Chicago: Moody Press.

4 J. C. Dillow, 1981.

precipitable water that such an atmosphere could hold is only 10.54 cm (about 4 inches).[5] Furthermore, if a massive amount of water vapor was placed above the atmosphere, distributed in hydrostatic equilibrium throughout the gravity field, it would immediately begin to diffuse toward the earth's surface, condensing and so precipitating out as rain. Thus, some kind of support mechanism would have to have held up this large amount of water vapor in such a canopy above the atmosphere that prevented downward diffusion of the water vapor. The key factor would be temperature, because higher temperatures increase the saturation vapor pressure, so that more water vapor can be maintained in each unit of volume. However, this requires the pre-Flood atmosphere to have been characterized by a different temperature structure from today's atmosphere, without the turbulent atmospheric mixing that occurs today. Indeed, because a vapor canopy would very effectively absorb infrared radiation coming upward from the earth's surface, and to a lesser degree some of the solar radiation coming down from above, a vapor canopy would automatically be much hotter than the earth's surface. Under these conditions, the changing temperature with altitude (known as the lapse rate) in the lower atmosphere would have been reversed from that experienced today, namely, the temperature would have increased with altitude from the earth's surface to the base of the canopy, rather than decrease with altitude upwards as it normally does today.

The crucial issue then becomes the question of whether under such canopy conditions the earth's surface temperature would be habitable for life, including a climate acceptable for human habitation. Thus, Dillow found that under a cloudless sky, such a vapor canopy may have resulted in the earth's surface temperature having been as high as 314°C (597°F). Nevertheless, he argued that once convection cells began to redistribute the heat of the canopy, a radiative-convective equilibrium profile would be established, with a canopy base temperature considerably less than this. Furthermore, the presence of a discontinuous cloud layer at the top of the canopy could have had the effect of reducing the solar input into the canopy-atmosphere system by as much as 35 percent, while in the lower regions of the canopy, where convective cells could have produced cloud formation, up to a 100 percent cloud layer could have been established, which would have raised the albedo of the earth considerably and thus further reduced the earth's surface temperature. With these constraints, Dillow was able to propose a temperature structure for the pre-Flood atmosphere and vapor canopy commencing with a temperature at the earth's surface of 23°C (73.4°F), and rising upwards through the atmosphere to 100°C (212°F) at the base of the vapor canopy at an altitude of 6 to 7 km (about 4 miles), before decreasing upwards through the vapor canopy at a lapse rate of 1 to 2°C per kilometer. This vertical temperature structure would have been hot enough to keep the vast amounts of water in the canopy in the form of steam vapor, and massive temperature inversion as a result of this structure would have eliminated any diffusion of vapor down into the atmosphere. The

5 H. R. Byers, 1974, *General Meteorology*, fourth edition, New York: McGraw Hill, 113.

daytime cloud cover would maintain pleasant temperatures at the earth's surface for human habitation, but would have cleared at night to provide uninterrupted viewing of the stars.

Nevertheless, Dillow found a major problem with his vapor canopy model. There first has to be a mechanism for providing sufficient condensation nuclei to precipitate the water vapor in the canopy as heavy continuous rainfall for forty days and nights. However, it is the total resulting heat load on the atmosphere, generated by the condensation of the vapor canopy, which causes a serious difficulty. Indeed, the latent heat of condensation of the water vapor in the canopy would have potentially resulted in the temperature of the atmosphere, as the canopy precipitated as rain, being raised by as much as 1,600°C (about 2,900°F). This is clearly intolerable! Dillow thus explored various heat loss mechanisms to alleviate the severity of this problem, such as heat loss by atmospheric expansion, by radiation, by droplet formation, by mass transport, and perhaps even by some pre-Flood cooling. Dillow also argued that the increased atmospheric pressures under the canopy would not have led to oxygen toxicity for human and animal life, and that with the resultant drop in pressure as the canopy collapsed during the early stages of the Flood, there would have been no decompression problems for Noah and his family.

Having established the potential scientific viability of his vapor canopy model, Dillow also drew on circumstantial evidences for the existence of a pre-Flood vapor canopy. Perhaps the most compelling of these circumstantial evidences is the incredible longevity of the pre-Flood patriarchs compared to their post-Flood descendants.[6] The average lifespan of the pre-Flood patriarchs (excluding Enoch) was more than 900 years, but from the time of the Flood onwards there was a dramatic decrease in the lifespans of the post-Flood patriarchs, eventually to a new equilibrium level of around 70 years. The implication is that something extremely significant happened to the earth and to man at the time of the Flood to cause this dramatic change in human lifespans. The collapse and removal of this water vapor canopy at the time of the Flood has thus been cited as the chief candidate, because it has also been argued that the existence of the vapor canopy in the pre-Flood era would have shielded the pre-Flood patriarchs from harmful cosmic radiations, which today are known to significantly contribute to the aging process. Thus, it was maintained, that the collapse of the water vapor canopy during the Flood would have removed that protection, so the genetic effects of cosmic radiations steadily accumulated in the post-Flood human population to produce the decline in lifespans that steadily increased in successive generations.

Confirmation of both the longevity of the pre-Flood human population, and of the existence of the pre-Flood vapor canopy, can be found in the mythologies of the early post-Flood civilizations. Furthermore, if there was indeed a pre-Flood

6 Whitcomb and Morris, 1961, 23-25, 399-405.

vapor canopy, with associated daytime cloud cover and nighttime mists, then the condensation of that vapor canopy at the time of the Flood would have left an indelible impression on the minds of Noah and his family, as they remembered the appearance of the pre-Flood heavens in comparison to the heavens after the Flood. Indeed, it is possible that, with the canopy gone, thousands of additional stars would have been visible in the post-Flood night sky, while the sun would have become a bright yellow ball, in contrast to the reddish disk in the pre-Flood cloud-covered sky. Dillow thus argued that these profound changes may well explain the prevalence of worship of the sun and stars by almost all the early post-Flood civilizations, practices that were then subsequently passed on to succeeding civilizations, even (sadly) to our present society. Finally, the higher atmospheric pressure produced by the pre-Flood vapor canopy, Dillow argued, was consistent with giantism in the fossil record; the higher atmospheric pressure produced more efficient oxygen diffusion in animal metabolism, resulting in some animals growing to giant proportions, compared to body sizes today—for example, the large dinosaurs. Furthermore, the higher atmospheric pressure would be consistent with the aerodynamics of the wingspans of gigantic flying reptiles, such as the pteranodons, the higher air pressure evidently enabling these creatures with wingspans of up to 16 meters to have taken off and flown in gentle breezes, in contrast to the strong breeze that would seem to be required by these same creatures if they were alive today.

As impressive as these arguments, circumstantial evidences, and scientific details are for the pre-Flood vapor canopy as presented by Dillow, more recent analyses have continued to raise serious problems for this vapor canopy model.[7] In these analyses of the vapor canopy, a two-layer model was chosen with an assumed surface temperature of 30°C (90°F), and a temperature at the base of the canopy of 100°C (212°F). Because the weight of the overlying water vapor in the canopy compresses the air below in the atmosphere, the base of the canopy at the top of the atmosphere was found in these analyses to occur at only about 7 km (4.35 miles), the resulting pressures being one atmosphere at the base of the canopy and two atmospheres at the earth's surface. As a result of attempting to estimate the rate of molecular diffusion of water vapor downward, which may have existed in such a vapor canopy, it was found that this vapor canopy was indeed stable, with molecular diffusion unlikely to remove a significant quantity of water vapor from it.

7 L. Vardiman, 1986, The sky has fallen, in *Proceedings of the First International Conference on Creationism*, Basic and Educational Sessions, vol 1, Pittsburgh, PA: Creation Science Fellowship, 113-119; D. E. Rush and L. Vardiman, 1990, Pre-Flood vapor canopy radiative temperature profiles, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 231-246; L. Vardiman and K. Bousselot, 1998, Sensitivity studies on the vapor canopy temperature profiles, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 607-618; L. Vardiman, 2001, A vapor canopy model, in *Climates Before and After the Flood: Numerical Models and their Implications,* El Cajon, CA: Institute for Creation Research, 7-21.

Even more critical is whether this vapor canopy could have been maintained in a balance between radiation coming from the sun, and infrared radiation coming from the earth's surface, without collapsing, and whether the resultant surface temperature conditions could have been livable under such extreme greenhouse conditions. Using computer simulations of vapor canopies containing the equivalent of 4 inches (10 cm), 20 inches (51 cm), 40 inches (102 cm), and 34 feet (more than 10 meters) of liquid water, it was found that, while vapor canopies of any magnitude could be maintained by solar radiation, only thin vapor canopies would allow livable conditions on the earth's surface. Any canopy containing more than about 20 inches (51 cm) of water produced such a strong greenhouse effect that surface temperatures became unsuitable for life, although cirrus clouds forming near the top of the canopy could possibly have alleviated this strong greenhouse effect.

With the aim of determining whether a vapor canopy could have held larger quantities of water while surface temperatures were still livable, this vapor canopy model was subjected to sensitivity studies for the effects of five constants related to the radiation balance—the solar constant (the rate of heating of the earth by the sun), the albedo (the average percent of reflective energy from the earth's surface), the solar zenith angle (the angle of the sun from the vertical), and the cirrus cloud height and thickness. Computer simulations of a vapor canopy containing the equivalent of 4 inches (10 cm) of liquid water revealed that temperatures on the earth's surface would have been most strongly affected by changes in the solar constant, a 50 percent reduction in that constant reducing the earth's surface temperature under the canopy from 60°C (140°F) to –31°C (-25°F). While the albedo, solar zenith angle, and cirrus cloud thickness also produced strong effects on the earth's surface temperature, none of the effects were dramatic enough to eliminate the concern over the water content of the canopy being limited because of resultant hot temperatures on the earth's surface. Even when all five parameters were introduced simultaneously into computer simulations, such that the earth's surface temperature was minimized, it was estimated that the water content of the canopy would only be increased to about 1 meter (about 3 feet), less than 10 percent of the water content in Dillow's vapor canopy model. Thus, in order for there to have been livable temperatures at the earth's surface, the amount of water that could have been held in a vapor canopy would not have been sufficient to contribute significantly to the rainfall, and thus the waters of the globe-encircling, mountain-covering Genesis Flood. However, there were other sources available when the Flood was initiated for both the intense global rainfall and the surface waters required to Flood the pre-Flood continent or continents (to be discussed later).[8]

8 J. R. Baumgardner, 1986, Numerical simulation of the large-scale tectonic changes accompanying the Flood, in *Proceedings of the First International Conference on Creationism*, vol. 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 17-30; J. R. Baumgardner, 1990, 3-D finite element simulation of the global tectonic changes accompanying Noah's Flood, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 35-45; Austin et al, 1994, 609-621.

84

The Pre-Flood Era—Climate Conditions Before the Flood

If there was indeed a vapor canopy above the earth's atmosphere in the pre-Flood world, even if it only contained the equivalent of 1 meter (about 3 feet) or less of liquid water, it would still have had a profound impact on the climate in the pre-Flood world, such as large differences in temperature, atmospheric stability, cloud formation, and precipitation from that experienced in today's climate.[1] Indeed, it has been suggested that there are a number of references, in the scriptural account of the pre-Flood world, to climate factors that can be used as circumstantial evidence for the existence then of a vapor canopy.

Perhaps the most quoted biblical passage, that is regarded as both relevant and significant, is Genesis 2:5-6, where we read, "For the LORD God had not caused it to rain upon the earth, and there was not a man to till the ground. But there went up a mist from the earth, and watered the whole face of the ground." The context, as well as the text itself, indicates that these verses apply specifically to the initial completed creation, but because there is apparently no mention made subsequently in the text of these early chapters of Genesis after the Fall of any change in this climate factor, it has been argued that there was thus no rainfall at all in the pre-Flood world.[2] Furthermore, it has often been argued that this inference of no rainfall before the Flood is supported also by the mention of the rainbow in Genesis 9:11-17 after the Flood as a new sign from God to man, which in turn is interpreted as strongly implying that rain as we know it today, and thus the rainbow produced when the sun is reflected through the water droplets, were then only experienced for the first time.[3]

This specific statement in Genesis 2:5-6 unquestionably states that up until the end of the Creation Week, when man had been created and placed in the Garden of Eden, there had not been any rain. However, is there scientific support for the interpretation that there was then no rainfall subsequently in the pre-Flood world, until the Flood itself began? If a pre-Flood vapor canopy did exist, then the computer simulations substantiate the claim that under canopy conditions it is quite likely that there would have been no rain on the earth's surface prior to the Flood.[4] Indeed, there is a consensus that under canopy climatic conditions, the earth's surface would have been watered by "mists," exactly as stated in Genesis

1 Vardiman, 2001, 21.

2 Whitcomb and Morris, 1961, 241-242; Dillow, 1981, 77-93.

3 Whitcomb and Morris, 1961, 241; Dillow, 1981, 93-98.

4 Dillow, 1981, 280-283; Vardiman, 2001.

2:6. Described as going up from the earth, it has been implied that these mists may have been due to the process of evaporation from both land and water surfaces on the pre-Flood earth.[5] Indeed, because the temperatures at the earth's surface would have been colder than temperatures higher in the atmosphere under the vapor canopy, the water vapor produced by evaporation near the earth's surface would be retained there, because to transport the water vapor upward toward the canopy would require temperatures on the earth's surface higher than those at the base of the canopy.[6] However, the calculations show that there would have been some diffusion of water vapor downward from the base of the vapor canopy. Furthermore, because the temperature decreases rapidly in the atmosphere beneath the canopy base, the water vapor that diffused downward would most likely have condensed out as rain, and fallen to moisten the lower atmosphere.[7] Whether this implies that there could actually have been rainfall under a vapor canopy in the pre-Flood world via this means would depend on how much water vapor diffused down into the atmosphere. If the quantity of the water vapor was small, then its condensation in the lower atmosphere may have simply added to the water vapor evaporated from the earth's land and water surfaces to enhance the mist described in Genesis 2:6.[8]

However, the geologic record may perhaps shed some light on these questions. Of primary significance is what clearly appears to be fossilized raindrop imprints preserved in Precambrian fine-grained, water-deposited volcanic ash and sandstone beds, found deep in the geologic record in South Africa and Norway, respectively.[9] In conventional terms, these occurrences are "dated" at 2.7 billion years (South Africa) and between 1.5 and 0.9 billion years (Norway), so they are here designated as belonging to the pre-Flood era. Of course, these trace fossils cannot be proved to be raindrop imprints, but careful comparison of them with present-day raindrop imprints on the surfaces of muddy sediments, complete with

5 Whitcomb and Morris, 1961, 241.

6 Vardiman, 2001, 12.

7 Vardiman, 2001, 12-13.

8 However, if as already indicated there is only a limited amount of liquid water equivalent that can be stored as vapor in the canopy to ensure livable temperatures at the earth's surface, then even with an extremely small diffusion rate of water vapor downward below the vapor canopy base there is the real possibility that in the 1,650 or more years between the Creation Week and the beginning of the Flood the entire vapor canopy may have diffused downward into the atmosphere below. For example, Vardiman (2001, pages 13 and 21) has indicated that the liquid water equivalent content of the vapor canopy could possibly be raised to as much as 1 meter (about 3 feet) without making the temperatures on the earth's surface intolerable for life, and yet he also indicates that the total amount of water vapor that might diffuse downward from the base of the vapor canopy in the 1,650 or so years in the pre-Flood era could be about 100 cm, which is exactly 1 meter (about 3 feet)! In other words, by the end of the pre-Flood era, the vapor equivalent to 1 meter of liquid water originally in a viable canopy would have all diffused down into the atmosphere, leaving no canopy at all by the time of the Flood! Any advantages to the pre-Flood climate would also have dissipated with the loss of this vapor canopy.

9 J. P. Singh, 1969, Primary sedimentary structures in Precambrian quartzites of Telemark, southern Norway, and their environmental significance, *Norsk Geologisk Tidsskrift*, 49: 1-31; W. A. Van Der Westhuizen, N. J. Grobler, J. C. Loock and E. A. W. Tordiffe, 1989, Raindrop imprints in the Late Archaean-Early Proterozoic Ventersdorp Supergroup, South Africa, *Sedimentary Geology*, 61: 303-309.

comparable desiccation cracks, shows a remarkable similarity that makes the case compelling. These would then be *prima facie* evidence of rainfall in the pre-Flood world. In any case, it is not unreasonable to expect that there was rainfall in the pre-Flood era, if the postulated water vapor canopy was of negligible thickness, or if the "waters above" were instead in the outer reaches of the universe.

The Hebrew word *ed* is usually translated as "mist," but old translations such as the Septuagint, Syriac text, and the Vulgate all translate the word as "spring."[10] Such a translation would seem relevant in the light of other biblical evidence for the existence of terrestrial and oceanic springs.[11] In Revelation 14:7, an angel declares, "Worship him that made heaven, and earth, and the sea, and the fountains of waters," which suggests that fountains or springs were an integral part of the created earth. It would have been the same fountains that were then "broken up" at the beginning of the Flood (Genesis 7:11, "were all the fountains of the great deep broken up"). The connotation in both the Greek and Hebrew words used in these verses, respectively, is of gushing springs where water bursts forth from inside the earth. It is also the connotation of a different Hebrew word used in Job 36, usually translated as "springs." Some, who have contended that Genesis 2:5 implies that there was definitely rain in the pre-Flood era, have thus suggested that the river that flowed through the Garden of Eden to water it, and that then split into four rivers (Genesis 2:10-14), had to be fed by these fountains or springs.[12] Of course, the biblical record does not specifically say there was a connection between these fountains or springs and the rivers on the pre-Flood earth. However, since the existence of these springs and fountains on both the land surface and the ocean floor are clearly mentioned in the Scriptures, then it is not unreasonable to expect at least some of the rivers on the pre-Flood earth were fed by springs. Furthermore, even though the Hebrew *ed* in Genesis 2:6 is probably correctly translated as "mist," the existence of springs and fountains on the pre-Flood earth is clearly mentioned in the other passages.

Nevertheless, we cannot be dogmatic that there was no rain for the entire pre-Flood era, even though Genesis 2:6 indicates that the mist "watered the whole face of the ground." In this way the pre-Flood land surface must have been well-watered and have produced lush vegetation. The latter, is of course, attested to by the huge volume of the coal beds in the geologic record. Thus, climate conditions in the pre-Flood era would seem to have been ideal for animal and

10 G. J. Wenham, 1987, *Word Biblical Commentary*, vol. 1, Genesis 1-15, Waco, TX: Word Books, 58; V. P. Hamilton, 1990, *The New International Commentary on the Old Testament, The Book of Genesis chapters 1-17*, Grand Rapids, MI: William B. Eerdmans, 154.

11 For a fuller discussion on this topic in the light of relevant Hebrew words, see D. M. Fouts and K. P. Wise, 1998, Blotting and breaking up: miscellaneous Hebrew studies in geocatastrophism, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 217-228.

12 J. Scheven, 1990, The geological record of Biblical earth history, *Origins (BCS)*, 3 (8): 8-13; J. Scheven, 1990, Stasis in the fossil record as confirmation of the belief in Biblical creation, in *Proceedings of the Second International Conference on Creationism*, vol. 1, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 197-215.

human habitation across the face of the earth, and must have been generally warm and humid. Though the Scriptures are silent on the subject, it could perhaps also be inferred that there may not have been the same extremes of weather conditions that we experience on today's post-Flood earth.

It has also been claimed that, along with there being no rain prior to the Flood, there were also no climatic seasons, with a mist watering the land surface and a global greenhouse environment. However, whereas the biblical evidence for the lack of rain is somewhat equivocal, there are specific references to seasons in the pre-Flood world. In Genesis 1:14, God specifically stipulates that the "lights in the firmament of the heaven" were not only to "divide the day from the night," but were to be for "signs and for seasons, and for days, and years." Furthermore, when God spoke to Noah when he left the Ark after the Flood, we read in Genesis 8:21-22 that He reassured Noah that "while the earth remaineth, seedtime and harvest, and cold and heat, and summer and winter, and day and night shall not cease." Noah was thus reassured that, even though the world he had been familiar with before the Flood had been destroyed, and he had now alighted onto a new harsh landscape, the pattern of the days, years, and seasons he had been familiar with in the pre-Flood world would continue in the post-Flood world. This mention of cold and heat, and summer and winter, would seem to confirm that the seasons God instituted at creation did include the associated climatic changes in the pre-Flood world. Furthermore, the trees that are fossilized in what seem to be Flood sediments, and that therefore grew in the pre-Flood world, have growth rings preserved in them.[13] Because these tree rings record changes in growth rates, they indicate that at least some areas of the earth's pre-Flood land surface experienced temperate conditions before the Flood (there are characteristic patterns in the tree rings of tropical and temperate climate trees). Although there is some evidence in those same fossilized pre-Flood trees that the earth may have been a bit warmer back then compared to today, there is also evidence of wet seasons and dry seasons, and even early and late frosts. This thus indicates that there couldn't have been a global greenhouse climate on the pre-Flood earth, and this is evidence of not only seasons, but of climatic zonation.

Furthermore, the growth rings in the fossilized pre-Flood trees thus also provide evidence of rainfall that watered the ground, in addition to the mist referred to in Genesis 2:6. It has been argued that when God designated the rainbow as a sign to Noah and his family of His covenant, "the water shall no more become a flood to destroy all flesh" (Genesis 9:12-17), this implies that Noah and his family had not previously seen a rainbow in the pre-Flood world, and therefore, there could not have been clouds and rainfall in the pre-Flood world. However, God refers to clouds covering the earth during Creation Week (Job 38:9). In any case, it is not unusual in Scripture for the sign of a covenant to already be

13 K. P. Wise, 1992, Were there really no seasons? Tree rings and climate, *Creation Ex Nihilo Technical Journal*, 6 (2): 168-172.

occurring prior to its appropriation and designation by God.[14] Examples include the practice of circumcision prior to the covenant with Abraham, the practice of the Sabbath instituted and followed at creation (Genesis 2:1-3; Mark 2:27) prior to the covenant with Israel at the giving of the law (Exodus 16:23, 20:8-11), and the breaking of bread and drinking of wine as a normal activity prior to them being designated as a sign of the new covenant by Christ (Matthew 26:26-29).

Thus, all the evidence taken together from Scripture and the geologic record would strongly suggest that there was rainfall in the pre-Flood world, and that there was climatic zonation from the equator to the poles, and according to topography. There were also seasons. We are given no hint as to by how much the topography varied, except that the Garden of Eden was at a high elevation, due to the river flowing from it dividing into four other rivers as it flowed downhill (Genesis 2:10-14). Perhaps the climatic differences between geographical regions were not as extreme as those we experience today, but we cannot be sure. Perhaps the elevated regions obtained higher rainfall and caused drier inland regions, in much the same way as happens today. Just where the pre-Flood continent(s) were situated relative to the equator and the poles is very uncertain, but if continent reconstructions based on the unraveling of the geologic record are in any way feasible, it may be that the pre-Flood land surface was largely concentrated in a supercontinent (conventionally called Rodinia) centered over the tropical to temperate portion of one half of the Southern Hemisphere.[15] This would be consistent with the climate data available from the growth rings in fossilized trees. Note also that there is no evidence to suggest that there were polar ice caps or glacial conditions anywhere on the pre-Flood earth surface.

14 K. P. Wise, 2002, *Faith, Form, and Time*, Nashville, TN: Broadman and Holman Publishers, 265.

15 Wise, 2002, 151. This theoretical supercontinent of Rodinia is in conventional terms dated to the earlier Neoproterozoic, which would be consistent with the interpretation here of that part of the geologic record that pertains to the pre-Flood world.

85

The Pre-Flood Era—The Biology and Geology

Some Unique Pre-Flood Biological Communities

The brief description of selected aspects of the pre-Flood earth given in the Scriptures can potentially be augmented by details preserved in the geologic record. Among the many fossils found in the post-Cambrian strata are some unusual plants that make up many of the coal beds of the Northern Hemisphere. Most of these plants are now extinct, though some of their relatives have survived into the present world but are today diminutive and minor compared to the huge volume of these plants found almost exclusively making up the thick coal beds, which stretch across many parts of the Northern Hemisphere. These plants had hollow roots and hollow trunks, but nevertheless grew to heights of ten meters and more, judging from the sizes of trunks found preserved, many times buried in upright positions. Such huge trees could not have grown in soils, for their roots would have been crushed. Instead, they must have grown in water. Indeed, the coal beds composed of the fossilized remains of these plants are buried by, and are interbedded with, sediments containing fossils of sea creatures, which indicates that these plants must have grown in the ocean basins of the pre-Flood world.

Based upon these observations, it has been proposed that these plants formed the basis of a large floating forest community (or biome) that grew on the pre-Flood ocean surface.[1] Given the lateral extent of the coal beds containing the fossilized remains of these plants, these floating forests may have been sub-continent-size, or even continent-size, which would in turn suggest that enormous stretches of the pre-Flood ocean surface were covered with these floating forests. These were perhaps similar in basic structure to what are known today as "quaking bogs," which are floating vegetation mats with outer edges made up of aquatic plants. Such plants expand the edge of the mat by means of root-like rhizomes. In from the edge of the mat, where the plants have been growing for some time, the rhizomes have become so intertwined that they are dense enough to have captured some soil, in which land plants can then grow. In the center of the floating mat, where it is thicker and has been established longer, enough soil accumulates for larger plants to grow, so that full-sized trees and all the understory plants of the entire forest would have developed. Of course, such a floating forest would have

1 J. Scheven, 1981, Floating forests on firm grounds: advances in Carboniferous research, *Biblical Creation (Journal of the Biblical Creation Society)*, 3 (9): 36-43; Wise, 2002, 170-173; K. P. Wise, 2003, The pre-Flood floating forest: a study in paleontological pattern recognition, in *Proceedings of the Fifth International Conference on Creationism*, R. Ivey, ed., Pittsburgh, PA: Creation Science Fellowship, 371-381.

formed an entire complex ecosystem, complete with everything from bacteria and fungi to other plants and also animals.

The existence of this floating forest biome in the pre-Flood world also has implications for the prevailing weather patterns. Given that the stormy seas during the Flood must have broken up and destroyed these floating forests, so that they were buried to become the coal beds, their absence in the post-Flood world would suggest that the choppy seas we experience today as a result of weather patterns were not conducive to these floating forests being able to grow again under such conditions. This in turn implies that the weather was not stormy enough, nor the seas choppy enough, in the pre-Flood world to disrupt the existence of these huge floating forest mats. In any case, if much of the ocean surface was covered with these floating forests, then the winds would generally not have had the open stretches of water to blow across and thus generate large waves. This in turn suggests that weather conditions in the pre-Flood world were generally calm, without the extremes we now experience, such as hurricanes that form over tropical ocean surfaces.

This pre-Flood floating-forest biome explains a number of features observed in the fossil record. The various members of this ecosystem are found buried in the Paleozoic portion of the geologic record, deposited during the Flood. From then on, most of these seemingly land plants and animals are absent from the record and are extinct today. It would be expected that, as the Flood began to destroy these pre-Flood floating forest mats, the edges would be broken off first, and thus buried first, while the centers of the mats would be last to be destroyed and buried. This explains the fossil progression observed in the Paleozoic geologic record. Plants on the edges of such floating forests were plants that love water, required standing water for reproduction, and were short. On the other hand, plants at the centers of these floating forests needed less water to survive, and less standing water for reproduction, as well as being tall. Such a progression is seen in plant fossils up through the Paleozoic strata, and in the presumed land animals that were associated with the different plants in this ecosystem (for example, certain now extinct tetrapods and amphibians, and well as large insects, that are unique and confined to the Paleozoic fossil record). Most of the fossil plants in Paleozoic strata have, instead of roots, rhizomes that are root-like structures incapable of penetrating through soils, but capable of intertwining with the rhizomes of other plants to have created the floating forests. Furthermore, many of these Paleozoic plants, especially the large ones, have rhizomes, branches, and even trunks that are largely hollow due to huge cavities, an ideal design for the entire plant to weigh less so that it would float in water. Indeed, *Stigmaria*, the most common rhizome in the plants that make up the coal beds, is hollow and circular in cross-section, with small, hollow rootlets branching off them. Neither these rhizomes nor the rootlets seem capable of penetrating soils, but would be ideal to support the floating in water of the large hollow trunks of the coal plants.

Another biological community that must have been unique to the pre-Flood era is that made up of the dinosaurs, and the plants and other animals found fossilized with them, in the Mesozoic portion of the geologic record.[2] Since the dinosaurs were land animals, they must have been created on Day Six of the Creation Week, and thus have lived on the earth at the same time as man in the pre-Flood world, only to be subsequently buried in sediments and become extinct due to the Flood. In the strata in which we find the dinosaurs fossilized are found other fossilized animals and plants that are either extinct or seen only infrequently. Among these fossilized animals are those that have been classified as mammals based upon their teeth, but they are strange mammals that are now extinct. Flowering plants are only rarely found fossilized with dinosaurs. Instead, the "naked seed" plants, or *gymnosperms*, that do not have flowers (like cycads and ginkgos), are found fossilized with the dinosaurs. It appears the dinosaurs probably ate gymnosperms rather than flowering plants, unlike humans. Thus, the gymnosperms probably formed the basis of a biome with dinosaurs separate from the one in which humans lived with flowering plants. Furthermore, it is likely that this gymnosperm-dinosaur biome was located at a lower altitude to the angiosperm-human biome, because the inference from Scripture is that the Garden of Eden and surrounding areas were at a high point geographically, as the river that flowed out of Eden split into four rivers in the surrounding areas (Genesis 2:10-14), and water flows downhill.

The existence of springs on the sea floor is mentioned in Job 38:16, which must surely identify the nature of some of the "fountains of waters" referred to in Revelation 14:7. For much of the Precambrian rock record, the only fossils found are generally dome-shaped structures known as stromatolites, which are made up of layers of organic material alternating with sediment particles, often lime sand. Indeed, these fossilized stromatolites are prolific in the Proterozoic portion of the geologic record, but are virtually absent from the Cambrian upwards. They have only survived to be relatively rare and small in the present world, where they tend to grow in extreme environments, such as hot springs or salty bays. The organic layers of modern stromatolites are composed of communities of cyanobacteria or blue-green algae that grow as an organic mat on a limey sediment surface, where they would provide food for any browsing animals that could survive in the hot and salty conditions. Since the springs on the ocean floor today are salty, hot water (hydrothermal) springs, and since the fossilized stromatolites are usually preserved in limey sedimentary rocks that also show signs of having been deposited from hydrothermal waters, it seems reasonable to postulate a stromatolite hydrothermal biome in the pre-Flood world.[3] Indeed, the limestones of the Precambrian rock record are dominated by dolomites (magnesium-rich limestone), rather than the

2 Wise, 2002, 173-174.

3 Wise, 2002, 174-175; K. P. Wise, 2003, The hydrothermal biome: a pre-Flood environment, in *Proceedings of the Fifth International Conference on Creationism*, R. Ivey, ed., Pittsburgh, PA: Creation Science Fellowship, 359-370; K. P. Wise and A. A. Snelling, 2005, A note on the pre-Flood/Flood boundary in the Grand Canyon, *Origins (Geoscience Research Institute)*, 58: 7-29.

usual limestones that are calcium-rich, and this is a puzzle that is solved once it is recognized these dolomites were deposited from hydrothermal springs.

The peak occurrence of fossilized stromatolites in the Precambrian rock record is in the middle to upper Mesoproterozoic and the Neoproterozoic, from around 1,400 to 600 million years ago in conventional dating (see Figure 20), which is the level in the rock record that seems to equate to sedimentation on the pre-Flood ocean floor. Many sites where fossilized stromatolites are found in these sediments tend to have a lot of evidence of hot spring activity, and seem to be located near what could have been the margins of the pre-Flood continent(s). It is thus postulated that around the pre-Flood continent(s) there existed offshore a long, wide zone of hot springs, which generated ideal living conditions for algae and bacteria to produce extensive fringing stromatolite reefs. These springs may have been related to the "fountains of the great deep" that were broken up at the onset of the Flood (Genesis 7:11). That catastrophic break-up would have destroyed those stromatolite reefs, and the hot springs, so that those stromatolite reefs no longer exist in the present world. The influence of these hot springs upon sedimentation on the pre-Flood ocean floor is also potentially illustrated by the occurrence of hydrothermally-deposited banded-iron formations in this part of the geologic record (see Figures 10 and 26). Furthermore, the offshore stromatolite reefs would have protected a lagoon between the reefs and the shoreline, where many multicellular organisms would have lived, leaving traces of their existence in the quiet sedimentation on the shallow sea floor, and perhaps occasionally their remains were buried and fossilized (see Figure 21).

The existence in the pre-Flood world of these distinct and geographically separated biological communities or biomes suggests that there was strong ecological zonation related to altitude, topography, and climatic zones. This would have its ramifications subsequently, when during the Flood the waters steadily rose up onto the pre-Flood continent(s) to progressively inundate these biomes and fossilize their animals and plants. This may potentially explain the order we see in the fossil record (to be further discussed later).

Geologic Activity in the Pre-Flood World

While the Scriptures are obviously silent on this issue, because of their abbreviated description of earth history (three chapters describing more than 1,650 years), it is still possible to infer that the pre-Flood earth was stable with no major catastrophe, and the geologic record would seem to confirm this. We are told in Genesis 7:11 that the Flood began with the breaking up of "the fountains of the great deep," a vivid description of catastrophic geologic activity. This implies that whatever caused this "breaking up" was restrained in the pre-Flood world. The Hebrew phrase translated "the great deep" is used in Scripture to refer to both oceanic and subterranean waters (Isaiah 51:10 and Psalm 78:15, respectively),[4] so as indicated previously, "the fountains of the great deep" were oceanic and terrestrial springs that clearly tapped the plentiful waters then residing within the earth's crust. Thus, the geologic activity referred to by the term "breaking up" must imply deep fracturing of the earth's crust, dramatic earth movements, and devastating earthquakes. Such geologic activity on a global scale must have been restrained and thus absent in the pre-Flood world.

Nevertheless, we cannot be so dogmatic about geologic activity in the pre-Flood world on a local scale, except to infer from the geologic record that any such activity had to be mild in its effects, otherwise there would have been some destruction of larger multi-cellular organisms, which would thus be found in the geologic record pertaining to this era. The fossil record in the Mesoproterozoic and Neoproterozoic consists almost exclusively of stromatolites, whose fossilization and preservation was a consequence of their growth in the sediments being deposited adjacent to the hydrothermal springs, due to the precipitation of calcium and magnesium carbonates and silica from the spring waters, and detrital material being washed onto the shallow sea floor from the adjacent land surfaces by rivers and tidal action. There is thus good reason to suppose that there was an ongoing steady accumulation of thick sequences of sediments on the pre-Flood ocean floor, especially carbonates and cherts in association with hydrothermal springs, but with the detrital contribution from weathering and erosion of the pre-Flood land surface. Where the prolific moist climatic conditions occurred, continuing deep chemical weathering would have been facilitated, and both the springs and the rainfall would have facilitated erosion of detritus into the pre-Flood rivers, which washed the sand, silt, and mud out to the ocean, just as happens in the present world. Nevertheless, the unique catastrophic conditions necessary for burial and fossilization of larger multi-cellular organisms were absent. Only bare traces of the passage across the sea floor of the occasional browsing organism have been preserved in the resulting rock record.

It is abundantly evident that by the time of the Flood there was a significant thickness of all types of sediments available on the earth's surface.[5] There are three reasons for believing this to be the case. First, the biologically optimum terrestrial and marine environments created during the Creation Week would have resulted in at least a small amount of sediment of each type having been created, in just the same way as God prepared the soil on the land surface for the plants He then created. Second, Archean and Proterozoic sediments, most of which date from the Creation Week and pre-Flood eras, contain substantial quantities of all types of sediments. Third, there is the practicality that it may not be possible to derive all the Flood sediments from igneous and/or metamorphic precursors by chemical

4 Whitcomb and Morris, 1961, 242; D. M. Fouts and K. P. Wise, 1998, Blotting and breaking up: miscellaneous Hebrew studies in geocatastrophism, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 222.

5 Austin et al, 1994, Catastrophic plate tectonics, 611.

weathering and physical erosion processes in the course of a single year-long flood. Indeed, substantial quantities of very fine detrital carbonate sediment must have existed in the pre-Flood oceans, primarily because not enough bicarbonate could have been dissolved in the pre-Flood ocean waters to produce the carbonate strata deposited during the Flood, unless substantial quantities were provided by outgassing of mantle and crustal fluids during the Flood. The existence of large quantities of mature, or nearly mature, pre-Flood quartz sand would certainly explain the otherwise puzzling clean, mature nature of the sandstones in the early Paleozoic portion of the geologic record, deposited early in the Flood (see below).

If as suggested such large quantities of very fine detrital carbonate sediments existed on the pre-Flood ocean floor, then there would have been a substantial chemical buffer in the pre-Flood ocean, perhaps contributing to very stable pre-Flood ocean water chemistry. This in turn would suggest that the water in the pre-Flood ocean was somewhat salty. However, just how saline is unknown. Salt crystals have been found in sedimentary strata that are believed to have been sediments on the pre-Flood ocean floor, but it may be that the salinity was only high in the region where these sediments were deposited in proximity to the hydrothermal springs.[6] Alternately, if the oceans were originally created with fresh water, then their saltiness today could have been caused during the Flood with all the volcanic emissions and erosion. However, it is more likely the pre-Flood oceans were originally saline, though not as salty as the ocean waters are today. Organisms that can only live in salt water today, for example, are very common as fossils in the sedimentary strata attributed to the Flood. Nevertheless, the many varieties of each kind of organism we see today are testimony to the fact that organisms were created with great potential for change. Thus, we find that some kinds of organisms have varieties that live in fresh water today and have closely related varieties that live in salt water, while some organisms can live in both fresh and salt water, and some can even migrate between the two. Thus, it is entirely possible that freshwater organisms before the Flood were able to adapt to salt water after the Flood. However, it is most likely the pre-Flood ocean water was salty, not only because of the evidence of saltiness found in pre-Flood sediments, but because this would require less biological transformation after the Flood.

While it is clearly evident that extensive sedimentation occurred on the pre-Flood ocean floor, it is not possible to be as dogmatic about the level of volcanic and/or tectonic activity in the pre-Flood world. Obviously, any volcanic or tectonic activity in the pre-Flood world would have to have been minimal, so as not to threaten the human population, at the very least. However, there must have been some volcanic activity, because we do find the remains of lava flows buried among the pre-Flood sediments, and there appear to be granites and other igneous rocks intruded into them. This is consistent with the operation of the hydrothermal springs ("fountains of the great deep") that would have required active heat sources

6 Wise, 2002, 152; Wise and Snelling, 2005.

to drive their water flow, in much the same way as hot water springs do today. Minor igneous activity in the pre-Flood world is not unreasonable as an aftermath to the much more extensive volcanic and igneous activity that must have occurred early in the Creation Week, during the formation of the earth's crust and the building of the dry land, as is evident from the rock record pertaining to that period of earth history. Perhaps most or all the volcanic and intrusive activity, and the associated tectonic movements, occurred in the ocean basins, and the areas proximal to the continental margins.

What is abundantly clear from the geologic record pertaining to the pre-Flood era is that much geologic activity, including the erosion and deposit of sediments, could in no way have been catastrophic in intensity or in geographical extent, for otherwise conditions suitable for fossilization would have resulted. Indeed, the most significant aspect of the pre-Flood geologic record is the almost total absence of fossilized organisms. Thus, in spite of erosion and deposition of sediments, and occasional somewhat muted volcanic, intrusive, and tectonic activity, the affects of these geologic processes were either sufficiently reduced in intensity, or remote geographically, to have had no destructive effect on all pre-Flood animal and plant life, except for some bacteria and algae, and some microorganisms. Nevertheless, in spite of the comparative quiescence geologically of the pre-Flood era, implied by the brief biblical record of it, there must still have been a steady build-up during the pre-Flood era of heat, magmas, and tectonic forces, held under restraint in readiness to be catastrophically unleashed at just the precise moment in earth and human history to trigger the Flood judgment under God's ultimate control.

86

The Flood—A Global Tectonic Catastrophe

There can be no doubt as to exactly how the Flood began, because the Scriptures give us a vivid description of the defining moment. In Genesis 7:11 we read, "The same day were all the fountains of the great deep broken up, and the windows of heaven were opened." Here the Bible claims that all these fountains were broken up on a single day to trigger the commencement of the Flood, the major geologic event in the history of the earth, second only to the creation of the earth itself during the Creation Week. The sense of the Hebrew word for "breaking up" appears to be that of cleaving open and shattering of the earth's crust. The description in Genesis 7:11 would also seem to imply that breaking up the earth's crust around these fountains almost simultaneously triggered the opening of "the windows of heaven," or the flood-gates, resulting in global torrential rainfall for forty days and nights.

As to exactly what was responsible for causing "the fountains of the great deep" to be broken up, the Scriptures are silent. Therefore, this has been the subject of much speculation, both reasonable and fanciful. Suggestions have included the passage of the earth through a meteorite storm, and sudden volcanic explosions that propelled large amounts of volcanic dust high into the atmosphere,[1] the impact or near-miss of an astronomical object(s), such as asteroids, meteorites, a comet, another moon of the earth, or even Venus, Mars, or Jupiter,[2] the natural collapse of rings of ice that were once around the earth, or perhaps even just radioactive heat build-up within the earth until a critical level was reached.[3] Of course, it cannot be ruled out that God directly intervened.[4] In any case, whether

1 Whitcomb and Morris, 1961, 258.

2 D. W. Unfred, 1984, Asteroidal impacts and the Flood-judgment, *Creation Research Society Quarterly*, 21 (2): 82-87; W. S. Parks, 1989, The role of meteorites in a creationist cosmology, *Creation Research Society Quarterly*, 26 (4): 144-146; D. W. Patten, 1966, *The Biblical Flood and the Ice Epoch: A Study in Scientific History*, Seattle, WA: Pacific Meridian; R. L. Whitelaw, 1983, The fountains of the great deep and the windows of heaven: a look at the canopy theory, and a better alternative, in *Science at the Crossroads: Observation or Speculation?,* Papers of the 1983 National Creation Conference, Minneapolis, MN: Bible-Science Association, 95-104.

3 J. F. Henry, 1992, Space age astronomy confirms a recent and special creation, in *Proceedings of the 1992 Twin-Cities Creation Conference*, St. Paul, MN: Twin Cities Association, 88-90; For full referencing of all these and other suggestions, see Austin et al, 1994, 609-621.

4 G. R. Morton, 1980, Prolegomena to the study of the sediments, *Creation Research Society Quarterly*, 17 (3): 162-167; G. R. Morton, 1987, *The Geology of the Flood*, Dallas, TX: DMD.; J. R. Baumgardner, 1987, Numerical simulation of the large-scale tectonic changes accompanying the Flood, in *Proceedings of the First International Conference on Creationism*, vol. 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 17-30; J. R. Baumgardner, 1990, 3-D finite element

God directly or indirectly intervened, numerous Scriptures insist that God was (and is) always ultimately in control according to His sovereign will, even if some apparently natural means was involved. The result was the same—catastrophic cracking and movement of the earth's crust surrounding springs on the pre-Flood ocean floor and possibly also the land surface, which by implication produced a simultaneous release and outpouring of water, steam, and molten rock, with the accompanying explosions blasting volcanic ash and pulverized rock into the earth's atmosphere, where it would have combined with the steam and water to produce heavy, sustained rainfall.

A Global Tectonic Catastrophe

Tectonics refers to the development and relationship of the larger structural and deformational features of the broad architecture of the outer part of the earth. Thus, given the description in Genesis 7:11 of the breaking up of the earth's crust wherever the fountains or springs were located qualifies as a significant tectonic event. The earth's cold outer layer, known as its *lithosphere*, is broken into a number of different pieces or plates that today exhibit imperceptibly slow residual movement along their boundaries relative to one another. At these boundaries, or adjacent to them, the motions of the plates relative to one another generate earthquakes and volcanic activity. The theory of plate tectonics has been developed to describe and explain the motion of these plates and has been successful in building a consistent explanation of many of the earth's current surface, and internal structural and geophysical, features.[5] The fact that the case is strong that all the present igneous ocean floor has been formed by sea floor spreading at mid-ocean ridges since much of the fossil-bearing sedimentary rock sequence had already been deposited on the continents means that a large amount of sea floor spreading and plate motion must logically have been an integral part of the Flood catastrophe. This implies that the entire pre-Flood ocean floor and much of the sea floor formed during the early stages of the Flood must have been recycled into the earth's interior in a very rapid manner. It can be shown that the gravitational potential energy associated with the pre-Flood ocean lithosphere is indeed capable of driving such a cataclysm. This model for the global Flood catastrophe has come to be called *catastrophic plate tectonics*,[6] with the gradual motions of crustal plates today being merely residual effects of the cataclysm.

To understand how plate tectonics theory might be a viable framework for understanding the global Flood tectonic catastrophe, it is important first to describe the essential elements of that theory as it pertains to present-day observations. In

---

simulation of the global tectonic changes accompanying Noah's Flood, in *Proceedings of the Second International Conference on Creationism*, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 35-45.

5 K. C. Condie, 1997, *Plate Tectonics and Crustal Evolution*, fourth edition, Oxford, UK: Butterworth Heinemann.

6 Austin et al, 1994.

today's ocean basins are found broad linear chains of mountains, approximately midway between the continents. These are called mid-ocean ridges, and they extend throughout the ocean basins, linking up with one another to encircle the globe. At the axes of these mid-ocean ridges are rift valleys, which are the sites of volcanic activity accompanied by earthquakes. The elevation of the mid-ocean ridges is due to uplift caused by hotter than average mantle rock beneath them These higher temperatures are the result of hot mantle rock rising from below to fill the gap caused by the diverging plates on either side of the ridge. Because the melting temperature of silicate minerals decreases with decreasing pressure, as this hot mantle rock rises, some of the minerals in the rising rock find themselves above their melting points, so they begin to melt and separate from the remainder of the rock, before the melting point of the entire rock is reached. The resulting partial melt does not contain all the minerals of the original rock, so it has a different composition. The lavas produced by the volcanic activity along the mid-ocean ridges are basalts, which have been demonstrated in the laboratory to form from the partial melting of the rocks that are known to exist in the earth's upper mantle. Thus, according to plate tectonics theory, mantle rock rising beneath the mid-ocean ridges undergoes partial melting along the rift zones at the mid-ocean ridge axes, and the resulting melt of basaltic composition is intruded and extruded to form new oceanic crust. The axial zones of the mid-ocean ridges are thus the boundaries between crustal plates on either side of them. New basaltic crust forms there as the plates on either side move apart from the axial rift zones, in what is thus known as sea floor spreading. Thus, the entire ocean floor underneath the thin veneer of sediments consists of basaltic oceanic crust, which is older the further away it is from the axes of the mid-ocean ridges. Just as the volcanic activity along the axial rift zones is fed by molten basalt from partially melted mantle rock, so likewise are other volcanoes across the ocean floor fed by basalt from partially melted mantle rock below them to produce the basalts that make up those volcanoes and volcanic islands (e.g., the Hawaiian Islands).

As the newly-forming oceanic lithosphere, capped with an approximately six-kilometer-thick basaltic crust, moves away from the active ridge, it cools, contracts, becomes denser, and therefore begins to sink and become lower in elevation relative to the active ridge. Ocean lithosphere consists of the surface layer of basaltic crust and a layer beneath it of relatively cool mantle rock that can vary in thickness from zero near the ridge axis to as much as 80 km at about 2,000 km or more away. The base of the lithosphere is defined by the transition from strong, mostly elastic/brittle behavior to weaker more plastic behavior due to higher temperature. As the oceanic lithosphere cools, shrinks, and ages as it spreads away from the mid-ocean ridge, any volcanoes on it that once stood up above the ocean water surface eventually sink also, becoming extinct as they are covered by ocean water to produce submarine mountains, or seamounts. If wave action erodes away their peak leaving them with a flat top, these seamounts are known as *guyots*. The older the oceanic lithosphere gets as it spreads away from the mid-ocean ridges, the more time there is for sediments to accumulate over it, so we observe that the total sediment thicknesses and the ages of the deepest sediments increase away from the mid-ocean ridges.

Since the warm oceanic lithosphere at the mid-ocean ridges is only newly formed, it has only cooled to shallow depth. Thus, the earthquakes that occur along the mid-ocean ridges, as a result of the masses of solid rock moving past one another, are restricted to shallow depths. As expected, these earthquakes along the ridge axes are extensional, reflecting the separation of the plates. It is common for a ridge axis to display abrupt jumps or offsets. Such offsets between segments of ridge axis create what are known as fracture zones. The sections of lithosphere on opposite sides of a fracture zone between segments of ridge axis move in opposite directions. As predicted by plate tectonics theory, the earthquakes caused by movement of the rocks sliding past one another along these features are restricted to the portions of the fracture zones found between the active spreading ridges, because only here does the side-by-side motion of the rocks occur.

A minor mineral within basalts is magnetite, an iron oxide mineral that is magnetic. As the molten basalt cools, magnetite grains form, and as they do they become magnetized in the direction of the earth's magnetic field prevailing at that time. Consequently, new basaltic oceanic crust forming in the rift zones along the spreading axes of the mid-ocean ridges records the present direction of the earth's magnetic field. As the newly formed crust moves away in both directions from the ridge because of sea floor spreading, the crustal rock at equal distance on either side of the spreading axis represents basalt formed at the same time and therefore will display the same orientation of its magnetic minerals. If the earth's magnetic field then changes its orientation, the magnetism recorded by the basalts forming at the spreading axis likewise changes its orientation. Many independent lines of evidence indicate the earth's magnetic field has reversed it polarity numerous times in the past. Multiple reversals have produced a series of bands (or stripes) of alternating magnetic orientations recorded in the basaltic ocean crust paralleling the mid-ocean ridges, and these parallel bands display a high degree of symmetry on opposite sides of the ridge. It was the discovery of this symmetric pattern of stripes of rock magnetized in alternating directions on opposite sides of the mid-ocean ridges in the early 1960s that provided some of the early persuasive support for the concept of sea floor spreading.

As the oceanic lithosphere cools, it becomes increasingly denser relative to the mantle rock beneath it, because of its cooler temperature. However, continental lithosphere has a much lower average density than oceanic lithosphere and also the underlying mantle because of the layer, typically about 35 km thick, of buoyant continental crust it includes that typically lies above a layer of cool mantle rock to form the lithospheric slab. Continental crust has a granitic composition that is typically about 20 percent less dense than mantle rock at the same temperature. The low density of the continental crust causes a column of continental lithosphere to "float" higher in the mantle than an equal mass column of oceanic lithosphere. This maintains continental land surfaces about 4 to 5 kilometers higher than the ocean bottom, and above sea level. On the other hand, because cold oceanic lithosphere is so much denser than the mantle beneath it, it has the natural tendency to peel away and sink into the mantle. This process is called *subduction*.

Where an oceanic plate plunges into the mantle, the ocean floor is also pulled downwards and becomes depressed to produce a long linear feature known as an ocean trench. That subduction is indeed occurring today is confirmed by the earthquakes generated as sinking slabs enter into the mantle. These earthquakes originate at the depths where the top of the sinking oceanic slab slides beneath the adjacent plate. As expected, the depths of these earthquakes increase as one moves beyond the trench in the direction of subduction. These earthquakes are compressional, as expected. The crustal portion of the subducting slab contains a significant amount of surface water, as well as water contained in hydrated minerals within the basalt itself. As the subducting slab descends to greater and greater depths, it progressively encounters greater temperatures and greater pressures that cause the surface rocks to release water into the mantle wedge overlying the descending plate. Water has the effect of lowering the melting temperature of the mantle wedge, thus causing it to melt. The magma produced by this mechanism varies from basalt to andesite in composition. It rises upward to produce a linear belt of volcanoes parallel to the oceanic trench. A good example of this is observed in the volcanoes of the Andes of South America, which parallel the trench offshore along the adjacent western coastline.

These and many other features of the present-day earth are explained by the theory of plate tectonics, particularly the geology and features of the earth's ocean basins. This huge number of diverse geological features readily explained by plate tectonics theory gives confidence in projecting motions of the earth's current plates backward in time. That plate tectonics is not only active today, but has been active in the earth's past, is indicated by the increasing "ages" of rocks on the ocean floor away from the mid-ocean ridges, and the accompanying parallel stripes of rocks magnetized with alternating magnetic polarity.

Furthermore, there is abundant evidence on the continents that they have moved across the earth's surface relative to one another. For example, it has long been recognized that the continents on either side of the Atlantic Ocean have complementary shapes, suggesting that at some time in the past they formed a single supercontinent, which subsequently broke apart, and as the continental fragments drifted apart, the Atlantic Ocean basin was formed. Supporting this conclusion are many geological features that can be matched across the continents on either side of the Atlantic Ocean, but are not found on the ocean floor. These include almost identical rock strata, fossils, directions of sediment transport, the occurrence of mountain fold belts, and mineral deposits. There are similar matchings between Antarctica and Australia, and between Antarctica and India.

Between the continents on either side of the Atlantic Ocean, and between these other continent pairs, there are mid-ocean ridges and ocean sediments that increase in "age" away from those ridges. Moreover, these ridges and ocean sediments are younger than the geological features that match on the continents on either side of the ocean basins. This is precisely the evidence we would expect to find had these continents once been together but later became separated, with the generation of new oceanic crust as a result of sea floor spreading between them.

Further evidence in continental rocks for the movement of continents across the earth's surface is the history of the directions of the earth's magnetic field preserved in continental rocks. This record of changing magnetic field directions indicates that the continents have moved with respect to the earth's magnetic poles. The relative motions implied by this record of rock paleomagnetism are called polar wander curves, because they were interpreted originally to be a result of movements of the earth's magnetic poles with respect to the continents. However, it was then discovered that, if the continents themselves are assumed to have been motionless, the polar wander curves from different continents were in conflict with one another. If, on the other hand, the continents have moved with respect to one another, as indicated by much geological evidence, but the magnetic poles have remained nearly fixed in position, then it was found that the polar wander curves coincide, just as one would expect from plate tectonic theory.

Given the vast explanatory power that the plate tectonics theory provides in accounting for so many of the presently observed features of the earth, can this theory also provide any insights for what happened during the Flood, which, based on the scriptural description, certainly appears to have involved global tectonic upheaval? Because the same natural laws that govern the operation of geologic processes today may well have been in operation during the Flood, it is possible that the geologic processes and events that occurred during the Flood may be geological processes and events that we are familiar with today, except that during the Flood they operated on larger and more rapid scales. It is noteworthy that, even though the plate tectonics theory has been successful in explaining many diverse geological features, other geological evidence cannot so simply be explained by projecting present plate motions and processes uniformly back into the past. For example, in some ocean trenches the sediments are flat-lying and undisturbed, rather than being deformed due to ongoing plate motion as predicted by standard plate tectonics theory. Also, all the high mountain ranges of the world, including the Himalayas, Alps, Andes, and Rockies, rose at an extremely high rate during the Pliocene/Pleistocene epochs, in conflict with the near constant plate motions assumed by standard uniformitarian plate tectonics theory. Such evidences are sometimes used as reasons to reject plate tectonics completely, but a better explanation appears to be that plate tectonics operated differently during and immediately after the Flood than it does today.

87

Catastrophic Plate Tectonics—The Driving Force of the Flood

As has been pointed out earlier, many lines of evidence indicate that the basaltic crust of all today's ocean floor is younger than the Paleozoic portion of the continental fossil-bearing sediment record. This, together with the convincing evidence that the basaltic oceanic crust forms at mid-ocean ridges as the direct result of sea floor spreading, means that the case is strong that the Flood catastrophe, if the fossil record represents its signature, involved a huge amount of sea floor spreading. It logically implies that all the pre-Flood ocean lithosphere was recycled into the earth's interior during a few month's time, which in turn means that rapid plate motions and tectonic catastrophism occurred on a vast scale during the Flood.[1] Cold dense ocean lithosphere lying above much hotter and therefore less dense mantle rock beneath it represents a huge store of gravitational potential energy. The rapid sinking of the pre-Flood ocean lithosphere to the base of the mantle transforms this vast store of potential energy into heat and mechanical work. Even a tiny fraction of this energy unleashed at the earth's surface is capable of driving a staggering amount of geological process. Because plate tectonics processes account for so many of the earth's physical characteristics largely independent of the rates of these processes, it is proposed here also that a catastrophic version of plate tectonics, which we refer to as catastrophic plate tectonics, is a viable model that can plausibly explain the processes that operated during the Flood to produce the geologic record.

But a critical issue is how the mantle of the earth could possibly become weak enough to allow slabs of oceanic plate to sink through it in only a matter of a few weeks. On timescales on the order of a second or so, that is, on the timescales of seismic waves, the elastic strength of mantle rock is almost that of steel! This result, recognized in the early days of seismology, is obtained simply and directly from the speed of seismic waves through the earth. On longer timescales, however, mantle rock deforms in a plastic manner by the migration of defects at the atomic level, via a class of processes known as solid-state creep. One can characterize the strength of mantle rock in this creep deformation regime in terms of a shear

1 Austin et al, 1994, 609-621.

viscosity.

There are multiple ways for estimating the viscous strength of mantle rock. One approach is to measure the properties of its constituent minerals, or even entire samples of the rock itself, in the laboratory under the appropriate temperature and pressure conditions. Another approach has been to infer the viscous strength of the upper mantle from observations of glacial rebound rates in areas that were heavily glaciated during the Ice Age. Peak uplift rates in these areas are observed to be about 1 cm/year. Similarly, one can infer the average viscosity over the full depth of the mantle from observed surface plate velocities, which today are on the order of a few centimeters per year, by making just a few assumptions about the thermal contrast between the lithospheric plates and the mantle. The inferred average value for the mantle using this approach is approximately 10^{22} Pa-s. With the perspective that the present is the key to the past, uniformitarian earth scientists generally are persuaded that plate velocities in the past must have been not much different from the plate velocities observed today because they cannot conceive how the strength of mantle rock could have changed in any significant way since early in the earth's history.

But laboratory measurements on the behavior of mantle minerals under mantle conditions of stress and temperature also reveal that mantle rock can weaken dramatically, by some ten orders of magnitude, under the sorts of stress levels that can arise inside a planet with the mass and composition of the earth. These laboratory studies of the deformation properties of silicate minerals have been performed and their results duplicated in many different laboratories around the world over the past forty years. But how might these results apply in the context of the Flood? The answer is straightforward. The combination of a gravitational body force acting on a cold slab of ocean lithosphere that possesses potential energy to release as it sinks within a lower density medium that weakens as the stress level increases provides the essential elements needed for an episode of runaway sinking. If the initial conditions allow the slab to begin sinking at a rate sufficient to heat the material immediately surrounding the slab at a rate that exceeds the rate of heat loss by thermal diffusion, this surrounding zone weakens, allowing the slab velocity to increase, which increases the stress level, which weakens the zone further, which allow the slab velocity to increase further, ultimately resulting in sinking rates many orders of magnitude higher than the normal strength of the rock would allow.

At least as far back as the early 1960s it has been known that the phenomenon of thermal runaway can potentially occur in materials whose effective viscosity is described by an Arrhenius-like relationship, in which the viscosity varies as $e^{(E^*/RT)}$, where T is absolute temperature, E* is the activation energy, and R is the gas constant. A large variety of materials, including silicate minerals, have viscosities that vary with temperature in this manner. In 1963 Gruntfest showed for a layer subject to constant applied shear stress and a viscosity with Arrhenius temperature dependence, both the deformation rate and the temperature within the layer can increase without limit, that is, run away.[2] The criterion for runaway to occur is that the time constant associated with viscous heating be much less than the characteristic thermal diffusion time of the layer.

Several investigators in the late 1960s and early 1970s explored the possibility of thermal runaway of lithospheric slabs in the mantle. Anderson and Perkins,[3] for example, suggested that the widespread Cenozoic volcanism in the southwestern U.S. might be a consequence of thermal runaway of chunks of lithosphere in the low-viscosity upper mantle. They conjectured that surges of melt associated with such runaway events might account for episodes of volcanism observed at the surface. Lithospheric slabs, because they display an average temperature some 1,000 K or more lower than that of the upper mantle but have a similar bulk chemical composition, are several percent denser than the surrounding upper mantle rock and therefore have a natural ability to sink. The gravitational body forces acting on a slab lead to high stresses, especially within the mechanical boundary layer surrounding the slab. As a slab sinks, most of its gravitational potential energy is released in the form of heat in these regions of high deformation. If conditions are right, the weakening arising from heating can lead to an increased sinking rate, an increased heating rate, and greater weakening. This positive feedback associated with thermal weakening can result in runaway, provided the criterion mentioned above is met.

Baumgardner[4] more recently has emphasized that silicate minerals weaken not only with increasing temperature, but also—and even more dramatically—with increasing levels of stress. He makes the point that the stress weakening leads to a spectacularly stronger runaway tendency. Baumgardner describes studies performed by many laboratories over the past forty years to measure the way silicate minerals deform under a wide range of temperature and stress conditions. He focuses attention on the fact that these laboratory studies demonstrate that silicate rocks can weaken by ten or more orders of magnitude for temperature and stress conditions that can exist inside the mantle of a planet like the earth. Baumgardner presents numerical results, using a viscosity law that depends both on temperature and on stress, which show that slab runaway causes the effective viscosity of the entire volume of the mantle to plummet by orders of magnitude

2 I. J. Gruntfest, 1963, Thermal feedback in liquid flow; plane shear at constant stress, *Transactions of the Society for Rheology*, 8: 195-207.

3 O. L. Anderson and P. C. Perkins, 1974, Runaway temperatures in the asthenosphere resulting from viscous heating, *Journal of Geophysical Research*, 79: 2136-2138.

4 J. R. Baumgardner, 2003, Catastrophic plate tectonics: The physics behind the Genesis Flood, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 113-126.

during the runaway episode. Therefore, motions throughout the mantle, far from the immediate vicinity of the slab, rise to values similar to that of the sinking slab itself. Thus, instead of viscosities on the order of 10^{22} Pa-s inferred for the mantle today, these numerical studies indicate that viscosities some ten orders of magnitude smaller, on the order of 10^{12} Pa-s, can occur through large portions of mantle during a runaway event. This allows a slab of lithosphere to sink through the depth of the mantle in a matter of weeks instead of requiring on the order of a hundred million years.

So what about the actual Flood? Given the catastrophe to follow, on the day the Flood began it is at least conceivable that the earth was balanced critically on the edge of that catastrophe. Today, seismic images of the mantle show evidence of lithospheric slabs penetrating from the surface all the way to the core-mantle boundary only in an extremely limited area. Beneath most subduction zones there is little, if any, slab signature evident in the lower mantle, except for what appears to be a quite prominent slab graveyard at the very bottom. Although seismic imaging does show slab material beneath subduction zones in most of the upper mantle, the amount of slab material is certainly not sufficient to lead any earth scientists to have any concern about impending runaway. By using the present as the key to the past, conventional plate tectonics theory assumes the relatively small amount of slab present in the upper mantle involved with the very slow plate motions observed in the present world also characterizes the past. On the other hand, the thermodynamics of phase transitions that occur at about 600 km depth (the base of the upper mantle) are such that motion of a cold slab from the upper mantle into the lower mantle is impeded, though not prevented. Thus, there is a tendency for cold slab material to pond at this depth. It is therefore not beyond the realm of possibility that in the original earth that God created there was a ring of cold mantle rock, representing ocean lithosphere subducted on Day Three of creation when the waters that were below the heavens were gathered together into one place and the dry land appeared, rock that lay just above this phase boundary in the upper mantle and below the perimeter of the large newly emerged land mass. Because this cold rock would have been gravitationally unstable, held in check only by the resistance of the phase boundary, the earth could be viewed as being on the knife edge of catastrophe. Very little would have been required to lose it on a trajectory leading to the Flood cataclysm. Perhaps that release occurred at the time of the Fall and was so subtle that it was undetectable at the earth's surface. It would then take another 1650 years or so for gradual motions suddenly to give way to runaway catastrophe.[5] The runaway sinking of this cold ring of rock in the upper mantle, in turn, pulled in the oceanic slabs at the dormant subduction zones surrounding the pre-Flood continent, splitting apart the mid-ocean ridges, causing "all the fountains of the great deep" to be "broken up" or "cleaved apart." Numerical modeling of various aspects of the ensuing physical

5 M. F. Horstemeyer and J. R. Baumgardner, 2003, What initiated the flood cataclysm?, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship,.155-163.

processes shows that a global Flood similar to that described in the Scriptures is the inevitable result.[6]

The numerical modeling reveals that, because the amount of deformational heating that arises during the runaway is proportional to the viscosity, the drastically reduced viscosity that accompanies the runaway and indeed makes it possible also reduces the deformation heating drastically to quite modest levels, such that little melting of the mantle occurs.

Because all the current oceanic crust seems to date from the Flood and post-Flood times, it is apparent that essentially all the pre-Flood oceanic lithosphere was subducted during the Flood. The gravitational potential energy released by the subduction of this oceanic crust would have been on the order of 10^{28} joules. This alone would probably have provided all the energy necessary to drive all the tectonic and geologic processes of the Flood event. The continental fragments on the same plates as the subducting slabs of oceanic crust would have been pulled toward the subduction zones, resulting in rapid horizontal displacement of these continental fragments at a rate of meters per second (several miles per hour). Subsequent collisions of continental fragments at subduction zones are the likely mechanism for the formation of mountain fold-and-thrust belts, such as the Appalachians, Himalayas, and the European Alps. The rapid deformation, burial, and subsequent erosion of early-formed mountain belts within the year of the Flood, at this orders of magnitude acceleration of geologic processes, would seem to provide the only adequate explanation for the existence of high-pressure, low-temperature minerals in the rocks in the cores of these deeply eroded mountain belts.

The subducting slabs of oceanic lithosphere, according to the catastrophic plate tectonics framework, would have sunk rapidly all the way to the bottom of the earth's mantle, accompanied by equally rapid large-scale flow throughout the entire mantle. The leading edges of present subducting slabs of oceanic crust reach deep into the mantle under the trenches, and are under compression, suggesting that the slabs are being resisted from passing through the phase boundary at the base of the upper mantle, which would thus seem to represent a barrier. Thus,

6 J. R. Baumgardner, 1987, Numerical simulation of the large-scale tectonic changes accompanying the Flood, in *Proceedings of the First International Conference on Creationism*, vol. 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 17-30; J. R. Baumgardner, 1990, 3-D finite element simulation of the global tectonic changes accompanying Noah's Flood, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 35-45; J. R. Baumgardner,1994, Computer modeling of the large-scale tectonics associated with the Genesis Flood, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsbursh, PA: Creation Science Fellowship, 49-62; J. R. Baumgardner, 1994, Runaway subduction as the driving mechanism for the Genesis Flood, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 63-75; J. R. Baumgardner, 2003, Catastrophic plate tectonics: the physics behind the Genesis Flood, in *Proceedings of the Fifth International Conference on Creationism*, R. Ivey, ed., Pittsburgh, PA: Creation Science Fellowship, 113-126.

some conventional slow-and-gradual plate tectonics models have suggested that subduction, flow, and circulation have at certain times been restricted to the upper mantle. In any case, according to conventional plate tectonics, even if the plates were to eventually penetrate this apparent barrier at the base of the upper mantle, they would be falling so slowly that they should have mostly equilibrated thermally with the surrounding hot mantle before reaching the bottom of the lower mantle. On the other hand, numerical modeling of catastrophic plate tectonics has demonstrated that the subducted slabs of oceanic lithosphere readily penetrate through this apparent barrier into the lower mantle, and because of the runaway rate, they sunk so quickly that they would have made it all the way through to the mantle/core boundary without any significant temperature increase. Indeed, it is a prediction of the catastrophic plate tectonic model that the subducted slabs of oceanic lithosphere should still be at the core/mantle boundary today and at near their original temperature, because their sinking occurred during the Flood only a few thousand years ago. Not surprisingly, recent seismic tomography studies have mapped zones of cooler material reaching down from the ocean trenches to the bottom of the mantle along the theorized paths of past subduction. This evidence confirms that large-scale flow occurred throughout the entire mantle, while cold material at the bottom of the mantle just above the core/mantle boundary indicates that oceanic lithosphere has sunk recently all the way through the mantle. Thus, the numerical modeling and predictions of catastrophic plate tectonics have been powerfully vindicated, and the expectations of conventional slow-and-gradual plate tectonics have been contradicted.

In the catastrophic plate tectonics framework for the Flood, as soon as the ocean's crust was broken up and oceanic lithosphere began to sink, mantle-wide circulation began. One important consequence of this mantle-wide flow would have been the transportation of shallower, cooler mantle material to lower positions in the mantle, right down to the core/mantle boundary. This process would thus have created different and cooler temperatures at the base of the mantle, which in turn would have had the effect of cooling the outer core, leading to strong convection within it. Because the outer core is liquid with a consistency similar to liquid water, if there were temperature differences in various places at the bottom of the mantle above it, the core material would have begun to circulate. Significantly, the earth's magnetic field is generated in the core, and thus convective circulation in the outer core would have caused the earth's magnetic field to rapidly and regularly reverse, in much the same way as the sun's internal circulation today causes the sun's magnetic field to reverse every eleven years.[7] However, the temperature contrasts in the earth's outer core suggested by the numerical modeling would have produced the reversals of the earth's magnetic field even more frequently,

7 D. R. Humphreys, 1987, Reversals of the earth's magnetic field during the Genesis Flood, in *Proceedings of the First International Conference on Creationism*, vol. 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 113-126; D. R. Humphreys, 1990, Physical mechanisms for reversals of the earth's magnetic field during the Flood, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 129-142.

perhaps as often as a few days, a rate rapid enough to have generated most of the known reversals during the year of the Flood. Furthermore, the low electrical conductivity of the subducting plates of oceanic crust would have split up the lower mantle's high electrical conductivity, so as to have lessened the mantle's attenuation of the magnetic field reversals generated in the core. This would have thus allowed these rapid magnetic field reversals to be expressed and recorded in the rocks forming at the earth's surface.

In conventional thinking these reversals of the earth's magnetic field would have required hundreds to thousands of years to occur, in stark contrast to the timescale of days or weeks at most within the catastrophic plate tectonics model. Field observations are available to test the two models. In particular, if the magnetic reversals actually occur on timescales of days to weeks, then such reversals can potentially be recorded within thin (0.5 to 1 meter thick) basalt lava flows as they cool. This is possible, because as the lava cools, the magnetic particles that have been free in the magma to orientate themselves to the earth's magnetic field become "frozen" in place. Therefore, if the earth's magnetic field changes after the outer surfaces of the lava flows have cooled, then the insides of the flows that are still molten will, when they cool, preserve a different magnetic field direction. Since the cooling times for such lava flows are easily calculated, it is possible to determine how long it took for the magnetic field reversal to occur. Much to the surprise of conventional geophysicists, two separate such basalt lava flows that record magnetic field reversals within a span of a week or two have been identified, confirming the catastrophic plate tectonics model.[8]

As slabs of oceanic lithosphere subducted, elsewhere the tension ripped apart the pre-Flood ocean floor and produced rapid extension along globe-encircling linear belts. This rifting of the oceanic crust would have allowed mantle material to upwell, the partial melting of it producing new basaltic ocean crust as sea floor spreading progressed. Because this rifting was so catastrophic and rapid, the pressure drop experienced by the upwelling mantle material was also rapid, causing many of the minerals to find themselves above their melting temperatures, which in turn would have resulted in rapid partial melting. The hot magma rapidly rising to the ocean floor to cool as new oceanic crust would have come in contact with the ocean water, instantly forming superheated steam. Together with the volatiles degassing from the magma itself, the steam would have erupted from the V-shaped rifts on the ocean floor at supersonic speed as spectacular jets, rising high into the earth's atmosphere. These jets would have entrained large amounts of liquid sea water and carried it aloft high into the atmosphere. Thus, there would have been a linear chain of geyser-like fountains along the tens of thousands of kilometers of globe encircling mid-ocean ridge, matching closely the description provided in Genesis 7:11. The entrained water carried into the atmosphere would have then fallen back to the earth as intense global rain,

8 R. S. Coe and M. Prevot, 1989, Evidence suggesting extremely rapid field variation during a geomagnetic reversal, *Earth and Planetary Science Letters*, 92: 292-299.

which suggests that the opening of the "windows of heaven" of Genesis 7:11 is describing the rather sudden onslaught of torrential rain from the water carried aloft by the globe-encircling fountains arising out of the great ocean depths. The steam in the jets would have spread out in the earth's upper atmosphere, cooled by radiation into space, and condensed to fall back to the earth's surface again as additional rain. However, the rate at which the latent heat of condensation can be radiated away from the surface of the atmosphere is severely limited, so that the fraction of the overall rainfall resulting from condensed steam may have been relatively small. As already discussed, vapor canopy models do not appear capable of containing the water equivalent to 150 days of continuous rainfall (including the first forty days of the most intense rainfall). However, this globe-encircling chain of geysers that carry aloft huge volumes of ocean water, as postulated in the catastrophic plate tectonics model for the Flood, provide bountifully the water needed for this rainfall.

As new basaltic oceanic crust formed at the mid-ocean ridges encircling the earth, the direction of the prevailing magnetic field at the time was frozen into the basalt lava as it cooled. Conventional plate tectonics assumes that plates spread apart at a few centimeters every year and that each reversal of the earth's magnetic field takes around 1,000 years, so at these rates, only a few tens of meters of new oceanic crust should be produced during each field reversal, with a mixture of magnetic field directions preserved in it. In contrast to this comparatively brief reversal period, it is claimed that an average of a million years or more separated these reversals, during which time many tens of kilometers of new oceanic crust would have been produced with no evidence of mixed-up magnetic field directions, but instead only one uniform magnetic field direction preserved. Thus, if the conventional model were correct, amid the parallel bands of alternating paleomagnetic directions in the new oceanic crust produced by sea floor spreading, there would be far less than one percent of the ocean floor displaying mixed-up magnetic field directions. On the other hand, however, if the catastrophic plate tectonics model is correct, then because the new oceanic crust was being generated during the Flood at miles per hour, with reversals occurring on a timescale of days to weeks, it is likely that there were always patches of the oceanic crust that remained hot from one reversal to the next. Thus, this model would predict that all the ocean crust today should be magnetically mottled, with adjacent patches throughout the basalt having opposite magnetic orientations, and even vertical variations also through the oceanic crust. Indeed, such locally patchy distribution of paleomagnetic orientations does seem to exist across all of today's ocean crust, and the same mottling seems to exist vertically in the basalts of the oceanic crust in every one of the hundreds of holes drilled into them. Thus, the catastrophic plate tectonics Flood model is strongly supported by this evidence, while the same model for the earth's magnetic field uniquely explains the low intensity of the paleomagnetic data through the strata of the Phanerozoic of the geologic record, deposited during the Flood.[9]

9 D. R. Humphreys, 1988, Has the Earth's magnetic field flipped? *Creation Research Society Quarterly*, 25 (3): 130-137.

The rapid emplacement of warmer and isostatically lighter mantle material beneath the mid-ocean spreading centers would have raised the level of the ocean floor to produce a linear chain of mountains encircling the globe, similar to today's mid-ocean ridge system. Consequently, the warmer and more buoyant oceanic lithosphere would thus have displaced ocean water onto the continents, with a rise of sea level of possibly as much as one kilometer from this mechanism alone. This would thus have resulted in inundation of much of the continents, the primary objective of the Flood event. Heat from the magma emplaced at the spreading centers would have heated the ocean waters throughout the duration of the Flood. This heating is confirmed by the gradual increase in oxygen-18/oxygen-16 ratios in carbonate rock units, and in the shells and tests of fossilized invertebrates, progressively upwards through the Paleozoic and Mesozoic strata of the geologic record.

An understanding of how sediments would have been produced rapidly is critical to confirmation of the year-long Flood event having produced a significant portion of the strata in the geologic record. A major sediment type in that record are *carbonates* (limestones), and the catastrophic plate tectonics model for the Flood event provides suitable explanatory mechanisms for their production. Contributions to Flood carbonates probably came from at least four sources—carbon dioxide would have been released by degassing of the cooling magmas at the spreading centers; bicarbonate dissolved in the pre-Flood ocean water would have precipitated as the ocean water temperatures rose during the Flood (given that carbonate dissolution rates are inversely related to temperature); pre-Flood carbonates (dominant among pre-Flood sediments) would have been eroded and redeposited; and pre-Flood shell debris would have been pulverized and redeposited. The origin of micro-crystalline carbonate (micrite) in limestones is puzzling, and otherwise unknown in the conventional uniformitarian model for the formation of the geologic record. However, the ubiquity of this micro-crystalline carbonate in Flood sediments is consistent with the large-scale rapid precipitation of carbonate during the Flood from degassing magmas and from ocean-water bicarbonate, as predicted in the catastrophic plate tectonics model. Further confirmation is provided by the presence of high-magnesium carbonates (dolomites) only among the early Flood strata—the postulated carbonate precipitation would have included the magnesium, dissolved in the pre-Flood ocean water, early in the Flood.

The degassing of, and the water being expelled from, the rapidly emplaced and cooling magmas at the spreading centers and elsewhere would also have generated prodigious quantities of dissolved salts, so when these salt-laden magmatic waters mixed with the colder ocean waters, the salts would have precipitated to form cherts, fine-grained limestones, anhydrite, and salt deposits. Such rocks would be more accurately described as precipitites, that is, sediments precipitated directly from supersaturated brines. Only the catastrophic plate tectonics Flood model provides a mechanism for the generation of supersaturated brines, and thus these precipitite sediments in association with the rapid horizontal divergence of newly-generated oceanic crust. The association of rock salt and anhydrite deposits with active sea floor tectonics and volcanism has already been noted, and catastrophist models for their formation have been proposed.[10] Thus, hot-rock/ocean-water interactions during the Flood, including on the continents as they were inundated, would explain many of the bedded chert deposits and fine-grained limestones found in the geologic record, along with the many anhydrite and salt deposits.

It is evident that most of the rock strata deposited by the Flood are found on the continents and continental margins, and not on the ocean floor where sediments might be expected to have ended up (as they often do today).[11] The catastrophic plate tectonics Flood model provides a number of mechanisms for the transportation of sediments, which would have been on the pre-Flood ocean floor, onto the continents where such sedimentary strata are primarily found today. First, the rapid sea floor spreading and ocean-plate motion would have transported the ocean-floor sediments toward the subduction zones, where the slabs of oceanic crust were entering the mantle, and thus the sediments would have been moved mostly toward the continents in a conveyor-belt fashion. Second, as the weight of the oceanic lithosphere forced it to quickly bend as it sank and was subducted into the earth's interior, it would have warped upward on the ocean side of the trenches. This would have raised the deep-sea sediments of the pre-Flood ocean floor above the typical depth at which they had been deposited, and this in turn would have reduced the amount of work that would have been required to move the sediments from the ocean floors onto the continents. Third, the rapid subduction of the oceanic plates would have also warped downward the margins of the continental plates on the continent side of the ocean trenches. This would again reduce the amount of energy needed to move the sediments onto the continents from the ocean floors. Fourth, as more and more of the cold pre-Flood oceanic crust was replaced with the hotter new oceanic crust from partial melting of the upwelling mantle, the ocean floor would have generally been gradually elevated. Displacement of the ocean water, as the sea level consequently rose by the inundation of the continents, would have also reduced the depths of the ocean waters covering these pre-Flood ocean-floor sediments. This would have also reduced the amount of work required to move the sediments from the ocean floors up onto the continents. Fifth, as the oceanic crust was subducted, the ocean sediments would have been scraped off the sinking ocean floor to be accreted to the adjoining continental crust margins, and/or to be transported and redeposited on the inundated continents. Sixth, wave refraction on the continental shelves, where the shallowing water depth produces higher and higher waves and tsunamis, would have tended to transport the ocean floor sediments shoreward. Finally, seventh, it is possible that some amount of tidal resonance may have been

---

10 K. P Rode, 1944, On the submarine volcanic origin of rock-salt deposits, *Proceedings of the Indian Academy of Science*, 20 (B): 130-142; V. I. Sozansky, 1973, *Geology and Genesis of Salt Formations* (Russian), Kiev: Izd Naukova Dumka.

11 G. R. Morton, 1987, *The Geology of the Flood*, Dallas, TX: DMD.

achieved.[12] This would have resulted from the tidal surges across a global ocean eventually building on top of one another, to produce an even bigger surge with very strong currents. Such currents would have been dominantly east-to-west, and would have tended to transport any sediments accumulated on the eastern continental margins into the continental interiors.

The global Flood would have involved much larger scales for geologic processes, such that sedimentation, for example, would be expected to have impacted much larger areas, have involved much greater volumes of sediment, and moved the sediments much farther from their sources than the prevailing conventional uniformitarian view of earth history generally accepted. Significantly, the Paleozoic and Mesozoic strata consist of sediments that were often deposited in great thicknesses, with remarkably uniform compositions, extending over very large areas of regional, inter-regional, and even continental scales, and many times displaced many hundreds of kilometers from their source areas or are of unknown provenance.[13] These sedimentary units also contain abundant evidence of catastrophic deposition.[14] All these evidences are totally consistent with the catastrophic plate tectonics Flood model, and not as easily explained by the conventional uniformitarian model. Sedimentation today is very localized, with the only larger-scale deposition being on the continental shelves, particularly around deltas, and almost imperceptibly slowly on the ocean floor, none of which is comparable with the strata sequences in the geologic record, unless catastrophism is invoked. Furthermore, on the present earth, the sediments are being transported toward and within the ocean in all directions, so that the sedimentary structures that indicate the direction of currents (such as ripples marks, dune structures or drag marks) show a random pattern on every continent. However, extensive compilation of measured paleocurrent direction indicators in the Paleozoic and Mesozoic strata of the geologic record on all continents reveals that during the deposition of these rocks the water currents all around the globe were consistently flowing in one direction—more or less east-to-west.[15] These data are consistent with east-to-west-dominated currents generated by some sort of global forcing during the Flood to transport ocean floor and continental sediments such long distances and over such large areas.

12 M. E. Clark and H. D. Voss, 1985, Gravitational attraction, Noah's Flood, and sedimentary layering, in *Science at the Crossroads: Observation or Speculation?,* Papers of the 1983 National Creation Conference, Minneapolis, MN: Bible Science Association, 42-56; M. E. Clark and H. D. Voss, 1990, Resonance and sedimentary layering in the context of a global Flood, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 53-63; M. E. Clark and H. D. Voss, 1992, Resonance on flooded planet earth, in *Proceedings of the 1992 Twin-Cities Creation Conference*, St. Paul, MN: Twin-Cities Association, 30-33.

13 S. A. Austin, 1994, Interpreting the strata of Grand Canyon, in *Grand Canyon: Monument to Catastrophe*, S. A. Austin, ed., El Cajon, CA: Institute for Creation Research, 21-56.

14 D. V. Ager, 1973, *The Nature of the Stratigraphical Record*, New York: MacMillan.

15 A. Chadwick, 2001, Lithologic, paleogeographic and paleocurrent maps of the world, http:\\geology.swau.edu\index.html. This conclusion is based on 640,000 paleocurrent measurements.

The volcanism associated with the rapid tectonics of the catastrophic plate tectonics Flood model would have been substantial in magnitude and worldwide in distribution, but concentrated in particular zones and sites. Based on laboratory experiments as well as three-dimensional numerical modeling, the rapid subduction-induced mantle-wide flow rapidly generates mantle plumes, whose mushroom heads would rise to, and erupt at, the earth's surface. Thus, catastrophic plate tectonics during the Flood provides an explanation for flood basalts, kimberlites, and other extensive explosive volcanic activity that the conventional uniformitarian plate tectonics model cannot so readily explain, simply because the mantle moved so much more rapidly during the Flood than it does at the present. These rapidly upwelling mantle plumes would have produced extensive flood basalts through enormous catastrophic fissure eruptions. Flood basalts are very thick sequences of voluminous basalt lava flows that typically cover huge areas. Examples include the Karoo basalts of South Africa, the Deccan Traps in India, the Siberian flood basalts, the Parana basalts of South America and related Etendeka basalts of Africa, the Antrim Plateau basalts of northern Australia and the Karmutsen Basalt of Alaska/Canada. This correlation between the formation and upwelling of mantle plumes and the eruption of flood basalts is now well established, and various studies of many of these flood basalts have suggested very rapid eruption times, on the order of days to weeks. This is extraordinarily catastrophic, given that the basalt lava flows from these eruptions are on average 10 to 20 meters thick, and flowed out over areas of thousands of square kilometers, repeatedly over a matter of days to weeks, the successive flows being stacked on top of one another to produce lava piles hundreds of meters thick.[16] No remotely comparable eruptions and lava flows are seen today. Even one-meter-thick basalt lava flows are rare, and areal extents are typically limited to only a few tens of square kilometers. The supply of such voluminous quantities of magma within days to weeks from the mantle can only be explained by extremely rapid and catastrophic movement of these upwelling mantle plumes, and thus mantle motion much faster than at present, just as the modeling of catastrophic plate tectonics demonstrates.

Kimberlites are an unusual and rare type of volcanic rock, are usually found in pipe-like intrusions at or near the earth's surface, and often contain diamonds. They originate deep in the upper mantle, probably at depths of 150 to 400 kilometers, because it is only at those depths that the pressures are high enough to produce diamonds. After the kimberlite magmas form at those depths, they have to rise through fractures, taking any diamonds with them, to be emplaced at or close to the earth's surface. However, if the transit time is not exceedingly rapid, any diamonds in the kimberlite magmas would be unstable at the lesser pressures, and thus would transform to graphite. Thus, the emplacement of diamond-containing kimberlite magmas requires extremely rapid vertical ascent

16 S. A. Weinstein, 1993, Catastrophic overturn of the earth's mantle driven by multiple phase changes and internal heat generation, *Geophysical Research Letters*, 20: 101-104.

of the magma at speeds of 100 to 200 kilometers per hour.[17] Thus, the eruption of these kimberlites is explosive, their catastrophic ascent propelled by gases such as carbon dioxide under pressure from those mantle depths. The generation and emplacement of kimberlite magmas and their contained diamonds are thus more readily explained by the rapid motion of mantle flow during catastrophic plate tectonics.

The whole cycle of mantle-wide flow and plate motions of meters per second had been initiated by simultaneous triggering of the rifting of the pre-Flood oceanic and continental crust to produce plates, and to simultaneously commence sea floor spreading and thermal runaway subduction that reached speeds of meters per second. As slabs of the oceanic lithosphere were catastrophically subducted, not all the ocean-floor sediments were scraped from the slabs. The presence of water lowers the melting point considerably, so upon reaching depths of about 100 km, the subducted sediments readily melt. Simultaneous dehydration reactions also release water into the overlying mantle wedge that also induces some melting of the mantle rock just above the inclined subducting slab, and perhaps even melting of some of the former oceanic crust in the slab itself. Thus, various combinations of magmas rapidly generated from these sources produced explosive volcanism over the compositional range from andesites to rhyolites continent-ward of the subduction zones, such as that found today in the Andes of South America and the Cascade Mountains of the northwest United States, and, for example, through parts of the Paleozoic geologic record in southeastern Australia. The huge volumes of these lavas suggest that these eruptions were not only catastrophic, but occurred at an enormous scale, orders of magnitude greater than any comparable volcanic activity experienced today, so this evidence is again more readily explained by the catastrophic plate tectonics Flood model.

The very rapid motions of the continental portions of the lithospheric plates, as oceanic portions were subducted and new oceanic lithosphere formed at mid-ocean ridges, resulted in some cases in collision between continental blocks. The forces exerted on the lithosphere still at the earth's surface by the rapidly sinking slabs were sufficient to fold and deform rocks and to uplift them as mountains in the collision zones. As indicated previously, the gravitational potential energy released by subduction of the cold pre-Flood ocean crust is of the order of 10^{28} joules, which alone would be sufficient energy to drive the Flood dynamics, including continental collisions and mountain-building. This is energy not available in conventional uniformitarian plate tectonics, which is thus unable to provide an adequate explanation for continental collisions and mountain-building.

17 G. C. Kennedy and B. E. Nordlie, 1968. The genesis of diamond deposits, *Economic Geology*, 63 (5): 495-503; D. H. Eggler, 1989, Kimberlites: How do they form?, in *Kimberlites and Related Rocks*, vol. 1, J. Ross, A. L. Jaques, J. Ferguson, D. H. Green, S. Y. O'Reilly, R. V. Danchin and A. J. A. Janse, eds., Melbourne, Australia: Geological Society of Australia Special Publication No. 14 and Blackwell Scientific Publications, 489-504; A. A. Snelling, 1993, Diamonds: evidence of explosive geological processes, *Creation Ex Nihilo*, 16 (1): 42-45.

This energy would also have driven a large number of other high-energy geologic processes evidenced in the earth's rock record, which are thus better explained by the catastrophic plate tectonics Flood model than by any of the alternate conventional theories. For example, there is evidence of strong earthquakes resulting from the collapse of the continental margins, and huge mountain-size blocks thousands of meters thick of sedimentary strata having been uplifted, thrust over the top of these same sedimentary strata, and then sliding for tens of kilometers.[18]

These rapid continental collisions would have also had the potential to generate sufficient pressure to produce high-pressure minerals deep below the earth's surface, in the cores of the collision zones and the mountain belts produced. The subsequent rapid erosion within the Flood to unroof the cores of these mountain belts, where the high-pressure minerals were generated, before the minerals in these rocks could equilibrate again to the lower pressures and temperatures near the earth's surface, can only be explained by the catastrophic plate tectonics model. Conventional old-age models thus can't grapple with the evidence of rocks containing minerals formed at both high pressure and low temperature in the cores of mountain belts, now exposed at the earth's surface, evidence that is fully explainable by catastrophic exhumation following the rapid collisions of continental fragments in the catastrophic plate tectonics Flood model. Indeed, the millions of years required by conventional plate tectonics to generate the high pressures needed to produce the high-pressure minerals would have allowed the rocks to also reach high temperatures at the required depths. Thus, the existence of high-pressure/low-temperature minerals is a complete enigma to conventional theories, but is easily explained by the catastrophic plate tectonics Flood model.

Moreover, many of these processes during the Flood would have made substantial modifications to the thickness of the pre-Flood continental crust. This change in crustal thickness occurred through the redistribution of sediments, such as those rapidly transported from the pre-Flood ocean floor up and across the continental crust; by the moving of ductile lower continental crust by its subduction under adjoining continental crust; by the addition of molten material to the underside of the continental crust where it cools and crystallizes (underplating); by stretching (for example, due to spreading); and by compression (for example, due to continental collisions). These rapid changes in crustal thicknesses would have resulted in isostatic disequilibrium, which would subsequently have led to large-scale isostatic adjustments, with their associated earthquakes, frictional heating, and deformation. Many of these tectonic processes would thus have involved vertical motions of sequences of rock strata, so that a tectonically-controlled rock cycle would have been established, particularly in the latter half of the

18 K. P. Wise and S. A. Austin, 1999, Gigantic megaclast within the Kingston Peak Formation (Upper Precambrian, Pahrump Group), south-eastern California: evidence for basin margin collapse, *Geological Society of America Abstracts with Programs*, 31: A455-456; As seen at the Lewis Overthrust in Glacier National Park and surrounding areas.

Flood, with residual effects continuing into the early post-Flood period.[19] Even more spectacular expression of vertical tectonics driven by a return to isostatic equilibrium after the large changes in crustal thickness was the rapid uplift of the high mountain ranges of the world soon after the Flood, including the Himalayas, Alps, Andes, and Rockies.[20]

All of these details of the catastrophic processes involved in the catastrophic plate tectonics model, and the evidence consistent with them, form a coherent and integrated whole model for the Flood, which explains many more details preserved in the geologic record than can be explained by the conventional geological synthesis based on uniformitarian plate tectonics. The replacement of the cold pre-Flood oceanic lithosphere with more expanded hot oceanic lithosphere, by subduction and sea floor spreading, respectively, raised the ocean floor. The strong pull of the subducting oceanic lithosphere into the mantle dragged those portions of the earth's lithospheric plates down, as upwelling mantle material rose to fill the gaps along the spreading centers. The rising ocean floor displaced water onto the continents, raised the sea level more than a kilometer, and the inundation thus resulted in the Flood itself. The rising ocean waters, complemented by the intense global rainfall from the seawater entrained and lofted into the atmosphere by the geysers along the spreading centers, would thus have raised the Ark upon their surface, and ultimately carried it up over the tops of the highest pre-Flood mountains, as recorded in the Scriptures.

When all the pre-Flood oceanic lithosphere had been replaced with new, warm, less-dense, less-subductable oceanic lithosphere, rapid plate motion would have ceased. This brought sea floor spreading almost to a standstill and terminated the spreading-center-associated geyser activity, so the global rainfall would have ceased. This would probably correlate with the 150-day point in the Genesis chronology for the Flood, when "the fountains also of the deep and the windows of heaven were stopped, and the rain from heaven was restrained" (Genesis 8:2). After the rapid horizontal motion of the plates stopped, cooling increased the density of the new oceanic lithosphere, producing deepening oceans, until they reached their current depth. This sinking of the ocean floor would have caused the waters covering the continents to recede from the land, as contemporaneous isostatic adjustments caused the thickened continental crust, including new mountain belts, to rise. The most superficial, and therefore, least lithified, continental sedimentary deposits would have been eroded off the continents and deposited at the new continental margins and on the ocean floor, leaving an unconformity on the new continents not reflected in ocean-floor stratigraphy. This erosion by the receding Flood waters would have been wide-scale sheet erosion, which would be expected to have planed off a substantial percentage of the newly-emerging

---

19 D. J. Tyler, 1990, A tectonically-controlled rock cycle, in *Proceedings of the Second International Conference on Creationism,* R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 293-299.

20 C. Ollier and C. Pain, 2000, *The Origin of Mountains*, London and New York: Routledge.

continental surfaces. This would explain such planar erosion features as the Canadian Shield, and the Kaibab and Coconino Plateaus of the Grand Canyon area, which cannot be so easily explained by the erosional processes available in the conventional uniformitarian model.

88

Where is the Pre-Flood/Flood Boundary in the Geologic Record?

In the catastrophic plate tectonics model for the Flood event, the onset of the Flood was the fracturing and rifting of the pre-Flood oceanic lithosphere, as "the fountains of the great deep" were broken up, which was caused by the nearly simultaneous runaway of cold rock in the upper mantle, the commencement of subduction of the cold pre-Flood oceanic lithosphere, and consequent mantle-wide flow that set in motion globe-encircling sea floor spreading. This subsequently led to rising of the ocean floor, which progressively caused inundation of the continents. Thus, the onset of catastrophic plate tectonics is argued to have been the cause of the Flood event itself. However, is it possible to pinpoint in the geologic record exactly where the pre-Flood era ended and the Flood event began?

It has been proposed that the pre-Flood/Flood boundary in the geologic record should be associated with five geologic discontinuities.[1] These five criteria are summarized as follows:

A Mechanical-Erosional Discontinuity

Energized by the onset of global catastrophic tectonic activity, the early Flood waters would have caused some of the most substantial mechanical erosion in the earth's history. Thus, in any particular stratigraphic section or local geologic column, the pre-Flood/Flood boundary is likely to correspond to the most substantial (or one of the most substantial) and significant regional, mechanical-erosional unconformities.

A Time or Age Discontinuity

By the time the Flood began, the pre-Flood sediments would have had more than two orders of magnitude more time (more than hundreds of years) for lithification than any sediments formed subsequently, particularly early in the

1 S. A. Austin and K. P. Wise, 1994, The pre-Flood boundary: as defined in Grand Canyon, Arizona and eastern Mojave Desert, California, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 37-47.

Flood. Even though many conglomerate strata would have been generated during the Flood, because of this factor just mentioned, conglomerates containing clasts of pre-Flood sediments would be expected to have been more common, thicker, of broader areal extent, and/or coarser than those conglomerates containing clasts of Flood-generated sediments. Furthermore, because later Flood deposition would bury pre-Flood source rocks, conglomerates with pre-Flood clasts are more likely to have been produced very early in Flood deposition in a given area. Thus, the pre-Flood/Flood boundary in any stratigraphic section is likely to be just beneath a conglomerate with clasts of underlying sediments units, particularly if it is associated with a dominant mechanical-erosional unconformity in the region, thus making the conglomerate unit the oldest preserved deposits of the Flood.

A Tectonic Discontinuity

The unparalleled magnitude of tectonism (earth movements) in the first moments of the Flood would be expected to leave a distinctive signature in many places across the earth's surface. Furthermore, the rapid plate motion of the ensuing catastrophic plate tectonics would have tended to leave the early Flood tectonism uniquely associated with the almost complete absence of volcanic rocks. Thus, the pre-Flood/Flood boundary in any stratigraphic section should be associated with evidences of tectonic disturbance in the region, such as rapid changes in the thicknesses of sedimentary units, conglomerates, breccias, megaclasts, megaslides, and detachment faulting, particularly if the greatest amount of this tectonic disturbance is accompanied by the dominant mechanical-erosional unconformities of that region.

A Sedimentary Discontinuity

As the Flood waters deepened at any given locality, the erosion at the onset of the Flood would have given way to deposition, so that the waning energies would be expected to deposit a megasequence of clastics fining-upward, to be capped by chemical sediments such as carbonates. Given that the unparalleled energies involved would likely have been unique to the onset of the Flood, and given the global extent of this surge of waters beginning the inundation of the continent early in the Flood, a transgressive megasequence should be the largest such sequence in local and regional stratigraphic columns, and should thus consist of sedimentary units that are identifiable regionally and inter-regionally. Thus, the pre-Flood/Flood boundary in any stratigraphic section would be where a dominant, fining-upward transgressive, clastic-to-chemical sedimentary megasequence sits on top of a dominant, mechanical-erosional onlap unconformity, particularly where this combination can be identified on a local and regional scale. The fining-upward sedimentary megasequence would thus represent the first sediments of the Flood in that region.

A Paleontological Discontinuity

Under the normal conditions in which animals and plants live and die, the probability of fossilization is proportional to the rate of sedimentation. Thus, in the pre-Flood world the slow deposition of sediments would have made fossilization of plant, animal, and fungal remains unlikely. Then, the initial erosion at the onset of the Flood would likely have destroyed or reworked many of the pre-Flood sediments, and thus any fossils contained in them. Consequently, sediments below the pre-Flood/Flood boundary capable of preserving fossils would probably only contain traces of the most abundant and easily fossilized life-forms, such as bacteria, algae, and protists, and probably in very low abundance. Plants, animal, and fungal fossils would thus be expected to only be found in high abundance above the pre-Flood/Flood boundary. Thus, the regional paleontology needs to be studied when the pre-Flood/Flood boundary is being defined in any stratigraphic section, and the abundance of fossils in each of the strata units should be noted, as well as how they were buried and fossilized. Consequently, where there is a dominant mechanical-erosional unconformity, which has (at most) uncommon fossils below it, and abundant plant, animal, and fungal fossils only above it, this is likely to represent the initial erosion at the onset of the Flood in that region.

Other than relying upon one criterion, the greatest strength of this analysis comes when all five criteria are applied simultaneously to the stratigraphic section of any region. Thus, the dominant, regionally-defined, mechanical-erosional unconformity that underlies a clastic unit incorporating the highest proportion of lithified clasts from below the boundary, has associated with it the greatest amount of tectonic disturbance, directly underlies the most dominant clastic-to-chemical sedimentary megasequence with regionally-deposited sediments, and which is underlain by low-abundance fossils of microorganisms, but overlain by high-abundance fossils of macroorganisms, can be confidently defined as the pre-Flood/Flood boundary in that region. Such an analysis has been used to define and correlate the pre-Flood/Flood boundary in the Grand Canyon region of northern Arizona and the Mojave Desert region of southern California.[2] By application of these five criteria, the pre-Flood/Flood boundary has been successfully identified as being at the unconformity beneath the Sixtymile Formation in the Grand Canyon, where the overlying Tonto Group is a fining-upward, clastic-to-chemical sediment megasequence, there is a paucity of microfossils below it, but an abundance of macrofossils above it, and this unconformity coincides with tectonic upheaval. In the Mojave Desert region of southern California, this unconformity, and thus the pre-Flood/Flood boundary, can be correlated with the unconformity within the Kingston Peak Formation, which is a substantial mechanical-erosional discontinuity where more than 3,000 meters of erosion has occurred in order to enclose clasts of underlying crystalline rocks in the megabreccia that immediately overlies it at the base of a fining-upward megasequence. In conventional terms,

2 Austin and Wise, 1994; Wise and Snelling, 2005.

this would place the pre-Flood/Flood boundary in the late Neoproterozoic, at around 700-740 billion years ago.[3] Significantly, this approximates the timing of the break-up of a postulated supercontinent called Rodinia, which may thus correlate with the initiation of catastrophic plate tectonics at the beginning of the Flood.

The defining of the pre-Flood/Flood boundary at this stratigraphic level within the geologic record is not all that far below the Precambrian/Cambrian boundary, the traditional placement of the beginning of the Flood.[4] Nevertheless, the lower stratigraphic placement of the boundary is justified by the five carefully defined criteria outlined above, and is consistent with the reasoning formerly used to place the boundary at the base of the Cambrian. There too, there is often a mechanical-erosional unconformity and a paleontological discontinuity, with the so-called "Cambrian explosion" of multi-cellular animal fossils. However, in recent decades, unusual multi-cellular animal fossils, the so-called Ediacara fauna, have been found in late Neoproterozoic sediments below the Precambrian/Cambrian boundary in those regions where the relevant portion of the geologic record has been preserved and exposed to view.[5] Furthermore, stratigraphically below those fossils, thick conglomerate units have been found that have been called diamictites, and interpreted as glacial deposits known as tillites, but which can equally be regarded simply as breccias that are consistent with a major tectonic disturbance. These units correspond to the Sixtymile Formation in the Grand Canyon, and the Kingston Peak Formation in the Mojave Desert region of southern California. They are also found in the Wasatch Mountains of central Utah, the MacKenzie Mountains of western Canada, in the Adelaidean and adjoining basins of southern and central Australia, and in the Otavi carbonate platform of the southern Kalahari craton of southern Africa.[6] Also of significance is the association with these diamictite units of carbonate strata that were deposited in warm water, which is hardly consistent

---

3 K. E. Karlstrom, S. A. Bowring, C. M. Dehler, A. H. Knoll, S. M. Porter, D. J. Des Marai, A. B. Weil, Z. D. Sharp, J. W. Geissman, M. A. Elrick, J. M. Timmons, L. J. Crossey and K. L. Davidek, 2000, Chuar Group of the Grand Canyon: Record of breakup of Rodinia, associated change in the global carbon cycle, and ecosystem expansion by 740 Ma, *Geology*, 28 (7): 619-622. This paper reports a U-Pb zircon age of 742±6 Ma for an ash layer at the top of Chuar Group, just below the unconformity at the base of the Sixtymile Formation which has been identified as the pre-Flood/Flood boundary.

4 N. Steno, 1677, *De solido intra solidum naturaliter contento dissertationis prodomus [Prodomus to a Dissertation on a Solid Body Naturally Contained Within a Solid]*, Florence, Italy; Whitcomb and Morris, 1961.

5 V. M. Narbonne, 1998, The Ediacara biota: a terminal Neoproterozoic experiment in the evolution of life, *GSA Today*, 8 (2): 1-6.

6 P. F. Hoffman, A. J. Kaufman and D. J. Halverson, 1998, Comings and goings of global glaciations on a Neoproterozoic tropical platform in Namibia, *GSA Today*, 8 (5): 1-9; P. F. Hoffman, A. J. Kaufman, G. P. Halverson, and D. P. Shrag, 1998, A Neoproterozoic snowball earth, *Science*, 281: 1342-1346; M. J. Kennedy, B. Runnegar, A. R. Prave, K. H. Hoffmann and M. A. Arthur, 1998, Two or four Neoproterozoic glaciations?, *Geology*, 26 (12): 1053-1063; Karlstrom et al, 2000; C. M. Dehler, M. B. Elrick, K. E. Karlstrom, G. A. Smith, L. J. Crossey and J. M. Timmons, 2001, Neoproterozoic Chuar Group (≈800-742 Ma), Grand Canyon: A record of cyclical marine deposition during global cooling and supercontinent rifting, *Sedimentary Geology*, 141-142: 465-499.

with these diamictites being interpreted as glacial deposits.[7] On the other hand, these warm-water carbonate rock units associated with these breccias at such distant locations around the global are consistent with the warm climate before the Flood, and with the warmth of the initial Flood waters from the warm water and steam that burst forth from the fountains of the great deep as they broke up. Therefore, these breccia units could well mark the tectonic upheaval that is to be expected for the onset of catastrophic plate tectonics, when the pre-Flood supercontinent and the pre-Flood ocean floor were broken up as the trigger for the commencement of the Flood.

7 Further discussion of the claimed Neoproterozoic Ice Age is in chapter 126.

89

The Destructive Power of Floods and Ocean Waves

One thing is absolutely certain, if the biblical record of the Flood is true, as is strongly affirmed here, then the Flood was a cataclysm of absolutely enormous scope and such potency that it must have accomplished an immense amount of geologic work during the year in which it prevailed over the earth. It is unreasonable to reject the Bible's account as of no historical value whatever, so the facts must be acknowledged that many of the earth's present rock strata must have been produced by the Flood. It has already been shown that the Bible quite clearly and emphatically teaches the historic fact of a global Flood, and thus it should be immediately obvious that if such a global Flood occurred, it must have been the greatest geologic and geomorphic agent acting on the earth since the creation of the earth itself! Anyone who can conceive of a worldwide Flood as being "tranquil"and geologically impotent should be easily able to equate east with west and black with white!

Even the relatively trivial floods of modern experience exert tremendous erosive force and sediment-carrying power. Indeed, in the words of the late Derek Ager, former geology professor at the University College of Swansea in Wales:

> The hurricane, the flood or the tsunami may do more in an hour or a day than the ordinary processes of nature have achieved in a thousand years.[1]

It is precisely because disastrous floods are rare events, that even the power of local floods and the geologic work they accomplish is often forgotten:

> The astonishing power exerted by a flood of rushing water, both in scouring and in transporting material, is rarely fully appreciated even today.[2]

Following is a striking account of floods and the carrying power of flooded streams

1 Ager, 1973, 49.

2 C. F. Fox, 1953, *Water*, New York: Philosophical Library, xiv.

in northeast India:

> [T]he water had risen only thirteen feet above the level at which it had stood a few days previously; the rush was tremendous—huge blocks of rock measuring some feet across were rolled along with an awful crashing, almost as easily as pebbles in an ordinary stream. In one night a block of granite, which I calculated to weigh upwards of 350 tons, was moved for more than 100 yards; while the current was actually turbid with pebbles of some inches in size, suspended almost like mud in the rushing stream…. In that region there now is practically no soil…and it is also noticeable that water carrying much mud in suspension (and its increased density therefrom) carries larger stones than clear water, for equal velocities.[3]

One must visualize flood action like this, not just in a limited area, but on a worldwide scale, not just for a few days or hours, but continuing for weeks and months, to appreciate the character of, and geologic work accomplished by, the biblical Flood.

From Utah comes an account of another modern flood:

> On this area the 1930 floods destroyed houses, broke in the east wall of the schoolhouse and deposited debris for a depth of several feet, including boulders of all sizes up to 20 tons in weight. Some larger boulders removed about 1000 feet from the canyon's mouth down a 4° gradient. Several of these weigh from 75 to 100 tons each, and two, previously mentioned, weight 150 and 210 tons respectively. The deep gorges freshly excavated for the full length of the flood canyons are no less impressive than the flood depositions in the valley. Cuts were made in typical canyon fill—in places to a depth of 70 feet. Long, continuous stretches of bedrock were exposed on the bottom of the channels. The canyon fill consisted of debris brought from further upstream by running water, and of materials collected from the adjacent canyon slopes. Included were boulders ranging up to 50 feet in diameter.[4]

Undoubtedly the most spectacular demonstration of the results of catastrophic water action is provided by the "Channeled Scabland" of the Pacific Northwest of the United States. This is a 16,000-square-mile area, mostly in eastern Washington state, that is essentially flat and underlain by thick and extensive basalt flows, with only a thin soil cover. However, into it has been eroded a braided pattern of deep, dry channels, with severely scrubbed bare rock surfaces. Geologists of the late

3 Fox, 1953, 70.

4 R. W. Bailey, C. L. Forsling and R. J. Becraft, 1934, *Floods and Accelerated Erosion in Northern Utah*, US Department of Agriculture Miscellaneous Publication 196, 9.

19th century thought that the large dry channels were eroded by streams very slowly during immense periods of time, when the region was more humid during the Ice Age, and when the edge of the great continental ice sheets and associated glaciers were in northern Washington.[5] In 1885 T. C. Chamberlain noted "a series of parallel water marks…sweeping around the valleys" in northwestern Montana, which he suggested were the remnants of an enormous lake that had been impounded by glacier ice. That drained lake became known as Lake Missoula. However, for more than 50 years geologists failed to make the connection between this former lake and the Channeled Scabland, except, that is, for J. Harlen Bretz, who in 1923 proposed a catastrophic flood hypothesis for the erosion of the channels in the scabland. He suggested that there had been a catastrophic drainage of Lake Missoula in Montana by breaching the glacier ice dam that had impounded the lake's waters, and thus water hundreds of feet deep had eroded the complex network of channels downstream catastrophically. But such was the stranglehold of uniformitarian orthodoxy on the geological establishment of the day that Bretz's hypothesis was considered outrageous and vigorously opposed. Undaunted, Bretz stood his ground in papers he wrote during the subsequent bitter debate, which spanned four decades, and yet single-handedly he eventually prevailed in the 1960s.[6]

It is estimated that ancient Lake Missoula covered an area of 3,000 square miles, having been formed by a glacier as much as 2,500 feet deep blocking a valley. The lake would have been at least 950 feet deep, where the town of Missoula now is. At an elevation of 4,200 feet above sea level, the lake was estimated to have had a volume of 500 cubic miles of water, about one-fifth the volume of Lake Michigan. When the ice dam failed catastrophically, it is estimated that 380 cubic miles of water were discharged in two days, the ice-charged waters surging across the Columbia Plateau of eastern Washington at an estimated rate of up to 10 cubic miles per hour. The Channeled Scabland was the 16,000-square-mile erosional product, from which an estimated 50 cubic miles of sediment and rock had been removed.

The surging floodwaters cut deep gorges or "coulees" in solid basalt, the largest of these being the Grand Coulee, which is 50 miles long and two miles wide, with walls up to 900 feet high. Almost ten cubic miles of solid basalt bedrock was removed to produce this enormous trench. There would also have been a series of great waterfalls, the best known being the Dry Falls in the Lower Grand Coulee,

5 See the discussion on the Ice Age in chapters 97-98.

6 J. H. Bretz, 1923, The Channeled Scabland of the Columbia Plateau, *Journal of Geology*, 31: 617-649; J. H. Bretz, 1927, Channeled Scabland and the Spokane Flood, *Washington Academy of Science Journal*, 17 (8): 200-211; J. H. Bretz, 1930, Lake Missoula and the Spokane Flood, *Geological Society of America Bulletin*, 41: 92-93; J. H. Bretz, 1959, Washington's Channeled Scabland, *Washington Division of Mines and Geology Bulletin*, 45; J. H. Bretz, 1969, The Lake Missoula Floods and the Channeled Scabland, *Journal of Geology*, 77: 505-543.

which are 350 feet high and three miles wide.[7] It is estimated that the flood of water as it flowed over Dry Falls would have been up to 300 feet deep and flowing at a rate of 386 million cubic feet (nearly 11 million cubic meters) per second, or about ten times the combined flow of all the rivers of the world! This great flood swept across eastern Washington at up to 45 miles per hour (more than 72 kilometers per hour). At Palouse Falls, a 180-foot-high waterfall was eroded, and now stands at the end of a 400-foot-deep gorge that is six miles long. If this flood lasted for as much as a week, the erosional retreat of the falls to carve the six-mile-long gorge into solid basalt would have averaged about 180 feet per hour, and the basalt would have been eroding at a rate of approximately 10 million cubic feet per hour! Yet this was only a local flood, so it is not difficult to conceive the erosional capacity of the year-long global Flood!

This controversy over the Channeled Scabland of eastern Washington centered on whether the catastrophic water flows could generate the magnitude and speed of erosion necessary to scour solid basalt bedrock to form what are today dry, deeply-incised channels.[8] Even some of the most famous geologists between 1930 and 1960 remained solidly uniformitarian and refused to believe in massive-flood erosion in eastern Washington:

> The role of floods in the erosion of stream channels has been one of the most controversial topics in fluvial geomorphology....Indeed, the famous Spokane flood debate, concerning the effects of the greatest known freshwater floods on the planet…centered on the issue of the erosive capability of running water....Those who disbelieved the flood theory of J. Harlen Bretz did so out of their experience that rivers did not behave as Bretz proposed. Subsequent work showed that their experience, not Bretz's theory, was inadequate.[9]

Investigations of the magnitude and speed of erosion of bedrock during catastrophic floods have determined that the processes of cavitation and plucking are dominant. Cavitation is a rock-pulverizing process associated with fluid flows greater than 30 feet per second (20 miles per hour), and occurs as the fluid detaches from irregularities in the bedrock, producing vacuum cavities ("bubbles") that implode (see Figure 54, page 1089). The cavitation process inflicts explosive, hammer-like blows on the bedrock surface, with pressures ranging as high as 30,000 atmospheres (440,000 pounds per square inch).[10] These extreme pressures,

---

7 D. V. Ager, 1993, *The New Catastrophism: The Importance of the Rare Event in Geological History*, Cambridge, UK: Cambridge University Press, 19-22.

8 V. R. Baker, 1978, The Spokane flood controversy and the martian outflow channels, *Science*, 202: 1249-1256.

9 V. R. Baker, 1988, Flood erosion, in *Flood Geomorphology*, V. R. Baker, R. C. Cochel and P. C. Patton, eds., New York: John Wiley, 89.

10 H. L. Barnes, 1956, Cavitation as a geological agent, *American Journal of Science*, 254: 493-505; F. R. Young, 1989, *Cavitation*, New York: McGraw-Hill.

with which cavitation literally hammers the rock, are many times greater than the rock's compressive strength, so the rock is literally pulverized and converted to powder.

Plucking is the second extremely rapid erosive process, whereby high-velocity flows are able to rip loose large blocks of bedrock along joint surfaces (see Figure 54). Once dislodged, the high-velocity flow is able to move and abraid the large blocks of bedrock. However, the most energetic phenomenon associated with the macro-turbulent flow in a catastrophic flood is a "kolk," a vortex of water with a very low pressure beneath the flowing water, the underwater equivalent of a tornado (see Figure 54).[11] The suction power of the kolk exerts intense hydraulic lifting forces, and can remove or pluck large slabs of bedrock. Thus, there can be no doubt that a catastrophic flood on a global scale is more than capable of eroding its way through thousands of meters of rock strata from the pre-Flood continental land surface.

Another agent of catastrophic erosion not usually considered, but relevant in the context of the Flood event, is explosive volcano activity. Just what a volcanic eruption can achieve is best illustrated by the extraordinary results of the May 18, 1980, and subsequent eruptions at Mount St. Helens in Washington state. There was exceptional variety in the major agents of erosion unleashed by the Mount St. Helens eruptions, concentrated within a limited and intensely-studied area:[12]

1. The direct blast—the 20-megaton-TNT equivalent, northward-directed steam blast at the onset of the May 18 eruption caused hot gas and rock fragments to abraid the slopes around the mountain.

2. Pyroclastic flows—explosive blasts on and after May 18 generated superheated, erosive "rivers" of ground-hugging volcanic ash and steam.

3. Debris avalanches—the movement of great masses of rock, ice, and debris over the ground surface next to the volcano caused significant abrasion of the ground surface.

4. Mudflows—viscous streams of mud gouged out soft volcanic ash deposits and, unexpectedly, even the hardest underlying rocks.

5. Water in channels—overland flow of water caused extraordinary rill and gully patterns to appear, even in nearly level slopes.

6. Water waves—enormous waves generated in nearby Spirit Lake by the avalanche on May 18 inflicted severe erosion on the slopes adjacent to the lake.

11 V. R. Baker, 1978, Paleohydraulics and hydrodynamics of scabland floods, in *The Channeled Scabland*, V. R. Baker and D. Nummedal, eds., Washington: National Aeronautics and Space Administration, 59-79.

12 S. A. Austin, 1984, Rapid erosion at Mt St Helens, *Origins (Geoscience Research Institute)*, 11 (2): 90-98.

7. Jetting steam—eruptions of steam from buried glacier ice reamed holes through hot volcanic ash deposits and formed distinctive explosion pits.

8. Mass wasting—gravitational collapse induced significant changes to unstable slopes, especially those areas sculptured by other agents, leaving behind a varied landscape.

The most fearsome sight would have been the colossal wave up to 650 feet high, generated on Spirit Lake by one-eighth of a cubic mile of avalanche debris from the summit and north slope of Mount St. Helens within the first minute of the May 18 eruption. This enormous water wave eroded the northern slopes of the lake, scouring it of soil and trees, and leaving a distinct clip line. Equally impressive were the mudflows that were responsible for the most extraordinary erosion features. On the slopes of the volcano, melted snow water mixed with volcanic debris formed mudflows that accelerated up to 90 miles per hour, causing very severe erosion, even into solid bedrock, on the flanks of the volcano. Two new canyons were catastrophically excavated to solid rock (old andesite lava flows) to depths of tens of feet, and one of these canyons is up to 700 feet deep (215 meters) and several miles long.

Two-thirds of a cubic mile of landslide debris from the May 18 eruption occupied 23 square miles in the valley to the north and west of the crater, deposited across its entire width for 16 miles. Averaging 150 feet in thickness, but reaching a maximum thickness of almost 600 feet near Spirit Lake, this debris blocked the natural drainage outlet from the Mount St. Helens and Spirit Lake area. Then an explosive eruption at Mount St. Helens on March 19, 1982, melted a thick snow pack in the crater, creating a destructive sheet-like flood of water that became a mudflow. This mudflow breached the deposits blocking the drainage in the valley, catastrophically downcutting through them to form anastomosing channels over much of the debris, and established a new dendritic pattern of channels, including a canyon system one-fortieth the scale of the real Grand Canyon in northern Arizona. Individual canyons have depths of up to 140 feet, with sheer cliffs of up to almost 100 feet high.

There is no doubt, therefore, that the great volcanic upheavals associated with the breaking up of the earth's crust at the onset of the Flood, and as a result of upwelling mantle, mantle plumes, and subducting oceanic crust due to catastrophic plate tectonics during the Flood, unleashed vast amounts of juvenile waters, and created profound disturbances both on the ocean floor and on the continental land surfaces as they were being inundated. So it must not be forgotten that catastrophic erosion at the onset on the Flood was not just due to the torrential rains pouring from the skies. Prodigious great tidal waves would have undoubtedly been generated by the earth movements and earthquakes associated with the fracturing of the earth's crust. Added to this, as the Flood progressed, the ocean waters would have been heated around the spreading centers encircling the globe, while the geysers blasting steam and water into the atmosphere would have generated extreme atmospheric turbulence. Thus, it has been postulated that exceedingly violent storms and catastrophic hurricanes ("hypercanes") would have been generated, producing enormous storm surges and storm waves, with incredible erosive potential as they reached the transgressing shorelines.[13]

Even the action of ordinary waves and littoral currents can, over relatively short periods of time, accomplish enormous amounts of erosion and/or deposition along coastlines, particularly when something happens to change the sediment balance normally existing:

> Any unusual conditions, whether natural or man-made, may upset the balance in such a way that what has been a very stable beach may quickly show significant erosion or accretion. For example, the hurricanes that at times sweep the Atlantic and Gulf Coasts of the United States frequently produce pronounced changes on the affected beaches.[14]

Obviously, the onset of the Flood would have presented profoundly "unusual conditions," and would have immediately resulted in the catastrophic erosion of the coastline of the pre-Flood continent(s). Furthermore, the destructive effect of ordinary storm waves is trivial compared to that of tidal waves or tsunamis, such as must have occurred with great frequency and complexity during the Flood. However, even ordinary waves display awesome power:

> Waves are seldom more than twenty-five feet high; but violent storms may raise them to sixty feet, and there are unverified reports of even greater heights…the immense striking power of a wave cannot be released until it hits an object that cannot float with it. Waves striking the shore of Terra del Fuego can be heard for 20 miles. Spray from a storm wave has been hurled to the top of a lighthouse nearly 200 feet above sea level. The force of waves striking the shore can be measured, and has been found to reach three tons per square foot.[15]

The immense erosive power of such wave forces should be obvious:

> Waves, particularly storm waves and tsunamis, are the most important agents of marine erosion. Smaller waves, such as those associated with surf, may carry on attrition of material and minor amounts of abrasion,

13 J. Woodmorappe, 1998, Hypercanes as a cause of the 40-day global Flood rainfall, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 645-658; L. Vardiman, 2003, Hypercanes following the Genesis Flood, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, ed., Pittsburgh, PA: Creation Science Fellowship, 17-28.

14 J. M. Caldwell, 1949, Beach erosion, *Scientific Monthly*, 69: 432.

15 T. Ting, 1953, *Water*, New York: McMillan, 49.

> but, just as a stream during a single flood may do more geologic work than it will for months or years at low-water stage, so storm waves during a short period may effect more change than ordinary waves will in months.…The enormous force exerted by breaking waves is attested by recorded movements of masses weighing many thousands of pounds. Air in joints and cracks is suddenly compressed and acts as if a wedge were suddenly driven into them. Recession of the water is accompanied by sudden expansion of air with explosive force. This driving of water into cracks not only exerts great mechanical stress but in soluble rocks may greatly accelerate solution.[16]

Wind-generated waves exceeding 100 feet in height have been measured, and some examples of the immense destructive forces that storm waves can develop have been described:

> At Sherbourg, France, a breakwater was composed of large rocks and capped with a wall 20 feet high. Storm waves hurdled 7,000-pound stones over the wall and moved 65-ton concrete blocks 60 feet…at Wick, Scotland, the end of the breakwater was capped by a 800-ton block of concrete that was secured to the foundation by iron rods 3.5 inches in diameter. In a great storm in 1872 the designer of the breakwater watched in amazement from a nearby cliff as both cap and foundations, weighing a total of 1350 tons, were removed as a unit and deposited in the water that the wall was supposed to protect. He rebuilt the structure and added a larger cap weighing 2600 tons, which was treated similarly by a storm a few years later.[17]

Probably the most destructive of all waves are tsunamis, caused by submarine earthquakes, volcanic eruptions, or debris slides. They have been known to attain velocities of 400 or more miles per hour and heights of 130 feet, traveling extraordinary distances.[18] The explosive volcanic eruption of Krakatoa in Indonesia on August 27, 1883, generated enormous waves at least 100 feet high and traveling up to 450 miles per hour, inundating neighboring islands, sweeping away a town and drowning nearly 40,000 people. A tsunami from this eruption was still two feet high as it passed Sri Lanka, and tidal gauges in South Africa, Cape Horn, and Panama (11,470 miles from Krakatoa) clearly recorded the progress of the sequence of waves! In April 1946, a tsunami originating from an earthquake and landslide in the trench associated with the Aleutian Islands traveled at 470 miles per hour across the Pacific and generated a 19-foot-high "tidal" wave on the shores of Hawaii, causing great destruction. At Scotch Cape in Alaska, the same

---

16 W. D. Thornbury, 1969, *Principles of Geomorphology*, second edition, New York: Wiley, 424-425.

17 W. Bascom, 1959, Ocean waves, *Scientific American*, 201 (2): 80.

18 P. H. Kuenen, 1950, *Marine Geology*, New York: Wiley, 80; F. P. Shepard, 1977, *Geological Oceanography*, Brisbane: University of Queensland Press, 50, 54.

tsunami destroyed a concrete lighthouse when a wave more than 100 feet high crashed onto the shore. A tsunami that swept across the Bay of Bengal in 1876 left 20,000 people dead.[19] Between 1900 and 1983 there were no fewer than 245 tsunamis that crossed the Pacific Ocean, an average of nearly three per year.[20] The tsunamis generated by the destructive Chilean earthquakes of 1960 demonstrate how their destructive power had widespread effects:

> The disastrous series of earthquakes that struck Chile late in May has brought death and destruction to countries on the perimeter of the entire Pacific. In the wake of the earthquakes, great tidal waves—up to 50 feet high and traveling at jet speeds of 525 miles an hour—caused extensive damage to Pacific ports, from Japan to California and from Alaska to New Zealand. The waves that wrecked the coastal villages of Japan a third of the way around the world were 32 feet high. In both Japan and Hawaii, which was struck by four waves, there was serious loss of life and extensive property damage.[21]

Thus, it is tsunamis like these, the most destructive of all types of waves, which would have been unleashed during the Flood by the breaking up of the earth's crust in continuing catastrophic earthquake activity and volcanic eruptions due to rapid plate motions, subduction, outpouring of lavas, etc. Furthermore, this breaking up of the earth's crust, with all its associated destructiveness, continued from the first day of the Flood (Genesis 7:11) through the same period of 150 days while the global rain fell, until both were stopped by God (Genesis 8:2). There can be absolutely no doubt about the destructive potential of this catastrophic global Flood to inflict the devastation intended by God as a judgment upon man, and upon the earth that he had corrupted.

19 Bascom, 1959, 81-83.

20 N. M. Ridgeway, 1984, Tsunamis—a natural hazard, *Pamphlet No 41*, New Zealand DSRI Science and Information Centre.

21 1960, Chile earthquake spreads disaster around the world, *Civil Engineering*, 30: 88.

90

Sedimentation and Fossilization During the Flood

The overall picture is one of awesome proportions. Magma and superheated steam were bursting up through the fractured fountains on the ocean floor, with steam and water being catapulted high into the atmosphere. Powerful tsunamis were being generated by the associated earth movements and earthquakes, as the ocean lithosphere began to move and be subducted. High in the atmosphere, the water lofted by the chain of ocean geysers fell back to earth as intense global rain. On the exposed land surface, rivers and waterways would have become swollen and then raging torrents, initiating erosion and transportation of the captured sediment load. The ocean water displaced by the rising spreading centers would have, in concert with the tsunamis, moved as a surging current toward the shorelines, picking up the sediments being scraped off the subducting ocean floor and from the continental shelves.

This globe-encircling interplay of catastrophic diastrophic and hydrodynamic forces must, beyond any question, have profoundly altered the pre-Flood topography and geology of the earth's crust. The powerful ocean currents, tsunamis, and tidal and storm surges, in particular, would have surged onto the continental land surfaces, inundating them, and together with the intense rainfall would have been extremely potent agents of immense, catastrophic erosion that produced sediments that were transported and deposited. Under the action of this combination of effects, almost any sort of sedimentary deposit or depositional sequence would have been produced, so that an immense variety of sedimentary strata must finally have been the result as the Flood ran its course. Even in the strata sequences locally deposited, the raging Flood waters would erode the tops of them before the next sediment-laden surges would have deposited yet more sedimentary strata sequences unconformably on top of them. The progressive cycle of catastrophic plate tectonics would ensure, as continental fragments collided, these strata sequences were buckled and folded, faulted and uplifted, perhaps to be temporarily above the Flood waters, only to be eroded again as the Flood continued. It is thus easy to envisage catastrophic formation of the strata sequences we now see exposed to view across the surface of today's continents, as a result of this global, cataclysmic tectonic, year-long Flood event.

The speed at which tectonic upheavals, mass wasting, and rapid, turbulent water flows can carry and deposit enormous quantities of sediment into strata layers has been well documented. One reads of 170 feet of debris being deposited in an hour as a result of a cloud-burst, and in 1958, 40 million cubic meters of rock fell in a landslip into Lituya Bay on the coast of Alaska.[1] Rock strata produced by such debris flows are well known in the geologic record, such as the diamictite units previously mentioned that are postulated to have been the first-formed strata layers of the Flood. Hurricanes are known to also deposit extensive layers of sediment as they move toward coastlines. For example, a hurricane in 1960 generated surging ocean waves, which flooded inland along the coast of southern Florida for up to five miles for six hours, and deposited a six-inch-thick mud layer, even with numerous thin laminae.[2]

Furthermore, volcanic eruptions also demonstrate the catastrophic accumulation of sediments. Indeed, even though the 1980 eruptions of Mount St. Helens in Washington state were relatively small compared to the eruptions of other volcanoes elsewhere in the world in historic times, they were nevertheless responsible for forming a thickness of up to 600 feet of strata. These deposits accumulated from the primary air blast, landslide, the wave on Spirit Lake, pyroclastic flows, mudflows, air fall, and stream water. The most interesting accumulations were the pyroclastic flow deposits, best illustrated by the 25-feet-thick stratified deposit of June 12, 1980.[3] The collapse of the eruption plume of debris over the volcano generated hurricane-velocity, ground-hugging, fluidized, surging turbulent slurries of fine volcanic ash and debris that moved off the flank of the volcano. In less than five hours, 25 feet of very extensive strata had accumulated, even containing thin laminae and cross-bedding from 1 mm thick to >1 meter thick, each representing just a few seconds to several minutes of accumulation.

Another graphic example of the sedimentation resulting from catastrophic flooding is the deposits produced from the erosion debris scoured from the Channeled Scabland of Washington state during the catastrophic drainage of Lake Missoula. It is estimated that more than 50 cubic miles of sediment, soil, and solid-rock basalt flows were eroded from the Channeled Scabland, and then deposited downstream as the floodwaters slowed. Noteworthy are the thick deposits of silt, sand, gravel, and boulders in the Quincy Basin, just downstream from the Grand Coulee, and the thick, rhythmically-bedded layers of silt up to 300 feet thick over an area of 300 square miles in the Walla Walla Valley.[4]

---

1 Ager, 1973, 47-48.

2 M. M. Ball, E. A. Shinn and K. W. Stockman, 1967, The geologic effects of Hurricane Donna in South Florida, *Journal of Geology*, 75: 583-597.

3 S. A. Austin, 1986, Mount St Helens and catastrophism, in *Proceedings of the First International Conference on Creationism*, vol. 1, Pittsburgh, PA: Creation Science Fellowship, 3-9.

4 J. H. Bretz, 1929, Valley deposits immediately east of the Channeled Scabland of Washington, *Journal of Geology*, 37: 393-427, 505-541; J. H. Bretz, 1930, Valley deposits immediately west of the Channeled Scabland, *Journal of Geology*, 38: 385-422; R. J. Carson, C. F. McKhaun and M. H. Pizey, 1978, The

There can be no doubt, therefore, that in spite of the complexity of the physical agencies involved, the Flood event provides an adequate explanation for the formation of the sedimentary strata in the geologic record attributed to it. Furthermore, it would have been the catastrophic deposition of sediments that was the necessary condition for the rapid burial and fossilization of many animals and plants that had been living in the pre-Flood world. The creatures of the ocean floors would have been universally overwhelmed by the toxicity and violence of the volcanic eruptions, as the ocean floor was lifted and the spreading centers formed, and by the heat and bottom currents thereby generated. These upheavals would have dislodged and scoured the veneer of mixed organic and inorganic ocean-floor sediments, and transported them along with the overwhelmed sea creatures, the mixture eventually to be redeposited either elsewhere on the ocean floor, or ultimately on the pre-Flood land surfaces as they were progressively inundated by the rising sea level surging shorewards. In similar fashion, the fish and other organisms living within the ocean nearer the surface would subsequently have been swept with sediments washing up onto the land surface, as it progressively became the bottom of a global ocean. These sediments and the animal remains they carried would have been transported and deposited on top of other sediments already being laid down. On the remaining land surfaces, the raging torrents of grossly flooded rivers would have carried great quantities of detritus toward the encroaching seas, occasionally consuming animals, together with great rafts of vegetation. These would normally have been deposited finally in some more or less quiescent part of these streams, or have finally been laid down in the encroaching sea on top sediment layers and their contained organic remains, already laid down by the strong sediment-laden ocean water surges progressively inundating the land.

There can thus be no doubt that under such conditions during the Flood, as the torrential rains fell and the ocean waters surged to inundate the land surfaces, burial and fossilization of myriads of animals and plants *en masse* was guaranteed. Whereas burial and fossilization of even a single animal or plant is an exceedingly rare happenstance, the abundance of fossils preserved in the geologic record, often in massive numbers in what have aptly been called fossil graveyards, is unmistakable, powerful testimony to the destructive effects of the watery cataclysm described in the Scriptures. Even after the first forty days, when the greatest of the rains and upheavals diminished, the biblical record says that the waters of the then universal ocean "prevailed" across the earth's surface for a further 110 days before their abatement began. Furthermore, this 110 days, in which the waters of the universal ocean continued to flow and surge around the globe, with each successive regular tide, coincided with the continued operation of the catastrophic plate tectonics process of mantle upwelling and steam expulsion as new oceanic crust was generated to cause sea floor spreading, plate motion, subduction of oceanic crust, and continental collisions. This great dynamic imbalance imposed on the

Touchet beds of the Walla Walla Valley, in *Channeled Scabland*, V. R. Baker and D. Nummedal, eds., National Aeronautics and Space Administration, 173-177.

earth for such a long time would certainly imply that extensive hydraulic and sedimentary activity continued right through that period, with even early Flood sedimentary strata, especially those deformed and uplifted during continental collisions, being re-eroded and reworked. Thus, some sediments may well have been transported and deposited several times before reaching their final resting places. Furthermore, where magmas had been intruded into these sediments and cooled, or where the deep burial of sediments had resulted in metamorphism, these new magmatic and metamorphic rocks would have been exposed to erosion by the stripping of any overlying sediments, so that all these erosion products would have been included in new sedimentary strata. These processes continued, guaranteeing the destruction of the pre-Flood earth surface, and the burial and fossilization of the animals and plants that had inhabited it.

91

The Order of the Strata Deposited by the Flood

The foregoing description of global tectonics, sedimentation, and fossilization processes catastrophically operating during the Flood must, of course, be subject to testing by comparison with the field data of the geologic record, with a view to establishing the general adequacy of the scriptural framework for organizing and harmonizing the geologic data. Obviously, a very substantial portion of the earth's crustal geology must be explained in terms of the Flood, if the biblical record is true.

For example, the most obvious implication of the biblical account is that a very large proportion of the earth's fossil deposits must be associated with catastrophic aqueous action especially, or with volcanism. The vast extent of the sedimentary strata is indicated as follows:

> About three-fourths, perhaps more, of the land area of the earth, 55 million square miles, has sedimentary rock as the bedrock at the surface or directly under the cover of mantle-rock. . . . The thickness of the stratified rocks ranges from a few feet to 40,000 feet or more at any one place. . . . The vast bulk of the stratified rocks is composed of shallow-water deposits.[1]

This is exactly what would be expected if the waters of a universal flood had covered the earth. Similarly, recent volcanic deposits are widely distributed across the earth's surface, which is again just as the biblical account would imply.

However, it is crucial to consider the all-important question of the sequence of deposition of the strata preserved in the geologic record. Even though the order of strata has been made the basis of the conventionally-accepted system of geochronology and historical geology, the physical reality of the strata order is generally not in dispute. Local strata sequences can be physically compiled by field work, and careful correlations between local areas and from region to

1 O. D. Von Engeln and K. E. Caster, 1952, *Geology*, New York: McGraw-Hill, 129.

region have clearly established the robustness of the overall strata sequence of the geologic record. Indeed, careful correlations have shown the inter-regional and sub-continental extent of some of the strata, which then is totally inexplicable in terms of deposition of the sediments according to conventional uniformitarian thinking, but becomes powerful evidence of catastrophic deposition during the Flood. Thus, it is not the order of the strata in the geologic record that is in dispute, but rather the uniformitarian interpretation of the order of the strata, and of their contained fossils as the backbone of the theory of organic evolution, with its purported display of gradual development of all forms of creatures from simple cells, and of the various geological ages as supposedly shown in the fossils contained in the sedimentary strata. By the false belief in the perpetual uniformity of geologic processes, the very plainest testimony to the global cataclysmic Flood in which the "world that then was, being overflowed with water, perished" (2 Peter 3:6) has been transformed instead into a supposed rock record of gradual organic evolution!

Of course, the complete geologic record is hardly ever, if at all, found in any one place on the earth's surface. Usually several or many of the strata systems are missing compared to the overall geologic record, but usually over a given region there is more complete preservation of the record via correlation and integration. However, quite commonly there is little or no physical or physiographic evidence of the intervening period of erosion or non-deposition of the missing strata systems, suggesting that at such localities neither erosion nor deposition ever occurred there. However, this is exactly what would be expected in the light of the biblical record of the Flood and its implications! In some areas would be deposited one sequence of sedimentary strata with their contained fossil assemblages, and in other areas entirely different strata sequences, depending on the source areas and directions of the currents transporting the sediments. Some strata units would have been deposited over wider areas than others, with erosion in some areas but continuous deposition in others, even when intervening strata units were deposited elsewhere. Thus, as a result of the complex interplay of currents, waves, and transported sediments with their entombed organisms, a variety of different types of sedimentary rocks and strata sequences would have been laid down directly on the pre-Flood strata sequences, and particularly the crystalline basement that probably dates back to the Creation Week itself:

> Further, how many geologists have pondered the fact that lying on the crystalline basement are found from place to place not merely Cambrian, but rocks of all ages?[2]

This seems to have been a rhetorical question, which ought to have been puzzling to conventional geologists because of the immense eons of time thus represented at some strata boundaries, with the evidence of the presumed uniformity of geologic

2 E. M. Spieker, 1956, Mountain-building chronology and nature of geologic time-scale, *American Association of Petroleum Geologists' Bulletin*, 40: 185.

processes in space and time being almost entirely absent. On the other hand, this pattern of deposition of the sedimentary strata sequences is entirely consistent with the strata record the Flood would have been expected to have produced.

It is also important to note, in passing, that even though the Cambrian, and the underlying Vendian or latest Precambrian (where they occur), rocks are the oldest strata containing megascopic animal fossils (excluding the stromatolite-building algae and bacteria, and associated multi-cellular organic remains), the evolutionary interpretation still faces an unsolvable problem:

> Most paleontologists today give little thought to fossiliferous rocks older than the Cambrian, thus ignoring the most important missing link of all. Indeed, the missing Pre-Cambrian record cannot properly be described as a link for it is in reality about nine-tenths of the chain of life: the first nine-tenths.[3]

Indeed, apart from the megascopic Ediacaran fauna found in some Vendian strata, conventional paleontologists and geologists are puzzled by the so-called "Cambrian explosion," the sudden appearance in the fossil record of all the different invertebrate phyla with their different body plans, and with no apparent evidence in the Vendian and other Precambrian sedimentary strata of any ancestors to the animals in these phyla that might suggest how they evolved.[4] It has thus been noted:

> Granted an evolutionary origin of the main groups of animals, and not an act of special creation, the absence of any record whatsoever of a single member of any of the phyla in the Pre-Cambrian rocks remains as inexplicable on orthodox grounds as it was to Darwin.[5]

Nevertheless, if the order of the strata and their contained fossil assemblages is not generally in dispute, then that order in the strata sequences still must reflect the geological processes and their timing responsible for the formation of the strata and their order. If, as it is assiduously maintained here, the order in the fossil record does not represent the sequence of the evolutionary development of life, then the fossil order must be explainable within the context of the tempo of geological processes during the global Flood cataclysm. Indeed, both the order of the strata and their contained fossils could well provide us with information about the pre-Flood world, and evidence of the progress of different geological processes during the Flood event. There are a number of factors that have been suggested to

3 H. S. Ladd, 1957, Introduction, in *Treatise on Marine Ecology and Paleoecology*, vol. II, Geological Society of America Memoir 67: 7.

4 S. C. Meyer, M. Ross, P. Nelson and P. Chien, 2003, The Cambrian explosion: biology's big bang, in *Darwinism, Design and Public Education*, J. A. Campbell and S. C. Meyers, eds., East Lansing, MI: Michigan State University Press, 323-402.

5 C. N. George, 1960, Fossils in evolutionary perspective, *Science Progress*, XLVIII: 5.

explain the order in the fossil record, and these must now be considered.

Pre-Flood Biogeography

As has already been suggested in the foregoing discussion of the pre-Flood era, there could well have been distinct biological communities in the pre-Flood world, spatially and geographically separated from one another. For example, there is evidence of a floating-forest biome that existed as a distinct ecosystem on the surface of much of the pre-Flood ocean. This biome not only included the unique lycopods, trees of various sizes containing large hollow cavities and root-like rhizomes, and associated similar plants, but also some unique animals, mainly amphibians, that lived in these forests. Similarly, the evidence in the fossil record would suggest other unique pre-Flood ecosystems, such as the hydrothermal biome where stromatolites grew as reefs adjacent to hydrothermal springs, a gymnosperm-dinosaur biome, and an angiosperm-mammal-man biome.[6]

Based on the spatial separation of the fossil remains of these biomes in the geologic record, it is evident that these biomes must have been spatially and geographically separated and isolated from one another in the pre-Flood world. This would clearly have been the case with the floating-forest biome on the pre-Flood ocean surface spatially and geographically separated from the gymnosperm-dinosaurs and angiosperm-mammal-man biomes that inhabited the pre-Flood land surface. Similarly, the hydrothermal-stromatolite reef biome was confined to hydrothermal spring systems on the floors of the shallow seas fringing the pre-Flood continent(s), where waters were too shallow and perhaps too saline for the floating-forest biome to have been present on the water surfaces above the stromatolite reefs. On land, it is also likely that the gymnosperm-dinosaurs biome was located at a lower altitude, or closer to the shorelines of the pre-Flood continent(s). This is consistent with the description in Genesis of the river out of the Garden of Eden dividing into four rivers, which implies that the Garden of Eden, with its fruit trees and other angiosperms, mammals, and man, was at a high point geographically. Additionally, and perhaps even alternatively, perhaps one or more island continents housed the gymnosperm-dinosaurs biome in the pre-Flood world, while other island continents separately housed the angiosperm-mammal-man biome.

When the Flood began, and as it progressed, these distinct ecosystems would have been effected at different stages of the Flood due to their geographical separation. With the breaking up of the oceanic crust particularly, and the formation of the mid-ocean ridges, the sudden surge of strong ocean currents picking up sediments from the ocean floor and moving landwards would have first of all overwhelmed the stromatolite reefs in the shallow seas fringing the shorelines. This would have been facilitated by the crust supporting the hydrothermal springs also

6 Wise, 2002, 170-175.

breaking up, and thus wiping out that environment conducive to the growth of the stromatolite reefs. With the subsequent destruction of the protected lagoons between the stromatolite reefs and the shorelines by these severe storms, the strange animals that probably were unique to these stromatolite reefs thus ended up being preserved in the lowermost Flood strata. Then as the ocean surface was disturbed by increasing storms and tidal surges, with tsunamis generated by the earth movements, earthquakes, and volcanism on the ocean floor, the floating-forest ecosystem would have been progressively broken up, and huge rafts of vegetation swept landwards to be beached with the sediment load on the land surfaces being inundated. Thus, the floating-forest vegetation would have been buried higher in the strata record of the Flood, well above the stromatolites and the strange animals that lived with them. It would have only been later in this first 150 days of the Flood that, as the waters rose higher across the land surface, the gymnosperm-dinosaurs ecosystem was first swept away and buried, followed later by the angiosperm-mammal-man ecosystem that lived at higher elevations. Thus, the existence in the pre-Flood world of these geographically-separated, distinct ecosystems could well explain their spatial separation and order of fossilization in the geologic record. This thus might explain why, for example, man and dinosaurs were not buried and fossilized together in the geologic record (see Figure 23, pages 449-450), simply because they didn't live spatially together in the pre-Flood world. This existence of unique pre-Flood ecosystems, spatially and geographically separated in a distinctive pre-Flood biogeography, has previously been proposed as ecological zonation.[7]

Early Burial of Marine Creatures

Even a cursory examination of the fossils preserved in the strata of the geologic record reveals that the vast majority of them by number are the remains of shallow-water marine invertebrates (brachiopods, bivalves, gastropods, corals, graptolites, echinoderms, crustaceans, ammonites, etc.). Indeed, in the lowermost fossiliferous strata (Cambrian, Ordovician, Silurian, and Devonian), the contained fossils are almost exclusively shallow-water marine invertebrates, with fish and amphibian fossils only appearing in progressively sparser numbers in the higher strata. With reference to the Cambrian strata, the following statement provides corroboration:

> At least 1500 species of invertebrates are known in the Cambrian, *all marine*, of which 60% are trilobites and 30% brachiopods.[8]

The same could largely be said of the Ordovician, Silurian, and Devonian strata sequences as far as their fossil fauna are concerned, although the first fish fossils are found in the Ordovician, and in the Devonian are found amphibians and

7 H. W. Clark, 1946, *The New Diluvialism*, Angwin, CA: Science Publications.

8 M. Gignoux, 1955, *Stratigraphic Geology*, Full French edition, G.G. Woodford, trans., San Francisco: W. H. Freeman and Company, 46.

the first evidence of continental-type flora (see Figure 23).[9] It is not until the Carboniferous (Mississippian and Pennsylvanian) and Permian strata are reached much higher in the geologic record that the first land animals are encountered.

None of this is at all unexpected, but would be predicted from the implications of the biblical account of the Flood, and by the catastrophic plate tectonics Flood model. The Flood began with the breaking up of the earth's crust, particularly on the pre-Flood ocean floor, where geysers expelling prodigious quantities of steam and lavas flowed at the forming of the mid-ocean ridges, and the oceanic crust near continental margins began to sink and be subducted. Strong and destructive ocean currents were generated and moved landwards from the rising mid-ocean ridges, scouring the sediments on the ocean floor and carrying them and the organisms living in and on them. Thus, as these currents and sediments reached the shallower continental shelves, where the shallow-water marine invertebrates lived in all their prolific diversity, unable to escape, these organisms would have been swept away and buried in the sediment load as it was dumped where the water crashed onto the land surface it was progressively encroaching upon and inundating. The fact that the lower Paleozoic strata of the geologic record are marine strata containing these marine invertebrate fossils therefore corroborates this implication of the biblical record of the Flood.

Other writers have followed this hypothesis in a similar attempt to explain how the fossils were deposited in the order in which they are now found in the geologic record.[10] Possible reconstruction of the pre-Flood landscape, based on a synthesis of what can be gleaned from the biblical and fossil records, would postulate that there was a system of shallow seas bordered by lowland, swampy environments. Many of the marine creatures from these shallow seas, and almost all the plants and animals from that swampy, lowland habit, are now extinct. In warm, humid lowlands inland from the sea, the gymnosperm-dinosaurs ecosystem would have occurred, with pterosaurs and other extinct reptiles, and plesiosaurs and other now extinct aquatic reptiles living in adjacent bodies of water. The higher elevations were home to most of the mammals, birds, and angiosperms (flowering plants), plus man. It is at once obvious that this proposed pre-Flood ecological zonation is very different from the ecology of the present world, but based on the data from the fossil record, it is evident that this difference is because some of these pre-Flood habitats did not become re-established after the Flood. This would have been due to the Flood destroying those ecosystems and all the creatures in them, so that they did not survive into the post-Flood world, and/or those organisms and creatures could not survive on the changed, cooler earth after the Flood.

---

9 Further study of the fossil record has only confirmed this pattern of fossil occurrence, as can be verified by referring to current textbooks such as: S. M. Stanley, 1989, *Earth and Life Through Time*, second edition, New York: W. H. Freeman and Company; R. Cowen, 2000, *History of Life*, third edition, Oxford, UK: Blackwell Scientific Publications.

10 Whitcomb and Morris, 1961, 273, 275-281; L. Brand, 1997, *Faith, Reason and Earth History*, Berrien Springs, MI: Andrews University Press, 279-283.

Thus, the mammals (including man) and birds, the angiosperms, the modern groups of reptiles and amphibians, and some of the fish that lived in the cooler upland areas, were the ones that primarily re-populated the post-Flood world, because they were better prepared to survive on the cooler earth.

With this ecological zonation in mind, it is to be expected that as the sea level rose and the ocean waters began to inundate the land, the strong sediment-laden ocean currents would first have deposited their load in the shallow seas, burying the marine creatures there, before then destroying the lowland, swampy habitats and burying the amphibians and reptiles living near the shore. As the waters rose to higher elevations, the habitats containing the dinosaurs were next destroyed, and finally at the highest elevations the birds, mammals, and angiosperms were buried and fossilized. Thus, from the perspective of a broad overview of the fossil record, this pre-Flood ecological zonation and biogeographical model can explain the order of fossils in the geologic record. However, other factors do need to be considered that enhance the explanatory power of this model.

Hydrodynamic Selectivity of Moving Water

Another factor tending to ensure the deposition of the supposedly simple marine organisms in the first-deposited strata, now deep in the geologic record, is the hydrodynamic selectivity of moving water for particles of similar sizes and shapes, together with the effect of specific gravity of the respective organisms. The so-called "Impact Law" states:

> The settling velocity of large particles is independent of fluid viscosity; it is directly proportional to the square root of particle diameter, directly proportional to particle sphericity, and directly proportional to the difference between particle and fluid density divided by fluid density.[11]

These criteria are derived from consideration of hydrodynamic forces acting on immersed bodies and are well established. Moving water, or moving particles in still water, exerts "drag" forces on those bodies, which depend on the above quoted factors. Particles in motion will tend to settle out in proportion mainly to their specific gravity (or density) and sphericity. It is significant that the marine organisms fossilized in the earliest Flood strata, such as the trilobites, brachiopods, etc., are very "streamlined" and quite dense. The shells of these and most other marine invertebrates are largely composed of calcium carbonate, calcium phosphate, and similar minerals, which are quite heavy, heavier than quartz, for example, the most common constituent of many sands and gravels. This factor alone would have exerted a highly selective sorting action, not only tending to deposit the simpler (that is, the more spherical and undifferentiated) organisms first in the sediments as they were being deposited, but also tending to segregate

11 W. C. Krumbein and L. L. Sloss, 1963, *Stratigraphy and Sedimentation*, second edition, San Francisco: W. H. Freeman and Company, 198.

particles of similar sizes and shapes, which could have thus formed distinct faunal stratigraphic "horizons," with the complexity of structure of deposited organisms, even of similar kinds, increasing progressively upwards in the accumulating sediments.

It is quite possible that this could have been one of the major processes responsible for giving the fossil assemblages within the strata sequence a superficial appearance of "evolution" of similar organisms in the progressive succession upwards in the geologic record. Generally, the sorting action of flowing water is quite efficient, and would definitely have separated the shells and other fossils in just the fashion in which they are found, with certain fossils predominant in certain stratigraphic horizons, and the complexity of such distinctive, supposedly "index," fossils increasing in at least a general way in a progressive sequence upwards through the strata of the geologic record. Of course, these very pronounced "sorting" powers of hydraulic action are really only valid statistically, rather than universally. Furthermore, local variations and peculiarities of turbulence, environment, sediment composition, etc., would be expected to cause local variations in the fossil assemblages, with even occasional heterogeneous combinations of sediments and fossils of a wide variety of shapes and sizes. Nevertheless, transitional fossil forms that are true stratomorphic intermediates expected by the evolutionary theory are exceedingly rare, and are not found at all among the groups with the best fossil records (shallow-marine invertebrates like mollusks and brachiopods).[12] Indeed, even conventional evolutionary researchers have found that successive fossil assemblages in the strata record invariably only show trivial differences between fossil organisms, the different fossil groups with their distinctive body plans appearing abruptly in the record, and then essentially staying the same ("stasis") in the record.[13]

Behavior and Higher Mobility of the Vertebrates

It is entirely reasonable to also expect, in the light of the biblical record of the Flood, that vertebrates would be found fossilized higher in the geologic record than the first invertebrates. In fact, if vertebrates were to be ranked according to their likelihood of being buried early in the fossil record, then we would expect oceanic fish to be buried first, since they live at the lowest elevation.[14] However, in the ocean the fish live in the water column and have greater mobility, unlike the invertebrates that live on the ocean floor and have more restricted mobility, or are even attached to a substrate. Therefore, we would expect the fish to only be buried and fossilized subsequent to the first marine invertebrates. Of course, fish would

12 Wise, 2002, 196-200.

13 N. Eldredge and S. J. Gould, 1972, Punctuated equilibria: an alternative to phyletic gradualism, in *Mammals in Paleobiology*, T. J. M. Schopf, ed., San Francisco: Freeman, Cooper and Company, 82-115; S. J. Gould and N. Eldredge, 1977, Punctuated equilibria: the tempo and mode of evolution reconsidered, *Paleobiology*, 3: 115-151; S. J. Gould and N. Eldredge, 1993, Punctuated equilibrium comes of age, *Nature*, 366: 223-227.

14 Brand, 1997, 282-283.

have inhabited water at all different elevations in the pre-Flood world, even up in mountain streams as well as the lowland, swampy habitats, but their ranking is based on where the first representatives of fish are likely to be buried. Thus, it is hardly surprising to find that the first vertebrates to be found in the fossil record, and then only sparingly, are the ostracoderms in Ordovician strata.

Fish fossils are found in profusion in the Devonian, often in great "fossil graveyards," indicating violent deposition, often in what has been interpreted as freshwater deposits. It is obvious that fish do not usually die and become fossilized under normal conditions, but usually either float on the water surface until decomposed, or are eaten and destroyed by scavengers. Thus, fossil fish beds are convincing evidence of the violent burial of fish in large masses of rapidly-moving sediments, the source of which often appears to have been continental in nature. This is true of some of the most famous Devonian beds containing fossil fish graveyards, such as those of the Old Red Sandstone of Britain, and the corresponding strata in the Catskill Mountains of the United States. These strata can only be explained by torrential runoff into flooded streams carrying vast quantities of sediments and depositing them in ancient lakes and deltas, where they overwhelmed and buried hundreds of thousands of fish and other aquatic creatures. This is impossible to account for under normal conditions, except during extreme flooding, which of course is consistent with the sustained catastrophic conditions of the biblical Flood.

A second factor in the ranking of the likelihood of vertebrates being buried is how animals would react to the Flood. The behavior of some animals is very rigid and stereotyped, so they prefer to stay where they are used to living, and thus would have had little chance of escape. Other more intelligent and adaptable animals would have recognized something was wrong, and thus made an effort to escape. Fish are the least intelligent and adaptable in their behavior, while amphibians come next, and then are followed by the reptiles, birds, and lastly, the mammals.

The third factor to be considered is the mobility of land vertebrates. Once they became aware of the need to escape, how capable would they then have been of running, swimming, flying, or even riding on floating debris? Amphibians would have been the least mobile, with reptiles performing somewhat better, but not being equal to the mammals' mobility, due largely to their low metabolic rates. However, birds, with their wings, would have had the best expected mobility, even being able to find temporary refuge on floating debris.

These three factors tend to support each other, as shown in Table 2. If they had worked against each other, then the order of vertebrates in the fossil record would be more difficult to explain. However, since they all do work together, it is somewhat realistic to suggest that the combination of these three factors could have contributed significantly to producing the general sequence we now observe in the fossil record.

Table 2. Three factors for Flood burial of vertebrates.

	Ecology	Behavior	Mobility	Mean
Birds	4	4	4	4.0
Mammals	4	5	3	4.0
Reptiles	3	3	2	2.3
Amphibians	2	2	1	1.7
Fish	1	1	—	0.7

Numbers indicate rank order in which they would be expected to be buried, as predicted by the ecological zonation hypothesis. A low number indicates that the first burials of members of that class would be expected to occur early, in relation to first burials of other vertebrate groups, if the indicated factor was the determining one. Ecology = successive elevations in a hypothesized pre-Flood ecology; behavior = intelligence and behavioral adaptability (after Brand, 1997, 283, Table 15.1).

In general, therefore, the land animals and plants would be expected to have been caught somewhat later in the period of the rising waters of the Flood and buried in the sediments in much the same order as that found in the geologic record, as conventionally depicted in the standard geologic column. That is, overlying sediment beds burying marine vertebrates would be beds containing fossilized amphibians, then reptile fossils, and finally beds containing fossils of birds and mammals. This is essentially in the order:

(1) Increasing mobility, and therefore increasing ability to postpone inundation and burial;
(2) Decreasing density and other hydrodynamic factors tending to promote earlier burial; and
(3) Increasing elevation of habitat and therefore time required for the Flood waters to rise and advance to overtake them.

This order is essentially consistent with the implications of the biblical account of the Flood, and, therefore, provides further circumstantial evidence of the veracity of that account. Indeed, in no sense is it necessary to capitulate to the claim that the order in the fossil record is evidence of the progressive organic evolution of today's plants and animals through various stages over millions of years from common ancestors.

Of course, there would have been exceptions to this expected general order, both in terms of omissions and inversions, as the water currents waxed and waned with the twice daily tidal surges, and their directions changed due to obstacles and obstructions as the land became increasingly submerged and more and more amphibians, reptiles, and mammals were overtaken by the waters. Thus, in any one locality we would not necessary expect to find a continuous series of strata containing all possible types of fossils in the "ideal" sequence, because the actual deposits found would depend on the local circumstances of current directions, sediment source areas, and the manner in which these had changed during the course of the Flood event. Furthermore, some fossil groups are difficult to explain in terms of their burial according to ecological zonation. For example, since the flowering plants were present on the pre-Flood land surface, why do we not find pollen from the flowering plants in the strata below the Cretaceous, which represent the bulk of the Flood deposits? There have been claims of such pollen being found, even as low in the geologic record as the Cambrian strata, but these have not been unequivocally documented.[15]

And why aren't at least a few mice or sparrows in Paleozoic or Mesozoic deposits? In other words, why weren't animals and plants from "higher zones" mixed and fossilized with those in "lower zones" during the massive river and valley flooding that must have been occurring, even early in the Flood event?

Other factors must have been significant in influencing the time when many groups of organisms met their demise. As the catastrophic destruction progressed, there would have been changes in the chemistry of seas and lakes from the mixing of fresh and salt water, and from contamination by leaching of other chemicals into the water. Each species of aquatic organism would have had its own physiological tolerance of these changes. Thus, there would have been a sequence of mass mortalities of different groups as the water quality changed. Changes in the turbidity of the waters, pollution of the air by volcanic ash, and/or changes in air temperatures would likely have had similar effects. So whereas ecological zonation of the pre-Flood world is a useful concept in explaining how the catastrophic geological processes during the Flood would have produced the order of fossils now seen in the geologic record, the reality was undoubtedly much more complex, due to so many other factors.

---

15 For example, some selected references (in chronological order) include: W. H. Lang and I. C. Cookson, 1935, On the flora, including vascular land plants, associated with *Monograptus*, in rocks of Silurian age, from Victoria, Australia, *Philosophical Transactions of the Royal Society of London B*, 224: 421-449; W. C. Darrah, 1937, Spores of Cambrian plants, *Science*, 86 (2224): 154-155; A. K. Ghosh and A. Bose, 1952, Spores and tracheids from the Cambrian of Kashmir, *Nature*, 169 (4312): 1056-1057; K. Jacob, C. Jacob and R. N. Shrivatsava, 1953, Spores and tracheids from the Vidhyan system, Indian: The advent of vascular plants, *Nature*, 172 (4369): 166-167; R. M. Stainforth, 1966, Occurrence of pollens and spores in the Roraima Formation in Venezuela and British Guyana, *Nature*, 210 (5033): 292-294; C. L. Burdick, 1966, Microflora of the Grand Canyon, *Creation Research Society Quarterly*, 3 (1): 38-46; C. L. Burdick, 1972, Progress report on Grand Canyon palynology, *Creation Research Society Quarterly*, 9 (1): 25-30; C. L. Burdick, 1975, Cambrian and other early pollen in the literature, *Creation Research Society Quarterly*, 12 (3): 175-176; A. V. Chadwick, 1981, Precambrian pollen in the Grand Canyon—a re-examination, *Origins*, 8 (1): 7-12; G. F. Howe, 1986, Creation Research Society studies on Precambrian pollen: Part I — A review, *Creation Research Society Quarterly*, 23 (3): 99-104; G. F. Howe, E. L. Williams, G. T. Matzko and W. E. Lammerts, 1988, Creation Research Society studies on Precambrian pollen: Part III: A pollen analysis of Hakatai Shale and other Grand Canyon rocks, *Creation Research Society Quarterly*, 24 (4): 173-182; W. E. Williams, 1997, Precambrian pollen—a response, *Creation Research Society Quarterly*, 33 (4): 239-242.

92

The Order of the Flood Strata—Other Considerations in the Strata Sequence

Bioturbation and Mass Extinctions

When the Flood began, the earth's geological balance was disrupted by the breaking up of "the fountains of the great deep," so new ocean currents began to transport sediments already on the ocean floor and redeposit them as the lower Paleozoic strata. The animals that could not escape were buried and preserved as fossils. Many others did escape initially, but were buried later. In the meantime, invertebrate animals would have still been alive and moving around, as demonstrated by the presence of abundant fossilized burrows and trails throughout the geologic record. These include many trilobite trails, feeding marks and burrows, escape burrows, and resting marks where the animals had dug into the sediment surface to rest while hidden in the mud.[1]

Animals that live within sediments continually burrow through them, destroying the original layering, an activity called bioturbation.[2] In the modern world, the activity of burrowing animals in underwater sediments results in a total bioturbation of those sediments, so that none of the original layering or other sedimentary structures remains (Figure 55, page 1090). For example, in 1961, Hurricane Carla deposited a thick layer of sediment on the continental shelf offshore of the central Texas coast, yet within twenty years subsequent bioturbation had obliterated all evidence of that bed.[3] In contrast, much of the sedimentary rock record has not been completely bioturbated, which therefore requires explanation. Indeed, trace fossils are only found in the top portions of some individual sedimentary rock units. Incomplete or no bioturbation would result if the sediments when deposited could not support animal life (for example, if they lacked oxygen), or if they were deposited so rapidly that the animals had no time to do their work.

1 E. N. K. Clarkson, 1993, *Invertebrate Palaeontology and Evolution*, third edition, New York: Chapman and Hall, 362-366.

2 R. G. Bromley, 1990, *Trace Fossils: Biology and Taphonomy*, Boston: Unwin Hyman.

3 R. H. Dott, Jr., 1983, Episodic sedimentation—How normal is average? How rare is rare? Does it matter?, *Journal of Sedimentary Petrology*, 53: 12

Most of the sedimentary rock units deposited during the global catastrophic Flood would have been deposited too quickly for complete bioturbation to have occurred. Those rock layers that have some bioturbation in their rock portions, however, would represent the passing of at least a few hours for the animals to have walked around and left their footprints and trails, or to have burrowed in the sediment surfaces before the next layers were deposited. These sedimentary rocks surfaces that are partially bioturbated with burrows, tracks, and other marks are sometimes referred to as "hardgrounds," and these have been suggested to be problematic for the year-long catastrophic Flood because of the time they supposedly require.[4] However, such claims grossly overestimate the time required for animals to make burrows, and leave tracks and marks, particularly as these animals would have been affected by the changing turbulent water conditions that only gave them brief times of respite to crawl across and burrow into sediment surfaces. To the contrary, the fact that there is so little bioturbation of sedimentary strata in the geologic record, and that it is only some strata surfaces that have burrows, tracks, and marks on and in them, is evidence for rapid deposition of the strata within a timeframe consistent with the global Flood catastrophe.

The first fish fossils found abundantly preserved in Silurian and Devonian strata were mostly armored, bottom-dwelling fish. Their probable behavior pattern of hiding from danger on the sea floor would not have been helpful for surviving the sudden influx of sediments, so they were the first vertebrates buried in large numbers.

The movement of water on a global scale would have deposited sediments over extensive areas, producing widespread sedimentary formations, which is consistent with the pattern observed in the geologic record of similar formations of the same geological "age" spread over many parts of the earth's surface. Furthermore, where there are claimed long gaps of many millions of years between strata in the geologic record, there is often little or no evidence of the passage of the claimed long periods of time at the strata boundaries. Indeed, most boundaries between sedimentary strata are planar, without relief from erosion or any of the weathering that should have occurred in the claimed long gaps of millions of years. Instead, these features of the geologic record are better explained by the sedimentary strata having been deposited in a rapid sequence of events, during which the most significant periods of time elapsed between deposition of the layers above and below the supposed gaps. The global scale of the geologic record with these features in it is thus consistent with the biblical Flood.

Investigations of the geologic record on a large geographic scale has identified an interesting pattern of six cycles of large-scale sedimentation across the North American continent known as megasequences, separated across the middle of the continent by unconformities, or supposed time gaps not represented by any

4 D. Tyler, 1996, A post-Flood solution to the chalk problem, *Creation Ex Nihilo Technical Journal*, 10 (1): 107-113.

rocks (Figure 38, page 464).[5] The same pattern continues worldwide with some variation in details, the major unconformities often coinciding with major mass extinctions. These phenomena have the potential to yield important insights into the large-scale processes operating during the global catastrophic Flood. For example, the unconformities would represent lowered water levels, or changes of the sediment source areas, resulting in no sediments at the unconformities without any long time periods elapsing. Of course, the so-called mass extinctions would be expected to coincide with these major unconformities, because the abrupt change in sedimentation, and/or lowered water levels, would likely have resulted in the mass burial of the creatures carried in each major wave of sedimentation, prior to different creatures being carried by the subsequent sedimentation.

Formation of Coal Beds

It is in the Permian and Carboniferous sedimentary strata, near the top of the Paleozoic sequence, that fossilized remains of land animals are first found. This obviously starts an important stage in the onset of the Flood waters over the land, when the smaller and less agile of the amphibians and reptiles were overtaken and buried in the Flood sediments. It is also at the same stage in the geologic record that vast quantities of plants have been buried *en masse* to form the vast coal measures. The Carboniferous (Mississippian and Pennsylvanian) coalfields of eastern North America appear to represent the remains of vast lowland swampy areas along the shores of the pre-Flood ocean, extending offshore to the open ocean. These areas were populated by some unique plants, amphibians, reptiles, and other animals, that together constituted a floating-forest biome, the progressive destruction and burial of which appears to explain the order in which these fossils are found in the geologic record.[6]

Many of these plants have features, such as roots with air spaces, which seem to indicate that they were more suited to growing in water, and therefore were floating plants unable to grow in soil. Furthermore, the vertical sequence of plant fossils in the strata record is consistent with a character trend toward increased resistance to desiccation (or increased terrestriality) that closely correlates with the stratigraphic order of both first appearance and maximum diversity. The rapid deposition and burial of plants and other fossils in the Flood model for these strata allows for the possibility that this pattern also represents horizontal succession of organisms in this pre-Flood floating-forest biome that was progressively destroyed by the Flood. It has therefore been suggested that in a fashion analogous to the plants of a quaking bog today, the floating-forest biome grew out over the pre-Flood ocean from the shores, through an ecological succession of rhyzomous plants of steadily increasing size that generated and thrived upon an increasingly

5 R. H. Dott and D. R. Prothero, 1994, *Evolution of the Earth*, fifth edition, New York: McGraw-Hill.

6 K. P. Wise, 2003, The pre-Flood forest: A study in paleontological pattern recognition, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, ed., Pittsburgh, PA: Creation Science Fellowship, 371-381.

thick mat of vegetation and soil. There was thus a succession of plants from open water inward toward the shore to the full forest biome, which included herbaceous lycopods and ferns on the forest floor, seed ferns in the understory, and arborescent sphenophytes and more lycopods making up the canopy. It has also been suggested that living in these floating forests was a succession of animals (those "land" animals uniquely fossilized in Paleozoic strata). This would have included the large Paleozoic insects, as well as the unique Devonian aquatic tetrapods (like *Ichthyostega*) in pools on thinner portions of the forest floor, and a wide variety of large amphibians (including the labyrinthodonts) in the thicker sections of the forest.

With the onset of the Flood catastrophe, the turbulence of the ocean surface would have progressively disrupted and destroyed the shoreline-fringing floating forests from their open ocean side inwards, the plants and animals being buried in the sediments having been transported from the adjacent areas and accumulating on the sea floor beneath. Thus, not only does the Flood destruction of these floating forests explain the first appearance and maximum abundance order of these fossil plants and animals, it also explains the strong association of Paleozoic plants with marine sediments and fossils, and how the pre-Flood world could have supported the plant biomass now fossilized in the extensive coal beds. The eventual destruction of the cores of these floating forests, with their large, tall lycopods, would have generated extensive floating log mats of this plant debris. As these log and debris mats became water-logged, the logs and plant debris would have sunk and been buried by clastic sediments to form the coal beds. The continuance of these floating log and plant debris mats for some time on the surface of the Flood waters, with currents and winds able to move them around, would have resulted in cyclic repetition of sinking logs and plant debris forming coal seams buried by clastic marine sediments, thus explaining the generation of cyclothems in coal measure sequences. Finally, the complete destruction of this pre-Flood floating-forest biome during the Flood, and the residual catastrophism of the immediate post-Flood period preventing its restoration in the post-Flood world, resulted in the extinction of most of these Paleozoic plants and "land" animals, as their remains are not found in the post-Paleozoic fossil record.

The physical evidence within the coal measure sequences plainly and emphatically demonstrates that both the coal beds and the inter-seam sediments are water-laid deposits. The progressive breaking up and sinking of the logs and plant debris from these floating forests generated the repetition of coal beds, interspersed in cycles of marine sedimentation that was concurrently occurring below the floating log and plant debris mats. This is in stark contrast to the conventional peat swamp model for coal bed formation, the claimed supporting evidence for which includes upright tree trunks in apparent growth positions and *Stigmaria* ("roots") in underclays or seat earths ("fossil soils"). However, these evidences are equally well, or better, explained by the catastrophic Flood model. As observed at Spirit Lake after the devastation of the May 18, 1980, eruption of nearby Mount

St. Helens,[7] in a catastrophic flood waterlogged trees often sink vertically, the thicker ends first with roots broken off, but otherwise appearing to have been buried in their growth positions. Furthermore, within the floating-forest biome it is envisaged that, between the intertwined roots, a mat of soil developed, overlain by a peat layer of rotting vegetative debris, so that upon break-up of these floating forests during the Flood catastrophe, these large laterally extensive soil and peat mats would have sunk in their entirety, to be buried on the sea floor beneath by continuing deposition of marine sediments. This gives the impression that these soil and peat layers with roots, now forming many coal seams, had grown *in situ*.

On the other hand, the conventional uniformitarian peat swamp model does not explain how the rhyzomous aborescent lycopod "roots" could penetrate traditional soils, or indeed the aquatic-plant-like anatomy of the coal plants generally. Furthermore, the conventional uniformitarian peat swamp model does not explain how the coal beds could be so widespread, and so often interbedded with marine sediments, especially when marine fossils are sometimes found even within the coal beds themselves. The uniformitarian explanation, therefore, requires the impossible scenario of vast peat swamps sinking and being invaded by the sea, and buried until the land rises again to form new peat swamps, with this process being repeated tens of times in succession in order to generate the cyclothems and coal measure sequences. Yet the upright fossil trees often found sitting on top of coal beds sometimes pass through one or more of the overlying sediment layers, and even through overlying coal beds, which implies that all these overlying layers, including the coal beds, had to have been deposited rapidly or else these upright trees would have rotted rather than having been fossilized. Many of these upright fossil trees are lycopods and therefore hollow, and some have been found containing fossilized amphibians buried inside them. Thus, the evidence is overwhelmingly consistent with the vast masses of plant debris forming the coal beds having been washed in and buried during the Flood catastrophe, rather than having grown in place repeatedly before slow burial.

The question now arises as to whether the plant remains, once transported by water and buried, could have been metamorphosed into coal in the relatively brief period of time since the Flood. The prevailing perception is that immense ages are required for the coal to form from the vegetative debris after its burial, but both experimental and field evidence suggest the opposite. For example, in one series of experiments, woody materials were heated to temperatures of only 150°C, which in geological terms are low, being obtained just by deep burial, in the presence of water and clay, and material indistinguishable from natural black coal was produced in a matter of weeks.[8] In earlier experiments, uniaxial pressure (applied

7 H. G. Coffin, 1983, Erect floating stumps in Spirit Lake, Washington, *Geology*, 11: 298-299; S. A. Austin, 1986, Mount St Helens and catastrophism, in *Proceedings of the First International Conference on Creationism*, vol. 1, Pittsburgh, PA: Creation Science Fellowship, 3-9.

8 R. Hayatsu, R. L. McBeth, R. G. Scott, R. E. Botto and R. E. Winans, 1984, Artificial coalification study: Preparation and characterization of synthetic macerals, *Organic Geochemistry*, 6: 463-471.

from one direction) was sufficient to produce artificial coal from the components of wood, again at geologically low temperatures, but in just a few days.[9] Such experiments confirm earlier field observations of wooden bridge piles that had been rammed into the ground, and thus due to the compressive force, the wood at the bottom of the piles had been transformed into what resembled black and brown coal, both visually and compositionally.[10] Thus, it is not surprising that even before the advent of more modern experiments, it was conceded that,

> From all available evidence it would appear that coal may form in a very short time, geologically speaking, if conditions are favourable.[11]

Indeed, due to the presence of clay and water with the vegetative debris when buried acting as catalysts, it is totally conceivable that, as a result of the applied pressures of rapid burial and the easily obtainable low geological temperatures of 150 to 200°C, the plant remains were rapidly transformed into coal, particularly during the continuing catastrophic upheavals of the Flood.

---

9 A. Davis and W. Spackman, 1964, The role of cellulosic and lignitic components of wood in artificial coalification, *Fuel*, 43: 215-224.

10 O. Stutzer, 1940, *Geology of Coal*, A. C. Noe, trans., Chicago, IL: University of Chicago Press, 105-106.

11 E. S. Moore, 1940, *Coal*, second edition, New York: Wiley, 143.

93

Animal Tracks and Fossils in Mesozoic Strata

Fossil vertebrate footprints are common in upper Paleozoic sedimentary strata, indicating that such animals were quite active on the new sediment surfaces before they were killed or buried.[1] Numerous amphibians or reptiles left their footprints on Permian cross-bedded sandstones, such as the Coconino Sandstone of northern Arizona and related sandstones in Colorado and Utah, as well as in similar sandstones in Europe, Africa, and other places.[2] These tracks are always much the same wherever they are found around the world, most being in trackways that indicate the animals that made them were climbing up the slopes of underwater sand dunes. It would logically seem that during the Flood these animals were washed by water currents from their natural habitats into areas where pure sand was being deposited, so as these animals tried to escape to go back to where they came from, they often had to climb up the lee sides of sand dunes against the prevailing water currents. It is hardly surprising that these animals were subsequently overwhelmed by the prevailing Flood waters, which increasingly left them without any land surfaces they could re-inhabit, so they eventually were buried in the subsequently deposited sediments. This is confirmed by the observation that in the fossil record the body fossils of amphibians and reptiles are usually found in the same or subsequent strata to where their tracks are found (see Figure 24, page 451).

As the Flood continued, its waters reached beyond the floating-forest biome that fringed the shorelines to encounter life zones with other characteristic animals, such as the adjoining pre-Flood lowland areas dominated by dinosaurs and other large reptiles, which were thus buried in the so-called Mesozoic strata. It is likely that the dinosaurs and these other reptiles were not found as fossils in the Paleozoic because they lived inland of the floating-forest biome that was destroyed and buried in upper Paleozoic strata. They also may have been more mobile, and could thus have escaped further before being progressively overwhelmed by the Flood waters as they covered their habitats. However, at many different levels

1 L. R. Brand and J. Florence, 1982, Stratigraphic distribution of vertebrate fossil footprints compared with body fossils, *Origins (Geoscience Research Institute)*, 9: 67-74.

2 P. J. McKeever, 1991, Trackway preservation in Eolian sandstones from the Permian of Scotland, *Geology*, 19: 726-729.

in the Mesozoic sedimentary deposits, additional types of dinosaurs and other animals appear in the rocks for the first time as they were affected progressively by the Flood waters. These include swimming reptiles such as plesiosaurs and ichthyosaurs, and flying reptiles or pterosaurs. Deposition also continued in the adjoining marine areas, as evidenced by the many extensive Mesozoic strata containing characteristic fossilized marine organisms, such as ammonites.

The creatures whose fossilized remains have generally captured the most attention are the dinosaurs, primarily because of the enormous sizes of some of their representatives, and because of the apparent mystery of their sudden extinction. Various theories have been suggested within the conventional uniformitarian model for the geologic record, the most popular contenders being meteorite, comet, or asteroid impact(s), globally widespread explosive and voluminous volcanic eruptions, or a combination of these, coupled with the devastating climatic consequences that destroyed habitats. However, none of these competing theories has prevailed, due to the inadequacies of all of them to account for all the observed details in the fossil record. However, at least there is a consensus that a global catastrophe is ultimately responsible for the demise of the dinosaurs.

Dinosaur fossils are found at many different levels in Mesozoic strata, particularly in large numbers in what can only be described as great dinosaur graveyards, found in numerous places around the globe. The scale of entombment of such large numbers of these great creatures necessitates some form of catastrophic action. One such location is the Dinosaur National Monument in Utah, where the Jurassic Morrison Formation has yielded the remains of more than 300 dinosaurs from at least 10 different kinds. Excavations have exposed in a 50 feet by 150 feet quarry wall more than 2,000 bones in a jumbled mass, together with the fossilized remains of crocodiles, turtles, lizards, frogs, and clams:

> The quarry area is a dinosaur graveyard, not a place where they died. The majority of the remains probably floated down an eastward flowing river until they were stranded on a shallow sandbar. Some of them, such as the stegosaurs, may have come from far-away dry-land areas to the west. Perhaps they drowned trying to ford a tributary stream or were washed away during floods. Some of the swamp dwellers may have mired down on the very sand bar that became their grave while others may have floated for miles before being stranded.[3]

One could hardly ask for a better description of the way in which these large creatures must have been overwhelmed, drowned, and buried by the sediment-laden Flood waters. The fossils include well-worn bone fragments, and relatively pristine and semi-articulated skeletal segments, unmistakably aligned in an east-southeast preferred orientation, and buried in a conglomeratic sandstone that was

3 J. M. Good, T. E. White and G. F. Stucker, 1958, *The Dinosaur Quarry*, US Government Printing Office, 20.

deposited by water velocities of 1 to 2 meters per second.[4] Furthermore, some 141 dinosaur fossil sites have so far been found in the Morrison Formation in the Colorado Plateau area alone, yet the Morrison Formation has been traced over an area of 1.5 million square kilometers, covering thirteen U.S. states and three Canadian provinces from Manitoba to Arizona and Alberta to Texas, even though in most places it is 100 meters or less thick. Such a scale of deposition must surely be consistent with the catastrophic global Flood.

Many amphibians and reptiles were actively leaving footprints on the surfaces of the sediments being deposited during this middle to late stage of the Flood. Amphibian footprints are almost entirely limited to the upper Paleozoic, the Triassic, and the lower Jurassic, these early-middle Flood footprints being the right size and shape to have been made by the now extinct Paleozoic amphibians. After deposition of the lower Jurassic strata, almost no more amphibian footprints are found, very few having been fossilized in subsequent strata (see Figure 24). The greatest diversity of reptile footprints occurs in Triassic and lower Jurassic strata, but body fossils (bones) are most abundant higher up the strata sequence in Cretaceous and Tertiary strata. Dinosaur tracks are quite diverse in Triassic and lower Jurassic strata, but the greatest diversity of their body fossils is in the Cretaceous (see Figure 24). Dinosaur tracks are very abundant, though, and yield insight into the lives of these animals.[5] Fossil tracks of small dinosaurs and other reptiles are almost entirely absent in upper Jurassic and higher strata, but abundant large dinosaur tracks are found in Cretaceous strata. The overall picture is of abundant vertebrate animal activity recorded in the middle Flood deposits, but by the time the last Jurassic strata were being deposited, most of the vertebrates still making tracks were only the large dinosaurs. All other tetrapods were either mostly dead, their carcasses having been buried, or they were not in the areas where sediments were then being deposited. After deposition of the Cretaceous strata, even the large dinosaurs and their tracks are no longer found in subsequent strata.

Other evidence of normal behavior of animals during deposition of the sedimentary strata is the presence of fossilized reptile "nests" full of eggs, sometimes containing fossil embryos. Indeed, abundant fossilized dinosaur eggs in apparent nests have been found on several continents, sometimes on several successive sedimentary layers.[6] It has been suggested that this poses a serious objection to the Flood

4 W. A. Hoesch and S. A. Austin, 2004, Dinosaur National Monument: Jurassic Park or Jurassic Jumble?, *Acts & Facts*, 33 (4).

5 D. D. Gillette and M. G. Lockley, 1989, *Dinosaur Tracks and Traces*, New York: Cambridge University Press; A. Thulborn, 1990, *Dinosaur Tracks*, New York: Chapman and Hall; M. Lockley, 1991, *Tracking Dinosaurs*, New York: Cambridge University Press; M. Lockley and A. P. Hunt, 1995, *Dinosaur Tracks and Other Fossil Footprints of the Western United States*, New York: Columbia University Press.

6 J. R. Horner, 1982, Evidence of colonial nesting and 'site fidelity' among ornithischian dinosaurs, *Nature*, 297: 675-676; J. R. Horner and D. B. Weishampel, 1989, Dinosaur eggs: the inside story, *Natural History*, 98 (12): 61-67; Gillette and Lockley, 1989, 87-118; K. Carpenter, K. F. Hirsch and J. R. Horner, eds., 1994, *Dinosaur Eggs and Babies*, New York: Cambridge University Press; K. F. Hirsch,

model for catastrophic deposition of these strata, because dinosaurs laying eggs in nests requires time, and successive fossilized nests and eggs would perhaps require much more time that just a few weeks within the Flood year.[7]

However, how much time is required by dinosaurs to lay eggs in nests? Quite obviously, there are no observations to answer that question. What is known is that many dinosaurs were actively walking and running across the newly-deposited sediment surfaces on which eggs were laid. These animals would also have been under the considerable stress of continually having to find dry land on which to escape destruction by the Flood waters. Having retained their eggs within their bodies, perhaps until the eggs were almost ready to hatch, like some modern reptiles do, as their time approached the female dinosaurs would have been desperate to find places to build nests and lay their eggs, so as soon as there was a suitable land surface available above the Flood waters, they would have built their "nests" and laid their eggs. However, within hours the next inflow of sediments would have catastrophically buried those "nests," and the eggs within them. Indeed, "nests" of eggs, including embryos within the eggs, could only be preserved by such rapid burial. And if the eggs were laid just before they hatched, then this would also explain those "nests" where fossilized, newly-hatched dinosaur babies have been found. When a subsequent land surface was again exposed, more of the still-surviving female dinosaurs with eggs ready to hatch would build more "nests" and lay eggs. This could have happened repeatedly over a matter of days, resulting in several levels of "nests" and eggs, and even newly-hatched babies, in successive sedimentary strata in the same geographic area. Because preservation of the eggs and newly-hatched babies requires catastrophic burial, successive horizons of fossilized dinosaur "nests" and eggs are thus further evidence of Flood deposition of the sediments, rather than the elapse of large amounts of time.

Fossil tracks and burrows made by invertebrate animals are also common in Mesozoic marine strata, implying that even late in the Flood many invertebrate animals were still moving around. Because the marine environment was their natural habitat, they weren't all destroyed and buried in the early stages of the Flood. Many continued to survive well into the Flood, because they were able to burrow up through the sediments that were burying them. (Some even survived right through the Flood into the post-Flood world, and still survive today.) If there were quiet periods of time, even only a few hours between tidal surges, the live animals would have made new feeding burrows, and when the next sediments accumulated over those burrows, some would have burrowed up through those sediments, leaving escape burrows. Others would have swum up in the water and come down on top of the next layers.

1994, The fossil record of vertebrate eggs, in *The Palaeobiology of Trace Fossils*, S. K. Donovan, ed., Baltimore, MD: The Johns Hopkins University Press, 269-294.

7 P. A. Garner, 1996, Where is the Flood/post-Flood boundary? Implications of dinosaur nests in the Mesozoic, *Creation Ex Nihilo Technical Journal*, 10 (1): 101-106.

Marine deposits are more abundant among Cretaceous strata, including the extensive chalk beds, than in the underlying Mesozoic strata. In fact, it is likely that the Flood waters reached their highest point at about this time, destroying all the pre-Flood upland areas. Whereas the smaller dinosaurs had been increasingly overwhelmed and buried in Triassic and Jurassic strata, the larger dinosaurs that had survived a little longer, perhaps because of their size and strength, now too were suddenly destroyed and buried in the last of the Cretaceous strata, consistent with destruction of the last remaining upland habitats of the pre-Flood earth. The first mammals and birds encountered in the fossil record are buried in Mesozoic strata (see Figure 24). Bird fossils are rare in Mesozoic strata and belong to extinct orders. Similarly, the mammals found fossilized in Mesozoic strata are all small (mouse to rat size), are all in groups, and none are common as fossils. Furthermore, apart from a few rare mammal tracks, only body fossils of mammals and birds are found in Mesozoic strata, and then primarily in Cretaceous strata. Even many of the plants found fossilized in Mesozoic strata are in extinct groups, though they are more familiar than the plants in Paleozoic strata. Indeed, the flowering plants are not preserved in the fossil record until the Cretaceous strata. This is again consistent with these groups of animals representing the ones that could escape the Flood waters longer than others, and/or organisms that lived at higher elevations with these plants in cooler upland environments that were finally overwhelmed by the Flood waters as they reached their highest point.

94

The Flood/Post-Flood Boundary in the Geologic Record

There has been much discussion about what point in the geologic record constitutes the boundary between the Flood strata and post-Flood strata, but little consensus has been reached. Whitcomb and Morris regarded the Tertiary strata as final Flood deposits, with the mountain-building coinciding with upper Tertiary strata representing the time at the end of the Flood when the mountains rose and the valleys sank, so that the Flood waters drained off the earth (Psalm 104:7-9).[1] More recently, there are those who would still argue for the Flood/post-Flood boundary being at the Tertiary/Quaternary boundary in the geologic record,[2] but others who would place the end of the Flood at the Cretaceous/Tertiary boundary,[3] or even lower in the geologic record within middle Carboniferous strata.[4] That there could be such a divergence of opinion is somewhat puzzling, until it is realized that different weightings to the relevant geologic data, and some perceived problems, have greatly influenced these vastly different choices for the Flood/post-Flood boundary in the geologic record. This is, therefore, not a simple matter to resolve, yet it is important to do so, because the outcome determines just how much geology has to be accounted for in the post-Flood to present era, and how the fossils in the post-Flood geologic record may be related to the present flora and fauna. Thus, it is important to briefly consider the factors that have been variously used in determined this all-important boundary. Furthermore, if perceived problems are also resolved, then resolution of the controversy over this boundary might be possible.

1 Whitcomb and Morris, 1961, 281-288.

2 For example, R. D. Holt, 1996, Evidence for a late Cainozoic Flood/post-Flood boundary, *Creation Ex Nihilo Technical Journal*, 10 (1): 128-167.

3 Austin et al, 1994, 609-621.

4 For example, S. J. Robinson, 1996, Can Flood geology explain the fossil record?, *Creation Ex Nihilo Technical Journal*, 10 (1): 32-69; M. Garton, 1996, The pattern of fossil tracks in the geological record, *Creation Ex Nihilo Technical Journal*, 10 (1): 82-100; P. Garner, 1996, Where is the Flood/post-Flood boundary? Implications of dinosaur nests in the Mesozoic, *Creation Ex Nihilo Technical Journal*, 10 (1): 101-106; P. Garner, 1996, Continental Flood basalts indicate a pre-Mesozoic Flood/post-Flood boundary, *Creation Ex Nihilo Technical Journal*, 10 (1): 114-127.

Biblical Considerations

After the first 150 days of the Flood, the scriptural account indicates that the Flood waters generally began to subside. By day 314 it is recorded that the waters of the Flood were dried up from off the earth, and the face of the ground was dry (Genesis 18:13). However, it wasn't for another 57 days that the earth was dried (Genesis 8:14), and Noah was then instructed by God to leave the Ark, taking his family and also all the animals. These descriptions can't be referring to the entire planet earth having dried up, because 70 percent of the planet is still covered by ocean waters. On the other hand, at the very least, the description given would have been from the perspective of Noah and those on board the Ark, because the ground in the region of the planet where the Ark had come to rest needed to be dry enough for them to disembark. Thus, it would seem that the scriptural account does not preclude the possibility that some parts of the continental land surfaces may have still been immersed by residual Flood waters, where sedimentation may still have continued in local basins in subsequent decades and centuries. Furthermore, it cannot be asserted by inference from the scriptural account of the Flood that when Noah and the animals left the Ark all catastrophic geological activity immediately ceased. Unless God supernaturally intervened at that time to immediately change the rate of geological activities from catastrophic to present-day normal (and the Scriptures nowhere state that this happened), then it is likely that there was an exponential decay in most geological process rates. This has been demonstrated to have been the case with volcanic activity, the extent and power of which has exponentially declined, as quantified from preserved Cenozoic volcanic deposits.[5] Thus, if declining catastrophic geological activity continued on into the post-Flood era in areas other than where Noah, his family, and all the animals disembarked from the Ark, then it may be extremely difficult to find a geological boundary in the record of global extent that marks the end of the Flood.

However, from the 150th day of the Flood onwards, the scriptural account indicates that the Flood waters were retreating from off the face of the earth, increasingly exposing the mountains and then eventually the new continental land surfaces, with vegetation rapidly re-establishing itself thereon. In Psalm 104:7-9, there is the inference that the draining of the Flood waters off the surfaces of new continental lands was achieved with the help of vertical earth movements, in which mountains were uplifted, valleys eroded, and the new ocean basins subsided. Because this would have been on a global scale, this process therefore should have left a global signature in the geologic record.

Geological Considerations

Based upon a qualitative assessment of geological maps worldwide, it has been suggested that the Flood/post-Flood boundary could be defined at the termination

5 S. A. Austin, 1998, The Declining Power of Post-Flood Volcanoes, *Acts & Facts*, 27 (8).

of global-scale erosion and sedimentation, which appears to correspond approximately to the Cretaceous/Tertiary boundary in the geological record, where the types of rock strata change from being worldwide or continental in character in the Mesozoic, to local or regional in the Tertiary.[6] This corresponds to the time in the geologic record when in North America the Rocky Mountains formed, and when the last phase of catastrophic plate tectonics was producing other large-scale tectonic features that are still currently found at the earth's surface.

That catastrophic rates and scales of earth movements were involved in the formation of these most recent mountain chains is shown by the many overthrusts in them. For example, a large part of the Canadian Rockies appears to be a gigantic overthrust belt, in which older, Flood-deposited strata sequences thousands of meters thick over areas of thousands of square kilometers moved along thrust faults up and over younger strata deposited later in the Flood, with whole mountain ranges catastrophically sliding sometimes tens of kilometers. Similarly, in the southwestern United States we can still see today where whole ranges of mountains were apparently pushed tens of kilometers along low-angle to almost horizontal detachment faults. However, rocks have finite compressive strength, much lower than needed to support the horizontal forces required to move such large piles of sediment, if applied at their edges. The only conceivable way such massive blocks of rock can be moved in such a coherent way is by means of a *body force* that acts on each individual parcel of rock. The obvious candidate for the body force is gravity. That is, these overthrusts must be huge gravity slides. This means that when these thrusts occurred, the slope of the terrain was much higher than it is today. Only the catastrophic forces at work during a global tectonic upheaval such as the Flood can explain how whole mountain ranges slid "uphill" tens of kilometers along such fault planes over thousands of square kilometers, while leaving minimal evidence of imbrication, brecciation, and pulverizing of the rocks either side of these fault planes.

It is likewise evident that only catastrophic plate tectonics still operating at the close of the Flood can explain the formation of the Himalayas, where the Indian Plate has collided with the Eurasian Plate and been pushed up over it along a 1,500 kilometer or more front. As a result, sedimentary layers containing marine fossils, which obviously were originally deposited on the ocean floor, were thrust up to where they are now some nine kilometers above sea level.[7] To envisage this stupendous uplift and movement of countless millions of tons of rock strata over such a vast area at uniformitarian plate movement rates of 5 to 10 millimeters per year is clearly incredible, and totally unbelievable. Only the dramatic weakening of the mantle and lithosphere associated with the runaway conditions during the Flood allows for such catastrophic deformation and uplift of whole mountain chains such as the Himalayas.

6 Austin et al, 1994, 614.

7 J. P. Davidson, W. E. Reed and P. M. Davis, 1997, The rise and fall of mountain ranges, in *Exploring Earth: An Introduction to Physical Geology*, Upper Saddle River, NJ: Prentice Hall, 242-247.

Vast regions of the earth's surface were thus catastrophically uplifted at the end of the Flood to form the European Alps, the Himalayas, the Rockies, the Andes, and related mountain chains, along with plateaus such as the Tibetan Plateau and Colorado Plateau. As a result, the Flood waters would have been displaced, and huge amounts of moving water around the earth would have catastrophically eroded into the newly emerging mountains, carving out deep valleys and canyon systems. This is confirmed by experiments that indicate that, if a continental area were under water, and then the water level drops to expose the land surface again, then one result is the carving of canyons or valleys similar to the Grand Canyon, Arizona.[8] The intriguing aspect of these experiments is that the investigators didn't discuss the results in terms of catastrophic geological processes, yet a global catastrophe would be required to explain where all the water necessary for this erosion originated.

A number of objections to the placement of the Flood/post-Flood boundary at approximately the Cretaceous/Tertiary boundary in the geologic record have been raised on geological and related grounds. Among the most serious objections are those pertaining to how the fossil record can be explained in terms of the Flood. The dominant premise of these objections is that the Carboniferous coal seams of the Northern Hemisphere formed as a result of the "beaching" of the pre-Flood floating forests on emerging land surfaces, that therefore represents the end of the Flood and the uplift associated with it.[9] In this view, the amphibian and reptile fossils found in Devonian, Carboniferous, and Permian strata represent the fauna of the pre-Flood floating forests, while the terrestrial fossils found in upper Triassic and higher strata represent the recolonization of the post-Flood world by the animals that had disembarked from the Ark, and the associated flora represents the revegetation of the post-Flood land.[10] Geological evidence cited to support this view is the presence of vertebrate tracks that, it is claimed, could not have formed under the turbulent conditions of the Flood, and whose fossilization required time for hardening under sub-areal conditions, only in Permian and later strata.[11] It is also claimed that successions of multiple nests of dinosaur eggs in numerous stratigraphic sequences would have required considerable periods of dry land conditions unexplainable within the Flood.[12] These inferences are further supported by the claim that, even though continental flood basalts represent huge catastrophic outpourings of lavas, the evidence that they were extruded sub-aerially means that the continental land surfaces onto which they were extruded could not have been under water at those times. Thus, because these basalts are

8 J. E. Coss, F. G. Ethridge and S. A. Schumm, 1994, An experimental study of the effects of base-level change on fluvial, coastal plain and shelf systems, *Journal of Sedimentary Research*, B64: 90-98.

9 J. Scheven, 1996, The Carboniferous floating forest—an extinct pre-Flood ecosystem, *Creation Ex Nihilo Technical Journal*, 10 (1): 70-81.

10 Robinson, 1996.

11 Garton, 1996.

12 Garner, Where is the Flood/post-Flood boundary? Implications of dinosaur nests in the Mesozoic, 1996.

absent from Paleozoic strata and present within Mesozoic and higher strata, this implies that continental land surfaces were not under water from the end of the Paleozoic onwards, the claimed post-Flood period.[13] Furthermore, the thick chalk beds among Cretaceous strata are claimed to have required a timescale for deposition significantly longer than days, weeks, or even months, and so had to have been deposited after the Flood.[14]

However, all of these claims can be adequately dealt with based on all available evidence. The coal beds, formed from the break-up of the pre-Flood floating-forest biome, were deposited within sequences of sediments containing marine fossils, so both the coal beds and the sediment layers were deposited in marine environments, thus during the Flood. Strata with marine fossils are found in the Mesozoic record above the coal beds in many parts of the world, so marine sedimentation continued, while land surfaces continued to be inundated, with more and more land creatures being progressively swept away and buried as the Flood waters reached higher elevations (as discussed previously).

The preservation of animal footprints has to be rapid, immediately after being made, because otherwise they would be quickly obliterated, just as they are so easily obliterated on today's land surfaces. Exceptional circumstances are required for track preservation. Such were present during the Flood, when the trackways were left by animals fleeing the Flood waters, as evident from the trackways left behind by animals climbing the underwater sand dune surfaces now preserved in the Coconino Sandstone of the Grand Canyon area.[15] Furthermore, the footprints of animals are often found preserved in strata below where their body fossils are found (see Figure 24), testimony to the animals subsequently being overwhelmed by the Flood waters they were endeavoring to escape.[16]

Similarly, because of being extinct we can't observe the dinosaurs building "nests" and laying eggs, so it is impossible to insist that the "clutches of fossilized dinosaur eggs" found on multiple horizons are true "nests." It is equally valid to regard these "nests" as eggs that were hurriedly laid on temporarily exposed land surfaces by dinosaurs in panic, as they continued to flee from the repeated surges of the rising Flood waters that eventually swept them away and entombed their remains catastrophically in fossil graveyards. It should also not be overlooked that during the deposition of the sediments that entombed the dinosaurs, elsewhere over large areas all around the earth's surface marine deposition of chalk was occurring,

13 Garner, Continental Flood basalts indicate a pre-Mesozoic Flood/post-Flood boundary, 1996.

14 D. J. Tyler, 1996, A post-Flood solution to the chalk problem, *Creation Ex Nihilo Technical Journal*, 10 (1): 107-113; J. Scheven, 1990, The Flood/post-Flood boundary in the fossil record, in *Proceedings of the Second International Conference on Creationism*, vol. 1, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 247-266.

15 L. R. Brand and T. Tang, 1991, Fossil vertebrate footprints in the Coconino Sandstone (Permian) of Northern Arizona: Evidence for underwater origin, *Geology*, 19: 1201-1204.

16 Brand and Florence, 1982.

testimony to the global scale of what had to have therefore been the waters of the Flood. The purity of the chalk is testimony to the catastrophic rate of its deposition, while the oft-cited "hardgrounds" with their evidences of burrows, hardening, erosion, and encrustation, do not necessarily represent claimed long periods of time, given that all these features can be produced rapidly (to be discussed further below).[17]

Finally, even if the continental flood basalts were extruded sub-aerially, they nevertheless represent rapid catastrophic volcanism intimately associated with the break-up of continental plates during the catastrophic plate tectonics of the global Flood catastrophe. Furthermore, those continental flood basalts that are found among Tertiary strata are generally not as voluminous or extensive as their pre-Tertiary counterparts, and the use of the Tertiary fauna as evidence for sub-aerial extrusion to conclude that the earlier flows were also sub-aerial could well be inappropriate. Indeed, if most of the Tertiary strata are post-Flood, then it is to be expected that the continental flood basalts among them would have been extruded sub-aerially. On the other hand, there is definitive evidence that at least one pre-Tertiary continental flood basalt was extruded underwater.

In stark contrast are the reasons and evidences that have been given for the Flood/post-Flood boundary to be toward the top of the Tertiary strata record, perhaps even at the base of the so-called Quaternary.[18] An analysis of the sediments globally represented in the Phanerozoic (Cambrian to the present) geologic record would suggest that if the Flood/post-Flood boundary were placed within middle or upper Carboniferous strata, then the volume of sediment deposited in the post-Flood period would have been more than twice as much the volume of sediments deposited in the Flood itself. Therefore, the amount of catastrophism and rainfall in the post-Flood period would have had to eclipse the catastrophism and rainfall during the Flood! This observation alone would clearly rule out placement of the Flood/post-Flood boundary so low in the strata record. The largest volume of sedimentation would appear to have occurred with deposition of the Cretaceous and Tertiary strata. However, that analysis could be heavily biased because of the erosion and reworking of earlier deposited sedimentary strata. The estimates of sediment volumes in the earlier part of the strata record were based only on the strata that have been preserved in the record, there being no way of quantifying what volume of strata have been eroded away and redeposited as later strata. Nevertheless, the huge disproportionate volume of Cretaceous and Tertiary strata, compared to the rest of the Phanerozoic geologic record, is consistent with these strata having been deposited during the mountain-building phase at the end of the Flood, when the uplift was exposing the new land surface and the resultant catastrophic run-off was occurring as the waters of the Flood drained

17 A. A. Snelling, 1994, Can Flood geology explain thick chalk layers?, *Creation Ex Nihilo Technical Journal* 8 (1): 11-15; A. A. Snelling, 1995, Coccolithophores and chalk layers, *Creation Ex Nihilo Technical Journal*, 9 (1): 33-35.

18 Holt, 1996, 128-167.

from off the continents into the present ocean basins. It is likely that the erosion and sedimentation resulting from run-off of the Flood waters continued as it tapered off in the early post-Flood period, while Noah, his family, and the animals were re-establishing themselves on the new land surface. Thus, placement of the Flood/post-Flood boundary at the boundary between Cretaceous and Tertiary strata would seem to be feasible, although the author of the analysis still argued for placement at the Quaternary/Tertiary boundary.

The analysis of the volumes of volcanic rocks among Phanerozoic strata shows that there were huge volumes of catastrophic volcanism that occurred up until the Cretaceous/Tertiary strata boundary, consistent with placement of the Flood/post-Flood boundary at that level in the record. If instead the Flood/post-Flood boundary were to be placed in the middle of the Carboniferous strata, there would have been as much catastrophic volcanism in the post-Flood period as in the Flood itself. Any catastrophic volcanism in the post-Flood period would have seriously affected the survival of Noah, his family, and the animals, because of the choking volcanic dust and gases blasted into the atmosphere. Even the significantly reduced residual volcanism recorded in Tertiary strata could have been severely detrimental to post-Flood life, suggesting that a placement of the Flood/post-Flood boundary higher in the Tertiary strata record could potentially be more feasible.

Various attempts have been made to estimate the changes in the global sea level during deposition of the Phanerozoic strata record, based on the assumption that the presence of marine fossils in strata indicates these areas were covered by the oceans, while the presence of terrestrial fossils indicates land apparently above sea level. Additionally, sea level changes are inferred from the interpretation of marine transgressions and regressions within the strata record.[19] The resulting curves estimating the global changes in sea level during deposition of the Phanerozoic strata show two broad episodes of global inundation peaking during deposition of the Ordovician and Cretaceous strata, with probable widespread exposure of land surfaces during the Triassic. However, if as claimed the Permian and Triassic onwards represent strata deposited in the post-Flood period, then the inundation peaking in the Cretaceous would have globally covered the earth's surface with the same depth of water that it had been covered with during deposition of the Ordovician strata, thus covering the post-Flood world in as much water as during the Flood itself! In any case, from the perspective of the biblical global Flood catastrophe, the use of terrestrial fossils to indicate land exposed above sea level is rather questionable, given that the mere fact of the burial and fossilization of terrestrial animals on a large scale requires catastrophic flooding of land surfaces.

19 P. R. Vail, R. M. Mitchum, Jr. and S. Thompson III, 1977, Global cycles of relative changes of sea level, in *Seismic Stratigraphy and Global Changes at Sea Level*, Memoir 26, E. D. Payton, ed., Tulsa, OK: American Association of Petroleum Geologists, 83-97; A. Hallam, 1984, Pre-Quaternary sea-level changes, *Annual Reviews of Earth and Planetary Sciences*, 12: 205-243; B. U. Haq, G. Hardenbol and P. R. Vail, 1987, Chronology of fluctuating sea levels since the Triassic, *Science*, 235: 1156-1167.

On the other hand, given that these estimates of global sea level are likely to be more accurate for the period from the end of the Flood to the present, it is highly significant that these curves show a rapid drop in global sea level immediately after the deposition of the Cretaceous strata, tapering off to the present sea level through the Tertiary, consistent with a Flood/post-Flood boundary at the Cretaceous/Tertiary strata boundary or soon thereafter. Nevertheless, depending on the identification of the resting place of the Ark, and thus the area into which Noah, his family, and the animals disembarked from the Ark in the biblical "mountains of Ararat," the most likely suggested disembarkation areas consist of upper Tertiary strata, thus perhaps forcing a placement of the Flood/post-Flood boundary after deposition of those strata.[20]

Finally, if as claimed the Carboniferous and Permian coal beds are the result of the beaching, break-up, and burial of pre-Flood floating forests at the beginning of the post-Flood era, then even more coal beds were formed in the Jurassic, Cretaceous, and Tertiary strata later in the post-Flood period. If this were the case, then the origin of the biomass they represent remains problematic, as there would be insufficient time to have grown the required plants and then have them catastrophically uprooted and buried. Even more compelling are the data that show that if the Flood/post-Flood boundary is placed in the middle Carboniferous, then about three times the volume of oil and gas sources rocks would have been deposited during the post-Flood period compared to those source rocks deposited in the Flood itself![21] On the other hand, if the Flood/post-Flood boundary is placed at approximately the Cretaceous/Tertiary strata boundary, then more than 70 percent of all the coal beds, and more than 85 percent of all the oil and gas source rocks, would have been deposited under the catastrophic conditions prevailing during the Flood. The biomass thus involved would largely represent growth in the pre-Flood and Creation Week eras, with some potential growth of algae and bacteria, for example, during the Flood itself. Even though there are large volumes of coal beds, and oil and gas source rocks, particularly oil shales and tar sands, among Tertiary strata, the depositional basins involved are only of local and regional extent, compared with the continental and greater distribution of deposition of Cretaceous strata. Therefore, these localized Tertiary strata would still not preclude a Cretaceous/Tertiary Flood/post-Flood boundary.

On balance, therefore, it is almost certain from all the above geological considerations that the Flood/post-Flood boundary simply cannot be placed as low in the strata record as the middle Carboniferous without causing insurmountable geologic difficulties. Those include sediment volumes, rainfall and erosion, volumes of volcanic rock, choking volcanic dust and gases in the atmosphere, global sea levels, and the volumes of coal beds, and oil and gas source rocks, not to forget the relative position of the strata making up the likely candidates for

---

20 Holt, 1996, 145-149.

21 Holt, 1996, 153-161.

the "mountains of Ararat." However, what about the Flood/post-Flood boundary being as high in the geologic record as the Tertiary/Quaternary strata boundary, compared with being lower down at the Cretaceous/Tertiary strata boundary? The strong argument against a Tertiary/Quaternary Flood/post-Flood boundary is that the Pleistocene strata immediately above that boundary represent the record of the post-Flood Ice Age (to be discussed below), which did not commence immediately after the Flood ended, but instead required several centuries to be fully initiated.[22] The Flood ending at the end of the Cretaceous, instead, provides time for the Tertiary strata to have accumulated in those early centuries of the post-Flood era before the onset of the Pleistocene Ice Age. Furthermore, whereas those who have claimed a middle Carboniferous Flood/post-Flood boundary have appealed to the fossil record as their major piece of evidence, it is the fossil record that really does support a Cretaceous/Tertiary or later Flood/post-Flood boundary.

Of particular relevance is the observation that, subsequent to the burial of the fossils found in the uppermost Cretaceous strata, all of the large reptiles, including the dinosaurs, became extinct, along with the pterosaurs and the swimming reptiles such as plesiosaurs, ichthyosaurs, and others, as well as many types of marine invertebrates. This is consistent with those strata being deposited during the Flood, because unlike other reptiles, the dinosaurs didn't survive in the post-Flood world, in spite of their representatives that disembarked from the Ark. On the other hand, whereas mammal and bird fossils are rarely found in Cretaceous and earlier strata, mammal and bird fossils are abundant, more common, and diverse in Tertiary strata (see Figure 24).[23] Indeed, the fossil mammals are used as index fossils to define the various biostratigraphic stages in Tertiary strata, and to correlate those strata between sedimentary basins on all the continents. Furthermore, in ascending the sequence of Tertiary strata, the numbers of contained mammal fossils that are identical to their modern counterparts increases, implying a lineage connection between the fossil and living mammal populations.

This is supported in two ways. First, a large number of mammal families have their fossil record and modern distribution limited to only one continent. For example, kangaroos are only found in Australia, and so are their fossils, in upper Tertiary strata. It hardly makes sense to suggest that the kangaroo fossils represent kangaroos buried within the Flood, and that the extant kangaroos are thus back in Australia after having traveled there from the Ark after the Flood. On the contrary, it is logical that the kangaroo fossils represent kangaroos that were buried by local catastrophes after the kangaroos traveled to Australia from the

22 M. J. Oard, 1987, An Ice Age within the Biblical timeframe, in *Proceedings of the First International Conference on Creationism*, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 157-166; M. J. Oard, 1990, *An Ice Age caused by the Genesis Flood*, El Cajon, CA: Institute for Creation Research; L. Vardiman, 1993, *Ice Cores and the Age of the Earth*, El Cajon, CA: Institute for Creation Research.

23 Brand and Florence, 1982.

Ark after the Flood. Thus, the upper Tertiary strata containing kangaroo fossils must be post-Flood, and the Flood/post-Flood boundary is therefore further down in the strata record. Second, it is within the Tertiary strata that we find stratomorphic series of mammal fossils that have been interpreted as representing post-Flood intrabaraminic diversification.[24] Confirmation of this comes from a baraminological analysis of nineteen fossil equid (horse) species, which found that they all belonged to a single monobaramin ("created kind").[25] The earliest of these fossil equids is found in Eocene strata, so since these fossil equids are clearly related to one another genetically as a stratomorphic series, they can be interpreted as rapid post-Flood genetic diversification. This suggests that the Flood/post-Flood boundary should be placed below those Eocene (lower Tertiary) strata.

On the other hand, there appears to be a strong constraint against placing most of the Tertiary strata and fossils after the Flood/post-Flood boundary. This constraint comes from the amount of Tertiary plate motion recorded in the sea floor rocks. From a map of sea floor age,[26] one readily observes that sea floor with Tertiary age exceeds more than a thousand kilometers on either side of a large portion of the mid-ocean ridge system. These sea floor ages are based on the microfossil content of cores from more than two thousand holes from the deep sea drilling project, from radioisotope dates from basaltic rocks dredged from the sea floor, from the magnetic reversal record obtained from surveys of the world ocean basins, and from the magnetic orientations of magnetic minerals in the deep sea sediment cores. It is only possible to have a large amount of sea floor spreading during the timescale of the Flood because of the dramatic weakening of the mantle that was part of the runaway of cold upper mantle rock and cold oceanic lithosphere. When this runaway shuts down, the viscosity of the mantle quickly recovers to its present high value. At the present value, plate velocities are on the order of a few centimeters per year. At a half spreading rate of five centimeters per year, there is only 215 *meters* of new ocean crust formed during the approximately 4,300 years since the Flood. So only a trivial amount of new sea floor forms after the mantle recovers its strength. Since it hard to imagine the mantle remaining weak more than a few months and at most only a few years after the runaway episode itself ended, it seems likely that most of the Tertiary sea floor was formed during the run-off stage during the year of the Flood.

Although there is still some dispute about where the Flood/post-Flood boundary should be placed in the geologic record, and thus further studies need to be conducted to allow for a more precise definition of this boundary, on balance the

24 K. P. Wise, 1994, *Australopithecus ramidus* and the fossil record, *Creation Ex Nihilo Technical Journal*, 8: 160-165; K. P. Wise, 1995, Towards a creationist understanding of 'transitional forms', *Creation Ex Nihilo Technical Journal*, 9 (2): 216-222.

25 D. P. Cavanaugh, T. C. Wood and K. P. Wise, 2003, Fossil equidae: A monobaraminic, stratomorphic series, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 143-153.

26 For example, http://www.ngdc.noaa.gov/mgg/image/images/g01167-pos-a0001.pdf.

available evidence suggests that the Flood/post-Flood boundary certainly must be above the Cretaceous/Tertiary boundary in the strata record. This approximately corresponds to a transition from worldwide/continental to regional/local deposition and therefore possibly more correctly marks the transition point to the regression stage of the Flood. Vertical earth movements and isostatic readjustments (vertical tectonics) built mountains and elevated plateaus after the Cretaceous, while the sea level rapidly fell as the Flood waters drained from off the surfaces of the continents, accompanied by massive erosion that carved out valleys and canyons and deposited new sediments off the continental margins. Continued volcanic activity declined in power and effect, as the rates of global tectonic and all geologic processes also rapidly declined to provide a new stable world safe enough for Noah, his family, and the animals to disembark from the Ark and to spread across and repopulate the earth's surface again.

95

The Post-Flood World

Post-Flood Geology

After the global effects of the Flood had ended, the earth took considerable time to recover as it continued to experience several hundred years of residual catastrophism.[1] Colliding plates during the Flood had produced mountains in days, and then they were eroded in weeks by the rapidly moving Flood waters. Earthquakes had moved rock strata up and down by thousands of meters in seconds, minutes, and hours. Hundreds of meters of water had covered the continents, pressing them down, and now only months later they were rapidly being uncovered again. With the close of the Flood, and plate motion rapidly decelerating, the plates and the rocks comprising them were totally out of isostatic balance, being either too elevated or too depressed relative to the appropriate equilibrium surface for the earth's crust "floating" on the mantle beneath. So at the end of the Flood, the crustal plates, and the various separate terranes within them, began rebounding toward their appropriate equilibrium positions. However, because of the rheology of the mantle, these isostatic (vertical) adjustments would require thousands of years, with most of the motion probably occurring in the first few hundreds of years after the Flood. Thus, some of this vertical motion would still be occurring today, which would explain the active earthquakes in old mountain chains, such as the Appalachians, and still rising mountains, such as the Tetons. Thus, current geologic activity can be explained as the continued isostatic adjustments after the catastrophic global tectonics during the Flood.

Modern earthquake and volcanic activity is in some sense relict Flood plate tectonics. As rapid horizontal tectonics ceased, when all the cold oceanic lithosphere had sunk during the Flood into the mantle, in the months and years following the Flood new warm oceanic lithosphere would have cooled, particularly the oldest oceanic lithosphere distant from the mid-ocean ridges. Once having cooled, this oceanic lithosphere would be denser than the mantle beneath it, and so gravity is even now pulling these colder lithospheric slabs at the edges of plates downward.

---

1 J. R. Baumgardner, 1990, 3-D finite element simulation of the global tectonic changes accompanying Noah's Flood, in *Proceedings of the Second International Conference on Creationism*, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 35-45.

Thus, the limited plate motions that still occur today, as a result of the sinking of colder lithosphere, explain the position, depth, and nature of most of the world's earthquakes. Early in the post-Flood period, this limited horizontal plate motion would have combined with vertical motions of crustal rocks, isostatically readjusting, to produce rather dramatic results. Mountains would have actually broken off from their foundations along detachment faults, and slid along those fault surfaces for tens of kilometers, a phenomenon not easily explained in the uniformitarian model of earth history.[2] After the initial rapid release of energy early in the post-Flood period, the energy being released would have quickly lessened, bringing more stable conditions to the post-Flood earth. Thus, this biblical model of earth history explains what the uniformitarian model cannot, namely, the incredible amount of energy unleashed around the San Andreas Fault in the past. It also explains why the frequency and sizes of earthquakes has been decreasing over the period we have been able to measure them.[3]

The large changes in crustal thicknesses produced during the Flood not only left the earth in isostatic disequilibrium, but some rocks where the crust was thickest had been quickly buried deeper in the earth's interior. There, the increased temperatures and pressures caused them to begin melting, thus forming less dense magmas that rapidly rose toward the earth's surface. Some of the magmas generated volcanoes, while other magmas cooled under the surface as intrusions. The source of the magma would determine its composition and how explosive any volcanoes would be. If basaltic crust had been subducted, partial melting of the basalt would have produced explosive andesitic volcanism, as in the Andes of South America. Where buried andesites were partially melted, even more explosive rhyolitic volcanism would result, such as in the Yellowstone area and the Taupo Volcanic Zone of New Zealand. The huge volumes of volcanic ash thus generated would have been ideal for fossil burial and preservation, such as the petrified trees in the Yellowstone area. Where lower crustal rocks had melted to produce granitic magmas, these cooled as shallow intrusions, which explains the many Tertiary granitic plutons throughout the western United States. However, concurrent with the mantle heating of thickened or subducted crust, isostatic readjustments would progress, so that less and less magma would be generated with time. The thickened crust would cool, so volcanoes could be expected to decrease in size, intensity, and frequency through the post-Flood period to the present, which appears to be the case with Cenozoic sialic volcanism in the western United States.[4]

---

2 S. H. Rugg, 1990, Detachment faults in the southwestern United States – evidence for a short and catastrophic Tertiary period, in *Proceedings of the Second International Conference on Creationism*, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 217-229; E. H. Frost, S. C. Suitt and M. Fattahipour, 1996, Emerging perspectives of the Salton Trough region with an emphasis on extensional faulting and its implications for later San Andreas deformation, *Sturzstroms and Detachment Faults, Anza Borrego Desert State Park, California*, P. L. Abbott and D. C. Seymour, eds., Santa Ana, CA: South Coast Geological Society, 81-121.

3 S. A. Austin and M. L. Strauss, 1999, Are earthquakes signs of the end times?, *Christian Research Journal*, 21 (4): 30-39.

4 F. V. Perry, D. J. DePaolo and W. S. Baldridge, 1991, Isotopic evidence for a decline in crustal

Because of the frequency and intensity of residual catastrophism after the Flood, post-Flood sedimentary processes were predominantly rapid. However, the local nature of such catastrophism restricted sedimentation to local areas, which explains the basinal nature of most Cenozoic sedimentation. The heavy rainfall in the early post-Flood years (see below) eroded mountainsides, washing the sediments into lakes, such as those in Wyoming, Utah, and Colorado, into which the Green River Formation was rapidly deposited, preserving millions of fossil fish and some frogs, turtles, lizards, snakes alligators, crocodiles, birds, bats, other mammals, and many invertebrates and plants.[5]

Post-Flood Climate

Enormous amounts of heat came from inside the earth during the Flood, particularly with the extrusion of new oceanic crusts, but also as a result of the volcanic rocks extruded on the continents, and the granite and other intrusions. Although much of the heat was probably passed into space,[6] some of the heat had to be taken up directly by the Flood waters that covered the earth. By the time the Flood waters had settled into the post-Flood ocean basins, they had accumulated enough heat to make the ocean waters as much as 20°C or more warmer than today's ocean waters.[7] These warmer oceans might be expected to have produced a warmer climate on the earth in the immediate post-Flood period than is experienced on the earth now.[8] Furthermore, a warm ocean would have resulted in a higher evaporation rate, and thus a lot more water in the atmosphere. Away from the coast, the continental interiors would have cooled quickly at night below the ocean water temperature, so the cool air from the continents would have moved over the oceans to replace the warm air rising from their surface. Thus, the warm, moisture-laden air above the oceans would have moved over the continents to replace the air moving seawards. Over the continents, this moist air would have cooled, causing condensation and lots of heavy precipitation.[9] However, over time

contributions to Caldera-forming rhyolites of the western United States during the middle to late Cenozoic, *Geological Society of America Abstracts with Programs*, 23 (7): A441; Austin, 1998.

5 L. Grande, 1984, *Paleontology of the Green River Formation, with a Review of the Fossil Fish Fauna*, second edition, Geological Survey of Wyoming, Bulletin 63; J. H. Whitmore, 2006, The Green River Formation: a large post-Flood lake system, *Journal of Creation*, 20 (1): 55-63.

6 J. R. Baumgardner, 2003, Catastrophic plate tectonics: the physics behind the Genesis Flood, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 113-126.

7 J. P. Kennett, R. E. Houtz, P. B. Andrews, A. R. Edwards, V. A. Gostin, M. Hajos, M. Hampton, D. G. Jenkins, S. V. Margolis, A. T. Ovenshine and K. Perch-Neilson, 1975, Site 284, *Initial Reports of the Deep Sea Drilling Project, 29*, J. P. Kennett et al, eds., 403-445; J. J. Shackleton and J. P. Kennett, 1975, Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: oxygen and carbon isotope analysis in DSDP sites 277, 279, and 281, *Initial Reports of the Deep Sea Drilling Project, 29*, J. P. Kennett et al eds., 743-755; Vardiman, 1993.

8 Oard, 1990.

9 L. Vardiman, 1994, A conceptual transition model of the atmospheric global circulation following the Genesis Flood, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 569-579; L. Vardiman, 1998, Numerical simulation of

the evaporation of water from the oceans would have gradually caused them to cool, resulting in progressively less precipitation being generated. Thus, in the centuries following the Flood, the entire earth would have gradually become drier.

In the early centuries of the post-Flood period, the warm oceans and cooler continental interiors would have resulted in a rather uniform warm climate along the continental margins, permitting a wider latitudinal range for temperature-limited organisms,[10] such as mammoths,[11] and tropical trees and forests.[12] The situation may have as a consequence facilitated the post-Flood dispersion of animals (to be further discussed below).[13] Furthermore, there would likely have been along the continental margins a rather high climatic gradient running from oceans toward the continental interiors, because the temperatures would have dropped further and faster than they do today from the coastlines inland. As a result of this temperature structure, there would have probably been different communities of flora and fauna closer to the coastlines than further inland. Furthermore, with the rapid temperature changes from the coastlines to the continental interiors, the biological communities would probably have been geographically narrow and overlapped with adjacent communities. This might explain why fossils of some Cenozoic plant communities found near the continental coastal margins include a mixture of plants and organisms from a wider range of climatic zones (that is, with different climatic tolerances) than we would expect to see today, for example, fossil Pleistocene communities,[14] and the Gingko Petrified Forest in Oregon.[15]

As the oceans and the earth cooled in the first few centuries after the Flood, the large amounts of water evaporated off the oceans decreased, so the precipitation rates over the cooler continental interiors gradually decreased. This cooling of the oceans is confirmed by oxygen isotope ratios in Cenozoic foraminifera of polar

---

precipitation induced by hot mid-ocean ridges, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 595-605.

10 M. J. Oard, 1979, A rapid post-Flood Ice Age, *Creation Research Society Quarterly*, 16 (1): 29-37; M. J. Oard, 1987, An Ice Age within the Biblical timeframe, in *Proceedings of the First International Conference on Creationism*, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 157-166; Oard, 1990.

11 C. E. Schweger et al, 1982, Paleoecology of Beringia – a synthesis, *Paleoecology of Beringia*, D. M. Hopkins et al eds., New York: Academic Press, 425-444.

12 K. P. Wise, 1992, Were there really no seasons?: Tree rings and climate, *Creation Ex Nihilo Technical Journal*, 6 (2): 168-172; C. Felix, 1993, The mummified forests of the Canadian Arctic, *Creation Research Society Quarterly*, 29 (4): 189-191.

13 J. Woodmorappe, 1990, Causes for the biogeographic distribution of land vertebrates after the Flood, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 361-367.

14 R. W. Graham and E. L. Lundelius, Jr, 1984, Coevolutionary disequilibrium and Pleistocene extinctions, *Quaternary Extinctions: A Prehistoric Revolution*, E. S. Martin and R. J. Klein, eds., Tuscon, AZ: University of Arizona, 223-249.

15 H. G. Coffin, 1974, The Gingko Petrified Forest, *Origins (Geoscience Research Institute)*, 1: 101-103.

bottom, polar surface, and tropical bottom waters,[16] and may have contributed to the general increase in the body sizes of vertebrates throughout the Cenozoic (what is known as Cope's Law).[17] As precipitation rates decreased, the earth dried and vegetation patterns changed. For example, the description in Genesis 13:10 of the Dead Sea region as well-watered everywhere "as the garden of the Lord" implies that there must have been higher precipitation rates there in Abraham's day, only a few centuries after the Flood. Furthermore, some 400 years later, the land of Canaan was still an incredibly fertile land described as flowing "with milk and honey" (Numbers 13:23-27). Today it is largely desert. It is to be expected that floral and faunal communities would have tracked this cooling of the oceans and the corresponding cooling and drying of the continents. This explains the trend in Cenozoic plant communities to progress from woodland that dwindled worldwide to be gradually replaced by extensive grasslands, as documented by the change in pollen in Tertiary sedimentary sequences.[18] As a consequence, there is a parallel trend in Cenozoic herbivores that change from browsers to grazers. Eventually, continued drying of the earth's surface generated the world's current deserts, which explains why beneath its wind-blown sands the Sahara Desert has evidence of being in the past a well-watered area with rivers and forests.[19]

The high precipitation rates in the early centuries after the Flood would have produced a greater volume of run-off water, which would have meant corresponding rates of both erosion and sedimentation. Such heavy rainfall concurrently over large areas would have resulted in peak flows of the water over the earth's surface, eroding sediments and strata in a planar fashion, rather than being channeled into streams. This would explain the widespread planar erosional surfaces found in Tertiary sedimentary strata. As they slowed down, these sediment-laden sheets of water would have deposited those sediments in sheets, consistent with the extensive, nearly-flat wedges of sediments found among Tertiary strata. As the rainfall decreased, deposition and erosion would have occurred over smaller areas, which would explain the large alluvial fans that cannot be produced under present climatic conditions. The higher rainfall would also have produced lakes into which sediments would have been deposited, such as the lakes cited earlier in which the Green River Formation was deposited.

---

16 Kennett et al, 1975; Shackleton and Kennett, 1975; L. Vardiman, 1996, *Sea-Floor Sediment and the Age of the Earth*, El Cajon, CA: Institute for Creation Research.

17 S. M. Stanley, 1973, An explanation of Cope's Rule, *Evolution*, 27 (1): 1-26.

18 B. E. Cerling and J. R. Ehleringer, 2000, Welcome to the C_4 world, in *Phanerozoic Terrestrial Ecosystems*, R. A. Gastaldo and W. A. DiMichele (convenors), The Paleontological Society, United States, 273-286.

19 J. F. McCauley et al, 1982, Subsurface valley and geoarcheology of the eastern Sahara revealed by shuttle radar, *Science*, 218: 1004-1020; H. J. Pachur and S. Kröplin, 1987, Wadi Howar: Paleoclimate evidence from an extinct river system in the southeastern Sahara, *Science*, 237, 298-300; R. A. Kerr, 1987, Climate since the ice began to melt, *Science*, 236: 326-327; This also provides a possible explanation for why the Sphinx shows signs of being eroded by water when younger Egyptian edifices such as the pyramids only have evidence of wind erosion: R. M. Schoch and J. A. West, 2000, Further evidence supporting a pre-2500BC date for the great Sphinx of Giza, Egypt, *GSA Abstracts with Programs*, 32 (7): A276.

With continued rainfall these post-Flood lakes may have overfilled, the excess water quickly cutting through whatever "dam" had held the lake-water in place and rapidly draining the lakes to catastrophically erode spectacular canyons. The most notable example is the lake system in which leftover Flood waters were impounded by the Kaibab Upwarp, as part of the Colorado Plateau, in northern Arizona. Subsequent post-Flood rainfall overfilled these lakes, so the excess water breached this natural dam, resulting in catastrophic draining of the lakes and erosion of the Grand Canyon.[20] Furthermore, with so much heavy rainfall in the early centuries of the post-Flood period, the resultant local catastrophic flooding would have meant that all the world's canyons were cut in those first centuries early in the post-Flood period. This explains why modern rivers are underfit, no longer downcutting into their basement rock, but merely eroding and readjusting their banks. Of course, during this intense period of canyon erosion, the sediments that were removed would have been deposited at the river mouths, thus forming deltas. This would explain the rapid origin of the great deltas at the mouths of the world's large rivers, including the huge deltas that have been built out onto the deep ocean floor. Finally, during this high-rainfall period it is possible that, with larger amounts of water percolating down into the ground, the large cave systems found today were carved out.

20 S. A. Austin, 1994, How was Grand Canyon eroded?, *Grand Canyon, Monument to Catastrophe*, S. A. Austin, ed., Santee, CA: Institute for Creation Research, 83-110.

96

The Post-Flood Ice Age— A Consequence of the Flood

Another feature of the earth's surface today, which therefore formed subsequent to the Flood during the post-Flood period to the present, are the deposits of glacial debris. These are found across North America, northern Europe, and northwest Asia in the Northern Hemisphere, and the southern half of South America, southernmost Africa, southeastern Australia and Tasmania, and New Zealand in the Southern Hemisphere, plus in many mountainous areas of the world, where glaciers do not exist today. Even in the tropics, glacial debris is found on the highest mountains, about 1,000 meters below existing glaciers. This debris consists of all different sizes of rock fragments chaotically mixed in a fine-grained matrix known as rock flour. End moraines similar to those associated with present-day mountain glaciers are abundant. Streamlined lens-shaped mounds called drumlins exist in large numbers, and large areas of North Dakota, Montana, and Saskatchewan, for example, are covered by parallel grooves with intervening ridges.[1] The hard-rock surfaces of some outcrops are also polished, scratched, and grooved, and so are called striated pavements. Rock protrudences known as *roche moutonnées* have one side smoothed with parallel scratches, and the opposing sides have plucked or sheared surfaces. All these landforms and features are difficult to account for except by means of the passage of glaciers across these land and rock surfaces, with rock debris in the ice capable of scratching and cutting hard rock. Indeed, there are many other abundant landforms that are indicative of glaciation.[2] The distribution of these various evidences thus indicates that the mid and high latitudes of the northern and southern hemispheres were once covered by large ice sheets, the remnants of which still cover Greenland, much of the Arctic Ocean centered on the North Pole, and Antarctica. Because these features are found on the land surface today, this glaciation had to have occurred after the Flood, so an explanation for this post-Flood glaciation is required.

In the conventional uniformitarian model of earth history, this period of the geologic record is known as the Ice Age within the Pleistocene Epoch, which

1 R. F. Flint, 1971, *Glacial and Quaternary Geology*, New York: John Wiley and Sons.

2 D. E. Sugden and B. S. John, 1976, *Glaciers and Landscape*, London: Edward Arnold.

supposedly spanned the period from 1.8 million to ten thousand years ago. Furthermore, it is claimed that during this period there were four advances and retreats of these continental ice sheets, which thus requires some explanation as to how the climate could have changed in such a cyclical manner to cause these continent-wide glaciations. Indeed, more than sixty theories have been proposed,[3] but all have serious difficulties:

> Pleistocene phenomena have produced an absolute riot of theories ranging from the remotely possible to the mutually contradictory and the palpably inadequate.[4]

It was once thought that colder winters were the main requirement for glaciation, but winters are still cold enough over areas that were once covered by ice sheets. In fact, winters are now too cold in places such as Siberia, where no glaciers now exist. Rather, to produce an ice sheet the winter snow must survive the summer and continue to accumulate year by year, so it is crucial that summers were colder than they are today for the snow to survive. For example, in Siberia today the summers are too warm for the snow to progressively accumulate year by year. Furthermore, enough snow must fall in the winter to survive through the cooler summer until the next winter. Thus, the requirements for an Ice Age would appear to be a combination of cooler summers and greater snowfall than today.[5] However, according to realistic climate simulations over snow cover, at least 10 to 12°C summers cooling and twice the snowfall are needed just to glaciate northeast Canada.[6]

However, such climate simulations still beg the question as to how such stringent requirements could have been initiated. Several proposed solutions are largely speculation. While many climate simulations indicate that an Ice Age could have developed easily with only a small change in higher latitude summer radiation, these climate simulations are crude, and glaciation is specified as a response to unrealistic variables.[7] The most popular proposal has been an extra-terrestrial explanation, namely, a decrease in solar output. Thus, probably the most widely adopted theory several decades ago was the "solar-topographic" hypothesis of the prominent Yale glacial geologist R. F. Flint, which tried to explain the glaciations in terms of the worldwide mountain uplifts toward the end of the Tertiary combined with assumed fluctuations in incoming solar radiation. Flint commented about

---

3 E. Eriksson, 1968, Air-ocean-icecap interation in relation to climatic fluctuations and glaciation cycles, in *Causes of Climatic Change*, J. M. Mitchell, Jr., ed., Meteorological Monographs, 8 (30), Boston: American Meteorological Society, 68-92.

4 J. K. Charlesworth, 1957, *The Quaternary Era*, London: Edward Arnold, 1532.

5 J. O. Fletcher, 1968, The influence of the Arctic pack ice on climate, in *Causes of Climatic Change*, J. M. Mitchell, Jr., ed., Meteorological Monographs, 8 (30), Boston: American Meteorological Society, 93-99.

6 L. D. Williams, 1979, An energy balance model of potential glacierization of northern Canada, *Arctic and Alpine Research*, 11: 443-456.

7 Oard, 1990.

his hypothesis:

> However, changes in the composition and turbidity of the atmosphere and changes in the earth's axis and orbit may have been factors.[8]

In the past twenty years, the astronomical theory of a mechanism for the Ice Age has grown immensely in popularity, so that many are now confident that the mystery of the Ice Age has been solved.[9] Commonly called the Milankovitch theory, this mechanism does not state how the Ice Age itself began, but it does suggest a solution to the glacial/interglacial fluctuations within the Ice Age. This astronomical theory suggests that periodic differences in the earth's orbit around the sun caused slight changes in the intensity of sunlight reaching the earth. The gravitational pull of the moon and the planets causes three orbital variations:

1. Slight changes in the eccentricity of the earth's orbit;
2. Small variations in the tilt of the earth's axis with the plane of the elliptic; and
3. The precession of the equinoxes.

It is the first variation that is considered to be the main cause of the glacial/interglacial oscillations. Because the earth's orbit changes from nearly circular to slightly elliptical and back to nearly circular about every 100,000 years, the variations in the amount of sunlight at higher latitudes in summers are periodic, the cooler temperatures that trigger ice sheets being separated by interglacials at regular intervals of 100,000 years. First proposed in the late 1800s, and then developed by Milankovitch in the 1920s and 1930s, this astronomical theory was not "proven," and thus did not become popular until the 1970s, when the earth's orbital variations were matched with slight differences in the oxygen isotopic compositions of small planktonic shells fossilized in the ocean-floor sediments.[10] Now, as many as twenty or thirty glacial periods, separated by interglacials of complete melting, are regarded as having developed in succession during the supposed 1.8 million years of the Pleistocene epoch.[11]

However, many serious problems have been overlooked in the uniformitarian establishment's enthusiasm for this theory.[12] For example, the changes in summer sunshine at higher latitudes postulated by the theory are actually too small to

8 R. F. Flint, 1957, *Glacial and Pleistocene Geology*, New York: John Wiley and Sons, 509.

9 J. Imbrie and K. P. Imbrie, 1979, *Ice Ages: Solving the Mystery*, Short Hills, NJ: Enslow Publishers.

10 J. D. Hays, J. Imbrie and N. J. Shackleton, 1976, Variations in the earth's orbit: Pacemaker of the Ice Ages, *Science*, 194, 1121-1132.

11 J. P. Kennett, 1982, *Marine Geology*, Englewood Cliffs, NJ: Prentice-Hall.

12 M. J. Oard, 1984, Ice Ages: The mystery solved? Part I: The inadequacy of the uniformitarian Ice Age, *Creation Research Society Quarterly*, 21: 66-76; M. J. Oard, 1984, Ice Ages: The mystery solved? Part II: The manipulation of deep-sea cores, *Creation Research Society Quarterly*, 21: 125-137; M. J. Oard, 1985, Ice Ages: The mystery solved? Part III: Paleomagnetic stratigraphy and data manipulation, *Creation Research Society Quarterly*, 21: 170-181.

cause the dramatic changes needed to produce ice sheets, the actual development of which the theory does not explain. Furthermore, the heating at higher latitudes only partially depends on sunshine, the important equator-to-poles transport of heat by the atmosphere and oceans being largely neglected by the theory's proponents. This transport would lessen the cooling at higher latitudes caused by reduced sunshine, one weakness of the theory known by meteorologists. Additionally, the 100,000-year periodicity determined by statistical correlations in the ocean-floor sediment data only matches the eccentricity variation of the earth's orbit, the smallest by far of the three variations. In any case, many poorly known processes can influence the oxygen isotopes in the plankton shells in the ocean-floor sediments.[13] For instance, the water temperature when the shells formed in the past must be known within one or two degrees, yet these planktonic animals often live in the surface layer of the ocean that exhibits seasonal changes of 10°C or more at mid and high latitudes. However, these planktonic animals also at times change depths to where the ocean water is much cooler, especially at lower altitudes, which introduces another large unknown error. Additionally, once these plankton shells accumulate in the ocean-floor sediments, they are commonly subject to erosion by ocean currents, to mixing by abundant bottom-feeding worms, and to the dissolution of the calcium carbonate, which can even change the oxygen-isotope ratios by the dissolving of thinner shells that are isotopically lighter.[14]

Thus, the Milankovitch astronomical theory is subject to serious scientific difficulties in explaining the Ice Age. Nevertheless, although a uniformitarian Ice Age seems meteorologically impossible and proposed solutions are inadequate, atmospheric climate simulations have shown that the small changes in solar radiation proposed by the Milankovitch theory supposedly do cause glacial periods. However, the desired results are actually the consequence of radiation-sensitive initial conditions, such as ice sheets already in place, uncertain values for input variables, and by inexact statistical representations of other poorly understood variables in the models. One variable that is favorable for the development of an Ice Age in these climate models is the albedo of snow, but the value used to make the models work is far too high for melting snow, and is especially too high for exposed glacial ice. Similarly, these Ice Age climate simulation models have generally used unreasonably high values of precipitation, such as 1.2 meters/year for northeastern North America, a rate 2 to 6 times too high for the average values in different parts of this region. It is, therefore, hardly surprising that with such extremely high values for snowfall and snow albedo being used, these simulation models do predict an Ice Age due to small changes in solar radiation

13 W. H. Berger and J. D. Gardner, 1975, On the determination of Pleistocene temperatures from planktonic foraminifera, *Journal of Foraminiferal Research*, 5: 102-113.

14 J. Erez, 1979, Modification of the oxygen-isotope record in deep-sea cores by Pleistocene dissolution cycles, *Nature*, 281: 535-538; M. C. Bonneau, C. Bergnaud-Grazzini and W. H. Berger, 1980, Stable isotope fractionation and differential dissolution in recent planktonic foraminifera from Pacific box-cores, *Oceanologica Acta*, 3: 377-382.

that are correlated to the Milankovitch oscillations. Nevertheless, one such model predicts that we should be in an Ice Age at the present![15] Thus, there are very basic problems with all of these climate models, the results generated being severely distorted by the choice of input values to give the desired results. Furthermore, the crucial explanation of what actually initiated the Ice Age still remains elusive, the apparent contrived success of the popular Milankovitch theory notwithstanding.

The Ice Age as a Consequence of the Flood

The aftermath of the global biblical Flood actually provided the initial conditions that made the Ice Age inevitable. As a consequence of the prodigious volumes of hot water that gushed from inside the earth through the fountains of the great deep during the Flood, coupled with the enormous outpourings of hot volcanic lavas whose remains are still preserved over many large areas in thick piles within the strata record, the waters of the oceans were heated to a temperature some 20°C warmer than they are today. This claim is based on placement of the Flood/post-Flood boundary at the Cretaceous/Tertiary boundary in the strata record, and is evidenced in the temperature-related oxygen isotope ratios of the shells of single-celled marine organisms, which suggest that ocean temperatures increased during deposition of the Paleozoic and Mesozoic strata, and then decreased during Tertiary (post-Flood) deposition.[16] Significantly, the uniformitarian model of earth history has no comprehensive explanation for these data.

At the end of the Flood, as the waters drained off the emerging land surfaces, the mixing would have resulted in the ocean waters being universally warm from pole to pole, and from top to bottom. Even though there continued to be large volcanic eruptions as part of catastrophism residual to the global tectonics of the Flood event, these were on a decreasing scale, as indicated by the smaller volumes of lavas preserved in the Tertiary strata record. The dust and aerosols generated by this volcanism would have provided a measure of cooling during the summers over the mid and high latitude portions of the continents, by reflecting a relatively large percentage of the summer sunshine back into space.[17] However, as already discussed, the warm oceans greatly increased the evaporation rates, and with the cooler continental interiors the warm moist air moved landwards, producing heavy rainfall over the continental interiors. This heavy rainfall would have cleaned the air of the volcanic dust and aerosols, but the cloud cover would have added to the summer cooling. Eventual combination of cold land and warm oceans would have caused major storm tracks to develop parallel to the east coasts of Asia and North America, and remain more-or-less stationary all year round.

15 M. J. Suarez and I. M. Held, 1976, Modelling climatic response to orbital parameter variations, *Nature*, 263: 46-47; M. J. Suarez and I. M. Held, 1969, The sensitivity of an energy balance climate model to variations in the orbital parameters, *Journal of Geophysical Research*, 84 (C8): 4825-4836.

16 T. F. Anderson, 1990, Temperature from oxygen isotope ratios, *Paleobiology: A Synthesis*, D. E. G. Briggs and P. R. Crowther, eds., Malden, MA: Blackwell, 403-406.

17 Oard, 1990.

Storm after storm would have developed and dropped most of their moisture over colder land, while the strongest evaporation from the warm oceans would have occurred near the continents. This prodigious evaporation removed heat from the oceans, so they began to progressively cool. Eventually, the world's oceans cooled sufficiently for the precipitation over the continents to come down to high altitudes and latitudes as snow, particularly in northeastern North America, eastern Antarctica, and the mountains of Scandinavia, Greenland, west Antarctica, and western North America.

It was, therefore, the copious amounts of moisture evaporated from the warm oceans that eventually triggered the Ice Age. Because this moisture eventually came down so quickly as snow, the summer warmth in these cool continental areas was not able to melt all the snow that had fallen the previous winter. As a result, the snow built up and was compacted in some places into ice, which in turn thus accumulated into huge ice sheets, which became so thick that they flowed under their own weight, surging over areas where there was no ice. Many areas closer to the warm oceans, such as the British Isles and the lowlands of northwestern Europe, would have initially been too warm for glaciers, while the lowlands of eastern Asia and Alaska would have escaped glaciation all together. The oceans adjacent to the developing ice sheets and in the paths of storms would have continued to be warm, due to a vigorous horizontal and vertical ocean circulation. As the ocean water was cooled by evaporation and by contact with the cold continental air, it would have become more dense and sunk, being replaced by warmer water from deeper in the oceans. The ocean currents along the east coast of Asia and North America would have continually transported warmer water northward. As the deeper oceans cooled, the ocean surface and atmosphere at mid and high latitudes would have slowly cooled, as the Ice Age progressed and ice sheets expanded. Mountain ice caps in many areas would have coalesced and spread to lower elevations.

Based on starting with the oceans 20°C warmer than today, and the placement of the Flood/post-Flood boundary at the Cretaceous/Tertiary strata boundary in the geologic record, early results from numerical climate modeling studies have successfully shown that the ice accumulated in the places where we know it actually did, and all this happened in a matter of a few centuries.[18] Indeed, this numerical climate modeling, which fits the biblical timescale, seems to be the only such modeling that has successfully produced ice sheets where we know they were. The ice began accumulating over just a few centuries, during which the Tertiary strata were deposited. When the ice had accumulated sufficiently, it surged out in a couple of decades, and then melted in another couple of decades, equivalent to the Pleistocene epoch of the geological record. This rapid ice accumulation and

18 Vardiman, 1993; L. Vardiman, 1994, An analytic young-earth flow model of ice sheet formation during the 'Ice Age', in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 561-579; L. Vardiman, 2001, *Climates Before and After the Genesis Flood: Numerical Models and Their Implications*, El Cajon, CA: Institute for Creation Research.

melting demonstrated by this numerical climate modeling, based on the biblical timescale and boundary conditions, is of course too rapid for the uniformitarian theory of the Ice Age, which in any case cannot explain how the oceans became warm to be the driving force that initiated the ice accumulation. Furthermore, it has been suggested that because of its brevity, this rapid build-up and surging of ice would be more appropriately called an "Ice Advance," rather than an Ice Age.[19] This Ice Advance model, confirmed by the numerical modeling that also extends its explanatory power, has a lot of advantages, because it is consistent in not only explaining the same evidence explained by the conventional uniformitarian Ice Age model, but is also consistent with much more evidence beyond that.

It is estimated that due to the unique post-Flood climate, glacial maximum would have been reached very rapidly in about 500 years, based on the length of time the controlling conditions could have operated. The main variable determining this timespan would have been the ocean warmth, which generated the required copious moisture. Once the ocean water had cooled to some threshold temperature, the supply of moisture would have critically declined, and thus deglaciation would have begun. This estimated time of 500 years needed to cool the ocean water was calculated from the oceanic and atmospheric heat-balance equations applied to the post-Flood climate.[20] The available moisture for an Ice Advance not only would have come from the warm mid and high latitude oceans, but also from the poleward transported water vapor from lower latitudes by the atmospheric circulation. Indeed, the modeling has shown that enormous hurricane-like storm cells would have developed over the poles, drawing in the moisture and then precipitating it in spiral rain-bands around the central "eye."[21]

This Ice Advance model suggests that there was only one ice advance, with minor surges around the lobes of the ice sheets. In the conventional uniformitarian Ice Age model, multiple glaciations alternating with interglacial periods are postulated, but the number of glaciations has never been firmly established. The glacial sediments are so complex that a case could be made for from one to six or more separate glaciations. Four glaciations were initially agreed upon, based on investigations in the Swiss Alps, but recently glaciologists have revised that to twenty or thirty glaciations that developed and dissipated in succession, as correlated with the ocean-floor sediment data supposedly supporting the Milankovitch astronomical theory. However, abundant evidence is consistent with one ice advance only, particularly given the very radical requirements for development of the ice advance[22] (including a warm ocean) were simply not

19 Wise, 2002, 215-216.

20 Oard, 1990.

21 L. Vardiman, 1994, A conceptual transition model of the atmospheric global circulation following the Genesis Flood, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 569-579; Vardiman, 1993.

22 Williams, 1979.

repeatable. The glacial sediments have not been transported far, the till cover is only thin, especially over interior regions, and nearly all the till was deposited during the last supposed glaciation, all of which is more reasonably consistent with only one thin advancing and retreating ice sheet. Moreover, since practically all of the glacial period fossils are found south of the former northern hemisphere ice sheets, and most of the related major faunal extinctions were only the result of the last supposed glaciation, there most likely never were interglacial periods. Indeed, the evidence for the claimed multiple glaciations is only found at the peripheries of the ice sheet, evidence that is actually rare, such as fossils in ancient soils between sheets of till. Even recognizing an ancient soil is difficult, because there simply are too many poorly known variables that make identification speculative, let alone using their properties for dating. Instead, this claimed evidence for multiple glaciations is more simply and adequately explained by just one dynamic ice advance, in which the ice sheets, like modern glaciers, would advance, retreat and then surge again as dictated by climate variations. In the post-Flood Ice Advance model, the ice sheets would have moved rapidly at their peripheries and slowly in their interiors. Rapid oscillations at their peripheries would have caused stacked thin till sheets, with non-glacial deposits sandwiched between them, occasionally containing engulfed fossil remains.

Another consequence of the Ice Advance model is that the ice would have been much thinner, and would not have remained in position as long as claimed by the conventional uniformitarian model. Therefore, it more easily explains how there could be ice-free or "driftless" areas, such as in Wisconsin, which the periphery of the ice sheet completely surrounded but never covered in glacial ice. On the other hand, thick ice sheets advancing and retreating more than twenty times, as in the conventional uniformitarian model, would surely have not missed covering such areas. Furthermore, if thick ice had remained on the continents for a long time, it would have slowed the continents down under its own weight. Since it takes the earth some 25,000 years to recover completely from being depressed in this fashion, it should still be rebounding. However, most of Ohio, Indiana, and Illinois show very little to no rebound, as if the ice was either very thin, and/or it did not cover this area for very long.

The modeling of the ice advance also enables the thicknesses of the ice sheets to be calculated, based on the aerial distributions of the available precipitation. Thus, the best estimate for the average ice depth over the Northern Hemisphere was found to be about 700 meters, and over the Southern Hemisphere about 1,200 meters. Though these thicknesses seem large, they are significantly less and more soundly based than uniformitarian estimates. It is usually assumed that past ice sheets were similar to the current Antarctic ice sheets, but there is much evidence from the interior and margin of the Laurentide (North American) Ice Sheet that indicates it was actually comparatively thin. The fatal problem for the uniformitarian Ice Age model is that inflated ice sheet thickness estimates only exacerbate the difficulties of generating the required precipitation, not just for the ice sheets for one glacial episode, but repeatedly for twenty or more such episodes!

However, the uniformitarian model claims to have far more time available for the required precipitation to accumulate, because drilling into the Greenland and Antarctic ice sheets has shown the ice to consist of thousands of thin layers that have been equated with annual cycles of precipitation and thawing. While such thin ice layers can be visually recognized in the drill-cores from the tops of the ice sheets, with increasing depth the pressures have obliterated the visual layering, and so recognition of the layering depends on oxygen isotope variations[23] and on the calculated age-depth relationship incorporating the generally accepted ice flow model.[24] However, if the oxygen isotope data from the ice cores are interpreted within the biblical timeframe for the post-Flood Ice Advance model, rather than the uniformitarian age-depth relationship, an entirely different outcome is obtained that fits extremely well with the overall climate modeling of the single, short, post-Flood Ice Age.[25]

The calculated curve for the thickness of the ice sheets, and the accumulation of the layers as a function of time, shows a rapid build-up of most of the thickness in the first few centuries of the post-Flood period, and is consistent with the very high precipitation rates during that time. However, if it is assumed that the fluctuations in oxygen isotopes within the ice do delineate layers that represent annual precipitation and thawing with the changes of seasons, then even though the age-thickness relationship exactly fits the post-Flood Ice Advance model, many of these thin, proposed annual ice layers have to have formed each year during the rapid build-up of the ice sheets in the early centuries after the Flood.

This apparent contradiction is easily resolved by a correct understanding of the significance of the variations in the oxygen isotope ratios of the ice, and then by recognizing the affects of the individual storms that carried the moisture and precipitated it as snow on the growing ice sheets. Although the primary factor that causes the oxygen isotope ratio in precipitation to change is the influence of the formation temperature on the fractionation of the two oxygen isotopes,[26] the variation in oxygen isotope ratios is also a function of the distance of an observation site from the source of the moisture, the relative concentration of oxygen isotopes at the source of moisture, and the type of precipitation process.[27]

23 S. J. Johnsen, W. Dansgaard, H. B. Clausen and C. C. Langway, Jr., 1972, Oxygen isotope profiles through the Antarctic and Greenland ice sheets, *Nature*, 235: 429-434.

24 W. Dansgaard, S. J. Johnsen, H. B. Clausen and C. C. Langway, Jr., 1971, Climatic record revealed by the Camp Century ice core, in *Late Cenozoic Glacial Ages*, K. K. Turekian, ed., New Haven and London: Yale University Press, 37-56.

25 Vardiman, 1993, 1994, and 2001.

26 H. Craig, 1961, Isotope variations in meteoritic water, *Science*, 133: 1702-1703.

27 J. R. Petit, M. Briat and A. Roger, 1981, Ice Age aerosol content from east Antarctic ice core samples and past wind strength, *Nature*, 293: 391-394; R. Bowen, 1991, *Isotopes and Climate*, London: Elsevier Applied Science; J. R. Petit, J. W. C. White, N. W. Young, J. Jouzel and Y. S. Korotkevich, 1991,

It has thus been shown that the observed oxygen isotope trends in the ice cores can be explained successfully in terms of the dispersion of oxygen isotope ratios as a function of the distance from the edge of a growing or retreating ice shelf.[28] Of course, the ice cores drilled in the Greenland and Antarctic ice sheets contain records of the oxygen isotope ratios in the snows that precipitated at those locations through a timespan in which the ice was accumulating. Thus, if the site of an ice core was a short distance from the open ocean (say 200 km) at the time the snow at the bottom of the ice core fell, then the value of the oxygen isotope ratio in that snow would be relatively high, compared to the value if an ice shelf was forming over the open ocean so that the distance was slowly increasing to 1,000 km. Moreover, if there was then a sudden reversal in the growth of the ice shelf, causing the distance to decrease rapidly to 400 km or so, then the value of the oxygen isotope ratio in the snow would increase rapidly to a moderate level. Finally, if the shelf were then to remain fixed at a constant distance from the ice core site, then the oxygen isotope ratios would level out at a constant value. This is exactly the overall pattern in the oxygen isotope ratio in the Greenland ice cores.

As for the thin ice layers delineated by the small-scale variations in the oxygen isotope ratios supposedly representing annual precipitation and thawing with the cycle of the seasons, the same pattern can be readily explained in terms of individual ice storms being responsible for each thin layer of precipitation.[29] Given that the climate modeling has shown that an enormous hurricane-like storm system was perpetually situated over each of the poles during the formation and growth of the ice sheets,[30] the spiral rain-bands imbedded in such systems would have brought periodic storms that repeatedly swept in from the open ocean across the ice sheets, dumping the moisture they carried as snow. As the snow precipitated the temperature would fall, only to rise again with the passing of each storm, which would be reflected in a difference between the oxygen isotope ratio values in the first snow precipitated compared to the snow at the surface that was affected by the temperature increase in the passing of the storm. Thus, if each of these thin ice layers defined by the change in the oxygen isotope values represent snow precipitation from individual storms, then it is to be expected that there were many such storms each year, particularly in the early stages of rapid accumulation of the ice sheets in those first few centuries after the Flood.

Deuterium excess in recent Antarctic snow, *Journal of Geophysical Research*, 96: 5113-5122.

28 Vardiman, 2001, 59-68.

29 J. Zavacky, 2003, M.S. thesis (unpublished), Santee, CA: Institute for Creation Research Graduate School.

30 Vardiman, 1993, 1994.

97

The Post-Flood Ice Age—Geomorphic Features and Ice-Age Animals

The unique post-Flood climate during the accumulation of the ice sheets, and their pattern of growth, would explain some long-standing observations that have puzzled uniformitarians. For example, at that time many large lakes filled enclosed basins in what are now arid or semi-arid regions of the earth. One was the Great Salt Lake in Utah, which was 285 meters deeper at its peak and 17 times the size that it is now, a volume that would have required six times more precipitation then than in today's climate.[1] While these fluvial lakes would have actually been filled briefly by leftover waters from the Flood, there is evidence that they were partially maintained during the post-Flood Ice Age, which would have required during that period at least three times the current precipitation rate, contrary to uniformitarian theory that usually specifies very dry weather during the Ice Age.

Another puzzling observation is that cold-tolerant animals like reindeer lived at this time with warm-tolerant animals like the hippopotamus. Indeed, the latter even migrated into northern England, France, and Germany. However, the post-Flood Ice Advance model easily accounts for this unique distribution of animals, because winters would have been mild and summers cool, with northwest Europe being relatively warm at first, because of the surrounding warm ocean and the generally westerly onshore flow of air. Indeed, because of the huge volumes of moisture evaporated from the warm oceans and carried landwards to precipitate as snow to form the ice sheets, the sea level would have dropped sufficiently to expose land-bridges, for instance, across the Bering Strait and the English Channel, which would have aided rapid animal dispersion. The climate of Siberia and Alaska would also have been mild during the first few centuries of the post-Flood period, because the Arctic Ocean was relatively warm and thus not covered by sea ice, making the temperatures over the surrounding continents significantly warmer than at present.[2] The warm north Atlantic and north Pacific oceans also

1 G. I. Smith and F. A. Street-Perrott, 1983, Fluvial lakes of the western United States, *Late-Quaternary Environments of the United States*, vol. 1, H. E. Wright, Jr., ed., Minneapolis: University of Minnesota Press, 190-212.

2 R. L. Newson, 1973, Response of a general circulation model of the atmosphere to removal of the Arctic ice-cap, *Nature*, 241: 39-40.

would have contributed to the warmth in these regions, and precipitation would have been higher. Consequently, the woolly mammoth, whose fossil remains have been found as far south as Mexico, and therefore was actually a warm-tolerant animal, and many other types of animals would have been suitably at home with adequate food in Siberia and Alaska.

Once the warm ocean at the end of the Flood had cooled to some threshold temperature, the supply of moisture would have critically declined, so glacial maximum was then reached, and subsequently deglaciation would have begun. Glacial maximum has been estimated to have been reached about 500 years after the Flood. During deglaciation, with the oceans now cooler and moisture supply drastically reduced, summers over the mid and high latitudes of the northern hemisphere would have been warm, but the winters would have become very cold due to the continued cooling of the atmosphere by the ice sheets.[3] The cold climate would now have caused sea ice to develop on the Arctic Ocean, and it would have also become more extensive than it is today in the north Atlantic and north Pacific oceans. Due to the cooler temperatures and the greater extent of sea ice, the atmosphere would also have become drier than at present. The storm tracks, which had been responsible for delivering the snow to build the ice sheets, would now have been displaced southward, and dry, windy storms would have tracked south of the ice sheets, blowing dust that would result in extensive sand and loess sheets. With this changing climate, even though the winters were colder, the ice sheets would have begun melting in the summers. Even with the summer temperatures around the periphery of the ice sheets 10°C colder than summer temperatures at present, the energy-balance equation indicates not only the winter snow cover, but the ice sheets themselves, would melt rapidly at the peripheries in less than 100 years.[4] The interiors of the ice sheets, though, would probably have taken a little longer to melt, perhaps as much as 200 years. It should also be noted that these melting rates are not unrealistic, since they are close to the observed melting rates in the present climate. Consequently, the total time for the post-Flood Ice Age would have only been about 700 years.

The rapidly melting ice sheets would have caused rivers to overflow and become choked with sediments. River valleys, already deeply filled with alluvium, would thus have had terraces eroded into that alluvium at the high flow levels. Large river meanders, close to where the edges of the ice sheets were, attest to the large volume of run-off. Of course, some of these geomorphic features would have initially formed at the end of the Flood, due to the erosion of the retreating Flood waters, but this enormous volume of meltwater from the ice sheets at the end of the Ice Age would have surely added its imprint. It was at this time that the catastrophic outbursting of glacial meltwaters dammed up in the former Lake Missoula in Montana carved out the Channeled Scabland in Washington state,

3 Oard, 1990.

4 Oard, 1990.

as described earlier.

Another well-known and spectacular example of the excessive erosion due to the waters from the rapid melting of the ice sheets is the cutting of the Niagara Gorge and the recession of Niagara Falls on the U.S.-Canada border.[5] While erosion at the end of the Flood may have begun to form the Great Lakes, it was the erosion by the passage southwards of the Laurentide Ice Sheet that produced their present shape. Thus, at the end of the Ice Age, huge volumes of meltwater flowed out through these lakes and down into the St. Laurence River. The Niagara River flows from Lake Erie over Niagara Falls and on into Lake Ontario, but initially the Falls had flowed over the Niagara escarpment where the Niagara River flows into Lake Ontario, some seven miles downstream of their current position. Extrapolating the observed erosion rate of 4 to 5 feet per year,[6] the recession of Niagara Falls seven miles upstream from the Niagara escarpment would have taken about 7,000 to 9,000 years. However, this doesn't take into account the much greater erosion rate at the end of the Ice Age, when the discharge rate through the Niagara River was very much higher due to the huge volumes of glacial meltwaters. When this is taken into account, along with the more dependable estimate of the timespan of erosion along the sides of the Niagara Gorge itself, the more realistic estimate for the recession of Niagara Falls would be 4,000 years at most, consistent with the timescale back to the post-Flood Ice Age.

The rapid change in the climate at mid and high latitudes during this brief, 200-year deglaciation period would have had profound effects upon both flora and fauna, the cold, dry climate particularly causing great stress to the abundant megafauna that had flourished during the wet, warm climate in areas where the ice sheets were not accumulating. The rapid fall in temperatures at polar latitudes, for example, would have caused the freezing of surface sediments and soils, which have produced today's vast stretches of permanently frozen soils in the Arctic and sub-Arctic known as permafrost. Many animals would thus have become extinct due to the rapid loss of their habitats, and with the assistance of man, the hunter, in some cases. Indeed, embedded in the frozen mucks of the Arctic are large numbers of fossil mammals, apparently trapped and, in some cases, partially frozen before the soft parts had decayed:

> The extensive silty alluvium, now frozen, in central Alaska contains a numerous mammal fauna….Freezing has preserved the skin and tissue of some of the mammals. The faunal list includes two bears, dire wolf, wolf, fox, badger, wolverine, sabre-tooth cat, jaguar, lynx, woolly mammoth, mastodon, two horses, camel, saiga antelope, four bisons, caribou, moose,

5 For a fuller treatment of this issue see: I. T. Taylor, 1984, *In the Minds of Men: Darwin and the New World Order*, Toronto, Canada: TFE Publishing, 81-84; J. D. Morris, 1994, *The Young Earth*, Colorado Springs, CO: Master Books, 48-49; Oard, 1990, 69-172.

6 G. K. Gilbert, 1907, Rate of recession of Niagara Falls, *United States Geological Survey, Bulletin 306*, Washington, DC: US Government Printing Office.

> stag-moose, elk, two sheep, musk-ox and yak types, ground sloth, and several rodents. The number of individuals is so great that the assemblage of the whole must represent a rather long time.[7]

It is quite obvious that these mammals, which were once living in forests and grazing on grassy meadows but are now fossilized in alluvium, represent a sharp change of climate:

> Vast herds of mammoths and other animals (the New Siberian Islands in the far north of Asia have yielded mammoth, woolly rhinoceros, musk ox, saiga antelope, reindeer, tiger, Arctic fox, glutton, bear and horse, among the 66 animal species) required forests, meadows and steppes for their sustenance…and could not have lived in a climate like the present, with its icy winds, snowy winters, frozen ground and tundra moss year round.[8]

The extinction of many members of this megafauna so suddenly at the end of the Ice Age still remains a mystery unexplainable by uniformitarian scenarios. The woolly mammoth is one member of this extinct megafauna, and the estimated number that were destroyed by this rapid climate change in Siberia and Alaska is at least hundreds of thousands, and likely more than a million. The extent and abundance of these mammoth deposits in the permafrost have often been understated:

> In Siberia alone some 50,000 mammoth tusks have been collected and sold to the ivory trade, and there are rare occurrences of whole animals being preserved in frozen ground.[9]

Indeed, the Arctic islands north of Siberia have been described as densely packed with the remains of elephants and other mammals, as well as dense tangles of fossil trees and other plants.

However, it is the frozen carcasses that have especially attracted attention. Although preserved only in permafrost areas, most of the mammoth carcasses are of animals that apparently were healthy and robust just before they died. Some had just eaten before their deaths, which at least in some cases was due to suffocation or asphyxia:

> The only direct evidence of the mode of death indicates that at least some of the frozen mammoths (and frozen woolly rhinoceroses as well) died of asphyxia, either by drowning or by being buried alive by a cave-in

7 Flint, 1957, 471.

8 Charlesworth, 1957, 650.

9 Flint, 1957, 470.

> or mudflow. As stated above, sudden death is indicated by the robust condition of the animals and their full stomachs.[10]

Nevertheless, the number of frozen carcasses, indicating sudden death and burial before major decomposition had occurred, must be kept in perspective. By 1929 there were only 39 known carcasses of woolly mammoths and rhinoceroses, but only about half a dozen of those were actually complete, most being only a few small remnants of soft tissue attached to bones.[11] Since 1929 several more carcasses have been unearthed, including a baby mammoth discovered in 1977.[12]

Many more carcasses than those known must still exist in this remote, barren frozen ground of Siberia, because once exposed, carcasses would likely decompose and completely rot before being found. Thus, most carcasses that have become exposed would have completely decayed without leaving a record, so the number of carcasses with some remaining soft parts is probably hundreds or thousands times the number known. This number is still small compared with the million or more mammoths whose remains are estimated to be entombed in the permafrost, so most mammoths must have decayed completely before, or while, becoming interred. This is confirmed by the carcasses found with signs of partial decay having occurred before they were buried and frozen in the permafrost.

It is the stomach contents of a few mammoth carcasses that have heightened the mystery over the deaths of the mammoths. Stomach contents were only half digested, a condition believed to occur only if the mammoths cooled very quickly.[13] Indeed, many of the plants in these stomach contents could still be identified, though there has been some dispute over whether the plants indicated a much warmer climate, or represented plant types found in the current Arctic tundra. Based on the stomach contents, it has been concluded that the time of death was late summer or early fall, while the presence of beans and other vegetation found in the teeth of one carcass suggests that mammoth must have died while eating its last meal. Thus, whatever happened to kill and bury a million or more mammoths in the permafrost so quickly must have been a climatic catastrophe. Because the flesh has remained frozen, the animals had to be buried while the permafrost developed. Thus, there must have been a catastrophic change, from a climate in which the mammoths grazed on grasslands and experienced mild winters, to a climate with cold winters and barren frozen soil. However, because nearly all the mammoth flesh decayed before or during burial, the climate change

---

10 W. R. Farrand, 1961, Frozen mammoths and modern geology, *Science*, 133: 729-735 (quote on p. 734).

11 I. P. Tolmachoff, 1929, The carcasses of the mammoth and rhinoceros found in the frozen ground of Siberia, *Transactions of the American Philosophical Society*, 23: 11-74.

12 J. M. Stewart, 1977, Frozen mammoths from Siberia bring the Ice Ages to vivid life, *Smithsonian*, 8: 60-69; J. M. Stewart, 1979, A baby that died 40,000 years ago reveals a story, *Smithsonian*, 10: 125-126; N. A. Dubrovo et al,1982, Upper Quaternary deposits and paleogeography of the region inhabited by the young Kirgilyakh mammoth, *International Geology Review*, 24: 621-634.

13 Dillow, 1981, 383-396.

could not have been the equivalent of snap freezing. Rather, the small number of frozen carcasses suggests they resulted from rare conditions involving rapid burial. Furthermore, the famished condition of the baby mammoth found in 1977, and the putrefied, structureless contents of its skull, are both features that required some time to elapse during progression of this catastrophic climate change. Of course, many other types of animals lived with the mammoths, but most of the remains are only of mammoths, so the other animals being more fleet must have mostly escaped the catastrophic climate change, probably being able to migrate out of the area. Thus, the cooling of the climate was relatively rapid to kill a million or more well-fed mammoths, along with many other types of animals, preserving their remains in the developing permafrost, but not so rapid as to prevent most of the other animals except the slower mammoths from escaping. The catastrophic climate change would not have been the original quick freeze, because there are only a few frozen carcasses among the countless thousands of mammoth carcasses that had enough time for decomposition before burial and freezing of the ground. Thus, the change from mild weather to a very cold climate was relatively rapid, but permanent because freezing conditions have been maintained to the present day.

As already described, such a rapid climate shift would have occurred at the end of the relatively brief post-Flood Ice Age. Instead of the warmer temperatures and more moisture for plant growth in Siberia and Alaska during the Ice Age, the Arctic Ocean and the surrounding areas now gradually cooled, so the animals living there had to adapt. With the onset of deglaciation, the climate of Siberia and Alaska would have turned colder and drier. The melting ice sheets would have provided fresh water to the Arctic Ocean, which would float on the denser salt water and rapidly form sea ice, reinforcing the colder temperatures. Consequently, Siberia and Alaska, previously kept warm by the ice-free Arctic Ocean, now would have rapidly turned much colder. Many animals had enough time to migrate to a less severe climate, but many of the slower-moving mammals became trapped and perished. Migrating away from the continental interior toward the Arctic Ocean where the climate had been warmer, the mammoths in particular were caught in droves by the sudden climate shift and died in the cold. The carcasses found with partially digested food in their stomachs may have suffocated after the passage of a strong late-summer or early-autumn cold front, accompanied by strong winds, the wind-chill factor greatly enhancing the cooling efficiency of the freezing temperatures. Practically all the mammoths decayed before final burial and freezing of the soil that entombed them. However, some happened to be buried quickly enough to partially preserve their flesh. With the rapid melting of the ice caps in the Asian mountains, the rivers of Siberia would have been swollen with water and sediment, so that many of these animals that died of cold would have been buried in the sediment on what now became vast flood plains, with the water in the sediments freezing. Subsequent to the deglaciation when water volumes decreased, the rivers would have eventually eroded into their alluvial flood plains, forming valleys and terraces containing the mammoth remains, mostly where they are found today. Thus, modeling of the climate changes during the 500-year post-Flood Ice Age and 200-year deglaciation period provides adequate answers to the apparent riddle (in the uniformitarian Ice Age model) of the sudden demise of the mammoths in Siberia and Alaska.

With the melting of most of the ice sheets, the sea level would have risen to its current level. It had, of course, been higher at the end of the Flood prior to the onset of the Ice Age, because at that time neither the Greenland nor Antarctic ice sheets existed. The maximum lowering of sea level during the Ice Age would have been significantly less than suggested by uniformitarian estimates, which are based on excessive ice thicknesses and many other poorly known variables. Thus, the sea level immediately following the Flood would have been about forty meters higher than at present, while the lowest sea level at glacial maximum, when the largest volume of water was locked up as ice on land, would have been of the order of 50 to 60 meters below the current sea level.[14] This estimate is based on an ice volume less than one-half of uniformitarian estimates, because of the evidence that the ice sheets were that much thinner. In any case, uniformitarian methods of estimating sea levels are faulty, and just estimating ancient shorelines above the current sea level is a major problem.[15] Nevertheless, if "non-movable" sea-level indicators are used, then the estimated sea level during maximum glaciation would be at about 50 to 70 meters below the present sea level,[16] consistent with the estimate based on modeling within the context of the biblical post-Flood Ice Age. Of course, during deglaciation the melting of the glacial ice sheets would have resulted in a rapid rise in the sea level to the present shorelines, also rapidly flooding the continental shelf areas and land-bridges that had been exposed at glacial maximum.

Finally, 47 percent of the present ocean floor is covered in an average thickness of 200 meters of carbonate ooze, which consists of the shells of foraminifera and of the coccoliths (scales) of planktonic coccolithophores. At the current rate of such carbonate sedimentation, which is on the order of 1 to 3 cm/1000 years,[17] this ocean floor carbonate ooze would require millions of years to accumulate. However, that estimated sedimentation rate is actually inferred from steady-state conditions, in which the carbonate deposition rate is balanced by the amount of new material brought into the ocean by rivers. In contrast, with the higher sediment input to the oceans from rivers immediately after the Flood, and during the post-Flood ice advance and deglaciation due to a higher rainfall and erosion

14 Oard, 1990, 173-176.

15 J. Donner, 1995, Book review of *Shorelines and Isostasy*, D.E. Smith and A.G. Dawson, eds., *Boreas*, 14: 257-258.

16 P. W. Blackwelder, O. H. Pilkey and J. D. Howard, 1979, Lake Wisconsinan sea levels on the southeast US Atlantic shelf based on in-place shoreline indicators, *Science*, 204: 618-620.

17 Kennett, 1982, 464.

rates, the carbonate sedimentation rate would have been very much higher.[18] Furthermore, the larger influx of water and sediments into the oceans from rivers would also bring a large nutrient input, which combined with a rapid mixing of ocean waters, plus the warm temperatures of the ocean waters, would all have contributed to a large, sustained supply of foraminifera and coccoliths, enough to have accumulated the current thickness of calcareous ooze on the ocean floors in less than 1,000 to 2,000 years under ideal conditions and assuming no dissolution. However, some dissolution would invariably have occurred, but not at the current rate and current ocean depths, due to a greater supply of carbonate ions, the warmer water temperatures, the rapid sedimentation producing water flow through the accumulating sediments, and the more rapid circulation of the surface and deep ocean water, all reducing the amount of carbon dioxide in the deep ocean water where carbonate sediments were rapidly accumulating. Thus, these ocean-floor biogenic sediments can be readily accounted for on a sound scientific basis within the timeframe of the post-Flood ice advance and deglaciation period, plus the time to the present. This has been confirmed by numerical modeling, in which ocean-floor sediments accumulated rapidly in the initial post-Flood period, and then decreased exponentially to today's rate.[19]

18 A. A. Roth, 1985, Are millions of years required to produce biogenic sediments in the deep ocean?, *Origins (Geoscience Research Institute)*, 12: 48-56.

19 Vardiman, 1996.

98

From the Ice Age to the Present World

After the approximate 200-year period of deglaciation, the earth's climate had again changed, but now began to stabilize into the present general pattern. The ocean water had cooled to its current temperature and most of the continental ice sheets had melted, leaving Greenland and Antarctica still largely covered by ice, while the sea ice had developed in the Arctic Ocean. In mid to low latitudes the climate became warmer and drier, so that areas such as the Sahara and central Australia, which were once well-watered and lusciously vegetated, now progressively became deserts. With the reduction in rainfall rates there was a drastic decrease in run-off in river systems, and therefore in sediment transport. This is seen in a sudden change from the deposition of sand to silt in the Mississippi delta, while more or less simultaneous rapid desiccation is seen in the pluvial lakes in the western U.S. and elsewhere:

> [I]t is clear that a major fluctuation in climate occurred close to 11,000 years ago. The primary observation that both surface ocean temperatures and deep sea sedimentation rates were abruptly altered at this time is supplemented by evidence from more local systems. The level of the Great Basin lakes fell from the highest terraces to a position close to that observed at present. The silt and clay load of the Mississippi was suddenly retained in the alluvial valley and delta. A rapid ice retreat opened the northern drainage systems of the Great Lakes below and terrestrial temperatures rose…in each case the transition is the most obvious feature of the entire record.[1]

Some of these changes coincided with the deglaciation, and the uniformitarian "date" corresponds with the beginning of what is known as the Holocene Epoch, essentially the post-Ice Age period to the present. The sea level was rising rapidly in response to the melting of the ice sheets and glaciers, so that present shorelines became established.

---

1 W. S. Broeker, M. Ewing and B. C. Heeze, 1960, Evidence for an abrupt change in climate close to 11,000 years ago, *American Journal of Science*, 258: 441.

In the early centuries after the Flood, and right through the Ice Age period, the residual tectonic and volcanic effects of the Flood were still being experienced as localized and limited catastrophes. From the meters-per-second movement of the crustal plates during the catastrophic plate tectonics of the Flood, plate movements abruptly declined, and then tapered off to the current centimeters per year, resulting in a rapid decline in the numbers and intensities of earthquakes. During this process of decline, there were still earth movements and volcanic eruptions on a scale much less than the Flood, but still greater than experienced today:

> The Pleistocene was an Ice Age only in certain regions. Sub-crustal forces were also operative; signs of Pleistocene volcanicity and earth movements are visible in all parts of the world….the Pleistocene indeed witnessed earth movements on a considerable, even catastrophic, scale. There is evidence that it created mountains and ocean deeps of a size previously unequalled—a post-Tertiary age has been proved for at least one deep-sea trench…faulting, uplifting and crustal warping have been proved for almost all quarters of the globe.[2]

By the end of the Ice Age and the deglaciation period, these tectonic and volcanic disturbances would have been greatly reduced in their scale and frequency, although some minor earth movements continued, and there have been occasional localized volcanic eruptions up to the present time. Most of the earth movements have involved uplift, which in some measure has been isostatic rebound in response to the removal of the "weight" of the continental ice sheets.

As is to be expected, there is strong evidence that much more water once filled the lakes and flowed in the rivers of the earth than is true at present. Not only was this due to leftover waters from the Flood, but also due to the higher rainfall in the post-Flood Ice Age period. This is evidenced by the raised beaches and terraces found all over the world, as well as the evidence that deserts were once well-watered. For example, as already noted, in the time of Abraham, which remotely corresponds to the time of glacial maximum, the Jordan Valley and Dead Sea area were well-watered and lushly vegetated, whereas by the time of Jesus Christ the Dead Sea area was desolate and dry.

> Almost all the drainage basins of the closed lakes of the world bear, above the modern lake level, raised beaches which clearly testify to high lake levels at a previous time; Bonneville and Lahontan are only two of the more dramatic examples.[3]

That the rivers of the world once carried much larger volumes of water than

2 Charlesworth, 1957, 601, 603.

3 G. E. Hutchinson, 1957, *A Treatise on Limnology*, vol. 1, New York: Wiley, 238.

do their present remnants is evidenced both by the raised river terraces nearly always found along their courses, and by the extensive deposits of alluvium along their floodplains. Indeed, many streams are actually called "underfit," because the valleys they traverse are much too large to have been constructed by them:

> In a stream valley, the width of the channel occupied by the current may be only a small fraction of the width of the valley floor. Further, the banks of the channels are regularly low compared to the height of the valley sides. In a word, valleys commonly appear to be far too large to have been formed by the streams that utilize them. A first thought is to infer that the stream was once a much greater current.[4]

There is also little actual evidence of extensive lateral erosion by streams, especially when cutting through bedrock. Alluvial streams, such as the lower Mississippi, of course have wide meander belts, but the streams are cutting into alluvial fill that had already been deposited by earlier flows of greater magnitude, so that the floodplains themselves are basically plains of deposition rather than erosion:

> If rivers that flow across floodplains many times wider than their meander belts are observed, it will be found that in relatively few places are the streams actually against and undercutting the valley sides. This suggests at least that there may be a limiting width of valley flat beyond which lateral erosion becomes insignificant....The valleys of many, if not most, of the world's large rivers are so deeply filled with alluvium that it may seem inappropriate to consider their floodplains as veneers over bedrock valley flats. The alluvial fills in such valleys as those of the Mississippi, Missouri, and Ohio in places are several hundred feet thick.[5]

Further proof that rivers formerly carried much larger quantities of water is found in the great size of their original channels as cut out of the bedrock:

> As has already been stated, the bed widths of the filled channels are some ten times those of the present channels in the same localities....The whole of the present annual precipitation, with no loss to percolation or evaporation, could similarly have been run off in no more than five days. It is therefore necessary to postulate a former precipitation greater, and probably considerably greater, than that which is now recorded.[6]

Clearly, this geomorphic evidence points to greater volumes of water having flowed across, and carved out, the present land surface with the retreating waters

4 O. D. von Engeln and K. E. Caster, 1952, *Geology*, New York: McGraw-Hill Book Company, Inc., 256-257.

5 Thornbury, 1969, 129-130.

6 G. H. Dury, 1954, Contribution to a general theory of meandering valleys, *American Journal of Science*, 252: 215.

at the end of the Flood, and of the higher volumes of water flowing in river valleys during the higher rainfall of the immediate post-Flood period. The present river levels are therefore testimony to the warming and drying out of the earth's climate after the post-Flood Ice Age.

Mention should also be made of the old marine shorelines and raised beaches that are now found all around the world's seacoasts:

> In many parts of the world elevated strandlines exist which had a marine origin. If these features were local in extent they might be attributed to the effects of local diastrophism, but they are so widespread that they seem to be related mainly to eustatic rise of sea level rather than uplift of the land. In some areas, as in southern California, Pleistocene marine terraces exist at heights of 1300 to 1700 feet above sea level. Obviously Pleistocene seas never stood this much higher than present sea level and a good part of the height of the terraces here may be attributed to local diastrophism. In areas where local uplift has operated there is no consistency in the altitudes of the terraces from one point to another, but along coastlines that are relatively stable, such as the Atlantic and Gulf of Mexico coasts, we do find a considerable degree of consistency in terrace altitudes. Some elevated strandlines owe their present height above sea level to isostatic rebound from the load which was imposed upon the earth's crust by the Pleistocene ice sheets.[7]

Obviously, many of these elevated marine strandlines and terraces are the result of local uplift and/or isostatic rebound at the end of both the Flood and the post-Flood Ice Age. Furthermore, the only time that sea level was so much higher than at present, probably about 40 meters higher, was at the end of the Flood and the immediate post-Flood period, before the sea level dropped as ocean water evaporated to be precipitated as snow to form the continental ice sheets of the post-Flood Ice Age.

There is much evidence of a former lower sea level. The topography of the continental shelves, the irregularity of coastlines, the submarine canyons, the seamounts, and many other factors seem to indicate that they were formed, at least in part, at a time when the sea level was 50 to 60 meters lower during the post-Flood Ice Age. With the melting of the ice sheets, the oceans rose to their present level and, with minor fluctuations, have remained at that level since. Of course, as mentioned previously, with the lowering of the sea level during the post-Flood Ice Age, land-bridges were exposed where the oceans were shallow, such as across the Bering Strait between Asia and North America, the English Channel between England and France, and much of the ocean between the Indonesian islands. These land-bridges appear to have been successfully used by both animals and humans to

7 Thornbury, 1969, 408.

migrate across the globe, as they dispersed from where they disembarked from the Ark when it landed "in the mountains of Ararat" (Genesis 8:4), and subsequently from Babel. Growth in the animal population would have been rapid in those first few centuries after the Flood, as the animals that disembarked from the Ark moved into empty ecological niches without competitors. For example, even with a population doubling time of twenty years, there would be more than a million mammoths 500 years later at glacial maximum (before their extinction during deglaciation) that had descended from the representative pair of the elephant kind that disembarked from the Ark. At the same time, rapid intrabaraminic (within created kinds) diversification was occurring to produce many new varieties of animals and plants that split into sub-populations to establish and fill all the different new ecological niches in the post-Flood world.[8]

However, the existence of these land-bridges does not explain the biogeographic distribution of the majority of plants and animals in our post-Flood world. Even the best evolutionary biogeography models have neither successfully explained the multi-taxon concurrence of trans-oceanic range disjunctions, nor why areas of endemism exist where they do. In contrast, a rafting dispersal mechanism, in which plants and animals rafted across oceans on and among masses of logs, plant debris, and vegetation mats, in the immediate post-Flood world, has successfully explained not only the data explained by the best evolutionary models, but also data that such models fail to explain.[9] Some plants in the present world are known to float for decades, as indicated by the floating log mat in Spirit Lake since the eruption of Mount St. Helens.[10] Of course, the Flood destroyed all the world's pre-Flood forests, and many of the pre-Flood plants were buried either directly, or after subsequently becoming waterlogged and sinking, in the sediments that accumulated, including the extensive coal beds, during the Flood. However, based upon the flotation times of modern plants, it is expected that many pre-Flood plants would have still been floating on the ocean surface after the Flood ended. Indeed, given the global destruction of forests, each system of post-Flood ocean currents may have been carrying billions of logs in the immediate post-Flood world.

Therefore, these log mats immediately after the Flood may have been nearly as efficient in dispersal of some of the terrestrial organisms as was the land itself, carrying many organisms across the oceans in the post-Flood world. Furthermore, due to the high rainfall rates in the early centuries after the Flood, and the residual

8 T. C. Wood, 2003, Perspectives on aging, a young-earth creation diversification model, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 479-489.

9 K. P. Wise and M. Croxton, 2003, Rafting: a post-Flood biogeographical dispersal mechanism, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 465-477.

10 S. A. Austin, 1991, Floating logs and log deposits of Spirit Lake, Mount St Helens volcano national monument, Washington, *Geological Society of America Abstracts with Programs*, 23: 7.

catastrophism, it is likely that much mass-wasting occurred in early post-Flood times, including the dislodging and floating of vegetation mats, complete with resident animals, such as those that have been occasionally observed on today's oceans. In any case, most of the raft debris itself was probably plant material that was intended to survive the Flood outside the Ark, and these plants and other organisms would thus have experienced trans-global dispersal, even before land began rising out of the Flood waters, and long before the organisms on the Ark were able to join them on these floating vegetation rafts. It is possible by this means that even freshwater organisms were transported across bodies of salt water. Faster-moving organisms, such as marsupials that don't have to stop as long to care for their young, may have been the first in the post-Flood world to ride these rafts over oceanic barriers and thus colonize island continents such as Australia and Antarctica, and even South America, which probably was only joined to North America by the Panama Isthmus as a result of post-Flood tectonic and geologic activity. By the time slower organisms made it to key locations, the plant rafts may have been destroyed. Nevertheless, this rafting dispersal mechanism on the ocean currents of our post-Flood world can successfully explain the biogeographic distribution of most plants and animals today.

Finally, when Noah and his family disembarked from the Ark, they brought with them the culture and technology developed before the Flood to a new and totally different world, where the pre-Flood land had been faulted, flooded, eroded, and buried with an average of two kilometers of sediment. All lakes and rivers, hills and mountains, and even the air and the soil, were different. Plants and animals were assembling into new and different communities, and genetically were rapidly diversifying. Life would initially have been hard, though the domesticated animals and plants brought with them off the Ark would help them to quickly re-establish homes and a manageable lifestyle. Metals such as copper and iron would have to be searched for in new locations. However, in the meantime, even with their advanced cultural and technical abilities, Noah and his descendants immediately after the Flood would have used whatever resources were available to them, so food would have to be gathered where it could be found, and tools would have to be fashioned from crude materials. It is thus easy to envisage that, as conditions stabilized and resources were found, the lifestyles of Noah and his descendants changed from a hunting-gathering, stone-tooled-based, and even cave-dwelling society into an agricultural, copper- and then iron-tool-based city-dwelling society. However, these changes would have occurred within just a few decades, well within the course of a single human lifetime.

For the first 100 to 200 years after the Flood, Noah and his descendants lived in the one society, in essentially the same location, that culminated in the Babel civilization, contrary to God's specific command to spread out across the earth (Genesis 9:1). In rebellion against God, the Tower of Babel was built, so God judged them by confusing the language (Genesis 11:1-10). Because of this breakdown in communication between the different family groupings, now speaking different languages, they were forced to disperse from Babel and begin migrating across the earth, taking their individual genetic characteristics with them. Each family group as it migrated to new land would have found itself in the same situation again, lacking shelter, agriculture, and metal for tools. In each situation, agriculture, metal-working, and cities would have progressively developed independently, so the rate of cultural development and the rise of civilizations again would have varied considerably from location to location, some even never moving out of the hunting-gathering mode at all. However, overall, culture developed again through stages of stone tools, then to copper and bronze tools, and beyond with city civilizations of the different cultures and languages.

This migration from Babel would have started some 100 to 200 years after the Flood, when the ice sheets of the post-Flood Ice Age were advancing across northern Eurasia and North America, and when the sea level was lower, exposing land-bridges. Man had refused to disperse immediately after the Flood, so he would have arrived at distant locations long after most animals and plants already had. This would explain why human fossils are found in the local surficial sediments above ape fossils, and why it took a while for humans to acquire full evidences of culture. Furthermore, at the same time these events were occurring, both animals and humans were experiencing rapid genetic diversification, and humans at least were experiencing rapidly shortening lifespans. This would, in turn, explain the differences between the human fossils that have been found, particularly the brain size differences, as the non-skull bones can hardly be distinguished from modern humans.

Section VIII

Problems in Biblical Geology Solved—Radioactive Dating and Geochronology

99

The Radioactive Methods for Dating Rocks

In the preceding section a systematized outline of earth history was presented that explains the data of the geologic record in a comprehensive, but more consistent, fashion compared to the uniformitarian and evolutionary framework that has dominated geological thinking for the past 150 years or so. The basic rationale for this alternate framework for understanding earth history is the frank recognition of the literal character of all historical narrative in the unique revelation of the Judaeo-Christian Scriptures. It must first be realized that because uniformitarian models are based on the assumption that present processes must be utilized as the primary means of understanding the earth's history, they have not provided, and cannot provide, a scientifically valid explanation of the earth's origin, development, and history consistent with all geological, geophysical, and biological data. Instead, it must be recognized that all absolute knowledge of what has happened in the earth's past, when no human observers were present, must have necessarily come by way of divine revelation.

The unique claim of the Bible is that it embodies this divine revelation. This claim is supported by the testimony of Jesus Christ Himself and 2,000 years of Christian history. Thus, the Bible provides a more than adequate reason to base a framework for earth history on the factual details recorded therein. Accordingly, an attempt has been made to determine how the actual data of the geologic record can be understood in full harmony with these revealed factual details, especially regarding the creation of a mature, fully-operational universe, and the catastrophic earth-destroying Flood. It is claimed here that the data, at least in the broad outline presented in the preceding chapters, have been shown to be remarkably consistent with the biblical record. Such a demonstrated harmony does not, of course, indicate any particular insight or originality, but only gives testimony to the veracity and perspicuity of the inspired accounts in the Bible.

It is certainly recognized that not all questions have been answered, or all problems resolved. A complete reorientation of the entire, voluminous accumulation of pertinent data and published interpretations would not take a mere few hundred pages, but countless large volumes, and would require the intensive efforts of a great number of specialists trained in the various branches of the earth sciences.

However, the comprehensiveness of the biblical framework points the way forward for such studies, and provides the basic keys by which all such perceived problems can be ultimately resolved.

The chapters in this section can only deal with some of the critical aspects of the perceived major problems. However, if it has indeed been shown that the general features of the geological data all harmonize with the biblical outline of earth history, and if it can now be shown that the major apparent difficulties in interpreting the geologic record within this framework can likewise be resolved and understood in these terms, then it is reasonable to conclude that any remaining smaller problems will also be eventually solved by further research and study.

The Radioactive Methods for Dating Rocks

Without doubt, the most important and serious of these perceived problems is the question of time. There are, of course, many lines of geological evidence that appear to strongly imply that the earth and its various rock strata are millions, and even billions, of years old, immensely older than the straightforward biblical interpretation. The latter, as presented here, involves the relatively recent creation and subsequent Flood as the causes of most of the earth's geologic features.

There have been many different ways used by geologists in their attempts to measure the absolute age of the earth and its various strata, deposits, and features. In each such method, some physical or chemical process is involved whose present rate of activity can be measured. The total accumulation of the product from the process must also be measured. It is then a simple matter of calculating how long that process must have been in operation in order to have produced its present results. Some of the processes which have been used at various times as supposed geologic chronometers have included the influx of sodium and other elements into the ocean, lakes and rivers, the erosion of canyons or other areas by either flowing water, wind or glaciers, the building of deltas, the deposition of sedimentary strata, the growth of chemical deposits in soils, caves or other places, the moving of rocks, the growth of annual bands in trees, the accumulation of seasonal cycles of sediments on lake beds, or other entities whose appearance may be affected by seasonal changes, the escape of terrestrial gases into the atmosphere, addition to the earth's surface of connate waters through volcanism, and various other similar processes. There are also various chronometers in astronomy that have been used to determine absolute age, most of them being based on the rate of expansion of the universe and its various component parts, and on the velocity of the light coming from distant galaxies.

However, the most important geologic chronometers are, of course, those based on the radioactive decay of various chemical elements. Some isotopes of certain elements are radioactive, disintegrating continuously by various processes into isotopes of other elements. The present rates of disintegration of these isotopes can be measured, and if both the parent and daughter isotopes are found in measurable quantities in a rock, or mineral within a rock, being analyzed, then a relatively simple calculation yields the time period during which the daughter isotopes have apparently been accumulating due to radioactive decay. This is then declared to be the age of the rock. The most important and routinely used of these radioactive dating methods involve the disintegration of uranium and thorium into radium, radon, helium, and lead, of rubidium into strontium, of potassium into argon, and of samarium into neodymium. More specialized methods involve the disintegration of lutetium into hafnium, and of rhenium into osmium. All the parent isotopes in these methods disintegrate very slowly, so these methods are used to supposedly measure long ages of millions and billions of years for all but the most recent rocks. In contrast to these long-age methods is the short-age radiocarbon method, based on the formation of the radioactive isotope of carbon in the atmosphere by cosmic radiation, and its subsequent decay to a stable nitrogen isotope. Of course, because carbon is the element on which organic materials are built (in contrast to silicon being the primary basis of rocks), the radiocarbon method can only be used for "dating" organic-based materials. However, because the disintegration of the radioactive carbon isotope is relatively rapid, the method can only yield relatively short ages of thousands of years.

There is no question that the vast majority of the geochronometers mentioned above have given estimates for the age of the earth and its strata immensely greater than any possible estimate based on biblical chronology. In particular, the radioactive dating methods, except for the radiocarbon method, have usually yielded ages of hundreds of millions, and even billions, of years. Indeed, the accepted age for the earth of 4.55 (±0.07) billion years is based on the uranium-thorium-lead dating of meteorites.[1] However, no matter how accurate the analyses of these radioactive parent isotopes and their daughter isotopes in rocks, minerals, and meteorites, the significance of any or all of these measurements depends on, and is limited by, the assumptions that are made when interpreting the data. To obtain the most reliable and extensive overviews on all these radioactive dating methods, it is recommended that the best specialist textbooks are read,[2] as well as good, simplified summaries.[3]

1 C. C. Patterson, 1956. Age of meteorites and the earth, *Geochimica et Cosmochimica Acta*, 10: 230-237; R. H. Steiger and E. Jäeger, 1977, Subcommission on geochronology: convention on the use of decay constants in geo- and cosmochronology, *Earth and Planetary Science Letters*, 36: 359-362.

2 G. Faure and T. M. Mensing, 2005, *Isotopes: Principles and Applications*, third edition, Hoboken, NJ: John Wiley & Sons; A. P. Dickin, 2005, *Radiogenic Isotope Geology*, second edition, Cambridge, UK: Cambridge University Press.

3 S. A. Austin, 1994, Are Grand Canyon rocks 1 billion years old?, in *Grand Canyon: Monument to Catastrophe*, S. A. Austin, ed., Santee, CA: Institute for Creation Research, 111-131; D. DeYoung, 2000, Radioisotope datingreview, in *Radioisotopes and the Age of the Earth: A Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 27-47.

The Assumptions of Radioactive Dating

The measurement of time by radioactive decay of a parent isotope is often compared to the measurement of time as sand grains fall in an hourglass (Figure 56, page 1090). The sand in the upper chamber of an hourglass represents a radioactive parent isotope, while the sand in the lower chamber is analogous to the respective daughter isotope. The sand grains fall from the upper chamber at a constant rate, said to be analogous to radioactive decay. If all the sand grains started in the upper chamber and then the number of sand grains were measured in the two chambers after some time elapsed, provided the rate at which the sand grains fall has been measured, simple mathematics can be used to calculate how long the hourglass has been in operation, and thus, the time when the process started. When applied to the radioactive decay "clock," this starting time is when the rock formed and is, therefore, its calculated age.

From this description of the analogy of the hourglass to radioactive decay of isotopes in rocks and minerals, it should be evident that the calculation of the "age" of a rock or mineral, based on the measurements of the quantities of the parent and daughter isotopes, and of the decay rate for the particular parent-daughter isotopes pair, requires three crucial assumptions:

1. The number of atoms of the daughter isotope originally in the rock or mineral when it crystallized can be known. In other words, it is assumed that we can know the initial conditions when the rock or mineral formed. In the potassium-argon method it is usually assumed that there was originally no daughter argon; therefore, all the argon measured in the rock or mineral was derived by radioactive decay from *in situ* parent potassium.

2. The numbers of atoms of the parent and daughter isotopes have not been altered since the rock or mineral crystallized, except by radioactive decay. In other words, it is assumed that the rock or mineral remained closed to loss or gain of the parent and/or daughter isotopes since crystallization.

3. The rate of decay of the parent isotope is known accurately, and has not changed during the existence of the rock or mineral since it crystallized.

These assumptions require careful evaluation for each rock or mineral being dated, and obviously impose certain restraints in the interpretation of the resultant calculated "ages." Indeed, these assumptions simply cannot be proven, because, when most rocks or minerals crystallized, no human observers were present to determine the original numbers of atoms of the daughter isotopes. Nor were human observers present throughout the histories of most rocks and minerals to determine whether the rocks and minerals have remained closed to loss or gain of parent and/or daughter isotopes, and if the rates of radioactive decay of the parent isotopes have not changed. Thus, it logically follows that these assumptions are, strictly speaking, not provable. It is often claimed that it is obvious where assumption two has failed, because anomalous results are obtained, that is, results not in agreement with the expected “ages.” Otherwise, the calculated “ages” are often what are expected, and so the methods are confidently accepted as valid. Of course, this is uniformitarianism in the extreme, because it is assumed that decay rates measured in the present (over the past century) have been constant for millions and billions of years, an extrapolation of up to seven orders of magnitude!

When a radioactive dating determination is performed on an individual rock or mineral, the calculated result is called a “model age.” Calculating the model age can only succeed if the original concentration of daughter isotope in the rock or mineral when it formed is known. In the case of potassium-argon dating, it is assumed that there was no daughter argon in the rock or mineral when it formed, because argon is an inert gas that would not have been chemically bonded within the rock or mineral. On the other hand, daughter strontium is usually included and chemically bonded into minerals and rocks when they formed, along with other isotopes of strontium not derived by radioactive decay. Since it is not known how much daughter strontium was incorporated in the mineral or rock when it formed, a method has been devised to determine that.

This is known as the “isochron age” method. At least four rock samples are obtained from the same geologic unit, or at least three minerals are separated from a single rock sample. It is safely assumed that these should have all formed at about the same time. However, the geologic processes that formed the sampled rock unit may have caused an uneven distribution in the rock unit of the parent rubidium and daughter strontium isotopes. When three or more minerals in a single rock are sampled, there will undoubtedly be different amounts of the radioactive parent and daughter isotopes, because the minerals have varying abilities to bind the chemically different elements in their crystal lattices. Nevertheless, it has to be assumed that within each rock sample or mineral there has been sufficient mixing to produce uniformity between the rock samples and the minerals with respect to the isotopic composition of the daughter strontium. Of course, over time the isotopic composition of the samples of the rock unit, and the minerals in each rock sample, will have been altered by radioisotope decay. However, for the isochron dating method to work, it is essential that all rock samples have to be from the same rock unit, and there has to be uniformity within the rock unit of the original daughter strontium isotope ratio. These two conditions replace the assumption about the original daughter isotope ratio being known (for example, no daughter argon originally), that has to be inserted into the “model age” calculation.

Figure 57 (page 1091) shows how the isochron method works. Here, hypothetical measurements of radioisotope ratios in six samples from the same rock unit are plotted, because all six samples are believed to have formed at the same time. A positive-sloping line can be plotted through the radioisotope measurements of five of the six rock samples, as shown in Figure 57(c). One of the six radioisotope analyses lies off the line described by the other five, and thus could be interpreted as having been altered by some geologic process. Such an outlier would usually be disregarded in the subsequent calculations. Therefore, the interpretation depicted in Figure 57(a) assumes the line through the five rock samples can provide an "age" for the rock unit represented by these five samples. Figure 57(b) shows how these five samples from the hypothetical rock unit can yield an "age" interpretation. When all parts of this rock unit formed at the same time, they all had the same abundance of the daughter isotope (zero time = zero slope). With the passage of time, the radioisotope decay of the parent increased the quantity of daughter in a uniform manner, according to the different abundances of the parent in the rock samples. Thus, all points of equal "age" lie on the same line. In Figure 57(b), it is evident that the slope or steepness of the line of "equal age" or "isochron" (from the Greek, *isos*, equal, and *chronos*, time) increases with elapsed time. The "isochron age" is calculated from the slope of the isochron line that best fits the radioisotope analyses of the rock samples, as shown in Figure 57(c).

The isochron method has become the most widely-used radioisotope dating technique among geologists for dating rocks. This is for two reasons. First, no assumption about the initial conditions is apparently necessary, because the isochron itself can be used to determine the initial daughter isotope abundance (see Figure 57). Second, if there has been any open-system behavior due to contamination, weathering, or other geologic processes, the rock samples in which that has occurred will not plot on the isochron line (or so it is assumed). Furthermore, the isochron method can be used for four or more samples from the same rock unit, or for three or more minerals from the same rock sample, the whole-rock radioisotope values also plotting on the resultant mineral isochron. The isochron method is primarily used in rubidium-strontium, samarium-neodymium, and uranium-thorium-lead radioisotope dating, but is also used in the lutetium-hafnium and rhenium-osmium radioisotope methods that have specialized applications.

100

The Pitfalls in the Radioactive Dating Methods—The Potassium-Argon and Argon-Argon Methods

Both these methods suffer from the same problems, because they are both based on the radioactive decay of potassium (K) to argon (Ar), a gas which does not bond with other elements. The argon-argon method is a refinement, in that some of the potassium (^{39}K which is regarded as a proxy for radioactive ^{40}K) in a rock or mineral is first converted in a nuclear reactor to ^{39}Ar, a different isotope of argon compared to that produced by radioactive decay of ^{40}K, which is ^{40}Ar. This argon-argon method is now regarded as more reliable, because these two argon isotopes can be measured together in a mass spectrometer, whereas the traditional potassium-argon method requires separate measurements of potassium and argon, compounding the likely measurement errors. Nevertheless, the pitfalls with both these methods are the same and have already been elaborated.[1]

"Excess" or Inherited Argon

The basis for the potassium-argon (and also the argon-argon) method has been stated strongly:

> The K-Ar method is the only decay scheme that can be used with little or no concern for the initial presence of the daughter isotopes. This is because the ^{40}Ar is an inert gas that does not combine chemically with any other element and so escapes easily from rocks when they are heated. Thus, while a rock is molten the ^{40}Ar formed by decay of ^{40}K escapes from the liquid.[2]

However, many cases have been documented of recent historic lava flows which yielded grossly incorrect potassium-argon ages because they contained more argon

1 A. A. Snelling, 2000, Geochemical processes in the mantle and crust, in *Radioisotopes and the Age of the Earth: A Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 123-304.

2 G. B. Dalrymple, 1991, *The Age of the Earth*, Stanford, CA: Stanford University Press, 91.

derived from radioactive potassium ($^{40}Ar^*$) than expected. This has been called "excess argon." This was $^{40}Ar^*$ initially in these rocks when they formed, and, therefore, it would have been inherited from the magma sources of the lavas, since it is often present in the gases released during volcanic eruptions. This violates the key assumption of non-zero concentrations of $^{40}Ar^*$ for the potassium-argon and argon-argon methods. Many examples are now well documented of recent and young volcanic rocks that have yielded grossly inaccurate potassium-argon ages as a result of this excess and inherited $^{40}Ar^*$.[3]

After the May 18, 1980, eruption of Mount St. Helens in Washington state, a new lava dome began developing from October 26, 1980, onwards within the volcano's crater. In 1986, less than ten years after it flowed and cooled, a dacite lava from this dome was sampled and analyzed.[4] The lava flow yielded a potassium-argon "age" of 350,000 years for the whole rock, and the constituent minerals yielded potassium-argon ages up to 2.8 million years. Similarly, the June 30, 1954, andesite lava flow from Mt. Ngauruhoe, central North Island, New Zealand, yielded potassium-argon model "ages" up to 3.5 Ma (million years) due to excess $^{40}Ar^*$.[5] Furthermore, a separate split of that flow sample also yielded a model "age" of 0.8 Ma, which indicates the variability in the excess $^{40}Ar^*$. Investigators also have found that excess $^{40}Ar^*$ is preferentially trapped in the minerals within lava flows, with one K-Ar "date" on olivine crystals in a recent basalt being greater than 110 Ma.[6] Even laboratory experiments have been used to test the solubility of argon in synthetic basalt melts and their constituent minerals, with olivine retaining as much as 0.34 ppm $^{40}Ar^*$.[7]

---

3 G. B. Dalrymple, 1969, $^{40}Ar/^{36}Ar$ analyses of historic lava flows, *Earth and Planetary Science Letters*, 6: 47-55; G. B. Dalrymple and J. G. Moore, 1968, Argon-40: Excess in submarine pillow basalts from Kilauea Volcano, Hawaii, *Science*, 161: 1132-1135; D. Krummenacher, 1970, Isotopic composition of argon in modern surface volcanic rocks, *Earth and Planetary Science Letters*, 8: 109-117; R. P. Esser, W. C. McIntosh, M. T. Heizler and P. R. Kyle, 1997, Excess argon in melt inclusions in zero-age anorthooclase feldspar from Mt Erebus, Antarctica, as revealed by the $^{40}Ar/^{39}Ar$ method, *Geochimica et Cosmochimica Acta*, 61: 3789-3801; A. A. Snelling, 2000, Geochemical processes in the mantle and crust, in *Radioisotopes and the Age of the Earth: A Young Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 123-304.

4 S. A. Austin, 1996, Excess argon within mineral concentrates from the new dacite lava dome at Mount St. Helens volcano, *Creation Ex Nihilo Technical Journal*, 10 (3): 335-343.

5 A. A. Snelling, 1998, The cause of anomalous potassium-argon 'ages' for recent andesite flows at Mt. Ngauruhoe, New Zealand, and the implications for potassium-argon 'dating', in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 503-525.

6 P. E. Damon, A. W. Laughlin and J. K. Precious, 1967, Problem of excess argon-40 in volcanic rocks, in *Radioactive Dating Methods and Low-Level Counting*, Vienna: International Atomic Energy Agency, 463-481. Also: A. W. Laughlin, J. Poths, H. A. Healey, S. Reneau and G. WoldeGabriel, 1994, Dating of Quaternary basalts using the cosmogenic ^{3}He and ^{14}C methods with implications for excess ^{40}Ar, *Geology*, 22: 135-138; D. B. Patterson, M. Honda and I. McDougall, 1994, Noble gases in mafic phenocrysts and xenoliths from New Zealand, *Geochimica et Cosmochimica Acta*, 58: 4411-4427.

7 C. L. Broadhurst, M. J. Drake, B. E. Hagee and T. J. Benatowicz, 1990, Solubility and partitioning of Ar in anorthite, diopside, forsterite, spinel, and synthetic basaltic liquids, *Geochimica et Cosmochimica Acta*, 54: 299-309; C. L. Broadhurst, M. J. Drake, B. E. Hagee and T. J. Benatowicz, 1992, Solubility and

The obvious conclusion most investigators have reached is that the excess $^{40}Ar^*$ had to be present in the molten lavas when extruded, and they did not completely degas when they cooled. This resulted in excess $^{40}Ar^*$ becoming trapped in constituent minerals and the rock fabrics themselves. However, from whence comes this excess $^{40}Ar^*$? This is ^{40}Ar, which cannot be attributed to atmospheric argon or *in situ* radioactive decay of ^{40}K, nor is it simply "magmatic" argon. The excess $^{40}Ar^*$ in the 1800-1801 Hualalai flow, Hawaii, was found to reside in fluid and gaseous inclusions in olivine, plagioclase, and pyroxene in ultramafic xenoliths in the basalt, and was sufficient to yield "ages" of 2.6 Ma to 2,960 Ma.[8] Thus, because the ultramafic xenoliths and the basaltic magmas came from the mantle, the excess $^{40}Ar^*$ must have initially resided there, having then been transported to the earth's surface in the magmas. Indeed, most investigators now concede that the excess $^{40}Ar^*$ in all Hawaiian lavas, including those from the active Loihi and Kilauea volcanoes, is indicative of the mantle source area from which the magmas have come. This is also confirmed by the considerable excess of $^{40}Ar^*$ measured in ultramafic mantle xenoliths from the Kerguelen Archipelago in the southern Indian Ocean, which is also regarded as being the result of extruding magmas from a mantle plume source.[9] Furthermore, data from single vesicles in mid-ocean ridge basalt samples dredged from the North Atlantic suggest the excess $^{40}Ar^*$ in the upper mantle may be almost double previous estimates, that is, almost 150 times more than the atmospheric content (relative to ^{36}Ar).[10] However, another study on the same sample indicates the upper mantle content of $^{40}Ar^*$ could be even ten times higher.[11]

Further confirmation comes from diamonds. Diamonds form deep in the mantle because of the required pressures, and are rapidly carried by explosive volcanism into the upper crust and to the earth's surface. When a K-Ar isochron "age" of 6 Ga (billion years) was obtained for ten Zaire diamonds, it was obvious excess $^{40}Ar^*$ was responsible, because the diamonds could not be older than the earth itself.[12] These same diamonds produced $^{40}Ar/^{39}Ar$ "age" spectra yielding an isochron "age" of approximately 5.7 Ga.[13] It was concluded that the ^{40}Ar is an

---

partitioning of Ne, Ar, K and Xe in minerals and synthetic basaltic melts, *Geochimica et Cosmochimica Acta*, 56: 709-723.

8 J. G. Funkhauser and J. J. Naughton, 1968, Radiogenic helium and argon in ultramafic inclusions from Hawaii, *Journal of Geophysical Research*, 73: 4601-4607.

9 P. J. Valbracht, M. Honda, T. Matsumoto, N. Mattielli, I. McDougall, R. Ragettli and D. Weis, 1996, Helium, neon and argon isotope systematics in Kerguelen ultramafic xenoliths: Implications from mantle source signatures, *Earth and Planetary Science Letters*, 138: 29-38.

10 N. Moreira, J. Kunz and C. Allègre, 1998, Rare gas systematics in Popping Rock: Isotopic and elemental compositions in the upper mantle, *Science*, 279: 1178-1181.

11 P. Burnard, D. Graham and G. Turner, 1997, Vesicle-specific noble gas analyses of "Popping Rock": Implications for primordial noble gases in the earth, *Science*, 276: 568-571.

12 S. Zashu, M. Ozima and O. Nitoh, 1986, K-Ar isochron dating of Zaire cubic diamonds, *Nature*, 323: 710-712.

13 M. Ozima, S. Zashu, Y. Takigimi and G. Turner, 1989, Origin of the anomalous ^{40}Ar-^{36}Ar age of Zaire cubic diamonds, Excess ^{40}Ar in pristine mantle fluids, *Nature*, 337: 226-229.

excess component which has no age significance and is found in tiny inclusions of mantle-derived fluid.

All this evidence clearly shows that excess $^{40}Ar^*$ is ubiquitous in recent and young volcanic rocks, because it has been inherited from the mantle source areas of the magmas. If this $^{40}Ar^*$ in the mantle predominantly represents primordial argon that is not derived from *in situ* radioactive decay of ^{40}K, it has no age significance. Furthermore, if this is primordial argon emanating from the mantle, then it is possible that all other rocks in the earth's crust are also susceptible to "contamination" by excess $^{40}Ar^*$. If so, then both the K-Ar and Ar-Ar "dating" of all crustal rocks would be similarly questionable.

When muscovite (a common mineral in crustal rocks) is heated to 740° to 860°C under high argon pressures for periods of 3 to 10.5 hours, it absorbs significant quantities of Ar, producing K-Ar "ages" of up to 5 billion years, and the absorbed Ar is indistinguishable from radiogenic argon ($^{40}Ar^*$).[14] In other experiments, muscovite was synthesized under similar temperatures and argon pressures, with the resultant muscovite retaining up to 0.5 wt % Ar, approximately 2,500 times as much Ar as is found in natural muscovite.[15] It has been found also that under certain conditions Ar can be incorporated into minerals which are supposed to exclude Ar when they crystallize.

It has been envisaged that noble gases from the mantle, including Ar, are migrating and circulating through the crust.[16] Noble gases in carbon-dioxide-rich natural gas wells confirm such migration and circulation. The isotopic signatures clearly indicate a mantle origin of the noble gases, including amounts of excess ^{40}Ar in some natural gas wells exceeding those in mantle-derived mid-ocean ridge basalts.[17] In fact, it has been estimated that the quantities of excess $^{40}Ar^*$ in the continental crust are as much as five times that found in such mantle-derived, mid-ocean ridge basalts, strongly implying that excess $^{40}Ar^*$ in crustal rocks and their constituent minerals could well be the norm, rather than the exception.

In reference to metamorphism and melting of rocks in the crust, it is well known that:

14 T. B. Karpinskaya, I. A. Ostrovsckiy and L. L. Shanin, 1961, Synthetic introduction of argon into mica at high pressures and temperatures, *Isu Akad Nauk S.S.S.R. Geology Series*, 8: 87-89.

15 T. B. Karpinskaya, 1967, Synthesis of argon muscovite, *International Geology Review*, 9: 1493-1495.

16 D. B. Patterson, M. Honda and I. McDougall, 1993, The noble gas cycle through subduction systems, in *Research School of Earth Sciences Annual Report 1992*, Canberra, Australia: Australian National University, 104-106.

17 P. Staudacher, 1987, Upper mantle origin of Harding County well gases, *Nature*, 325: 605-607; C. J. Ballentine, 1989, Resolving the mantle He/Ne and crustal $^{21}Ne/^{22}Ne$ in well gases, *Earth and Planetary Science Letters*, 96: 119-133; P. Burnard, D. Graham and G. Turner, 1997, Vesicle-specific noble gas analyses of "Popping Rock": Implication for primordial noble gases in the earth, *Science*, 276: 568-571; M. Moreira, J. Kunz and C. J. Allègre, 1998, Rare gas systematics in Popping Rock: Isotopic and elemental compositions in the upper mantle, *Science*, 279: 1178-1181.

> If the rock is heated or melted at some later time, then some or all of the ^{40}Ar may escape and the K-Ar clock is partially or totally reset.[18]

Thus, $^{40}Ar^*$ escapes to migrate in the crust to be incorporated in other minerals as excess $^{40}Ar^*$, just as $^{40}Ar^*$ degassing from the mantle migrates into the crust. Excess $^{40}Ar^*$ has been recorded in many minerals (some with essentially no ^{40}K) in crustal rocks, and the Ar-Ar method has also been used to confirm the presence of excess $^{40}Ar^*$ in feldspars and pyroxenes.[19] Ten profiles across biotite grains in high-grade metamorphic rocks yielded 128 apparent Ar-Ar "ages" within individual grains ranging from 161 Ma to 514 Ma (Figure 58, page 1092).[20] This cannot be solely due to radiogenic build-up of $^{40}Ar^*$, but due to the incorporation of excess $^{40}Ar^*$ by diffusion from an external source, namely, from the mantle and other crustal rocks and minerals. Indeed, excess $^{40}Ar^*$ was found to have accumulated locally in the intergranular regions of a gabbro via diffusion from its hornblende grains according to a well-defined law.[21]

This crustal migration of $^{40}Ar^*$ is known to cause grave problems in regional rock-dating studies. For example, in the Precambrian Musgrave Ranges Block of northern South Australia, a wide scatter of K-Ar mineral "ages" was found, ranging from 343 Ma to 4,493 Ma due to inherited (excess) $^{40}Ar^*$, so no meaningful age interpretation could be drawn from those rocks.[22] Likewise, when Ar "dating" was attempted on Precambrian high-grade metamorphic rocks in the Fraser Range of Western Australia, and on the Strangways Range of central Australia, it was found that important minerals contained excess $^{40}Ar^*$ which rendered the Ar "dating" useless because it produced "ages" higher than expected.[23] It was concluded that this excess $^{40}Ar^*$ was probably incorporated at the time of mineral formation, and calculations suggest that the Proterozoic lower crust of Australia (which extends over half the continent) contains so much of this excess $^{40}Ar^*$ that it produces a partial pressure equivalent to approximately 0.1 atmospheres. This is consistent with an Ar-Ar "dating" study of Proterozoic high-grade metamorphic rocks in the Broken Hill region of New South Wales that documented widely distributed

18 G. B. Dalrymple, 1991, *The Age of the Earth*, Stanford, CA: Stanford University Press, 91.

19 J. G. Funkhauser, I. L. Barnes and J. J. Naughton, 1966, Problems in the dating of volcanic rocks by the potassium-argon method, *Bulletin of Volcanology*, 29: 709-717; A. W. Laughlin, 1969, Excess radiogenic argon in pegmatite minerals, *Journal of Geophysical Research*, 74: 6684-6690; M. A. Lanphere and G. B. Dalrymple, 1976, Identification of excess ^{40}Ar by the $^{40}Ar/^{39}Ar$ age spectrum technique, *Earth and Planetary Science Letters*, 12: 359-372.

20 C. S. Pickles, S. P. Kelley, S. M. Reddy and J. Wheeler, 1997, Determination of high spatial resolution argon isotope variations in metamorphic biotites, *Geochimica et Cosmochimica Acta*, 61: 3809-3833.

21 T. M. Harrison and I. McDougall, 1980, Investigations of an intrusive contact, north-west Nelson, New Zealand—II. Diffusion of radiogenic and excess ^{40}Ar in hornblende revealed by $^{40}Ar/^{39}Ar$ age spectrum analysis, *Geochimica et Cosmochimica Acta*, 44: 2005-2030.

22 A. W. Webb, 1985, Geochronology of the Musgrave Block, *Mineral Resources Review, South Australia*, 155: 23-27.

23 A. K. Baksi and A. F. Wilson, 1980, An attempt at argon dating of two granulite-facies terranes, *Chemical Geology*, 30: 109-120.

excess $^{40}Ar^*$.[24] Plagioclase and hornblende were most affected, step heating Ar-Ar "age" spectra yielding results up to 9.588 Ga (Figure 59, page 1092). Of course, such unacceptable "ages" were produced by release of excess $^{40}Ar^*$, this being obvious because of the expected interpreted "ages" of these rocks.

Domains within the mantle and crust have been identified, and the interaction between them described in terms of the migration and circulation of Ar (and therefore excess $^{40}Ar^*$) from the lower mantle through the crust.[25] In the proposed steady-state upper mantle model, at least some of the $^{40}Ar^*$ must be primordial, that is, not derived from radioactive decay of ^{40}K. But just how much is primordial is unknown, because primordial ^{40}Ar is indistinguishable from $^{40}Ar^*$. Therefore, because it is known that excess $^{40}Ar^*$ is carried from the mantle by plumes of basaltic magmas up into the earth's crust, it is equally likely that much of the excess $^{40}Ar^*$ in crustal rocks could also be primordial ^{40}Ar. Additionally, $^{40}Ar^*$ released from minerals and rocks during lithification and metamorphism adds to the continual migration and circulation of $^{40}Ar^*$ in the crust. Thus, when crustal rocks are analyzed for K-Ar and Ar-Ar "dating," one can never be sure if the $^{40}Ar^*$ in the rocks is from the *in situ* radioactive decay of ^{40}K since their formation, or if some or all of it came from the mantle or from other crustal rocks and minerals. Thus, we have no way of knowing if any of the $^{40}Ar^*$ measured in crustal rocks has any age significance at all.

Argon Loss

For the K-Ar and Ar-Ar "dating" methods to work successfully, the rocks and minerals to be dated must not contain any excess $^{40}Ar^*$ (whether inherited or primordial), but also they must have retained all of the $^{40}Ar^*$ produced within them by the radioactive decay of *in situ* ^{40}K. However, $^{40}Ar^*$ loss from minerals is claimed to be a persistent problem. Because Ar is a noble (non-reactive) gas, it does not form chemical bonds with other atoms in a crystal lattice, so no mineral locks Ar into its structure. Thus, it is often claimed that $^{40}Ar^*$ can be readily lost from the minerals where it was originally produced.[26] Yet this explanation is often resorted to in order to resolve conflicts between K-Ar and Ar-Ar "dating" results and the expectations based on the evolutionary timescale.

Nevertheless, a very good demonstration of apparent $^{40}Ar^*$ loss from different minerals in a thermal event is provided in the contact metamorphic zone

24 T. M. Harrison and I. McDougall, 1981, Excess ^{40}Ar in metamorphic rocks from Broken Hill, New South Wales: Implications for $^{40}Ar/^{39}Ar$ age spectra and the thermal history of the region, *Earth and Planetary Science Letters*, 55: 123-149.

25 B. Harte and C. J. Hawkesworth, 1986, Mantle domains and mantle xenoliths, in *Kimberlites and Related Rocks*, *Proceedings of the Fourth International Kimberlite Conference*, vol. 2, Special Publication No. 14, Sydney, Australia: Geological Society of Australia, 649-686; D. Porcelli and G. J. Wasserburg, 1995, Transfer of helium, neon, argon, and xenon through a steady-state upper mantle, *Geochimica et Cosmochimica Acta*, 59: 4921-4937.

26 Faure and Mensing, 2005, 116.

associated with the Eldora granite in the Front Range of Colorado.[27] The biotite, hornblende, and K-feldspar in the adjoining Precambrian metamorphic rocks were found to have lost varying amounts of $^{40}Ar^*$ at increasing distances from the contact with the intruded granite body (Figure 60, page 1093). This resulted in profound affects on the K-Ar mineral "ages," even though there were only very minor contact metamorphic effects. The fraction of $^{40}Ar^*$ lost from each mineral decreased as a function of distance from the contact, and the effects of this $^{40}Ar^*$ loss could be traced for more than two kilometers from the contact, well beyond the thermal contact zone of the intrusive granite body.

Such diffusion of $^{40}Ar^*$ from minerals as a result of heating is now in fact the basis of the Ar-Ar "dating" method. A K-bearing mineral is heated in the "dating" laboratory so that the $^{40}Ar^*$ accumulated escapes by diffusion and is then measured for the "age" calculation. Thus, the $^{40}Ar^*$ diffusion rates due to heating have been experimentally determined for the minerals relevant to the Ar-Ar "dating" method.[28]

Since recent lava flows often contain excess $^{40}Ar^*$, it is conceivable that "ancient" lava flows would likewise have initially had excess $^{40}Ar^*$. But because of the experimental evidence of $^{40}Ar^*$ diffusion and geological evidence of $^{40}Ar^*$ loss, whenever a K-Ar "date" for an "ancient" lava flow is not what is expected according to the uniformitarian timescale, the perceived discrepancy is usually attributed to net $^{40}Ar^*$ loss. This is the conventionally offered explanation for the apparent failure of K-Ar "dates" to match what is regarded as the acceptable Rb-Sr "date" for the middle Proterozoic Cardenas Basalt of the eastern Grand Canyon, Arizona.[29] Yet the 516 Ma K-Ar isochron "age," which is less than half the accepted uniformitarian "age" of 1,100 Ma, when plotted actually indicates some initial excess $^{40}Ar^*$. Therefore, if there has been no $^{40}Ar^*$ loss from these lava flows since their extrusion, then it could be argued that their K-Ar "age" is their maximum age, and that the uniformitarian timescale is hardly an objective yardstick for assessment of what constitutes valid "dates."

Nevertheless, there is a steady measured loss of $^{40}Ar^*$ from crustal rocks to the atmosphere of 1-6 x 10^9 atoms/m^2/sec, which is the result of degassing of

27 S. R. Hart, 1964, The petrology and isotopic-mineral age relations of a contact zone in the Front Range, Colorado, *Journal of Geology*, 72: 493-525.

28 T. M. Harrison, 1981, Diffusion of ^{40}Ar in hornblende, *Contributions to Mineralogy and Petrology*, 78: 324-331; T. M. Harrison, I. Duncan, and I. McDougall, 1985, Diffusion ^{40}Ar in biotite: Temperature, pressure and compositional effects, *Geochimica et Cosmochimica Acta,* 49: 2461-2468; M. Grove, and T. M. Harrison, 1996, $^{40}Ar^*$ diffusion in Fe-rich biotite, *American Mineralogist*, 81: 940-951.

29 E. H. McKee and D. C. Noble, 1976, Age of the Cardenas lavas, Grand Canyon, Arizona, *Geological Society of America Bulletin*, 87: 1188-1190; E. E. Larson, P. E. Patterson and F. E. Mutschler, 1994, Lithology, chemistry, age, and origin of the Proterozoic Cardenas basalt, Grand Canyon, Arizona, *Precambrian Research*, 65: 255-276; S. A. Austin and A. A. Snelling, 1998, Discordant potassium-argon model and isochron "ages" for Cardenas basalt (middle Proterozoic) and associated diabase of eastern Grand Canyon, Arizona, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 35-51.

primordial ^{40}Ar and $^{40}Ar^*$ from the mantle and crust.[30] Thus, even though this $^{40}Ar^*$ flux produces a build-up of excess $^{40}Ar^*$ in both mantle-derived and crustal rocks, $^{40}Ar^*$ loss can clearly be a problem locally, resulting in "ages" much younger than conventionally expected. Therefore, when the $^{40}Ar^*$ contents of rocks are measured, there is no way of determining categorically whether there has been $^{40}Ar^*$ loss, or gain (by excess $^{40}Ar^*$), even when the calculated "ages" are compatible with other radioisotopic "dating" systems or conventional "ages" based on the strata record, all of which renders such K-Ar and Ar-Ar "dates" questionable at best.

30 J. Drescher, T. Kirsten and K. Schäfer, 1998, The rare gas inventory of the continental crust, recovered by the KTB Continental Deep Drilling Project, *Earth and Planetary Science Letters*, 154: 247-263.

101

The Pitfalls in the Radioactive Dating Methods—the Rubidium-Strontium Dating Method

The rubidium (Rb)–strontium (Sr) radioisotope system is still one of the most widely used for rock and mineral "dating." However, the results are not always easy to interpret because of conflicting claims. On the one hand, it is claimed that both Rb and Sr are relatively mobile elements, so the isotopic system may be readily disturbed either by influx of fluids or by a later thermal event.[1] On the other hand, it has been stated that thermal inducement of radiogenic ^{87}Sr to leave its host mineral in quantities commeasurable to the loss of ^{40}Ar* under geologically feasible conditions has not been experimentally demonstrated, even though it is not uncommon to find minerals in nature which have lost both ^{40}Ar* and ^{87}Sr due to a thermal event.[2] Thus, the geological interpretation of Rb-Sr isochrons is guided by the required consistency with the uniformitarian timescale, in spite of numerous demonstrated problems.

Anomalous Rb-Sr Isochrons

The Rb-Sr isochron method presumes that a suite of rock samples from the same rock unit should all have the same "age" due to the entire rock unit being formed at the same time, should have the same initial ^{87}Sr/^{86}Sr ratio, and should have acted as a closed system. However, these basic assumptions have been questioned. It has become apparent that in an increasing number of geological situations the linear relationships between the ^{87}Sr/^{86}Sr and ^{87}Rb/^{86}Sr ratios sometimes yield anomalous isochrons that have no distinct geological meaning, even when there is an excellent goodness of fit of the isochrons to the data.[3] Thus, it is now recognized that basalt magma will invariably inherit the isotopic composition of its mantle

1 H. Rollison, 1993, *Using Geochemical Data: Evaluation, Presentation, Interpretation*, Harlow, UK: Longman.

2 G. N. Hanson and P. W. Gast, 1967, Kinetic studies in contact metamorphic zones, *Geochimica et Cosmochimica Acta*, 31: 1119-1153.

3 Y.-F. Zheng, 1989, Influences of the nature of the initial Rb-Sr system of isochron validity, *Chemical Geology*, 80: 1-16.

source, and, in some instances, also the parent/daughter ratio.[4] Indeed, when plotted on an isochron diagram, the Rb-Sr data for fourteen different ocean island basalts yielded a positive correlation with a slope "age" of approximately 2 Ga.[5] The basalts on individual ocean islands occasionally also define linear arrays with positive slopes. Because it was suggested that these apparent "ages" represented the time since the magma source areas were isolated from the convecting mantle, they were called "mantle isochrons."[6]

This mantle isochron concept was even found to apply to both volcanic and plutonic continental igneous rock suites. Although selected examples were all "ancient," unlike most of the recent ocean island basalts, when their measured $^{87}Sr/^{86}Sr$ ratios, corrected for their calculated initial ratios at the presumed time of the formation of these rocks, were plotted against their Rb/Sr ratios, the resultant data for each rock suite studied formed linear arrays that were termed "pseudo-isochrons."[7] Another example of correlated $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ ratios was reported for lava flows from two volcanic centers about 160 kilometers apart in east Africa.[8] They are known to be quite young because of volcanic activity in historic times, yet these lava flows yielded an apparent isochron "age" of 773 Ma. This isochron was interpreted as probably resulting from a mixing process in the mantle source region, because it could not be due to decay of ^{87}Rb in these rocks since their recent formation. Two other observed trends are worth noting. In modern volcanic rocks there is an overall approximate inverse correlation between their initial $^{87}Sr/^{86}Sr$ ratios and their Sr contents,[9] while in a general way the $^{87}Sr/^{86}Sr$ ratios of oceanic basalts correlate positively with their relative K contents.[10]

Yet another trend observed in some basaltic rocks is their $^{87}Sr/^{86}Sr$ ratios increase with their increasing SiO_2 contents, which has been suggested is due to crustal contamination.[11] Furthermore, apparently cogenetic (formed at the same time)

---

4 Dickin, 2005.

5 S. S. Sun and G. N. Hansen, 1975, Evolution of the mantle: Geochemical evidence from alkali basalt, *Geology*, 3: 297-302.

6 C. Brooks, S. R. Hart, A. Hoffmann and D. E. James, 1976, Rb-Sr mantle isochrons from oceanic regions, *Earth and Planetary Science Letters*, 32: 51-61.

7 C. Brooks, D. E. James and S. R. Hart, 1976, Ancient lithosphere: Its role in young continental volcanism, *Science*, 193: 1086-1094.

8 K. Bell and J. L. Powell, 1969, Strontium isotopic studies of alkalic rocks: The potassium-rich lavas of the Birunga and Toro-Ankole Regions, east and central equatorial Africa, *Journal of Petrology*, 10: 536-572.

9 G. Faure and J. L. Powell, 1972, *Strontium Isotope Geology*, Berlin: Springer-Verlag.

10 Z. E. Peterman and C. E. Hedge, 1971, Related strontium isotopic and chemical variations in oceanic basalts, *Geological Society of America Bulletin*, 82: 493-500.

11 G. Faure, R. L. Hill, L. M. Jones and D. H. Elliot, 1971, Isotope composition of strontium and silica content of Mesozoic basalt and dolerite from Antarctica, *SCAR Symposium*, Oslo, Norway: University Press.

suites of both oceanic and continental volcanic rocks have been found to have significant within-suite variations in their $^{87}Sr/^{86}Sr$ ratios.[12] It was suggested that in general these variations could have been caused by either differences in the initial $^{87}Sr/^{86}Sr$ ratios at the source regions of the rocks in the upper mantle and lower crust, or by variable contamination of their parent magmas with "foreign" Sr via bulk assimilation, wall-rock reaction, selective migration of radiogenic Sr, and/or isotopic exchange and equilibration. Thus, it has been argued that the assumption that all rocks in a co-magmatic igneous complex started with the same initial $^{87}Sr/^{86}Sr$ ratio may be invalid.[13] Indeed, variations in the initial $^{87}Sr/^{86}Sr$ ratios for suites of young lavas from a single volcano have been found.[14] Therefore, the assumption of a well-defined initial ratio for many suites of rocks is difficult to defend, and yet this is a crucial assumption for successful Rb-Sr isochron dating.

Magma contamination is a case in point. One cannot assume that all the Sr of the contaminants has been uniformly mixed into the magma; therefore, the assumption that all rocks in the same intrusive suite initially had the same $^{87}Sr/^{86}Sr$ ratio cannot be justified. Indeed, contamination is one of the main sources of mineralogical and geochemical variation in granitic rocks, and all main types of likely contaminant have compositions that would lead to an under-estimation of the initial $^{87}Sr/^{86}Sr$ ratio, and an over-estimation of the "age" of crystallization.[15] Obviously, the nature of the Rb-Sr system at the initial instant of time in the formation of a rock is of crucial importance in understanding the meaning of an isochron. Yet even suites of samples which do not have identical "ages" and initial $^{87}Sr/^{86}Sr$ ratios can be fitted to isochrons.[16] Furthermore, supposed multi-stage development of a geological system increases the complexity of interpreting Rb-Sr data for "dating" purposes. For example, a two-stage ^{87}Sr development for a rhyolite rock unit in the Lake District of England has been suggested in order to account for its anomalous whole-rock Rb-Sr isochron "age."[17] Also, the "rotation of the isochron" was used to describe the perceived distortion of the Rb-Sr system in some German volcanics, due to presumed post-magmatic processes.[18]

---

12 Faure and Powell, 1972.

13 P. S. McCarthy and R. G. Cawthorn, 1980, Changes in initial $^{87}Sr/^{86}Sr$ ratio during protracted fractionation in igneous complexes, *Journal of Petrology*, 21: 245-264.

14 M. Cortini and O. D. Hermes, 1981, Sr isotopic evidence for a multi-source origin of the potassic magmas in the Neapolitan area (S. Italy), *Contributions to Mineralogy and Petrology*, 77: 47-55.

15 A. Hall, 1996, *Igneous Petrology*, second edition, Harlow, UK: Addison Wesley Longman.

16 H. Cöhler and D. Müller-Sohnius, 1980, Rb-Sr systematics on paragneiss series from the Bavarian Moldanubium, Germany, *Contributions to Mineralogy and Petrology*, 71: 387-392; U. Haack, J. Hoefs and E. Gohn, 1982, Constraints on the origin of Damaran granites by Rb/Sr and $\delta^{18}O$ data, *Contributions to Mineralogy and Petrology*, 79: 279-289.

17 W. Compston, I. McDougall and D. Wyborn, 1982, Possible two-stage ^{87}Sr evolution in the Stockdale rhyolite, *Earth and Planetary Science Letters*, 61: 297-302.

18 H. Schleicher, H. J. Lippolt and I. Raczek, 1983, Rb-Sr systematics of Permian volcanites in Schwalzwald (S.W.-Germany) Part II. Age of eruption and the mechanism of Rb-Sr whole-rock age distortions, *Contributions to Mineralogy and Petrology*, 84: 281-291.

Because of the different geochemical behaviors of Rb and Sr, variations in initial $^{87}Sr/^{86}Sr$ ratios may result from Rb/Sr fractionation.[19] Furthermore, the three variables, ^{87}Sr, ^{86}Sr, and ^{87}Rb, are not independent of each other, and as a result the measured $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ ratios are not necessarily two dependent variables on an Rb-Sr isochron diagram, making invalid the "age" derived from the isochron.[20] Indeed, because a geological system cannot have had a homogenous ^{86}Sr distribution, and because the ^{86}Sr is used as a common variable in the conventional isochron equation, the observed correlation in the Rb-Sr isochron plot is enhanced. Given then that the present-day observed linear array on an isochron diagram is in fact the combination of the initial linear relationship between $^{87}Sr/^{86}Sr$ and $^{87}Rb/^{86}Sr$ ratios, corresponding to pseudo-isochrons, and the accumulation of radiogenic ^{87}Sr since the time of rock formation, the observed isochron can only be an apparent isochron. Therefore, it can be argued that the nature of the initial Rb-Sr system has considerable influence on the validity of an isochron, and this inherited initial Rb-Sr array may have rotated any valid present-day isochron, changing its slope and, therefore, the resultant calculated apparent "age."[21]

Open-System Behavior, Mixing and Resetting

The effects of some of these processes on a geological system are illustrated by granitic rocks of southeastern Australia. Regional variations of isotopic and chemical compositions of these granitic rocks are not too dissimilar to the granitic rocks of southern California. There has been much debate over the source rocks and mode of formation of these granitic rocks in southeastern Australia, which have been classified on the basis of their mineral and chemical compositions being derived either from the melting of mantle or sedimentary rocks. However, much evidence would suggest that many granite bodies are, in fact, blends or mixtures of both mantle and crustal sources, which has been demonstrated by radioisotope studies. For these granites in southeastern Australia, using the initial $^{87}Sr/^{86}Sr$ of each granite body as a measure of the mean $^{87}Sr/^{86}Sr$ of the source rocks at the time of their melting, a source Rb-Sr isochron diagram was plotted, from which a "source isochron" was derived for these source rocks that melted to form the granites.[22] However, whereas the age of these granites was regarded as 420 Ma, the source isochrons yielded an "age" for the source rocks of 1,100 Ma, consistent with the "ages" of supposedly inherited zircon grains in these granites.[23] This, of

19 C. E. Hedge and F. G. Walthall, 1963, Radiogenic strontium-87 as an index of geological processes, *Science*, 140: 1214-1217; C. J. Allègre, 1987, Isotope geodynamics, *Earth and Planetary Science Letters*, 86: 175-203.

20 Zheng, 1989.

21 Zheng, 1989.

22 W. Compston and B. W. Chappell, 1978, Estimation of source Rb/Sr for individual igneous-derived granitoids and the inferred age of the lower crust in southeast Australia, *US Geological Survey, Open-File Report 78-701*, 79-81.

23 Y. D. Chen and I. S. Williams, 1990, Zircon inheritance in mafic inclusions from Bega Batholith

course, suggests that Precambrian crustal material was incorporated in the granite magmas.

Other radioisotope investigations confirm this mixing of crustal and mantle components to form these granitic rocks. When the initial $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of some of these granitic rocks were used, they plotted along a curved trajectory typical of binary mixtures.[24] The granites in fact plotted in two overlapping clusters along the curved trajectory on this isotope correlation diagram (Figure 61, page 1093), which represents a mixing curve formed from crustal and mantle components. A subsequent study went further by showing that a three-component mixture of mantle-derived magma and two contrasting crustal components could successfully explain the radioisotope compositions of these southeastern Australian granites.[25] Indeed, it was possible to construct three-component radioisotope mixing curves that incorporated the radioisotope signatures of these granites, indicating that they all appear to be mixtures of a mantle component and two crustal components, one of which is the host sediments. Thus, it was suggested that the supposedly inherited zircon grains in these granites could instead be zircons that were originally inherited by the host sedimentary rocks during their sedimentation.

Magma mixing, therefore, as a major process of generating igneous rocks has received considerable attention, and contamination/assimilation of mantle-derived magma with crustal rocks during emplacement has now been accepted as the mixing mechanism. Furthermore, the resultant effects of this mixing on Rb-Sr "dating" have now been recognized.[26] The present-day measured Rb-Sr data may not define a valid isochron, but rather the production of an apparent isochron that can be a mixing isochron or an inherited linear array. Of course, this would only be realized if the isochron produced was not in accord with the expected "age" based on the uniformitarian timescale.

Mineral and whole-rock Rb-Sr radioisotope systems may respond differently to the heat and fluids during the metamorphism of a rock. ^{87}Sr tends to migrate out of crystals if subjected to a thermal pulse.[27] If fluids in the rock remain static, Sr released from Rb-rich minerals such as micas and K-feldspar will tend to be taken up by the nearest suitable mineral, such as plagioclase. Thus, individual minerals will be open systems during metamorphism. However, a whole-rock domain of a

---

granites, southeastern Australia: and ion microprobe study, *Journal of Geophysical Research*, 95: 17,787-17,796; I. S. Williams, 1992, Some observations on the use of zircon U-Pb geochronology in the study of granitic rocks, *Transactions of the Royal Society of Edinburgh*, 83: 447-458.

24 M. T. McCulloch and B. W. Chappell, 1982, Nd isotopic characteristics of S- and I-type granites, *Earth and Planetary Science Letters*, 58: 51-64.

25 S. Keay, W. J. Collins and M. T. McCulloch, 1997, A. three-component Sr-Nd isotopic mixing model for granitoid genesis, Lachlan Fold Belt, eastern Australia, *Geology*, 25: 307-310.

26 Zheng, 1989.

27 Dickin, 2005.

certain minimum size will remain an effective closed system during the thermal event, and thus, is regarded as "dating" the initial crystallization of the rock, provided there is no Rb remobilization, loss, or contamination.

A classic example of the effect of the temperatures of metamorphism is the apparent mineral "ages" with outward distance from the contact of the Eldora granite in the Front Range of Colorado (Figure 60).[28] The coarse biotites in the Precambrian metamorphic rocks intruded by the granite show even greater disturbance of the Rb-Sr system than the K-Ar system due to the heat of the intruding granite. Only 20 feet (just over 6 meters) from the contact, the coarse biotite has lost 88 percent of its radiogenic ^{87}Sr. In a subsequent study of the effect of thermal metamorphism, it was concluded that the relative stability of mineral "ages" in the contact metamorphic zone appeared to be hornblende K-Ar >muscovite Rb-Sr>muscovite K-Ar>biotite Rb-Sr>biotite K-Ar, although for the micas the Rb-Sr and K-Ar "ages" were essentially concordant.[29] Nevertheless, if uniformitarian timescale assumptions are ignored, and the isotopic ratios are simply interpreted as a geochemical signature of the rocks, then the heat from the intrusion studied was responsible for migration and redistribution of ^{87}Sr in commensurate quantities to ^{40}Ar*. It has also been found that Rb-Sr isotopic data require that Sr was redistributed during amphibolite facies (>650°C, >7kbar) regional metamorphism on a scale of at least tens of meters, fluid transport facilitating that Sr isotopic resetting.[30]

What is even of greater concern is how easily and quickly Rb and Sr can be leached from fresh rock. Experiments on granites have demonstrated that a mildly acidic solution will, in less than a day, leach large amounts of Rb from granite.[31] Rb was about ten times more leachable than Sr, and hence the ^{87}Sr/^{86}Sr ratio of the leaching solution was controlled by the leached Rb-fraction (and ^{87}Sr), which resulted in a higher ^{87}Sr/^{86}Sr ratio in solution compared to that in the rock. Thus, when the calculated isotopic compositions of the leached rock samples were plotted on an isochron diagram, they shifted along the isochron produced by the fresh rock samples. In other granites, Sr was up to fifty times more leachable than Rb, and hence the ^{87}Sr/^{86}Sr ratio of the solution was controlled by the Sr-fraction whose isotopic composition was that of "common" ^{86}Sr, similar to the initial ^{87}Sr/^{86}Sr ratio of the granite, and lower compared to the present-day fresh whole-rock ratio. Thus, the calculated isotopic composition of the leached rocks plotted away from the isochron produced by the fresh rock samples, effectively rotating

28 Hart, 1964.

29 G. N. Hanson and P. W. Gast, 1967, Kinetic studies in contact metamorphic zones, *Geochimica et Cosmochimica Acta*, 31: 1119-1153.

30 S. C. Patel, C. D. Frost and B. R. Frost, 1999, Contrasting response of Rb-Sr systematics to regionally and contact metamorphism, Laramie Mountains, Wyoming, USA, *Journal of Metamorphic Geology*, 17: 259-269.

31 W. Irber, W. Siebel, P. Möller and S. Teufel, 1996, Leaching of Rb and Sr (^{87}Sr/^{86}Sr) of Hercynian peraluminous granites with application to age determination, in *V.M. Goldschmidt Conference, Journal of Conference Abstracts*, vol. 1 (1), 281.

the isochron. Investigations of alteration sequences have thus shown that, during most common types of alteration, a spread of Rb/Sr whole-rock ratios occurs due to drastic loss of Sr, whereas the Rb increases due to formation of sericite (fine-grained white mica). Because such changes due to chemical weathering by the atmosphere and meteoritic water are systematic, false isochrons can be generated which, therefore, may not be distinguishable from the "true" isochrons and "ages."

Mounting evidence of whole-rock Rb-Sr open-system behavior has meant that the widely used whole-rock Rb-Sr method has lost credibility.[32] For example, Rb-Sr isochrons in metamorphic terrains can yield good linear arrays, whose slopes are, nevertheless, meaningless averages of the original rocks and metamorphic "ages." Whole-rock Rb-Sr systems can be disturbed and reset to give good-fit secondary isochrons, even by relatively low-grade metamorphism.[33] Indeed, the Rb-Sr systems in metamorphic rocks are complicated by two factors, namely, whether the initial $^{87}Sr/^{86}Sr$ ratios have been homogenized by the metamorphism, or whether the Rb and Sr elemental abundances have been redistributed during the metamorphism. In reality, few systems are perfectly homogenized during metamorphism. Furthermore, minerals separated from single whole-rock specimens may yield distorted internal mineral isochrons also dependent on the degree of Sr isotopic homogenization. In some cases, gain or loss of Rb and Sr from rocks is so regular that linear arrays can be produced on the conventional isochron diagrams, and biased isochron results give spurious "ages" and initial $^{87}Sr/^{86}Sr$ ratio estimates. Thus, it has been concluded that:

> As it is impossible to distinguish a valid isochron from an apparent isochron in the light of Rb-Sr isotopic data alone, caution must be taken in explaining the Rb-Sr isochron age of any geologic system.…An observed isochron does not certainly define a valid age information for a geologic system, even if a goodness of fit of the experimental data points is obtained in plotting $^{87}Sr/^{86}Sr$ vs. $^{87}Rb/^{86}Sr$. This problem cannot be overlooked, especially in evaluating the numerical timescale.[34]

In conclusion, all of these considerations combine to cast a "shadow" over the Rb-Sr radioisotope system as a reliable geochronometer. The repeatedly demonstrated mobility of Sr and Rb in fluids, and at elevated temperatures, invariably disturbs the Rb-Sr systematics to yield invalid or meaningless "ages." Anomalous and false isochrons are prolific, their status only being apparent when such results are compared with other radioisotope systems, and/or the stratigraphic setting. Thus, recognition of inheritance, open-system behavior, contamination and mixing, and the later effects of weathering, together have increasingly caused Rb-Sr radioisotope "dating" to be regarded as unreliable.

---

32 Dickin, 2005.

33 Zheng, 1989.

34 Zheng, 1989, 14.

102

The Pitfalls in the Radioactive Dating Methods—The Samarium-Neodymium Dating Method

Samarium (Sm) and neodymium (Nd) are light rare earth elements that occur in trace amounts in common rock-forming minerals, where they replace major ions. They may also reside in accessory minerals, particularly apatite and monazite (phosphate minerals), and zircon (zirconium silicate). Minerals exercise a considerable degree of selectivity in admitting rare earth elements into their crystal structures, affecting the rare earth element concentrations of the rocks in which the various minerals occur. Thus "age" determinations by the Sm-Nd radioisotope method are usually made by analyzing separated minerals of cogenetic suites of rocks in which the Sm/Nd ratios vary sufficiently to define the slope of an isochron. It is claimed that, because Sm and Nd are much less mobile than Rb, Sr, Th, U, and Pb during regional metamorphism, hydrothermal alteration, and chemical weathering, the Sm-Nd radioisotope "dating" method supposedly "sees through" younger events in rocks where the Rb-Sr and U-Pb isotopic chemistry has been disturbed. Furthermore, it is claimed that whole-rock Sm-Nd "dating" has an advantage over mineral Sm-Nd "dating," in that the scale of sampling is much larger (the meters or kilometers extent of a rock unit instead of the millimeters scale between minerals), so that the possibility of post-crystallization isotopic re-equilibration between samples is reduced.[1]

The chief limitations on the Sm-Nd technique are the long half-life of ^{147}Sm (106 billion years), and the relatively small variations in Sm/Nd ratios found in most cogenetic rock suites. It is often claimed that the long half-life limits the usefulness of this method to only "very old" rocks. The second limitation has led some investigators to combine a wide range of rock types on the same isochron in order to obtain a spread of Sm/Nd ratios.[2] However, such samples from different sources with very different histories plotted on the same isochrons have produced spurious results. Furthermore, it is difficult to obtain precise initial ^{143}Nd/^{144}Nd ratios, because no common minerals have their ^{147}Sm/^{144}Nd ratio

1 D. J. DePaolo, 1988, *Neodymium Isotope Geochemistry: An Introduction*, Berlin: Springer-Verlag.

2 Rollinson, 1993.

near zero. Therefore, on isochron plots, long extrapolations are usually required to determine the intercepts, which produce relatively large uncertainties.[3] Indeed, variations in initial ratios for suites of young lavas from a single volcano have been found, suggesting that the assumption of a well-defined initial ratio for many suites of rocks is difficult to defend.[4] This is a critical problem for Sm-Nd whole-rock "dating," because the relatively small range of ^{143}Nd/^{144}Nd ratios in most rock suites means that any differences in the initial ratios that are larger than the analytical uncertainties could substantially affect the calculated "age," leading to serious errors. For example, rocks from the Peninsula Ranges Batholith of southern California, which is supposed to be about 100 million years old, plot on an apparent Sm-Nd isochron of 1.7 billion years.[5] Even Archean rock suites yield an excellent whole-rock isochron with a grossly erroneous "age."[6]

The Sm-Nd method has frequently been applied to "dating" the "age" of the supposed original igneous rocks of what is now high-grade metamorphic basement, where other radioisotope systems have evidently been reset.[7] However, when this application to a suite of granitic and basaltic metamorphic rocks of different grades in northwest Scotland was further investigated, it was evident that the basaltic rocks had "retained" an older Sm-Nd isochron "age," whereas the Sm-Nd whole-rock systems in the non-basaltic rocks seemed to have been "reset" to the same "age" as the U-Pb zircon and other whole-rock radioisotope systems.[8] Thus, it was concluded that the Sm-Nd radioisotope system had only remained closed in the basaltic rocks during the metamorphic event, while the Sm-Nd radioisotope system in the other metamorphic rocks was disturbed. This is contrary to the usual claim that the less mobile Sm and Nd are not disturbed by events subsequent to the initial formation of their host rocks. Thus, if these isotopes are indeed mobile in ways similar to the other radioisotope systems, then the reliability of Sm-Nd "ages" is equally questionable.

It has now been clearly demonstrated that, under certain hydrothermal conditions, the mobility of rare earth elements perturbs the Sm-Nd radioisotope system.[9] The net result of hydrothermal alteration is leaching of the rare earth elements from the rocks. Furthermore, the perturbation of the Sm-Nd radioisotope system

---

3 DePaolo, 1988.

4 C.-Y. Chen and F. A. Frey, 1983, Origin of Hawaiian tholeiite and alkalic basalt, *Nature*, 302: 785-789.

5 D. J. DePaolo, 1981, A neodymium and strontium isotopic study of the Mesozoic calc-alkaline granitic batholiths of the Sierra Nevada and Peninsula Ranges, California, *Journal of Geophysical Research*, 86: 10,470-10,488.

6 C. Chauvel, B. Dupre and G. A. Jenner, 1985, The Sm-Nd age of Kambalda volcanics is 500 Ma too old!, *Earth and Planetary Science Letters*, 74: 315-324.

7 P. J. Hamilton, R. K. O'Nions, N. M. Evensen and J. Tarney, 1979, Sm-Nd systematics of Lewisian gneisses: Implications for the origin of granulites, *Nature*, 277: 25-28.

8 M. J. Whitehouse, 1988, Granulite facies Nd-isotopic homogenisation in the Lewisian Complex of northwest Scotland, *Nature*, 331: 705-707.

9 F. Poitrasson, C. Pin and J.-L. Duthou, 1995, Hydrothermal remobilization of rare earth elements and its effect on Nd isotopes in rhyolite and granite, *Earth and Planetary Science Letters*, 130: 1-11.

was found not to be solely due to significant modification of the Sm/Nd ratio after emplacement of the granitic rocks studied. Therefore, it was concluded that the isotopic compositions were modified by a component introduced from the hydrothermal fluid that had contrasting $^{143}Nd/^{144}Nd$ ratios. It was also found that rare earth elements were transported over distances exceeding several tens to hundreds of meters, even where mineralized fractures were absent. Indeed, isotopically perturbed samples could not be discriminated readily from unperturbed samples because of the lack of obvious indicators of different degrees of fluid-rock interactions. Thus, Sm and Nd are not as immobile as often claimed, nor does the Sm-Nd radioisotope system escape being significantly perturbed, which raises similar doubts about the reliability of the Sm-Nd "dating" system, as with other radioisotope dating systems.

Nevertheless, the Sm-Nd mineral isochron method has been widely applied to the "dating" of high-grade metamorphic rocks, because mineral isochrons have the advantage that variations in partition coefficients between minerals may have caused moderately large variations in Sm/Nd ratios. The best metamorphic mineral to use has been garnet. It has high Sm/Nd ratios in contrast to other metamorphic minerals. This results in a large range in Sm/Nd ratios, and thus better statistics, in the "age" determined from mineral isochrons using garnets, and one or more other metamorphic minerals. However, mineral systems may be opened sufficiently during metamorphism to disrupt the original mineral chemistry. It is claimed that certain minerals will close to element mobility at different so-called blocking temperatures, and the different radioisotope systems in the same mineral will also close at different closure temperatures, below which the radioisotope "clocks" are switched on.

However, the closure temperature of the Sm-Nd radioisotope system in metamorphic garnet has been the subject of continued debate, with experimental determinations and theoretical considerations showing that a sufficiently restricted range of closure temperature cannot be assigned.[10] Nevertheless, the resetting of the Sm-Nd radioisotope system in garnet does take place.[11] While it has been found that the effective diameter for diffusion may only be of the order of 1 mm, it is admitted that reliable chronological constraints are essential for the unambiguous interpretation of metamorphic rock textures because of this diffusion and resetting. Thus, the U-Th-Pb radioisotope system has been used to also "date" garnets. However, this has also proved problematical, because the U, Th, and Pb isotopes do not reside in the garnet lattice, but instead are hosted by inclusions of minerals such as zircon, which are invariably older than the garnets.[12]

10 J. Ganguly, M. Tirone and R. L. Hervig, 1988, Diffusion kinetics of samarium and neodymium in garnet, and a method for determining cooling rates of rocks, *Science*, 281: 805-807.

11 E. J. Hensen and B. Zhou, 1995, Retention of isotopic memory in garnets partially broken down during an overprinting granulite-facies metamorphism: Implications for the Sm-Nd closure temperature, *Geology*, 23: 225-228.

12 T. P. DeWolf, C. J. Zeissler, A. N. Halliday, K. Mezger and E. J. Essene, 1996, The role of inclusions in U-Pb and Sm-Nd garnet geochronology: Stepwise dissolution experiments and trace uranium mapping

Consequently, because of the implied mobility of the Sm and Nd isotopes at moderate to high temperatures, attempts at Sm-Nd mineral isochron "dating" are still dependent on calibrations with other radioisotope "dating" systems and assume their consistency with the uniformitarian timescale.[13] In any case, a study of the Sm-Nd radioisotope systematics in minerals in two granites has shown that hydrothermal fluids interacting with the host rocks, as the granite intrudes and crystallizes, are capable of carrying Sm and Nd in the rocks over distances of at least 1 km.[14] The minerals in both these granites produced statistically acceptable mineral isochrons, but these yielded otherwise meaningless "ages" that had to be interpreted as either inherited, or due to hydrothermal convection long after crystallization of the granites. Clearly, the Sm-Nd radioisotope "dating" system in both whole-rocks and minerals is not as "foolproof" as often claimed, sometimes being arbitrarily subject to resetting and disturbance due to diffusion and fluid migration at all scales.

Sm-Nd Model Ages

Of considerable importance in the use of the Sm-Nd radioisotope system are "model ages." These are defined as a measure of the length of time a sample has been separated from the mantle source from which it was originally derived.[15] Of course, this assumes a knowledge of the isotopic compositions of mantle sources, the absence of parent/daughter isotopic fractionation (separation) after extraction from the mantle sources, and the immobility of the parent and daughter isotopes. In the case of Sr isotopes, none of these criteria is usually fulfilled.[16] Nevertheless, Sm-Nd "model ages" are commonly calculated for individual rocks, using each single pair of parent-daughter isotopic ratios. However, they must be interpreted with care, primarily because of the assumptions about the isotopic compositions of the mantle source regions.[17] The two frequently assumed "models" of the Sm-Nd radioisotope system in mantle sources are the chondritic uniform reservoir (CHUR), and the depleted mantle (DM) reservoir.[18]

---

by fission track analysis, *Geochimica et Cosmochimica Acta*, 60: 121-134; B. Vance, M. Meier and F. Oberli, 1998, The influence of U-Th inclusions on the U-Th-Pb systematics of almandine pyrope garnet: Results of a combined bulk dissolution stepwise-leaching, and SEM study, *Geochimica et Cosmochimica Acta*, 62: 3527-3540.

13 K. Mezger, E. J. Essene and A. N. Halliday, 1993, Closure temperatures on the Sm-Nd system in metamorphic garnets, *Earth and Planetary Science Letters*, 113: 397-409.

14 F. Poitrasson, J.-L. Paquette, J.-M. Montel, C. Pin and J.-L. Duthou, 1998, Importance of late-magmatic and hydrothermal fluids on the Sm-Nd isotope mineral systematics of hypersolvus granites, *Chemical Geology*, 146: 187-203.

15 Rollinson, 1993.

16 S. L. Goldstein, 1988, Decoupled evolution of Nd and Sr isotopes in the continental crust, *Nature*, 336: 733-738.

17 Rollinson, 1993.

18 D. J. DePaolo and G. J. Wasserburg, 1976, Nd isotopic variations and petrogenetic models, *Geophysical Research Letters*, 3: 249-252; D. J. DePaolo and G. J. Wasserburg, 1976, Inferences about magma sources and mantle structure from variations of $^{143}Nd/^{144}Nd$, *Geophysical Research Letters*, 3: 743-746; D. J. DePaolo, 1981, Neodymium isotopes in the Colorado Front Range and crust-mantle evolution in the

However, the assumptions upon which these calculated "model ages" are based are not always fulfilled. First is the assumption about the isotopic composition of the chosen mantle reservoir model, which raises three further problems.[19] The choice of reservoir model can make a huge difference between the calculated Nd "model ages." There are now several possible competing mantle models in use, and there is confusion over the actual numbers for the mantle values that should be used in the "age" calculations. The second assumption used in "model age" calculations is that the Sm/Nd ratio of a sample has not been modified by fractionation (separation of the parent and daughter isotopes from one another) after separation of the rock sample from its original mantle source. However, as has already been noted, hydrothermal fluids can redistribute Sm and Nd and thus disturb the Sm/Nd ratios. Finally, the third assumption is that all material pertaining to the rock sample being "dated" came from the mantle in a single event, which may not always be the case, and cannot really be demonstrated.

Nevertheless, the meaning of these "model ages" is somewhat problematic. For example, Nd "model ages" for metamorphic rocks from central Australia have been reported with differences in each sample of up to 1.3 billion years, depending on the mantle reservoir model used.[20] Consequently, it has been admitted that the establishment of credible Sm-Nd "model ages" for crustal rocks clearly requires "precise" geochronological information, regarded as typically being provided by U-Pb isotopic measurements of zircons, plus agreed models for Nd isotopic evolution in the mantle sources of continental crust, and for Nd isotopic evolution of crustal reservoirs subsequent to their formation.[21] Additionally, models are required for the formation of certain types of granitic rocks in the crust, for a mechanism for mixing of materials to form a hybrid crust, and for the development of the lower parts of the continental crust. All these factors are problematic, but the greatest uncertainties are due to the lack of adequate information on the lower crustal processes and composition. Clearly, the usefulness of Sm-Nd "model ages" and the "dating" method is very much dependent on interpretative models, and on the other radioisotope "dating" systems that also have their own sets of problems. Indeed, as independently concluded, the Nd "model age" method requires geochronological confirmation by other radioisotope "dating" methods, because of the problem of mixing of Sm/Nd isotopes.[22] Thus, each of the radioisotope "dating" methods has its problems, and; therefore, the Sm-Nd method is dependent upon, and only as good as, any

---

Proterozoic, *Nature*, 291: 193-196.

19 Rollison, 1993.

20 D. P. Windrim and M. T. McCulloch, 1986, Nd and Sr isotopic systematics of central Australian granulites: Chronology of crustal development and constraints on the evolution of the lower continental crust, *Contributions to Mineralogy and Petrology*, 94: 289-303.

21 D. J. DePaolo, A. M. Linn and G. Schubert, 1991, The continental crust age distribution: Method of determining mantle separation ages from Sm-Nd isotopic data an application to the southwestern United States, *Journal of Geophysical Research*, 96: 2071-2088.

22 Dickin, 2005.

of the other methods.

103

The Pitfalls in the Radioactive Dating Methods—The Uranium-Thorium-Lead Dating Method

Historically, uranium (U)-thorium (Th)-lead (Pb) "dating" was the first method to be used on minerals, particularly U-bearing minerals. As the appropriate technology became available, this method was also applied to whole rocks. However, as with the other radioisotope "dating" methods, the U-Th-Pb radioisotope "dating" systems have their inherent problems that render them questionable at best.

Open-System Behavior

Even early studies in whole-rock U-Th-Pb "dating" of crystalline rocks showed the method to be of little value as a geochronological tool, because unfortunately, the U-Pb and Th-Pb systems rarely stay closed due to the mobility of Pb, Th, and especially U.[1] Indeed, it was found that U appeared to have been lost from samples which exhibited no discernible effects of alteration, so it was even suggested the leaching of U from surficial rocks might be a universal phenomenon.[2] This was because concentrations of U, Th, and Pb, and the isotopic composition of Pb, for whole-rock samples of granites, showed that open-system behavior is nearly universal in the surface and near-surface environment, and that elemental mobility is possible to depths of several hundred meters. Identified controlling factors included mineralogical sites for U and its daughter products, the access and volume of circulating ground water, and the chemistry of that ground water. In practice, therefore, the mobility of U, Th, and Pb renders the use of simple U-Pb isochron "dates" very limited. However, it is claimed that "age" information can still be obtained using the two parent U isotopes and their respective daughter Pb isotopes as a result of the consistent relationship between them and their coherent chemical behavior. Nevertheless, the focus has shifted back to using the U-Th-Pb "dating" technique on minerals. This has become the most popular and

1 Dickin, 2005.

2 J. S. Stuckless, 1986, Applications of U-Th-Pb isotope systematics to the problems of radioactive waste disposal, *Chemical Geology*, 55: 215-225.

highly regarded radioisotope dating method currently in use. The primary targets are grains of zircon ($ZrSiO_4$), baddeleyite (ZrO_2), titanite or sphene ($CaTiSiO_5$), and/or monazite ((Ce, La, Th) PO_4), though other minerals are sometimes used.

Concentrations of U and Th in zircon, for example, average 1,350 and 550 ppm respectively.[3] The presence of these elements in zircon is a result of U and Th atoms substituting for Zr atoms in its crystal lattice due to their similar sizes and their same electric charge. However, equally important is the fact that Pb is excluded from the zircon crystal lattice due to the larger size of its atoms and their lower charge. Therefore, zircon is believed to contain very little Pb, and thus very high U/Pb and Th/Pb ratios, at the time of its formation. This means that the radioisotope ratios now measured are due to all their radiogenic Pb being derived by radioactive decay from U and Th, which enhances zircon's sensitivity as currently the most popular geochronometer. However, radiogenic Pb can be inherited during crystallization of the mineral grains, and open-system behavior is common, resulting in radiogenic Pb loss by diffusion, due to the way the Pb is not bonded in the crystal lattices.

Even early dating work on U-rich minerals soon revealed that most samples yielded discordant U-Pb "ages," which were attributed to Pb loss.[4] Minerals that yielded discordant U-Pb "ages", nevertheless, defined a linear array when plotted, which was attributed to Pb loss by a continuous diffusional process.[5] It was then demonstrated that leakage of intermediate radon by gaseous diffusion through microfissures in minerals could account for the disparity in U-Pb "ages."[6] Subsequently, it was postulated that the intermediate members of the U-decay series generally were ejected into microfissures in mineral lattices, where they were removed by diffusion or leaching, accounting for continuous Pb loss.[7]

However, an alternative model was also proposed that invoked episodic Pb loss from minerals due to a thermal event subsequent to their formation.[8] Such open-system behavior explained U-Pb "dates" that were otherwise unsuccessful, because they failed the crucial assumptions about initial conditions and a closed system.[9] Indeed, the postulated Pb loss by continuous diffusion over "geological time" was confirmed by experimental demonstration that Pb diffuses from zircon and

3 Faure and Mensing, 2005, 221.

4 A. Holmes, 1954, The oldest dated minerals of the Rhodesian Shield, *Nature*, 173: 612-617.

5 L. H. Ahrens, 1955, Implications of the Rhodesia age pattern, *Geochimica et Cosmochimica Acta*, 8: 1-15.

6 E. J. Giletti and J. L. Kulp, 1955, Radon leakage from radioactive minerals, *American Mineralogist*, 40: 481-496.

7 R. D. Russell and L. H. Ahrens, 1957, Additional regularities among discordant lead-uranium ages, *Geochimica et Cosmochimica Acta*, 11: 213-218.

8 G. W. Wetherill, 1956, An interpretation of the Rhodesia and Witwatersrand age patterns, *Geochimica et Cosmochimica Acta*, 9: 290-292.

9 E. W. Wetherill, 1956, Discordant uranium-lead ages, I, *Transactions of the American Geophysical Union*, 37: 320-326.

U-bearing minerals, even at low temperatures.[10]

This Pb loss by diffusion is facilitated by the α-radiation damage to the host mineral lattices.[11] Indeed, not only has it been confirmed that radiation damage can drastically increase the rate of Pb diffusion, but higher temperatures induce even faster diffusion.[12] This is dramatically illustrated by the contact metamorphic effects of the heat from a granite intrusion on zircon crystals in the surrounding regionally metamorphosed sediments and volcanics (Figure 62, page 1094).[13] Within 15 meters (50 feet) of the contact, the U-Pb "ages" decrease dramatically from 1,405 million years to 220 million years. Furthermore, it has also been demonstrated that larger zircon grains lose less Pb than smaller ones (due to the larger surface area/volume ratio of the latter), and that zircon grains with low U contents lose less Pb than high-U zircons (due to greater radiation damage suffered by the latter).[14] However, zircon crystals are often chemically and physically inhomogeneous (zoned) due to progressive growth during crystallization, and both zoned and unzoned zircon crystals may be found in the same rock. Thus, unzoned crystals can be the result of recrystallization of zoned crystals accompanied by loss of U, Th, and Pb, which results in "resetting" of the U-Pb "ages."[15] Such recrystallization can be due to regional metamorphism, which has been found to reduce U-Pb zircon "ages" by hundreds of millions of years, even within single samples.[16] Similarly, even when a spectrum of concordant zircon U-Pb "ages" are obtained, they are nevertheless meaningless, due to the high-temperature Pb loss during metamorphism by volume, and/or fracture-assisted diffusion.[17]

10 J. R. Tilton, 1960, Volume diffusion as a mechanism for discordant lead ages, *Journal of Geophysical Research*, 65: 2933-2945.

11 E. J. Wasserburg, 1963, Diffusion processes in lead-uranium systems, *Journal of Geophysical Research*, 68: 4823-4846; S. S. Goldich and M. J. Mudrey, Jr., 1972, Dilatancy model for discordant U-Pb zircon ages, in *Contributions to Recent Geochemistry and Analytical Chemistry*, A. I. Tugrainov, ed., Moscow: Nauka Publishing Office, 415-418; A. Meldrum, L. H. Boatner, W. J. Weber and R. C. Ewing, 1998, Radiation damage in zircon and monazite, *Geochimica et Cosmochimica Acta*, 62: 2509-2520.

12 J. K. W. Lee, I. S. Williams and D. J. Ellis, 1997, Determination of Pb, U and Th diffusion rates in zircon, *Research School of Earth Sciences Annual Report 1996*, Canberra, Australia: Australian National University, 121-122.

13 E. L. Davis, S. R. Hart and G. R. Tilton, 1968, Some effects of contact metamorphism on zircon ages, *Earth and Planetary Science Letters*, 5: 27-34.

14 L. T. Silver and S. Deutsch, 1963, Uranium-lead isotopic variations in zircons: A case study, *Journal of Geology*, 71: 721-758.

15 R. T. Pidgeon, 1992, Recrystallisation of oscillatory zoned zircon: Some geochronological and petrological implications, *Contributions to Mineralogy and Petrology*, 110: 463-472.

16 A. Kröner, P. J. Jaeckel and I. S. Williams, 1994, Pb-loss patterns in zircons from a high-grade metamorphic terrain as revealed by different dating methods, U-Pb and Pb-Pb ages for igneous and metamorphic zircons from northern Sri Lanka, *Precambrian Research*, 66: 151-181.

17 L. D. Ashwal, R. D. Tucker and E. K. Zinner, 1999, Slow cooling of deep crustal granulites and Pb-loss in zircon, *Geochimica et Cosmochimica Acta*, 63: 2839-2851.

Inheritance

Another significant problem for zircon U-Pb "dating" are zircon crystals that yield much older "ages" than the expected/accepted "ages" of the rocks containing them. In metamorphic rocks, this is usually interpreted as inheritance of those zircon grains that were in the original sediments, the zircon U-Pb "ages" not having been reset by the metamorphism.[18] In granitic rocks, these "older" zircons are likewise interpreted as having been inherited from the source rocks that melted to produce the granitic magmas.[19] Indeed, some of these so-called inherited zircons are 5-10 times "older" than those matching the accepted "ages" of the granites—for example, up to 1,753 million years in a Himalayan granite supposed to be 21 million years old,[20] up to 3,500 million years in a southeast Australian granodiorite supposed to be 426 million years old,[21] and up to 1,638 million years in a New Zealand granite supposed to be 370 million years old.[22] Of course, if the accepted "age" of a rock according to the uniformitarian timescale is unknown, then there is no way of being sure from such zircon U-Pb "ages" what is the real age of the rock!

However, if Pb is lost from some mineral grains, then it could be inherited by other crystals during and subsequent to the formation of the host rocks. Thus, in Precambrian rocks many potassium feldspar grains, which have never contained U, nevertheless contain radiogenic Pb.[23] However, such excess radiogenic Pb producing anomalously high "ages" can also be found in zircon crystals themselves.[24] Similar situations also result in "ages" hundreds of millions of years more than expected, and are interpreted as being due to excess radiogenic Pb, the origin of which is either explained as mixing from older source materials which melted to form the magmas, and/or due to subsequent migration as a result of

---

18 E. O. Froude, T. R. Ireland, P. O. Kinny, I. S. Williams and W. Compston, 1983, Ion microprobe identification of 4100-4200 Ma-old terrestrial zircons, *Nature*, 304: 616-618; Kröner et al, 1994.

19 I. S. Williams, W. Compston and B. W. Chappell, 1983, Zircon and monazite U-Pb systems and histories of I-type magmas, Berridale Batholith, Australia, *Journal of Petrology*, 24: 76-97; Y. D. Chen and I. S. Williams, 1990, Zircon inheritance in mafic inclusions from Bega Batholith granites, south-eastern Australia: An ion microprobe study, *Journal of Geophysical Research*, 95: 17,787-17,796.

20 I. R. Parrish and R. Tirrul, 1989, U-Pb age of the Baltoro Granite, northwest Himalaya, and implications for monazite U-Pb systematics, *Geology*, 17: 1076-1079.

21 I. S. Williams, 1992, Some observations on the use of zircon U-Pb geochronology in the study of granitic rocks, *Transactions of the Royal Society of Edinburgh*, 83: 447-458.

22 R. J. Muir, T. R. Ireland, S. D. Weaver and J. D. Bradshaw, 1996, Ion microprobe dating of Paleozoic granitoids: Devonian magmatism in New Zealand and correlations with Australia and Antarctica, *Chemical Geology*, 127: 191-210.

23 A. R. Ludwig and L. T. Silver, 1977, Lead isotope inhomogeneities in Precambrian igneous K-feldspars, *Geochimica et Cosmochimica Acta*, 41: 1457-1471.

24 I. S. Williams, W. Compston, L. B. Black, T. R. Ireland and J. J. Foster, 1984, Unsupported radiogenic Pb in zircon, a cause of anomalously high Pb-Pb, U-Pb and Th-Pb ages, *Contributions to Mineralogy and Petrology*, 88: 322-327.

fluids, temperature, and pressure.[25] This, of course, again begs the question—should "anomalously old" zircons be interpreted as inheritance of the zircon crystals, or of "excess" radiogenic Pb in the crystals?

The advent of more sophisticated analytical technology has since provided new means to evidently circumvent these problems in the U-Th-Pb "dating" of zircons and other minerals. For example, individual zircon grains are blasted with air to remove outer layers that may represent younger overgrowths on older grains, which is followed by hand-picking of the best grains.[26] A completely different approach is the *in situ* analysis of U/Pb and Pb isotopic ratios within zircon grains using an ion microprobe. A very narrow ion beam is focused on 2-micron-wide spots within zircon or other crystals, enabling the analysis and consequent "dating" of different growth zones in them. However, utilizing this technique, radiogenic Pb has been found to vary within most tested zircon grains on a 20-micron spatial scale.[27] Some spots were characterized by huge excesses of radiogenic Pb, up to thirty times the "expected" values. Furthermore, pronounced reproducible differences in apparent "ages" have been demonstrated between four differently oriented faces of a large baddeleyite crystal, an effect concluded to be a primary crystal growth feature.[28] Additionally, isotopic ratios were measured on the same crystal faces of 47 baddeleyite crystals, but at different orientations with respect to the ion beam. The results revealed a striking, approximately sinusoidal, variation in U/Pb apparent "ages" of hundreds of millions of years with orientation (Figure 63, page 1094). However, while similar significant differences in apparent U/Pb "ages" were not detected in zircon or monazite crystals, within the analytical statistics, other Pb and isotopic Th/U ratios vary systematically with orientation, suggesting these were real compositional variations that reflected zones of primary crystal growth.

Nevertheless, some monazite crystals have been found to contain random submicroscopic blotchy patches that can vary up to 700 million years in "age" from one another.[29] Similarly, discordant U-Pb "ages" that still plotted as linear arrays were obtained for monazite grains in high-grade metamorphic rocks, and high spatial resolution examination of the grains revealed domains with greatly

25 L. S. Zhang and U. Schärer, 1996, Inherited Pb components in magmatic titanite and their consequence for the interpretation of U-Pb ages, *Earth and Planetary Science Letters*, 138: 57-65; P. Copeland, R. R. Parrish and T. M. Harrison, 1988, Identification of inherited radiogenic Pb in monazite and its implications for U-Pb systematics, *Nature*, 333: 760-763.

26 T. E. Krogh, 1982, Improved accuracy of U-Pb zircon ages by the creation of more concordant systems using the air abrasion technique, *Geochimica et Cosmochimica Acta*, 46: 637-649.

27 W. Compston, 1997, Variation in radiogenic Pb/U within the SL13 standard, *Research School of Earth Sciences Annual Report 1996*, Canberra, Australia: Australian National University, 188-121.

28 M. T. D. Wingate and W. Compston, 2000, Crystal orientation effects during ion microprobe, U-Pb analysis of baddeleyite, *Chemical Geology*, 168: 75-97.

29 A. Cocherie, O. Legeandre, J. J. Peucat and A. N. Kouamelan, 1998, Geochronology of polygenetic monazites constrained by *in situ* electron microprobe Th-U-total lead determination: Implications for lead behaviour in monazite, *Geochimica et Cosmochimica Acta*, 62: 2475-2497.

contrasting U-Th and Pb concentrations.[30] Significantly, monazite grains can also yield negative "ages," such as -97 million years in a supposedly 20 million year old Himalayan granite that also contains zircon grains yielding "ages" up to 1,483 million years, a discordance of almost 7,500 percent![31]

Clearly, the results of U-Th-Pb mineral dating, currently the most popular method, are highly dependent on the investigators' interpretations, which are usually based on expectations determined by the geological contexts of the rocks being "dated." Radiogenic Pb is easily lost by diffusion from some crystals, and the process is accelerated by heat, water, radiation damage, and weathering, while in other crystals it is inherited in excess. Uranium is readily dissolved by ground waters at considerable depths and leached from rocks and their constituent minerals. Thus, without the geological context and the expected "ages" to guide the investigators, one cannot be sure, as with whole-rock U-Th-Pb dating, that the analytical results and the derived "ages" are pristine and, therefore, represent the formation ages of the rocks. After all, apparent "ages" vary significantly within crystals at sub-microscopic scales, on different crystal faces, and at different crystal orientations. These effects must all combine to make U-Th-Pb "dating" of whole mineral grains and zones within them highly questionable, given that it is not always clear apart from outside assumptions as to what the "dates" really mean.

In any case, a consistent systematic pattern of discordant U-Th-Pb "ages" obtained from different minerals was recognized early in the history of this method.[32] In uraninite (the primary U ore mineral), zircon, monazite, and titanite, the Th "ages" were consistently younger than the ^{238}U "ages," which were consistently younger than the ^{235}U "ages," a pattern also obtained on five uraninite samples from the Koongarra uranium deposit of the Northern Territory of Australia.[33] The reason for this consistent pattern has apparently never been determined, but it may be related to the rate of decay of the parent radioisotopes, Th having the slowest rate of decay (largest half-life), and ^{235}U the fastest rate of decay (shortest half-life).

Pb-Pb Isotope "Dating," Inheritance and Mixing

Even though the U-Pb isochron method for dating of whole rocks has been discredited, the Pb-Pb isochron method continues to be used. Both parent U

---

30 J. L. Crowley and E. D. Ghent, 1999, An electron microprobe study of the U-Th-Pb systematics of metamorphosed monazite: The role of Pb diffusion verses overgrowth and recrystallization, *Chemical Geology*, 157: 285-302.

31 R. R. Parrish, 1990, U-Pb dating of monazite and its applications to geological problems, *Canadian Journal of Earth Sciences*, 27: 1431-1450.

32 J. L. Kulp and W. R. Eckelmann, 1957, Discordant U-Pb ages and mineral type, *American Mineralogist*, 42: 154-164.

33 J. H. Hills and J. R. Richards, 1976, Pitchblende and galena ages in the Alligator Rivers Region, Northern Territory, Australia, *Mineralium Deposita*, 11: 133-154.

radioisotopes appear to be always present in the same constant ratio, and both they and their respective Pb isotope end members show coherent chemical behavior. Thus, it is argued, if a group of rock samples all have the same age and initial whole-rock Pb isotopic composition, then they will have developed, with time, different present-day, whole-rock Pb isotopic compositions according to their respective present-day U-Pb ratios.[34] Provided they have remained closed systems, the present-day whole-rock Pb isotopic compositions of a suite of rock samples should plot as an isochron line that yields an "age" for the rock unit sampled. As long as the U-Pb system has remained closed since the rock unit formed, it is claimed that even under present weathering conditions, in which U is known to be highly mobile, the Pb isotope ratios in the rock unit will not have been perturbed, and thus should still yield its formation "age."[35]

The first application of the whole-rock Pb-Pb dating technique was actually on meteorites. A Pb-Pb isochron "age" of 4.55±0.07 billion years was obtained from a suite of three stony meteorites and two iron meteorites, which was interpreted as the age of the earth.[36] Thus, this Pb-Pb isochron became known as the geochron. One of the minerals in one of the iron meteorites had such a low Pb isotopic composition, that it was concluded that no observable change in Pb isotopic composition could have resulted from radioactive decay since that meteorite formed; therefore, this must represent the "primordial" Pb isotope composition of the earth and the solar system.

Now Pb is widely distributed throughout the earth, not only as the radioactive decay daughter of U and Th, but also in minerals from which U and Th have been excluded. Therefore, the isotopic composition of Pb varies between wide limits, being a record of the chemical environments in which the Pb has resided. Because U/Pb and Th/Pb ratios are changed by the generation of magmas, by hydrothermal and metamorphic processes, and by weathering, the Pb isotopic composition in samples of a particular rock unit may have been modified both by decay of U and Th, and by mixing with Pb having different isotopic compositions. As a result, the isotopic compositions of Pb in rocks display complex patterns of variation that supposedly reflect their particular geologic histories. Consequently, various attempts have been made to construct graphical models of how Pb isotopic compositions of Pb ore minerals have changed and developed in the earth over the claimed geologic timescale.[37] Such models start with a "primordial"

---

34 Dickin, 2005.

35 J. N. Rosholt and A. J. Bartel, 1969, Uranium, thorium and lead systematics in Granite Mountains, Wyoming, *Earth and Planetary Science Letters*, 7: 14-17.

36 C. C. Patterson, 1956, Age of meteorites and the earth, *Geochimica et Cosmochimica Acta*, 10: 230-237.

37 A. Holmes, 1946, An estimate of the age of the earth, *Nature*, 157: 680-684; F. G. Houtermans, 1946, Die isotopen-haufigkeiten im naturlishen blei und das Aalter des urans, *Naturwissenschaften*, 33: 185-187; V. M. Oversby, 1974, A new look at the lead isotope growth curve, *Nature*, 248: 132-133; G. L. Cumming and J. R. Richards, 1975, Ore lead isotope ratios in a continuously changing earth, *Earth and Planetary Science Letters*, 28: 155-171.

Pb isotopic composition within the earth's mantle equivalent to that in the mineral from the iron meteorite, which is then added to by the decay of U and Th over geologic time. At different times through the earth's history, magmas with particular Pb isotopic compositions have been extracted from the mantle to build the earth's crust, while there has probably been circulation of material in the mantle, including recycling of portions of the crust.[38] It is therefore claimed that there are distinct Pb isotopic reservoirs within the earth's mantle and crust, but where they are actually located is not clear.

Isotopic analyses of historic and recent basalt lava flows on ocean islands, and on the mid-ocean ridges, have been used to demonstrate that the mantle sources from which the magmas came are not homogeneous.[39] When the Pb isotopic compositions of these basalts are plotted on a Pb-Pb "isochron" diagram, they define a series of different groups and linear arrays to the right of the "geochron," which is supposedly the isochron representing Pb isotopic compositions of zero "age" (Figure 64, page 1095). The slopes of these linear arrays correspond to apparent Pb-Pb isochron "ages" of between 1 and 1.5 billion years for what are only recent lava flows! Apparent heterogeneity of the upper mantle, the source of these lavas, is a worldwide phenomenon and Pb-Pb isotopic linear arrays may be interpreted in three principal ways: as resulting from discrete magma-forming events in the mantle, as products of two-component mixing processes, or resulting from continuous development of reservoirs with changing U-Pb ratios.[40] What is clear is that whole-rock Pb-Pb "dating" of these recent basalt lavas produces anomalously old "ages," which represent inheritance of Pb isotopic compositions from the mantle source areas of the magmas. Thus far, five end-member reservoirs with discrete isotopic compositions have been delineated in the mantle, and three in the continental crust, with a variety of mixing processes regarded as capable of explaining all observed rock isotopic compositions.[41]

The Pb isotopic compositions of volcanic rocks on the continents also form linear arrays, and have also been interpreted as mixtures derived from the crust and mantle. For example, the volcanic and intrusive rocks on the Isle of Skye of northwest Scotland plot on a Pb-Pb isotope diagram along a strong linear

---

38 G. R. Doe and R. E. Zartman, 1979, Plumbotectonics, in *Geochemistry of Hydrothermal Ore Deposits*, second edition, H.L. Barnes, ed., New York: John Wiley & Sons, 22-70.

39 B. W. Gast, G. R. Tilton and C. Hedge, 1964, Isotopic composition of lead and strontium from Ascension and Gough Islands, *Science*, 145: 1181-1885.; M. Tatsumoto, 1966, Genetic relations of oceanic basalts as indicated by lead isotopes, *Science*, 153: 1094-1101; S. S. Sun, 1980, Lead isotopic study of young volcanic rocks from mid-ocean ridges, ocean islands and island arcs, *Philosophical Transactions of the Royal Society of London*, A297: 409-445.

40 Dickin, 2005.

41 E. N. Taylor, N. W. Jones and S. Moorbath, 1984, Isotopic assessment of relative contributions from crust and mantle sources to magma genesis of Precambrian granitoid rocks, *Philosophical Transactions of the Royal Society of London*, A310: 605-625; A. Zindler and S. R. Hart, 1986, Chemical geodynamics, *Annual Review of Earth and Planetary Sciences*, 14: 493-571.

array that represents an apparent isochron "age" of approximately 3 billion years.[42] However, because these are relatively recent lavas and granites, this linear array is interpreted as a mixing line between mantle-derived Pb and ancient crustal Pb.[43] This is why an important word of caution has been given: "Not all linear arrays on the Pb-Pb diagram are isochrons."[44] This is because linear correlations of Pb isotopic ratios can also result from the mixing of Pb of different isotopic compositions in varying proportions, resulting in false apparent isochrons.

An extreme example of a false isochron achieved by mixing Pb of different isotopic compositions graphically illustrates the pitfalls in whole-rock Pb-Pb isochron dating. The Pb-Pb isochron "ages" of the uranium ore minerals containing Pb at Koongarra in the Northern Territory, Australia, are nearly identical as evident by the clear relationship between them.[45] Subsequent to its formation, the uranium ore has been exposed to weathering, so that U has been dispersed in the weathered rock zone and soils downslope in the direction of groundwater flow.[46] Yet all 113 soil samples, collected from near the uranium ore, from the immediate surrounding areas, and from as far afield as 17 kilometers away, plotted as a near perfect line on a Pb-Pb isotopic diagram, equivalent to an apparent isochron with an "age" of 1,445 million years (Figure 65, page 1095).[47]

It has to be concluded, therefore, that U-Th-Pb "dating" involves many pitfalls, which are really only surmounted by making further assumptions, and by dependence on uncertain cross-checks. Both U and Pb mobility undermine whole-rock "dating," and Pb migration within, and loss from, individual mineral grains is so prevalent that interpreting the resultant isotopic data is largely dependent upon the bias of the investigators to produce the desired outcomes. In this way an entire edifice has been built that looks impregnable and internally consistent. However, fundamental problems remain. Modern basalt lavas reveal inconsistent Pb isotopic heterogeneities in their mantle sources, even from successive flows on the same ocean island, which yield vastly erroneous old "ages," and which are totally at variance with all models of Pb isotopic "evolution." Isotope inheritance,

42 S. Moorbath and H. Welke, 1969, Lead isotope studies of rocks from the Isle of Skye, northwest Scotland, *Earth and Planetary Science Letters*, 5: 217-230.

43 R. N. Thompson, 1982, Magmatism of the British Tertiary Volcanic Province, *Scottish Journal of Geology*, 18: 49-107.

44 G. Faure, 1986, *Principles of Isotope Geology*, second edition, New York: John Wiley & Sons, 327.

45 Hills and Richards, 1976.

46 A. A. Snelling, 1984, A soil geochemistry orientation survey for uranium at Koongarra, Northern Territory, *Journal of Geochemical Exploration*, 22: 83-99; A. A. Snelling, 1990, Koongarra uranium deposits, in *Geology of the Mineral Deposits of Australia and Papua New Guinea*, F. E. Hughes, ed., Melbourne, Australia: The Australasian Institute of Mining and Metallurgy, 807-812.

47 B. L. Dickson, B. L. Gulson and A. A. Snelling, 1985, Evaluation of lead isotopic methods for uranium exploration, Koongarra area, Northern Territory, Australia, *Journal of Geochemical Exploration*, 24: 81-102; B. L. Dickson, B. L. Gulson and A. A. Snelling, 1987, Further assessment of stable lead isotope measurements for uranium exploration, Pine Creek Geosyncline, Northern Territory, Australia, *Journal of Geochemical Exploration*, 27: 63-75.

migration, and mixing in the U-Th-Pb system are prevalent chronic problems at all observational scales. What is known of patterns in U-Th-Pb "ages" hints at some underlying fundamental, non-time-dependent process that would render all "age" interpretations invalid. Clearly, even though the constructed "age" system edifice looks internally consistent, the individual "dating" results within it are nevertheless questionable, and the foundations it is built on appear to be systematically in error.

104

The Pitfalls in the Radioactive Dating Methods—Sundry Methods and Revealing Considerations

The Lutetium-Hafnium and Rhenium-Osmium Radioisotope Dating Methods

These two radioisotope dating methods are somewhat specialized, because the elements involved are only present in trace amounts in most rocks and minerals. However, hafnium (Hf) is virtually identical in the size of its atom and electric charge with zirconium (Zr), so it occurs in Zr-bearing minerals, most notably zircon. Because both Lu (lutetium) and Hf are dispersed elements, they do not form their own minerals. On the other hand, rhenium (Re) has similar chemical properties to molybdenum (Mo), which it replaces in molybdenite (MoS_2) and other Mo-bearing sulfide minerals. Similarly, Re tends to occur in copper sulfide minerals, as Re tends to be captured in place of Cu. Furthermore, on rare occasions, osmium is found as a metallic alloy with iridium (Ir) (osmiridium), both being related to platinum. Both methods have been used to "date" meteorites. The Re-Os method has been particularly "successful," especially for the iron meteorites because of their high contents of these metallic elements.

Not only are both methods utilized to obtain whole-rock and mineral isochron "ages" for rocks and meteorites using the appropriate radioisotope ratios, but both methods are also used to derive "model ages" for minerals. However, to obtain "model ages" in both methods, it has to be assumed that the primordial endowment of these radioisotopes in the earth's mantle was equivalent to the initial Hf and Os radioisotope ratios determined from meteorite isochrons. It has to also be assumed that meteorite isochrons have determined the age of the earth as 4.55 billion years, and that from those initial Hf and Os radioisotope ratios, the mantle reservoir of these isotopes has developed in a predictable manner, based on the present-day measurements of the radioactive decay rates of the parent Lu and Re isotopes, respectively. In the case of the development of the Os isotopes in the mantle reservoir, a cross-check is evidently provided by Os isotope ratios determined on Os-bearing alloys and minerals of supposedly known age, independently determined by the other radioisotope dating methods.

Both these radioisotope dating methods have primarily been used on ancient (Precambrian) rocks and minerals, because of the very slow decay rates of the parent isotopes as measured today. However, both the isochron and "model age" Re-Os methods have been applied with apparent success to the "dating" of sulfide and other ore deposits and/or minerals. Nevertheless, the viability of these radioisotope dating methods is very much dependent on the accuracy with which the present decay rates of the parent isotopes have been determined. However, these are also very much dependent on assumptions about the age of the earth, the earth's relationship to the meteorites, and the reliability of the independent radioisotope "dating" of the meteorites used to determine the decay rates of the Lu and Re parent isotopes. Furthermore, the reproducibility of the Lu and Hf measurements is not always as good as expected based on analytical errors alone, because of the inhomogeneous distribution of Lu and Hf in various rocks, due to the uneven distribution of the accessory minerals in which these trace elements reside.[1] In addition, accessory minerals are sensitive to alteration during metamorphism, and some, such as zircon, may contain detrital cores that may have acquired overgrowths during metamorphism. On the other hand, in many cases the Os in molybdenites consist almost entirely of radiogenic Os, such that their Re and Os isotopic ratios have large values approaching infinity, and, therefore, are difficult to measure accurately. Furthermore, such ore minerals are often formed during an episode of hydrothermal activity later than the rocks hosting them, and/or radiogenic Os can be lost during subsequent regional metamorphism. Thus, similar to the principal radioisotope methods, these two specialized radioisotope "dating" methods are also plagued with assumptions about initial conditions, and with open-system behavior. Therefore, the "dates" obtained by them often only make sense in the context of the "ages" obtained on the relevant rocks by the other radioisotope "dating" methods.

How Much Radioactive Decay Has Actually Occurred?

These radioisotope "dating" methods for rocks and minerals are based on analyses of the radioactive parent and radiogenic daughter isotope pairs. The calculation of "ages" from those isotope analyses depends on crucial assumptions, particularly that the daughter isotopes have been derived by radioactive decay of the parent isotopes. If this assumption was shown to be false, that so much radioactive decay has not occurred, then it could be argued that the measured daughter isotopes are merely an artifact of the mineral compositions, and of the geochemistry of the rocks and the sources from which they were derived.

So do we have physical evidence that radioactive decay has actually occurred? Yes, there are several evidences of this:

1. The presence of daughter isotopes such as lead and helium present with the

1 Faure and Tensing, 2005.

parent isotopes of uranium in the right proportions to have been derived by radioactive decay;

2. The observable physical scars left by the alpha (α)-particles during radioactive decay as radiohalos; and

3. The observable physical scars left by the nuclear decay of uranium atoms as they split or fission, which are known as fission tracks.

It has been estimated that from 500 million to 1 billion α-particles from uranium decay are required to form a dark uranium radiohalo, which equates to at least 100 millions years worth of decay at today's measured rates.[2] Such uranium radiohalos are ubiquitous in granites at most relative time levels in the geologic record, suggesting that hundreds of millions of years worth (at today's rates) of radioactive decay has occurred through earth history.[3] This is confirmed by the physically observed quantities of fission tracks, which equate to hundreds of millions of years of such nuclear decay measured at today's rates being equivalent to the radioisotope "ages" for the same rock units.[4] Therefore, it must be concluded that hundreds of millions of years worth of radioactive and nuclear decay must have occurred during the accumulation of the geologic record.

Furthermore, because the quantities of fission tracks often match the radioisotope "ages" for rock units, it is likely that the radioisotope ratios measured in the rock units to derive the respective radioisotope "ages" do often equate to those quantities of radioisotope decay (at today's measured rates) having physically occurred. Thus, the inescapable conclusion is that the radioisotope ratios in many rock units have resulted from hundreds of millions of years, and even billions of years, of radioactive decay (at today's measured rates), so they are not merely an artifact of mineral compositions, and of the geochemistry of the rocks and the sources from which they were derived. These latter factors have played a role, as already repeatedly documented, but radioactive decay has been the dominant producer of the measured daughter isotopes alongside their parent radioisotopes.

Do Radioisotope "Ages" Match the Claimed Stratigraphic "Ages"?

Geologists had assigned stratigraphic "ages" to rock units by various means before the advent of the radioisotope "dating" methods. This included the fossil contents

2 R. V. Gentry, 1988, *Creation's Tiny Mystery*, Knoxville, TN: Earth Science Associates.

3 A. A. Snelling, 2005, Radiohalos in granites: evidence for accelerated nuclear decay, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 101-207.

4 A. A. Snelling, 2005, Fission tracks in zircons: evidence for abundant nuclear decay, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 209-324.

of the rock units, which also enabled their correlation beyond where they could be physically traced. Assumptions were made about the rates of the geological processes responsible for accumulation and formation of the rock units, and for the evolutionary development of the organisms that became their contained fossils. By the time the radioisotope "dating" methods had been developed, the geological timescale had already been imposed on the globally-correlated rock sequence.

With the advent of radioisotope "dating," the "ages" assigned to various rock units have often only been refined. Often the fossil-bearing sedimentary strata cannot be directly "dated" by use of the radioisotope methods, unless they contain a "datable" mineral that only formed at the time the sediments were being deposited and compacted. Instead, the focus has been on the radioisotope "dating" of volcanic rock units interbedded in strata sequences above and below fossil-bearing rock layers. In this way, the stratigraphic "ages" of strata have been adjusted to conform with the timescale generated by the application of the radioisotope "dating" methods to the rock strata. Thus, there is now a direct correlation between the radioisotope "ages" of strata and their stratigraphic "ages," because the latter have been made to conform to the former by the application of the radioisotope methods to the "dating" of the strata sequences.

Do "Ages" Determined by the Different Radioisotope "Dating" Methods Agree?

Any reading of geology textbooks gives the impression that the "ages" derived by the different radioisotope "dating" methods applied to the same rocks are generally always in agreement. Sometimes this is specifically stated. Even in textbooks on the radioisotope "dating" methods, though numerous problems with them are discussed, the underlying message clearly evident is that the "ages" obtained by the different methods are normally in agreement. But is this really the case?

Upon detailed investigation of the relevant geological literature, it is discovered that rarely, if ever, have all the major radioisotope "dating" methods been applied to the same samples from the same rock units. More often than not, only one of the methods is used, though sometimes two of the methods are applied to the same samples from the same rock unit. In fairness, several factors have been at work. First, at the time a rock unit has been "dated," only the radioisotope method or methods currently available and/or in vogue were utilized. Second, depending on the nature of the rock unit and its expected "age," the choice would have been made as to which of the radioisotope methods was best suited to the "dating" of it. This was not unreasonable. Because of the different minerals present in different rocks, some radioisotope methods are better suited to "dating" those rocks and their constituent minerals. Furthermore, because the different parent isotopes have different half-lives (that is, decay rates), as measured today, those parent isotopes with the slowest decay rates are not necessarily suited to rock units with expected young "ages." This is because there wouldn't have been sufficient time for enough daughter isotopes to have accumulated, in order to provide an accurate measure of the supposed elapsed time. In any case, given the expectation that the different radioisotope "dating" methods should by definition yield the same "ages" on the same rock units, it is hardly surprising that if "dating" the rock unit with the chosen radioisotope method yields the expected "age," then it would be deemed unnecessary to commit further time and resources to "dating" the same rocks with the other radioisotope methods.

Nevertheless, invariably where two or more of the radioisotope "dating" methods have been applied to the same rock unit, different "ages" have often been obtained. Where this has been reported in the scientific literature, the different radioisotope "ages" on the same rock unit are usually the outcome of different studies completed by different investigators on different samples and/or minerals. Nevertheless, there have been reported studies where two or more of the radioisotope dating methods have been applied to the same samples and have yielded different "ages." However, in all these instances, the explanation given for these different radioisotope "ages" for the same rock unit invariably is that there has been some geochemical process or geological event that has perturbed one or more of the radioisotope systems, and not the other or others. The most frequently used explanation is hydrothermal fluids and alteration, even where there is no other evidence, either geochemical or mineralogical, for such having occurred. Otherwise, it may be legitimate to invoke varying closure temperatures for the different radioisotope systems in different minerals as the explanation for different radioisotope "ages" in those minerals. But this cannot be the case with different whole-rock radioisotope "ages" on the same samples.

Some examples illustrate the above observations. Different radioisotope "ages" were obtained on the Stuart Dyke swarm of south-central Australia, and the Uruguayan Dike swarm in Uruguay. The Stuart Dyke swarm yielded a Sm-Nd mineral "isochron age" of 1,076±33 million years, and a Rb-Sr mineral "isochron age" of 897±9 million years.[5] Similarly, the Uruguayan Dike swarm yielded a Rb-Sr "isochron age" for 15 whole rocks of 1,766±124 million years, and a Rb-Sr mineral "isochron age" of 1,366±18 million years.[6] In neither of these cases is a satisfactory and feasible explanation given for these different radioisotope "ages" yielded by the same rock units.

In contrast, an "explanation" has been offered for different radioisotope "ages" yielded by the Great Dyke of Zimbabwe, a 550-km-long by 3 to 11-km-wide

5 J. Zhao and M. T. McCulloch, 1993, Sm-Nd mineral isochron ages of Late Proterozoic Dyke swarms in Australia: Evidence for two distinctive events of mafic magmatism and crustal extension, *Geochemical Geology*, 109: 341-354.

6 W. Teixeira, P. R. Renne, G. Bossie, N. Campal and M. S. D'Agrella Filho, 1999, ^{40}Ar-^{39}Ar and Rb-Sr geochronology of the Uruguayan Dike swarm, Rio de la Plata Craton and implications for Proterozoic intraplate activity in western Gondwana, *Precambrian Research*, 93: 153-180.

intrusion in southeast Africa. A Rb-Sr whole-rock "isochron age" (eight samples) for the Great Dyke of 2,477±90 million years[7] was subsequently reconfirmed very precisely with a Rb-Sr whole-rock and mineral "isochron age" (five whole rocks and four minerals) of 2,455±16 million years.[8] Both of these radioisotope "ages" were again subsequently reconfirmed. Eleven samples from a single drill-hole into the dyke yielded an Rb-Sr whole-rock and mineral "isochron age" of 2,467±85 million years.[9] Yet even though these independently determined Rb-Sr "ages" on different samples are identical, within the stated error margins, and had been widely accepted, recent radioisotope data supposedly indicate this intrusion is about 120 million years older. The same study that used drill-hole samples and reported a Rb-Sr "isochron age" of 2,467±85 million years, also reported an Sm-Nd whole-rock "isochron age" of 2,586±16 million years, a Pb-Pb mineral and whole-rock "isochron age" of 2,596±14 million years, and a U-Pb "concordia age" using the mineral rutile of 2,587±8 million years. These radioisotope "ages" determined by three different methods are clearly identical within the stated error margins, and were subsequently confirmed by another study that reported identical U-Pb "concordia ages" using the mineral zircon.[10] Thus, even though three independent studies had all yielded an identical Rb-Sr "age" for this intrusion, it was rejected in favor of the older, identical radioisotope "age" obtained by the Sm-Nd, Pb-Pb and U-Pb methods. The reason given for rejecting the younger Rb-Sr "age" was that hydrothermal alteration must have reset the Rb-Sr system, in spite of the fact that there is no observational evidence, or any other geochemical indicators, of such hydrothermal alteration!

However, recent studies have been undertaken in which the same rock and mineral samples from the same rock units were "dated" using all four of the main radioisotope methods. Four rock units in the Grand Canyon of northern Arizona were targeted. The diabase sill at Bass Rapids, deep in the central Grand Canyon area, was considered ideal for radioisotope "dating," because it formed as molten magma that was homogenized when it was injected between the host sedimentary strata. Furthermore, after its intrusion, while it was cooling, some separation of the crystallizing minerals occurred, producing a compositional variation from top to bottom within the sill. Such compositional variation in an originally homogenous rock unit is ideal for the isochron method of radioisotope "dating." Eleven whole-rock samples yielded a K-Ar "isochron age" of 841.5±164 million

7 R. D. Davies, H. L. Allsopp, A. Erlank and J. W. I. Manton, 1970, Sr isotopic studies of various layered mafic intrusions in Southern Africa, in *Symposium on the Bushveld Igneous Complex and Other Layered Intrusions*, Geological Society of South Africa, Special Publication 1, 576-593.

8 J. Hamilton, 1977, Sr isotope and trace element studies of the Great Dyke and Bushveld mafic phase and their relation to early Proterozoic magma genesis in southern Africa, *Journal of Petrology*, 18: 24-52.

9 S. B. Mukasa, A. H. Wilson and R. W. Carlson, 1998, A multielement geochronologic study of the Great Dyke, Zimbabwe: the significance of the robust and reset ages, *Earth and Planetary Science Letters*, 164: 353-369.

10 T. Oberthür, B. W. Davis, T. G. Blenkinsop and A. Höhndorf, 2002, Precise U-Pb mineral ages, Rb-Sr and Sm-Nd systematics for the Great Dike, Zimbabwe – constraints on Late Archean events in the Zimbabwe craton and Limpopo belt, *Precambrian Research*, 113: 293-305.

years, a Rb-Sr "isochron age" of 1,055±46 million years, and a Pb-Pb "isochron age" of 1,250±130 million years. Additionally, the minerals separated from one diabase sample yielded a Rb-Sr mineral "isochron age" of 1,060±24 million years, and a Sm-Nd mineral "isochron age" of 1,379±140 million years.[11] Even though there is overlap between the error margins of some of these "ages" (Figure 66, page 1096), the "ages" themselves are sufficiently different for each radioisotope system. Furthermore, it is evident from this diagram (Figure 66) that the parent isotopes that α-decay yielded older "ages" compared to the parent isotopes that β-decay.

Three other major rock units in Grand Canyon have similarly been "dated" by these same four radioisotope methods applied to the same rock samples. The Cardenas Basalt consists of a group of about twelve lava flows, approximately halfway up the middle-upper Precambrian sequence of sedimentary strata in the eastern Grand Canyon.[12] The lower six lava flows are believed to be related to six diabase sills in the central Grand Canyon, including the Bass Rapids diabase sill. Yet the Cardenas Basalt flows yielded a potassium-argon "isochron age" of only 516±30 million years, which is less than half the rubidium-strontium "isochron age" of 1,111±81 million years, while the samarium-neodymium "isochron age" of 1,588±170 million years is more than three times the potassium-argon "isochron age"! The marked disagreement between these three "ages" can clearly be seen in Figure 67 (page 1096). Again, the α-decaying parent, samarium, gave an older age than the β-decaying parents, rubidium and potassium. Also, among the β-decayers, the parent rubidium with the longer half-life has the older "age."

The next rock unit studied in the Grand Canyon was metamorphosed basalt lava flows called the Brahma amphibolites, deep in the crystalline basement exposed in the Upper Granite Gorge. Twenty-seven samples yielded potassium-argon "model ages" ranging from 405.1±10 to 2,574.2±73 million years.[13] Even worse

11 A. A. Snelling, S. A. Austin and W. A. Hoesch, 2003, Radioisotopes in the diabase sill (upper Precambrian) at Bass Rapids, Grand Canyon, Arizona: An application and test of the isochron dating method, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 269-284; S. A. Austin, 2005, Do radioisotope clocks need repair? Testing the assumptions of isochron dating using K-Ar, Rb-Sr, Sm-Nd, and Pb-Pb isotopes, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 325-392.

12 S. A. Austin and A. A. Snelling, 1998, Discordant potassium-argon model and isochron 'ages' for Cardenas Basalt (Middle Proterozoic) and associated diabase of eastern Grand Canyon, Arizona, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 35-51; A. A. Snelling, 2005, Isochron discordances and the role of inheritance and mixing of radioisotopes in the mantle and crust, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 393-524.

13 A. A. Snelling, 2005, Isochron discordances and the role of inheritance and mixing of radioisotopes in the mantle and crust, 393-524; A. A. Snelling, 2008, Significance of highly discordant radioisotope dates for Precambrian amphibolites in Grand Canyon, USA, in *Proceedings of the Sixth International Conference on Creationism*, A. A. Snelling, ed., Pittsburgh, PA: Creation Science Fellowship and Dallas, TX: Institute for Creation Research, 407-424.

were two samples collected only 0.84 meters apart from the same outcrop. They yielded potassium-argon "model ages" of 1,205.3±31 and 2,574.2±73 million years. Otherwise, these samples yielded a rubidium-strontium "isochron age" of 1,240±84 million years, a samarium-neodymium "isochron age" of 1,655±40 million years, and a lead-lead "isochron age" of 1,883±53 million years. It can be clearly seen in Figure 68 (page 1097) that there is no overlap in these "ages." Again, the α-decayers give older "ages" than the β-decayer, but the longer half-life, α-decaying samarium, did not give an older "age" than the shorter half-life, α-decaying uranium.

The other Grand Canyon rock unit tested was the Elves Chasm Granodiorite, also in the crystalline basement of the Upper Granite Gorge, and regarded as the oldest rock unit in Grand Canyon. Samples of it yielded a rubidium-strontium "isochron age" of 1,512±140 million years, a samarium-neodymium "isochron age" of 1,664±200 million years, and a lead-lead "isochron age" of 1,993±220 million years. Even though there is obvious overlap in these "ages," there is the same pattern in the differences between them as found in the Brahma amphibolites.

These four Grand Canyon rock units consistently yield different "ages" on the same samples via the four radioisotope "dating" methods, totally destroying the common popular conception reinforced by textbooks that these four different methods give the same ages for the same rock units. Furthermore, it is obvious that the different "ages" for each rock unit are not random, but consistently follow several systematic patterns. Indeed, for any one of these rock units, the α-decaying parent isotopes (U and Sm) always yield older "ages" than the β-decaying parent isotopes (K and Rb). Furthermore, among the β-decayers, the parent isotope with the longer half-life (Rb) always gives the older "ages." In contrast, the α-decayers don't always follow this half-life versus "age" trend. Alternately, another potential systematic relationship can be seen in the "isochron age" versus atomic weight plot in Figure 69 (page 1097). The approximate trend line is consistent with the shorter half-life and heavier, α-decaying uranium yielding older "ages" than the longer half-life and lighter, α-decaying samarium.

These examples should be sufficient to conclusively demonstrate the unreliability of the radioisotope methods for "dating" rocks. Nevertheless, one further example, again from the Grand Canyon, should surely suffice. Across the Uinkaret Plateau, on the north rim of the western Grand Canyon, are up to 160 volcanic cones from which basalt lavas have flowed, and most of them poured southward into the inner gorge of Grand Canyon. Thus, these basalt lavas are so recent that, having erupted after the Grand Canyon had been eroded into its present form, they cascaded down the north wall of the Grand Canyon and formed dams that temporarily filled the inner gorge of Grand Canyon to different heights, blocking the flow of the Colorado River. Today only erosion remnants remain. These basalt lavas, therefore, yield various potassium-argon "model ages" of around 0.5-1.0 million years.

However, the same basalt lavas yield a rubidium-strontium “isochron age” of 1,143±220 million years! Such an “age” is virtually identical with the rubidium-strontium “isochron ages” of 1,111±81 million years and 1,060±24 million years for the Cardenas Basalt and Bass Rapids diabase sill, respectively. In other words, the youngest basalt lavas in Grand Canyon, so recent that they flowed down the walls of the Canyon after it formed, yield the same rubidium-strontium “isochron age” as some of the oldest rocks in the Canyon, the Cardenas Basalt lavas and the Bass Rapids diabase sill. Because all these rocks cooled from basaltic magmas that were sourced in the mantle underneath the Grand Canyon region, the recent Uinkaret Plateau basalts must have inherited their rubidium-strontium “isochron age” from their mantle source. Thus, it can be argued that the rubidium-strontium isotopic compositions of all these magmas being the same must be a reflection of the isotopic geochemistry of the mantle just below the Grand Canyon region, and, therefore, have little to do with the true ages of these rocks. All these contradictions and disagreements between the “ages” derived from these different radioisotope methods render these methods both unreliable and highly questionable.

105

The Pitfalls in the Radioactive Dating Methods—Variations in Radioactive Decay Rates and "Apparent Age"

Because there appears to be systematic trends in the radiometric "ages" derived by the four commonly-used radioisotope systems, there would appear to be some underlying process responsible. One suggested way of reconciling these systematically different radioisotope "ages" on the same rocks is accepting that the decay of the different parent radioisotopes occurred at much different and faster rates during some event or events in the past.[1] In other words, the radioactive decay of the different radioisotope parents was accelerated by different amounts according to their mode of decay, atomic weights and half-lives. As such, for example, the uranium-lead and samarium-neodymium α-decaying radioisotope systems would have had their decay rates accelerated more than the potassium-argon and rubidium-strontium β-decaying radioisotope systems, resulting in the former parent radioisotopes appearing to have decayed longer over the same time periods , and thus yielding older "ages" than the latter parent radioisotopes. Furthermore, among the β-decaying parent radioisotopes, rubidium always gives older "ages" than potassium. Thus, the radioactive decay of rubidium must have been accelerated more than potassium according to their respective half-lives, rubidium having a longer half-life than potassium. On the other hand, the patterns of "ages" yielded by the α-decaying parent uranium and samarium radioisotopes are not consistent. Sometimes uranium-lead "ages" are older than the samarium-neodymium "ages," perhaps due to the heavier atomic weight of the parent uranium radioisotopes. In other instances the samarium-neodymium "ages" are older, probably due to the longer half-life of the parent samarium radioisotope. Furthermore, at other times the uranium-lead and samarium-neodymium radioisotope "ages" are virtually identical (e.g., in the case of the Great Dyke of Zimbabwe referred to above), so perhaps in these instances the effects of the half-lives and atomic weights on the acceleration of the parent uranium and samarium radioisotopes are evenly balanced.

1 L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., 2005, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society.

These systematic differences between radioisotope "ages" determined on the same rocks are not the only evidence for this suggested accelerated radioactive decay of parent radioisotopes during some event or events in the past. Furthermore, these other evidences provide some quantification of how much the radioactive decay has been accelerated. These evidences include:

1. Young (6,000 years) helium diffusion ages of zircons in a granite that yield zircon uranium-lead radioisotope "ages" of 1,500 million years;[2]

2. The concurrent formation of ubiquitous uranium and polonium radiohalos found together in biotite mica flakes in many granites around the world;[3]

3. The resetting of the uranium-lead radioisotope system by the intense heat generated by radioactive decay only within zircons within volcanic ash beds that were otherwise relatively unheated;[4] and

4. The consistent presence of measurable radiocarbon yielding young (<60,000 years) "ages" in coal and diamonds, that are supposed to be millions and billions of years old, respectively, based on radioisotope "dating."[5]

The fact that these many lines of evidence all confirm the possibility that accelerated radioisotope decay occurred during some event or events in the past certainly makes this suggestion a very strong explanation for these documented systematic differences between the different radioisotope "ages" on the same rocks. The helium diffusion ages of zircons in the granite studied are based on reproducible laboratory measurements of the physical process of helium diffusion in zircon, which occurs in accordance with a known physical law. Thus, the young ages for these zircons derived by that physical process are far more reliable than the uranium-lead radioisotope "age" for the same zircons. Indeed, to reconcile the two different age determinations on these zircons would require the zircons to have been at a temperature of -78°C, slowing the helium diffusion sufficiently to also yield helium diffusion ages of 1,500 million years. Thus, the logical conclusion is that 1,500 million years worth (at today's measured radioactive decay rate) of decay of the parent uranium radioisotopes in the zircons occurred during an event or events only 6,000 years ago!

---

2 D. R. Humphreys, 2005, Young helium diffusion age of zircons supports accelerated nuclear decay, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 25-100.

3 Snelling, 2005, Radiohalos in granites, 101-207.

4 Snelling, 2005, Fission tracks in zircons, 209-324.

5 J. R. Baumgardner, 2005, ^{14}C evidence for a recent global Flood and young earth, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 587-630.

As already noted, uranium radiohalos are a physical record of at least 100 million years worth of uranium decay (at today's measured rates). A by-product of such uranium decay is the daughter radioisotopes of polonium. It is therefore significant that ubiquitous polonium radiohalos are found alongside uranium radiohalos in the same biotite mica flakes in many granites around the world at all levels in the geologic record. The only nearby available source of polonium is the uranium decay that produced the neighboring uranium radiohalos. Therefore, the uranium and polonium radiohalos had to have formed concurrently, side-by-side at the same time, with the polonium having been transported by fluids moving along the cleavages between and within the biotite flakes from the uranium radiohalo sources to nearby polonium deposition sites.[6] However, these polonium radioisotopes have very short half-lives of 164 microseconds (^{214}Po), 3.1 minutes (^{218}Po), and 138 days (^{210}Po), thus, these polonium radiohalos had to have formed within minutes, hours, and days, respectively. Since 100 million years worth of uranium decay (at today's measured rates) had to have occurred to supply the polonium needed to form the polonium radiohalos, the 100 million years worth of uranium decay had to have occurred within days! Therefore, the uranium decay rate had to be accelerated by several orders of magnitude.

Measurable quantities of radiocarbon yielding "ages" of approximately 50,000 years for coal beds that are supposedly 300 million years old (based on radioisotope "dating" of adjacent strata) also confirms that hundreds of millions of years of radioisotope decay at today's measured rates must have occurred only thousands of years ago. Of course, radiocarbon decay would also have been accelerated, but because of its much shorter half-life (5,730 years) as a β-decayer, its decay rate would have barely been accelerated at all compared to the much longer half-lives of potassium (1.25 billion years) and rubidium (48.8 billion years).

These evidences together indicate how much accelerated radioisotope decay occurred and when. Coal beds were formed during the Flood year, approximately 4,500 years ago, as were many of the granites that contain uranium and polonium radiohalos, because the granites intruded into Flood-deposited strata. Thus, it is concluded that hundreds of millions of years worth of radioisotope decay (at today's measured rates) must have occurred during the Flood year, only about 4,500 years ago. Given that many other geologic processes were occurring at catastrophic rates during the Flood year (such as plate tectonics and sedimentation), it is not only reasonable but rather consistent that accelerated radioisotope decay was also occurring at the same time. The by-product of such decay is heat, which would be available to drive the catastrophic geologic processes during the Flood event. The fact that such heat was not excessive is evidenced by the survival of the radiohalos, which are obliterated if the rock temperatures rise above 150°C. Their survival indicates that the heat produced from the accelerated radioisotope decay was not sufficient to melt minerals and rocks.

---

6 Snelling, 2005,Radiohalos in granites.

However, Precambrian granite, containing the zircon grains that yielded helium diffusion ages of 6,000 years compared to uranium-lead radioisotope "ages" of 1,500 million years, would appear to have formed prior to the Flood event. Similarly, the diamonds containing measurable radiocarbon, that are otherwise regarded as billions of years old based on radioisotope "dating," would have formed early in the earth's history. Thus, it would appear that there could have been an earlier burst of accelerated radioisotope decay early in the earth's history, most likely during the first two and a half days of the Creation Week, from the initial creation of earth through the formation of dry land.[7]

It is made quite clear, by the careful use of the Hebrew verbs in the biblical account in Genesis chapter 1 describing the creation of all things, that after the initial creation of the earth out of nothing, God then shaped the earth, and organized it and its materials to progressively prepare the earth to be man's home. Thus, God would have creatively used accelerated geologic and other processes to form and shape the continental mass (or masses) that ultimately formed the dry land mid-way through Day Three of the Creation Week. This would have included the catastrophic formation of many different types of rocks that are now foundational to the earth's continental crust. This shows that accelerated radioisotope decay is completely consistent within the context of God's activities of building the continental crust in the early part of the Creation Week. Once again, the heat generated by this accelerated radioisotope decay would have helped to drive many geologic and other processes at catastrophic rates. Furthermore, given that the strata assigned to the Flood event appear to record 500 to 700 million years worth (at today's measured rates) of accelerated radioisotope decay, yet the earth's earliest rocks which are foundational to the continental crust yield radioisotope "ages" up to 4 billion years, it is thus likely that several billion years worth (at today's measured rates) of accelerated radioisotope decay must have occurred during this early part of the Creation Week.

These considerations, of course, then raise the question as to how, by what mechanism or mechanisms, this acceleration of radioisotope decay might have occurred. Consequently, several theoretical mechanisms have been suggested and supporting evidence for them discussed.[8] Indeed, the possibility of variations in

7 Vardiman et al, 2005.

8 D. R. Humphreys, 2000, Accelerated nuclear decay: A viable hypothesis? in *Radioisotopes and the Age of the Earth: A Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 333-379; E. F. Chaffin, 2000, Mechanisms for accelerated radioactive decay, *Creation Research Society Quarterly*, 37: 3-9; E. F. Chaffin, 2000, Theoretical mechanisms of accelerated radioactive decay, in *Radioisotopes and the Age of the Earth: A Young-Earth Creationist Research Initiative,* L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 305-331; E. F. Chaffin, 2003, Accelerated decay: Theoretical models, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 3-15; E. F. Chaffin, 2005, Accelerated decay: Theoretical considerations, in *Radioisotopes and the Age of the Earth: Results of a Young Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling, and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley,

radioisotope decay rates, and mechanisms for their acceleration, were initially discussed more than four decades ago.[9] The technical details are of course complex, but it likely involved changes in the forces within the nuclei of atoms, forces that control how radioisotope decay occurs.

As already indicated, there are two primary modes of radioisotope decay. Both the parent uranium and samarium radioisotopes undergo α-decay, which involves the emission of two protons and two neutrons from the nuclei of these atoms. As they are emitted, these sub-atomic particles combine to form the nuclei of helium atoms, attracting stray electrons to produce helium as the final by-product. The parent rubidium radioisotope decays via β-decay, which involves the emission of an electron (a β-particle) and a neutrino from the nucleus. The parent potassium radioisotope also β-decays to calcium, but at the same time the nuclei of some of its atoms capture an orbital electron and form argon. Each of these processes is understood essentially as a statistical process, with the particular rate of decay being a probability function, related to the mode of decay and to the parent radioisotope concerned.

Each is known to be related to the structure of the atomic nucleus, and the various nuclear forces and particles. Yet, although there has been intensive experimental research in nuclear physics over many decades that has yielded an enormous amount of information about the various nuclear particles and reactions, most formulations that explain how and why the nucleus behaves as it does are still largely theoretical.

The α-decay process has been fairly well described in terms of wave mechanics and statistical probabilities. In this formulation, although the energy of the α-particle is apparently too small to permit it to escape through the "nuclear potential barrier" of energy surrounding the nucleus, nevertheless, it has a small probability of doing so. It is as if the α-particle is largely held within a potential energy "well" (hole), the depth, radius, and slope of the walls of which depend on the range or distance through which the α-particle can move within the nucleus. Of course, this is also related to the radius of the nucleus, which is directly proportional to the range of what is known as the strong nuclear force. Normally, an α-particle rebounds from the walls of this potential well, as it were, because it spends most of its life in the nucleus bouncing around within it, unable to escape because it doesn't have sufficient energy to do so. However, the so-called quantum fluctuations in the various energies and modes of the wave function of the α-particle allow it to do what classical mechanics completely prohibits, namely, to "tunnel" through the potential barrier and escape the nucleus entirely. Now the probability that a given α-particle will "tunnel" through the potential barrier and escape the nucleus, which determines the half-life of the parent radioisotope and its decay

---

AZ: Creation Research Society, 525-585.

9 Whitcomb and Morris, 1961, 346-355.

constant, is related to both the radius of the nucleus and the range of the strong nuclear force. If there is a change in the range of the strong nuclear force, then the radius of the nucleus is automatically changed, and so is the half-life of the α-decay. Thus, it is highly significant that the doubling of the radius of the radium radioisotope in the uranium decay chain reduces its half-life (and therefore its decay rate) by a factor of trillions!

Unfortunately, β-decay does not seem to be nearly as well-understood at a fundamental level like α-decay. This is because β-decay originates at a deeper level in the nucleus than α-decay, within the neutrons or protons themselves. The force involved is called the "weak" nucleus force, although it appears to be about as strong as electromagnetic force, but within an extremely short range. There are also other parameters, within other mathematical formulations in describing and understanding the nucleus and its constituent particles, that if varied would result in large changes to the rate of β-decay.

Thus, it is theoretically possible for radioisotope decay rates to have been accelerated as a result of changes to the strong and weak nuclear forces within parent radioisotopes. What could have triggered such changes to have occurred remains unknown. However, from the biblical standpoint, the quest to find an explainable cause for each effect, back along the chain of deeper and deeper levels of cause and effect, ultimately must lead back to God the Creator Himself. After all, it is clear from 2 Peter 3:5-6 that not only was God supernaturally involved in the creation of the world from the beginning (Genesis 1), but also during the Flood event. Furthermore, as far as the very building blocks of the universe are concerned, that is, the atoms that make up all matter and how they are held together, we are reminded in Colossians 1:16 that by the Creator Himself "all things consist," which in the Greek literally means, "are held together." Thus, at the most fundamental level, God the Creator still holds the matter of the universe together by His power, and thus, if and when He chooses to simply make a change to the nuclear forces involved in holding atoms, their nuclei, and their constituent particles together, then it is perfectly allowable and reasonable for Him to do so. Why might He so choose to intervene? It is evident that speeding up radioisotope decay rates generates heat that drives geologic and other processes at catastrophic rates. Perhaps this is the means by which God chose to accomplish His work in the Creation Week to shape the primordial earth He had created out of nothing at the beginning, to form the continental crust and dry land for the establishment of man's home, and then later to catastrophically re-form and re-shape the earth during the Flood event.

A "Grown" Creation with an "Apparent Age"

It has already been shown earlier that the Bible quite plainly and irrefutably teaches the fact of a "grown" creation—one with an "apparent age" from our perspective today, if we were to assume only natural processes had occurred at today's observed rates. The primary example of this inherent principle taught in Genesis 1 is God's creation of a mature Adam, who at the first instant of his existence had an apparent age equivalent to a fully grown adult human. Adam was not created as a baby, who then had to go through years of development and growth to become an adult. The reality of apparent age is inescapably inherent in the doctrine of creation by the eternally existent, all-powerful Creator God described in the Scriptures. Indeed, this inherent principle was dramatically observed by human witnesses when the Creator Himself, Jesus Christ (John 1:1-3; Colossians 1:16-17), instantly transformed water into wine (John 2:1-11) This wine was identical in every respect to wine produced from grapes grown on vines which had time to mature. That wine clearly had an apparent age.

Similarly, Genesis 1:11-12 records that God commanded the soil covering the land surface to "bring forth" grasses, herbs yielding seeds, and fruit trees already yielding fruit. Within hours, during the close of that third day, God's command had been carried out, so that the land surface was covered in mature grasses, herbs, and trees already carrying seeds and fruit. Thus, at the end of this third day of the Creation Week, God was very satisfied with the outcome of His command, and declared that all was good according to His character and will. Nevertheless, these plants and trees had appeared and developed to maturity within hours. Of course, the processes in operation to cause that to happen are processes that we now no longer observe and experience, yet no deception was involved on God's part, because He has revealed to us what happened as a result of His creative activity. Yet from our experience and observation today, plants and trees take many years to grow and mature, so by comparison these plants and trees that God created had already "grown," and fully matured, thus intrinsically having an apparent age.

Now even though the response to God's command was immediate ("and it was so"), and the growth and development of these plants and trees was virtually instantaneous from the perspective of a human observer, creative processes of growth and development were involved, albeit at exceptionally accelerated rates. God had already created the raw materials when He created the earth from nothing at the beginning of the Creation Week. Now He was combining those raw materials, and shaping them to make and form these plants and trees. Similarly, creative processes are implied when earlier on the third day of the Creation Week, God commanded the waters to be gathered into one place and the dry land to appear (Genesis 1:9-10). This description implies God took the pre-existing earth materials, and shaped and formed them with earth movements to raise the land surface above the waters, which until then completely covered the globe. Of course, once the dry land surface appeared, it was a fully mature landscape, with an apparent age equivalent to the timespan such a landscape would take to form according to our present-day observations and experience.

When God initially created the earth on Day One of the Creation Week, this must have included all the chemical elements from which He would subsequently make plants, trees, animals, the dust of the earth, and the human body. Because all chemical elements consist of numerous isotopes, it is likely that all these were also present in the earth after the initial creation. Furthermore, because some elements and their isotopes only exist today as a result of the radioactive decay of parent isotopes, it is quite possible that radioactive decay of certain isotopes was present in the initial creation of the earth. On the other hand, radioactive decay (or nuclear transformations) may have been initiated after the initial creation of the earth, when God began taking the raw materials He had created, and then shaping and forming them through Days Two and Three of the Creation Week to build the earth's internal structure, and the continental crust with the dry land surfaces distinct from the surrounding oceans. As already suggested, the heat generated by radioactive decay would have helped to drive the geologic and other processes that God may have employed at catastrophic rates to achieve His creative work of shaping the earth and building the continental crust, so accelerating decay rates would have helped facilitate these creative processes. The net result would have been that, within three literal 24-hour days of the Creation Week, the earth's crustal rocks would have "aged" by billions of years, according to the radioisotope "clocks" if calibrated at today's measured decay rates. In other words, the earth's crustal rocks would have appeared, like the rest of the creation, to be mature with an apparent age, when in fact they were only three days old.

Such a concept is undoubtedly unreasonable and unallowable to consistent uniformitarians, but there is nothing impossible or unreasonable about it. In fact, short of denying the existence of any Creator or original creation at all, one must logically come to some place in the long chain of secondary causes where something was created. If so, that something, at the instant of its creation, must have had an appearance of age. And the only way we could then determine its true age would be through divine revelation. Of course, to admit such is a complete anathema to uniformitarians, who insist that only natural causes can be evoked to explain all of reality. An apparent age might be deduced for that created object on the basis of any processes of change which were then observed in connection with it subsequently, but this would not be its true age.

This is exactly the situation with respect to these radioactive elements, and with many other geochronometers. It is eminently reasonable and consistent with the basically efficient and beneficent character of God, as well as with His revelation concerning the fact, that He would have created the entire universe as a complete, operational, functioning mechanism. On the other hand, the grossly cruel and wasteful processes of an almost interminable evolution leading up to man's arrival as its goal, as usually envisaged by uniformitarians (or at least theistic uniformitarians), are utterly inconsistent with the character and wisdom of God! It is therefore not ridiculous after all, but perfectly reasonable, to suppose that the radioactive elements, like all other elements, were created directly by God, who then produced the daughter elements at whatever rates He chose to fulfill His purposes in forming and shaping the earth, including its rocks and minerals.

The obvious question then arises as to whether the apparent ages of the rocks and minerals so created, as indicated by the relative amounts of parent and daughter elements contained therein, would all be diverse from each other or all exhibit some consistent value, and if they exhibit a consistent value, what value of apparent age might be implied. In the absence of specific revelation, it is of course impossible to decide this question with finality. However, it is more satisfying teleologically, and, therefore, more reasonable, to infer that all these primeval "clocks" should now "read" the same "age" since they were all "wound up" at the same time. Whatever that "setting" was, it could be called the apparent age of the earth, but the true age of the earth can only be known by means of divine revelation. The fact that the earth's crystalline rocks, which are in effect foundational to the continental crust and to the original land surface made by God on the third day of the Creation Week, yield a diversity of radioisotope "ages" in the range of billions of years, when the true age of the earth revealed by divine revelation is only approximately 6,000 years, means that God chose to accelerate the radioisotope decay rates in order to serve His purposes in making and forming the continental crust and the original land surface. Furthermore, if God chose to do that during the Creation Week, then He could do the same during the Flood event, again to serve His purposes in destroying and renovating the earth's surface as judgment on a rebellious humanity.

106

The Pitfalls in the Radioactive Dating Methods—The Radiocarbon Dating Method

Reference has already been made to the results of radiocarbon "dating" which are evidence of the acceleration of radioactive and nuclear decay during the Creation Week and the Flood. However, further discussion of this "dating" method is warranted here, because it has become widely used in archaeology and other studies to apparently supply absolute "dates" for events supposedly within the past 30,000-40,000 years. The materials so "dated," of course, correspond to the period covered by biblical history, as well as more recent dates, bearing directly upon the question of the dates of the Flood and other related events.

The radiocarbon method was first developed by Willard F. Libby in 1946. Since then, thousands of radiocarbon "dates" have been determined for a great variety of archeological and recent geological materials in many different laboratories. The formation of radiocarbon (carbon-14, the radioactive isotope of ordinary carbon) by cosmic radiation was first discovered, however, by Serge Korff, an authority at that time on cosmic rays. He describes the carbon-14 dating method as follows:

> Cosmic ray neutrons, produced as secondary particles in the atmosphere by the original radiation, are captured by nitrogen nuclei to form the radioactive isotope of carbon, the isotope of mass 14. This isotope has a long half-life, something over 5,500 years. By the application of some very well thought-out techniques, Libby and his colleagues have actually not only identified the radiocarbon in nature, but have also made quantitative estimates thereof. Since this carbon in the atmosphere mostly becomes attached to oxygen to form carbon dioxide, and since the carbon dioxide is ingested by plants and animals and is incorporated into their biological structures, and further, since this process stops at the time of the death of the specimen, the percentage of radiocarbon among the normal carbon atoms in its system can be used to establish the date at which the specimen stops metabolizing.[1]

1 S. A. Korff, 1957, The origin and implications of the cosmic radiation, *American Scientist*, 45: 298.

There can be no doubt that this constitutes a very ingenious dating tool, provided of course that the inherent assumptions are valid. There are two basic assumptions in the carbon-14 dating method.[2] First, the cosmic ray flux has to have been essentially constant, at least on a scale of centuries. Second, the carbon-14 concentration in the carbon dioxide cycle must remain constant. To these two basic assumptions we should add the assumption of the constancy of the rate of decay of carbon-14 atoms, the assumption that dead organic matter is not later altered with respect to its carbon content by any biologic or other activity, the assumption that the carbon dioxide contents of the ocean and atmosphere has been constant with time, the assumption that the huge reservoir of oceanic carbon has not changed in size during the period of applicability of the method, and the assumption that the rate of formation and the rate of decay of radiocarbon atoms have been in equilibrium throughout the period of applicability. However, every one of these assumptions is highly questionable in the context of the events of creation and the Flood.

Nevertheless, it has been maintained that the method has been verified beyond any question by numerous correlations with known dates. However, closer investigation reveals that where historical dates are well established, back beyond about 400 BC, the radiocarbon "dates" increasingly diverge, as they also do from tree-ring dates.[3] Thus, it is obvious that any genuine correlation of the radiocarbon method with definite historical chronologies is limited only to some time well after the Flood and the dispersion of people from the Tower of Babel. The major assumptions in the method would therefore appear to be valid for this period. This does not prove their validity for more ancient times, the periods in which we would infer that the assumptions are very likely wrong due to conditions in the atmosphere and biosphere being different from today, and, therefore, their datings would also be wrong.

Attempts to apply the carbon-14 method to produce earlier "dates" have been called into serious question by geologists, archaeologists, and other scientists. Of particular concern has been the danger of contamination of samples by external sources of carbon, especially in damp locations. Hence, the radiocarbon method has been sharply criticized:

> In appraising C 14 dates, it is essential always to discriminate between the C 14 age and the actual age of the sample. The laboratory analysis determines only the amount of radioactive carbon present….However, the laboratory analysis does not determine whether the radioactive carbon is all original or is in part secondary, intrusive, or whether the amount has

2 J. L. Kulp, 1952, The carbon 14 method of age determination, *Scientific Monthly*, 75: 261.

3 S. Bowman, 1990, *Radiocarbon Dating*, London: British Museum Publications, 16-18; Faure and Mensing, 2005, 617-619.

been altered in still other irregular ways besides by natural decay.[4]

As the radiocarbon method became more widely used, questions of contamination of samples become more acute, especially with the discovery of modern organisms with unexpectedly lower levels of carbon-14 equivalent to anomalously old "ages," including modern mollusk shells from river environments yielding radiocarbon "ages" in the range of 1,010 to 2,300 years,[5] and snails living in artesian springs with carbon-14 contents equivalent to an "age" of 27,000 years.[6] As a consequence of the increasing problems with the radiocarbon method, skepticism began to be more openly expressed:

> C 14 dating was being discussed at a symposium on the prehistory of the Nile Valley. A famous American colleague, Professor Brew, briefly summarized a common attitude among archaeologists towards it, as follows:
>
> "If a C 14 date supports our theories, we put it in the main text. If it does not entirely contradict them, we put it in a footnote, and if it is completely 'out of date' we just drop it."
>
> Few archaeologists who have concerned themselves with absolute chronology are innocent of having sometimes applied this method, and many are still hesitant to accept C14 dates without reservations.[7]

A further decade of radiocarbon "dating" only served to make the criticisms more intense:

> In the light of what is known about the radiocarbon method and the way it is used, it is truly astonishing that many authors will cite agreeable determinations as *"proof"* for their beliefs....
>
> Radiocarbon dating has somehow avoided collapse onto its own battered foundation, and now lurches onward with a feigned consistency. The implications of pervasive contamination and ancient variations in carbon-14 levels are steadfastly ignored by those who base their arguments upon the dates.

---

4 E. Antevs, 1957, Geological tests of the varve and radiocarbon chronologies, *Journal of Geology*, 65: 129.

5 M. L. Keith and G. M. Anderson, 1963, Radiocarbon dating: Fictitious results with mollusk shells, *Science*, 141: 634-635.

6 A. C. Riggs, 1984, Major carbon-14 deficiency in modern snail shells from southern Nevada springs, *Science*, 224: 58.

7 T. Säve-Söderbergh and I. U. Olsson, 1970, C 14 dating and Egyptian chronology, in *Radiocarbon Variations and Absolute Chronology*, Proceedings of the Twelfth Nobel Symposium, I. U. Olsson, ed., Stockholm: Almqvist & Wiksell and New York: John Wiley & Sons, New York, 35.

> The early authorities began the charade by stressing that they were "not aware of a single significant disagreement" on any sample that had been dated at different labs. Such enthusiasts continue to claim, incredible though it may seem, that "no worse discrepancies are apparent." Surely 15,000 years of difference on a single block of soil is indeed a *gross* discrepancy! And how could the excessive disagreement between the labs be called insignificant, when it has been the basis for the reappraisal of the standard error associated with each and every date in existence?
>
> Why did geologists and archaeologists still spend their scarce money on costly radiocarbon determinations? They do so because occasional dates *appear* to be useful. While the method cannot be counted on to give good, unequivocal results, the numbers do impress people, and save them the trouble of thinking excessively. Expressed in what *look* like precise calendar years, figures *seem* somehow better—both to layman and professional not versed in statistics—than complex stratigraphic or cultural correlations, and are more easily retained in one's memory. "Absolute" dates determined by a laboratory carry a lot of weight, and are extremely helpful in bolstering weak arguments....
>
> No matter how "useful" it is, though, the radiocarbon method is still not capable of yielding accurate and reliable results. There *are* gross discrepancies, the chronology is *uneven* and *relative*, and the accepted dates are actually *selected* dates. "This whole blessed thing is nothing but 13th-century alchemy, and it all depends upon which funny paper you read."[8]

The presence of detectable carbon-14 in fossils, which according to the uniformitarian timescale should be entirely carbon-14-dead, has been reported from the earliest days of radiocarbon "dating." For example, a published survey on all the "dates" reported in the journal *Radiocarbon* up to 1970 commented that for more than 15,000 samples reported: "All such matter is found datable within 50,000 years as published."[9] The samples involved included coal, oil, natural gas, and other allegedly very ancient material. The reason these anomalies were not taken seriously is because the measuring technique used in the early decades of radiocarbon "dating" had difficulty distinguishing genuine low intrinsic levels of carbon-14 in samples from the background cosmic radiation. Thus, the low carbon-14 levels measured in many samples, which according to their location in the geologic record ought to have had no carbon-14 in them, were simply attributed to the background cosmic radiation. However, the complication of

8 R. E. Lee, 1981, Radiocarbon: Ages in error, *Anthropological Journal of Canada*, 19 (3): 9-29, 1981. (Reprinted in the *Creation Research Society Quarterly*, 19 (2): 117-127; quotes are from pages 123 and 125).

9 R. L. Whitelaw, 1970, Time, life, and history in the light of 15,000 radiocarbon dates, *Creation Research Society Quarterly*, 7 (1): 56-71.

the background cosmic radiation infusing the carbon-14 measurements was overcome with the advent of the accelerator mass spectrometer (AMS) technique in the early 1980s. Nevertheless, over the past 25 years, organic samples from every level in the Cambrian to Recent portion of the geologic record were still found to contain significant and reproducible amounts of carbon-14 when tested by the highly sensitive AMS method. In hindsight, it is almost certain that many of the earlier radiocarbon analyses were indeed recording low levels of carbon-14, also intrinsic to those samples.

About seventy AMS carbon-14 measurements that were published in the standard radiocarbon literature between 1984 and 1998 demonstrate that significant levels of carbon-14 are routinely found in organic material. According to the conventional uniformitarian timescale, these samples should have been entirely devoid of any carbon-14 because they are supposedly older than 100,000 years.[10] Additionally, AMS radiocarbon analyses were obtained on fossilized wood from Tertiary, Mesozoic, and upper Paleozoic strata that have conventional uniformitarian ages ranging from 32 to 250 million years.[11] All fossilized wood samples yielded significant quantities of carbon-14, equivalent to radiocarbon "ages" of between 20,000 and 45,000 years. With a half-life of only 5,730 years, after one million years (or 175 half-lives) the amount of carbon-14 expected would be so small as to exclude even a single carbon-14 atom being left from a beginning mass of carbon-14 equal to the mass of the earth itself! Thus, the presence of any intrinsic carbon-14 in these fossilized wood samples, that are supposed to be 32 to 250 million years old, represents a profound challenge to the uniformitarian timescale, because the measured carbon-14 limits the ages of these fossilized woods to merely thousands of years.

It is now common knowledge, even in the standard radiocarbon literature, that organic samples from every portion of the Phanerozoic (Cambrian to Recent) geologic record display detectable amounts of carbon-14 well above the analytical threshold of the AMS equipment. This has come about because samples claimed to be millions of years old, which should have contained no

10 P. Giem, 2001, Carbon-14 content of fossil carbon, *Origins*, 51: 6-30; J. R. Baumgardner, A. A. Snelling, D. R. Humphreys and S. A. Austin, 2003, Measurable ^{14}C in fossilized organic materials: Confirming the young earth Creation-Flood model, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 127-147; Baumgardner, 2005, 587-630.

11 A. A. Snelling, 1997, Radioactive "dating" in conflict! Fossil wood in ancient lava flows yields radiocarbon, *Creation Ex Nihilo*, 20 (1): 24-27; A. A. Snelling, 1998, Stumping old-age dogma: Radiocarbon in an "ancient" fossil tree stump casts doubt on traditional rock/fossil dating, *Creation Ex Nihilo*, 20 (4): 48-51; A. A. Snelling, 1999, Dating dilemma: Fossil wood in "ancient" sandstone, *Creation Ex Nihilo*, 21 (3): 39-41; A. A. Snelling, 2000, Geological conflict: Young radiocarbon dating for ancient fossil wood challenges fossil dating, *Creation Ex Nihilo*, 22 (2): 44-47; A. A. Snelling, 2000, Conflicting "ages" of Tertiary basalt and contained fossilized wood, Crinum, central Queensland, Australia, *Creation Ex Nihilo Technical Journal*, 14 (2): 99-122; A. A. Snelling, 2008, Radiocarbon in "ancient" fossil wood, *Acts & Facts*, 37 (1): 10-13; A. A. Snelling, 2008, Radiocarbon ages for fossil ammonites and wood in Cretaceous strata near Redding, California, *Answers Research Journal*, 1: 123-144.

carbon-14 atoms, have been used as "procedural blanks" in the AMS equipment during analytical runs to determine presumed background carbon-14 levels due to sample preparation procedures in the labs, and any other contamination of the equipment. Consequently, most radiocarbon laboratories have been at pains to thoroughly investigate potential sources and various contributions of supposed contamination to the presumed carbon-14 background in their AMS systems,[12] and have been searching for specific materials to use as procedural blanks that contain as low a carbon-14 background level as possible.[13] However, even when the utmost care has been taken in the preparation of procedural blanks, which are regarded as "radiocarbon-dead" because of their presumed Precambrian age, detectable levels of carbon-14 well above the AMS instrument threshold have still been detected and reported.[14]

Invariably this supposedly anomalous detected carbon-14 in these procedural blanks has been claimed to be "contamination," which has led to the admission that there appears to be a "radiocarbon barrier" of 55,000 to 60,000 "radiocarbon years" for the apparent "ages" of even supposedly "ancient" samples, no matter their supposed ages. However, it can be argued that instrument error can be eliminated on experimental grounds as an explanation for the alleged contamination in these supposedly "ancient" "radiocarbon-dead" organic samples, which have, nonetheless, yielded significant carbon-14 measurements.[15] Similarly, it has also been shown that contamination of the carbon-14-bearing fossil material *in situ* is unlikely, but theoretically possible, and is a testable hypothesis. Furthermore, while contamination during sample preparation is a genuine problem, the literature has shown it can be reduced to low levels by proper laboratory procedures. Thus, it must be concluded that the carbon-14 detected in these organic samples from the geologic record would most likely have originated from the organisms themselves from which the fossilized materials were derived. Because most of this fossil carbon seems to have roughly the same amounts of carbon-14, it is clearly a logical possibility that all these fossil organisms had lived together on the earth at the same time.

In order to test all these earlier findings, more recent studies were undertaken to analyze ten coal samples representative of the economic important coalfields of the United States, and five diamonds from African kimberlite pipes.[16] Three of the coal samples were from Eocene seams, three from Cretaceous seams, and four from Pennsylvanian seams, yet the average carbon-14 values from these coal

12 J. S. Vogel, D. E. Nelson and J. R. Sothern, 1987, ^{14}C background levels in an accelerator mass spectrometry system, *Radiocarbon*, 29: 323-333.

13 R. P. Beukens, 1990, High-precision intercomparison at IsoTrace, *Radiocarbon*, 32: 335-339.

14 M. I. Bird, L. K. Ayliffe, L. K. Fifield, C. S. M. Turney, R. G. Cresswell, T. T. Barrows and B. David, 1999, Radiocarbon dating of 'old' charcoal using a wet oxidation, stepped-combustion procedure, *Radiocarbon*, 41 (2): 127-140.

15 Giem, 2001.

16 Baumgardner et al, 2003; Baumgardner, 2005.

samples over each of these three geological intervals were remarkably similar to one another, around 50,000 years, even though the uniformitarian ages range from 40 million years to 350 million years. The diamonds chosen for analysis came from underground mines where contamination would be minimal. In any case, being the hardest natural mineral, diamonds are extremely resistant to contamination via chemical exchange with the external environment. Furthermore, the diamonds chosen are regarded by uniformitarian geologists to have formed in the earth's mantle between one and three billion years ago, so they should have definitely been "radiocarbon-dead." Nevertheless, they still contained significant levels of carbon-14, well above the detection threshold of the AMS equipment, but virtually equivalent to the carbon-14 values found in fossilized organic materials from the Precambrian portion of the geologic record.[17] Given the supposed antiquity of these diamonds, and their source deep inside the earth, one possible explanation for these detectable carbon-14 levels is that the carbon-14 is primordial. However, if this were the case, the apparent "age" of the earth itself would only be less than 55,000 years!

The radiocarbon "dates" equivalent to the significant levels of carbon-14 detected in fossilized wood, coals, diamonds, and other "ancient" fossil carbon are, of course, calculated on the assumption that the decay rate of carbon-14 has been constant throughout earth history. However, if, as other evidence cited previously indicates, there were brief episodes of accelerated nuclear decay during Creation Week and the Flood, then much of the carbon-14 in these materials would have been generated during these periods, making the radiocarbon "dates" grossly enlarged. In any case, with a date for the Genesis Flood of only about 4,500 years ago, which is less than the carbon-14 half-life, one would expect that today there would still be detectable carbon-14 in the plants and animals buried and fossilized in that cataclysm. Furthermore, a huge amount of carbon from living organisms would have been buried during the Flood cataclysm to form today's coal seams, oil shales, and oil deposits, probably most of the natural gas, and some fraction of today's fossiliferous limestones. Estimates for the amount of carbon in this inventory suggests that the biosphere just prior to the Flood would have had, conservatively, greater than 300 to 700 times the total carbon that resides in the biosphere today.[18] The living plants and animals in the pre-Flood world would have contained most of this biospheric carbon, with only a tiny fraction of the total resident in the atmosphere. Furthermore, the vast majority of this carbon would have been normal carbon-12 and carbon-13, since even in today's world only about one carbon atom in a trillion is carbon-14.

All radiocarbon "ages" are also calculated on the assumption that before the

17 Baumgardner, 2005.

18 R. H. Brown, 1979, The interpretation of C-14 dates, *Origins*, 6: 30-44; Giem, 2001; G. R. Morton, 1984, The carbon problem, *Creation Research Society Quarterly*, 20: 212-219; H. W. Scharpenseel and T. Becker-Heidmann, 1992, Twenty-five years of radiocarbon dating soils: Paradigm of erring and learning, *Radiocarbon*, 34: 541-549.

plant or animal died it contained approximately the same ratio of radiocarbon to ordinary carbon that is present in living things today. However, prior to the Flood, the ratio of radiocarbon to ordinary carbon would have been much lower than it is at present, even if we assume that the total number of atoms of carbon-14 was similar to what exists in today's world. Assuming that is the case, this carbon-14 was distributed uniformly throughout the biosphere, and the total amount of carbon in the biosphere was, for example, 500 times that in today's world, then the resulting ratio of radiocarbon to ordinary carbon would have been 1/500 of today's level. Of course, this is only a very tentative estimate due to the large uncertainty in knowing the total amount of carbon-14 in the pre-Flood world. The short timespan of less than 2,000 years between creation and the Flood would not have been sufficient to generate the same amount of carbon-14 by cosmic rays in the atmosphere as what we find in today's world, even with today's magnetic field strength. A stronger magnetic field in the past (discussed later) would have provided more effective deflection of charged cosmic ray particles, and thus there would have been even less carbon-14 generated in the atmosphere in the past.

On the other hand, there may well have been some significant amount of carbon-14 generated during the early part of the Creation Week, as a consequence of the large amount of accelerated nuclear disintegration of radioactive elements such as uranium and the resulting neutron interactions with nitrogen-14.[19] Indeed, it is possible to calculate how much carbon-14 might have been generated by neutron interactions early in earth history, because diamonds contain significant levels of nitrogen-14, and were formed early in the earth's history deep inside the earth. Such calculations show that neutron interactions would not have been capable of producing anywhere near the significant carbon-14 levels measured in deep-earth diamonds, even as a consequence of accelerated radioactive and nuclear decay.[20] On the other hand, the acceleration of radioisotope decay would have only marginally increased both the decay of carbon-14, and consequently the reduction of the carbon-14 inventory produced by the accelerated neutron interactions with nitrogen-14. However, the accelerated neutron interactions would not have prevailed in increasing the carbon-14 levels to those measured in the deep-earth diamonds. Therefore, if the total mass of carbon-14 in the pre-Flood world was not much greater than that in our present world, then the carbon-14 decay over the span of 4,500 years since the Flood catastrophe reduces that pre-Flood level by a factor of 0.6. Therefore, the carbon-14 to total carbon ratio of 1/500 of today's level 4,500 years ago would display today as a ratio of less than 1/800, which is exactly the carbon-14 level measured in the deep-earth diamonds and other organic carbon from the pre-Flood world, as is well documented in the standard radiocarbon literature.

---

19 R. Zito, D. J. Donahue, S. N. Davis, H. W. Bentley and P. Fritz, 1980, Possible subsurface production of carbon-14, *Geophysical Research Letters*, 7 (4): 235-238.

20 Baumgardner, 2005.

After the Flood cataclysm it was necessary for the carbon-14 to total carbon ratio to have increased dramatically and rapidly by a factor on the order of 500 to reach its present-day value. Not only would carbon-14 production in the atmosphere have increased immediately after the Flood, due to the decreasing strength of the earth's magnetic field (discussed later), but the presence of high levels of crustal neutrons arising from the accelerated nuclear decay during the Flood would have converted substantial amounts of crustal nitrogen to carbon-14, most of which would have been oxidized to carbon dioxide and eventually escape to the atmosphere. The striking carbon-14 differences measured in the shell of a single snail specimen confirms that large spatial and temporal variations in the carbon-14 to total carbon ratio did indeed exist during the interval immediately following the Flood cataclysm.[21] Furthermore, the equilibrium condition between the generation and decay of carbon-14, which has to be assumed in making any age calculation by the radiocarbon method, would obviously not be applicable for quite a long time after the Flood cataclysm. Even with the marked increase in the rate of formation of carbon-14 as a result of the Flood, and of the decreasing strength of the earth's magnetic field, it would still have taken many years for the total amount of carbon-14 in the biosphere's carbon inventory to build up to the equilibrium condition where generation and decay of carbon-14 would be equal. This would mean that some organisms living in those early years and centuries after the Flood would have only received a proportionately smaller amount of carbon-14 into their systems than those organisms living in later times. Of course, as the radiocarbon production increased as time went on, the present equilibrium rates would have been reached.

This is why radiocarbon "dates" for the last 2,000 years seem to show a generally good correlation with historically verified artifacts and specimens, although of course, there would still be many discrepancies and a larger margin of error the further back in time comparisons are made. However, for early post-Flood dates, the levels of contained carbon-14 would be such that, if "ages" were then calculated on the basis of the present equilibrium conditions and rates, they would be very much older than their real-time ages, with the amount of error increasing progressively with the age of the material. This is also the case with the organic material buried during the Flood cataclysm, including the plant material buried and fossilized to form coal, which still contains significant, relatively high levels of carbon-14. Ages for this Flood-deposited organic material calculated on the basis of present equilibrium conditions and rates would yield incorrect, much older "ages." Thus, the biblical framework of earth history, including the Flood cataclysm and the recovery of the biosphere from that event, adequately explains the data from carbon-14 studies, accounting for the agreement with historically-dated recent events, but at the same time indicating that earlier unverified datings must be too high, as would be inferred from the biblical records. Furthermore, the fact that Eocene, Cretaceous, and Pennsylvanian coal seams, which in

21 M.-J. Nadeau, P. M. Grootes, A. Voelker, F. Bruhn, A. Duhr and A. Oriwall, 2001, Carbonate ^{14}C background: Does it have multiple personalities?, *Radiocarbon*, 43 (2A): 169-176.

uniformitarian terms are dated at 40 to 350 million years old, all contain similar (essentially identical) significant levels of carbon-14, when in uniformitarian terms there should be no carbon-14 in them at all, is testimony to this fossilized plant material all having been buried at the same time during the Flood cataclysm only 4,500 years ago.

Consequently, it is abundantly clear that the data from all the radioactive methods of geochronometry, properly understood, harmonize perfectly with the biblical records and inferences associated with the creation and the Flood. These events must be dated at only some thousands of years ago according to the Bible. Even the presence of significant detectable levels of carbon-14 in deep-earth diamonds, that in uniformitarian terms are "dated" at 1-3 billion years old, is in fact testimony to the earth only being thousands of years old. So evidence that has been brought against the biblical testimony has now been shown rather to harmonize quite satisfactorily with the biblical record. In fact, it would seem highly probable that no method of geochronometry has been devised that permits determination of dates earlier than the Flood, since all such geological and geophysical processes were profoundly disturbed and altered by the events of that global cataclysm. The Scriptural description is that "the world that then was, being overflowed with water perished" (2 Peter 3:6), and the context shows that this statement comprises the total earth! The only possible way in which men can *know* the true age of the earth is by means of divine revelation!

Section IX

Contradictions In Geochronology— Support for Biblical Geology

107

Supernovas and Comets

Even aside from the biblical testimony in opposition to the estimated radioactive decay "age" for the earth and its rock strata, there are numerous geological and astronomical evidences against the validity of those highly inflated age estimates. The currently accepted age for the earth, as deduced from the lead isotopes (from the radioactive decay of uranium) in meteorites, is just over 4.5 billion years. However, there are many geological and astronomical processes and evidences that appear just as suitable for geochronometry as radioactive decay, but give much lower estimates. Of course, none of these is sufficiently precise for accurate measurements, and all involve various assumptions similar to the radioactive dating methods. However, whereas the radioactive dating methods involve analyzing individual rock and mineral samples from outcrops on a local scale, these astronomical and geological evidences mostly involve processes on a whole-earth global scale, in the solar system, and beyond. Therefore, these dating methods should be regarded as far more reliable and meaningful as geochronometers, and thus, it is important to examine the age-of-the-earth estimates they provide, as they cast serious doubts on the reliability of the radioactive decay age estimates. Furthermore, the list of astronomical and geological evidences discussed here is by no means exhaustive.

Supernova Remnants

A supernova is a violently exploding massive star that is one of the most brilliant objects in the sky, even visible during the daytime. The gas and dust debris from such explosions form huge clouds that expand outwardly rapidly, and are known as supernova remnants. A well-known example is the Crab Nebula in the constellation of Taurus, which was produced by a supernova so bright that it could be seen in the day sky for a few weeks in 1054. According to astronomical observations, galaxies like our own, the Milky Way, should experience on average one supernova every 25 years. By applying the known physical laws, astronomers can predict what should happen to the huge cloud of debris (the supernova remnant) after the supernova explosion. It should expand outwardly so rapidly that it reaches a diameter of about 3,100 trillion kilometers (or 1,900 trillion miles) in about 120,000 years, and yet remains visible for over a million years as the cloud continues to expand.

The number of supernova remnants in our galaxy can easily be observed and counted, and this provides an excellent test to determine whether the universe is old or young. If the universe is only about 6,000-7,000 years old, no supernova remnants would have had time to reach large diameters, and they all should still be clearly visible. On the other hand, if the universe were billions of years old, we should be able to observe many of these supernova remnants. Indeed, it is possible to calculate just how many of these supernova remnants at the given dimensions should be visible after 7,000 years, and just how many should still be visible after billions of years.[1] These calculations indicate that if our galaxy was billions of years old, then there would be at least 2,256 supernova remnants visible at the second stage of expansion, more than 300 years after the supernovas exploded. Whereas, if our galaxy was only 7,000 years old, only about 268 second stage supernova remnants should be observed.[2] So just how many of these supernova remnants (gas and dust clouds) do we observe in our galaxy? The stark reality is that we actually observe only 200 such supernova remnants, a number that is totally consistent with a 6,000-7,000 years old galaxy, and, therefore, an earth of the same age.

Now if the discrepancy between the calculated number of visible supernova remnants for a galaxy billions of years old, and the actual observed number of supernova remnants is real, then it should be recognized and acknowledged by astronomers who claim our galaxy is billions of years old. Indeed, they have recognized this discrepancy. For example, the National Research Council Astronomy Survey Committee in Canada has commented:

> Major questions about these objects that should be addressed in the coming decade are: where have all the remnants gone?[3]

The discrepancy between the calculated and observed numbers is obvious, because if the universe were really billions of years old, then more than 79 percent of the supernova remnants that should be in our galaxy are obviously missing! That's why astronomers, in the context of trying to find solutions to this stark shortfall, have commented: "Why have the large number of expected remnants not been

1 Band, D. L. and E. P. Liang, 1988, in *Supernova Remnants and the Interstellar Medium*, Roger and T. L. Lamdecker, eds., Colloquium Proceedings, Cambridge: Cambridge University Press, 69-72; Cioffi, D. F. and C. F. McKee, 1988, in *Supernova Remnants and the Interstellar Medium*, R. S. Roger and T. L. Lamdecker, eds., Colloquium Proceedings, Cambridge University Press, 437.

2 K. Davies, 1994, Distribution of supernova remnants in the galaxy, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 175-184.

3 National Research Council, 1983, *Challenges to Astronomy and Astrophysics*, working documents of the Astronomy Survey Committee, Canada: National Academy Press, 166.

detected?"[4] And they go on to refer to "the mystery of the missing remnants."

Lest it be argued that this discrepancy is merely a characteristic of just the Milky Way galaxy, it should be noted that the same discrepancy is found in one of our satellite galaxies, the Large Magellanic Cloud. In a radiotelescope survey, a total of only nine supernova remnants could actually be found.[5] Based on the belief that this galaxy is billions of years old, it was expected there should be about 340 supernova remnants, above the limit of detection of the instrument. One astronomer later commented: "The observations have caused considerable surprise and loss of confidence."[6] Since this initial radiotelescope survey, more sensitive surveys have discovered another twenty supernova remnants in the Large Magellanic Cloud.[7] Given that the Large Magellanic Cloud is approximately one-tenth the size of our galaxy, if this galaxy were also 6,000-7,000 years old, then about 24 supernova remnants should be visible. Once again, the observed numbers (29) are consistent with the predicted numbers using calculations based on a 6,000-7,000-year-old galaxy (and universe).

The only solutions offered by astronomers are conjectural and assume flaws in their own estimates. However, there is no mystery about the assumed large numbers of missing supernova remnants. Repeated observations confirm that the numbers of supernova remnants are only consistent with an earth and a universe that are 6,000-7,000 years old, the age derived from a straightforward reading of the Scriptures.

Disintegration of Comets

Comets are literally "dirty snowballs" that move through the solar system in highly elliptical orbits around the sun. From the Greek *comētē* (long-haired), a comet looks like a hairy star due to the tail of dust streaming from it. The icy nucleus of a comet is usually a few kilometers across. The diameter of the most famous comet, Halley's Comet, is about ten kilometers, and the diameter of one of the largest comets known, Hale-Bopp seen in 1997, is about forty kilometers. When a comet passes close to the sun, some of its icy nucleus evaporates and forms a coma about 10,000 to 100,000 kilometers wide. At the same time, solar radiation pushes away the dust particles released through evaporation to generate the tail that curves gently away from the sun and backwards. Sunlight illuminates both the coma and the tail, giving the comet the appearance of a hairy star.

4 D. H. Clark and J. L. Caswell, 1976, A study of galactic supernova remnants, based on Molonglo-Parkes observational data, *Monthly Notice of the Royal Astronomical Society*, 174: 267-306.

5 D. S. Mathewson and J. N. Clarke, 1973, Supernova Remnants in the Large Magellanic Cloud, *Astrophysical Journal*, 180: 725-738.

6 D. Cox, 1986, The Terrain of Evolution of Isotropic Adiabatic Supernova Remnants, *Astrophysical Journal*, 304: 771-779.

7 K. Davies, 1994.

This loss of material, therefore, means that comets are gradually disintegrating and being destroyed every time they come close to the sun. Indeed, many comets have been observed to have been much dimmer during later passes. Furthermore, some comets have been observed to break up and totally dissipate. Thus, it has been estimated that all known comets can be expected to break up and vanish within a timeframe that is very short in uniformitarian and evolutionary terms. This has long been recognized by astronomers:

> It has been estimated that the break-up of many comets is taking place at such a rate that they will be entirely disrupted within a million years. It is an immediate inference that these comets cannot have been moving around the Sun as they are at present for much longer than a million years, since otherwise they would already have been broken up.[8]

According to evolutionary theory, comets are supposed to be the same age as the solar system, approximately five billion years old. However, the problem for evolutionary astronomers is that, given the observed rate of disintegration of comets and the maximum possible size of a comet's orbit, comets could not have been orbiting the sun for the alleged billions of years since the solar system formed.[9] Indeed, more realistic estimates suggest comets could not survive much longer than about 100,000 years. Studies of observed comets have concluded that many comets have typical ages of less than 10,000 years.[10] Since all astronomers agree that the comets came into existence at approximately the same time as the solar system, the natural inference is that the maximum age of the solar system would be approximately 10,000 years based on the observed age of comets.

In order to explain away this acknowledged discrepancy, evolutionary astronomers have had no alternative but to postulate hypothetical sources that have supposedly generated comets progressively through time to replace the comets that have totally disintegrated. As early as 1950, the Dutch astronomer Jan Oort proposed that there was a spherical shell of comets well beyond the orbit of Pluto. In this spherical shell passing stars, gas clouds, and galactic tides are supposedly able to knock comets from this "Oort Cloud" into orbits within the inner solar system:

> Oort postulated that the cometary cloud may contain as many as 100 billion comets very few of which come as close to the Sun as the planets. Occasionally, however, the random passage of a star disturbs the motions of some comets sufficiently to make them swing into the sphere of gravitational attraction of Jupiter or another major planet. In this way

8 F. Hoyle, 1955, *Frontiers of Astronomy*, New York: Harper and Brothers, 11.

9 D. R. Faulkner, 1997, Comets and the age of the Solar System, *Creation Ex Nihilo Technical Journal*, 11 (3): 264-273.

10 E. F. Steidl, 1983, Planets, comets, and asteroids, in *Design and Origins in Astronomy*, G. Mulfinger, ed., Norcross, GA: Creation Research Society Books, 73-106.

> comets are taken one by one from the "deep freeze" of the solar swarm and are pulled into relatively short-period orbits. With their hibernation period over, they become active and disintegrate into gas and meteoritic particles during a few hundred or a few thousand revolutions around the Sun.[11]

However, there are several fatal problems with this hypothetical Oort Cloud:

1. This hypothetical Oort Cloud has never been observed, so rather than being even a scientific theory, it is in reality an *ad hoc* device to explain away the obvious discrepancy that is fatal to the dogma of the earth and the solar system being billions of years old:

   "Many scientific papers are written each year about the Oort Cloud, its properties, its origin, its evolution. Yet there is not yet a shred of direct observational evidence for its existence."[12]

2. Collisions between the supposed comet nuclei in this hypothetical, unobserved Oort Cloud would have destroyed most of those comet nuclei.[13]

3. To overcome the problem of these collisions it is then postulated that there has to be a hundred times more of these comets than what we actually observe, and that this abundance of comets must disrupt before we get a chance to see them![14]

So far, none of these proposed explanations has been substantiated, either by observations or realistic calculations. It seems desperate for astronomers to propose an unobserved source and mechanism to keep comets supplied for the alleged billions of years and then make excuses as to why this hypothetical source doesn't feed in comets as fast as it should!

In recent years, with the failure of the hypothetical Oort Cloud to supply the needed comets, attention has focused on the Kuiper Belt, a donut-shaped disc of supposed comet sources lying in the plane of the solar system just beyond the orbit of Neptune and outside the orbit of Pluto. To solve the evolutionary astronomers' dilemma, there would have to be billions of comet nuclei in this Kuiper Belt. However, astronomers have so far only found less than a thousand icy asteroid-sized bodies in this Kuiper Belt. Yet these so-far-discovered Kuiper Belt objects do

11 F. L. Whipple, 1955, Comets, in *The New Astronomy*, New York: Simon and Schuster, 201-202.

12 C. Sagan and A. Druyan, 1985, *Comets*, New York: Random House, 201.

13 S. A. Stern and P. R. Weissman, 2001, Rapid collisional evolution of comets during the formation of the Oort Cloud, *Nature*, 409 (6820): 589-591; D. R. Faulkner, 2001, More problems for the Oort Comet Cloud, *TJ*, 15 (2): 11.

14 H. F. Levison et al, 2002, The mass disruption of Oort Cloud Comets, *Science*, 296 (5576): 2212-2215; M. E. Bailey, 2002, Where have all the comets gone? *Science*, 296 (5576): 2251-2253.

not solve the evolutionists' problem, because these objects typically have diameters of more than a hundred kilometers, whereas a typical comet nucleus is around ten kilometers in diameter. Thus, in fact, there has been no discovery of comets *per se* in this Kuiper Belt, which was supposed to have been supplied with comet nuclei from the hypothetical unobserved Oort Cloud! Therefore, the Kuiper Belt is, so far, a non-answer.[15] Many astronomers now refer to these bodies according to their position beyond Neptune, without any assumptions that they may be related to a comet source. Thus, because no source of comets has been found to supposedly replenish the comets that disintegrate within the solar system, the maximum age of 10,000 years for the comets must also be the maximum age for the solar system, and, therefore, the earth.

15 R. Newton, 2002, The short-period comets "problem" (for evolutionists): Have recent "Kuiper Belt" discoveries solved the evolutionary/long-age dilemma? *TJ*, 16 (2): 15-17.

108

The Earth's Magnetic Field

The earth has a magnetic field, which is why a compass needle points north. All the evidence we have indicates that the earth's magnetic field is generated in its core, which is composed mainly of iron and nickel at temperatures of more than 3,400-4,700°C (6,100-8,500°F). In 1820, Orsted discovered that a sustained electric current produces a magnetic field, and in 1831, Faraday found that a changing magnetic field induces an electric voltage. It was thus postulated that if the earth began with a large electrical current in its core, that would have produced a strong magnetic field. However, because there would be no ongoing power source, that current would decay and the magnetic field would decay also. However, this decaying magnetic field as it changed would itself induce another electrical current, weaker than the original one. Because the magnetic field is strong enough, its exponential decay rate can be accurately calculated.

In the early 1970s, it was noted that measurements since 1835 of the main (or dipole) part of the earth's magnetic field showed that it had been decaying at a rate of 5 percent per century.[1] Archaeological measurements show that the earth's magnetic field was 40 percent stronger in AD 1000 than it is today.[2] Thus, it was proposed that the earth's magnetic field was caused by a freely-decaying electric current in the earth's core, which is entirely consistent with the demonstrated rate of field decay and experiments on the materials that make up the earth's core.[3] Furthermore, it was calculated that the current could not have been decaying for more than 10,000 years; otherwise its starting strength would have been sufficient to melt the earth. Thus, the earth must be less than 10,000 years old.

However, because uniformitarian geologists maintain the earth is billions of years

1 A. L. McDonald and R. H. Gunst, 1967, An analysis of the earth's magnetic field from 1835 to 1965, *ESSA Technical Report, IER 46-IES 1*, Washington: US Government Printing Office; T. G. Barnes, 1971, Decay of the earth's magnetic field and the geochronological implications, *Creation Research Society Quarterly*, 8 (1): 24-29.

2 R. T. Merrill and M. W. McElhinney, 1983, *The Earth's Magnetic Field*, London: Academic Press, 101-106.

3 T. G. Barnes, 1971; F. D. Stacey, 1967, Electrical resistivity of the earth's core, *Earth and Planetary Science Letters*, 3: 204-206.

old, and this decaying current model for the origin of the earth's magnetic field is incompatible with that timescale, their preferred model is a self-sustaining dynamo. In their model, the earth's rotation and convection circulates the molten, liquid iron/nickel in the outer core, thus producing an electric current that generates the magnetic field. However, sustained research has not produced a workable geodynamo model, because there are many problems such a model must overcome, including explaining the measured electrical currents in the sea floor.[4] Nevertheless, recently a numerical model of the supposed geodynamo has been produced that even displays reversal behavior.[5] However, this numerical geodynamo model is based on computer simulations, which could easily have hidden flaws, and that also depend on the starting parameters used. Indeed, to make the simulations appear to work, values for one component of the magnetic field must be made ten times higher than the true value based on actual measurements, and the electrical conductivity of the molten metal in the outer core must be made more than twelve times higher than laboratory measurements would allow.[6]

Nevertheless, the major criticism used by uniformitarian geologists against the young-earth, freely-decaying electric current model for the earth's magnetic field is the evidence in volcanic rocks that the magnetic field has reversed numerous times in the past. While volcanic lavas are still molten, the magnetic domains within some of the crystallizing magnetite (iron oxide) grains partly align themselves in the direction of the earth's magnetic field at that time, so that once the rock is fully cooled, that magnetic alignment is "frozen in." Thus, volcanic rocks, particularly on the ocean floor, contain a permanent record of the earth's magnetic field through time. However, even though uniformitarian geologists do not have a good explanation for these magnetic field reversals, they maintain, of course, that the young-earth, freely-decaying electric current model must be invalid. Furthermore, their geodynamo model requires at least thousands of years for a reversal to occur. Therefore, with their dating assumptions, they believe reversals occur at intervals of millions of years, in keeping with their insistence that the earth is old.

Unlike uniformitarian geologists' geodynamo model, the young-earth, freely-decaying electric current model for the earth's magnetic field is easily modified to explain field reversals consistent with the paleomagnetic data in volcanic rocks. As the liquid molten metal in the earth's inner core flowed upward due to convection,

4 L. J. Lanzerotti et al, 1986, Measurements of the large-scale direct-current earth potential and possible implications for the geomagnetic dynamo, *Science*, 229: 47-49.

5 G. A. Glatzmaier and P. H. Roberts, 1995, A three-dimensional convective dynamo solution with rotating and finitely conducting inner core and mantle, *Physics of the Earth and Planetary Interiors*, 91: 63-75; G. A. Glatzmaier and P. H. Roberts, 1995, A three-dimensional self-consistent computer simulation of a geomagnetic field reversal, *Nature*, 377: 203-209.

6 D. R. Humphreys, 1996, Can evolutionists now explain the earth's magnetic field? *Creation Research Society Quarterly*, 33 (3): 184-185.

this would make the field reverse quickly.[7] Furthermore, the catastrophically subducting tectonic plates during the Flood cataclysm would have sharply cooled the outer parts of the core, driving convection in the outer core.[8] Thus, most of the reversals would have occurred during the year of the Flood, every week or two, and then after the Flood there would have been large fluctuations due to residual motion. This is supported by measurements on archaeological materials from about 1000 BC and AD 1000, which show that the surface geomagnetic field intensity slowly increased to a maximum about the time of Christ, and then declined slowly before becoming approximately exponential from AD 1000 onwards. However, the reversals and fluctuations would not have halted the loss of energy, which would decay even faster through the whole period.

This modified young-earth model also explains why the sun, as a gigantic ball of hot, energetically-moving, electrically-conducting gas, reverses its magnetic field every eleven years.[9] On the other hand, the dynamo model has trouble explaining how the sun not only reverses its magnetic field, but also regenerates it and maintains its intensity, supposedly over billions of years. A test was also proposed for the young-earth magnetic field model, namely, that magnetic reversals should be found in volcanic rocks known to have cooled in days or weeks. For example, it was predicted that in a thin lava flow, the outside would cool first and record the earth's magnetic field in one direction, while the inside would have cooled a short time later and have recorded the field in another direction. Three years after this prediction appeared in print, leading paleomagnetism researchers found such a thin lava layer that had cooled within fifteen days and had 90° of reversal recorded continuously in it.[10] Furthermore, a few years later the same investigators reported finding similar evidence of an even faster reversal.[11] This evidence thus corroborates the modified young-earth, freely-decaying electric current model for the earth's magnetic field, and conclusively demonstrates the impossibility of the billions-of-years uniformitarian geodynamo model.

In order to deal with this devastating quandary, evolutionists have sought to find various arguments or loopholes by which they might yet salvage the billions-of-years geodynamo model. Some have suggested that the decay of the magnetic field

---

7 D. R. Humphreys, 1986, Reversal of the earth's magnetic field during the Genesis Flood, in *Proceedings of the First International Conference on Creationism*, vol. 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 113-126.

8 J. R. Baumgardner, 1986, Numerical simulation of the large-scale tectonic changes accompanying the Flood, in *Proceedings of the First International Conference on Creationism*, vol. 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 17-30.

9 Humphreys, 1986.

10 R. S. Coe and M. Prévot, 1989, Evidence suggesting extremely rapid field variation during a geomagnetic reversal, *Earth and Planetary Science Letters*, 92 (3/4): 292-298; A. A. Snelling, 1991, "Fossil" magnetism reveals rapid reversals of the earth's magnetic field, *Creation Ex Nihilo*, 13 (3): 46-50.

11 R. S. Coe, M. Prévot and P. Camps, 1995, New evidence for extraordinarily rapid change of the geomagnetic field during a reversal, *Nature*, 374 (6564): 687-692; A. A. Snelling, 1995, The "principle of least astonishment"! *Creation Ex Nihilo Technical Journal*, 9 (2): 138-139.

is linear rather than exponential.[12] However, experimental measurements indicate that currents in resistance/inductance circuits always decay exponentially, not linearly, after the power source is switched off. Thus, even if a linear fit of the very recent measurements of the magnetic field looks reasonable, it's physically absurd when dealing with the real world of electric circuits, where exponential decay is an intrinsic component of electromagnetic theory. Furthermore, the originator of the young-earth model for the magnetic field was a professor of physics who had written university textbooks on electromagnetism! In any case, if the decay had been linear, the upper limit for the age of the earth's magnetic field would still only be 90 million years, well short of the uniformitarian 4.5 billion years, and future linear decay would mean the earth's magnetic field would soon disappear all together!

Other evolutionists have suggested that, even though the dipole component of the earth's magnetic field has been decaying, the strength of the non-dipole field has been increasing, so the total magnetic field has remained almost constant.[13] However, this apparent loophole has already been dealt with and categorically closed.[14] In fact, this claim results from confusion between measurements of the magnetic field intensity and its energy. The non-dipole component of the magnetic field may experience a small increase in its field intensity, but it does not represent a large enough increase in energy to compensate for the enormous amount of energy being lost from the dipole component. Indeed, using the data from the International Geomagnetic Reference Field for the most accurately recorded period from 1970 to 2000, the measurements show that the dipole part of the field steadily lost 235±5 billion megajoules of energy, while the non-dipole part gained only 129±8 billion megajoules, so that over that 30-year period, the net loss of energy from all observable parts of the field was 1.41±0.16 percent.[15] At that rate, the total energy stored in the earth's magnetic field (including both the dipole and non-dipole components) is decreasing with a half-life of 1,465±166 years.

The implication of this demonstrable conclusion, based on hard and accurate published field data, is that the young-earth creationist model has been emphatically confirmed. At creation, the earth's magnetic field was generated by freely-decaying electric currents in the outer core, but convection in the outer core during the Flood cataclysm caused reversals in the polarity of the field, followed by subsequent intensity fluctuations. Nevertheless, the magnetic field has rapidly

12 A. Hayward, 1987, *Creation and Evolution: The Facts and the Fallacies*, London: Triangle SPCK, 137-139.

13 R. Ecker, 1990, *Dictionary of Science and Creationism*, Buffalo, NY: Prometheus Books, 105.

14 D. R. Humphreys, 1990, Physical mechanism for reversal of the earth's magnetic field during the Flood, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 129-142.

15 D. R. Humphreys, 2002, The earth's magnetic field is still losing energy, *Creation Research Society Quarterly*, 39 (1): 1-11.

and continuously lost total energy ever since it was created, and the rate of that loss indicates that the earth and its magnetic field were created only about 6,000 years ago.

109

Sea Salt, Erosion, and Sediments

Salt in the Sea

Many processes continually add salts and other chemicals to the waters of the earth's oceans and seas, particularly weathering and erosion of land surfaces, and river transportation of chemicals and sediments. However, these salts aren't as readily removed from the sea, resulting in a steady increase in the sea's saltiness. How much salt is in the sea and the rates at which salts are added into and removed from the sea can be calculated from appropriate measurements. Assuming how these rates varied in the past and how much salt was in the sea originally, it is possible to calculate a maximum age for the sea. This method of estimating the age of the earth was first proposed by Halley in 1715.[1] Subsequently, Joly estimated that the oceans were no more than 80 to 90 million years old.[2] Obviously, even this estimate is far too young for uniformitarian geologists and evolutionists, who believe that the oceans are at least three billion years old.

The most common chemicals in ocean water are sodium and chlorine, which are the constituents of common table salt (sodium chloride). Measurements reveal that every kilogram of seawater contains about 10.8 grams of dissolved sodium. Because the ocean contains 1,370 million cubic kilometers of water, there is a total of 14,700 trillion tons of sodium in the oceans. It is thus easy to make a calculation of the age of the oceans by analyzing data from conventional geological sources of the input and output rates of sodium.[3]

Every year, rivers and other sources dump about 457 million tons of sodium

1 E. Halley, 1715, A short account of the saltness of the ocean, and of the several lakes that emit no rivers; with a proposal, by help thereof, to discover the age of the world, *Philosophical Transactions of the Royal Society of London*, 29: 296-300.

2 J. Joly, 1899, An estimate of the geological age of the earth, *Science Transactions of the Royal Dublin Society, New Series*, 7 (3); Reprinted in *Annual Report of the Smithsonian Institution*, June 30, 1899, 247-288.

3 S. A. Austin and D. R. Humphreys, 1990, The sea's missing salt: A dilemma for evolutionists, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 17-33.

into the oceans[4] For example, water on the land leaches sodium from weathered minerals, and that sodium is carried into the ocean by rivers. Some salt is also supplied by water flowing through the ground directly into the sea. This water often has a high salt concentration. Furthermore, ocean-floor sediments release sodium into the ocean water, as do hot springs (hydrothermal vents) on the ocean floor. Volcanic dust also contributes some sodium. Even if sodium input to the oceans in the past was less, using assumptions for inflow rates that are most generous to evolutionists, the minimum possible amount in the past would have been 356 million tons of sodium input per year.

However, the rate of sodium output is far less than the input. In fact, only about 122 million tons of sodium, or 27 percent of the sodium input, manages to leave the sea each year.[5] The major process that removes sodium from the sea is salt spray. Some sodium is lost from the ocean when water is trapped in pores and sediments on the ocean floor. Another major process of sodium loss is ion exchange, when clays absorb sodium in exchange for calcium that is released into the ocean water. There are also minerals with crystal structures that absorb sodium from the ocean water. The maximum possible amount of sodium that leaves the oceans every year, even if assumptions that are most generous to evolutionists are used in the calculation, is 206 million tons per year.

All observations suggest that all of the incoming sodium that isn't returned to the land simply accumulates in the oceans. Thus, if the oceans originally contained no sodium, then the sodium in them today would have accumulated in less than 42 million years at today's input and output rates. Even this maximum age for the oceans is far less than the uniformitarian age of at least 3 billion years. The usual response from uniformitarian evolutionists is that this discrepancy is due to past sodium inputs being much less and outputs being much greater. However, if input and output rates are used in the calculations that are most generous to evolutionary scenarios, then the estimated maximum age is still only 62 million years. Nevertheless, a more recent study shows that salt is entering the oceans even faster than previously thought, because groundwater directly discharging to the sea is as much as 40 percent of the discharge via river flow, much greater than the previously estimated 10 percent.[6] Furthermore, additional calculations for many other seawater elements yield much younger ages for the oceans.[7] Therefore, it is quite obvious that even 42 million years may be a generous maximum age for the

4 M. Meybeck, 1979, Concentrations des eaux fluvials en majeurs et apports en solution aux oceans, *Revue de Géologie Dynamique et de Géographie Physique*, 21 (3): 215-246; F. L. Sayles, and P. C. Mangelsdorf, 1979, Cation-exchange characteristics of Amazon with a suspended sediment and its reaction with seawater, *Geochimica et Cosmochimica Acta*, 43: 767-779.

5 Sayles and Mangelsdorf, 1979; Austin and Humphreys, 1990.

6 W. S. Moore, 1996, Large groundwater inputs to coastal waters revealed by ^{226}Ra enrichments, *Nature*, 380 (6575): 612-614; T. M. Church, 1996, An underground route for the water cycle, *Nature*, 380 (6575): 579-580.

7 S. Nevins, 1973, Evolution: The Ocean Says NO!, *Acts & Facts*, 2 (11).

oceans using all these calculations.

However, it's important to stress that this is not the actual age of the oceans, but only a maximum age based on the assumption that there was no salt originally dissolved in the oceans. On the other hand, in the biblical model of earth history, there can be no doubt that God created the oceans initially containing some saltiness, in order that saltwater fish could live within them. Furthermore, during the Flood cataclysm much more salt would have found its way into the oceans due to all the erosion, sedimentation, and volcanism. During this time, the sodium input would have been an order of magnitude or more higher than current input rates. Furthermore, there would have been a much higher input rate of salts as the Flood waters retreated and eroded the current land surface. Thus, the true age of the oceans, using realistic assumptions governed by the biblical framework of earth history, would more likely be only thousands of years.

Erosion of Continents

The earth's land surfaces are constantly being weathered and eroded by the water falling on them as rain and flowing over them. Soil, rock, and mineral grains are washed into rivers that transport these as sediments out to the oceans. The rate at which sediments have been transported to, and deposited in, the ocean basins can easily be estimated by measuring the volume of sediments rivers carry at their mouths. River sediment measurements can also be used to calculate the rate at which rivers are eroding the land surfaces they drain. Such measurements show that some rivers are eroding their basins at a rate of 35 inches (900 mm) or more in height per thousand years, while others erode only 0.04 inches (1 mm) per thousand years.[8] Thus, the average height reduction for all the continents across the earth's surface is estimated to be about 2.4 inches (61 mm) per thousand years.

This average rate of land erosion might seem quite slow, but it needs to be seen from the perspective of the uniformitarian geologic timescale, and the current thinking that there has been exposed land surfaces available for erosion for 3.5 billion years.[9] As has already been pointed out, using an estimated average erosion rate of 61 mm per thousand years, the North American continent would be eroded flat to sea level in "a mere 10 million years."[10] Even if the slowest erosion rate of

8 J. N. Holleman, 1968, The sediment yield of major rivers of the world, *Water Resources Research*, 4: 737-747; E. W. Sparks, 1986, Geomorphology, in *Geographies for Advanced Study*, S. H. Beaver, ed., London and New York: Longman Group, 509-510; J. D. Milliman and J. P. M. Syvitski, 1992, Geomorphic/tectonic control of sediment discharge to the ocean: The importance of small mountainous rivers, *Journal of Geology*, 100: 525-544; A. Roth, 1998, *Origins: Linking Science and Scripture*, Hagerstown, MD: Review and Herald Publishing, 264.

9 R. Buick, J. R. Thornett, N. J. McNaughton, J. B. Smith, M. E. Barley and M. Savage, 1995, Record of emergent continental crust ≈3.5 billion years ago in the Pilbara Craton of Australia, *Nature*, 375: 574-577.

10 S. Judson and D. F. Ritter, 1964, Rates of regional denudation in the United States, *Journal of Geophysical Research*, 69: 3395-3401; R. H. Dott, Jr. and R. L. Batten, 1988, *Evolution of the Earth*,

only 1 mm per thousand years is used, based on an average of 623 meters above sea level for the continents, the continents would have eroded to sea level in only 623 million years. This, of course, begs the question to why the earth's continents are still above sea level if they are up to 3.5 billion years old. This question is even more acute when one considers mountains ranges such as the Caledonides of western Europe and the Appalachians of eastern North America, which geologists assume are several hundred million years old. Why are these ranges still here today if they are so old? After all, rates of erosion are fast in mountainous regions, with erosion rates as high as 1,000 mm per thousand years in the Himalayas.[11]

However, another way of highlighting this glaring discrepancy is to again consider the erosion rates based on quantities of sediments delivered by rivers to the ocean basins from the continents. Calculations have varied from 8,000 million to 58,000 million metric tons per year.[12] These estimates are probably low, because normal measuring procedures do not account for the rare catastrophic events (such as local floods), during which the transport of sediments increases considerably. They also do not consider the sediments that are rolled or pushed along the beds of rivers. Nevertheless, the average rate from a dozen studies is 24,108 million metric tons per year. At this rate, the average height of the world's continents (623 meters) above sea level would erode away in about 9.6 million years, a figure close to the already published 10 million year figure for North America.

Geologists often maintain that mountains still exist because uplift is constantly renewing them from below.[13] However, even though mountains are still rising, the process of uplift and erosion could not continue long without eradicating ancient sedimentary layers contained in the mountains. Yet sedimentary strata that are supposedly very ancient are still well represented in the earth's mountain ranges, as well as elsewhere. Even taking into account that human agricultural practices have increased erosion rates, such an explanation does little to resolve the discrepancy. Proposing a dry climate in the past, and thus slower erosion rates, also will not resolve the discrepancy, because estimates of global precipitation suggest variable but average, or even slightly wetter, conditions over the past three billion years.[14]

Another problematic discrepancy for the supposed long geologic ages is allegedly ancient planar land surfaces, which stretch over large areas and yet show little or no evidence of erosion. For example, Kangaroo Island off the southern Australian coast covers an area of about 87 miles (140 km long) by 37 miles (60 km wide)

---

fourth edition, New York, St. Louis, and San Francisco: McGraw-Hill Book Company, 155.

11 H. W. Menard, 1961, Some rates of regional erosion, *Journal of Geology*, 69: 154-161.

12 Roth, 1998, 265, Table 15.2, based on sources indicated therein.

13 H. Blatt, G. Middleton and R. Murray, 1980, *Origin of Sedimentary Rocks*, second edition, Englewood Cliffs, NJ: Prentice-Hall, 18.

14 L. A. Frakes, 1979, *Climates Throughout Geologic Time*, Figure 9-1, Amsterdam, Oxford, and New York: Elsevier, 261.

and is extremely flat. However, the surface is estimated to be at least 160 million years old, based on both fossil and potassium-argon "dating."[15] How could such a surface exist for 160 million years without rainfall and surface water flow resulting in some pattern of channelized erosion, when there is very little evidence of such?

The alleged antiquity of erosion surfaces compared with the overall rate of erosion of land surfaces is indeed an insurmountable problem for uniformitarian dating methods. Nevertheless, evolutionary geologists still cling to the dates in the face of "common sense," as has been admitted:

> If some facets of the contemporary landscape are indeed as old as is suggested by the field evidence they not only constitute denial of commonsense and everyday observations but they also carry considerable implications for general theory.[16]

Quite clearly, the earth's continental land surfaces aren't all that old, and thus neither is the earth itself.

Sea Floor Sediments

The sediments eroded from the continental land surfaces are carried by rivers to ultimately be deposited on the floors and margins of the ocean basins. As noted above, the average rate of delivery to the oceans of sediments eroded from the continental land surfaces transported by rivers, calculated from twelve studies, is more than 24 billion metric tons per year. Yet this estimate is probably somewhat lower than the actual volume of sediments delivered by rivers to the ocean basins, because the studies from which this average figure was derived did not include the rock material that rolls along river beds. All this sediment and rock eventually accumulates on the basaltic ocean crust that makes up the ocean floor. It has been estimated that the average depth of all the sediments on the ocean floors worldwide is less than 400 meters.[17]

There is only one known mechanism by which sediments are removed from the ocean floor and that is during subduction of the ocean floor at trenches. As the sea floor slides slowly (a few cm per year) beneath the continents at the trenches, it is estimated that about 1 billion tons of sediment per year is subducted into the mantle with the sea floor.[18] As far as is known, the other 23 billion tons

15 E. Daily, C. R. Twidale and A. R. Milnes, 1974, The age of the laterized summit surface on Kangaroo Island and adjacent areas of South Australia, *Journal of the Geological Society of Australia*, 21 (4): 387-392.

16 C. R. Twidale, 1998, Antiquity of landforms: An "extremely unlikely" concept vindicated, *Australian Journal of Earth Sciences*, 45: 657-668.

17 W. W. Hay et al, 1988, Mass/age distribution and composition of sediments on the ocean floor and the global rate of sediment subduction, *Journal of Geophysical Research*, 93 (B12): 14,933-940.

18 Hay et al, 1988.

of sediment per year simply accumulate on the ocean floors. At that rate the sediments accumulating on the ocean floor as a result of erosion of the continents would have accumulated in approximately 12 million years.

Yet according to the uniformitarian timescale of the evolution and development of the earth, erosion and tectonic plate subduction have been occurring as long as the oceans have existed, at least 3 billion years. Furthermore, even just considering the latest and present cycle of plate tectonics, the present ocean basins have been in existence for at least 200 million years. If that were so, then according to the present rate of accumulation of sediments on the ocean floors, the ocean basins should now be massively choked with sediments many kilometers deep. Since they aren't, the measurements of sediments carried to the ocean basins, and the rate of accumulation on the ocean floors, don't support the claim that the earth and its ocean basins are millions of years old.

On the other hand, because the present ocean basins were only formed in the biblical framework for earth history toward the end of the Flood cataclysm some 4,500 or so years ago, the present amount of sediments on the ocean floors had to be deposited in a short time. This was largely accomplished, not at present rates of accumulation, but as a result of the Flood waters catastrophically draining off the emerging continental land surfaces at the end of the Flood. These erosion rates would have been orders of magnitude greater than the presently measured erosion rates. It is thus the biblical model of earth history that is consistent with the evidence.

110

Volcanic Activity and Helium

Crustal Growth through Volcanic Activity

The sedimentary strata exposed in the continents are not the only rock layers that make up the earth's continental crust. There are many volcanic rock layers, the result of volcanic eruptions spewing out lavas and ash. Single eruptions produce anywhere from small volumes to many cubic kilometers of volcanic material. In most instances, the original molten rock was generated at the top of the earth's mantle, so the outpourings of lavas at the earth's surface are regarded as being added to the earth's crust. In this way, it has been suggested that the earth's crust has developed:

> Emission of lava at the present rate of 0.8 km^3 year throughout the earth's history of 4.5 x 10^9 years or even for the 3 x 10^9 years since the oldest known rocks were formed would have poured out lava of the order of 3 x 10^9 km^3 on the Earth's surface. This corresponds approximately to the volume of the continents (about 30 km x 1.1 x 10^8 km^2). A slightly higher rate of volcanism in the early stages of the Earth would allow for the emission of the oceanic crust as well.[1]

A subsequent calculation, based on a conservative estimate of an average of 1 cubic kilometer of volcanic material per year being ejected by the earth's volcanoes, suggested that in 3.5 billion years the entire earth should have been covered by a thick blanket of volcanic material reaching a height of 7 km![2] Of course, since estimates of the volume of volcanic rocks in the geologic record indicate only a small fraction of that amount, it was concluded the rate of volcanic activity in the past must have been erratic.

However, a more realistic estimate is that at present the world's volcanoes eject an average of about four cubic kilometers of lavas and ash per year. Single major

1 J. T. Wilson, 1959, Geophysics and continental growth, *American Scientist*, 47: 14.

2 G. B. Gregor, 1968, The rate of denudation in post-Algonkian time, *Koninkalijke Nederlandse Academie van Wetenschapper*, 71: 22-30.

eruptions can produce significant volumes, yet an estimate of only the major eruptions during four decades (1940-1980) suggests an average of three cubic kilometers per year.[3] However, that figure does not include a multitude of smaller eruptions, such as those that occur periodically in Hawaii, Indonesia, Central and South America, Iceland, Italy, and elsewhere. So an average volume of four cubic kilometers per year has been proposed as the best estimate.[4]

Now as far as the geologic record is concerned, it has been suggested that the surface of the earth contains 135 million cubic kilometers of sediment of volcanic origin, which represents 14.4 percent of the estimated total volume of sedimentary strata.[5] While 135 million cubic kilometers of volcanic materials is an impressive amount, at a rate of accumulation of four cubic kilometers per year, this volume found in the geologic record would have accumulated in less than 34 million years. Expressed another way, if the current production rate of volcanic material were extended over 2.5 billion years, there should be layers of volcanic material with a cumulative thickness of more than 19 kilometers all over the earth's surface, 24 times the amount of volcanic material that is found now.

The removal of this volcanic material by erosion does not offer a good solution to this inconsistency for the long uniformitarian geological ages, because erosion would only transfer the volcanic material from one place to another. Furthermore, removal of volcanic material would also eliminate the other rock layers containing it. In any case, the geologic record that contains this volcanic material is still well represented worldwide. Indeed, even recent historic major eruptions are dwarfed by the catastrophic volcanic eruptions that must have occurred in the past, during the outpouring of hundreds of millions of cubic kilometers of so-called flood basalts, such as those of the Deccan and Siberian Traps.

Therefore, no matter which way the evidence is viewed, volcanoes simply could not have been erupting for the 2.5 to 3.5 billion years during which the strata record of earth's continental crust has supposedly been accumulating. Put another way, the earth's continental crust simply cannot be that old. Within the biblical framework, much of the earth's continental crust would have been built catastrophically during the Creation Week, and in the year-long Flood cataclysm. The evidence for continental crustal growth via volcanic activity is most definitely consistent with that biblical framework for earth history.

3 S. Simkin, L. Siebert, L. McClelland, D. Bridge, C. Newhall and J. H. Latter, 1981, *Volcanoes of the World: A Regional Directory, Gazetter, and a Geochronology of Volcanism during the last 10,000 Years*, Stroudsburg, PA: Smithsonian Institution, Hutchinson Ross Publishing Company.

4 R. Decker and B. Decker, eds., 1982, *Volcanoes and the Earth's Interior: Readings from Scientific American*, San Francisco: W. H. Freeman and Company, 47.

5 A. D. Ronov and A. A. Yaroshevsky, 1969, Chemical composition of the earth's crust, in *The Earth's Crust and Upper Mantle: Structure, Dynamic Processes, and their Relation to Deep-Seated Geological Phenomena*, P. J. Hart, ed., American Geophysical Union, Geophysical Monograph 13: 37-57.

Helium in Rocks and in the Atmosphere

Uranium and thorium contained in rocks and minerals generate helium atoms as they are transformed by radioactive decay to lead. Helium is the second lightest element and is a noble gas, which means its atoms do not bond with atoms of other elements. So the small helium atoms in rocks and minerals easily fit between the atoms in crystal lattices and diffuse (leak) out of, and so escape from, the minerals and rocks. The hotter the rocks, the faster the helium escapes, and the deeper one goes into the earth, the hotter the rocks.

In a study of a deep, hot Precambrian granitic rock, drilled for potential geothermal energy, it was found that zircon crystals that contained uranium also contained large amounts of helium.[6] Even the deepest and hottest zircons (at 197°C or 387°F) contained far more helium in them than expected, given the uranium-lead radioisotope "age" for the zircon crystals of 1.5 billion years. At the time of that study, no experimental measurements of the leakage or diffusion rate of helium from zircons was available. But it was still possible to calculate that in some of the zircon crystals, up to 58 percent of the helium that would have been generated from uranium decay over 1.5 billion years was still present in them.

Now several experimental determinations of the helium leakage (diffusion) rate from zircons of several different rock units, including this Precambrian granitic rock, are available and are in agreement.[7] These experimental measurements all showed that helium diffuses so rapidly out of zircon crystals that it should have all but disappeared after about 100,000 years. Because the uranium-lead radioisotope decay system indicates that originally there would have been 1.5 billion years worth of helium generated in these zircon crystals, the amounts of helium left in them should have long since leaked out. The measured amounts of retained helium in these zircon crystals, combined with the measured diffusion rate of helium from zircon, can be used to calculate their helium diffusion age. Indeed, there is so much helium still left in these zircons that based on the measured rate of helium diffusion from zircons, these zircon crystals have an average helium diffusion age of only 6,000 (±2,000) years.

Helium starts diffusing out of zircon crystals as soon as it is produced by

---

6 R. V. Gentry, G. L. Glish and E. H. McBay, 1982, Differential helium retention in zircons: Implications for nuclear waste containment, *Geophysical Research Letters*, 9 (10): 1129-1130.

7 S. W. Reiners, K. A. Farley and H. J. Hicks, 2002, He diffusion and (U-Th)/He thermochronometry of zircon: Initial results from Fish Canyon Tuff and Gold Butte, Nevada, *Tectonophysics*, 349 (1-4): 297-308; D. R. Humphreys, S. A. Austin, J. R. Baumgardner and A. A. Snelling, 2003, Helium diffusion rates support accelerated nuclear decay, in *Fifth International Conference on Creationism*, R. L. Ivey Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 175-196; D. R. Humphreys, 2005, Young helium diffusion age of zircons supports accelerated nuclear decay, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 25-100.

radioactive decay. Therefore, the radioactive decay that produced the helium must have occurred within that timeframe of only about 6,000 years. Yet measurements of the uranium-lead radioisotope system in these same zircons indicate that 1.5-billion-years worth of uranium decay has occurred in these zircons. How then could 1.5 billion years worth of helium have been produced and accumulated in so little time? The best answer is that at some time in the recent past there had to have been an episode (or episodes) of grossly accelerated nuclear decay in which the radioactive decay timescale was enormously compressed, from 1.5 billion radioisotope years into 6,000 years of real time. Within the biblical framework for earth history, such an episode of accelerated nuclear decay logically occurred during Creation Week, during the year-long Flood cataclysm, or more likely both, when geological processes were also occurring at catastrophic rates.

Because this contradiction is so glaring and devastating to the uniformitarian long-ages timescale, attempts have been made to discredit this evidence. For example, it has been suggested that perhaps helium has instead diffused into the zircon crystals from outside sources, thus giving them this incorrect young diffusion age. However, such criticism ignores the experimental measurements of the helium concentration in the biotite flakes in which the zircon crystals were embedded.[8] The helium concentration in biotite flakes was actually much lower than the helium concentration in the zircon crystals, which means that according to the well-known fundamental diffusion law, the helium would have been diffusing from the higher concentration in the zircon crystals out into the lower concentration in the surrounding biotite flakes. In fact, the amount of helium in the biotite flakes was found to be exactly equivalent to the amount of helium that has leaked out of the zircon crystals. So any and every external source of helium cannot rescue the uniformitarian timescale, because the experimental evidence demonstrates conclusively that the helium generated by uranium decay in the zircon has been diffusing out into the surrounding biotite flakes in only about 6,000 years.

Another critic has suggested that there could have been resistance to the diffusion of helium out of the zircon crystals at the boundary or interface between the zircon crystals and the surrounding biotite flakes. This resistance would stop the helium from diffusing out of the zircon crystals and cause the retention of anomalous high helium concentrations. However, this desperate postulation was also easily refuted, because the zircon crystals are always found sitting in between the parallel stacked sheets that make up the biotite flakes. Therefore, there is an intrinsic weakness within the biotite flakes that would have in fact made it easier for the helium to leak out of the zircon crystals between the biotite sheets into the biotite flakes. Thus, all available evidence confirms that the true age of the zircon crystals, and the granitic rock containing them, is not 1.5 billion years, but only 6,000±2,000 years.

8 D. R. Humphreys, S. A. Austin, J. R. Baumgardner and A. A. Snelling, 2004, Helium diffusion age of 6000 years supports accelerated nuclear decay, *Creation Research Society Quarterly*, 41 (1): 1-16; Humphreys, 2005.

The net result of the helium leakage from minerals and rocks is that ultimately this radiogenic helium (helium produced by radioactive decay) diffuses through the earth's crust to the earth's surface and leaks out into the atmosphere. More than 50 years ago, it was realized that there is not nearly enough helium in the atmosphere to correspond to the supposed age of the earth, and to the rate at which helium is escaping from crustal rocks into the atmosphere.[9] Indeed, it was in 1957 that the problem with helium in the atmosphere was forcefully brought to the attention of the scientific community. Estimates of the leakage rate of helium from crustal rocks into the atmosphere and the helium content of the atmosphere were highlighted, and then contrasted with the resultant question: "Where is the earth's radiogenic helium?"[10] In answer to the question, it was stated that the helium problem "… leads…to an 'anomalous' atmospheric chronometry."

Here then is the helium problem. The measured flux, or rate of introduction, of helium from the crust of the earth into the atmosphere is estimated to be 2×10^6 atoms per cm^2 per second (13 million helium atoms per square inch each second).[11] On the other hand, the estimated flux, or theoretical rate of escape, of helium from the atmosphere to space due to thermal escape is 5×10^4 atoms per cm^2 per second (about 0.3 million atoms per square inch each second). Other escape mechanisms such as the polar wind, solar wind sweeping, and hot-ion exchange have not been found to be important contributors to the loss of helium in space. Therefore, the helium in the atmosphere has been accumulating at a very rapid rate. The current measured column density of helium in the atmosphere is 1.1×10^{20} atoms per cm^2. If the earth's atmosphere had no helium when it formed, and the helium accumulated in the atmosphere at the current estimated rate, then the present density of helium in the atmosphere would have accumulated in less than only 1.8 million years. Of course, this is not to say that this is the age of the earth's atmosphere, but 1.8 million years is more than 2,500 times shorter than the presumed age of the earth of more than 4.5 billion years. Consequently, long-age atmospheric physicists admit that "…there appears to be a problem with the helium budget of the atmosphere,"[12] and that this helium escape problem "…will not go away, and it is unsolved."[13]

This estimate of less than only 1.8 million years for the atmosphere's helium to accumulate is, of course, based on the assumption that the earth's atmosphere contained no helium at its beginning. The second assumption is that the helium flux from the crustal rocks into the atmosphere has always been the same throughout

9 G. E. Hutchinson, 1947, Marginalia, *American Scientist*, 35: 118.

10 M. A. Cook, 1957, Where is the earth's radiogenic helium? *Nature*, 179 (4557): 213.

11 L. Vardiman, 1990, *The Age of the Earth's Atmosphere: A Study of the Helium Flux through the Atmosphere*, El Cajon, CA: Institute for Creation Research.

12 J. C. G. Walker, 1977, *Evolution of the Atmosphere*, London: McMillan.

13 J. W. Chamberlain and D. M. Hunten, 1987, *Theory of Planetary Atmospheres*, second edition, London: Academic Press.

the earth's history. However, neither of these assumptions would be valid within the biblical framework of earth history. First, at the creation of the earth it is likely that God created the atmosphere with some helium in it, along with all the other atmospheric gases, because the helium in the atmosphere does serve a useful purpose. Second, and more importantly, as a result of the catastrophic geologic processes operating during the year-long Flood cataclysm, including accelerated nuclear decay that would have produced more helium at an accelerated rate, the rate of helium flux from crustal rocks into the atmosphere would have been far greater than at present. Thus, as a result of these two considerations, the time for the accumulation of the atmosphere's current helium content would have been much less than the estimated 1.8 million years. Therefore, the helium in the atmosphere is completely consistent with the earth and its atmosphere only being 6,000-7,000 years old, rather than the age of 4.5 billion years claimed by uniformitarians.

Two final considerations are worth noting. First, the usual method used by old-earth advocates, to avoid this helium evidence for a young atmosphere and earth, is to assume that the enormous quantities of helium generated during past eons somehow attained the required escape velocity, overcame gravity, and escaped from the atmosphere completely into space.[14] However, this requires temperatures in the outermost portion of the atmosphere that are extremely high, much higher than those required for all the necessary helium to reach escape velocity. Second, making this helium problem worse for uniformitarians is the discovery that there are large volumes of helium in the earth's crust that have not been derived by radioactive decay, but instead are considered primordial, that is, they have been present inside the earth since its beginning.[15] This means there is even more helium to escape through the earth's crustal rocks into the atmosphere than just the helium that has been generated by radioactive decay. It also means that if the earth is 4.5 billion years old there has been even more helium that has needed to escape into outer space from the earth's atmosphere by this postulated heating in the outermost atmosphere. On the contrary, the presence of this primordial helium only serves to suggest that the maximum age of the atmosphere measured by helium accumulation is much less than the calculated 1.8 million years.

14 L. Spitzer, 1949, The terrestrial atmosphere above 300km, in *The Atmospheres of the Earth and Planets*, G. P. Kuiper, ed., Chicago: University of Chicago Press, 211-247; D. M. Hunten, 1973, The escape of light gases from planetary atmospheres, *Journal of the Atmospheric Sciences*, 30: 1481-1494.

15 H. Craig and J. E. Lupton, 1976, Primordial neon, helium and hydrogen in oceanic basalts, *Earth and Planetary Science Letters*, 31: 369-385.

111

Radiohalos, Radiocarbon and Tree Rings

Radiohalos

Referred to previously, radiohalos are the physical scars in minerals produced by alpha (α)-particles during radioactive decay, primarily of uranium and its daughter atoms. The black mica biotite is the most common mineral in which radiohalos are found. Tiny zircon inclusions in the biotite flakes contain uranium. The α-particles are ejected from these radiocenters to produce the microscopic discolored spheres known as uranium radiohalos (Figure 70, page 1098). The discoloration is the most intense where the α-particles stop, leading to a dark ring. However, in the uranium decay chain there are eight steps at which α-particles are emitted as uranium progressively decays through its chain of daughter products to its stable lead end member. The α-particles emitted at each of these eight α-decay steps has a characteristic energy, so the α-particles from these eight α-decay steps travel different distances in the surrounding host biotite (Figure 71, page 1099). This results in a fully-formed uranium radiohalo containing eight distinctive rings (Figure 70b).[1]

The three last α-decay steps, and thus the last three rings to form in a uranium radiohalo, are "parented" by three isotopes of the rare metal polonium (Po). These three polonium isotopes decay extremely rapidly, as measured by their very short half-lives: 3.1 minutes for polonium-218, 164 microseconds for polonium-214, and 138 days for polonium-210. What is highly significant is that in many of the same rocks in which biotite flakes host uranium radiohalos, there are also radiohalos with only the rings produced by these three polonium isotopes (Figures 71 and 72, pages 1099-1100). That means no uranium could have been present in the radiocenters of these ^{218}Po, ^{214}Po, and ^{210}Po radiohalos, named due to their ring structures that indicate the polonium radioisotopes in the radiocenters that parented the radiohalos. However, herein lays a profound dilemma. The polonium responsible for generating these radiohalos had to somehow have a separate

1 R. V. Gentry, 1973, Radioactive halos, *Annual Review of Nuclear Science*, 23: 347-362; A. A. Snelling, 2000, Radiohalos, in *Radioisotopes and the Age of the Earth: A Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 381-468.

existence from the uranium that normally "parents" it. Furthermore, after ten half-lives only about 1,000th of the original parent isotope is left, and after 20 half-lives only about 1 millionth is left. This means that the polonium radiohalos could only have formed within about 20 half-lives, which is a very short timescale for these polonium isotopes. For example, 20 half-lives for ^{218}Po would be just over one hour since its half-life is only 3.1 minutes. Quite clearly, these polonium radiohalos had to have formed extremely rapidly compared to the uniformitarian timescale for geological processes, so evolutionary geologists have had to admit that these polonium radiohalos are "a very tiny mystery."[2]

The solution to this supposed mystery, which explains how these polonium radiohalos form extremely rapidly, has further implications regarding the ages of rocks and the rapid rate of important geological processes. As has been explained earlier, the closest source for the polonium isotopes, which concentrated in the radiocenters to form the polonium radiohalos, is the polonium produced by uranium decay in the zircons that are the radiocenters for the adjacent uranium radiohalos in the same biotite flakes. Thus, it has been postulated that hydrothermal (hot water) fluids, produced from the granite magmas as they cool, have transported the polonium isotopes the very short distances (<1 mm), between the sheets in the biotite flakes' crystal structure, from the zircons to the polonium halo centers.[3] The transport and concentration of the polonium isotopes by hydrothermal fluids to produce the polonium radiohalos has been subsequently confirmed. It has been repeatedly demonstrated that where there are other evidences of the past presence of these hydrothermal fluids, there is a direct correlation with the greater numbers of polonium radiohalos.[4] The implications are that not only did the transport of polonium isotopes have to be rapid, or else the polonium radiohalos would not have likewise formed rapidly before the polonium isotopes decayed away, but that the uranium decay in the zircons had to be grossly accelerated to rapidly supply

2 R. V. Gentry, 1974, Radiohalos in a radiochronological and cosmological perspective, *Science*, 184: 62-66; R. V. Gentry, 1988, *Creation's Tiny Mystery*, Knoxville, TN: Earth Science Associates; Snelling, 2000.

3 A. A. Snelling and M. H. Armitage, 2003, Radiohalos—A tale of three plutons, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 243-267; A. A. Snelling, 2005, Radiohalos in granites: Evidence for accelerated nuclear decay, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 101-207.

4 Snelling, Radiohalos in granites, 2005; A. A. Snelling, 2005, Polonium radiohalos: The model for their formation tested and verified, *Acts & Facts*, 34 (8); A. A. Snelling, 2006, Confirmation of rapid metamorphism of rocks, *Acts & Facts*, 35 (2); A. A. Snelling, 2008, Testing the hydrothermal fluid transport model for polonium radiohalo formation: The Thunderhead Sandstone, Great Smoky Mountains, Tennessee-North Carolina, *Answers Research Journal*, 1: 53-64; A. A. Snelling, 2008, Radiohalos in the Cooma metamorphic complex, NSW, Australia: The mode and rate of regional metamorphism, in *Proceedings of the Sixth International Conference on Creationism*, A. A. Snelling, ed., Pittsburgh, PA: Creation Science Fellowship and Dallas, TX: Institute for Creation Research, 371-387; A. A. Snelling, 2008, Radiohalos in the Shap Granite, Lake District, England: Evidence that removes objections to Flood geology, in *Proceedings of the Sixth International Conference on Creationism*, A. A. Snelling, ed., Pittsburgh, PA: Creation Science Fellowship and Dallas, TX: Institute for Creation Research, 389-405; A. A. Snelling and D. Gates, 2009, Implications of polonium radiohalos in nested plutons of the Tuolumne Intrusive Suite, Yosemite, California, *Answers Research Journal*, 2: 53-77.

the needed polonium isotopes (discussed earlier), and geological processes such as the formation of granites and metamorphic rocks (to be discussed later) had to also occur extremely rapidly. Thus, polonium radiohalos are physical evidence of rapid geological processes, once claimed to require up to millions of years, but the timescales for which have now been shown to be compatible with the biblical timescales of a young earth and the year-long global Flood.

Somewhat unusual was the discovery of ^{210}Po radiohalos in partially coalified logs recovered from uranium mines on the Colorado Plateau.[5] These partially coalified logs were found in sedimentary strata from three different geological units of Jurassic, Triassic, and Eocene "ages" (supposedly from 35 to 245 million years old). It has been demonstrated that these uranium ore deposits formed as a result of uranium being transported through the sedimentary strata by ground waters, so this coalified wood would have been saturated in uranium-rich ground waters. Polonium produced by radioactive decay of some of the uranium would have also been present in the ground waters, and thus polonium atoms must have been preferentially attracted by sulfur and selenium atoms in nucleation centers, where they decayed to form the surrounding radiohalos. However, only ^{210}Po radiohalos were found in this partially coalified wood. The other polonium radiohalos did not form, which implies that because those polonium isotopes decay even more rapidly than ^{210}Po, there was insufficient time for them to diffuse through the coal and be attracted to the radiocenters. Thus, it is possible to deduce that the time for infiltration and formation of the ^{210}Po radiohalos would have only been a few months; otherwise the ^{210}Po would have decayed before being concentrated in the radiocenters.

However, many of these ^{210}Po radiohalos are elliptical, which means that after they had formed they were squashed. Even more remarkable is the observation that some of these squashed ^{210}Po radiohalos also have the normal spherical ^{210}Po ring superimposed on them. This means that after being squashed, there was still enough ^{210}Po in the radiocenters to form continuing normal spherical ^{210}Po radiohalos. In other words, there could only have been a few months between infiltration of the ground waters into the partially coalified logs and compression of the host sedimentary strata. Significantly, these so-called dual ^{210}Po radiohalos were found in partially coalified wood in each of the three different sedimentary formations that allegedly span more than 200 million years of the uniformitarian timescale. However, there was only the one groundwater infiltration event to form these radiohalos in these three sedimentary formations, followed by the same earth movement event responsible for compressing these strata and uplifting them to form the Colorado Plateau. Furthermore, these ground waters would have been present in the sedimentary rock units from the time of the deposition of the sediments. Thus, the deposition of these three sedimentary rock units

5 R. V. Gentry, W. H. Christie, D. H. Smith, J. F. Emery, S. A. Reynolds, R. Walker, S. S. Christy and P. A. Gentry, 1976, Radiohalos in coalified wood: New evidence relating to the time of uranium introduction and coalification, *Science*, 194: 315-318.

supposedly spanning more than 200 million years, followed by the formation of the ^{210}Po radiohalos in the partially coalified logs within them, and the earth movements causing compression and uplift of the plateau, all had to happen within a few months, rather than over those supposed 200 million years required by the uniformitarian scenario. In the same partly coalified wood were uranium radiohalos. Analyses of their radiocenters revealed large quantities of parent uranium, but hardly any daughter lead, confirming that the parent uranium and these radiohalos had only been generated a few thousand years ago.

Radiocarbon and Tree Rings

The problems with the radiocarbon dating method were discussed earlier. It was concluded that, because of long-age assumptions in conventional usage of this method, glaring inconsistencies and contradictions in geochronology have been misunderstood and the implications ignored. Instead, over the past 25 years, the use of the more sensitive and accurate accelerator mass spectrometry (AMS) technique for radiocarbon analyses has revealed significant evidence in favor of a young earth and a recent global Flood cataclysm. In particular, the presence of significant radiocarbon levels, well above equipment detection limits, in deep-earth diamonds that are supposedly 1 to 3 billion years old can only be reconciled if the diamonds are instead only thousands of years old, which also implies the earth is young.[6] The hardness of diamonds and the fact that they cannot be contaminated *in situ* with recent carbon underlines the significance and robustness of this discovery and its implications. Furthermore, the finding of almost identical detectable levels of radiocarbon in Eocene, Cretaceous, and Pennsylvanian coal seams, which in uniformitarian terms are dated at 40 to 350 million years old, indicates that all this fossil plant material was buried essentially at the same time only thousands of years ago, another testimony to the Flood cataclysm being only 4,500 years ago.[7] Consistent with this evidence are the radiocarbon levels found in the fossilized wood from Oligocene, Eocene, Cretaceous, Jurassic, Triassic, and Permian strata, conventionally dated from 32 to 250 million years old, that instead indicate that fossilized wood is only thousands of years old.[8]

---

6 J. R. Baumgardner, A. A. Snelling, D. R. Humphreys and S. A. Austin, 2003, Measurable ^{14}C in fossilized organic materials: Confirming the young earth Creation-Flood model, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 127-147; J. R. Baumgardner, 2005, ^{14}C evidence for a recent global Flood and a young earth, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 587-630.

7 Baumgardner et al, 2003; Baumgardner, 2005.

8 A. A. Snelling, 1997, Radioactive "dating" in conflict! Fossil wood in ancient lava flows yields radiocarbon, *Creation Ex Nihilo*, 20 (1): 24-27; A. A. Snelling, 1998, Stumping old-age dogma: Radiocarbon in an "ancient" fossil tree stump casts doubt on traditional rock/fossil dating, *Creation Ex Nihilo*, 20 (4): 48-51; A. A. Snelling, 1999, Dating dilemma: Fossil wood in "ancient" sandstone, *Creation Ex Nihilo*, 21 (3): 39-41; A. A. Snelling, 2000, Geological conflict: Young radiocarbon dating for ancient fossil wood challenges fossil dating, *Creation Ex Nihilo*, 22 (2): 44-47; A. A. Snelling, 2000, Conflicting "ages" of Tertiary basalt and contained fossilized wood, Crinum, central Queensland,

This evidence of detectable radiocarbon (real, not contamination) in "ancient" fossil wood has a significant bearing on another form of dating used by archaeologists, namely, tree-ring dating or dendrochronology. This method is based on the annual growth rings and their patterns in common trees. Both living and dead trees have been used in dendrochronology by matching sequences of ring patterns, between living trees and wooden beams cut from contemporary trees, with still earlier wooden beams in older houses and buildings, and then with logs buried in soils and peat swamps. Of course, the ring patterns are produced in the trees mainly by the temperature and precipitation variations from season to season and year to year.

The longest tree-ring chronology first established was achieved using the stunted bristlecone pine, found primarily in the White Mountains of California where the semi-desert habitat has facilitated the great longevity of this tree, and has permitted good preservation of the dry wood after death:

> Microscopic study of growth rings reveals that a bristlecone pine tree found last summer at nearly 10,000 feet began growing more than 4600 years ago and thus surpasses the oldest known sequoia by many centuries....Many of its neighbors are nearly as old; we have now dated 70 bristlecone pines 4000 years old or more.[9]

Thus, a continuous master tree-ring chronology has been erected reaching back over 7,000 years based on several living trees and 17 specimens of dead wood.[10] Further work has extended this chronology back to nearly 8,700 years (to 6700 BC), and includes the oldest living tree, which is claimed to be more than 4,600 years old.[11]

In Europe the most important tree for dating and for detailed calibration purposes is the oak.[12] This is partly because the oak very rarely has missing annual growth rings. The oak is also ideal because it is a long-lived, large tree that displays good resistance to decay after death. In contrast, the widespread alder may lack up to 45 percent of its annual rings.[13]

Australia, *Creation Ex Nihilo Technical Journal*, 14 (2): 99-122; A. A. Snelling, 2008, Radiocarbon in "ancient" fossil wood, *Acts & Facts*, 37 (1): 10-13; A. A. Snelling, 2008, Radiocarbon ages for fossil ammonites and wood in Cretaceous strata near Redding, California, *Answers Research Journal*, 1: 123-144.

9 E. Schulman, 1958, Bristlecone pine, oldest living thing, *National Geographic*, 113: 355.

10 D. W. Ferguson, 1970, Dendrochronology of Bristlecone pine, *Pinus aristata*. Establishment of a 7484-year chronology in the White Mountains of eastern-central California, USA, in *Radiocarbon Variations and Absolute Chronology,* I. U. Olsson, ed., Proceedings of the 12th Nobel Symposium, New York: John Wiley & Sons, 571-593.

11 C. W. Ferguson and D. A. Graybill, 1983, Dendrochronology of Bristlecone pine: A progress report, *Radiocarbon*, 25: 287-288.

12 M. G. L. Baillie, 1992, *Tree-ring Dating and Archaeology*, Chicago: The University of Chicago Press, Chicago.

13 B. Huber, 1970, Dendrochronology of central Europe, in *Radiocarbon Variations and Absolute Chronology*, I. U. Olsson, ed., Proceedings of the 12th Nobel Symposium, New York: John Wiley &

The question arises as to how these tree-ring chronologies are constructed, when dead trees and wood are used to extend the so-called master curves back beyond the ages of the living trees. The process of constructing a master curve for a long tree-ring chronology starts with living trees or timbers where the zero-age ring is present and the year of felling is known. The timescale is then extended using large felled timbers with ring-width patterns sufficiently overlapping the existing chronology to be certain of a unique match. This is known as cross-dating, that is, being able to associate, on the basis of duplication of pattern, a tree-ring sequence of unknown age with one of known age. This, of course, is based on the assumption that trees of the same species growing in the same or similar localities should have similar temporal patterns of ring widths that are uniquely defined, like a signature, by their common history. When no overlap is found in the ring patterns between two pieces of wood, a "floating" chronology is established, which is a sequence, possibly built up from several pieces of wood, the position of which in time is not known. The floating chronology can only be tied down if pieces of wood providing the missing links are found. It is here that radiocarbon analyses can provide approximate ages for wood samples, to show whether they are likely to be of value in linking or extending existing chronologies.[14] In other words, radiocarbon dating is used to match tree-ring sequences between different wood samples, enabling the construction of the master curves of the tree-ring chronologies.

Highly significant is the fact that the tree-ring chronologies as established have been used to calibrate radiocarbon dating. A set of 315 radiocarbon measurements on bristlecone pine samples, used to construct that tree-ring chronology, was used to construct the first continuous calibration curve for radiocarbon against tree-ring chronology from 5200 BC to the present.[15] One of the prominent features of this calibration curve was the presence of numerous "wiggles," with wavelengths of 100-300 years, superimposed on longer-term variations. This calibration curve attracted much criticism, because it had been drawn by eye through the measure points, rather than using a statistical curve fit. A great deal of work was done by others attempting to establish whether or not these wiggles were valid or a product of the imprecision of the measurements. It was maintained that the second-order wiggles in the calibration curve were an artifact of statistical uncertainties in the data and had no real meaning.[16] However, the reality of these wiggles in the ancient radiocarbon record (around 3500 BC) was finally established.[17] In the

Sons, 233-235.

14 S. Bowman, 1990, *Radiocarbon Dating*, London: British Museum Publications.

15 H. E. Suess, 1970, Bristlecone-pine calibration of the radiocarbon time-scale 5200 BC to the present, in *Radiocarbon Variations and Absolute Chronology*, I. U. Olsson, ed., Proceedings of the 12th Nobel Symposium, New York: John Wiley & Sons, 303-311.

16 G. W. Pearson, J. R. Pilcher, M. G. L. Baillie and J. Hillam, 1977, Absolute radiocarbon dating using a low altitude European tree-ring calibration, *Nature*, 270: 25-28.

17 A. F. M. DeJong, W. G. Mook and B. Becker, 1979, Confirmation of the Suess wiggles: 3200-3700 BC, *Nature*, 280: 48-49.

meantime, a bewildering number of calibration curves appeared, together with an equally confusing number of statistical interpretations and compilations of the curves. These have now all been superseded, in the period back to 2500 BC at least, by curves that have been adopted as the new international standard.[18]

The convoluted shape of these calibration curves introduced ambiguities into radiocarbon dating within many periods, since a single radiocarbon "age" can correspond to more than one historical age. These ambiguities can only be resolved by applying historical constraints, if available. In the dating of wood samples to construct a tree-ring chronology, these ambiguities may be avoided if a piece of wood spanning more than about 50 growth rings can be ^{14}C dated. This tree-ring sequence then forms a small "floating" calibration curve itself, which can be "wiggle-matched" with the known calibration curve to hopefully yield a much more accurate timespan for the growth of the wood in that particular sample. However, to obtain the highest-quality calibration curve, it is desirable to ^{14}C date wood samples representing single annual growth rings. Nevertheless, in the case of the bristlecone pine, its small size limits the precision that can be obtained, because of the limited amount of sample for analysis. Thus, there are many uncertainties in the construction of the bristlecone pine tree-ring chronology and the calibration of radiocarbon against it, which is why other work has been devoted to obtaining more detailed calibration curves from larger trees, such as the oaks in Europe.

Nevertheless, because of the uncertainties in radiocarbon dating around about 1000 BC back to where it can be reliably calibrated against historically dated materials,[19] and because of the detectable radiocarbon corresponding to "dates" of 20,000 to 45,000 years in fossilized wood conventionally dated 32 to 250 million years,[20] it is by no means certain that radiocarbon analyses can be used to "date" these tree-ring chronologies back to 8,700 years ago or further. Furthermore, the cross-matching of tree rings between different samples of wood from different trees or logs is fraught with difficulty. The width of rings is easily influenced by the external environment, and is, therefore, variable if the trees had come from different areas with different weather patterns and thus different growth variations.[21] Indeed, even the production of one growth-ring each year is not a certain process, and it is possible under certain conditions for a tree to miss a growth-ring or to produce two growth-rings in one season.[22]

18 G. W. Pearson and M. Stuiver, 1986, High-precision calibration of the radiocarbon time scale, 500-2500 BC, *Radiocarbon*, 28: 839-862; M. Stuiver and G. W. Pearson, 1986, High-precision calibration of the radiocarbon time scale, AD 1950-500 BC, *Radiocarbon*, 28: 805-838.

19 H. N. Michael and E. K. Ralph, eds., 1970, *Dating Techniques for the Archaeologist*, Cambridge, MA: MIT Press.

20 Snelling, 1997, 1998, 1999, 2000, 2008.

21 A. P. Dickin, 2005, *Radiogenic Isotope Geology*, second edition, Cambridge, UK: Cambridge University Press, 389.

22 Baillie, 1992, 51-52.

These issues of the effects of climatic variations and weather patterns on the growth of tree rings would have been particularly critical in the first thousand or more years after the Flood, when climatic conditions and weather patterns were extremely variable, due to the after-effects of the Flood cataclysm and the climatic readjustments associated with the post-Flood Ice Age. Continuing volcanic eruptions spewing aerosols and gases into the atmosphere, and the unpredictable directions of daily storm tracks, would have resulted in big differences in weather conditions in adjoining geographic areas, plus seasonal variations would have been largely obliterated. It was extremely likely that trees would have grown multiple rings in many of the early calendar years after the Flood. Therefore, all tree-ring chronologies are likely to be seriously in error prior to 1000 BC, because they are all based on the assumption of essentially one growth-ring per calendar year. Consequently, tree-ring chronologies, such as that derived from the bristlecone pines, cannot validly date back to the claimed 8700 BC. Instead, the trees used in constructing the chronology grew on the post-Flood land surface in the last 4,500 years.

112

Human Population Statistics and Lifespans

In the final analysis, the only real reliable recorder of time is man himself! In any kind of natural process that might be used to determine past time, there is always the possibility that the rates may have changed, as well as uncertainty regarding its initial condition. It is thus absolutely impossible to know beyond question that a particular formation or deposit has a certain age, unless that age is supported by reliable human records of some kind.

It is, therefore, highly significant that no truly verified archaeological datings go back beyond about 3000 BC or even later. Older dates have been frequently assigned to various archaeological artifacts and evidences of past human cultures, but these are always based on radiocarbon or other geological methods, rather than written human records. There are numerous extant chronologies that have been handed down from various ancient peoples, and it is highly significant that none of them yield acceptable evidence that the history of these or other peoples stretch back beyond the biblical date for Noah's Flood.

Evolutionary anthropologists insist that man (*Homo sapiens*) has been around much longer than even the biblical timescale back to creation, since man supposedly evolved from his hominid ancestors. The latest suggestion is that *Homo sapiens* existed for at least 185,000 years before they developed agriculture.[1] During this long period of human cultural development, called the Stone Age, the world population of humans is said to have been roughly constant, between 1 and 10 million people. Of course, all through that time those people buried their dead, often with artifacts. According to that scenario, it is easily calculated that these Stone Age people would have buried at least 8 billion bodies.[2] If the evolutionary timescale is correct, then buried human bones should be able to survive intact for much longer than 200,000 years. Thus, many of the supposed 8 billion buried Stone Age skeletons should have survived to still be easily found near the present land surface, along with all their buried artifacts. However, only a few thousand

1 I. McDougall, F. H. Brown and J. G. Fleagle, 2005, Stratigraphic placement and age of modern humans from Kibish, Ethiopia, *Nature*, 433 (7027): 733-736.

2 E. S. Deevey, 1960, The human population, *Scientific American*, 203 (3): 194-204.

have been found. This must imply that the Stone Age was much shorter than evolutionists believe, perhaps only a few hundred years in many areas.

On the other hand, the Bible pictures pre-Flood man as having been destroyed by the Flood cataclysm, so that all traces of human remains, whether bones, artifacts, or cultural remnants, must date from after the Flood, only about 4,500 years ago. The biblical record, in fact, describes the dispersal of people after the Flood from the same geographical areas implied also by archeology and secular history. The most ancient people leaving historical records were the inhabitants of the Tigris-Euphrates valley, the Nile valley of Egypt, and other near-eastern areas. This correlates perfectly with the biblical record, that pictures Noah and his descendants first inhabiting the Tigris-Euphrates area, followed by a centrifugal movement of tribes outwards from the first kingdom of Babylon (Babel, Genesis 11:9). The so-called Stone Age, therefore, the evidence for which is found on and in the post-Flood land surface, must correlate with this dispersal of tribes from the Tigris-Euphrates area, given that Noah and his descendants brought a sophisticated technology with them from the pre-Flood world when they re-established civilization with supporting agriculture, etc. The biblical record describes the dispersion from Babel as a dramatic event. The tribes that moved into inhospitable regions without having taken sufficient technology with them from their former civilization at Babel would have had to survive by reverting to a stone tool technology to hunt animals and for agriculture, until life became more settled and they had time to re-develop better tools and technology.

The archaeological testimony is confirmed further by botanical studies. Systematic agriculture was necessary for the existence of stable and civilized communities, and so the beginning of agriculture would be one of the best indicators of the beginning of post-Flood culture. The following comment is therefore significant:

> Thus, we may conclude from present distribution studies that the cradle of Old World plant husbandry stood within the general area of the arc constituted by the western foothills of the Zagros Mountains (Iraq-Iran), the Taurus (southern Turkey), and the Galilean uplands (northern Palestine) in which the two wild prototypes occur together. We may conclude, further, that wheat played a more dominant role than barley in the advent of plant husbandry in the Old World.[3]

It is remarkable, but not surprising, just how many different lines of evidence of a historical nature point back to a time around 3000 BC as dating the beginning of true civilization practicing agriculture.[4] The usual evolutionary picture has man existing as hunters and gatherers for at least 185,000 years during the Stone Age, before discovering agriculture as little as 5,000 years ago. However, the available

---

3 H. Helbaek, 1959, Domestication of food plants in the Old World, *Science*, 130: 365.

4 Deevey, 1960; J. O. Dritt, 1990, Man's earliest beginnings: discrepancies in evolutionary timetables, in *Proceedings of the Second International Conference on Creationism*, vol. 1, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 73-78.

paleoanthropological and archaeological evidences show that Stone Age men were as intelligent as we are. So the obvious question is why did none of the 8 billion people estimated to have lived during the Stone Age discover that food plants could be grown from seeds in a systematic manner? To the contrary, it is far more likely that men were only without agriculture for a very short time after the Flood, if at all, given the biblical account of Noah's vineyard. Indeed, man similarly began to make written records only about 4,000-5,000 years ago. Yet so-called Stone Age men built megalithic monuments, made beautiful cave paintings, and even kept records of lunar phases.[5] So why would such men wait more than 185,000 years before using the same skills to record history? The only logical conclusion is that the timescale for the existence of man and his civilization had to have been drastically shorter, much more likely in keeping with the timescale of the biblical record.[6]

There have been speculations and claims about earlier periods of human civilization, but nothing concrete. For example, with reference to Egyptian civilization, it has been stated:

> We think that the First Dynasty began not before 3400 and not much later than 3200 BC....A. Scharff, however, would bring the date down to about 3000 BC; and it must be admitted that his arguments are good, and at any rate it is more probable that the date of the First Dynasty is later than 3400 BC than earlier.[7]

Even this date is very questionable, as it is based primarily upon the king-lists of Manetho, an Egyptian priest around 250 BC, whose work has not been preserved, except in a few inaccurate quotations in other ancient writings. As has been pointed out long ago:

> The number of years assigned to which king, and consequently the length of time covered by the dynasty, differ in these two copies, so that, while the work of Manetho forms the backbone of our chronology, it gives us no absolute reliable chronology. It is for this reason that the chronological schemes of modern scholars have differed so widely.[8]

Other scholars think that some of Manetho's lists may actually represent simultaneous dynasties in upper and lower Egypt, which would still further reduce the date for the beginning of the Egyptian dynasties. Furthermore, the length of the pre-Dynastic period is quite unknown, but there is no necessary reason to regard it as no more than a few centuries at the very most.

5 A. Marchack, 1975, Exploring the mind of Ice Age man, *National Geographic*, 147: 64-89.

6 Dritt, 1990.

7 H. R. Hall, 1956, Egypt: Archeology, in *Encyclopedia Britannica*, vol. 8, 37.

8 G. A. Barton, 1941, *Archeology and the Bible*, Philadelphia: America Sunday School Union, 11.

In Babylonia, the earliest peoples leaving written monuments were the Sumerians, who were later displaced by the Semitic Babylonians. These people likewise are dated about the same time:

> The dates of Sumer's early history have always been surrounded with uncertainty, and have not been satisfactorily settled by tests with the new method of radiocarbon dating….Be that as it may, it seems that the people called Sumerians did not arrive in the region until nearly 3000 BC.[9]

The Egyptians and Babylonians were probably of Hamitic and Semitic origin (from Noah's sons Ham and Shem, respectively), as were most of the other tribes who settled in Africa and Asia. The Japhetic peoples (descended from Noah's son Japheth), on the other hand, according to the Table of Nations of Genesis 10 (which the highly-respected archaeologist, Dr William Foxwell Albright, regards as "an astonishingly accurate document"[10]), migrated largely into Europe, where they became the people of the Indo-European languages who radiated from a common center (probably in central Europe). Studies of ancient agricultures in Europe, based mainly on pollen analyses and radiocarbon dating, point to the same conclusion as linguistic studies for the date of this migration at around 2600-2800 BC.[11] On the other hand, the earliest historical cultures in China date to somewhat later than this time:

> The earliest Chinese date which can be assigned with any probability is 2250 BC, based on an astronomical reference in the *Book of History*.[12]

This later date for the settlement of China is significant support for the biblical migration from Babel, the journey to China logically taking a little longer to be achieved.

The worldwide testimony of trustworthy, recorded history is, therefore, that such human history begins about 2500-3000 BC and not substantially earlier. This is indeed surpassingly strange if men actually had been living throughout the world for many tens or hundreds of thousands of years prior to these dates! But on the other hand, if the biblical records are true, then this is of course exactly the historical evidence we would expect to find. All trace of earlier human civilization was obliterated by the Flood cataclysm, and the dispersal from Babel, where human civilization was re-established, occurred only about a century later. Of

---

9 S. N. Kramer, 1957, The Sumerians, *Scientific American*, 197 (1): 72.

10 W. F. Albright, 1955, Recent discoveries in Bible lands, in *Young's Analytical Concordance*, New York: Funk & Wagnalls, 30.

11 E. Thieme, 1958, The Indo-European language, *Scientific American*, 199 (1): 74; J. Trols-Smith, 1956, *Neolithic* period in Switzerland and Denmark, *Science*, 124: 879.

12 R. Linton, 1955, *The Tree of Culture*, New York: Alfred A. Knopf Publishing Company, 520.

course, it is also relevant to mention again that the worldwide incidence of Flood legends, as discussed in an earlier chapter, is also confirmation of the historicity of the biblical record. It is not at all, therefore, unreasonable to conclude that the clear testimony of all recorded human history points back to the stark reality of the global Flood cataclysm, which totally reshaped the earth's surface and remade the world in the days of Noah.

The statistics of human populations give further support to the biblical record of human history. Ever since the famous studies of Malthus, it has been known that human populations (applied to animal populations by Charles Darwin in developing his theory of evolution by natural selection) have tended to increase geometrically with time. That is, the world population tends to double itself repeatedly at approximately equal increments of time. This is the basis for projections that the world will become overpopulated:

> The central document which has influenced me is that of Malthus, who 160 years ago gave his theory that there was a natural tendency for man, like any other animal, to increase by geometrical progression....[13]

This means that, if the time for the population to double itself is called T, then starting from an initial population of two people, after T years there would be four people, after twice T years there would be eight people, after three times T years 16 people, and so on. At any time nT after the start of this process, the total population of the world would be two multiplied by itself in n times or two raised to the nth power, 2^n. The total time required to attain this population is nT, but this can be determined only if the time increment T and the exponent n are known. The latter is easily found by equating numeral 2^n to the present world population, which is more than 6.5 billion people. This calculation gives a value of n of almost 32. Since the value $n = 1$ corresponds to the initial human pair, it is obvious that the starting population of one man and one woman has gone through more than 30 "doublings."

The value of T, the time increment for one doubling, is less certain. However, there are data that enable a reasonable calculation:

> At the time of the birth of Christ, there presumably were some 250 to 350 million persons on this planet. Some 700 years later, there was about the same number—say 300 million—a long slow decline in total population having been followed by a compensating increase.
>
> It took roughly 950 more years, namely, until 1650, for this 300 million to double to 600 million. But then it took only 200 years, from 1650 to 1850, for the next doubling up to 1200 million, or 1.2 billion. From

13 C. Darwin, 1958, Population problems, *Bulletin of the Atomic Scientists*, 114: 322.

> 1850 to 1950, in only 100 years, the earth's population doubled again, to about 2.4 billion.[14]

Obviously the figures given for world populations prior to the modern era are only guesses, since no one has any real knowledge of the populations of America, Africa, Asia, etc., during those centuries. The 1650 figure is the first one with any degree of validity. From 1650 to 1950, therefore, the population increased from 600 million to 2,400 million, representing two doublings in 300 years, or a value of T of 150 years. It could be argued that this figure is perhaps too low, because of being influenced by the very rapid population growth of the past century, which has spectacularly accelerated in recent decades. However, this is not typical, and is attributable almost entirely to advances in medicine and sanitation:

> It is fallacious to think that booming birth rates are responsible for this speed-up. Actually, birth rates have declined in many countries. Falling death rates account for most of the spectacular growth.[15]

Indeed, the spectacular population growth in the last fifty years to now over 6.5 billion people worldwide is very much due to advances in medicine and general health care, with rising living standards in many countries. However, all things considered, it would seem that the period from 1650 to 1850 would be as typical as any for one doubling. The accuracy of the figures, then, may not have been as good as it has been in more recent years, but birth rates would have still been higher than they are today to compensate for the poorer quality of health care in that period. One could thus split the difference between the previous 150-year figure and this 200-year figure and estimate that the possible value of T is about 175 years. This value, multiplied by the almost 32 doubling, leads us back to about 2500 BC as the time of the birth of Noah's first son.

Of course, this calculation is not completely rigorous, because of the uncertainty in the value of the doubling period. However, this calculation is certainly far more reasonable than that necessitated by the scenario that the first human pair evolved up to one million or more years ago. In that scenario the figure for the doubling period would be more than 30,000 years! Of course, that scenario is simply ludicrous, particularly when one considers that, to compensate for the population doublings of a period of only 200 or so years in recent recorded history, the doubling period in man's early history would have to have been 40,000 to 50,000 years! On the other hand, if one adds to the far more realistic and reasonable calculation outlined above all the other evidence for the beginning of the present order of human civilization on the earth after the Flood only several thousands years ago, then this further testimony is quite impressive.

---

14 W. Weaver, 1954, People, energy and food, *Scientific Monthly*, 78: 359.

15 R. C. Cook, 1956, The population bomb, *Bulletin of the Atomic Scientist*, 12: 296.

Furthermore, when the biblical account of human history is accepted as reliable and true, one must also reckon with the probability that population increase rates in the early centuries after the Flood, as well as those before the Flood (when "man began to multiply on the face of the earth" as recorded in Genesis 6:1), may have been abnormally high, owing to the great longevity in human lifespans at that time. According to the biblical accounts, before the Flood men lived on average for 900 years or more. Thus, they had many more years in which to produce many more children. One of the strongest evidences of the validity of these figures is the fact that, after the Flood, the ages of the patriarchs exhibit a slow but steady decline from that of Noah who lived 950 years, through Eber 464 years, Abraham who died at 175 years, and Moses who died an old man at 120 years, to the familiar biblical 70-year lifespan (Psalm 90:2), which is very close to the average lifespan today. Large early post-Flood populations are also intimated by the large listing of people groups (Table of Nations) in Genesis 10, and the account of the dispersion of these people groupings from Babel in Genesis 11. Thus, these early high rates of doubling would more than counterbalance whatever evidence there may be of slower rates during the first 1,500 years after Christ. Furthermore, they would likely reduce the average doubling period and thus reduce the calculated time back to the birth of Noah's first son, in line with the tight biblical chronology.

When the lifespans of the pre-Flood and early post-Flood patriarchs are graphically plotted, as in Figure 1 (page 441), it is immediately evident that in the early post-Flood period there was a dramatic and systematic decrease in human lifespans, indicating that something must have occurred during the Flood to trigger this dramatic post-Flood decline in human lifespans. The long-standing explanation has been the collapse of a pre-Flood water vapor canopy at the outset of the Flood year, when "the windows of heaven were opened" (Genesis 7:11).[16] It was argued that the presence of the pre-Flood vapor canopy shielded the pre-Flood human population from the radiations bombarding the earth from outer space that would otherwise have had damaging effects on the human genome. Radiations from outer space are known to significantly increase the generation of deleterious mutations in the human genome that cause deterioration, increasing the rate of aging and thus shortening lifespans. However, as has been detailed earlier (see chapter 83), available evidence no longer supports the concept of a significant pre-Flood water vapor canopy. Therefore, the levels of radiations coming from outer space before and after the Flood were probably not all that different from one another. Thus, the dramatic progressive decline in the lifespans for the post-Flood patriarchs must have been due to some other cause.

It is now known that if a large fraction (50 percent or more) of the population is wiped out, the remaining population suffers from a genetic bottleneck. Such bottlenecks are well known for increasing the effects of genetic drift and natural selection, causing the rapid deterioration of a species' genome. Thus, a reputable

16 Whitcomb and Morris, 1961.

physical explanation for the systematic decrease in the longevity of the post-Flood patriarchs would be a loss of "longevity genes" by genetic drift. This genetic drift would have resulted from the dramatic population decrease at the Flood (from a pre-Flood human population of perhaps a billion or more people to just Noah's three sons and their wives), and the subsequent splitting of that gene pool as a result of the division and dispersion of the human population at Babel.

A recently-discovered viable explanation of longevity involves the role of telomeres, which are lengths of repetitive DNA on the ends of chromosomes that serve to protect the stored genetic information. Each cell division reduces the lengths of the telomeres until they are eventually lost. Once that happens, the genetic information stored on the chromosomes can be corrupted, resulting in cells dying. On the other hand, an enzyme called telomerase has been found to elongate the telomeres. Thus, when telomerase genes are added to cultured human cells they give them an unlimited capacity for cell divisions.[17] Unfortunately, telomerase is often active in cancer cells, too, so they divide uncontrollably. Nevertheless, telomerase is active in the reproductive cells, which means that the information passed on to offspring has been protected and is, therefore, still fairly "fresh." However, once the telomerase becomes inactive, the telomeres "age" until chromosomes become unprotected, resulting in the corruption of genetic information, cell death, and, ultimately, the death of the whole organism.

Further support for a genetic cause of longevity is provided by the mechanism for the premature aging disease called progeria. Those who suffer from progeria age five to ten times faster than normal and die by the age of about 13, usually from heart attack or stroke. It has recently been discovered that progeria is caused by a mutation changing only one of the 25,000 base pairs in the lamin A (*LMNA*) gene.[18] Thus, if this single change from cytosine to thymine can cause a ten-fold drop in lifespans, then perhaps a similar mutation could have caused a lifespan drop by a similar factor after the Flood.

In conclusion, the biblical record of post-Flood human history is convincingly vindicated, both as to its nature and to its duration, by all true historical and archaeological records, and by many lines of scientific evidence. The shortness of this post-Flood human history is attested to by the shortness of recorded history, the recent advent of agriculture, the paucity of Stone Age skeletons and artifacts, and human population statistics, while the dramatic early post-Flood progressive and systematic decrease in human lifespans is supported by the mutational outcomes of the genetic bottleneck of the human population at the time of the Flood, and then Babel.

17 A. G. Bodnar, N. Ouellette, M. Frolkis, S. E. Holt, C.-P. Chie, G. B. Morin, C. B. Harley, J. W. Shay, S. Lichtsteiner and W. E. Wright, 1998, Extension of life-span by introduction of telomerase into normal human cells, *Science*, 279 (5349): 349-352.

18 M. Eriksson et al, 2003, Recurrent *de nova* point mutations in lamin A cause Hutchinson-Gilford progeria syndrome, *Nature*, 423 (6937): 293-298.

Section X

Problems for Biblical Geology Solved—Formations Implying Slow Deposition

113

Deposition and Lithification

Perhaps the major objection to the concept of geological catastrophism on the scale envisaged in the Flood is that many rock formations appear to be of such character, and contain such features, as to have required long ages for their construction and development, much longer than the biblical chronology and the Flood year could allow.[1] However, it has already been shown how many geologic formations do give real evidence of their catastrophic formation, especially those rock layers that contain large numbers of fossils, and the great many that have been water-laid, as well as all the huge volcanic outpourings of lavas and explosive eruptions of volcanic ash layers. Furthermore, it has been conclusively demonstrated how the radioactive and other dating methods, which are supposed to have provided an absolute chronology for earth history in terms of millions and billions of years, can instead be understood in terms of the framework provided in the biblical record.

Nevertheless, there are a number of unique types of deposits which, although they may not yield absolute time estimates, do give the superficial appearance of requiring great ages to have formed. Space only permits a brief examination here of a few of these, but it needs to be emphasized that it is again quite possible to explain these deposits and geologic formations from the perspective of biblical geology.

Deposition and Lithification

Many types of sedimentary deposits are claimed to be only explainable in terms of long periods of time. Of course, it is natural to think that great masses of water-laid sediment beds, often thousands of feet thick, must have taken long ages to have been deposited. However, this is reckoning in uniformitarian terms, that is, assuming that today's observed, generally slow rates of sediment deposition are the same rates at which all sedimentary rock layers have been deposited in the past. On the other hand, it is not difficult to see, if one is willing to see, how

1 For example, D. Wonderly, 1977, *God's Time-Records in Ancient Sediments*, Flint, MI: Crystal Press; and D. E. Wonderly, 1987, *Neglect of Geologic Data: Sedimentary Strata Compared with Young-Earth Creationist Writings*, Hatfield, PA: Interdisciplinary Biblical Research Institute.

they could have formed in a very short period if the hydraulic and sedimentation activity were intense enough, as it undoubtedly was during the Flood.

Even though this surpassingly important discontinuity in uniform geologic processes is spurned and ignored by contemporary geologists, it is now generally recognized that sedimentary thicknesses are not necessarily an indication of the *duration* of deposition.

> The rate of sedimentation shows extremely wide variations from place to place at the present time. It is virtually impossible to determine an average rate of sedimentation for the present; it is more difficult to do so for past times.[2]

Most contemporary geologists, therefore, are not as committed to the uniformitarianism advocated by Charles Lyell, in which he rigidly assumed that the deposition of sediment layers in the past must always have occurred at the rates we observe today. Many contemporary geologists are now open to catastrophism when and where the evidence demands it, but still cling to uniformitarian assumptions by insisting many catastrophes during earth history were only local or regional in extent, and were but brief episodes that interrupted the normal slow-and-gradual geological processes operating over eons of time. In the words of the late Derek Ager:

> In a phrase that has often been quoted since, I have summed up geological history as being like the life of a soldier: 'Long periods of boredom and short periods of terror'.[3]

However, as discussed previously at length (see chapters 63-67), there is abundant, convincing evidence that the sediments that compose most sedimentary rock layers, whether sandstones, shales or limestones, were deposited under catastrophic conditions on a scale unlike normal, or even catastrophic, conditions and rates of geologic processes experienced today. For example, the cross-beds in sandstones are remnants of underwater sand waves that testify of the sand being transported and deposited by fast-moving currents in deep water, which would have resulted in thick sand beds of regional extent in a matter of hours to days. Even the thin layers or laminae frequently abundant in fine-grained shales, often considered to represent successive seasonal deposition over long time periods, have been shown instead to have been rapidly deposited all at once by hurricane-velocity, surging sediment-laden water and turbidity currents. Perhaps even more remarkable is the evidence that limestones, which are usually claimed to have formed as a result of tiny lime particles slowly settling on the ocean floor with the debris from marine

2 F. J. Pettijohn, 1957, *Sedimentary Rocks*, second edition, New York: Harper & Row, 688.

3 D. Ager, 1993, *The New Catastrophism: The Importance of a Rare Event in Geological History*, Cambridge, England: Cambridge University Press, xix.

organisms over countless years, were instead deposited catastrophically, either as lime sands transported in sand waves leaving behind cross-beds, or as lime muds in turbidity currents or debris flows that entombed marine organisms.

Yet the uniformitarian mindset of contemporary geologists is usually perpetuated by an appeal to the laws of physics, such as Stokes' Law, which describes the way a sediment particle in suspension moves through a fluid such as water under the influence of gravity. By adopting the appropriate figures into the Stokes' Law equation, it is easy to show that fine-grained sediments must have taken a long time to settle out of suspension in the water that transported them, so it is thus claimed that catastrophic deposition of such fine-grained sediments is just physically not possible.

The underlying problem with this argument is that it assumes we understand how all facets of geological processes interrelate and work together, when in fact we are still making new and surprising discoveries. The following relevant example is appropriate here.

Mount Pinatubo in the Philippines erupted in 1991 and large quantities of volcanic ash fell into the sea. Volcanic ash is, of course, largely fine-grained, akin to the sediment particles in shales, which sometimes contain a large component of volcanic ash. Thus, application of Stokes' Law would suggest a timescale of three months for the volcanic ash particles to settle onto the sea floor. However, it was surprisingly discovered that the resultant ash layer formed on the sea-bed within just three days![4] Obviously, some previously unrecognized factor was not taken into account in the analysis. It was not that the laws of physics had changed in some way making Stokes' Law wrong. Rather, it was the understanding of how the volcanic ash was deposited on the sea floor that was deficient. The ash did not behave as independent particles in suspension, as they would be expected to do according to Stokes' Law. An alternative explanation, supported by laboratory experimental simulations, was that when the ash fell on the ocean surface it produced density currents that rapidly flowed downwards to the sea floor.[5] In other words, the ash falling into the seawater created a fluid of higher density than the surrounding ash-free seawater, so that fluid descended coherently and rapidly through the surrounding seawater. Thus instead of behaving independently, the ash particles in suspension formed a density current that flowed at two to three orders of magnitude greater than expected.[6] Quite clearly, catastrophic conditions dramatically change the way sediments are deposited, even when the sediment particles are fine-grained.

---

4 M. G. Wiesner, Y. Wang and L. Zheng, 1995, Fallout of volcanic ash to the deep South China Sea induced by the 1991 eruption of Mount Pinatubo (Philippines), *Geology*, 23: 885-888.

5 V. Manville and C. J. N. Wilson, 2004, Vertical density currents: A review of their potential role in the deposition and interpretation of deep-sea ash layers, *Journal of the Geological Society,* 161: 947-958.

6 Wiesner et al, 1995.

Deposition of the sediment particles is, however, only the first stage in the process of forming sedimentary rocks. Once deposited, the sediment particles require compaction and solidification to be transformed into sedimentary rock. These processes of diagenesis and lithification are usually claimed to have required long time periods. It has further been claimed that the lithification of muds, for example, requires a thickness of other overlying sediments of at least a mile in order to compact the fine grains, squeeze out the pore water, and provide enough pressure to cause solidification.[7] Thus, any sedimentary rock now appearing at the earth's surface must at some time in its history have had at least a mile of other sediments lying on top of it, which have since been eroded away. Of course, exactly these conditions would have occurred during the global Flood, when enormous thicknesses of sediments were eroded, transported, and deposited on top of one another, the last deposited sediment layers then being subsequently eroded away as the Flood waters retreated off today's land surfaces into the current ocean basins.

This scenario, of course, assumes that vertical pressure is the sole factor affecting compaction and lithification of sediments, whereas it is really only one of many factors:

> The amount and rate of compaction depend on the porosity of the original sediment, on the size and shape of the particles, on the rate of deposition and thickness of the overburden, and on the factor of time.[8]

To these factors should be added the increasing heat generated by the depth of burial, the chemicals in the pore water, and even the tectonic forces of uplift and lateral compression facilitating the removal of the pore water. Tectonics forces unleashed during the Flood would have helped to "squeeze" pore waters out of sedimentary beds, and uplift at the close of the Flood would have caused much contained water to drain away simply due to gravity.

There are two main steps in the overall lithification of sediments to transform them into sedimentary rocks:

> …the following sections describe two common processes of diagenesis… compaction is a reduction in bulk volume of the sediment, caused mainly by the vertical force exerted by an increasing overburden. Compaction is conveniently expressed as a change in porosity brought about by the tighter packing of the grains.…cementation is the deposition of minerals in the interstices of a sediment. It is one of the commonest diagenetic changes, and produces rigidity of a sediment by binding the particles

7 J. L. Kulp, 1950, Flood geology, *Journal of the American Scientific Affiliation,* January: 4.

8 W. C. Krumbein and L.L. Sloss, 1951, *Stratigraphy and Sedimentation*, first edition, San Francisco: Freeman and Company, 217.

> together. Cementation may occur essentially simultaneously with sedimentation, or the cement may be introduced at any later time.[9]

Some have insisted that "the lithification of practically all kinds of sedimentary rock is of necessity a slow change—slow because of the very nature of the several processes involved."[10] However, such dogmatism ignores the field and experimental observations that the process of lithification can take place quite rapidly under some conditions, and thus it is not necessarily related to time.

> Time is a factor, but not the deciding one, and sands, clays, and silts of the Cambrian are known that are as nearly unindurated and little cemented as they were in the days of deposition….On the other hand, some Pleistocene outwash deposits are known that have become fairly well lithified.[11]

Lithification has been defined as follows:

> The conversion of a newly deposited, unconsolidated sediment into a coherent, solid rock, involving processes such as cementation, compaction, desiccation, crystallization. It may occur concurrent with, soon after, or long after deposition.[12]

On the other hand, diagenesis has been defined as:

> All the chemical, physical, and biologic changes undergone by a sediment after its initial deposition, and during and after its lithification, exclusive of surficial alteration (weathering) and metamorphism….It embraces those processes (such as compaction, cementation, reworking, authigenesis, replacement, crystallization, leaching, hydration, bacterial action, and formation of concretions) that occur under conditions of pressure (up to 1 kb) and temperature (maximum range of 100°C to 300°C) that are normal to the surficial or outer part of the earth's crust; and it may include changes occurring after lithification under the same conditions of temperature and pressure.[13]

Many chemical processes are involved in lithification and diagenesis, all of which would have been readily facilitated by conditions during the Flood, because "water

---

9 W. C. Krumbein and L.L. Sloss, 1963, *Stratigraphy and Sedimentation*, second edition, San Francisco: Freeman and Company, 269-271.

10 D. E. Wonderly, 1987, *Neglect of Geologic Data: Sedimentary Strata Compared with Young-Earth Creationist Writings*, Hatfield, PA: Interdisciplinary Biblical Research Institute, 33.

11 W. H. Twenhofel, 1950, *Principles of Sedimentation*, second edition, New York: McGraw-Hill, 279.

12 K. K. E. Neuendorf, J. P. Mehl, Jr., and J. A. Jackson, eds., 2005, *Glossary of Geology*, fifth edition, Falls Church, VA: American Geological Institute, 375.

13 Neuendorf et al, 2005, 176.

is the main agent of diagenesis, and organic matter is an auxiliary."[14] Of course, water was the medium by which most of the sediments were deposited, and an abundance of it would have been trapped between the sediment grains to become the pore water in the sediment layers. Furthermore, under the catastrophic Flood conditions there was an abundance of organic matter available for burial in the sediments, either dispersed through them or in concentrated layers. It is thus obvious that conditions during the Flood, and its immediate aftermath, would have been highly conducive to rapid initiation of diagenesis, with resultant early lithification.

> It seems, rather that diagenesis sometimes follows sedimentation so closely that it begins while the deposit is still on the sea bottom.[15]

Various cementing materials occur in sedimentary rocks, especially silica (quartz) and calcite. "The cementing material may be derived from the sediment or its entrapped water, or may be brought in by solution from extraneous sources."[16] Of course, during the Flood, the waters would have contained many chemicals from the weathering products eroded on a massive scale from across the earth's surface, plus the chemicals introduced into the Flood waters by all the concurrent volcanic activity. So as sediments were deposited, the chemical-laden waters would have been trapped in the pore spaces between the sediments. With compression of the overlying sediments, the chemical conditions changing in the pore spaces of the buried sediments would have resulted in potentially rapid precipitation of the dissolved chemicals, thus facilitating rapid lithification of the sediments.

> It appears that indentation of grain against grain is sufficient to cause lithification....The success of lithification by compaction is correlated directly with the content....Mud will be converted into mudrock by a relatively small thickness of overburden; lithic sandstones require a much greater thickness...intimate grain-to-grain contact in most sandstones must be achieved largely by the introduction of chemical precipitates—that is, cements....The intimate contact of quartz cement with the detrital quartz grain produces a stronger bond than the contact of calcite cement with the quartz grain, but both types of pore filling cause the rigidity that converts a loose pile of sand into rock.[17]

The problem of lithification of sediments is, therefore, not at all a serious one for biblical geology. There are no mysteries or difficulties if these questions are approached, not on the basis of uniformity with present processes, but are

14 Z. L. Sujkowski, 1958, Diagenesis, *Bulletin of the American Association of Petroleum Geologists*, 42: 2694.

15 Sujkowski, 1958, 2697.

16 Krumbein and Sloss, 1963, 271.

17 H. Blatt, 1992, *Sedimentary Petrology*, second edition, New York: W. H. Freeman and Company, 128-129.

envisaged in terms of rapid deposition of great masses of sediments mixed with various chemicals and organic matter, because the conditions in a global Flood quite obviously afforded an ample source of silica, calcite, and other cementing materials. It is highly consistent with the whole character of the catastrophic action, responsible for deposition of the sediments during the Flood, to further the processes of compaction, cementation, drying, etc., leading to final lithification that could have been accomplished quite rapidly.

114

Bioturbation, Hardgrounds, and Trace Fossils

Within many carbonate rock layers are found what are known as hardgrounds, or hardground surfaces. They are particularly evident within the thick Cretaceous chalk beds, but are also found in limestones. Such layers have visible characteristics on their upper surfaces of where marine organisms burrowed into what were then soft sediments, followed by hardening of those surfaces, some erosion of them, and finally the encrustation on them by marine organisms, such as oysters, now fossilized. Many of these apparently eroded surfaces have also been "bored" by sponges and other types of marine animals. Thus, it is claimed that these hardgrounds are a record of the passage of large amounts of time—weeks, months or even years—when there was no sedimentation occurring on these surfaces.[1] The implication is, of course, that because these hardgrounds frequently occur at many levels in chalk and limestone formations, these repeated occurrences of large amounts of elapsed time are hardly compatible with the deposition of these chalk and limestone beds within the year-long Genesis Flood.[2]

A similar elapsed time issue is posed by the preserved evidence in sedimentary strata of bioturbation, and by what are collectively called trace fossils (or ichnofossils), preserved on many sedimentary strata surfaces. Bioturbation occurs when invertebrate animals such as worms and brachiopods, that live within sediments, have continually burrowed through those sediments, destroying the original layering.[3] In the present world, the activity of burrowing animals in underwater sediments can be observed, and results in the total bioturbation of such sediments so that the original layering and other sedimentary structures over time are progressively obliterated (see Figure 55). Because bioturbation requires the passage of time, the degree of bioturbation found preserved in sedimentary strata at numerous levels in the rock record would likewise presumably testify to the passage of perhaps significant amounts of time between the successive deposition of those strata. And because it is claimed that such bioturbation can

---

1 Wonderly, 1987, 12-13.

2 D. J. Tyler, 1996, A post-Flood solution to the chalk problem, *Creation Ex Nihilo Technical Journal*, 10(1): 107-113.

3 R. G. Bromley, 1990, *Trace Fossils: Biology and Taphonomy*, Unwin Hyman, Boston.

take days, weeks, months, or even years, this is taken as proof that these strata cannot have been deposited during the Flood year.

This is same argument that is used with respect to other trace fossils (or ichnofossils), such as invertebrate animal trails and burrows, vertebrate animal footprints (such as the many trackways of dinosaur footprints), and even vertebrate eggs and claimed "nests" (such as those of dinosaurs). Owing to the ubiquity of these trace fossils throughout the Phanerozoic sedimentary strata record, combined with the inferred spans of time necessary for the construction of each trace fossil, trackway, or "nest" of eggs (supposedly at one stratigraphic horizon at a time), such trace fossils have been regularly perceived as an insurmountable challenge to Flood geology. After all, how could dinosaurs, for example, have been repeatedly walking across successive sedimentary strata horizons, leaving behind their footprints and "nests" of eggs, in the middle of the mountain-covering global Flood?[4]

The reality is that much of the sedimentary strata record has not been completely bioturbated. Some of the sedimentary layers have trace fossils only in the top portions of the individual sediment laminae. Obviously, incomplete bioturbation or no bioturbation would result if the sediments when deposited could not support animal life (e.g., if they lacked sufficient oxygen), or if they were deposited so rapidly that the burrowing animals had no time to do their work. Indeed, most of the sediments deposited during the global Flood catastrophe would have been deposited too quickly for complete bioturbation to have occurred. Sedimentary strata with only some bioturbation may well only represent the passing of at least a few hours, just sufficient time for some animals to walk around and leave their footprints, or to burrow in the sediment surface, before the next sedimentary layer was deposited. In fact, we should expect to find abundant evidence of biological activity by living organisms during the year of the Flood, because the sediment surfaces available for them to live in and on were constantly being buried, as the successive sediment layers accumulated rapidly. Indeed, some fossilized burrows have been identified as escape burrows, where the sediment accumulation has been so rapid that the animal has burrowed upwards to the sediment surface to escape being buried and suffocated.

The logical question is this: Has it been observed and measured just how quickly animals burrow into sediment layers and bioturbate them? Extensive bioturbation of individual sedimentary layers can happen rapidly. For example, certain urchins are known to rework the upper 5 cm of sediment in three days.[5] By contrast, other organisms can produce burrows as rapidly as 1,000 cm per hour, although the

4 M. Garton, 1996, The pattern of fossil tracks in the geological record, *Creation Ex Nihilo Technical Journal*, 10(1): 82-100; P. Garner, 1996, Where is the Flood/post-Flood boundary? Implications of dinosaur nests in the Mesozoic, *Creation Ex Nihilo Technical Journal*, 10(1): 101-106.

5 A. N. Lohrer and others, 2005, Rapid reworking of subtidal sediments by burrowing spatangoid urchins, *Journal of Experimental Marine Biology and Ecology*, 321: 155-169.

usual rate is much slower.[6] Indeed, depending primarily upon the density of fast-burrowing organisms such as callianassid shrimp, a 12-cm-thick layer of sediment can be 67 percent bioturbated in as little as 5.5 hours.

> Of course, these values provide only the loosest constraints upon the duration of the burrowing interval for this bed. However, it is clear that extensively bioturbated horizons do not necessarily require protracted intervals of time for their development.[7]

There are numerous organisms capable of rapid burrowing and do not require clear water.[8] Fast-acting animals, such as certain bivalves, crustaceans, and both polychaete and oligochaete worms, can burrow through sediments even during their active deposition. Thus, during rapid Flood deposition, the organisms most capable of disturbing the sediments are those that can burrow through or across centimeters to tens of centimeters of sediment in a matter of seconds to minutes. Among the many such organisms, for which such burrowing rates have been measured, are annelid worms,[9] numerous kinds of bivalves,[10] certain razor clams,[11] a pelecypod,[12] several different kinds of gastropods,[13] many crustaceans,[14] and various crabs.[15] Furthermore, it is unclear whether trace fossils also necessarily

6 J. D. Howard and C. A. Elders, 1970, Burrowing patterns of haustoriid amphipods from Sapelo Island, Georgia, *Trace Fossils*, T. P. Crimes and J.C. Harper, eds., Geological Journal Special Issue No. 3: 243-262; P. M. Kranz, 1974, The anastrophic burial of bivalves and its paleoecological significance, *Journal of Geology*, 82: 237-265; S. M. Stanley, 1970, Relation of shell form to life habits of the bivalvia (Mollusca), *Geological Society of America Memoir,* 125.

7 K. A. Grimm and K. B. Föllmi, 1994, Doomed pioneers: Allochthonous crustacean tracemarkers in anaerobic basinal strata, Oligo-Miocene Sand Gregorio Formation, Baja California Sur Mexico, *Palaios*, 9: 328.

8 P. L. McCall and M. J. S. Tevsz, 1982, Preface in: *Animal-Sediment Relations*, P. L. McCall and M. J. S. Trevsz, eds., New York: Plenum Press, x.

9 E. Zuckerkandl, 1950, Coelomic pressures in *Sipunculus nudus*, *Biological Bulletin*, 98: 167-168; V. Lobza and J. Schieber, 1999, Biogenic sedimentary structures produced by worms in soupy, soft-muds, *Journal of Sedimentary Research*, 69: 1046; J. H. Trevor, 1978, The dynamics and mechanical energy expenditure of the polychaetes *Nephtys Cirrosa, Nerus diversicolor* and *Arenicola-marina* during burrowing, *Estuarine and Coastal Marine Science*, 6: 608, 612-613.

10 S. M. Stanley, 1970, Relation of shell form to life habits of the bivalvia (mollusca), *Geological Society of America Memoir,* 125: 56-57; S. M. Stanley, 1977, Coadaptation in the Trigoniidae, A remarkable family of burrowing bivalves, *Paleontology*, 20: 875; A. Seilacher and E. Seilacher, 1994, Bivalvian trace fossils: A lesson from actuopaleontology, *Courier Forschungsinstitute Senckemberg*, 169: 6.

11 S. M. Henderson and C. A. Richardson, 1994, A comparison of the age, growth rate and burrowing behaviour of the razor clams, *Ensis silqua* and *E. ensis*, *Journal of the Marine Biological Association of the United Kingdom*, 74: 949.

12 M. J. S. Tevsz, 1975, Structure and habits of the 'living fossil' pelecypod *Neotrigonia*, *Lethaia*, 8: 325-326.

13 P. J. Vermeij and E. Zipser, 1986, Burrowing performance of some tropical Pacific gastropods, *Veliger*, 29: 201-203.

14 J. D. Howard and C. A. Edlers, 1970, Burrowing patterns of haustoriid amphipods from Sapelo Island, Georgia, in *Trace Fossils,* T. P. Crimes and J. C. Harper, eds., Liverpool: Seel House Press, 250-257.

15 E. W. Hill, 1979, Biogenic sedimentary structures produced by the mole crab *Lepidopa websteri*

require long time periods to be formed, given that well-known trace fossils have been observed being produced by organisms within, at the very most, 4-5 days.[16] Additionally, a common trilobite self-burial trace fossil is similar to the traces produced by a modern crab, which can completely conceal itself within sediment in a few seconds.[17] Even a common trace fossil that consists of tapering branches, once interpreted as having been slowly constructed in the growth of an animal, is now understood to have been generated rapidly.[18] Furthermore, it is very significant that large and complex individual trace fossils, including common ones, as well as less common meter-sized ones, can all form within sediment layers, which of course means that the deposition of the sediments does not have to be interrupted during their construction.[19]

It is, of course, obvious that the footprints and trackways left behind by vertebrate animals, such as dinosaurs, were formed instantaneously as the animals traversed across sediment surfaces. Furthermore, it is readily observed that once footprints and trackways are produced, they are quickly degraded and obliterated by wind, rainfall, and surface water flow under present climatic conditions. Therefore, it should be self-evident that footprints and trackways, as well as surface trace fossils, need to be rapidly covered over and buried in order to be preserved. However, it is normally expected and observed that the wind or water carrying the sediments to bury footprints, trackways or surface traces will invariably disturb and/or erode the sediment surfaces they pass over, degrading or obliterating any footprints, trackways or traces on those sediment surfaces. Therefore, even researchers committed to uniformitarianism would have to concede that for the footprints, trackways, and traces to be preserved and fossilized, the sediment surfaces on which they were produced would have to have been rapidly and sufficiently hardened or partially lithified almost immediately after the passage of the animals, and certainly before the deposition of the overlying sediments.[20]

Very rapid cementation of the sediment surface immediately after deposition

---

Benedict, *Texas Journal of Science*, 31: 49; E. Savazzi, 1982, Burrowing habits and cuticular sculptures in recent sand-dwelling Brachyuran decapods from the Northern Adriatic Sea, *Neues Jahrbuch fur Geologie und Palaeontologie Abhandlungen*, 163: 276; E. Jaramillo, J. Dugan and H. Contreras, 2000, Abundance, tidal movement, population structure and burrowing rate of *Emerica analoga* (Anomura, Hippidae) at a dissipative and reflective sandy beach in south central Chile, *Marine Ecology*, 21: 121-123.

16 S. Jensen and R. J. A. Atkinson, 2001, Experimental production of animal trace fossils, with a discussion of allochthonous trace fossil producers, *Neues Jahrbuch fur Geologie und Palaeontologie Monatschefte*, 2001: 594-606.

17 R. G. Osgood, 1970, Trace fossils of the Cincinnati area, *Palaeontographica Americana*, 6: 305.

18 M. F. Miller, 1991, Morphology and paleoenvironmental distribution of Paleozoic *Spirophyton* and *Zoophycos*, *Palaios*, 6: 419-420.

19 R. Goldring, 1985, The formation of the trace fossil *Cruziana*, *Geological Magazine*, 122: 65-72; E. Seilacher-Drexler and A. Seilacher, 1999, Undertraces of sea pens and moon snails and possible fossil counterparts, *Neues Jahrbuch fur Geologie und Palaeontologie Abhandlungen*, 215: 195-210.

20 J. Woodmorappe, 2006, Are soft-sediment trace fossils (ichnofossils) a time problem for the Flood?, *Journal of Creation*, 20(2): 113-122.

is conceivable, given that dissolved carbonate minerals are always present in significant quantities in the pore waters of sediments, and carbonate minerals are one of the most common sediment-cementing agents. Indeed, early precipitated cement is known forming at, or not far below, the depositional surface, which increases the bearing strength of the sediment as subsequent sediments are deposited.[21] Several types of mechanisms for rapid carbonate cementation in sediments are known, such as the formation of beachrock in a matter of hours.[22] The repeated percolation of meteoritic and marine water is an important factor,[23] and is one that would have occurred on a large scale during the Flood. The mechanical agitation of saturated water, a process that is obviously relevant to Flood conditions, can also precipitate a layer of carbonate in a matter of hours.[24] Even large releases of carbon dioxide bubbles facilitates carbonate precipitation in a matter of minutes.[25] As rapid carbonate lithification at sediment surfaces continues to be studied, such processes are all relevant to the rapid cementation during the Flood of sediment surfaces which contain footprints, trackways and other traces.[26]

Such rapid carbonate lithification at the sediment surface also solves the question of hardgrounds, claimed to be a time problem for Flood geology. It is, in fact, because these hardgrounds are in carbonate sediment layers (in limestone and chalk beds) that it is reasonable to expect this mechanism for their formation. As soon as the carbonate sediments were deposited, organisms began to scurry across, and burrow into, their surfaces. However, hardening of the carbonate cement in the sediments would have been rapid at the same time, thus fossilizing the burrows and trails, while oysters attached themselves to these hardened surfaces. Nevertheless, within a few hours, these now hardened sediment surfaces, or hardgrounds, would have been eroded by the next tidal surges of sediment-laden waters, the newly-deposited carbonate sediments from them also burying and preserving the hardgrounds, and further fossilizing the burrows, trails, and now the encrusted fauna.

The finding of what are claimed to be "nests" of dinosaur eggs fossilized at

---

21 E. W. Choquette, 1987, Diagenesis #12. Diagenesis in limestones—3. The deep burial environment, *Geoscience Canada*, 14: 5.

22 J. S. Hanor, 1978, Precipitation of beachrock cements: mixing of marine and meteoritic waters *vs.* CO_2 degassing, *Journal of Sedimentary Petrology*, 48: 489-501.

23 F. Longhitano, 2001-2002, Sedimentary features of incipient beachrock deposits along the coast of Simeto River delta (eastern Sicily, Italy), *GeoActa*, 1: 95-110.

24 D. D. Zhang, Y. Zhang, A. Zhu and X. Cheng, 2001, Physical mechanisms of river waterfall tufa (travertine) formation, *Journal of Sedimentary Research*, 71: 205-216.

25 H. S. Chafetz, P. F. Rush, and N. M. Utech, 1991, Microenvironmental controls on mineralogy and habit of $CaCO_3$ precipitates: an example from an active travertine system, *Sedimentology*, 38: 107-126.

26 D. Kneale and H. A. Viles, 2000, Beach cement: Incipient $CaCO_3$-cemented beachrock development in the upper intertidal zone, North Uist, Scotland, *Sedimentary Geology*, 132: 165-170.

numerous strata levels in the geologic record locally and on several continents[27] raises another aspect of this claimed problem for deposition of the fossil-bearing sedimentary strata during the Flood year. It is presumed that the presence of dinosaur footprints, trackways, and eggs in "nests" are evidence that some time elapsed at that sediment surface which contains these fossilized remains, while the dinosaurs walked around and laid eggs in "nests." Sometimes only fossilized eggshell fragments are found, and rarer still the associated fossilized remains of baby dinosaurs. It is claimed that such occurrences require days or even months to pass at that sediment surface before subsequent burial and fossilization, so that repeated horizons in the strata record of such occurrences would surely rule out the deposition of such sediment layers during the Flood year.[28]

However, because the nesting and egg-laying behavior of dinosaurs cannot be observed today, it is far from certain that these claimed fossilized dinosaur "nests" are exactly that. The tidal nature of the Flood waters, as they surged up on to the continents from the ocean basins, would have resulted in large areas where sediments were deposited from shallow water that retreated and fell to expose the sediment surfaces before the next tidal advance surged over the area to deposit more sediments. Dinosaurs swept away by the advancing tide, that survived by floating and swimming in those shallow waters until the tide retreated, would then have opportunity to walk across these exposed sediment surfaces, leaving behind their footprints and trackways. In such stressful situations it is conceivable that dinosaur mothers thus laid their eggs on these temporarily exposed sediment surfaces, sometimes in groups that could be interpreted as "nests," before the next tidal surge of sediment-laden waters covered the eggs while sweeping the dinosaur mothers away.

In any case, in several situations where the sedimentary strata containing these supposed "nests" fossilized eggs and eggshell fragments have been closely examined, it has been found that they are cross-bedded sandstones deposited by fast-moving water currents and storm surges.[29] Indeed, there is abundant evidence at many localities that not only egg shell fragments, but also whole eggs, were transported by sediment-laden waters, only to be deposited within the resultant sediments or on top of them. That eggshells can survive transport and abrasion in sediment-laden water without damage or destruction has been tested experimentally.[30] Eggs could even have floated and been transported for days or weeks before coming

27 K. Carpenter and K. Alf, 1994, Global distribution of dinosaur eggs, nests and babies, *Dinosaur Eggs and Babies*, K. Carpenter, K.F. Hirsch and J.R. Horner, eds., UK: Cambridge University Press, 15-30.

28 Garner, 1996, Where is the Flood/post-Flood boundary?

29 D. Dashzeveg and others, 1995, Extraordinary preservation in a new vertebrate assemblage from the Late Cretaceous of Mongolia, *Nature*, 374: 446-449; E. G. Kennedy, 1995, An unusual occurrence of dinosaur eggshell fragments in a storm surge deposit, Lamargue Group, Patagonia, Argentina, *Geological Society of America Abstracts with Programs*, 27: A-318.

30 D. T. Tokaryk and J. E. Storer, 1991, Dinosaur eggshell fragments from Saskatchewan, and evaluation of potential distance of eggshell transport, *Journal of Vertebrate Paleontology*, 11(3 sppl): 58A.

to rest on a sediment surface. This could also explain fossilized hatchlings found beside the broken eggs they apparently hatched from. These would have been beached eggs that were ready to hatch before the next sediment-laden tidal surge buried and fossilized eggshell fragments and baby dinosaurs. Further research is obviously needed, but it is clear from this analysis that not only dinosaur footprints and trackways, but even supposed "nests" of fossilized eggs and broken shells with hatchlings, are not evidence incompatible with rapid deposition of sedimentary strata during the global Genesis Flood.

115

Chalk and Diatomite Beds, and Deep-Sea Sediments

One of the most challenging examples of a sedimentary rock whose deposition is claimed to have taken millions of years is the study of chalk beds, which are prominent in the so-called Cretaceous period of the geologic column. The Latin word for chalk is *creta*, so the Cretaceous is regarded as the "chalk age." Chalk is sediment made up of the calcium carbonate residues of algae known as coccolithophores. The hard parts are called coccoliths, having effective settling diameters in the range of 2 to 12 microns. These shell-like structures often fall apart to produce fragments. Under today's conditions it can take the larger fragments at least a year to descend and settle on the sea floor, but the broken fragments are estimated to take more than 100 years! Thus it is claimed that one meter thickness of chalk must represent about 100,000 years of deposition. In the modern oceans, coccolithophores are found in nutrient-poor waters, and when the coccoliths slowly descent to the sea floor, they are always mixed with other materials in the resultant sea floor sediments. Thus the calcareous oozes on the ocean floors today, which are regarded as the modern version of the chalk beds found in the geologic record, have a coccolith content of 5 to 33 percent by weight in the Atlantic, and of 4 to 71 percent on the floor of the Indian Ocean.[1]

It is, therefore, highly significant that the chalk beds found in the geologic record are very much purer than their supposed analogous calcareous oozes. The calcium carbonate content of the French chalk beds, for instance, varies between 90 and 98 percent, while the Kansas chalk is 88-98 percent calcium carbonate (average 94 percent).[2] Furthermore, the chalk beds of southern England are estimated to be around 405 meters (about 1,329 feet) thick. These chalk beds are said to span the complete duration of the so-called Late Cretaceous geologic period,[3] estimated to account for 30 to 35 million years of geologic time. Thus, the average rate of chalk accumulation through this time period is simply calculated to be 1.16 to

1 C. V. Jeans, P. F. Rawson, ed., 1980, *Andros Island, Chalk and Oceanic Oozes*, UK: Yorkshire Geological Society, Leeds, Occasional Publication No. 5.

2 F. J. Pettijohn, 1957, *Sedimentary Rocks*, New York: Harper and Rowe, 400-401.

3 M. House, 1989, *Geology of the Dorset Coast*, London: The Geologists' Association, Field Guide, 4-10.

1.35 centimeters (0.45 to 0.53 inches) per thousand years, which is slightly less than the 2 to 10 centimeters (0.78 to 3.93 inches) per thousand years rate for accumulation of oozes today dominated by coccoliths.[4] Yet the chalk beds in the geologic record are so pure in comparison to today's sea floor calcareous oozes. If the chalk beds accumulated at an even slower rate than today's sea floor calcareous oozes, then why are they so pure and not have more other materials mixed into them? This observation alone must rule out the accumulation of today's sea floor calcareous oozes as the model for the formation of the chalk beds in the geologic record.

Nevertheless, it is asserted that if all the fossilized coccolithophores within the chalk beds were resurrected, they would cover the earth's surface to a depth of at least 45 centimeters (18 inches), making it problematical as to what they could all have possibly eaten.[5] It is thus claimed the laws of thermodynamics prohibit the earth from supporting that much animal biomass, and with so many animals trying to get their energy from the sun, the available solar energy would not nearly be sufficient.[6] As well as blithely claiming this supposed organic problem for the huge volume of microorganisms found in the chalk beds having all lived at the same time, it is insisted that the quantity of carbon dioxide necessary to provide the calcium carbonate needed for the growth of all these calcareous microorganisms could simply not be sustained by the earth's atmosphere.[7]

Similar supposed problems are claimed for the deposition and formation of the diatomite beds, also found in the geologic record. These beds are made up of countless billions of diatoms, which are the siliceous bodies of single-celled algae that live in oceanic surface waters today. When these diatoms die today, their siliceous skeletons slowly descend to the ocean floor to become part of the sediment accumulating there. Because the diatom skeletons are commonly in the range of 10 to 200 microns, according to Stokes' Law they would require between one week and two years to sink and be deposited on the sea floor. In today's ocean basins the rates of accumulation for diatom skeletons on the sea floor are low, being of the order of 40-73 centimeters (16-28 inches) of diatomaceous ooze per thousand years. Furthermore, these diatomaceous oozes on the sea floors today, though containing a significant proportion of diatom skeletons, nonetheless contain other sediment particles mixed in with them. However, the diatomite beds in the geologic record are exceedingly pure, so that many of them are of commercial interest, because the relatively pure silica in them favors their use in chemical processing. Once again, today's impure diatomaceous oozes on the sea floors can hardly be a model for the deposition and formation of the diatomite beds in the geologic record, that consist of relatively pure silica. Nevertheless, the

4 Z. Kukal, 1990, The rate of geological processes, *Earth Science Reviews*, 28: 109-117.

5 R. J. Schadewald, 1982, Six 'Flood' arguments creationists can't answer, *Creation/Evolution,* IV: 13.

6 A. Hayward, 1987, *Creation and Evolution: The Facts and the Fallacies*, London: Triangle (SPCK), 91-93.

7 G. R. Morton, 1984, The carbon problem, *Creation Research Society Quarterly*, 20(4): 212-219.

diatomite beds are still inferred to have formed over thousands of years.

Contrary to what has been claimed, none of these supposed problems are insurmountable "hurdles" to explaining the deposition and formation of both chalk and diatomite beds during the Flood. Biological productivity does not appear to be a limiting factor, given that coccolithophores are among the fastest growing planktonic algae, sometimes multiplying at a rate of 2.25 divisions per day.[8] Using this dividing rate, and reasonable assumptions for the volume and average growth rate of each coccolith,[9] the number of coccoliths produced by each coccolithophore, and the numbers of each coccolithophores per liter of ocean water,[10] then the calculated potential production rate is 55 centimeters (over 21 inches) of calcium carbonate per year from the top 100 meters (305 feet) of the ocean.[11] At this rate it is possible to produce an average 100 meter (305 feet) thickness of coccoliths as calcareous ooze on the ocean floor in less than 200 years. Furthermore, assuming all limestones in the upper Cretaceous and Tertiary layers of the geologic column are chalks (which they are not), then the calculated volume would only require 4.1 percent of the earth's surface to be coccolith-producing seas to produce the volume of coccoliths to form all those limestones in only 1,600-1,700 years.[12] However, while these calculations certainly show that the quantities of calcareous oozes on today's ocean floors are easily producible in the timespan since the Flood, they are insufficient to show how these chalk beds were produced during the Flood itself.

Even today coccolith accumulation is not steady-state but highly episodic. Under the right conditions, significant increases in the concentrations of these marine microorganisms can occur, as in plankton "blooms," red tides, and in intense "white water coccolith blooms in which micro-organism numbers experience a two orders of magnitude increase."[13] Though poorly understood, the suggested reasons for these blooms include turbulence of the sea, wind, decaying fish, nutrients from freshwater inflow and upwelling, and temperature.[14] It is known

8 E. Paasche, 1968, Biology and physiology of coccolithophores, *Annual Review of Microbiology*, 22: 71-86.

9 S. Honjo, 1976, Coccoliths: Production, transportation and sedimentation, *Marine Micropaleontology*, 1: 65-79.

10 M. Black and D. Bukry, 1979, Coccoliths, in *The Encyclopedia of Paleontology*, Volume 7, R.W. Fairbridge and D. Jablonski, eds., Stroudsberg, PA: Dowden, Hutchinson and Ross, 194-199.

11 A. A. Roth, 1985, Are millions of years required to produce biogenic sediments in the deep ocean?, *Origins*, 12(1): 48-56.

12 J. Woodmorappe, 1986, The antediluvian biosphere and its capability of supplying the entire fossil record, in *Proceedings of the First International Conference on Creationism*, Volume 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 205-218.

13 H. H. Seliger, J. H. Carpenter, M. Loftus and W. D. McElroy, 1970, Mechanisms for the accumulation of high concentrations of dinoflagellates in a bioluminescent bay, *Limnology and Oceanography*, 15: 234-245; J. L. Sumich, 1976, *Biology of Marine Life*, Dubuque, IA: William C. Brown, 118, 167.

14 W. B. Wilson and A. Collier, 1955, Preliminary notes on the culturing of *Gymnodinium brevis* Davis, *Science*, 121: 394-395; B. Ballantyne and B. C. Abbott, 1957, Toxic marine flagellates; Their occurrence

also that the element iron can seed algal blooms, but experiments have indicated that the mere presence of iron is not enough, as it must be in a form that the marine microorganisms can use. Recent observations show that a relatively high level of sulfur dioxide present is able to convert the iron to a more soluble form that algae can use.[15] Furthermore, there is now experimental evidence that low Mg/Ca ratios and high Ca concentrations in seawater, similar to the levels in so-called Cretaceous seawater, promote exponential growth rates of coccolithophores.[16]

Quite clearly, all of these necessary conditions for explosive blooming of coccolithophores would have been present during the cataclysmic global upheavals during the Flood. Torrential rain, sea turbulence, decaying fish and other organic matter, and the violent volcanic eruptions, on the ocean floor, associated with the "fountains of the great deep," and on land, both occurrences causing steam, carbon dioxide, sulfur dioxide, iron, and other elements to be spewed into the ocean waters and atmosphere, would have resulted in explosive blooms of coccolithophores on a large and repetitive scale in the oceans. Ocean water temperatures would have been higher toward the end of the Flood because of the heat released during the cataclysm, both from volcanic and magmatic activity, and from the latent heat of condensation of water.[17] Furthermore, thermodynamic considerations would definitely not prevent a much larger biosphere being produced, because oceanic productivity 5 to 10 times greater than at present could be supported by the available sunlight if the nutrients (especially nitrogen), were available.[18] The rapid production of the necessary quantities of calcareous ooze, enough to ensure its purity to form the chalk beds in the geologic record toward the end of the Flood year, is realistically conceivable.[19]

In spite of well-argued claims that the deposition and formation of the chalk beds required a longer period than a few weeks toward the end of the Flood year,[20] it is the extreme purity of the chalk beds that argues for their rapid deposition and

---

and physiological effects on animals, *Journal of General Microbiology*, 16: 274-281; R. D. Pingree, P.M. Holligan and R. N. Head, 1977, Survival of dinoflagellate blooms in the western English Channel, *Nature*, 265: 266-269.

15 N. Meskhidze, W. L. Chameides and A. Nenes, 2005, Dust and pollution: A recipe for enhanced ocean fertilization?, *Journal of Geophysical Research (Atmospheres)*, 110: D03301.

16 S. M. Stanley, J. B. Ries and L. H. Hardie, 2005, Seawater chemistry, coccolithophore population growth, and the origin of Cretaceous chalk, *Geology*, 33: 593-596.

17 J. J. Shackleton and J. P. Kennet, 1975, Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: Oxygen and carbon isotope analysis in DSDP Sites 277, 279, and 281, *Initial Reports of the Deep Sea Drilling Project*, 29, J. P. Kennet et al, ed., 743-755.

18 H. Tappan, 1982, Extinction or survival: Selectivity and Causes of Phanerozoic Crises, *Geological Society of America, Special Paper,* 190: 270.

19 A. A. Snelling, 1994, Can Flood geology explain thick chalk layers?, *Creation Ex Nihilo Technical Journal*, 8(1): 11-15.

20 W. H. Johns, 1995, Coccolithophores and chalk layers, *Creation Ex Nihilo Technical Journal*, 9(1): 29-33; D. J. Tyler, 1996, A post-Flood solution to the chalk problem, *Creation Ex Nihilo Technical Journal*, 10(1): 107-113.

formation. Furthermore, in many places the chalk layers are rhythmically bedded, with regularly-spaced, joint-like breaks or bedding planes, and the occasional thick marl bands.[21] This rhythmicity/cyclicity matches the cyclic variation in the oxygen isotopic composition of the carbonate, which is consistent with fluctuations of up to 4.5°C in the water temperatures when the chalk was deposited.[22] These fluctuating warmer ocean-water temperatures correlate with explosive production of coccolithophores and deposition of the pure chalk, which is consistent with copious quantities of nutrient-carrying hot waters being explosively added to the ocean waters by volcanic eruptions late in the Flood year. The presence of more than 100 regularly-spaced, thin bentonite seams between the chalk layers in the American chalk beds is consistent with explosive volcanic activity coinciding with rapid coccolith production and generation of the chalk beds, because the bentonite is derived from *in situ* decomposition of volcanic ash.[23]

What is often overlooked is that chalk pebbles occur in some of the marls, and marl-chalk junctions are cut by erosion hollows in some places.[24] Furthermore, the chalk ooze was not merely deposited in "flat spreads," but was sometimes piled into heaps and banks up to 50 meters high and 1.5 kilometers in length, accompanied by slumping. Smaller and less obvious carbonate banks with and without detectable cross-bedding are widespread in the English chalk beds. Submarine erosion surfaces are common in the chalk, and some fine-grained chalks show a textural, parallel lamination bedding. All of these features are indicative of deposition involving rapid current flows, and not the slow-and-gradual deposition over millions of years that is usually claimed. It is to be expected that rapidly-flowing density currents could have resulted from the massive aggregation of coccoliths, from the widescale explosive coccolithophore blooms, so even though the individual coccoliths are microscopic, a mass of them would have been deposited rapidly on the ocean floors. This would also explain the rapid burial of large ammonites and other marine creatures whose fossil remains are so often found in the chalk beds.

Similar arguments apply to the vast, thick, and pure diatomite beds in the geologic record. The scale and purity of these beds necessitates diatom accumulation rates significantly higher than in today's oceans, with abundant explosive diatom blooms resulting from abundant food supplies and favorable conditions for reproduction, combined with ocean currents rapidly accumulating and then depositing them on the ocean floor. The presence of volcanic ash in some of these diatomite beds is

21 J. M. Hancock, 1975, The petrology of the chalk, *Proceedings of the Geologists' Association*, 86(4): 499-535.

22 P. Ditchfield and J. D. Marshall, 1989, Isotopic variation in rhythmically bedded chalks: Paleotemperature variation in the Upper Cretaceous, *Geology*, 17(9): 842-845.

23 B. E. Hattin, 1982, Stratigraphy and depositional environment of the Smoky Hill Chalk Member, Niobara Chalk (Upper Cretaceous) of the time area, western Kansas, *Kansas State Geological Survey Bulletin,* 225, Lawrence, KS: University of Kansas Publications.

24 Hancock, 1975, 508-510.

also highly significant. Such explosive volcanic activity would have helped provide the nutrients for the abundant explosive diatom blooms, and the ash would have added to the density currents that rapidly swept the diatom skeletons to the ocean floor. It is also known that many diatoms form multi-cellular chains that can be several millimeters in length, so the diatom skeletons aggregate instead of being independent particles in suspension, and thus their settling is not subject to Stokes' Law.

However, major evidence for more rapid modes of deposition of diatomite beds arises from the presence of huge fossil vertebrates in some of them. The most striking examples are the fossilized baleen whales in the diatomite beds of the Pisco Formation of Peru,[25] and in the Monterey Formation in the Lompoc area of California.[26] Within the Peruvian Pisco Formation, 346 fossilized baleen whales 5 to 13 meters long have been found in a 1.5 square kilometer area of exposed outcrop. The burial of these huge whales and their fossilization was so rapid, that occasionally soft tissues have been preserved, including the baleen. Other common fossils found with these baleen whales are sharks' teeth, but this formation has also yielded fossilized fish, turtles, seals, porpoises, penguins, and even ground sloths. By comparison, in the Californian Monterey Formation, five fossilized whales were found by mining operations in a two-month period, including a baleen whale estimated to be about 25 meters long! Other fossils found abundantly in these diatomite beds include fish of many varieties, seals, and even birds. It is quite obvious that the accumulation of the diatomite to bury these huge whales, and to also preserve such an abundance of other fossils, had to have been catastrophic, in an event that affected land (ground sloths), air (birds), and the sea. Thus the evidence is totally consistent with the catastrophic formation of these diatomite beds, along with the chalk beds, toward the end of the global Flood cataclysm.

25 L. R. Brand, R. Esperante, A.V. Chadwick, O. P. Porras and M. Alomfa, 2004, Fossil whale preservation implies high diatom accumulation rate in the Miocene-Pliocene Pisco Formation of Peru, *Geology*, 32(2): 165-168.

26 A. A. Snelling, 1995, The whale fossil in diatomite, Lompoc, California, *Creation Ex Nihilo Technical Journal*, 9(2): 244-258.

116

Coral Reefs and Limestone

Another type of sedimentary deposit that is claimed to require a long time for accumulation are coral reefs.[1] Coral reefs appear to represent vast accumulations of the calcium carbonate remains of coral organisms that grew over time, the living organisms growing on the remains and debris of their predecessors. Thus, when local and regional structures that contain fossilized coral and reef-related organisms are found in limestone beds and look like present-day reefs, it is then claimed they are fossilized reefs that must have taken eons of time to accumulate and be built, so the limestone beds containing them must likewise represent eons of time for deposition and accumulation.[2] Of course, the total mass of material in the reef is not only a function of time, but also of the numbers and sizes of the multiplying reef-building corals. Thus, large coral reefs would just as well have formed in relatively short time periods.

Detractors usually cite the reefs of Enewetok Atoll in the Pacific Ocean as an example of modern reefs that must have taken a long time to grow, given the usual estimate of coral growth rates. Drilling on this atoll has penetrated 1,405 meters of apparent reef material before reaching the basaltic rock of the ocean floor.[3] Of course, coral doesn't grow if it is more than 50 meters below the ocean surface, so the Enewetok Reef must have begun growing when the ocean there was quite shallow, and then evidently continued growing as the ocean floor gradually subsided. At the rates of coral growth assumed by most investigators, it would, of course, have taken up to hundreds of thousands of years to form a reef as thick as this.

One critic of the biblical model of earth history has claimed that the Enewetok Reef would have to have grown at a rate of at least 140 millimeters per year to have formed in less than 10,000 years since the Flood, and states: "Such rates have

1 Wonderly, 1977, 23-47.

2 Wonderly, 1977, 68-112.

3 H. S. Ladd and S. O. Schlanger, 1960, Drilling operations on Enewetok Atoll: Bikini and nearby Atolls, Marshall Islands, *US Geological Survey Professional Paper*, 260Y: 863-905.

been shown to be quite impossible."[4] However, this claim is ignorant of earlier published, well-documented, direct measurements of reef growth rates of 280-414 millimeters per year,[5] which are far more accurate than many published estimates based on radiocarbon "dating" for coral growth rings. Similarly, growth rates of the corals that build the frames of reefs have also been measured at 120-432 mm per year.[6] Analyzing these direct measurements, it can be easily calculated that coral growth would have been rapid enough to build the Enewetok Reef in only 3,400 years, well within the time since the Genesis Flood. The Enewetok Atoll reefs are an extreme example, because other reefs around the world are not as thick as these. For example, the enormous Great Barrier Reef of Australia, while being more than 2,000 kilometers long, is less than 250 meters thick.[7] Thus, based on the above reference measurements of coral reef growth, all living reefs today around the world would easily have grown in the time since the Genesis Flood.

Much is claimed about daily growth-lines produced in many corals as they grow, and used to infer estimates of exceedingly slow coral growth rates. These growth-lines form seasonal patterns, but the counting of these growth-lines in corals is quite subjective, because they are often ill-defined. Some individuals will find twice as many as others on the same sample.[8] Furthermore, environmental factors such as water depth affect the number of growth-lines formed.[9]

The occurrence of what are alleged to be fossil reefs in limestones in various portions of the geologic column appear to be a difficult problem to reconcile with both the deposition of such limestones during the Flood, and the biblical chronology. Many abundantly fossiliferous limestones are claimed to be organically constructed "reefs" that slowly accumulated over thousands of years as innumerable generations of marine organisms chemically cemented themselves on top of one another to construct huge, wave-resistant framework structures. Field investigators have documented hundreds of these claimed fossil reefs throughout

4 A. Hayward, 1985, *Creation and Evolution: The Facts and the Fallacies*, London: Triangle (SPCK), 85.

5 J. Th. Verstelle, 1921, The growth rate at various depths of coral reefs in the Dutch East Indian Archipelago, *Treubia*, 14: 117-126; R. B. S. Sewell, 1935, Studies on coral and coral formations in Indian waters, in Geographic and Oceanographic Research in Indian Waters, No. 8, *Memoirs of the Asiatic Society of Bengal*, 9: 461-539.

6 J. B. Lewis, S. Axelsen, I. Goodbody, C. Page and D. Chislett, 1968, Comparative growth rates of reef corals in the Caribbean, *Marine Science Manuscript Report 2*, Montreal, QC: Marine Sciences Center, McGill University; R. W. Vuddemeier and R. A. Kinzie III, 1976, Coral growth, *Oceanography and Marine Biology: An Annual Review*, 14: 183-225; A. H. Gladfelter, 1984, Skeletal development in *Acropora cervicornis*. III. A comparison of monthly rates of linear extinction and calcium carbonate accretion measured over a year, *Coral Reefs*, 3: 51-57.

7 H. Blatt, V. Middleton and R. Murray, 1980, *Origin of Sedimentary Rocks*, second edition, Englewood Cliffs, NJ: Prentice-Hall, 36.

8 C. D. Clausen, 1974, An evaluation of the use of growth lines in geochronometry, geophysics, and paleoecology, *Origins*, 1: 58-66; D. N. Crabtree, C. D. Clausen and A. A. Roth, 1980, Consistency in growth line counts in bivalve specimens, *Paleogeography, Paleoclimatology, Paleoecology*, 29: 323-340.

9 J.-L. Liénard, 1986, *Factors Affecting Epithecal Growth Lines in Four Coral Species, with Paleontological Implications,* Th. D. dissertation, Department of Biology, Loma Linda University, Loma Linda, CA.

the geologic column, from the Precambrian upwards.[10] With notable exceptions, these fossil reefs are usually very small compared to present living reefs.

However, authenticating fossil reefs requires that many problems must be overcome, not least of which is the confused definition of a reef. Many of these so-called fossil reefs appear to be only accumulations of sediments swept in by water, which obviously would have occurred rapidly. In Grand Canyon,[11] the Redwall Limestone does not contain any organically-bound structures or reefs, nor coral and sponge-reef structures,[12] and even laminated algal structures particularly show concentric internal structure due to the algal masses having been transported by rolling.[13] Indeed, there is much evidence throughout the Redwall Limestone, including a two meter thick unit within it deposited catastrophically by a hyperconcentrated sediment gravity flow that mass-killed and buried billions of large nautiloids, which demonstrates that it was formed rapidly under conditions consistent with the Genesis Flood.[14]

One famous, classic example of a claimed fossil "barrier reef" is the Permian reef complex of the Guadalupe Mountains of southeastern New Mexico and western Texas, more commonly referred to as simply the "Capitan Reef." However, careful field research of the Capitan Limestone, and associated strata that make up the alleged reef, cast doubt on the various claimed depositional and ecologic environments said to be associated with this fossil reef.[15] The so-called "backreef lagoon" and "forereef talus" deposits were not contemporaneous with "reef" accumulation. Furthermore, the Capitan Limestone lacks large, *in situ*, organically-bound frameworks and deposits of broken debris that can be shown to be derived from an organic framework. Instead, the Capitan Limestone is composed primarily of broken fossil fragments in a fine-grained matrix of lime silt and sand, which were not wave-resistant when deposited. The fossil flora and fauna of the "Capitan Reef" represent a shallow-water assemblage, which was not especially adapted to a wave or strong current environment. Reef-forming organisms, which would have bound the sediments and built frameworks, are either all together absent or largely inconspicuous. All of these features, particularly the

10 P. H. Heckel, 1974, Carbonate buildup in the geologic record: A review, in *Reefs in Time and Space*, L. F. Laporte, ed., Society of Economic Paleontologists and Mineralogists Special Publication 18: 90-154.

11 E. D. McKee and R. D. Gutschick, 1969, History of the Redwall Limestone in Northern Arizona, *Geological Society of America Memoir,* 114: 557.

12 L. R. Hopkins, 1990, Kaibab Formation, in *Grand Canyon Geology*, S.S. Beus and M. Morales, eds., New York: Oxford University Press, 243.

13 S. A. Austin, ed., 1994, *Grand Canyon: Monument to Catastrophe*, Santee, CA: Institute for Creation Research, 26-28.

14 S. A. Austin, 2003, Nautiloid mass kill and burial event, Redwall Limestone (Lower Mississippian), Grand Canyon region, Arizona and Nevada, in *Proceedings of the Fifth International Conference on Creationism*, R.L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 55-99.

15 S. E. Nevins, 1972, Is the Capitan Limestone a fossil reef?, *Creation Research Society Quarterly*, 8(4): 231-248.

lack of large organically-bound structures, suggest that deposition was very rapid, consistent with deposition during the Genesis Flood. Other investigators "have expressed frustration at using modern reefs to interpret their ancient counterparts, including this Capitan Reef."[16]

Many fossil-bearing limestone deposits that once were interpreted as fossilized reefs have been reinterpreted as debris flows or other non-reef structures. A well-known example of a supposed fossilized reef is the so-called Nubrigyn Reef complex near the village of Stuart Town in eastern Australia.[17] Instead of being formed by coral, this so-called reef was built by algae. However, careful examination of the outcrops reveals that the so-called reef complex is in fact made up of a mixture of pieces of broken fossil algae and non-reef-like types of rocks, literally "floating" in a matrix of fine-grained sediments, which is why this is now not regarded as a fossilized reef, but as megabreccia resulting from a debris flow.[18] Thus, this once famous "fossilized reef" represents the remains of a reef that grew elsewhere (likely before the Flood), which was destroyed in a watery catastrophe, so it is no longer an example of a reef grown in place that can be used as an argument against the catastrophic Genesis Flood. Similar doubts can be raised about the claimed Devonian reef complexes of the Canning Basin in the northwest of Western Australia.[19] These supposed reef complexes consist of isolated high-relief fossiliferous limestone platforms, flanked by steep marginal-slope facies limestones, which were deposited by debris flows that contain allochthonous blocks of "reef" limestone. The edges of these platforms are claimed to be the reefs, but this is a subjective interpretation, given that apart from containing a wider variety of fossils, the marginal-slope limestone is no different from the rest of the limestone platforms. These platforms could instead be regarded as remnants of the continuous limestone bed that was eroded, with debris flows leaving behind flanking megabreccias around the isolated remnant platforms to form the marginal-slope facies. Thus, any comparison with living reefs is only superficial.

A number of these so-called fossil reefs in various parts of the world have now

16 D. K. Hubbard, A. I. Miller and D. Scaturo, Production and cycling of calcium carbonate in a shelf-edge reef system (St. Croix US Virgin Islands): Applications to the natural reef systems in the fossil record, *Journal of Sedimentary Petrology*, 60: 335-360; R. Wood, J. A. D. Dickson and B. Kirkland-George, 1994, Turning the Capitan Reef upside down: A new appraisal of the ecology of the Permian Capitan Reef, Guadalupe Mountains, Texas and New Mexico, *Palaios*, 9: 422-427; R. Wood, J. A. D. Dickson and B. L. Kirkland, 1996, New observations on the ecology of the Permian Capitan Reef, Texas and New Mexico, *Paleontology*, 39: 733-762.

17 I. G. Percival, 1985, *The Geological Heritage of New South Wales*, Volume 1, Sydney: New South Wales National Parks and Wildlife Service, 16-17.

18 P. J. Conaghan, E. W. Mountjoy, D. R. Edgecombe, J. A. Talent and D. E. Owen, 1976, Nubrigyn algal reefs (Devonian) eastern Australia: Allochthonous blocks and megabreccias, *Geological Society of America Bulletin*, 87: 515-530.

19 P. E. Playford, 1984, Platform-margin and marginal-slope relationships in Devonian reef complexes of the Canning Basin, in *The Canning Basin W.A.*, P.G. Purcell, ed., Perth: Geological Society of Australia and Petroleum Exploration Society of Australia Symposium, 189-214.

been reinterpreted as resulting from rapidly accumulating debris flows,[20] while even the classic fossil Steinplatte Reef of the Austrian Alps has been described as a "sand pile."[21] Indeed, sedimentologists have reported that:

> Closer inspection of many of these ancient carbonate "reefs" reveals that they are composed largely of carbonate mud with the larger skeletal particles "floating" within the mud matrix. Conclusive evidence for a rigid organic framework does not exist in most of the ancient carbonate mounds. In this sense, they are remarkably different from modern, coral-algal reefs.[22]

The skeletal particles floating in a mud matrix would likely have been deposited rapidly.

Whether an ancient fossilized "reef" really does represent an authentic and original biological entity is often determined by analyzing the orientation of the fossils in it. If corals, for example, are in an upright (growth) position, it is assumed that they must have grown where they are now found. However, such observations mean little, because transport of reef material would result in components ending up in almost any position. Nevertheless, it has been shown that in some fossil "reefs" the preferred orientation of the supposed reef-producing components is upright, as expected if in the position of growth.[23] However, such observations do not negate the evidence that massive reef cores, which had earlier grown elsewhere, were transported and deposited during a catastrophic upheaval. Blocks of former reef material, that has been transported and deposited in other sediment layers, have been noted in the geologic literature, and in the Austrian Alps huge layers of sediments containing suggested "fossil reefs" have been thrust over other sedimentary layers for many hundreds of kilometers during the formation of the Alps.[24]

20 E. W. Mountjoy, H. E. Cook, L. C. Pray and P. N. McDaniel, 1972, Allochthonous carbonate debris flows—worldwide indicators of reef complexes, banks or shelf margins, in *International Geological Congress, Section 6, Stratigraphy and Sedimentology*, D.J. McLaren and G.V. Middleton, eds., Montreal, Canada: 24th International Geological Congress, 172-189.

21 R. J. Stanton, Jr. and E. Flügl, 1988, The Steinplatte, a classic upper Triassic Reef—that is actually a platform-edge sand pile, *Geological Society of America Abstracts with Programs*, 27(7): A201.

22 H. Blatt, G. Middleton and R. Murray, 1980, *Origin of Sedimentary Rocks*, second edition, Englewood Cliffs, NJ: Prentice-Hall, 447.

23 L. T. Hodges and A. A. Roth, 1986, Orientation of corals and stromatoporoids in some Pleistocene, Devonian, and Silurian reef facies, *Journal of Paleontology*, 60: 1147-1158.

24 K. A. Giles, 1995, Allochthonous model for the generation of lower Mississippian Waulsortian mounds and implications for prediction of facies geometry and distribution, *American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists Annual Meeting Abstracts*, 4: 33A; K. P. Polan, 1982, *The allochthonous origin of 'bioherms' in the early Devonian Stewart Bay Formation, of Bathurst Island, Arctic Canada*, M.Sc. thesis, Montreal: Department of Geological Sciences, McGill University; W. R. Janoschek and A. Matura, 1980, Outline of the geology of Austria, *Abhandlungen der Geologischen Bundesanstalt*, 34: 40-46; R. Lein, 1987, On the evolution of the Austroalpine realm, in *Geodynamics of the Eastern Alps*, H.W. Flügel and T. Faupl, eds., Vienna: Franz Deuticke, 85-102;

If what have been mis-identified as fossilized reefs instead represent former reefs that have been transported *en masse* or eroded, fragmented, and incorporated in debris flows to form megabreccias, then the question of long time periods for their *in situ* formation at these current locations in the geologic record becomes totally irrelevant. In the context of the biblical framework of earth history, many reefs would have grown in the pre-Flood world, and as a result of the upheaval of the Flood would have then been destroyed, and the debris transported and deposited in Flood sediments. Of course, some of those pre-Flood reefs may well have been buried *in situ* by Flood sediments, but such occurrences of "fossilized reefs" would be now found at the base of the geologic record of the Flood.[25] Even though it has not been established that all ancient "fossilized reefs" are the result of rapid sediment transport, their identification as *in situ* structures has been shown to often be questionable. Indeed, the interpretations of both living and fossilized reefs involves abundant conjectures. Thus, our present knowledge indicates that the question of time for the formation of claimed fossilized reefs, and limestones generally, is not a serious challenge to either a recent creation or a global cataclysmic Flood.

A. Tollman, 1987, Geodynamic concepts of the evolution of the eastern Alps, in Flügel and Faupl, 1987, 361-378.

25 K. P. Wise and A. A. Snelling, 2005, A note on the pre-Flood/Flood boundary in the Ground Canyon, *Origins*, 58: 7-29.

117

Evaporites

Another type of sedimentary deposit that may at first seem difficult to compress into the short timespan of the Flood is the thick beds of so-called "evaporites." These consist mainly of halite (common salt or sodium chloride), gypsum and anhydrite (calcium sulfate), and other salts in bedded layers between other sedimentary rock units. The term "evaporite" is applied to these sedimentary deposits because it is believed they were formed by long periods of intense evaporation from inland seas or lakes containing saline water. Among the modern examples that are cited as a depositional model is the Dead Sea, where the evaporation rate is very high at about 120 inches annually, and where the water continually entering the lake has no other outlet apart from evaporation. As a result, the Dead Sea has an extremely high concentration of many salts, and it is believed that continued evaporation over long ages would thus produce beds of evaporates, similar to those found in many places in the geologic record. However, at present rates, this process would obviously require hundreds of thousands of years to produce the thick beds of evaporites that are actually found among the world's sedimentary strata.

As usual, the difficulty here is the unrelenting application of uniformitarianism. It is assumed that evaporite beds must have formed in some depositional environment or environments, the same or similar to those found today, in which salt deposits are being produced by evaporation that can be measured. Modern evaporite deposits accumulate in a variety of subaerial environments, such as coastal and continental sabkhas, or salt flats, pans or playas, and interdune environments, and shallow subaqueous environments such as saline coastal lakes called salinas.[1] The only possible modern example of a deep-water evaporite basin would be the Dead Sea. However, most geologists still believe that many of the thick, laterally extensive, ancient evaporite deposits did accumulate in deep-water basins.

Some ancient evaporite deposits, such as those of the so-called Zechstein of Europe, exceed 2,000 meters in thickness, yet evaporation of a column of seawater 1,000 meters thick will produce only about 15 meters of evaporites. Thus, to produce

1 A. C. Kendall, 1992, Evaporites, in *Facies Models: Response to Sea Level Change*, R. G. Walker and N. P. James, eds., Geological Association of Canada, chapter 19, 375-409.

the Zechstein evaporite deposits by the evaporation of seawater would have required a column of seawater 130,000 meters (or 130 kilometers) thick! Indeed, evaporation of all the water in the Mediterranean Sea, for example, would yield a mean thickness of evaporites of only about 60 meters. Of course, to circumvent the obvious difficulties of envisaging the evaporation of so much seawater to produce the ancient evaporite deposits, geologists must resort to special pleading:

> Obviously, special geologic conditions operating over a long period of time are required to deposit thick sequences of natural evaporites. The basic requirements for deposition of marine evaporites are a relatively arid climate, where rates of evaporation exceed rates of precipitation, and partial isolation of the depositional basin from the open ocean. Isolation is achieved by means of some type of barrier that restricts free circulation of ocean water into and out of the basin. Under these restricted conditions, the brines formed by evaporation are prevented from returning to the open ocean, causing them to become concentrated to the point where evaporite minerals are precipitated.[2]

Although geologists agree on these general requirements for formation of evaporites, considerable controversy has existed regarding deep-water versus shallow-water depositional mechanisms for many ancient evaporite deposits. There are three possible models for deposition of thick sequences of marine evaporites.

First, there is the deep-water, deep-basin model, which assumes the existence of a deep basin separated from the open ocean by some type of topographic barrier that prevents the free interchange of water in the basin with water in the open ocean, but allows enough water into the basin to replenish that lost by evaporation.

Second, the shallow-water, shallow-basin model, which assumes the evaporative concentration of brines in a shallow basin protected from the open ocean by a topographic high, and the accumulation of great thicknesses of evaporites is due to the continued subsidence of the floor of the basin.

Third, the shallow-water, deep-basin model requires that the brine level in the basin be reduced below the level of the topographic high, with recharge of seawater from the open ocean taking place only by seepage through the barrier, or by periodic overflow of it.

Geologists have found the application of these models to explain the formation of ancient evaporite deposits to be a challenging task, and have not always agreed upon the interpreted sedimentary environment. Over time, geologists' concept for evaporite deposition has swung from deep-water to shallow-water

---

2 S. Boggs, Jr., 1995, *Principles of Sedimentology and Stratigraphy*, second edition, Upper Saddle River, NJ: Prentice Hall, 243-244.

deposition, then from tidal sabkha regime to very moderate water depths.[3] This is well illustrated by the debate over how the thick evaporite beds formed in the Mediterranean Basin, in what has been called the "Messinian Salinity Crisis."

During the Deep Sea Drilling Project in the early 1970s, the sediments on the floor of the Mediterranean Sea were drilled into, revealing the existence of extensive, thick evaporite beds, which subsequently stimulated "an unusual quantity of researches" and generated "lively and even conflicting debates."[4] A deep basin-shallow water model for evaporite deposition was initially proposed,[5] but subsequent debate questioned that interpretation and most of the major aspects of previous "classical models" for evaporite deposition.[6] Nevertheless, it is now claimed that new data supports an integrated scenario that revives the key points of the deep-basin, shallow-water model, with two stages of evaporite deposition that affected successively the whole Mediterranean Basin, the distribution of the evaporites and their depositional timing being constrained by a high degree of paleogeographical differentiation, and by threshold effects that governed the water exchanges. So according to the most recent interpretative synthesis, 1,600 meters of layered evaporite deposits were formed in only 700,000 years (a relatively brief period of geologic time), due to the "interplay of both glacio-eustatic changes and fluctuations of the circum-Mediterranean climate."

However, do the sequences of salt beds found in these so-called evaporite deposits match the sequence of salts produced by evaporation of sea water? While it is often claimed the answer is yes, discrepancies between the sequence observed in laboratory experiments and the sequences observed in the rock record are the rule. That there is a definite sequence of minerals that precipitate when ocean water is evaporated in the laboratory was first demonstrated by Usiglio in 1848.[7] Minor quantities of carbonate minerals begin to form when the original volume of seawater is reduced by evaporation to about one half. Then gypsum (calcium sulfate) appears when the original volume has been reduced to about 20 percent, and halite (sodium chloride) forms when the water volume reaches approximately 10 percent of the original volume. Magnesium and potassium salts are then only deposited when less than about 5 percent of the original volume of seawater remains.

On the other hand, in general, the proportion of calcium sulfate (gypsum and

3 P. Sonnenfeld and G. C. St. C. Kendall (conveners), 1989, Marine evaporites: Genesis, alteration, and associated deposits: Penrose Conference Report, *Geology*, 17: 573-574.

4 2006, Editorial, The Messinian Salinity Crisis revisited, *Sedimentary Geology*, 188-189: 1-8.

5 K. J. Hsü, M. B. Cita and W. B. F. Ryan, 1973, The origin of the Mediterranean evaporites, in *Initial Reports of the Deep Sea Drilling Program*, volume 13, W. B. F. Ryan et al, eds., Washington, D.C.: US Government Printing office, 1203-1231.

6 J. M. Rouchy and A. Caruso, 2006, The Messinian Salinity Crisis in the Mediterranean Basin: A reassessment of the data and an integrated scenario, *Sedimentary Geology*, 188-189: 35-67.

7 F. W. Clarke, 1924, *The Data of Geochemistry*, 5th edition, US Geological Survey, Bulletin 770.

anhydrite) is greater and the proportion of sodium-magnesium sulfates is less in natural deposits than observed in laboratory experiments.[8] Furthermore, the thickest sequences of evaporite deposits in the Mediterranean Basin begin with more than 500 meters thickness of massive halite,[9] whereas the lower portion of the Castile Formation, from the 1,300-meter-thick evaporite deposits of the Delaware Basin of western Texas and southeastern New Mexico, is composed of alternating thin laminae of calcite, anhydrite, and organic matter.[10] So to account for these anomalous mega-occurrences, special *ad hoc* conditions need to be postulated. The deposition of relatively thick sequences of gypsum and/or anhydrite, such as in the Castile Formation, is said to imply that there was a source of new seawater or other brine being made available for evaporation, and that the brine was seldom allowed to concentrate to the point of halite precipitation. If the concentrated brine is removed from the sedimentary basin at the same time new sea water is added, then the claim is made that it is possible to maintain the concentration at an equilibrium value and precipitate only gypsum. On the other hand, if as the seawater evaporates new seawater is constantly added to the depositional basin to maintain the original volume, then it is claimed the brine will soon become concentrated to the point of only precipitating halite, as in the massive beds in the western Mediterranean Basin.[11]

The following comment sums up the failure of the uniformitarian evaporite model to explain the formation of bedded salt deposits:

> Although the order observed by Usiglio agrees in a general way with the sequence found in some salt deposits, many exceptions are known. Also many minerals known from salt beds did not appear in the experimentally formed residues. The crystallization of the brine is very complex, and depends not only on the solubility of the salts involved but also upon the concentration of the several salts present and the temperature.... Inasmuch as many evaporite deposits show marked exceptions to the above requirements, simple evaporation of sea water did not occur, and either the parent brine was not formed from sea water or the evaporation took place under special conditions that will explain the anomalies.[12]

However, even though the impression often given is that evaporite deposits are simply the product of chemical precipitation owing to evaporation of seawater, it is well documented that many evaporite deposits are not just passive chemical

8 H. Borchert and R. O. Muir, 1964, *Salt Deposits: The Origin, Metamorphism, and Deformation of Evaporites*, London: Van Nostrand.

9 Rouchy and Caruso, 2006.

10 H. Blatt, 1992, *Sedimentary Petrology*, second edition, New York: W. H. Freeman and Company, chapter 10, 338-341.

11 H. Blatt, G. Middleton, and R. Murray, 1972, *Origin of Sedimentary Rocks*, Engelwood Cliffs, NJ: Prentice-Hall, 501-504.

12 F. J. Pettijohn, 1957, *Sedimentary Rocks*, second edition, New York: Harper and Rowe, 483-484.

precipitates.[13] The "evaporite" minerals have, in fact, been transported and reworked in the same way as the constituents of sandstones, siltstones, shales, and limestones. Transport can occur by normal fluid-flow processes, or by mass-transport processes such as slumps and turbidity currents. Turbidity current transport mechanisms may have been particularly important in deposition of many "ancient" deep-water evaporite deposits.[14] Thus evaporite deposits display sedimentation features the same as sandstones, siltstones, shales, and many limestones, including both normal and reverse grain-size grading, cross-bedding, and ripple marks. Such features are clearly related to water-transport and deposition. Thus, the alternating thin laminae of calcite, anhydrite, and organic matter in the Castile Formation of the Delaware Basin of western Texas and southeast New Mexico, and in the Prairie Formation of the Williston Basin of Saskatchewan, Canada, and North Dakota, were clearly deposited as a result of turbidity currents, and therefore rapidly, as demonstrated in the laboratory,[15] and in observational field studies.[16]

However, if the sedimentation features in evaporite deposits indicate rapid deposition, then there is clearly a major problem, because the slow-and-gradual evaporation of seawater to produce evaporite deposits is totally incompatible with this observational evidence of rapid deposition. On the other hand, if there were an alternate means by which salt deposits could be produced rapidly, then this would be consistent with the observed field evidence. Indeed, evaporation of seawater is not the only means by which a highly-concentrated brine is formed from which salts precipitate. Volcanic waters and hydrothermal fluids are usually very saline, and when they mix with bodies of cold water, the sudden temperature drop causes the water mixture to become super-saturated in the salts, so that the solution can no longer hold the salts, which rapidly precipitate.[17] This is precisely what happens around deep-sea hot hydrothermal vents,[18] where layers of highly

---

13 Boggs, 1995, 245.

14 E. C. Shrieber, M. E. Tucker and R. Till, 1986, Arid shorelines and evaporites, in *Sedimentary Environments and Facies*, H. G. Reading, ed., Blackwell, 189-228.

15 P. H. Kuenen, 1966, Experimental turbidite lamination in a circular flume, *Journal of Geology*, 74: 523-545; G. Berthault, 1986, Experiments of lamination of sediments, resulting of a periodic graded-bedding subsequent to deposit, *Compte Rendu Academie des Sciences, Paris*, 303: 1569-1574; G. Berthault, 1988, Sedimentation of a heterogranular mixture: Experimental lamination in still and running water, *Compte Rendu Academie des Sciences, Paris*, 306: 717-724.

16 M. M. Ball, E. A. Shinn, and K. W. Stockman, 1967, The geologic effects of hurricane Donna in south Florida, *Journal of Geology*, 75: 583-597; E. D. McKee, E. J. Crosby and H. L. Berryhill, Jr., 1967, Flood deposits, Bijou Creek, Colorado, June 1965, *Journal of Sedimentary Petrology*, 37: 829-851; S. A. Austin, 1986, Mount St. Helens and catastrophism, *Proceedings of the First International Conference on Creationism*, Volume 1, Pittsburgh, PA: Creation Science Fellowship, 3-9; D. J. W. Piper, 1972, Turbidite origin of some laminated mudstones, *Geological Magazine*, 109: 115-126.

17 K. B. Krauskopf, 1967, *Introduction to Geochemistry*, New York: McGraw-Hill; M. Hodes, P. Griffiths, K. A. Smith, W. S. Hurst, W. J. Bowers, and K. Sako, 2004, Salt solubility and deposition in high temperature and pressure aqueous solutions, *American Institute of Chemical Engineers Journal*, 50(9): 2038-2049.

18 P. A. Rona, G. Klinkhammer, T. A. Nelson, H. Trefry and H. Elderfield, 1986, Black smokers, massive

saline supercritical waters may have ponded on the ocean-bottom.[19]

These and related observations are consistent with the long-proposed, hydrothermal model for the deposition of what should be called precipitite (rather than evaporite) deposits.[20] This hydrothermal precipitite model answers many questions left unexplained by conventional evaporite models. Its geologic setting requires a period of intense undersea volcanic or igneous intrusive activity in the depositional basin of no specific water depth, in which there are also widespread hydrothermal vent systems through which much water is circulating. Derivation of the salts for deposition is due to enrichment of the salts in seawater by the circulation of normal seawater through the hydrothermal vent system, and by direct addition of salts in hydrothermal fluids given off by intrusive magmas and during the intense volcanic activity. The resulting super-saline, hot supercritical waters consequently stratify in layers at the bottom of the depositional basin, as has been currently observed at the bottom of the Red Sea.[21] These salt deposits then are precipitated by several mechanisms acting together.

1. As the hot saline waters ascend, salt precipitation occurs as they are cooled by the colder seawater above.

2. Salts that are less soluble in hot saline water, such as calcium carbonate and calcium sulfate (gypsum and anhydrite), precipitate due to the heating caused by the hotter supercritical water coming up from below, and/or from variations in magmatic activity.

3. Salt precipitation results from the pressure release as the hot super-saturated brine mass rises.

4. Salt precipitation results from changes in the Eh and pH of the super-saturated brines.

---

sulfides and vent biota at the Mid-Atlantic Ridge, *Nature*, 321: 33-37; K. L. VonDamm, 1990, Seafloor hydrothermal activity: black smoker chemistry in chimneys, *Annual Review of Earth and Planetary Sciences*, 18: 173-204.

19 R. P. Lowell and L. N. Germanovich, 1997, Evolution of a brine-saturated layer at the base of a ridge-crest hydrothermal system, *Journal of Geophysical Research*, 102(B5): 10,245-10,255; K. L. VonDamm, M. D. Lilley, W.C. Shanks III, M. Bockington, A. M. Bray, K. M. O'Grady, E. Olson, A. Graham, and B. Proskurowski, 2002, Extraordinary phase separation and segregation in vent fluids from the southern East Pacific Rise, *Earth and Planetary Science Letters*, 196: 1-4.

20 V. I. Sozansky, 1973, Origin of salt deposits in deep-water basins of the Atlantic Ocean, *American Association of Petroleum Geologists Bulletin*, 57(3): 589-590; D. I. Nutting, 1984, *Origin of Bedded Salt Deposits: A Critique of Evaporative Models and a Defence of a Hydrothermal Model*, M.S. Thesis (unpublished), El Cajon, CA: Institute for Creation Research Graduate School; M. Hovland, H. G. Rueslåtten, H. K. Johnsen, B. Kvanne and T. Kuznetsova, 2006, Salt formation associated with sub-surface boiling and supercritical water, *Marine and Petroleum Geology*, 23: 855-869.

21 J. L. Bischoff, 1969, Red Sea geothermal brine deposits: their mineralogy, chemistry and genesis, in *Hot Brines and Recent Heavy Metal Deposits in the Red Sea: A Geochemical and Geophysical Account*, E. T. Dedgens and D. A. Ross, eds., New York: Springer –Verlag, 368-401; M. Hovland et al, 2006.

5. Salt precipitation results from a process of brine mixing, where two brines of different salinities react.[22]

It is thus now well-documented that this hydrothermal precipitite model accounts for the salt beds forming on the floor of the Red Sea today, beneath hydrothermal brine layers in pools within basins.[23] That the presently-active hydrothermal precipitation of these bedded salt deposits are related to the formation of ancient evaporite deposits is confirmed by the bedded salt deposits up to 5,000 meters thick on the flanks of the Red Sea, and underneath where salt beds are precipitating today.[24] Further evidence that supports the hydrothermal precipitite model for the formation of ancient salt deposits includes:

1. The proportion of the different salt minerals found in ancient salt beds is completely different from what theoretical and experimental geochemical methods would predict based upon the uniformitarian evaporite model.[25] As already noted, salt beds contain great thicknesses of primarily one salt mineral to the exclusion of all others. Furthermore, some of the more soluble salts, such as magnesium sulfate, are absent in large salt beds, whereas they generally form in the claimed modern analogous evaporative lagoons.[26]

2. Some of the associations of salt minerals indicate high temperatures of deposition, such as 83°C for a magnesium sulfate salt with potassium chloride.[27] For example, the huge German Zechstein salt beds contain large amounts of these salt minerals that require high depositional temperatures near the boiling point of water, temperatures that are not found in modern depositional settings for evaporite deposits.

3. Bedded salt deposits are frequently associated with volcanics.[28] For example, volcanics are associated with the huge evaporite deposits of the Mediterranean Basin.[29]

---

22 O. B. Raup, 1970, Brine mixing: An additional mechanism for formation of basin evaporites, *American Association of Petroleum Geologists Bulletin*, 54(12): 2246-2259; F. L. Wilcox and S. T. Davidson, 1976, Experiments on precipitation brought about by mixing brines, *Creation Research Society Quarterly*, 13(2): 87-89.

23 Hovland et al, 2006.

24 G. Savoyat, A. Shiferaw and T. Balcha, 1989, Petroleum exploration in the Ethiopian Red Sea, *Journal of Petroleum Geology*, 12: 187-204; F. Orszag-Sperber, P. Harwood, A. Kendall and B.H. Purser, 1998, A review of the evaporites of the Red Sea-Gulf of Suez Rift, in *Sedimentation and Tectonics of Rift Basins: Red Sea-Gulf of Aden*, B. H. Purser and D. W. J. Bosence, eds., London: Chapman and Hall, 409-426.

25 Krauskopf, 1967, 319-353.

26 V. B. Porfir'ev, 1974, Geology and genesis of salt formations, *American Association of Petroleum Geologists Bulletin*, 58: 2543-2544.

27 F. H. Stewart, 1963, Marine evaporites, in *Data of Geochemistry*, sixth edition, M. Fleischer, ed., US Geological Survey Professional Paper 440-Y; Krauskopf, 1967, 346.

28 Sozansky, 1973; Porfir'ev, 1974.

29 W. B. Nesteroff, F. C. Wezel and G. Pautot, 1973, Summary of lithostratigraphic findings and problems,

4. Bedded salt deposits are frequently associated with rifting, mountain-building, and faulting that coincide with magmatic, volcanic, and hydrothermal activity.[30]

5. Bedded salt deposits are frequently associated with large accumulations of hydrocarbons.[31] Indeed, almost every major oil-producing province of the world is associated either directly or indirectly with bedded salt deposits. The connection to hydrothermal activity is evident from discovery of the natural generation of petroleum by hydrothermal fluids flowing through organic material in sediments on the sea floor of the Guaymas Basin in the Gulf of California.[32]

6. Bedded salt deposits are frequently associated with sulfur and heavy metal sulfides in some of the world's major sedimentary-hydrothermal metal sulfide deposits, and salt minerals are often associated with many of the world's major hydrothermal metal deposits.[33]

In conclusion, during the global Genesis Flood cataclysm, bedded salt deposits would have been formed catastrophically as a result of the intense volcanic and magmatic activity, with the associated voluminous quantities of saline hydrothermal fluids "bursting forth" from the earth's crust that was torn apart during catastrophic plate tectonics.[34] Both the purity of the bedded salt deposits and their frequent, thin repeating laminae are testimony to the rapid water transport and deposition by turbidity currents, while the salt minerals rapidly precipitated as supercritical saline hydrothermal fluids catastrophically mixed with the colder ocean waters. Not only is the hydrothermal precipitite model more viable for this rapid formation of bedded salt deposits within the year-long Genesis Flood, but it is clear that the geologic evidence is far more consistent with that model than with the uniformitarian evaporite model.

---

in *Initial Reports of the Deep-Sea Drilling Project*, volume XIII, W. B. F. Ryan, K. Hsü et al, eds., Washington DC: US Government Printing Office, 1021-1040; L. Jolivet, R. Augier, C. Robin, J.-P. Suc and J. M. Rouchy, 2006, Lithospheric-scale geodynamic context of a Messinian Salinity Crisis, *Sedimentary Geology*, 188-189: 9-33.

30 G. Pautot, J. Auzende and X. Pichon, 1970, Continuous deep sea salt layer along north Atlantic margins related to early phase of rifting, *Nature*, 227: 351-354.

31 A. D. Buzzalini, 1969, Evaporites and petroleum: Introduction, *American Association of Petroleum Geologists Bulletin*, 53(4): 775.

32 B. Simoneit, and P. F. Lonsdale, 1982, Hydrothermal petroleum in mineralized mounds at the seabed of Guaymas Basin, *Nature*, 295: 198-202.

33 A. R. Renfro, 1974, Genesis of evaporite-associated stratiform metalliferous deposits-a sabkha process, *Economic Geology*, 69: 33-45; M. L. Jensen and A. M. Bateman, 1981, *Economic Mineral Deposits*, third edition, New York: John Wiley and Sons; R. G. Roberts and P. A. Sheahan, eds., 1988, *Ore Deposit Models*, Geoscience Canada, reprint series 3, Geological Association of Canada; R. W. Boyle, A. C. Brown, J. W. Jefferson, E.C. Jowett and R. V. Kirkham, eds., 1989, *Sediment-Hosted Stratiform Copper Deposits*, Geological Association of Canada Special Paper 36; H. L. Barnes, ed., 1997, *Geochemistry of Hydrothermal Ore Deposits*, third edition, New York: John Wiley and Sons.

34 Austin et al, 1994.

118

Varves and Rhythmites

Another type of sedimentary deposit claimed to have taken millions of years to form are thinly laminated shales known as varves or rhythmites. The laminae are thinner than one centimeter, and can be as thin as one millimeter. Often the laminae grade in color from light to dark, and a varve usually consists of a pair of such laminae, one light and the other dark. Each varve has been interpreted as an annual deposit, the laminae couplet representing seasonal alternation of sedimentary conditions, a feature known in some modern lake sediments. The lighter and coarser lamina represents deposition during the summer, while the darker, more organic-rich lamina is regarded as the winter deposition during the annual cycle. If this interpretation is valid for such ancient laminated shales, then varves could be used not only as qualitative indices of time duration, but as an actual measurement of years during which the successive couplets of laminae were deposited. The dating of such lake-bed varve deposits was first used as the basis of varve chronology for the glacial and post-glacial periods in particular, due to the glacial lakes in northern Europe.

There are several obvious and important difficulties with this varve dating method, however, one of which is the impossibility of knowing that the couplets of laminae all actually represent annual cycles of deposition. Many other phenomena could conceivably produce such varves, such as the variation in flow and sediment load of the stream or streams feeding the lake or depositional basin. Any brief flooding discharge into the lake, seasonal or unseasonal, would cause an initial layer of larger-size particles, followed by gradual settling of the finer particles with suspended organic matter, and this would thus give the appearance of laminae as a varve couplet. There are also other causes:

> The causes of such laminations are variations in the rate of supply or deposition of the different materials. There variations might result from changes in the quantity of the silt, clay or calcium carbonate, or organic matter in the seawater or to changes in the rate of accumulation of these materials. Such variations have been attributed to the fortuitous shift in the depositing current, to climatic causes (especially cyclical changes

> related to diurnal or annual rhythms), and also to aperiodic storms or floods.[1]

Obviously, these factors are not necessarily annual in character. Indeed, they are usually unpredictably sporadic, so it is very difficult to determine absolutely that a given bed of laminated muds was actually laid down as annual varves. This is why the more general term of rhythmites has been introduced, because of the uncertainty of these couplets of laminae representing annual cycles of deposition.

Not only is there doubt about the yearly nature of these varves, but an even more important question is whether the laminae of several ancient lakes can be correlated with each other by matching the patterns of the varying thicknesses of the laminae. Such a method is hardly objective.

> Rhythmites belonging to a segment of the same period were studied in Finland…showed that correlation based on thickness alone could lead to error…the correlation of rhythmites, as described above, depends on the judgment of the person who matches the curves, and therefore is not wholly objective. The literature does not report any attempt at independent correlation by several persons.[2]

Not surprisingly, therefore, problems arise when attempts are made to correlate the laminae from different localities.[3]

> Even the varve correlation…through the very short distance between Denmark and southern Sweden was severely criticized on the grounds that the implied relative dates of the several Danish deposits concerned are in complete conflict with the stratigraphic evidence. The whole matter of the reliability and usefulness of the varve correlation is at present in an unsatisfactory state.[4]

Both in Sweden and in North America, extensive studies attempting to combine sequences of a few hundred laminae, many of them considered to be annual glacial varves, ran into trouble. A suggested combined chronology of 28,000 years for North America underwent reinterpretation to little more than 10,000 years when rechecked with radiocarbon dating.[5] Indeed, more than 30 radiocarbon dates generally increase with depth through the laminae, and together the laminae

1 Pettijohn, 1957, 163.

2 R. F. Flint, 1957, *Glacial and Pleistocene Geology*, New York: Wiley, 297.

3 M. J. Oard, 1992, Varves – The first 'absolute' chronology. Part I – Historical development and the question of annual deposition, *Creation Research Society Quarterly*, 29(2): 72-80; M. J. Oard, 1992, Varves – The first 'absolute' chronology. Part II – Varve correlation and the post-glacial timescale, *Creation Research Society Quarterly*, 29(3): 120-125.

4 R. F. Flint, 1947, *Glacial Geology and the Pleistocene Epoch*, New York: Wiley, 397.

5 R. F. Flint, 1971, *Glacial and Quaternary Geology*, New York: John Wiley and Sons, 406.

and radiocarbon dates sometimes extend to 10,000 to 13,000 years.[6] However, there are problems with the laminae-radiocarbon correlation, such as the laminae usually being more reliable than the radiocarbon dates, so that the researchers use the laminae to correct the radiocarbon dates. Given the problems noted earlier with radiocarbon dating, it is hardly surprising that the two systems do not give the same results. Furthermore, serious difficulties arise in counting the laminae, with sections sometimes assumed to be missing or found to be undefined, and some of the laminae are so fine that it is difficult to identify them. Thus different investigators report different numbers, and also acknowledge some selection of radiocarbon dates.[7] Thus, it can be readily concluded that the laminated muds or varves of Ice Age glacial lakes offer no problem to biblical chronology, these varves being deposited annually and over shorter intervals within the post-Flood period.

An apparently more serious difficulty is encountered in connection with laminated shales and supposed varves in more supposedly ancient sedimentary strata. The classical example usually cited is the Eocene Green River Formation of Colorado, Utah, and Wyoming.

> There are more than a million vertically superimposed varve pairs in some parts of the Green River Formation. These varve deposits are most certainly fossil-lake sediments. If so, each pair of sediment layers represents an annual deposit….The total number of varve pairs indicates that the lakes existed for a few million years.[8]

One estimate puts the timeframe for the deposition of the varves of the Green River Formation at more than 7.5 million years.[9] Clearly, such a calculation just for one geological formation is a serious challenge to the biblical chronology of only thousands of years, with a recent year-long global Flood. Furthermore, the Green River Formation is not the only claimed ancient varve deposit; others include the Triassic Lockatong Formation in the northwestern United States and

6 I. Hajdas, S.D. Ivey, J. Beer, G. Bonani, D. Imboden, A. Lotter, M. Sturm and M. Suter, 1993, AMS radiocarbon dating and varve chronology of Lake Soppensee: 6000 to 12,000 ^{14}C years BP, *Climate Dynamics*, 9: 107-116; I. Hajdas, E. Zolitschka, S. D. Ivey-Ochs, J. Beer, G. Bonani, S. A. G. Leroy, J. W. Negendank, M. Ramrath, and M. Suter, 1995, AMS radiocarbon dating of annual laminated sediments from Lake Holzmaar, Germany, *Quaternary Science Reviews*, 14: 137-143; I. Hajdas, S. D. Ivey-Ochs and G. Bonani, 1995, Problems in the extension of the radiocarbon calibration curve (10-13 kyr BP), *Radiocarbon*, 37(1): 75-79; I. Hajdas, S. D. Ivey, J. Beer, G. Bonani, D. Imboden, A. Lotter, M. Sturm and M. Suter, 1993, AMS radiocarbon dating and varve chronology of Lake Soppensee: 6000 to 12,000 ^{14}C years BP, *Climate Dynamics*, 9: 107-116.

7 S. Björck, P. Sandgren, and B. Holmquist, 1987, Magnetostratigraphic comparison between ^{14}C years and varve years during the late Weichselian, indicating significant differences between the timescales, *Journal of Quaternary Science*, 2(2): 133-140.

8 D. A. Young, 1990, The discovery of terrestrial history, in *Portraits of Creation*, H. J. Van Till, R. E. Snow, J. H. Stek and D. A. Young, eds., Grand Rapids, MI: William B. Eerdmans, 77.

9 R. C. Selley, 1975, *Ancient Sedimentary Environments and Their Sub-Surface Diagenesis*, third edition, Ithaca, NY: Cornell University Press, 108.

the Carboniferous Seaham Formation of the Sydney Basin, Australia.[10]

Apparently, the only in-depth study of the supposed varves of this well-known Green River Formation was made almost 80 years ago, and all later writers simply refer to that study.[11] However, only two very inadequate reasons are given in that study for the layers being annual. One is a calculation purporting to show the amount of sediment in the formation is of the same order of magnitude as the probable amount of erosion from the ancient drainage basin contributing to the lakes, whose beds are supposed to form these varved shales. Such a calculation is, however, entirely speculative and hypothetical, based on rank guesswork about the unobserved past. The other reason for concluding the laminations in the Green River Formation to be annual varves was their similarity of appearance to the varved clay deposits of the Pleistocene (Ice Age), and, to a lesser extent, the banded sediments found in certain modern lakes. The resemblance, however, is largely superficial, because the Pleistocene varves are much thicker than the Green River laminations, which average less than six thousandths of an inch in thickness (0.15 mm). Furthermore, whereas the Pleistocene varves reflect glacial melt-water deposition, the Green River shales consist of a cyclic repetition of organic and inorganic matter. Contrary to this application of uniformitarianism, no modern lake deposits have such distinct thin laminations that are the equivalent of these laminated Green River oil shales.

The classic thinking of uniformitarian geologists is that catastrophic sedimentary action should homogenize fine clay-rich sediments, and thus deposit a massive, non-laminated formation. However, a large body of experimental and observational data refutes this notion that laminae in shale generally had to be deposited slowly.[12] In fact, laminated, fine-grained sediments form by rapid sedimentation, even as observed in some modern situations. A 1960 Florida hurricane flooded inland and deposited a six-inch-thick mud layer with numerous thin laminae.[13] A 12-hour flood in Colorado deposited more than 100 laminae.[14] Field observations and laboratory experiments suggest laminae can form in as little as a few minutes, seconds, or almost instantaneously, such as during the June 12, 1980, eruption of Mount St. Helens, when a hurricane-velocity, surging-flow of volcanic ash accumulated a 25-foot thickness of finely-laminated ash.[15] Analysis of recent

10 Selley, 1975, 109, 111.

11 W. H. Bradley, 1929, *The Varves and Climate of the Green River Epoch*, US Geological Survey Professional Paper 158: 87-110.

12 S. A. Austin, 1984, *Catastrophes in Earth History*, El Cajon, CA: Institute for Creation Research.

13 M. M. Ball, E. A. Shinn and K. W. Stockman, 1967, The geologic effects of Hurricane Donna in south Florida, *Journal of Geology*, 75: 583-597.

14 E. D. McKee, E. J. Crosby and H. L. Berryhill, Jr., 1967, Flood deposits, Bijou Creek, Colorado, June 1965, *Journal of Sedimentary Petrology*, 37: 829-851.

15 A. V. Jopling, 1966, Some deductions on the temporal significance of laminae deposited by current action in clastic rocks, *Journal of Sedimentary Petrology*, 36(4): 880-887; S. A. Austin, 1986, Mount St. Helens and catastrophism, *Proceedings of the First International of Creationism*, vol. 1, Pittsburgh, PA:

sedimentation in the Walensee of Switzerland revealed that an average of two laminae had developed per year, while in some years as many as five laminae had been deposited by rapid, turbid-water, underflow processes.[16]

Not only are there numerous modern examples where natural catastrophic events accumulated laminae rapidly, but horizontal laminae in fine-grained sediment have been produced by high-velocity currents in an experimental circular flume.[17] Other experiments also show that sediments consisting of a homogenized mixture of clay and silt can sort themselves into thin laminae at a rate of several per second, producing a turbidite-like deposit.[18] Even experiments where the sediment was allowed to settle in quiet water without lateral transport, several laminae formed in a few hours.

Many geologists have disputed the notion that laminated shales formed slowly. A classic study of the marine black shale of Scotland showed that they intertongue with large boulders, which had to have been moved during a submarine earthquake, the subsequent enormous tsunami rapidly depositing the laminated clay-rich muds on top of them.[19] Large boulders found within the Bright Angel Shale of Grand Canyon would have required rapid deposition of the shale, similar to the rapid deposition from high-velocity dense suspensions of sediment and water of laminated shales and mudstones in Ireland, England and Canada.[20] The 300 feet thick sequence of thin laminae and beds of clay, silt, and sand known as the Touchet beds in Washington have been recognized as being due to slack-water deposition associated with the catastrophic flooding which formed the Channeled Scabland.[21]

These evidences for rapid deposition of laminated shales demonstrate that the laminated Green River Formation shales could likewise have been deposited rapidly. Indeed, there are several factors that make it highly doubtful that the laminae could possibly represent annual varves. The laminae are entirely too thin

---

Creation Science Fellowship, 3-9.

16 A. Lambert and K. J. Hsü, 1979, Nonannual cycles of varvelike sedimentation in Walensee, Switzerland, *Sedimentology*, 26: 453-461.

17 P. H. Kuenen, 1966, Experimental turbidite lamination in a circular flume, *Journal of Geology*, 74: 523-545.

18 G. Berthault, 1986, Experiments on lamination of sediments, resulting for a periodic graded-bedding subsequent to deposit, *Compte Rendu Academie des Sciences, Paris*, 303: 1569-1574; G. Berthault, 1988, Sedimentation of a heterogranular mixture: experimental lamination in still and running water, *Compte Rendu Academie des Sciences, Paris*, 306: 717-724; H. A. Makse, S. Havlin, P. R. King and H. E. Stanley, 1997, Spontaneous stratification in granular mixtures, *Nature*, 386: 379-382.

19 E. B. Bailey and J. Weir, 1932, Submarine faulting in Kimmeridgian times, east Sutherland, *Transactions of the Royal Society of Edinburgh*, 57: 429-454.

20 E. J. W. Piper, 1972, Turbidite origin of some laminated mudstones, *Geological Magazine*, 109: 115-126.

21 R. J. Carson, C. R. McKhann and M. H. Pizey, 1978, The Touchet beds of Walla Walla Valley, in *The Channeled Scabland*, B.R. Baker and D. Nummedall, eds., Washington, D.C.: National Aeronautics and Space Administration, 173-177.

and uniform, and extend over too wide an area, to have been deposited on the floor of the abnormally calm lakes. Indeed, in any lake the bottom sediments are occasionally stirred by storms and river floods washing in and dumping large quantities of sediment. In the Green River Shales there are occasional pebbles that could only have been carried by fast-moving water currents, and the laminae are draped over them.[22] Furthermore, numerous thin (2-25 cm) volcanic ash (tuff) beds are interbedded with, and regularly spaced within, the laminated shales, representing numerous volcanic eruptions during deposition of the laminated shales.[23]

Such volcanic ash layers are recognized by geologists as being "event horizons," because of each being laid down essentially instantaneously by single volcanic eruptions, and so these have been radioisotope dated. Thus, since each tuff bed represents a time marker through the Green River Formation shales, if the laminae represented annual varves there should be the same number of varves (years) between any two volcanic ash layers anywhere across the depositional basin. However, near Kemmerer, Wyoming, two tuff beds in the Green River Formation, each 2-3 cm thick, are separated by 8.3 to 22.6 cm of shale laminae at two different localities, and the number of laminae between the two tuff beds varies from 1,089 to 1,566, with an overall increase in the numbers of laminae (up to 35 percent) and laminae thickness from the basin center to the basin margin.[24] The organic content of the shale laminae also changes, so these laminae cannot represent annual depositional layers, as there should be the same number of varves between the two volcanic ash layers, and the laminae should be of consistent thickness and organic content if that were the case.

Furthermore, the Green River Formation is also rich in well-preserved fossils that are abundant and widespread throughout the laminated shales.[25] Indeed, the Green River Formation is famous for its fish fossils.

> [F]ossil catfish are distributed in the Green River basin over an area of 16,000km^2....The catfish range in length from 11 to 24 cm, with a mean of 18 cm. Preservation is excellent. In some specimens, even the skin and

22 A. G. Fischer and L. T. Roberts, 1991, Cyclicity in the Green River Formation (Lacustrine Eocene Wyoming), *Journal of Sedimentary Petrology*, 61(7): 1146-1154.

23 W. H. Bradley, 1964, *Geology of Green River Formation and Associated Eocene Rocks in Southwestern Wyoming and Adjacent Parts of Colorado and Utah*, US Geological Survey Professional Paper 496-A; M. E. Smith, B. Singer and A. Carroll, 2003, $^{40}Ar/^{39}Ar$ geochronology of the Eocene Green River Formation, Wyoming, *Geological Society of America Bulletin*, 115(5): 549-565.

24 H. P. Buchheim and R. Biaggi, 1988, Laminae counts within a synchronous oil shale unit: A challenge to the 'varve' concept, *Geological Society of America Abstracts with Programs*, 30: A317; H. P. Buchheim, 1994, Paleoenvironments, lithofacies and varves of the Fossil Butte Member of the Eocene Green River Formation, southwestern Wyoming, *Contributions to Geology, University of Wyoming*, 30(1): 3-14.

25 L. Grande, 1984, *Paleontology of the Green River Formation, with a Review of the Fish Fauna*, second edition, Geological Survey of Wyoming, Bulletin 63.

other soft parts, including the adipose fin, are well preserved.[26]

As well as enormous quantities of many varieties of fish, the inventory of fossils includes amphibians, turtles, lizards, snakes, crocodilians, birds, bats and many mammals, sponge spicules, worm trails, snails, clams, spiders, ticks, mites, clam shrimps, crustaceans, crayfish, prawns, many varieties of insects including beetles, flies, mosquitoes, wasps and moths, as well as many varieties of plants, including ferns, sycamore, maple, oak, pines, and even well-preserved flowers. Among the bird fossils are enormous concentrations of an extinct shore bird.[27] Additionally, some of the fish have been fossilized in the process of eating other fish! How does one explain such extraordinary circumstances of fossilization while sediments are slowly accumulating at a rate of six thousandths of an inch per year?

The Green River Formation can hardly be any ordinary lake deposit, because modern lakes on which the varve concept is modeled do not provide conditions needed for such exquisite preservation of abundant fossil fish, birds, bats, and flowers. It has been shown experimentally that, even on the muddy bottom of a marsh in oxygen-poor conditions, fish carcasses decay quite rapidly, all flesh having decayed, and even the bones becoming disconnected, after only six and a half days.[28] Some fish may have taken a day or two to have been buried and fossilized because of being found preserved with scales scattered and even exploded.[29] However, birds have hollow bones that tend not to be well preserved in the fossil record, so how then did these birds lay dead on the bottom of a lake protected from scavenging and decay for thousands of years, until a sufficient number of very thin annual varve layers had built up to bury them?

All of these evidences combine to make it absolutely clear that the laminated shales in the Green River Formation are not annual varves, but instead the shales had to have accumulated rapidly to entomb so many well-preserved fossils between volcanic eruptions. The apparent absence of graded bedding in these shales is also significant, given that if the sediments simply settled to the bottom of a quiet lake, each lamina should have been marked by a gradual decrease in particle size upwards. Instead, it is eminently reasonable to explain the rapid accumulation of these Green River shales due to shallow turbidity currents transporting muds and organic matter into large lake-like depositional basins within a matter of days or months, depending on whether this occurred late in the year of the

26 H. P. Buchheim and R. C. Surdam, 1977, Fossil catfish and the depositional environment of the Green River Formation, Wyoming, *Geology*, 5: 196-198.

27 A. Feduccia, 1978, *Presbyornis* and the evolution of ducks and flamingos, *American Scientist*, 66(3): 298-304.

28 R. Zangerl and E. S. Richardson, 1963, The paleoecological history of two Pennsylvanian black shales, *Fieldiana: Geology Memoirs 4*.

29 J. H. Whitmore, 2003, *Experimental Fish Taphonomy with a Comparison to Fossil Fishes*, Ph.D. dissertation (unpublished), Loma Linda, CA: Loma Linda University.

Flood catastrophe, or in the months following its end.[30] Furthermore, the abundant evidence that laminated shales and other fine-grained rhythmites can be shown experimentally and observationally to have been formed rapidly under catastrophic conditions confirms that these ancient finely-laminated sedimentary layers, so often claimed to have accumulated as annual varves, can be better and more reasonably explained as a result of catastrophic deposition during the year-long Flood cataclysm.

30 M. J. Oard and J. H. Whitmore, 2006, The Green River Formation of the west-central United States: Flood or post-Flood?, *Journal of Creation*, 20(1): 46-85.

119

Buried Forests

Another important sedimentary phenomenon that seems to require much longer periods of time than the Bible would allow is found in other cyclically repeated deposits, where each cycle seems to require measurable time in which to be formed. An often-quoted example is the succession of so-called buried forests in Yellowstone National Park, where well-preserved petrified tree stumps are found in great numbers in beds of volcanic ash and lavas.

> In Yellowstone Park there is a stratigraphic section of 2,000 feet exposed which shows 18 successive petrified forests. Each forest grew to maturity before it was wiped out with a lava flow. The lava had to be weathered into soil before the next forest could even start. Further this is only a small section of the stratigraphic column in this area. It would be most difficult for Flood geology to account for these facts.[1]

At Mt. Amethyst-Specimen Ridge 27 successive levels of these supposed buried forests have been counted,[2] 31 levels on Mt. Hornaday, and at least 65 levels in the Specimen Creek area.[3] The most striking feature of these petrified trees is the erect position of many of the stumps, which appears to be convincing evidence that the trees are in their *in situ* original growth position. If after a volcanic eruption it took 200 years for reforestation to commence, and then another 500 years for tree growth, based on the average largest tree size for each level, then it would have taken more than 45,000 years to grow and bury the trees and forests of the 65 levels counted in the Specimen Creek area. Added to this is the time for the erosion at current rates of the more than 1,200 vertical meters (3,400 feet) of volcanic ash, sediments, and lavas to expose these petrified "forests." Thus, if this conventional interpretation is correct, then these successively buried forests

1 J. L. Kulp, January 1950, Flood geology, *Journal of the American Scientific Affiliation*, 10.

2 E. Dorf, 1960, Tertiary fossil forests of Yellowstone National Park, Wyoming, *Billings Geological Society Guidebook, 11th Annual Field Conference*, 253-260; E. Dorf, 1964, The petrified forests of Yellowstone National Park, *Scientific American*, 210: 106-114.

3 H. G. Coffin, 1997, The Yellowstone Petrified "Forests," *Origins* (Geoscience Research Institute), 24(1): 5-44.

represent an enormous challenge to a strict biblical chronology for the earth's history.

However, there are numerous features of these petrified tree stumps that conclusively indicate that these trees grew elsewhere, and were then transported and buried catastrophically into their present locations.[4] Both upright and horizontal trees are found in these buried forests, with the percentage of upright trees varying from location to location, from 28 percent of the 208 petrified trees in three levels of the Amethyst Mountain area, to 75 percent of the 40 visible petrified trees in the Petrified Tree area. If the fossilized tree stumps are not upright, they are horizontal. In fact, a puzzling feature of all these Yellowstone petrified forests is the absence of diagonal or leaning tree stumps. The upright tree stumps range in height from just above ground level to over six meters, with a common height of 3 to 4 meters. The tops of many of the tree stumps terminate at or just below the next organic/forest level. Most of the wood tissue of these petrified tree stumps is well preserved, even though limbs and bark are usually absent.

Where exposed, the petrified trees have broken roots. These are frequently small roots often oriented in a downward direction. Absent are the larger roots of fully-developed root systems. The larger roots of these petrified tree stumps appear to have been broken off to the bases of the stumps, with only "root balls" left, similar to what is observed when trees are uprooted or bulldozed. Clearly, the tree roots were broken off before the tree stumps were transported and buried by volcanic muds and gravels.

Usually the upright tree stumps on one level appear broken off at their tops, only about a vertical foot below the beginning of the next "forest" level. However, occasionally a tree stump in one level extends through or into the "forest" level above it. If these were successive forests that grew in place, the tops of any tree stumps protruding into the next growing forest would be subject to infestation by insects, rotting, and decay, yet the petrified wood tissue in these tree stumps looks as fresh as the wood tissue in living trees, with no evidence of weathering and decay. Furthermore, the alignment of the fallen petrified trees, and the long axes of the cross-sections of the tops of standing tree stumps, on any particular level show a tendency to be aligned in the same direction. Such parallel orientation is not seen in living forests.[5] On the other hand, volcanic lahars (fast-moving volcanic mudslides) or currents of water and mud would have acted on both roots and tree stumps, as well as logs, to produce the similar observed alignment of both the buried stumps and logs.

Because of the good preservation of the wood tissue, rings are clearly visible,

---

4 H. G. Coffin, 1983, The Yellowstone Petrified "Forests," in *Origins by Design*, Washington, D.C.: Review and Herald Publishing Association, chapter 11, 134-151; Coffin, 1997.

5 H. G. Coffin, 1976, Orientation of trees in the Yellowstone petrified forests, *Journal of Paleontology*, 50(3): 539-543.

and often reveal variable widths suitable for tree-ring studies, not for dating the trees, but for comparing the ring patterns on trees from the same and different levels. Thus several small fossil trees in the Specimen Creek area were found to have similar bands of distinctive anomalous growth-ring patterns.[6] Furthermore, two fossil trees on the same level on Specimen Ridge have been cross-matched.[7] Indeed, the matching of growth-ring patterns in upright tree stumps separated by one or more levels would be most unlikely if these were upright trees that had grown in these positions, because such sequential living forests would not have grown at the same time under the same weather conditions, and therefore have the same patterns of wide and narrow rings. On the other hand, the fact that these same ring patterns are found in tree stumps on several different levels is a strong argument that these trees originally grew at the same time, under the same conditions, and were subsequently transported to be buried in successive volcanic mudslides.

The most abundant of the fossilized tree stumps are *Sequoia* (redwoods), with pines being second in abundance. From identification of the fossil wood, pollen, leaves, and needles, the number of plant species represented in these Yellowstone petrified forests is over 200.[8] This represents a diverse grouping of species, including exotic genera such as cinnamon, breadfruit, katsura, and Chinquapin that are presently restricted to southeastern Asia. We would not expect such ecological diversity if the trees represent a forest in the position of growth. These species range from temperate (pines, redwoods, willows) to tropical and exotic (figs, laurels, breadfruit), and from semi-desert to rainforest types. This mixed flora is most easily explained by the transport of trees and plants from different habitats and geographical locations into a flooded basin, where lahars, mudflows, or turbidity currents left sequential accumulations of sediments with this flora buried in them. Likewise, if these petrified trees are standing where they originally grew, then it is significant why there are no animal fossils, such as those of land snails, some amphibians and reptiles, many insects, spiders, and worms, and their traces, that would have not escaped *in situ* burial with these fossil "forests."

---

6 M. J. Arct, 1979, *Dendrochronology in the Yellowstone Fossil Forests*, M. A. Thesis (unpublished), Loma Linda, CA: Loma Linda University; M. J. Arct, 1991, *Dendroecology in the Fossil Forests of the Specimen Creek Area, Yellowstone National Park,* Ph.D. Thesis (unpublished), Loma Linda, CA: Loma Linda University.

7 R. Ammons, W. J. Fritz, R. B. Ammons and A. Ammons, 1987, Cross-identification of ring signatures in Eocene trees (*Sequoia magnifica*) from the Specimen Ridge locality of the Yellowstone fossil forests, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 60: 97-108.

8 C. E. Read, 1933, Fossil floras of Yellowstone National Park, Part 1. Coniferous woods of Lamar River flora, *Carnegie Institute of Washington Publication*, 416: 1-19; L.H. Fisk, M.R. Aguirre and W.J. Fritz, 1978, Additional conifers from the Eocene Amethyst Mountain 'fossil forest,' Yellowstone National Park, Wyoming, *Geological Society of America Abstracts with Programs*, 10(5): 216; P. L. DeBord, 1979, Palynology of the Gallatin Mountain 'fossil forest' of Yellowstone National Park, Montana: Preliminary report, First Conference on Scientific Research in National Parks, US Department of the Interior, *National Parks Service Transactions, Proceedings Series 5*, 159-164; A. Chadwick and T. Yamamoto, 1983, A paleoecological analyses of the petrified trees in the Specimen Creek area of Yellowstone National Park, Montana, USA, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 45: 39-48.

However, if the trees and organic debris making up the proposed soil levels were instead transported in by water, then the separation of animals from the plants before burial is much easier to explain.

This also raises the issue of whether the organic levels, where the trees supposedly grew, are in fact true soils. Many of the organic levels of the Yellowstone petrified "forests" are thin and contain insufficient organic matter to qualify as soils. Furthermore, there has been taxonomic sorting of the constituents in the organic bands, whereas in true soils leaves, needles, limbs, and bark, etc. fall as a well-mixed litter onto the forest floor year by year. Furthermore, the majority of the organic levels give evidence of water sorting, rather than being true soil profiles.[9] There is also not a good match between the types of wood and pollen in each organic level, as would be expected in *in situ* forests. The formation of clay in soils occurs by the breakdown of minerals such as feldspar, yet analyses of the Yellowstone organic levels shows no detectable amounts of clays. So not only are these not soil horizons, but the lack of clay suggests no significant passage of time was involved in the sequential deposition of the organic levels burying these fossilized tree stumps. Furthermore, not only do these organic levels have a high volcanic ash content, but trace element analyses have revealed poor trace element profiles, which interfinger in an irregular manner through the entire sequence of fossil "forest" organic levels, and which can only be explained by quick burial of the whole sequence from the same volcanic source(s).

The overwhelming evidence, then, supports the transporting of these tree stumps with volcanic ash in mudslides and catastrophic muddy water flows. This interpretation is fully substantiated by a recent modern analog. On May 18, 1980, Mount St. Helens in Washington state erupted, blasting nearly 400 meters from the top of the mountain with a force equal to 500 Hiroshima atomic bombs.[10] Millions of trees in 600 km^2 (150 square miles) of prime forest were blown down or killed as a blast of ash-charged superheated gas was flung northwards. The concurrent avalanche spread from the summit of the mountain into nearby Spirit Lake as the north face collapsed, causing a wave of water from the lake almost 900 feet high to scour the adjacent slopes. Thus many of the trees from the blast zone found their way into Spirit Lake, but others were transported upright in mudslides and turbid floods down the North Fork of the Toutle River.[11] Many erect stumps in various stages of burial ended up in distant mud flats and gravel bars. One huge stump over 2 m in diameter and 13 m high was left sitting upright on the toe of a 24 km long debris flow. As the mudflows moved rapidly downstream, many tree

9 Coffin, 1983 and 1997.

10 R. Findley, 1981, Mountain with a death wish, *National Geographic*, 159(1): 3-65; P. W. Lipman and D. R. Mullineaux, eds., 1981, *1980 Eruptions of Mount St Helens, Washington*, US Geological Survey Professional Paper 1250; C. L. Rosenfeld, 1980, Observations on the Mount St Helens eruption, *American Scientist*, 68: 494-509.

11 W. J. Fritz, 1980, Stumps transported and deposited upright by Mount St Helens mudflows, *Geology*, 8: 586-588.

stumps moved along at the same rate as the mudflows, upright with the denser root ends down.

When the eruption was over, there was a huge floating mat of logs and debris covering more than half of the surface of Spirit Lake. It consisted of plant material ranging from chips of bark, to trees with trunks nearly 2.5 m in diameter. Many of the logs still retained their root systems. Within six months, many of these tree stumps were floating upright in the water, some eventually becoming grounded on the bottom, and their root ends were buried in mud and organic debris as they became waterlogged and sank.[12] Subsequent investigations of the lake bottom using side-scan sonar showed that thousands of tree stumps, up to 20 m in length, had become buried in the lake bottom muds, as if they had been buried where they had grown in place.[13] With time, more and more floating logs became waterlogged and sank, the denser ends where roots had been broken off sinking first into the mud on the lake bottom. Thus, both the mudflows in the Toutle River with upright stumps imbedded in them, and the sinking of the upright tree stumps to be buried in the lake bottom muds, provide a model for interpreting the upright petrified trees of Yellowstone. Saturated organic debris sank to the bottom of Spirit Lake to produce a layer of organic matter, while upright floating trees also dropped out of suspension to be buried in the bottom muds of Spirit Lake in a spacing pattern similar to that of growing forests. If there had been continued adequate sediment input to bury the sinking logs and stumps in volcanic ash, then the burial of successive logs and stumps as they sank would exactly mirror the buried Yellowstone fossil "forests." The logs in Spirit Lake had even been stripped of their bark, which when it became waterlogged and sank added to the organic debris buried in the lake bottom muds.

Rather than being a difficulty for a global Flood cataclysm 4,500 years ago, the evidence in the Yellowstone fossil "forests" clearly is consistent with catastrophe transport and deposition of tree stumps in volcanic mudflows and catastrophic water flows, to be successively buried upright in a sequence of repeating organic levels that give the appearance of successive buried forests. Given the position of the Yellowstone fossil "forests" in the geologic record, this would have been at the close of the Flood year, or soon thereafter, as residual catastrophism, involving local volcanic eruptions larger than Mount St. Helens, but in a repetitive sequence, built up the successive buried tree stump layers in Yellowstone. The same model of catastrophic deposition of upright tree stumps can also be applied to many other situations in the geologic record, where upright fossilized tree stumps are claimed to have required hundreds to thousands of years for their burial where they supposedly grew.[14]

---

12 H. G. Coffin, 1983, Erect floating stumps in Spirit Lake, Washington, *Geology*, 11: 198-199.

13 H. G. Coffin, 1987, Sonar and scuba survey of a submerged allochthonous 'forest' in Spirit Lake, Washington, *Palaois*, 2: 179-180.

14 T. W. E. David, 1970, Geology of the Hunter River Coal Measures, New South Wales, *Geological Survey of New South Wales, Memoir #G4*.

Lest it be argued that, even if the tree stumps were buried rapidly, it still takes many thousands of years to petrify the wood, much experimental evidence demonstrates the contrary—petrification is rapid. Indeed, as part of a study of the petrified wood in the Petrified Forest National Park of Arizona, an experiment was conducted in which blocks of wood were placed in hot alkaline springs in the Yellowstone National Park to test the rate at which silica is deposited in the cellular structure of the wood.[15] The measured rate was between 0.1 and 4.0 mm/year. Other similar experiments have been conducted in laboratories.[16] Furthermore, as a result of testing for petrification in a Japanese volcanic spring, it was concluded that petrified wood in ancient volcanic ash beds in sedimentary strata in volcanic regions could have thus been silicified by hot flowing ground water with high silica content in "a fairly short period of time, in the order of several tens to hundreds of years."[17] Such rapid petrification of wood is confirmed by many field observations of trees cut down by early settlers in Australia that were subsequently buried in the soil, then later dug up and found to be petrified, including the axe marks.[18] The bottoms of wooden fence posts that have been buried for some years in the soil have also found to become petrified. Thus, the evidence indicates the claim that, under the right conditions, wood can be rapidly petrified by silicification, as is the case with the Yellowstone fossil tree stumps. Therefore, the timeframe for the formation of petrified wood within the geologic record is totally compatible with the biblical timescale of a recent creation and the subsequent devastating global Flood.[19]

15 A. C. Sigleo, 1978, Organic geochemistry of silicified wood, Petrified Forest National Park, Arizona, *Geochimica et Cosmochimica Acta*, 42: 1397-1405.

16 E. Scurfield and E. R. Segnit, 1984, Petrifaction of wood by silica minerals, *Sedimentary Geology*, 39: 149-167; R. W. Drum, 1968, Silicification of Betula woody tissue *in vitro*, *Science*, 161: 175-176; R. F. Leo and E. S. Barghoorn, 1976, Silicification of wood, *Harvard University Botanical Museum Leaflets*, 25: 1-47.

17 H. Akahane, T. Furuno, H. Miyajima, T. Yoshikawa and S. Yamamoto, 2004, Rapid wood silicification in hot spring water: An explanation of silicification of wood during the earth's history, *Sedimentary Geology*, 169: 219-228.

18 R. Piggott, January 1970, *The Australian Lapidary Magazine*, 9; R. C. Pearce, June 1970, Petrified wood, *The Australian Lapidary Magazine*, 33.

19 A. A. Snelling, 1995, 'Instant' petrified wood, *Creation*, 17(4): 38-40.

120

Coal Beds

The formation of coal beds has already been discussed (chapters 71-72), but further comments are warranted here. It continues to be claimed that the numbers of stacked coal beds in many sedimentary basins around the globe, and the evidence associated with them, does not favor the formation of the coal beds during the year-long Genesis Flood, but requires the millions of years of conventional geologic thought.[1]

Nevertheless, even in such attempts to discredit the Flood origin of today's coal beds, it is admitted that the upright polystrate tree stumps often found associated with coal beds required catastrophic deposition to bury and preserve them. Furthermore, it is maintained that years were required for these trees to grow in place associated with peat swamps that were slowly forming coal beds, before they and the tree stumps were buried. However, such claims totally ignore the actual physical evidence that many of these upright tree stumps associated with coal beds could not have grown in place, because their roots are broken off, like the tree stumps in the Yellowstone fossil "forests," and those buried in the muds at the bottom of Spirit Lake at Mount St. Helens. Furthermore, the trees and vegetation associated with the northern hemisphere coal beds, and the trees and plants associated with the southern hemisphere (Gondwanan) coal beds, though different from one another, are plants and trees that are known to not have been associated with peat swamps as we observe them today. The northern hemisphere coals are dominated by lycopods that grew in forests that floated on the ocean surface out from the coastlines.[2] The Gondwanan coal beds consist of the *Glossopteris* flora, extinct plants of unknown habitat, but often have tree stumps associated with them of pine trees that are not known to grow in swamps.[3]

1 R. A. Gastaldo, 1999, Debates on authochthonous and allochthonous origin of coal: Empirical science versus the diluvialists, in *The Evolution-Creation Controversy II: Perspectives on Science, Religion and Geological Education*, volume 5, W.L. Manger, ed., The Paleontological Society Papers, 135-167.

2 K. P. Wise, 2003, The pre-Flood forest: A study in paleontological pattern recognition, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, ed., Pittsburgh, PA: Creation Science Fellowship, 371-381.

3 T. W. E. David, 1907, Geology of the Hunter River Coal Measures, New South Wales, *Geological Survey of New South Wales, Memoir G.4*; E. P. Plumstead, 1958, The habit and growth of *Glossopteridae*,

There is, therefore, no question that, despite the nebulous and unsubstantiated assertions to the contrary, the May 18, 1980, Mount St. Helens eruption is an entirely suitable analog model for not only the catastrophic burial of upright tree stumps with their roots broken off, but also for the formation of peat layers that are the precursors to coal beds.[4] In this model for the formation of the coal beds during the Genesis Flood, the multiple stacked coal beds in many sedimentary basins would have formed by the progressive devastation of both the pre-Flood floating-forest biome, with its in-built peat layer of rotting vegetative debris, added to by the destruction of the living trees and vegetation, and the extensive forests, growing on the pre-Flood land surfaces. As on Spirit Lake, logs and other vegetative debris would have floated on the Flood waters for many months before progressively being waterlogged and sinking, the process aided by the turbulence of the Flood waters and the daily tidal surges, along with the changing sediment-laden water currents, and the repeated catastrophic volcanic eruptions. This model would also easily explain the presence of marine fossils in the sediments associated with coal beds.

On the other hand, the conventional uniformitarian peat swamp model does not easily explain how coal beds are so widespread across adjoining continents and so often interbedded with sediments containing marine fossils, even within the coal beds themselves. The uniformitarian explanation requires the impossible scenario of vast peat swamps sinking and being invaded by the sea, remaining buried until the land rises again to form new peat swamps, with this process being repeated many times in succession in order to generate the so-called cyclothems and coal measure sequences. Thus, with its 80 stacked coal beds, the Illinois Basin would require 80 cycles of peat swamps being invaded by the sea and then the land rising again! The actual field evidence is far more consistent with repeated sediment deposition cycles, in which various portions of the broken-up floating vegetative mat on the Flood waters were buried to become the coal beds, sometimes with the upright tree stumps buried with them. Once the vegetative debris was buried, it was easily and rapidly transformed into coal, as numerous experiments at easily obtainable low geological temperatures have shown.

The exact quantity of coal found in the earth's sedimentary basins can only be estimated, but all authorities are agreed that all the vegetation on the earth's surface today, if converted to coal, would only represent a small fraction of the earth's known coal reserves, possibly as little as 1 to 3 percent. Thus, it would be argued that if the present is the key to the past, then it would take at least thirty global floods to repeatedly destroy the earth's complete vegetation cover, obviously

---

Transactions of the Geological Society of South Africa, 61: 81-94; E. D. Pant, 1977, The plant of *Glossopteris*, *The Journal of the Indian Botanical Society*, 56(1): 1-23.

4 S. A. Austin, 1986, Mount St. Helens and catastrophism, in *Proceedings of the First International Conference on Creationism*, volume 1, Pittsburgh, PA: Creation Science Fellowship, 3-9; S. A. Austin, 1991, Floating logs and log deposits of Spirit Lake, Mount St. Helens Volcano National Monument, Washington, *Geological Society of America Abstracts with Programs*, 23(5): 85.

staggered in time for the vegetation to grow again between each flood, in order to generate all the known coal beds. Therefore, it is concluded that a single Genesis Flood could not have produced the world's coal beds.

However, while such arguments are based on valid estimates of the volume of vegetation currently on today's land surfaces, they assume that at least a thickness of 12 meters of peat (accumulated, decomposing vegetation) is necessary to produce one meter of ordinary (bituminous black) coal,[5] although some antagonists have inflated that figure to a 30-meter-thick layer of peat to generate a one meter thick coal bed.[6] However, textbooks on coal geology describe compaction ratios of eight or ten meters of peat to form one meter of coal,[7] or as little as 5-6 meters of peat to form one meter of bituminous coal.[8] Such estimates are based on measuring how thin laminae in coal beds, called plies, are draped over and compacted around what are known as coal balls. These are mineralized nodular masses found within some coal beds that are composed essentially of limestone and contain plant fossils and/or fossils of marine animals, such as gastropods and brachiopods.[9] However, the compaction around some coal balls, and of the wood sometimes found in coal beds, would suggest that the compaction ratio might be as little as 1 to 2 meters of vegetative debris in each meter of coal. If that were generally the case, then today's volume of vegetation would compact down to 15 to 30 percent of the known coal reserves.

In any case, three other factors are ignored when detractors claim all the coal beds could not have formed by the catastrophic burial of vegetation during the year of the Genesis Flood. First, they are assuming that the thickness and volume of today's vegetative cover have always been the same throughout earth's past history. However, more than half of today's land surface is covered by deserts, vast ice sheets, or only sparse vegetation. In the desert and semi-desert areas of central Australia, and under the Sahara Desert of Africa, there is evidence of there having been more lush vegetation growing there, even in the recent past after the Ice Age, while the thick coal beds under some of the Antarctic ice sheet suggest that that continent too was once covered in lush vegetation. Thus, if all today's land surfaces were covered with lush vegetation, then the volume of such vegetation would be at least doubled, and with minimal compaction, thus accounting for up to 50 percent or more of the known coal reserves.

---

5 A. Holmes, 1965, *Principles of Physical Geology*, new and fully revised edition, London: Thomas Nelson and Sons, 441; Gastaldo, 1999, 147.

6 E. N. Strahler, 1987, *Science and Earth History-the Evolution/Creation Controversy*, Buffalo, NY: Prometheus Books, 218.

7 C. F. K. Diessel, 1992, *Coal-bearing Depositional Systems*, Berlin: Springer-Verlag, 1, 12.

8 E. Stach, M.-Th. Mackowski, M. Teichmüller, G. H. Taylor, D. Chandra and R. Teichmüller, 1982, *Stash's Textbook of Coal Petrology*, third revised and enlarged edition, Berlin: Gebrüder Borntraeger, 17-18.

9 S. H. Mamay and E. L. Yochelson, 1962, *Occurrence and Significance of Marine Animal Remains in American Coal Balls*, U. S. Geological Survey Professional Paper 354I: 193-224.

Second, uniformitarian calculations assume that the areas of land surface available for vegetation to grow have always been the same as those today. This assumption is likely incorrect for several reasons. In the description of God forming the dry land on Day Three of the Creation Week (Genesis 1:9-10), the waters that initially covered the entire globe were gathered into one place, which implies that the land which God thus formed was also in one place. In today's world, the earth's surface is roughly 30 percent land and 70 percent oceans, but the implication of this description is that on the pre-Flood earth, there may have been one landmass or supercontinent that occupied as much as 50 percent or more of the earth's surface, surrounded by the one inter-connected sea. If this were the case, then there could have been up to double the land surface available for vegetation to grow on than on today's earth surface.

However, the third factor was the presence also of this floating-forest biome in the pre-Flood world. Vast mats of floating forests grew out from the coastlines, fringing the supercontinent, particularly where the seas were shallow. Just how much of the pre-Flood sea surface was covered with these floating-forest mats is uncertain, but the volume of this unique vegetation, which is now preserved in the Carboniferous coal beds of the Northern Hemisphere, would suggest that a large portion of the pre-Flood sea surface was covered with these floating forest mats, perhaps as much as half of the sea surface. If that were the case, then as much as 75 percent of the pre-Flood earth's surface could have been covered by lush vegetation, more than six times the area covered by vegetation on the present earth's surface. All these calculations taken together would thus indicate that there was more than enough vegetation growing lushly on the pre-Flood earth surface to provide the volume of vegetation needed to be destroyed and buried to form the coal beds during the Flood year.

There is, however, another way of comparing vegetation growth and volume with the world's coal beds. Comparing stored energy in vegetation with that in the coal beds is probably a far more reliable indication of just how much vegetation is in the coal beds. It has been estimated that the amount of solar energy falling on the earth's surface in 14 days is equal to the known energy of the world's supply of fossil fuels.[10] Yet only 0.3 percent of the solar energy arriving at the earth's surface is stored as chemical energy in vegetation through photosynthesis. This information enables an estimate to be made of how many years of today's plant growth would be required to produce the stored energy equivalent in today's known coal beds. If 14 days of solar energy input to the earth's surface is equal to the known energy in the world's coal beds, but only 0.03 percent of that solar energy is stored as chemical energy by photosynthesis in vegetation, then the length of time to grow vegetation and store chemical energy in it via photosynthesis in order to achieve the equivalent of 100 percent of the known energy in the world's coal beds would be almost 46,700 days, or about 128 years of solar input to vegetation growth via

10 M. Archer, 1975, *Journal of Applied Electrochemistry*, 5: 17.

photosynthesis. In other words, it would take only 128 years of plant growth, at today's rate of growth and volume, to provide the energy equivalent of the stored chemical energy in today's known coal beds. And that's simply using today's vegetation cover of the present earth's land surface.

As the above calculations have shown, far more of the earth's surface was covered with lush vegetation in the pre-Flood world, so fewer years of vegetation growth would have been required to provide the volume of vegetation necessary and stored chemical energy, equivalent to the stored energy value of today's known coal beds. Furthermore, because in the biblical timescale of earth history there were about 1,600 years between creation and the Genesis Flood, there was ample time for the necessary plant growth to produce the vegetation that was buried in the coal beds during the Flood year. Thus, whichever way the calculation is made, by comparison of the chemical energy stored in vegetation growth and in the coal beds (via the time factor), or by vegetation growth, climate, geography, land area, and compaction ratio (via the volume factor), it can be shown conclusively that there was ample time, space, and vegetation growth for the year-long Genesis Flood to have produced all of today's known coal beds, and objections to the contrary are deemed invalid.

121

Oil Deposits

Uniformitarian geology is frequently defended on the grounds that it has worked so well in leading to the discovery of economically important deposits of petroleum. It is argued that the use of the uniformitarian system in geology must be basically correct, or else it could not have served so well as a guiding philosophy in petroleum geology. However, the techniques that have been found helpful in petroleum exploration, such as seismic surveying and the analysis of organic matter found in sedimentary rock sequences, do not really depend on the historical aspects of geology at all, but only on recognition of the structural, sedimentary, and organic petrological markers that experience has shown are associated with, and a guide to the finding of, petroleum deposits.

> Petroleum exploration, in its simplest terms, consists of studying large regions that do or could contain petroleum, identifying progressively smaller areas of progressively greater interest in these until a prospect worth drilling has been identified, and discovering oil or gas in one or more of these.…the exploration geologist is concerned with regional geology deduced from surface outcrop, geophysical surveys, and the results of any boreholes drilled in the area.[1]

There can be no question of the immense size of the oil industry, and that it is a major employer of geologists, not only in oil companies, but in academia and government agencies. Thus, with so much of the world's geological brain-power being expended on those aspects of geology concerned with how oil and gas accumulations form and can be found, one would expect that evolutionary historical geology would find its most productive application in this field, and would have good success. However, the opening remarks in the preface to a recent major textbook on petroleum geology are noteworthy.

> The fascination of petroleum geology lies both in its complexity and in its importance to society. There is still much that we do not understand; and there is much to learn if remaining undiscovered reserves of oil and

1 R. E. Chapman, 1983, *Petroleum Geology*, Amsterdam: Elsevier, 67-68.

> gas are to be found economically. It is also good geology with a healthy practical component.[2]

Thus it is entirely conceivable that biblical geology in its present state of development might well lead to more effective results than uniformitarian geology in the search for additional oil deposits. There has already been one Canadian success as a result of applying the principles of Flood geology to the search for oil.[3]

Indeed, uniformitarian geology has not yet been able to develop an understanding of the origin and migration of petroleum to form oil deposits.

> Although agreement on the organic origin of petroleum is nearly complete, there are many differences of opinion about the details of the processes by which it was formed and about the relative importance of the different source materials. Were they primarily marine or terrestrial? How much petroleum was derived from hydrocarbons that were part of living organisms and how much was derived from the transformation of hydrocarbon compounds into petroleum? What was the nature of the energy involved in the transformation? Bacterial action, heat and pressure, radioactive bombardment, and catalytic phenomena have all been suggested as energy sources that may have made conversion possible.[4]

> Processes of primary and secondary migration are so far poorly understood.…Likewise, there is little information on movement and distribution of petroleum compounds inside the pores of source rocks. Therefore, it should be realized that the following discussion on petroleum migration is largely theoretical and should not be considered definitive.[5]

> It is impossible at present to distinguish in logic between the generation of petroleum and its primary migration. We believe we can recognize petroleum source rocks from the nature of their organic contents: we can identify petroleum accumulations. No migration path has ever been recognized physically with confidence and reported, so the connection between source and accumulation is *inferred* from analyses of the oil and analyses of the organic content of the supposed source rock, and from geological considerations. It is for this reason that we cannot claim to *understand* the origin and migration of petroleum. At best, we can

---

2 Chapman, 1983, vii.

3 Personal testimony of Larry Sheldon, a Canadian petroleum geologist.

4 A. I. Levorsen, 1967, *Geology of Petroleum,* second edition, San Francisco: W.H. Freeman and Company, 499.

5 B. P. Tissot and D. H. Welte, 1978, *Petroleum Formation and Occurrence: A New Approach to Oil and Gas Exploration*, Berlin: Springer-Verlag, 258-259.

construct plausible hypotheses.[6]

It is surely significant that in this most important (both economically and in numbers of geologists involved) of geological disciplines, the uniformitarian interpretative framework has been of little practical use. Although geologists can identify a given formation from two or more well logs by the microfossils contained in the cuttings, this is primarily done on a local scale within each formation across the sedimentary basin. However, microfossils are not nearly as important as other factors revealed by geophysical logging of drill-holes. This is confirmed by the fact that in the subject indexes of the three major petroleum geology textbooks of recent decades (quoted from above), neither "micropaleontology" nor "microfossils" appears. Of course, microfossils and macrofossils are mentioned in occasional places in these textbooks, but never in any substantive manner crucial to the elucidation of petroleum formation and exploration. Thus, evolutionary geology, based on the assumption of the slow accumulation of the fossil-bearing sedimentary strata, can hardly claim to be instrumental in understanding and discovering oil deposits. Sequences of sedimentary strata are an observable fact of field geology, and naming them are merely labels for identification. Even the so-called geologic timescale merely provides labels that enable recognition of the order of strata in sequences, irrespective of the assumption of long time periods. Thus, petroleum geology would not be adversely affected by utilizing catastrophism as a basic geologic philosophy, which could even provide material benefits.

More than half the world's production and reserves of petroleum are from rock strata that have been labeled as Tertiary, and more than 25 percent from so-called Mesozoic strata, the remainder occurring in Paleozoic strata. Nevertheless, oil can be found in rocks of practically all geologic ages, except the Pleistocene and Holocene. However, there are some commercial oil and gas fields in Precambrian rocks supposedly up to 1 billion years old in the former Soviet Union, Oman and China, but indigenous "live" oil has been found in rock supposedly 1.4 billion years old in the MacArthur Basin of northern Australia.[7] Oil has even been found preserved in fluid inclusions in Archean sandstones supposedly up to 3 billion years old in Canada, South Africa and Australia.[8]

Petroleum occupies the pore spaces or cavities in the reservoir rocks in which it is found. Petroleum almost certainly has been formed elsewhere in what are known as source rocks, from which the petroleum has migrated until trapped to pool as oil and gas deposits. Thus, petroleum occurrences seem to have no particular relation

6 Chapman, 1983, 180.

7 M. J. Jackson, T. G. Powell, R. E. Summons and I. P. Sweet, 1986, Hydrocarbon shows and petroleum source rocks in sediments as old as 1.7×10^9 years, *Nature*, 322: 727-729; A. Dutkiewicz, H. Volk, J. Ridley and S. George, 2003, Biomarkers, brines, and oil in the Mesoproterozoic, Roper Superbasin, Australia, *Geology*, 31(11): 981-984.

8 A. Dutkiewicz, B. Rasmussen and R. Buick, 1998, Oil preserved in fluid inclusions in Archaean sandstones, *Nature*, 395: 885-888.

to specific stratigraphic sequences or structural forms. Neither the paleontologic nor deformational history appears to bear any necessary relationship to the actual oil and gas deposits.

> The reservoir rocks that contain petroleum differ from one another in various ways. They range in geologic age from Precambrian to Pliocene, in composition from siliceous to carbonate, in origin from sedimentary to igneous, in porosity from 1 to 40 percent, and in permeability from one millidarcy to many darcies.
>
> There is a wide variation also in the character of the trap or barrier that retains the pool. The trap may have been chiefly due to structural causes, to stratigraphic causes, or to combinations of these causes....
>
> The geologic history of the trap may vary widely—from a single geologic episode to a combination of many phenomena extending over a long period of geologic time. Pools trapped in limestone and dolomite reservoir rocks, moreover, have the same relations that pools trapped in sandstone rocks have for such things as reservoir fluids, oil-water and oil-gas contacts, and trap boundaries. Yet the chemical relations of the reservoir rock and the effects of solution, cementation, compaction, and recrystallization are quite different in sandstone and carbonate reservoirs.[9]

Given that petroleum forms in source rocks and then subsequently migrates, the most immediately apparent conclusion is that this subsequent accumulation of petroleum into traps must have occurred after most, if not all, of the sedimentary strata were laid down. These pools of trapped petroleum are apparently independent of the particular type of reservoir rock, but these strata are nevertheless similar to each other in hydraulic characteristics. The main feature that all oil and gas deposits seem to have in common is that of being associated with water.

> Nearly every petroleum pool exists within an environment of water—free, interstitial, edge, and bottom water. This means that the problem of migration is intimately related to hydrology, fluid pressures, and water movement.[10]

Another extremely important conclusion is that the accumulated evidence points to an organic origin for most, if not all, petroleum.

> Early ideas lean toward the inorganic sources, whereas the modern theories, with few exceptions, assume that the primary source material

9 Levorsen, 1967, 540-541.

10 Levorsen, 1967, 539.

was organic.[11]

A few scientists have maintained that some natural gas could have formed deep within the earth, where heat melting the rocks might have generated it inorganically.[12] Indeed, this process of abiotic formation of hydrocarbons has been demonstrated and observed where hydrothermal fluids are reacting with the olivine-rich oceanic crust, in the presence of trace metals acting as catalysts, to produce hydrocarbons within mid-ocean ridge hydrothermal systems.[13] However, even in these locations, subsequent investigations have shown that all the heavier or long-chained and branched hydrocarbons have been generated from the organic matter in the sediments on the ocean floor through which the hydrothermal fluids have also circulated.[14] Proof of such processes having occurred even early in the earth's history are the hydrocarbons trapped in fluid inclusions and as bituminous residues in cavities within an early Archean deep-sea volcanogenic massive sulfide deposit in the Pilbara of Western Australia,[15] which is comparable to similar massive deposits forming at the volcanogenic hydrothermal vent systems on the ocean floor today. There can thus be no doubt that the weight of evidence now favors an organic origin for petroleum.

While the exact nature of the organic material from which the petroleum in each oil and gas field came has to be independently elucidated, there now seems little doubt that most petroleum was generated from the vast reservoirs of the organic remains of plants, and perhaps animals, which were buried and fossilized in the sedimentary rocks.

> Production, accumulation and preservation of undegraded organic matter are prerequisites for the existence of petroleum source rocks. The term "organic matter" or "organic material"…refers solely to material comprised of organic molecules in monomeric or polymeric form derived directly or indirectly from the organic part of organisms.[16]

The petroleum generated in the source rocks was then chemically altered, as it migrated, into crude oil and gas that became trapped in pools in the reservoir rocks.

---

11 Levorsen, 1967, 499.

12 T. Gold and S. Soter, 1980, The deep-earth gas hypothesis, *Scientific American*, 242(6): 154-161.

13 N. G. Holme and J. L. Sharlou, 2001, Initial indications of abiotic formation of hydrocarbons in the Rainbow ultramafic hydrothermal system, mid-Atlantic Ridge, *Earth and Planetary Science Letters*, 191: 1-8; E. I. Foustoukos and W. E. Seyfried Jr., 2004, Hydrocarbons in hydrothermal vent fluids: the role of chromium-bearing catalysts, *Science*, 304: 1002-1005.

14 B. R. T. Simoneit and A. Y. Lein, B. I. Peresypkin and G. A. Osipov, 2004, Composition and origin of hydrothermal petroleum and associated lipids in the sulfide deposits of the Rainbow Field (mid-Atlantic Ridge at 36°N), *Geochimica et Cosmochimica Acta*, 68(10): 2275-2294.

15 B. Rasmussen and R. Buick, Oily old ores: Evidence for hydrothermal petroleum generation in Archean volcanogenic massive sulfide deposit, *Geology*, 28(8): 731-734, 2000.

16 Tissot and Welte, 1978, 3.

The chemistry of oil provides crucial clues as to its origin. Petroleum is a complex mixture of organic compounds, primarily chains of different lengths of hydrocarbons. However, one complex chemical in crude oils is called porphyrin.

> Petroleum porphyrins…have been identified in a sufficient number of sediments and crude oils to establish a wide distribution of these geochemical fossils.[17]

Porphyrins are organic molecules that are structurally very similar to both chlorophyll in plants and hemoglobin in animal blood.[18] They are classified as tetrapyrrole compounds, and often contain metals such as nickel and vanadium.[19] Of significance is the fact that porphyrins are readily destroyed by oxidizing conditions and by heat.[20] Thus, petroleum geologists maintain that the porphyrins in crude oils are evidence of the petroleum source rocks having been deposited under reducing conditions.

> The origin of petroleum is within an anaerobic and reducing environment. The presence of porphyrins in some petroleums means that anaerobic conditions developed early in the life of such petroleums, for chlorophyll derivatives, such as the porphyrins, are easily and rapidly oxidized and decomposed under aerobic conditions. The low oxygen content of petroleums, generally under 2 percent by weight, also indicates that they were formed in a reducing environment.[21]

It is very significant that porphyrin molecules break apart rapidly in the presence of oxygen and heat. Therefore, the fact that porphyrins are still present in crude oils today must mean that petroleum source rocks, and the plant (and animal) fossils in them, had to have been kept from the presence of oxygen when they were deposited and buried. There are two ways this could have been achieved:

1. The sedimentary rocks were deposited under oxygen deficient (or reducing) conditions, as already indicated above; and/or

2. The sedimentary rocks were deposited so rapidly that no oxygen could destroy the porphyrins in the plant and animal fossils.

However, even where sedimentation is relatively rapid by today's standards, such

17 Tissot and Welte, 1984, 128.

18 D. R. McQueen, 1986, The chemistry of oil—explained by Flood geology, *Acts & Facts,* 15(5).

19 Tissot and Welte, 1984, 409-410.

20 W. L. Russell, 1960, *Principles of Petroleum Geology*, second edition, New York: McGraw-Hill Book Company, 25.

21 Levorsen, 1967, 502.

as in river deltas in coastal zones, conditions are still oxidizing.[22] Thus, to preserve organic matter containing porphyrins requires its slow degradation in the absence of oxygen, such as in the Black Sea today.[23] But such environments are too rare to explain the presence of porphyrins in all the many petroleum deposits found around the world. Thus, the only consistent explanation is the catastrophic sedimentation that occurred during the recent global Genesis Flood. The total devastation of the earth's surface resulted in enormous quantities of vegetation being violently uprooted and animals killed, so that huge amounts of organic matter were buried so rapidly that the porphyrins in it were removed from the oxidizing agents that could have destroyed them.

The amounts of porphyrins found in crude oils vary from traces to 0.04 percent (or 400 parts per million).[24] Experiments have produced a concentration of 0.5 percent porphyrin (of the type found in crude oils) from plant material in just one day,[25] so millions of years are not required to produce the small amounts of porphyrins found in crude oils. Indeed, a crude oil porphyrin can be made from plant chlorophyll in less than twelve hours. However, other experiments have shown that plant porphyrin breaks down in as little as three days when exposed to temperatures of only 210°C (410°F) for only twelve hours. Therefore, the petroleum source rocks, and the crude oils generated from them, cannot have been deeply buried to such temperatures for millions of years, as would be the case in the conventional uniformitarian framework for earth history.

Crude oils themselves, therefore, do not take long to be generated from appropriate organic matter.

> Nearly all shales and carbonates contain disseminated organic matter of three general kinds: soluble liquid hydrocarbons, soluble asphalts, and insoluble kerogen.[26]
>
> Kerogen is the most important form of organic carbon on earth. It is 1,000 times more abundant than coal plus petroleum in reservoirs and is 50 times more abundant than bitumen and other dispersed petroleum in nonreservoir rocks.…In ancient nonreservoir rocks, e.g., shales or fine-grained limestones, kerogen represents usually from 80 to 99 percent of the organic matter, the rest being bitumen.[27]

22 A. R. Walker et al, 1983, A model for carbonate to terrigenous clastic sequences, *Geological Society of America Bulletin*, 94: 700-712.

23 Tissot and Welte, 1978, 11-12.

24 Tissot and Welte, 1978, 364.

25 R. K. Di Nello and C. K. Chang, 1978, Isolation and modification of natural porphyrins, in *The Porphyrins, Volume 1: Structure and Synthesis*, Part A, D. Dolphin, ed., New York: Academic Press, 328.

26 Levorsen, 1967, 506.

27 Tissot and Welte, 1978, 124.

Kerogen appears to be an association of various kinds of organic debris, the larger fragments being identified as spores, pollens, and plant tissues, and algae. Thus, most petroleum geologists are convinced that crude oils form mostly from plant material, such as many varieties of algae and diatoms (single-celled marine and freshwater photosynthetic organisms),[28] dispersed land plant debris, and where such plant debris has been concentrated in huge fossilized masses found in oil beds.[29]

> It is natural that one should enquire whether the two great fossil fuels, coal and petroleum, have any significant geological relationship; and this enquiry has been going on for more than a century. Coal results from the diagenesis of vegetable organic matter that accumulated in an environment largely devoid of sediment. Conditions on the actual surface of accumulation may have been reducing or oxidizing; but close below this surface reducing conditions prevailed. Coal consists largely of carbonized plant tissues, wood and bark, with spores (particularly the most durable spore coatings), leaf cuticles, waxes and resins.…This line of thought with the associated idea that petroleum was a distillation product (a demonstrable process to some extent) became out of fashion as a marine origin for oil became fashionable. But it has returned with increasing evidence that some petroleums can hardly have had a marine source, and that some crude oils, particularly those with high wax content, have an important component of vegetable organic origin.[30]

Indeed, the diagenesis of vegetable organic matter to generate petroleum has long been well established,[31] and continued experimentation to the present has reinforced the evidence that oil is generated from coal beds.[32] Indeed, coal beds are believed to be the source of most Australian crude oils and natural gas, because coal beds are in the same sequences of sedimentary rock layers in the sedimentary basins where the oil and gas deposits are found. Furthermore, the coal beds are found below the reservoir rocks, which clearly trapped and pooled the oil and natural gas after it had been generated from the coal beds and migrated upwards.[33]

---

28 J. Marinelli, 2003, Power plants —the origin of fossil fuels, *Plants and Gardens News* 18(2), www.bbg.org/gar2/pgn/2003su_fossilfuels.html.

29 R. W. T. Wilkins and S. C. George, 2002, Coal as a source rock for oil: A review, *International Journal of Coal Geology*, 50: 317-361.

30 Chapman, 1983, 213-214.

31 J. D. Brooks and J. W. Smith, 1967, The diagenesis of plant lipids during the formation of coal, petroleum and natural gas. I. Changes in the *N*-paraffin hydrocarbons, *Geochimica et Cosmochimica Acta*, 31: 2389-2397; J. D. Brooks and J. W. Smith, 1969, The diagenesis of plant lipids during the formation of coal, petroleum and natural gas. II. Coalification and the formation of oil and gas in the Gippsland Basin, *Geochimica et Cosmochimica Acta*, 33: 1183-1194.

32 R.-F. Weng, W.-L. Huang, C.-L. Kuo and S. Inan, 2003, Characterization of oil generation and expulsion from coals and source rocks using diamond anvil cell pyrolysis, *Organic Geochemistry*, 34: 771-787.

33 R. B. Leslie, H. J. Evans and T. L. Knight, eds., 1976, *Economic Geology of Australia and Papua New*

The oil and gas deposits in many other places have also been shown to be derived from deeper coal beds, even in Pennsylvania, where the relationship was first established.[34] Indeed, one measure that has come to be used as a guide to the potential for finding oil or gas when exploring new sedimentary sequences is the vitrinite reflectance, which is the capacity to reflect light from vitrinite, one of the components of coal and of dispersed organic matter in sediments.[35]

At what rate can petroleum be generated from organic matter in sedimentary source rocks and from coal beds? The well documented example of laboratory experiments and field observations that demonstrate the recent and rapid generation of oil and gas deposits from underlying coal beds is the Gippsland Basin of Victoria in southern Australia and offshore in Bass Strait. In the earliest laboratory experiments, brown coals from the onshore part of the basin were heated under conditions that simulated accelerated sedimentary burial conditions.[36] Such thermal treatment in the presence of water brought about an increase in the carbon content of the coal corresponding to its conversion to a high-volatile bituminous (black) coal, accompanied by the formation of liquid and gaseous hydrocarbons from the contained waxes, and leaf, pollen, and spore cuticles, all in a matter of two to five days. These laboratory experiments are easily connected to field observations. In the offshore part of the basin, the main coal beds are buried more deeply under Bass Strait and have experienced higher temperatures of burial to become bituminous coal, while the oil and gas deposits trapped in the strata above these offshore coal beds are identical in composition to the oil and gas produced in the laboratory experiments. A subsequent series of experiments simulated this process of petroleum generation from these brown coals in a subsiding offshore basin over a longer period of six years, with the same outcome and conclusions.[37] Indeed, as a result of recognizing that the offshore sedimentary layers are still subsiding, so that the coal beds are continuing to sink into the "oil generation window," it has been concluded that petroleum generation must still be occurring at the present time, with the products migrating relatively rapidly either into traps or even to the surface.[38] This conclusion is consistent with the facts that the hydrocarbon traps under Bass Strait were full when discovered, and most of the oil in the reservoirs was low in sulfur, indicating there had been insufficient time since generation and migration for it to have been extensively

Guinea—3. Petroleum, Monograph No. 7, Melbourne, Australia: The Australasian Institute of Mining and Metallurgy.

34 Tissot and Welte, 1978, 223-224; Chapman, 1983, 213; Wilkins and George, 2002.

35 Chapman, 1983, 214-215.

36 Brooks and Smith, 1969.

37 J. D. Saxby, A. J. R. Bennett, J. F. Crocroan, D. E. Lambert and K. W. Riley, 1986, Petroleum generation: Simulation over six years of hydrocarbon formation from torbanite and brown coal in a subsiding basin, *Organic Geochemistry*, 9(2): 69-81.

38 M. Shibuoka, J. D. Saxby and G. H. Taylor, 1978, Hydrocarbon generation in Gippsland Basin, Australia—Comparison with Cooper Basin, Australia, *American Association of Petroleum Geologists Bulletin*, 62(7): 1151-1158.

altered by bacterial and other processes.

Of further relevance is the discovery of the ongoing natural formation of petroleum on the ocean floor. In the Guaymas Basin in the Gulf of California is a series of long, deep fractures from which hydrothermal fluids at temperatures above 200°C are flowing from deep-seated magma chambers below through the 500-m-thick layers of sediments on the basin floor.[39] The sediments consist of diatomaceous ooze and silty mud, and as the hydrothermal fluids percolate through these sediments, the contained organic matter is being thermally broken down to produce discrete globules of oil, similar to reservoir crude oils, that are continually being released from the sediments with the fluids into the ocean waters above. The hydrocarbon and elemental compositions of this naturally-formed petroleum are within the ranges of typical crude oils, as are the contents of some of the significant organic components and their distribution, while other key analyses give results that are compatible with a predominantly bacterial/algal origin of this oil and gas. Furthermore, radiocarbon dating of this oil confirmed that the generation of this hydrothermal petroleum from these diatomaceous ooze layers has occurred over a very short timescale of only a few thousand years. Indeed, the relatively mild temperature conditions of this hydrothermal petroleum generation is consistent with the temperature conditions in laboratory experiments that have similarly generated petroleum from organic matter and coal.

It is also possible, of course, that because porphyrins are also found in animal blood, some crude oils may have been derived from the animals also buried and fossilized in many sedimentary rock layers, but this is not clearly established. Nevertheless, laboratory experiments have been turned into reality. Turkey and pig slaughterhouse wastes are now routinely trucked into a bio-refinery, where these wastes are put through a thermal conversion processing plant to produce high-quality oil within two hours.[40] This same thermal conversion technology is also reported as being adaptable to the processing of sewerage, old tires, and mixed plastics to produce oil. Of course, these exact same conditions are not what have obviously occurred naturally to produce petroleum, but they do confirm that the natural process did not necessarily require millions of years.

The remaining process is the migration of the petroleum from the source rocks to accumulate in traps to form oil and gas deposits. However, given that the sediments where the petroleum is generated contain water, and the oil and gas reservoirs also contain water, then these processes are basically a matter of hydraulics. Oil droplets and gas due to their buoyancy and density would tend to rise through

39 D. R. T. Simoneit and P. F. Lonsdale, 1982, Hydrothermal petroleum in mineralized mounds at the seabed of Guaymas Basin, *Nature*, 295: 198-202; D. R. T. Simoneit, 1985, Hydrothermal petroleum, genesis, migration and deposition in Guaymas Basin, Gulf of California, *Canadian Journal of Earth Sciences*, 22: 1919-1929; P. M. Didyk and D. R. T. Simoneit, 1989, Hydrothermal oil of Guyamas Basin and implications for petroleum formation mechanisms, *Nature*, 342: 65-69.

40 E. Lemley, 2006, Anything into oil, *Discover*, 24(4).

the water surrounding them, and flow of that water would aid the migration and transport of the oil and gas upwards in the sedimentary sequence, until structural and other traps block their upward passage to pond them. Thus, the other crucial factors will be the hydraulic gradients and the permeabilities of the strata through which the water, oil, and gas need to flow, such migration of the water, oil, and gas being aided by compaction of the sediments.[41] Given the proximity of the reservoir rocks and structural traps to the source rocks, from which the petroleum has been generated, the small distances over which the petroleum has to have migrated would thus have not required enormous transit times.

The formation of oil and gas deposits, therefore, can easily be accounted for within the biblical framework of earth history, with the global Flood cataclysm only about 4,500 years ago. The devastation of the pre-Flood earth surface and its catastrophic erosion would have resulted in the rapid accumulation of thick sequences of sedimentary rock layers, containing organic matter and interbedded coal layers, in the world's great sedimentary basins. The rapid deposition of the sediments would have ensured that oxygen was excluded from the organic matter and coal beds, so that the porphyrins would not be oxidized. As soon as deposition and deep burial of the organic matter had occurred, petroleum generation would have begun, especially where the waters trapped in the sediments were at the same time heated by nearby volcanic sources and magma chambers, which also added hydrothermal fluids to the hot waters fluxing through the organic matter and coal beds. That's why it is not surprising that liquid hydrocarbons have been found in recent sediments in the Gulf of Mexico,[42] and petroleum is still being generated on the ocean floor of the Guaymas Basin. After deposition of the sediments and petroleum generation had begun, the ongoing tectonics of the Flood would have resulted in the folding and faulting of strata that provided the structural and other traps needed to subsequently pond the migrating water, oil, and gas.

Indeed, certain traps that have ponded some oil deposits in earlier-deposited strata have been shown to have only formed as late as during Pleistocene time, which in the biblical framework is post-Flood.

> An example is the Kettleman Hills pool in California; the oil and gas of this pool are in the Miocene Tremblor Formation, but the fold that forms the trap cannot be earlier than Pleistocene, for the Tremblor Formation fold is parallel to the Pleistocene rocks at the surface of the ground. This places the accumulation in late Pleistocene or post-Pleistocene time, possibly within the last 100,000 years and certainly within a million years [conventionally speaking]….The time it takes for oil to accumulate into pools may be geologically short, the minimum being measured, possibly,

41 T. W. Biederman Jr., 1978, Crude-oil composition and migration, in *The Encyclopedia of Sedimentology*, R. W. Fairbridge and J. Bourgeios, eds., Stroudsburg, PA: Dowden, Hutchinson and Ross, 212-220.

42 P. V. Smith Jr., 1952, Occurrence of hydrocarbons in recent sediments from the Gulf of Mexico, *Science*, 116: 437.

> in thousands or even hundreds of years.[43]

Thus, there is no reason to reject the Flood as a possible framework for the formation of the great oil deposits of the world. The character of petroleum deposits, and such field and experimental observations as have been accumulated regarding the origin, generation, and migration of oil, harmonize perfectly well within the year-long global cataclysm only about 4,500 years ago in the biblical framework for earth history.

43 Levorsen, 1967, 540.

122

Limestone Caves and Cave Deposits

Another claimed slow geologic process that is incompatible with the biblical timescale for earth history is the formation of limestone caves, and the cave deposits within them, the stalactites and stalagmites, known technically as speleothems.

> If it can be shown that either the excavation of caverns or their subsequent filling must require a vastly longer time to accomplish than the post-Flood limit, literal acceptance of the Genesis chronology is untenable. We turn first to rates of removal of limestone by the process of carbonic-acid reaction.[1]

Of course, the above statement is based on three assumptions, none of which are valid in the context of the Genesis Flood cataclysm and the biblical timescale. First is the assumption that the processes responsible for the excavation of caverns within limestones could only have occurred after the Flood. Second is the assumption that caverns are only dissolved by the percolation of carbon dioxide rich ground water through joints or along bedding planes in limestone beds due to the weak carbonic acid solution reacting with the limestone.[2] And third, it is of course assumed that because carbonic acid is the only acid that forms in significant quantities in ground water today, that's the only process that could have dissolved out caverns in limestones in the past, and only at the rates of such dissolution processes today (according to strict uniformitarian belief).

The catastrophic deposition of limestone beds during the year-long Flood cataclysm has already been discussed and defended (chapter 64). After the lime sediment layers were deposited, they would have been buried rapidly under thousands of feet of other sediment layers, the weight of this overburden compacting the lime sediments and tending to expel the interstitial water (the water trapped between the

---

1 A. N. Strahler, 1987, *Science and Earth History—The Evolution/Creation Controversy*, Buffalo, NY: Prometheus Books, 280.

2 C. C. Plummer and D. McGeary, 1996, *Physical Geology*, seventh edition, Dubuque, IA: William C. Brown Publishers, 243-245.

lime sediment particles during deposition).[3] However, although the fluid pressure within the resultant limestone beds would have been great, the lack of a direct escape route for this pore water would have impeded water loss and prevented complete lithification. Major water loss would only have occurred through joints formed during the early stage of compaction. However, with the enormous catastrophic outpouring of lavas and large-scale catastrophic magmatic activity during the Flood, associated with catastrophic plate tectonics, copious quantities of hydrothermal fluids would have been generated and circulated through the earth's crust, including through the thick sequences of sedimentary strata that were being rapidly deposited contemporaneously. Because hydrothermal fluids are acidic, due to the dissolved sulfur in them, limestone layers would have been particularly susceptible to being dissolved by the passage of these hydrothermal fluids along joints and other fractures.[4]

In the later stages of the Flood catastrophe, tectonic activity would have resulted in the folding and faulting of the strata in sedimentary basins, and as the Flood waters subsequently receded, massive sheet and then channelized erosion would have stripped many sedimentary layers overlying limestone beds, and sometimes carving deeply into them. Both the tectonic movements and the removal of the overburden would have eased the compaction pressures and opened up joints, catastrophically releasing fluids that had been under pressure, particularly closest to the earth's surface. Thus, the mixture of now released acidic pore waters and the acidic hydrothermal fluids would have rapidly dissolved out huge caverns along joints and fractures, so that huge cave systems would have developed by rapid dissolution of the limestone beds at rates far exceeding today's rates. By comparison, today's rates of limestone dissolution are quiescent, whereas the conditions and rates at the end of Flood and early in the post-Flood era, when the earth was recovering from the upheavals of the Flood year, were still rapid and somewhat catastrophic.

Thus the process of forming the world's cave systems would have commenced during the Flood catastrophe itself, reaching its climax at the close of the Flood and in the subsequent immediate post-Flood period, as volcanic, magmatic, and tectonic activity waned, geologic conditions began to re-stabilize and the catastrophic process rates of the Flood year waned. Continued draining of water from sediments in the immediate post-Flood period would have ensured that horizontal groundwater flows would have been significant. With decaying of organic matter at the earth's surface, these ground waters would have been highly acidic, and these horizontal flows of highly acidic ground waters would have further enhanced the dissolution of limestone beds just below the water table, to further enlarge the developed cave systems. By contrast, the underground streams

3 S. A. Austin, 1980, Origin of limestone caves, *Acts & Facts,* 9(1).

4 E. Silvestru, 2003, A hydrothermal model of rapid post-Flood karsting, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 233-241.

flowing out of cave systems today are but a trickle in comparison to the combined ground water and hydrothermal fluid flows responsible for rapidly dissolving the limestones to generate the cave systems. Uniformitarian geologists have wrongly used today's groundwater flows and acid levels in the ground waters to miscalculate vast time periods for the formation of these cave systems.

Confirmation of the role of sulfuric acid in the rapid formation of large cave systems comes from the evidence that at least 10 percent of the caves in the Guadalupe Mountains of southeastern New Mexico and west Texas were primarily excavated by sulfuric acid in solution in warm ground water.[5] The products of sulfuric acid dissolution were found in the caves, especially the larger caves such as Carlsbad Cavern. It was found that sulfuric acid had formed by hydrogen sulfide being oxidized and dissolved in the hydrothermal fluids, the hydrogen sulfide rising from nearby oil deposits trapped in strata underneath the limestone bed in which the caves have been formed. Indeed, excavation of the Big Room at Carlsbad, a cavern of more than a million cubic meters (35 million cubic feet) was calculated to have only needed about 10 percent of the hydrogen sulfide from the annual commercial production of the neighboring gas fields.[6] Because sulfuric acid is much stronger than carbonic acid, sulfuric acid dissolution is believed to be much more rapid, speleogenesis possibly only taking centuries, not only for the caves in the Guadalupe Mountains, but in 10 percent or more of the known major caves worldwide.[7] Furthermore, other sources have been found for hydrogen sulfide production to aid sulfuric acid dissolution, such as bacteria, which are also capable of directly dissolving limestone too.[8] Just how prolific sulfuric acid dissolution is in the formation of cave systems is very likely to be of greater significance than realized hithertofore, because it has only been in the caves and dry areas where this process has been recognized due to the dissolution products being found, whereas in more humid climates the reactants may have been washed out of the caves.[9]

---

5 V. J. Polyak, W. C. McIntosh, N. Güven and P. Provencio, 1998, Age and origin of Carlsbad Cavern and related caves from $^{40}Ar/^{39}Ar$ of alunite, *Science*, 279: 1919-1922; I. D. Sasowsky, 1998, Determining the age of what is not there, *Science*, 279: 1874; V. J. Polyak and P. P. Provencio, 2000, Summary of the timing of sulfuric-acid speleogenesis for Guadalupe Caves based on ages of alunite, *Journal of Cave and Karst Studies*, 62(2): 72-79.

6 C. A. Hill, 1987, Geology of Carlsbad Caverns and other caves in the Guadalupe Mountains, New Mexico and Texas, *New Mexico Bureau of Mines and Mineral Resources Bulletin*, 117; D. Jagnow, C. A. Hill, D. Favis, H. DuChene, K. Cunningham, D. Northup and M. Queen, 2000, History of the sulfuric acid theory of speleogenesis in the Guadalupe Mountains of New Mexico, *Journal of Cave and Karst Studies*, 62(2): 54-59; C. A. Hill, 1990, Sulfuric acid speleogenesis of Carlsbad Caverns and its relationship to hydrocarbons, Delaware Basin, New Mexico and Texas, *American Association of Petroleum Geologists Bulletin*, 74: 1685-1694.

7 J. Gunn, 1981, Limestone solution rates and processes in the Waitomo district, New Zealand, *Earth Surface Processes*, 6: 427-445; D. Ford and P. Williams, 1991, *Karst Geomorphology and Hydrology*, London: Chapman and Hall, 113; A. N. Palmer, 1991, Origin and morphology of limestone caves, *Geological Society of America Bulletin*, 103: 1-21; Polyak et al, 1998.

8 L. Hose and J. Pisarowicz, 1999, Cueva de Villa Luz, Tabasco, Mexico: Reconnaissance study of an active sulfide spring cave and ecosystem, *Journal of Cave and Karst Studies*, 61(1): 13-21.

9 Palmer, 1991, 18-19.

However, even carbonic acid dissolution of limestones is more powerful and faster than is often portrayed. Because there are at least eight complex variables that determine the rate of solution of limestone,[10] another way of estimating limestone solution rates is to study a large cave-containing area where water chemistry and flow rates are known. For example, the large limestone and dolostone Sinkhole Plain-Mammoth Cave upland region of central Kentucky comprises several hundred square kilometers, receives 122 cm (48 inches) of rainfall annually, and naturally has about 51 cm (20 inches) of average annual runoff, yet the area has virtually no surface streams.[11] The runoff is instead channeled into sinkholes, which distribute the water into a widespread limestone and dolostone formation that is about 100 m (330 feet) thick, where caves and solution conduits transport most of the water until it is discharged at springs. Based on chemical analyses of the area's ground water,[12] and assuming that all the dissolved calcium and magnesium in the ground water must have come from solution of calcite and dolomite in the limestone and dolostone (because rainwater only has traces of calcium and magnesium), it can be shown that these concentrations represent 0.16 gram of dissolved calcite and dolomite per liter of ground water. Assuming about 100 cm of the mean annual rainfall infiltrates into the limestone and dolostone aquifer, each square kilometer of central Kentucky therefore receives about one million cubic meters, or one billion liters of water infiltrating into it, resulting in 176 tons of calcite and dolomite being dissolved each year from within each square kilometer of land surface. This equates to a volume of 59 cubic meters of calcite and dolomite dissolved each year, from one square kilometer of central Kentucky, and if this amount dissolved from just one groundwater conduit, a cave one square meter by 59 meters long would be excavated in just a single year![13]

Indeed, at this rate, the entire layer of limestone and dolostone over 100 meters thick would have been completely dissolved off central Kentucky in two million years, the conventionally assumed duration of the Pleistocene epoch, and the inferred age of many caves, including the Mammoth Caves, within this limestone and dolostone bed in central Kentucky. Nevertheless, the ground water in central Kentucky is actually undersaturated with respect to calcite and dolomite, meaning that the full dissolving power of the acidic water is not being fully utilized in attacking this limestone and dolostone bed. By contrast, the more humid, cooler climate of the Pleistocene (the early post-Flood period) would have resulted in increased groundwater flow due to the Flood waters still draining off, and therefore increased rates of limestone and dolostone solution. So combined with

10 J. F. Thrailkill, 1968, Chemical and hydrologic factors in the excavation of limestone caves, *Geological Society of America Bulletin*, 79: 19-46; R. F. Sipple and E. D. Glover, 1964, Solution alteration of carbonate rocks: The effects of temperature pressure, *Geochimica et Cosmochimica Acta,* 28: 1401-1417.

11 Austin, 1980; U. S. Geological Survey, 1970, *The National Atlas of the United States of America*, Department of Interior, Washington D.C., 97, 119.

12 J. F. Thrailkill, 1972, Carbonate chemistry of aquifer and stream water in Kentucky, *Journal of Hydrology*, 16: 93-104.

13 A. C. Swinnerton, 1932, Origin of limestone caverns, *Geological Society of America Bulletin*, 46: 678-679.

the contribution of sulfuric acid dissolution, it is conceivable that all the world's major (and minor) cave systems could have been rapidly produced at the end of the Flood cataclysm, and in the first few centuries of the post-Flood period at these rapid dissolution rates.

Once the ground waters and hydrothermal fluids were largely drained from cave systems, and the water table had dropped, the cave systems became filled with air instead of water. However, rainwater continued to infiltrate through the ground above the caves and into the limestone and dolostone beds, where it concentrated along cracks and tiny conduits to eventually be discharged into the cave systems by drip or flow. Once in the cave chambers, this water evaporates in the air, leaving behind deposits of calcite and dolomite lining the cave ceilings, walls, and floors as the various varieties of cave formations known as speleothems—stalactites hanging from the ceiling, stalagmites built up from the floor, columns formed by the joining of stalactites and stalagmites, and sheet-like layered flowstones on the walls or floors. Obviously, the rate of formation of these speleothems depends mainly on the rate of percolation of the lime-bearing waters into the roofs of caves, and on the evaporation rate in the caves. Some of these speleothems are very large, such as the 1.9-meter-tall stalagmite called the Great Dome in Carlsbad Cavern. Because many observations of speleothems suggest their rate of growth is very slow, along with old radiocarbon ages for the carbonate minerals in speleothems, it is often declared that stalactites, stalagmites, and other speleothems in caves could not have grown in the 4,500 years since the Genesis Flood.[14]

However, just because the formation rates for speleothems may be very slow at present certainly does not mean they have always been so.

> Various attempts have been made to estimate the rate of formation of cave travertine (speleothems), but so many variable factors affect the rate of deposition that it is doubtful if cavern ages arrived at by this method are accurate.[15]

Furthermore, radiocarbon ages of speleothems are deceptive, because the carbon incorporated in the speleothem minerals is out of equilibrium with the atmospheric carbon.

Most stalactites and stalagmites in modern caves are not growing, so it seems impossible to estimate their former rates of growth. However, in a summary of some of the early literature, stalactite growth was reported as averaging about 1.25 cm (0.5 inch) per year, with some observed to grow over 7.6 cm (3 inches)

---

14 Strahler, 1987, 281.

15 W. D. Thornbury, 1969, *Principles of Geomorphology*, second edition, New York: John Wiley and Sons, 325.

in a year.[16] Stalagmites were also observed to have grown 0.6 cm (0.25 inch) in height and 0.9 cm (0.36 inch) in diameter at the base each year. If this rate of height increase were applied to the 1.9 m tall Great Dome stalagmite in Carlsbad Cavern, it would have grown in less than 4,000 years. However, because most observations of the rapid growth of stalactites and stalagmites have been made in tunnels, under bridges, in dams and mines, or other dated man-made structures with approximate cave conditions, such observed growth rates are often dismissed as inapplicable to vast speleothem growth in caves. Nevertheless, such rejection of those rapid growth rate observations is unwarranted, particularly where observations have been made in underground mines where conditions are very similar to those in caves. These include such examples as a 1.6 meter high stalagmite that grew in an abandoned gold mine in central New South Wales, Australia, (where there are limestones nearby and cave systems) in less than 140 years, a growth rate of more than 1 cm per year, and numerous stalactites, some as long as 5 meters, in level 5 of the Mt. Isa lead-zinc mine in northwestern Queensland, Australia, which had grown in less than 55 years, a growth rate of up to 9 cm per year.[17] However, where measurements and experiments have been conducted in cave systems where stalactites and stalagmites are still growing, measured growth rates are both significant and comparable with those observed in man-made structures. For example, in Australia's famous Jenolan Caves in New South Wales, a drink bottle placed under a dripping stalactite shawl in the early 1950s had deposited on it within thirty years a stalagmite almost 20 cm high, a growth rate of almost 0.7 cm per year.[18]

Thus, it is possible at these present rates to account for the growth of speleothems in cave systems within the last 4,500 years, since the cave systems themselves formed at the end of the Flood and soon thereafter. Furthermore, because in the immediate post-Flood period (the Pleistocene) there was higher rainfall and higher humidity than today, it is probable that most speleothems grew at a much faster rate than the measured rates today. These initial faster growth rates, coupled with higher rainfall and humidity conditions, would account for the many speleothems that are not now growing under present conditions. Consequently, to attribute great lengths of time to the formation of caves in limestones, and the growth of cave deposits (speleothems), is not only unnecessary, but unreasonable.

16 L. W. Fisher, 1934, Growth of stalactites, *American Mineralogist*, 19: 429-431.

17 D. Batten, 1997, 'Instant' stalagmites!, *Creation*, 19(4): 37; Anonymous, 1998, Rapid stalactite formation, *Creation Ex Nihilo Technical Journal*, 12(3): 280.

18 Anonymous, 1995, Bottled stalagmite, *Creation*, 17(2): 6.

123

Granite Formation, Intrusion, and Cooling

Exposed at the earth's surface today are large areas of granites, mapped as individual bodies ranging in size from 1 square kilometer to more than 1,000 square kilometers. In many regions of the world, hundreds of these granite plutons are found in belts hundreds to thousands of kilometers long that are called batholiths, such as that in the Sierra Nevada mountain range of California. On that scale, granites are a major component of the earth's surface, and it is estimated that 86 percent of the intrusive rocks within the upper continental crust are of granitic composition.[1]

Deep in the earth's crust the temperature is sometimes high enough to melt the rocks locally, so that large "blobs" of granitic magmas are thus generated. Due to the buoyancy of the less dense molten rock, the magma rises to be intruded into the upper crust where the granite plutons crystallize and cool. Conventionally these processes of granite formation, intrusion, and cooling are regarded as taking millions of years.

> My guess is that a granitic magma pulse generated in a collisional origin may, in a complicated way involving changing rheologies of both melt and crust, take 5-10 Ma [million years] to generate, arrive, crystallize and cool to the ambient crustal temperature.[2]

Thus, it has been insisted that an immense granite batholith like that in southern California required a period of about 1 million years in order to crystallize completely, so it is obviously impossible to reconcile the complete process of magma generation, injection, and cooling on the order of 10 million years with the global Genesis Flood on a young earth.[3]

---

1 A. H. Wedepohl, 1969, Composition and abundance of common igneous rocks, *Handbook of Geochemistry*, vol. 1, Berlin: Springer-Verlag, 227-249.

2 W. S. Pitcher, 1993, *The Nature and Origin of Granites*, Blackie Academic and Professional, London, 187.

3 D. A. Young, 1977, *Creation and the Flood: An Alternative to Flood Geology and Theistic Evolution*, Baker Book House, MI: A. Hayward, 1985, *Creation and Evolution: The Facts and the Fallacies*, Triangle SPCK, London: Strahler, 1987.

Because we don't observe granites forming today, debate has raged for centuries as to how granites form. While there is now much consensus, some details of the processes involved are still being elucidated. Significantly, though the conventional wisdom has been adamant that granites take millions of years to form, recently that view has changed because of radical new ideas based on observation and experiments.[4] The essential role of rock deformation is now recognized. Previously accepted granite formation models required unrealistic deformation and flow behaviors of rocks and magmas, or did not satisfactorily explain available structural or geophysical data. Thus it is now claimed that mechanical considerations suggest granite formation was a "rapid, dynamic process" operating at timescales of less than 10,000 years, or even only thousands of years.

Several steps are required to form granites. The process starts with partial melting of continental sedimentary and metamorphic rocks 20-40 km (12-25 miles) down in the earth's crust, a process called generation.[5] This must be followed by the collection of the melt, called segregation, then transportation of the now less dense, buoyant magma upwards (ascent), and finally the intrusion of the magma to form a pluton in the upper crust (emplacement). There, as little as 2-5 km (1-3 miles) below the earth's surface, the granite mass fully crystallizes and cools. Subsequent erosion exposes it at the earth's surface. It is thus not difficult to understand why it has been hithertofore envisaged that this sequential series of processes in granite formation must surely have taken millions of years, such claimed estimates of course being supported by radioisotope dating.

Magma Generation by Partial Melting

Typical geothermal gradients of 20°C per km do not generate the greater than 800°C temperatures at 35 km depth in the crust needed to melt common crustal rocks.[6] However, there are at least three other factors, besides temperature, that are important in melt generation: water content of magma, pressure, and the influence of mantle-derived basalt magmas. Temperatures required for melting are significantly lowered by increasing water activity up to saturation, and the amount of temperature lowering increases with increasing pressure.[7] Indeed, water solubility in granitic melts increases with pressure, the most important controlling

4 N. Petford, A. R. Cruden, K. J. W. McCaffrey and J.-L. Vigneresse, 2000, Granite magma formation, transport and emplacement in the earth's crust, *Nature*, 408,: 669-673; J. D. Clemens, 2005, Granites and granitic magmas: Strange phenomena and new perspectives on some old problems, *Proceedings of the Geologists' Association*, 116: 9-16.

5 M. Brown, 1994, The generation, segregation, ascent and emplacement of granite magma: The migmatite to crustally-derived granite connection in thickened orogens, *Earth Science Reviews*, 36: 83-130.

6 A. B. Thompson, 1999, Some time-space relationships for crustal melting and granitic intrusion at various depths, in *Understanding Granites: Integrating New and Classical Techniques*, A. Castro, C. Fernández and J.-L. Vigneresse, eds., London: The Geological Society, Special Publication 168: 7-25.

7 A. Ebadi and W. Johannes, 1991, Beginning of melting and composition of first melts in the system Qz-Ab-Or-H_2O-CO_2, *Contributions to Mineralogy and Petrology*, 106: 286-295.

factor,[8] so that whereas at 1 kilobar (generally equivalent to 3 to 4 km depth) the water solubility is 3.7 weight %,[9] at 30 kilobars (up to 100 km depth, though very much less in tectonic zones) it is approximately 24 weight %.[10] This water is supplied by the adjacent rocks, subducted oceanic crust, and hydrous minerals present in the melting rock itself.

Nevertheless, local melting of deep crustal rocks is even more efficient where the lower crust is being heated by basalt magmas generated just below in the upper mantle.[11] Partial melting of crustal rocks pre-heated in this way is likely to be rapid.[12] Experiments on natural rock systems have also shown the added importance of mineral reactions to rapidly produce granitic melts.[13] One such experiment found that a quartzo-feldspathic source rock undergoing water-saturated melting at 800°C could produce 20-30 volume % of homogeneous melt in less than one to ten years.[14]

A crucial consequence of fluid-absent melting is reaction-induced expansion of the rock that results in local fracturing and a reduction in rock strength, due to the increase pore fluid (melt) pressures.[15] Stress gradients can also develop in the vicinity of an intruding basalt heat source and promote local fractures. These processes, in conjunction with regional tectonic strain, are important in providing enhanced fracture permeabilities in the region of partial melting, which aids subsequent melt segregation.[16]

Melt Segregation

The small-scale movement of magma (melt plus suspended crystals) within the source region is called segregation. The granite melts' ability to segregate

8 W. Johannes and F. Holtz, 1996, *Petrogenesis and Experimental Petrology of Granitic Rocks*, Berlin: Springer-Verlag.

9 F. Holtz, H. Behrens, D. B. Dingwell and W. Johannes, 1995, Water solubility in haplogranitic melts: Compositional, pressure and temperature dependence, *American Mineralogist*, 80: 94-108.

10 W. L. Huang and P. J. Wyllie, 1975, Melting reactions in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2 to 35 kilobars, dry with excess water, *Journal of Geology*, 83: 737-748.

11 E. W. Bergantz, 1989, Underplating and partial melting: Implications for melt generation and extraction, *Science*, 254: 1039-1045.

12 C. E. Huppert and R. S. J. Sparks, 1988, The generation of granitic magmas by intrusion of basalt into continental crust, *Journal of Petrology*, 29: 599-642; Thompson, 1999.

13 M. Brown and T. Rushmer, 1997, The role of deformation in the movement of granitic melt: Views from the laboratory and the field, in *Deformation-Enhanced Fluid Transport in the Earth's Crust and Mantle*, M. Holness, ed., London: Chapman and Hall: 111-144; Thompson, 1999.

14 A. Acosta-Vigil, D. London, G. B. Morgan, V. I. and T. A. Dewers, 2006, Dissolution of quartz, albite, and orthoclase in H_2O-saturated haplogranitic melt at 800°C and 200 MPa, diffusive transport properties of granitic melts at crustal anatectic conditions, *Journal of Petrology*, 47: 231-254.

15 J. B. Clemens and C. K. Mawer, 1992, Granitic magma transport by fracture propagation, *Tectonophysics*, 204: 339-360; Brown and Rushmer, 1997.

16 Petford et al, 2000.

mechanically from its matrix is strongly dependent on its physical properties, of which viscosity and density are the most important. Indeed, the viscosity is the crucial rate-determining variable, and is a function of melt composition, water content, and the temperature.[17] It has been demonstrated that the temperature and melts' water content are interdependent,[18] yet the viscosities and densities of granitic melts actually vary over quite limited ranges for melt compositions varying between tonalite (65 weight % SiO_2, 950°C) and leucogranite (75 weight % SiO_2, 750°C).[19] An important implication is that the segregation and subsequent ascent processes, which are moderated by the physical properties of the melts, thus occur at broadly similar rates, regardless of the tectonic setting and the pressures and temperatures to which the source rock has been subjected over time. Furthermore, granitic magmas are only 10 to 1,000 times more viscous than basaltic magmas, which readily flow.[20]

Most field evidence points to deformation (essentially "squeezing") as the dominant mechanism that segregates melt flow in the lower crust.[21] Rock deformation experiments indicate that when 10 to 40 percent of a rock is a granitic melt, the pore pressures in a rock are equivalent to the confining pressure, so the residual grains move relative to one another, resulting in macroscopic deformation due to melt-enhanced mechanical flow.[22] These experiments also imply that deformation-enhanced segregation can in principle occur at any stage during partial melting. Furthermore, the deformation-assisted melt segregation is so efficient in moving melt from its source to local sites of dilation ("squeezing") over a timescale of only a month up to 1,000 years. Thus, the melts may not attain chemical or isotopic equilibrium with their surrounding source rocks before final extraction and ascent.[23]

---

17 J. Woodmorappe, 2001, The rapid formation of granitic rocks: More evidence, *TJ*, 15(2): 122-125; E. B. Dingwell, N. S. Bagdassarov, G. Y. Bussod, and S. L. Webb, 1993, Magma rheology, in *Experiments at High Pressure and Applications to the Earth's Mantle*, R.W. Luth, ed., Short course handbook, vol. 21, Ottawa: Mineralogical Association of Canada, 131-196.

18 B. Scalliet, F. Holtz and M. Pichavant, 1998, Phase equilibrium constraints on the viscosity of silicic magmas—1. Volcanic-plutonic association, *Journal of Geophysical Research-Solid Earth*, 103B: 27257-27266.

19 J.D. Clemens and N. Petford, 1999, Granitic melt viscosity and silicic magma dynamics in contrasting tectonic settings, London: *Journal of the Geological Society*, 156: 1057-1060.

20 E. R. Baker, 1996, Granitic melt viscosities: Empirical and configurational entropy models for their calculation, *American Mineralogist*, 81: 126-134; B. Scalliet, F. Holtz, M. Pichavant, and M. Schmidt, 1996, Viscosity of Himalayan leucogranites: Implications for mechanisms of granitic magma ascent, *Journal of Geophysical Research—Solid Earth*, 101B: 27691-27699; Clemens and Petford, 1999.

21 J.-L. Vigneresse, P. Barbey and M. Cuney, 1996, Rheological transitions during partial melting and crystallization with application to felsic magma segregation and transfer, *Journal of Petrology*, 37: 1579-1600; Brown and Rushmer, 1997.

22 E. H. Rutter and D. H. K. Neumann, 1995, Experimental deformation of partially molten Westerly Granite under fluid-absent conditions, with implications for the extraction of granitic magmas, *Journal of Geophysical Research—Solid Earth*, 100B: 15697-15715; Brown and Rushmer, 1997.

23 E. W. Sawyer, 1991, Disequilibrium melting and rate of melt-residuum separation during migmatization of mafic rocks from Grenville Front, Quebec: *Journal of Petrology*, 32: 701-738; G. R. Davies and S.

These rapid timescales for melt extraction are well-supported by geochemical evidence in some granites. For example, some Himalayan leucogranites are strongly undersaturated with respect to the element zirconium,[24] because the granitic melt was extracted so rapidly from the residual matrix (in less than 150 years), that there was insufficient time for zirconium to be re-equilibrated between the two phases. Similarly, based on comparable evidence in a Quebec granite, the inferred time for the extraction of the melt from its residuum was only 25 years.[25]

Magma Ascent

Gravity is the essential driving force for large-scale vertical transport of melts (ascent) in the continental crust.[26] However, the traditional idea of buoyant granitic magma ascending through the continental crust as slow-rising, hot diapirs or by stoping (that is, large-scale veining)[27] has been largely replaced by more viable models. These models involve the very rapid ascent of granitic magmas in narrow conduits, either as self-propagating dikes[28] along pre-existing faults,[29] or as an interconnected network of active shear zones and dilational structures.[30] The advantage of dike/conduit ascent models is that they overcome the severe thermal and mechanical problems associated with transporting very large volumes of granite magmas through the upper brittle continental crust,[31] as well as explaining the persistence of near-surface granite intrusions and associated silicic volcanism. However, yet to be resolved is whether granite plutons are fed predominantly by a few large conduits or by dike swarms.[32]

Tommasini, 2000, Isotopic disequilibrium during rapid crustal anatexis: Implications for petrogenetic studies of magmatic processes, *Chemical Geology*, 162: 169-191.

24 N. Harris, D. Vance and M. Ayres, 2000, From sediment to granite: Timescales of anatexis in the upper crust, *Chemical Geology*, 162: 155-167.

25 Sawyer, 1991.

26 Petford et al, 2000.

27 R. F. Weinberg and Y. Podladchikov, 1994, Diapiric ascent of magmas through power law crust and mantle, *Journal of Geophysical Research—Solid Earth*, 99B: 9543-9559.

28 J. D. Clemens and C. K. Mawer, 1992; J.D. Clemens, N. Petford and C.K. Mawer, 1997, Ascent mechanisms of granitic magmas: Causes and consequences, in *Deformation-Enhanced Fluid Transport in the Earth's Crust and Mantle*, M. Holness, ed., London: Chapman and Hall, 145-172.

29 N. Petford, R. C. Kerr and J. R. Lister, 1993, Dike transport of granitoid magmas, *Geology*, 21: 845-848.

30 R. S. D'Lemos, M. Brown and R. A. Strachan, 1993, Granite magma generation, ascent and emplacement within a transpressional origin, *Journal of the Geological Society, London*, 149: 487-490; W. J. Collins and E. W. Sawyer, 1996, Pervasive granitoid magma transport through the lower-middle crust during non-coaxial compressional deformation, *Journal of Metamorphic Geology*, 14: 565-579.

31 B. D. Marsh, 1982, On the mechanics of igneous diapirism, stoping and zone melting, *American Journal of Science*, 282: 808-855.

32 M. Brown and G. S. Solar, 1999, The mechanism of ascent and emplacement of granite magma during transpression: A syntectonic granite paradigm, *Tectonophysics*, 312: 1-33; R. F. Weinberg, 1999, Mesoscale pervasive felsic magma migration: Alternatives to dyking, *Lithos*, 46: 393-410.

The most striking aspect of the ascent of granitic melts in dikes is the extreme difference in the magma ascent rate compared to diapiric rise, the dike ascent rate being up to a million times faster, depending on the magma's viscosity and the conduit width.[33] The narrow dike widths (1-50 meters) and rapid ascent velocities predicted by fluid dynamical models are supported by field and experimental studies.[34] For example, for epidote crystals to have been preserved as found in the granites of the Front Range (Colorado), and of the White Creek batholith (British Columbia), required an ascent rate of between 0.7 and 14 km per year. Therefore, the processes of melt segregation at more than 21 km depth in the crust, and then magma ascent and emplacement in the upper crust, all had to occur within just a few years.[35] Such a rapid ascent rate is similar to magma transport rates in dikes calculated from numerical modeling,[36] and close to measured ascent rates for upper crustal magmas.[37] Indeed, a granite melt could be transported 30 km through the crust along a 6-m-wide dike in just 41 days at a mean ascent rate of about 1 cm per second.[38] At that rate, the Cordillera Blanca batholith in northwest Peru, with an estimated volume of 6,000 cubic kilometers, could have been filled from a 10-km-long dike in only 350 years.

It is obvious that magma transport needed to have occurred at such fast rates through such narrow dikes, or else the granite magmas would "freeze" due to cooling within the conduits as they ascended. Instead, there is little geological, geophysical, or geochemical evidence to mark the passage of such large volumes of granite magmas up through the crust.[39] Because of the rapid ascent rates, chemical and thermal interaction between the dike magmas and the surrounding country rocks will be minimal. Typical ascent rates of 3 mm per second to 1 m per second have been calculated, which assuming there is continuous, efficient supply of magma to the base of the fracture system, translates to between

33 Petford et al, 1993; Clemens et al, 1997.

34 B. Scalliet, A. Pecher, P. Rochette and M. Champenois, 1994, The Gangotri Granite (Garhwal Himalaya): Laccolith emplacement in an extending collisional belt, *Journal of Geophysical Research—Solid Earth*, 100B: 585-607; A. D. Brandon, T. Chacko and R. A. Creaser, 1996, Constraints on granitic magma transport from epidote dissolution kinetics, *Science*, 271: 1845-1848.

35 Brandon et al, 1996.

36 Clemens and Mawer, 1992; Petford et al, 1993; N. Petford, 1995, Segregation of tonalitic-trondhjemitic melts in the continental crust: The mantle connection, *Journal of Geophysical Research—Solid Earth*, 100B: 15735-15743; N. Petford, 1996, Dykes or diapirs?, *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 87: 105-114.

37 R. Scandone and S. D. Malone, 1985, Magma supply, magma discharge and readjustment of the feeding systems of Mount St. Helens during 1980, *Journal of Volcanology and Geothermal Research*, 23: 239-262; W. W. Chadwick Jr., R. J. Archuleta and A. Swanson, 1988, The mechanics of ground deformation precursory to dome-building extrusions at Mount St. Helens 1981-1982, *Journal of Geophysical Research—Solid Earth*, 93B: 4351-4366; M. J. Rutherford and P. M. Hill, 1993, Magma ascent rates from amphibole breakdown: An experimental study applied to the 1980-1986 Mount St. Helens eruptions, *Journal of Geophysical Research—Solid Earth*, 98B: 19667-19685.

38 Petford et al, 1993.

39 Clemens and Mawer, 1992; Clemens et al, 1997.

5 hours and 3 months for 20 km of ascent.[40] Such rapid rates make granite magma ascent effectively an instantaneous process, bringing plutonic granite magmatism more in line with timescales characteristic of silicic volcanism and flood basalt magmatism.[41]

Magma Emplacement

The final stage of magma movements is horizontal flow to form intrusive plutons in the upper continental crust. This emplacement is controlled by a combination of mechanical interactions, either pre-existing or placement-generated wall-rock structures, and density effects between the spreading flow and its surroundings.[42] The mechanisms by which the host rocks make way for this incoming magma have challenged geologists for most of the past century and have been known as the "space problem."[43] This problem is particularly acute where the volumes of magmas forming batholiths (groups of hundreds of individual granite plutons intruded side-by-side over large areas, such as the Sierra Nevada of California) are 100,000 cubic kilometers or greater, and are considered to have been emplaced in a single event.

New ideas that have alleviated this problem are: the recognition of the important role played by tectonic activity in making space in the crust for the incoming magma;[44] the realistic interpretation of the geometry of granitic intrusions at depth; and the recognition that emplacement is an episodic process involving discrete pulses of magma. Physical models indicate that space for incoming magmas can be generated through a combination of lateral fault opening, roof lifting, and lowering of the growing magma intrusion floor.[45] For example, space is created by uplift of the strata above the intrusion, even at the earth's surface, and their erosion.

The three-dimensional shapes of crystallized plutons provide important information on how the granitic magmas were emplaced. The majority of plutons

40 Clemens, 2005.

41 Petford et al, 2000.

42 D. H. W. Hutton, 1988, Granite emplacement mechanisms and tectonic controls: Influences from deformation studies, *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 79: 245-255; J. P. Hogan and M. C. Gilbert, 1995, The A-type Mount Scott Granite sheet: Importance of crustal magma traps, *Journal of Geophysical Research—Solid Earth,* 100B: 15779-15792.

43 Pitcher, 1993.

44 Hutton, 1988.

45 D. Roman-Berdiel, D. Gapais and J. P. Brun, 1997, Granite intrusion along strike-slip zones in experiment and nature, *American Journal of Science*, 297: 651-678; K. Benn, F. O'Donne and M. de Saint Blanquat, 1998, Pluton emplacement during transpression in brittle crust, new views from analogue experiments, *Geology*, 26: 1079-1082; A. R. Cruden, 1998, On the emplacement of tabular granites, *Journal of the Geological Society of London*, 155: 853-862; C. Fernández and A. Castro, 1999, Pluton accommodation at high strain rates in the upper continental crust. The example of the Central Extremadura batholith, Spain, *Journal of Structural Geology*, 21: 1143-1149.

so far investigated using detailed geophysical (gravity, magnetic susceptibility, and seismic) surveys appear to be flat-lying sheets to open funnel-shaped structures with central or marginal feeder zones,[46] consistent with an increasing number of field studies (collecting fabric and structural data) that find plutons to be internally sheeted on the 0.1 m to kilometer scale.[47]

Considerations of field and geophysical data suggest that growth of a laterally-spreading and vertically-thickening intrusive flow obey a simple mathematical scaling or power-law relationship (between thickness and length) typical of systems exhibiting scale-invariant (fractal) behavior and size distributions.[48] This inherent preference for scale-invariant tabular sheet geometries in granitic plutons from a variety of tectonic settings is best explained in mechanical terms by the intruding magma flowing horizontally some distance initially before vertical thickening then occurs, either by hydraulic lifting of the overburden (particularly above shallow-level intrusions) or sagging of the floor beneath.[49] Plutons thus go from the birth stage characterized by lateral spreading to an inflation stage marked by vertical thickening.

This intrusive tabular sheet model envisages larger plutons growing from smaller ones according to a power-law inflation growth curve, ultimately to form crustal-scale batholithic intrusions.[50] Evidence of this growth process has been revealed by combined, field, petrological, geochemical, and geophysical (gravity) studies of the 1,200-km-long Coast batholith of Peru.[51] On a crustal scale this exposed batholith was formed by a thin (3-7 km thick) low-density granite layer that coalesced from numerous smaller plutons with aspect ratios of between 17:1 and 20:1. Thus this batholith would only amount to 5 to 10 percent of the crustal volume of this coastal sector of the Andes,[52] which greatly reduces the so-called

46 D. J. Evans, W. J. Rowley, R. A. Chadwick, E. S. Kimbell and D. Millward, 1994, Seismic reflection data and the internal structure of the Lake District batholith, Cumbria, northern England, *Proceedings of the Yorkshire Geological Society*, 50: 11-24; L. Améglio, J.-L. Vigneresse and J. L. Bouchez, 1997, Granite pluton geometry and emplacement mode inferred from combined fabric and gravity data, in *Granite: From Segregation of Melt to Emplacement Fabrics*, J. L. Bouchez, D. H. W. Hutton and W. E. Stephens, eds., Dordrecht, The Netherlands: Kluwer Academic Publishers: 199-214; L. Améglio and J.-L. Vigneresse, 1999, Geophysical imaging of the shape of granitic intrusions at depth: A review, in *Understanding Granites: Integrating New and Classical Techniques*, A. Castro, C. Fernández and J.-L. Vigneresse, eds., London: The Geological Society, Special Publication 168: 39-54; N. Petford and J. D. Clemens, 2000, Granites are not diapiric!, *Geology Today*, 16 (5): 180-184.

47 Améglio et al, 1997; J. Grocott, A. Garden, D. Chadwick, A. R. Cruden and C. Swager, 1999, Emplacement of Rapakivi granite and syenite by floor depression and roof uplift in the Paleoproterozoic Ketilidian orogen, south Greenland, *Journal of the Geological Society of London*, 156: 15-24.

48 K. J. W. McCaffrey and N. Petford, 1997, Are granitic intrusions scale invariant?, *Journal of the Geological Society of London*, 154: 1-4; Petford and Clemens, 2000.

49 Petford et al, 2000.

50 McCaffrey and Petford, 1997; Cruden, 1998.

51 M. P. Atherton, 1999, Shape and intrusion style of the coastal batholith, Peru, in *4th International Symposium on Andean Geodynamics*: 60-63.

52 Petford and Clemens, 2000.

space problem. Detailed studies of the Sierra Nevada batholith of California reveal a similar picture, in which batholith construction occurred by progressive intrusion of coalescing granitic plutons 2 to 2,000 square kilometers in area, supposedly over a period of 40 million years (as determined by radioisotope dating).[53]

Emplacement Rates

The tabular three-dimensional geometry of granite plutons and their growth by vertical displacements of their roofs and floors enables limits to be placed on their emplacement rates.[54] Taking conservative values for magma viscosities, wall-rock/magma density differences, and feeder dike dimensions results in pluton filling times of between forty days and one million years for plutons under 100 km across. If the median value for the volumetric filling rate is used, then at the fastest magma delivery rates most plutons would have been emplaced in much less than 1,000 years.[55] Even a whole batholith of 1,000 cubic kilometers could be built in only 1,200 years, at the rate of growth of an intrusion in today's non-catastrophic geological regime.[56]

Thus, the formation of granite intrusions in the middle to upper crust involves four discrete processes—partial melting, melt segregation, magma ascent, and magma emplacement. According to conventional geologists, the rate-limiting step in this series of processes in granite magmatism is the timescale of partial melting,[57] but "the follow-on stages of segregation, ascent and emplacement can be geologically extremely rapid—perhaps even catastrophic."[58] However, the required timescale for partial melting is not incompatible with the 6,000- to 7,000-year biblical framework for earth history, because a very large reservoir of granitic melts could have been generated in the lower crust in the 1,650 years between creation and the Flood,[59] particularly due to residual heat from an episode of accelerated nuclear decay during the first three days of the Creation Week.[60] This very large reservoir of granitic melts would then have been mobilized and progressively intruded

53 P. C. Bateman, 1992, *Plutonism in the Central Part of the Sierra Nevada Batholith, California*, Denver, CO: Professional paper 1483, United States Geological Survey.

54 Petford et al, 2000.

55 Harris et al, 2000; Petford et al, 2000.

56 Clemens, 2005.

57 Petford et al, 2000; Harris et al, 2000.

58 Petford et al, 2000, 673.

59 Woodmorappe, 2001.

60 D. R. Humphreys, 2000, Accelerated nuclear decay: A viable hypothesis?, in *Radioisotopes and the Age of the Earth: A Young Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research, and St. Joseph, MO: Creation Research Society, 333-379; L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., 2005, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, El Cajon, CA: Institute for Creation Research, and Chino Valley, AZ: Creation Research Society.

into the upper crust during the global, year-long Flood cataclysm, when the rates of these granite magmatism processes would have been greatly accelerated with so many other geologic processes, due to another episode of accelerated nuclear decay,[61] and catastrophic plate tectonics,[62] the likely driving mechanism of the Flood event.

Crystallization and Cooling Rates

The so-called space problem may have been solved, but what of the heat problem, that is, the time needed to crystallize and cool the granite plutons after their emplacement? Given that it has now been established that the world's granitic plutons are mostly tabular in shape, and typically only a few kilometers thick, it is a simple matter to model the cooling of granitic plutons by conduction.[63] When using typical values for physical properties of the magma and wall-rock temperatures, thermal conductivities, and heat capacities, a 3-km-thick sheet of granitic magma would take around 30,000 years to completely solidify from the initially liquid magma.

However, this calculation completely ignores the field, experimental, and modeling evidence that the crystallization and cooling of granitic plutons occurred much more rapidly as a result of convection, due to the circulation of hydrothermal and meteoric fluids, evidence that has been known about for more than 25 years.[64] The most recent modeling of plutons cooling by hydrothermal convection takes into account the multiphase flow of water and the heat it carries in the relevant ranges of temperatures and pressures, so that a small pluton (1 km x 2 km, at 2 km depth) is estimated to have taken 3,500-5,000 years to cool, depending on the system permeability.[65] But this modeling does not take into account the relatively

61 Humphreys, 2000; Vardiman et al, 2005.

62 S. A. Austin, J. R. Baumgardner, D. R. Humphreys, A. A. Snelling, L. Vardiman and K. P. Wise, 1994, Catastrophic plate tectonics: A global Flood model of earth history, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship: 609-621.

63 H. S. Carslaw and J. C. Jaeger, 1980, *Conduction of Heat in Solids*, second edition, Oxford, UK: Oxford University Press; Clemens, 2005.

64 L. M. Cathles, 1977, An analysis of the cooling of intrusives by ground-water convection which includes boiling, *Economic Geology*, 72: 804-826; P. Cheng and W. J. Minkowycz, 1977, Free convection about a vertical flap plate embedded in a porous medium with application to heat transfer from a dike, *Journal of Geophysical Research—Solid Earth*, 82B: 2040-2044; D. Norton and J. Knight, 1977, Transport phenomena in hydrothermal systems: Cooling plutons, *American Journal of Science*, 277: 937-981 D. Norton, 1978, Sourcelines, sourceregions, and pathlines for fluid in hydrothermal systems related to cooling plutons, *Economic Geology*, 73: 21-28; K. E. Torrance and J. P. Sheu, 1978, Heat transfer from plutons undergoing hydrothermal cooling and thermal cracking, *Numerical Heat Transfer*, 1: 147-161; E. M. Paramentier, 1981, Numerical experiments on ^{18}O depletion in igneous intrusions cooling by groundwater convection, *Journal of Geophysical Research—Solid Earth* 86B: 7131-7144; H. C. Hardee, 1982, Permeable convection above magma bodies, *Tectonophysics*, 84: 179-195; F. J. Spera, 1982, Thermal evolution of plutons: A parameterized approach, *Science*, 207: 299-301.

65 E. O. Hayba and S. E. Ingebritsen, 1997, Multiphase groundwater flow near cooling plutons, *Journal of Geophysical Research—Solid Earth*, 102B: 12235-12252.

thin, tabular structure of plutons that would significantly reduce their cooling times. Similarly, convective overturn caused by settling crystals in the plutons would be another significant factor in the dissipation of their heat.[66]

Convective Cooling: The Role of Hydrothermal Fluids

Granitic magmas invariably have huge amounts of water dissolved in them that are released as the magma crystallizes and cools. As the magma is injected into the host strata, it exerts pressure on them that facilitates fracturing of them.[67] Also, the heat from the pluton induces fracturing as the fluid pressure in the pores of the host strata increases from the heat,[68] this process repeating itself as the pluton's heat enters these new cracks.

Following the emplacement of a granitic magma, crystallization occurs due to this irreversible heat loss to the surrounding host strata.[69] As heat passes out of the intrusions at its margins, the *solidus* (the boundary between the fully crystallized and partially crystallized magma) progressively moves inwards toward the interior of the intrusion.[70] As crystallization proceeds, the water dissolved in the magma that isn't incorporated in the crystallizing minerals stays in the residual melt, so its water concentration increases. When the saturation water concentration is lowered to the actual water concentration in the residual melt, first boiling occurs and water (as superheated steam) is expelled from the solution in the melt, which is consequently driven toward higher crystallinities as the temperature continues to fall. Bubbles of water vapor then nucleate and grow, causing second (or resurgent) boiling within the zone of crystallization just underneath the solidus boundary and the already crystallized granite (Figure 73, page 1101).

As the concentration and size of these vapor bubbles increase, vapor saturation is quickly reached, but initially these vapor bubbles are trapped beneath the immobile crystallized granite margin of the pluton.[71] The vapor pressure thus increases, until the aqueous fluid can only be removed from the sites of bubble nucleation through the establishment of a three-dimensional critical percolation

66 A. A. Snelling and J. Woodmorappe, 1998, The cooling of thick igneous bodies on a young earth, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship,: 527-545.

67 R. B. Knapp and D. Norton, 1981, Preliminary numerical analysis of processes related to magma crystallization and stress evolution in cooling plutons environments, *American Journal of Science*, 281: 35-68.

68 R. B. Knapp and J. E. Knight, 1977, Differential thermal expansion of pore fluids: Fracture propagation and microearthquake production in hot plutonic environments, *Journal of Geophysical Research—Solid Earth*, 82B: 2515-2522.

69 P. A. Candela, 1992, Controls on ore metal ratios in granite-related ore systems: An experimental and computational approach, *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 83: 317-326.

70 P. A. Candela, 1991, Physics of aqueous phase evolution and plutonic environments, *American Mineralogist*, 76: 1081-1091.

71 Candela, 1991.

network, with advection of aqueous fluids through it, or by means of fluid flow through a cracking front in the already crystallized granite and out into the surrounding host strata. Once such fracturing of the pluton has occurred (because the cracking front will go deeper and deeper into the pluton as the solidus boundary moves progressively inwards toward the core of the intrusion), not only is magmatic water released from the pluton carrying heat out into the host strata, but the cooler meteoric water in the host strata is able to penetrate into the pluton and thus establish a convective hydrothermal circulation, through the fracture networks in both the granite pluton and the surrounding host strata. The more water dissolved in the magma, the greater will be the pressure exerted at the magma/granite and granite/host strata interfaces, and thus the greater the fracturing in both the granite pluton and the surrounding host strata.[72]

Thus, by the time the magma has totally crystallized into the constituent minerals of the granite, the solidus boundary and cracking front have both reached the core of the pluton as well. It also means that a fracture network has been established through the total volume of the pluton and out into the surrounding host strata, through which a vigorous flow of hydrothermal fluids has been established. These hydrothermal fluids thus carry heat by convection out through this fracture network away from the cooling pluton, ensuring the temperature of the granitic rock mass continues to rapidly fall. The amount of water involved in this hydrothermal fluid convection system is considerable, given that a granitic magma has enough energy due to inertial heat to drive roughly its mass in meteoric fluid circulation.[73] The emplacement depth and the scale of the hydrothermal circulatory system are first-order parameters in determining the cooling time of a large granitic pluton.[74] Water also plays a "remarkable role" in determining the cooling time. For a granitic pluton 10 km wide emplaced at 7 km depth, the cooling time of the magma to the solidus decreases almost tenfold as the water content of the magma increases from 0.5 weight % to 4 weight %. As the temperature of the pluton/host rock boundary drops through 200°C during crystallization, depending on the hydrothermal fluid/magma volume ratio, with only a 2 weight % water content, the pluton cooling time decreases 18-fold. As concluded:

> Hydrothermal fluid circulation within a permeable or fractured country rock accounts for most heat loss when magma is emplaced into water-bearing country rock.…Large hydrothermal systems tend to occur in the upper parts of the crust where meteoric water is more plentiful.[75]

72 Knapp and Norton, 1981; J. Zhao and E. T. Brown, 1992, Thermal cracking induced by water flow through joints in heated granite, *International Journal of Rock Mechanics*, 17: 77-82.

73 D. Norton and L. M. Cathles, 1979, Thermal aspects of ore deposition, in *Geochemistry of Hydrothermal Ore Deposits*, second edition, H. L. Barnes, ed., New York: John Wiley and Sons: 611-631; L. M. Cathles, 1981, Fluid flow and genesis of hydrothermal ore deposits, in *Economic Geology: 75th Anniversary Volume*, B. J. Skinner, ed., Economic Geology Publishing Company: 424-457.

74 Spera, 1982.

75 Spera, 1982, 299.

Of course, granitic magmas rapidly emplaced during the Flood cataclysm would have been intruded into sedimentary strata that were still wet from having just been deposited only weeks or months earlier. Furthermore, complete cooling of such granitic plutons did not have to all occur during the Flood year.

It is also a total misconception that the last crystals found in granites required slow cooling rates.[76] All the major minerals found in granites have been experimentally grown over laboratory timescales,[77] so macroscopic igneous minerals can crystallize and grow rapidly to requisite size from a granitic melt.[78] So how long then does it take to form the plagioclase feldspar crystals in a particular granite? Linear crystal growth rates of quartz and feldspars have been experimentally measured, and rates of $10^{-6.5}$ m per second to $10^{-11.5}$ m per second seem typical. This means that a 5-mm-long crystal of plagioclase could have grown in as short a time as one hour, but probably no more than 25 years.[79] Actually, extraneous geologic factors, not potential rate of mineral growth, constrain the sizes of crystals attained in igneous bodies.[80] Indeed, it has been demonstrated that the rate of nucleation is the most important factor in determining growth rates and eventual sizes of crystals.[81] Thus, the huge crystals (meters long) sometimes found in granitic pegmatites have grown rapidly at rates of more than 10^{-6} cm per second, from fluids saturated with the components of those minerals within a few years.[82]

Crystallization and Cooling Rates: The Evidence of Polonium Radiohalos

There is a feature in granites that severely restricts the timescale for their

76 W. C. Luth, 1976, Granitic rocks, in *The Evolution of the Crystalline Rocks*, D. K. Bailey and R. McDonald, eds., London: Academic Press, 333-417 (405-411); J. M. Wampler and P. Wallace, 1998, Misconceptions of crystal growth and cooling rates in formation of igneous rocks: The case of pegmatites and aplites, *Journal of Geological Education*, 46: 497-499.

77 R. H. Jahns and C. W. Burnham, 1958, Experimental studies of pegmatite genesis: Melting and crystallization of granite and pegmatite, *United States Geological Survey Bulletin*, 69: 1592-1593; H. G. F. Winkler and H. Von Platen, 1958, Experimentelle gesteinmetmorphose—II. Bildung von Anatektischen Granitischen Schmelzen bie der Metamorphose von NaCl—führenden Kalkfreien Toten, *Geochimica et Cosomochimica Acta*, 15: 91-112; D. A. Mustart, 1969, Hydrothermal synthesis of large single crystals of albite and potassium feldspar, *EOS, Transactions of the American Geophysical Union*, 50: 675; S. E. Swanson, J.A. Whitney and W. C. Luth, 1972, Growth of large quartz and feldspar crystals from synthetic granitic liquids, *EOS, Transactions of the American Geophysical Union*, 53: 1172.

78 S. E. Swanson, 1977, Relation of nucleation and crystal-growth rate to the development of granitic textures, *American Mineralogist*, 62: 966-978; S. E. Swanson and P. M. Fenn, 1986, Quartz crystallization in igneous rock, *American Mineralogist*, 71: 331-342.

79 Clemens, 2005.

80 P. D. Marsh, 1989, Convective style and vigour in magma chambers, *Journal of Petrology*, 30: 479-530.

81 G. Lofgren, 1980, Experimental studies on the dynamic crystallization of silicate melts, in *Physics of Magmatic Processes*, R. B. Hargreaves, ed., Princeton, New Jersey: Princeton University Press: 487-551; A. Tsuchiyama, 1983, Crystallization kinetics in the system $CaMgSi_2O_6$-$CaAl_2Si_2O_8$: The delay in nucleation of diopside and anorthite, *American Mineralogist*, 68: 687-698.

82 D. London, 1992, The application of experimental petrology to the genesis and crystallization of granitic pegmatites, *Canadian Mineralogist*, 30: 499-540.

emplacement, crystallization, and cooling to just days or weeks at most—polonium radiohalos.[83] Radiohalos are minute spherical (circular in cross-section) zones of darkening due to radioisotope decay in tiny central mineral inclusions within the host minerals (refer back to chapter 111).[84] They are generally prolific in granites, particularly where *biotite* (black mica) flakes contain tiny zircon inclusions that contain uranium. As the uranium in the zircon grains radioactively decays through numerous daughter elements to stable lead, the α-radiations from eight of the decay steps produce characteristic darkened rings to form uranium radiohalos around the zircon radiocenters. Also present adjacent to these uranium radiohalos in many biotite flakes are distinctive radiohalos formed only from the three polonium radioisotopes in the uranium decay chain. Because they have been parented only by polonium they are known as polonium radiohalos.

The significance of these polonium radiohalos in granites is that they had to form exceedingly rapidly, because the half-lives (decay rates) of these three polonium radioisotopes are very short—3.1 minutes (polonium-218), 164 microseconds (polonium-214), and 138 days (polonium-210). Furthermore, each visible radiohalo requires the decay of at least 500 million parent radioisotope atoms to form them, which in the case of uranium radiohalos, at the current rate of uranium decay is the equivalent of up 100 million years worth of radioactive decay.[85] Zircons at the centers of the uranium radiohalos adjacent to polonium radiohalos are the only nearby source of polonium (from decay of the same uranium that produces the uranium radiohalos). The hydrothermal fluids released by the crystallization and cooling of the granites is able to flow between the sheets making up biotite flakes, and because of their chemistry are able to transport the polonium from the zircons to the adjacent concentrating sites only microns distant, that then become the radiocenters which produce the polonium radiohalos.[86] Furthermore, all the radiohalos can only form after the granites have crystallized and cooled below 150°C, the annealing temperature of the radiohalos,[87] which is very late in the granite cooling process, when all the minerals have crystallized and the hydrothermal fluids have been generated to remove heat from the cooling plutons by convection. Yet uranium decay in the zircons and hydrothermal transport

83 A. A. Snelling and M. H. Armitage, 2003, Radiohalos—A tale of three plutons, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey Jr., ed., Pittsburgh, PA: Creation Science Fellowship: 243-267; A. A. Snelling, 2005, Radiohalos in granites: Evidence for accelerated nuclear decay, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society: 101-207.

84 R. V. Gentry, 1973, Radioactive halos, *Annual Review of Nuclear Science*, 23: 342-362; A. A. Snelling, 2000, Radiohalos, in *Radioisotopes and the Age of the Earth: A Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 381-468.

85 Gentry, 1973; Snelling, 2000.

86 Snelling and Armitage, 2003; Snelling, 2005.

87 R. Laney and A. W. Laughlin, 1981, Natural annealing of pleochroic haloes in biotite samples from deep drill holes, Fenton Hill, New Mexico, *Geophysical Research Letters*, 8(5): 501-504.

of daughter polonium isotopes starts much earlier when the granites are still crystallizing and then cooling respectively. Nevertheless, because of the very short half-lives of these three polonium radioisotopes, the hydrothermal fluid transport of the polonium to generate the polonium radiohalos had to be extremely rapid, within hours to a few days. Furthermore, if too much of the uranium and polonium had decayed away while the granite was crystallizing and cooling below 150°C when the radiohalos could start forming, then the required large quantities of polonium would have decayed before they could form the polonium radiohalos.[88] Thus it is estimated that the granites also need to have crystallized and cooled within six to ten days. Such a timescale for the crystallization and cooling of granite plutons, along with the generation of them and emplacement of the granite magmas as already discussed, is certainly compatible with the biblical timescales for the global Flood event and for earth history. Any claims that radioisotope dating has "proven" granite formation, intrusion, and cooling must have instead taken millions of years are totally contradicted by the evidence for accelerated nuclear decay that renders radioisotope "dating" completely unreliable.[89]

88 Snelling and Armitage, 2003; Snelling, 2005; A. A. Snelling, 2008, Radiohalos in the Shap Granite, Lake District, England: Evidence that removes objections to Flood geology, in *Proceedings of the Sixth International Conference on Creationism*, A. A. Snelling ed., Pittsburgh, PA: Creation Science Fellowship, and Dallas, TX: Institute for Creation Research: 389-405; A. A. Snelling and D. Gates, 2009, Implications of polonium radiohalos in nested plutons of the Tuolumne Intrusive Suite, Yosemite, California, *Answers Research Journal*, 2: 53-77.

89 L. Vardiman et al, 2005; A. A. Snelling, 2008, Catastrophic granite formation: Rapid melting of source rocks, and rapid magma intrusion and cooling, *Answers Research Journal*, 1: 11-25.

124

Regional Metamorphism

Metamorphic rocks, the third class of the earth's crustal rocks after sedimentary and igneous rocks, constitute a major portion of the earth's crust.

> Much of the earth's surface is immediately underlain by vast tracks of crystalline metamorphic rock. Much of the exposed rock of the eastern two-thirds of Canada consists of metamorphic rocks. The Blue Ridge Mountains of the southern Appalachians, the southern Piedmont, virtually all of New England, New York's Manhattan Island, and nearly the entire area between Philadelphia and Washington, D.C., consist of metamorphic rock. So do large areas of the mountainous western parts of the United States and Canada. Metamorphic rocks also are widely exposed in other parts of the world such as Australia, Scandinavia, Siberia, and India.[1]

There are two major types of metamorphism—contact and regional. Contact metamorphism is basically the baking of rocks around intruding and cooling magmas, and thus primarily involves elevated temperatures. Given it has now been demonstrated granitic plutons are intruded rapidly, and it can be shown that the magmas crystallize and cool rapidly, with hydrothermal convective flows carrying heat out into the wall-rocks, contact metamorphism must likewise occur rapidly, and is thus explainable within the biblical timescales for the Flood cataclysm and the young earth.

However, in regional metamorphism it is conventionally believed that the sedimentary strata over areas of hundreds of square kilometers were subjected to high temperatures and pressures due to deep burial and deformation/tectonic forces, processes operating over millions of years. The resultant mineralogical and textural transformations are said to be due to mineral reactions in the original sediments under the prevailing temperature-pressure conditions of this regional metamorphism. The catastrophic rate of sedimentation during the Flood would

1 D. A. Young, 1977, *Creation and the Flood: An Alternative to Flood Geology and Theistic Evolution*, Grand Rapids, MI: Baker Book House, 193-194.

deeply bury some sedimentary strata in only a matter of weeks or months, producing the necessary pressure increases needed for metamorphism of the sediments, but uniformitarian geologists argue that it takes many millions of years to heat sediments buried 20 kilometers beneath the earth's surface to the required temperatures for metamorphism.

A good example is the metamorphic terrain of New England, where the original sedimentary character of many of these rocks is, apart from differences from various compositional, textural, and structural characteristics, firmly established by the discovery in places of several fossils within these metamorphic rocks.[2] Thus, because of these contained fossils, it would be argued that the original sediments from which these metamorphic rocks developed were deposited during the Flood year. However, to the south, these metamorphic rocks are unconformably overlain by unmetamorphosed fossiliferous sedimentary rocks, so it is necessary to conclude that the New England metamorphic rocks had to have been metamorphosed within the Flood year. Furthermore, since it has been possible to experimentally determine the ranges of stability of almost all important metamorphic minerals, in terms of pressure and temperature, and the pressure and temperature at which many important metamorphic mineral reactions may occur, it can be concluded that the mineral assemblages of the New England metamorphic rocks indicate that many of the precursor sedimentary and volcanic rocks must have been subjected to temperatures approaching 600°C and pressures of 5 kilobars.[3] Such conditions are interpreted as implying that the sediments were buried under a load of strata 16-19 km thick. Thus, within the Flood year, the precursor sedimentary strata of these New England metamorphic rocks had to have been deposited rapidly, then progressively buried to a depth of between 16 and 19 km, in turn to be progressively metamorphosed as the temperatures rose to around 600°C, before being uplifted and then eroded to eventually be exposed as metamorphic rocks at today's earth surface.

Like other terrains of regionally metamorphosed rocks in other parts of the world, the New England area has been carefully mapped, and the rocks divided into metamorphic zones and facies according to the mineral assemblages that are confined to each zone and confined to it within each facies respectively. It is assumed that these mineral assemblages reflect the metamorphic transformation conditions specific to each zone, so that by traversing across these metamorphic zones, from the chlorite zone through the biotite zone, garnet zone, staurolite zone, and sillimanite zone to the K-feldspar zone in pelitic rocks (for example),

---

2 A. J. Boucot, G. J. F. MacDonald, C. Milton and J. B. Thompson, 1958, Metamorphosed middle Paleozoic fossils from central Massachusetts, eastern Vermont, and western New Hampshire, *Geological Society of America Bulletin*, 69: 855-870; A. J. Boucot, and J. B. Thompson, 1963, Metamorphosed Silurian brachiopods from New Hampshire, *Geological Society of America Bulletin*, 74: 1313-1334.

3 J. B. Thompson and S. A. Norton, 1968, Paleozoic regional metamorphism in New England and adjacent area, in *Studies of Appalachian Geology: Northern and Maritime*, E-an Zen, W. S. White, J. B. Hadley and J. B. Thompson, eds., New York: Wiley Interscience Publishers, 319-327.

higher metamorphic grades (due to former higher temperature-pressure conditions) are progressively encountered, from low to high grade respectively. Among the metamorphic mineral assemblages diagnostic of each zone are certain minerals whose presence in the rocks is indicative of each zone, and these are called index minerals, which are thus used to name each zone. It is envisaged that the mineral assemblages in these zones and facies are the result of mineral reactions, whereby the temperature and pressure conditions, along with active components like water, have induced the minerals in the original rocks to react and form new minerals. Thus, for example, at the boundary between the biotite and garnet zones in typical pelitic rocks is the first appearance of garnet according to the reaction:

chlorite+muscovite+quartz = garnet+biotite+water

Such reactions vary according to which minerals are available to react with one another in the original rocks, according to their bulk compositions. Considerable effort has therefore been expended to elucidate all possible reactions between minerals in the almost limitless potential variations in original bulk compositions.

Although there have been some doubts expressed, it is widely accepted among geologists that the achievement of chemical equilibrium in regional metamorphism is the rule rather than the exception. Metamorphic petrology today is based on the assumption that chemical equilibrium is virtually always attained, and hence that mineral assemblages can be evaluated in the context of the Phase Rule.[4] It also appears to be generally accepted that diffusion occurs over distances large enough to permit mineral reactions to occur through large volumes of rock, and that with rise in temperature and pressure, such reactions occur in progressive fashion, so that any particular set of pressure-temperature conditions manifest itself through the development, in rocks of like chemical composition, of a particular set of metamorphic minerals. In this way, grades of metamorphism and metamorphic gradients in zones are identified, and metamorphic rocks of different compositions are linked with the facies principle. The issue of regional metamorphism is now so well established, that it constitutes an essentially unquestioned basis for some very highly refined studies of relationships between mineral chemistry and metamorphic grade.

However, more precise studies, on the scale of the microscope and the electron microprobe, are beginning to place severe limits on the distances involved in metamorphic diffusion, which in turn sets critical limits to the extent to which minerals may react, so that metamorphic equilibrium is obtained. From some of the earliest observations of the delicate preservation of bedding in some metamorphosed strata, it was concluded that "the mineral formed at any point

4 K. Bucher and M. Frey, 2002, *Petrogenesis of Metamorphic Rocks*, seventh edition, Berlin: Spring-Verlag; M. B. Best, 2003, *Igneous and Metamorphic Petrology*, second edition, Malden, MA: Blackwell Publishing.

depends on the chemical composition of the rock mass within a certain very small distance around that point."[5] Diffusion distances were thus estimated to be probably of the order of 1 mm.[6] Recently, it has been observed that what little evidence there is seems to indicate that metamorphic diffusion is probably effective at most over distances measured in only centimeters, conventionally over times of the order of millions of years.[7] In contrast, another recent estimation of the diffusion limits is of the order of 0.2 to 4.0 mm.[8] Opinion probably remains diverse, though the view of many modern investigators is:

> There are many indications that rocks constitute a "closed" thermodynamic system during the short time required for metamorphic crystallization. The transport of material is generally limited to distances similar to the size of newly formed crystals. It has been observed frequently that minute chemical differences of former sediments are preserved during metamorphism. Metamorphism is essentially an *isochemical* process.[9]

Thus, it can be argued that the chemical components of a metamorphic grain, now occupying the given domain, are derived directly from those chemical components occupying that domain immediately prior to the onset of metamorphism, so that metamorphic mineral must represent the *in situ* growth and/or transformation of a pre-metamorphic material of similar overall composition, or it must be one or two or more products of the *in situ* breakdown of pre-metamorphic material of appropriate composition. The development of metamorphic minerals would thus stem from simple grain growth, ordering of randomly-disposed structures, and solid-solid transformations, not from "mineral reactions" as these are currently visualized. Clear evidence under the microscope of mineral reactions in rocks, as distinct from solid-solid transformations, is usually very hard to find, even where minerals that might be expected to react lie in contact. It is therefore significant that none of the major metamorphic petrology textbooks of recent years show a single photograph illustrating the destruction of one mineral and the simultaneous development of another.[10] This almost general absence of direct evidence of mineral reactions has led some observers to suggest that metamorphic

---

5 A. Harker, 1893, On the migration of material during the metamorphism of rock-masses, *Journal of Geology*, 1: 574-578.

6 A. Harker and J. E. Marr, 1893, Supplementary notes on the metamorphic rocks around the Shap Granite, *Quarterly Journal of the Geological Society of London*, 49: 359-371.

7 F. J. Turner and J. Verhoogen, 1960, *Igneous and Metamorphic Petrology*, second edition, New York: McGraw-Hill Book Company.

8 D. M. Carmichael, 1969, On the mechanism of prograde metamorphic reactions in quartz-bearing pelitic rocks, *Contributions to Mineralogy and Petrology*, 20: 244-267.

9 H. G. F. Winkler, 1979, *Petrogenesis of Metamorphic Rocks*, fifth edition, New York: Springer-Verlag, 16 (emphasis in original).

10 S. J. Turner, 1968, *Metamorphic Petrology: Mineralogical and Field Aspects*, New York: McGraw-Hill Book Company; A. Miyashiro, 1973, *Metamorphism and Metamorphic Belts*, London: George Allen and Unwin; Winkler, 1979.

rocks may attain their mineral assemblages directly, rather than by a series of mineral reactions, hence without passing through each successive grade.[11]

Coupled with the doubts concerning the reality of many postulated reactions are doubts on equilibrium. Preservation of zoning in garnets, for example, indicates that even at high grades of metamorphism, equilibrium may remain unattained even in a single crystal. Evidence of the preservation of compositional inhomogeneities in other minerals, including sulfides,[12] is now mounting, indicating that compositional equilibrium may not have been attained even in the most sensitive crystal structures, and even where these have been subjected to the highest grades of metamorphism.

The unique opportunity to study the results of metamorphic processes over small scales is provided by conformable or stratiform sulfide ore deposits in sedimentary and metasedimentary strata. The sulfide ore minerals have the appearance of being an integral, and hence normal, component of the sedimentary or metasedimentary rocks in which they occur, being simply grains within a granular rock. The orebodies are usually lens-shaped and grossly elongated, with their long dimensions parallel to the stratification of the enclosing rocks. They themselves commonly display good internal bedding, which may usually be demonstrated to be continuous with that of the enclosing pelitic sediments. Many stratiform ore deposits contain, and are immediately ensheathed by, metamorphosed pelitic rocks displaying distinctive metamorphic mineral assemblages. It is now generally accepted that the sulfide minerals of these ores were laid down as fine chemical precipitates as part of the original sediments themselves, as found and observed where modern-day analogues are forming on the sea floor associated with hydrothermal springs.[13] These sulfide ores are thus intrinsic parts of the rocks in which they occur, so the metamorphic mineral assemblages within and surrounding the ores must result from the metamorphism of the sedimentary materials laid down with, and adjacent to, the sulfide precipitates. Thus. they are genuine metamorphic rocks, and they therefore have been used in a landmark series of studies[14] of metamorphic phenomena in metamorphosed pelitic rocks

11 H. S. Yoder, 1952, The $MgO-Al_2O_3-SiO_2-H_2O$ system and related metamorphic facies, *American Journal of Science*, Bowen Volume: 569-627; H. S. Yoder, 1955, The role of water in metamorphism, *Geological Society of America Special Paper 62*: 505-524; M. P. Atherton, 1965, The chemical significance of isograds, in *Controls of Metamorphism*, W. S. Pitcher and G. W. Flinn, eds., Edinburgh and London: Oliver and Boyd, 169-202.

12 S. D. Scott, R. A. Both and S. A. Kissin, 1977, Sulfide petrology at Broken Hill, New South Wales, *Economic Geology*, 72: 1410-1425.

13 P. F. Lonsdale, J. L. Bischoff, V. M. Burns, M. Kastner and R. E. Sweeney, 1980, A high-temperature hydrothermal deposit on the seabed at a Gulf of California spreading center, *Earth and Planetary Science Letters*, 49: 8-20; P. A. Rona, 1986, Mineral deposits from sea-floor hot springs, *Scientific American*, 254(1): 66-74; J. B. Alt and W. -T. Jiang, 1991, Hydrothermally precipitated mixed-layer illite-smectite in recent massive sulfide deposits from the seafloor, *Geology*, 19: 570-573.

14 R. L. Stanton, 1982, An alternative to the Barrovian interpretation? Evidence from stratiform ores, *Proceedings of the Australasian Institute of Mining and Metallurgy*, 282: 11-32; R. L. Stanton, 1989, On the potential significance of "chemical" materials in the elucidation of regional metamorphic processes,

that not only question the conventional explanation for regional metamorphism, but provide an alternative explanation requiring only moderate temperatures on short timescales, commensurate with the biblical framework for earth history.[15]

Studying the assemblages of mineral species and their compositional variations in these metasedimentary sheets around the stratiform sulfide orebodies shows that original sedimentary features, even at the finest scale (1 mm or less), have been preserved through claimed millions of years, and the supposed highest grades of metamorphism of pelitic rocks. Metamorphic diffusion was concluded to have been confined, at least in some cases, to distances of a small fraction of a millimeter. For example, garnet crystals varied significantly in composition between and within one another, even within the same strata on a scale of 1mm or less, the observed finely layered compositional arrangement being a direct reflection of the original sedimentary bedding preserved through a proposed period claimed to be at least 1.8 billion years, and through a very high grade metamorphic episode.[16] Even within single crystals, the presence of these substantial compositional inhomogeneities indicates very little diffusion at all.[17]

Furthermore, microscopic evidence of metamorphic reactions is usually poor and ambiguous, or absent, whereas it will be conventionally expected to be present.[18] Given that some stratiform ore zones possess a very wide range of high grade metamorphic minerals within volumes of only a few cubic centimeters, it might have been expected that evidence of such reactions would be found here, even if they could not be found in other metamorphic rocks. The inference is that metamorphic mineral reactions, as they are conventionally visualized, are unlikely

in *Pathways in Geology: Essays in Honour of Edwin Sherbon Hills*, R. W. LeMaitre, ed., Melbourne, Australia: Blackwell Scientific Publications, 425-438; R. L. Stanton, 1989, The precursor principle and the possible significance of stratiform ores and related chemical sediments in the elucidation of processes of regional metamorphic mineral formation, *Philosophical Transactions of the Royal Society of London*, A328: 529-646.

15 A. A. Snelling, 1994, Towards a creationist explanation of regional metamorphism, *Creation Ex Nihilo Technical Journal*, 8 (1): 51-77.

16 R. L. Stanton and J. P. Vaughan, 1979, Facies of ore formation: A preliminary account of the Pegmont deposit as an example of potential relations between small 'iron formations' and stratiform sulphides ores, *Proceedings of the Australasian Institute of Mining and Metallurgy*, 270: 25-38; J. P. Vaughan and R. L. Stanton, 1986, Sedimentary and metamorphic factors in the development of the Pegmont stratiform Pb-Zn deposit, Queensland, Australia, *Transactions of the Institution of Mining and Metallurgy*, 95: B94-B121; R. L. Stanton and K. L. Williams, 1978, Garnet compositions at Broken Hill, New South Wales as indicators of metamorphic processes, *Journal of Petrology*, 19: 514-529; A. A. Snelling, 1994, Regional metamorphism within a creationist framework: What garnet compositions reveal, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 485-496.

17 R. L. Stanton, 1982, Metamorphism of a stratiform sulphide ore body at Mount Misery, Queensland, Australia: 1—Observations, *Transactions of the Institution of Mining and Metallurgy*, 91: B47-B71; R. L. Stanton, 1982, Metamorphism of a stratiform sulphide ore body at Mount Misery, Queensland, Australia: 2—Implications, *Transactions of the Institution of Mining and Metallurgy*, 91: B72-B80.

18 R. L. Stanton, 1976, Petrochemical studies of the ore environment at Broken Hill, New South Wales: 2—Regional metamorphism of banded iron formations and their immediate associates, *Transactions of the Institution of Mining and Metallurgy*, 85: B118-B131; Stanton, 1982.

to have been a significant factor in the development of these particular extensive metamorphic mineral assemblages. Indeed, the whole spectrum of metamorphic index minerals may occur within centimeters of each other, indicating either that metamorphic mineral equilibrium is not established even over very small distances, but some factor other than, or additional to, temperature and pressure is responsible for the development of these minerals. If, in fact, the supposed long periods of presumed millions of years available for these metamorphic processes had indeed occurred, chemical equilibrium should have been attained, whereas this lack of chemical/metamorphic equilibrium raises crucial questions about the timescales involved.

This lack of metamorphic equilibrium, even on the scale of centimeters, in metamorphic rocks generally has been noted by numerous investigators.[19] However, the most striking evidence of this apparent lack of metamorphic equilibrium is provided by the total assemblages of the ore zones of sulfide deposits in metasedimentary rocks.[20] Each of the metamorphic mineral assemblages in these ore zones is extensive, and covers the whole spectrum of metamorphic index minerals of all the presumed zones of progressive regional metamorphism. Yet each assemblage is contained within what is, compared to the regional scale of the classic metamorphic zones, an almost infinitesimally small volume of rock over distances from 3-20 meters, and even in some cases, within a single rock thin microscope section. Total volumes of rocks concerned are far too small to have sustained differences in temperature, pressure, or partial pressures of volatiles, even over any significant period of time. Thus, the huge array of metamorphic minerals displayed must affect variations in the compositions of the parent shales, and of variations in temperature and pressure.

If, as this evidence suggests, metamorphic minerals may represent essentially *in situ* transformations of earlier sedimentary-diagenetic materials, then what might have been these precursor materials? A number of possibilities are well recognized.[21]

19 B. E. Tilley, 1925, Petrographic notes on some chloritoid rocks, *Geological Magazine*, 42: 309-318, M. P. Atherton, 1968, The variation in garnet, biotite and chlorite composition in medium grade pelitic rocks from the Dalradian, Scotland with particular reference to the zonation of garnet, *Contributions to Mineralogy and Petrology*, 18: 347-371; W. H. Blackburn, 1968, The spatial extent of chemical equilibrium in some high-grade metamorphic rocks from the Granville of southeastern Ontario, *Contributions to Mineralogy and Petrology*, 19: 72-92; W. C. Phinney, 1963, Phase equilibria in the rocks of St. Paul Island and Cape North, Nova Scotia, *Journal of Petrology*, 4: 90-130; A. F. Hagner, S. Leung and J. M. Dennison, 1965, Optical and chemical variations in minerals from a single rock specimen, *American Mineralogist*, 50: 341-355; R. Kretz, 1966, Metamorphic differentiation at Einasleigh, northern Queensland, *Journal of the Geological Society of Australia*, 13: 561-582; A. L. Albee, A. A. Chodes and L. S. Hollister, 1966, Equilibration volumes for different species in three assemblages of kyanite-zone schists, Lincoln Mountain, Vermont, *Abstracts of the American Geophysical Union Transactions*, 47: 213; J. R. Ashworth, 1975, Staurolite at anomalously high grade, *Contributions to Mineralogy and Petrology*, 53: 281-291.

20 Stanton, 1989.

21 R. L. Stanton and W. P. H. Roberts, 1978, The composition of garnets at Broken Hill, and their relevance to the origin of the lode, *Journal de Mineralogica Recife*, 7: 143-154; M. Osada, and T. Sudo,

Numerous examples of minerals found in metamorphic rocks, that have been, or can be, produced from simple or complex precursors of near identical compositions, and even at low temperatures, have been provided.[22] Consequently, the development of a particular metamorphic mineral assemblage can thus be seen to have devolved from constitutional features in the wider sense, that is, not only from simple bulk chemistry, but from this in combination with the detailed features of the precursor crystal structure, or mixtures of structures. Indeed, the nature of such structures, and particularly of the mixed layering of clays-chlorites-Al/Fe oxides/hydroxides-zeolites, and of the admixture of these with amorphous silica and silica/alumina gels, is likely to be just as important as, or even more important than, bulk composition in the development of a particular metamorphic mineral.

Therefore, these stratiform ores and their metamorphic assemblages reflect original sedimentation in sea floor hydrothermal environments mixing with "normal" marine sedimentation, the clay and other minerals in the sediments being the precursors to the metamorphic assemblages now present. The waters of mineral-bearing hot springs on the sea floor are often in areas of volcanic activity, and the relatively high temperature, acidic hydrothermal waters contrast with the cold, slightly alkaline ocean water that they mix with. As well as iron, calcium, and other metal compounds, the hot spring waters usually contain substantial quantities of silica, alumina, and silica-alumina gels, the basic materials of the clay minerals, and due to their acidic nature cause the variable breakdown of detrital feldspars and other minerals to a variety of clays within the surrounding sea floor sediments. This leads to accumulations of sediments, not only of highly varying chemical composition, but also containing a wide variety of clay and associated chemicals/detrital minerals over very short distances and thicknesses of sediments.

These relatively small-scale sedimentary environments of stratiform ores thus indicate that the larger-scale regional metamorphic zones in pelitic rocks could have stemmed in many cases from semi-regional variations in clay and related mineral assemblages, consequent upon the variations in the nature and conditions of sedimentation. Indeed, the tendency of the clay and related layered silicate minerals to develop zonal patterns of distribution during shallow marine sedimentation is well established.[23] In the sediments of Monterey Bay,

---

Mineralogical study on the clay rich in chlorite associated with the gypsum deposit of the Owami Mine, Shimane Prefecture, *Clay Science*, 1: 29-40; P. R. Segnit, 1961, Petrology of the zinc lode, New Broken Hill Consolidated Ltd, Broken Hill, New South Wales, *Proceedings of the Australasian Institute of Mining and Metallurgy*, 199: 87-112, R. L. Stanton, 1983, The direct derivation of sillimanite from a kaolinitic precursor: Evidence from the Geco Mine, Manitouwadge, Ontario, *Economic Geology*, 78: 422-437.

22 Stanton, 1989.

23 P. W. Smoot, 1960, Clay mineralogy of some pre-Pennsylvanian sandstones in shales of the Illinois Basin, Part III—Clay minerals of the various facies in some Chester Formations, *Illinois State Geological Survey*, 293: 1-19; G. Millot, 1970, *Geology of Clays*, London: Chapman and Hall; A. Hallam, 1966, Depositional environment of British Liassic ironstones considered in the context of their facies relationship, *Nature*, 209: 1306-1309; S. P. Ellison, 1955, Economic applications of palaeoecology,

California, biotite-rich sandy sediments have been laid down in nearshore zones, and glauconite muds have been deposited further out to sea.[24] Deposition and current action in the Gulf of Mexico have produced an orderly distribution of different clay species, and therefore a gradational pattern of different clay minerals parallel to the coastline.[25] Similarly, iron-rich minerals in the modern sediments of the Niger delta of West Africa display a clear zoning of goethite, chamosite, and glauconite parallel to the shoreline,[26] which is significant, because it is these other two minerals that are the possible precursors to garnet and biotite, respectively. Furthermore, along the South American continental shelf, receiving sediments from the Amazon River, a clear zoning of clay minerals developed both along and across the shelf has been found, which has been attributed quite simply to sorting by size.[27]

Thus, extension of this precursor principle from the sea floor hydrothermal sedimentation environments, that produced stratiform sulfide ores and their metamorphic assemblages to wider zones of sedimentation, reveals that both in present-day marine shelf environments and in the depositional environments reflected in a number of ancient sedimentary basins, there are wide zones of pelitic sediments containing different clay and related mineral assemblages, such that if these metamorphosed they would result in metamorphic mineral assemblages that would mimic the zones of regional metamorphism with their characteristic index minerals (Figure 74, page 1102).[28] On this basis, the regional metamorphic zones in pelitic rocks may simply reflect subtle variations in the clay mineral assemblages when the precursor sedimentary rocks were deposited.[29]

The evidence of some stratiform ore environments, therefore, indicates that even within a restricted and relatively uniform group of rocks such as the pelites, there may be sufficient constitutional variation to induce the development of a wide range of metamorphic minerals, indeed, virtually all of the metamorphic minerals known, at a given temperature and pressure. This is precisely the conclusion reached from experimental evidence, which showed that for the same temperature

---

Economic Geology, 50th Anniversary Volume: 867-884; R. Schoen, 1964, Clay minerals of the Silurian Clinton ironstones, New York State, *Journal of Sedimentary Petrology*, 34: 855-863; C. V. Jeans, 1978, The origin of the Triassic clay assemblages of Europe with special reference Kueper Marl and Rhaetic of parts of England, *Philosophical Transactions of the Royal Society of London*, A289: 549-639.

24 E. W. Galliher, 1935, Geology of glauconite, *Bulletin of the American Association of Petroleum Geologists*, 19: 1569-1601.

25 G. M. Griffen, 1962, Regional clay-mineral facies—Products of weathering intensity and current distribution in the north-eastern Gulf of Mexico, *Geological Society of America Bulletin*, 73, 737-768.

26 D. H. Porringa, 1967, Glauconite and chamosite as depth indicators in the marine environment, *Marine Geology*, 5: 495-501.

27 R. J. Gibbs, 1977, Clay mineral segregation in a marine environment, *Journal of Sedimentary Petrology*, 47: 237-243.

28 Stanton, 1982; Snelling, 1994.

29 Stanton and Vaughan, 1979.

and pressure it is possible to have assemblages within a restricted compositional system corresponding to every one of the accepted minerals of the metamorphic facies in stable equilibrium.[30] The same experiments showed that changes in a few percent in composition (including water) may produce great differences in mineralogy, and that the mineralogical differences interpreted as resulting from changes in temperature-pressure conditions[31] might actually be for the most part due to subtle changes in bulk composition.

Furthermore, it has been demonstrated that these transformations of precursor minerals/materials into metamorphic mineral assemblages can occur at low to moderate temperatures. Some of these metamorphic minerals have been found with remnants of their low-temperature precursor materials alongside, the two co-existing in rocks that are supposed to have experienced the highest grade of metamorphism.[32] The most extreme example, the presence of distinctly hydrous "quartz" in high-grade metamorphic rocks, even after 1.8 billion years and such metamorphism,[33] can only mean that temperatures were low to moderate and the timescale was very short. Yet it has been insisted that this distinctly hydrous "quartz" was originally chemically-deposited silica gel, that with diagenesis and aging dehydrated and transformed *in situ* to quartz at low temperatures.

Thus, it is feasible to conclude that the conventional zones of regional metamorphism represent zonal patterns of the original sedimentation, and that the precursor clay and associated minerals have undergone transformation to metamorphic mineral assemblages at low to moderate temperatures and pressures. Furthermore, this implies that the depths of burial required were considerably less, and consequently the timescales as well. The problem of the elusive metamorphic reactions in the natural *milieu* is thus resolved. Preservation of what appear to be disequilibrium concentration gradients and mineral assemblages follows naturally, if the materials formed at low temperatures and pressures, particularly in wet sedimentary and sedimentary-hydrothermal depositional regimes, simply undergo early water loss followed by *in situ* solid-solid transformation with rising temperatures and pressures. Puzzled conventional speculation that some metamorphic rocks might attain their mineral assemblages directly, rather than through a series of mineral reactions, hence without passing through each successive grade, appears to be answered.

It is conceivable that regional metamorphic terrains with their zones of "classical" index minerals could thus have been produced as a result of catastrophic sedimentation, burial, and tectonic activities over short timescales, the zones only being a reflection of variations in original sedimentation, as can be demonstrated

30 Yoder, 1952.

31 P. Eskola, 1920, The mineral facies of rocks, *Norsk Geologisk Tiddsskrift*, 6: 143-194.

32 Stanton, 1982; Stanton, 1983.

33 Stanton, 1989.

in continental shelf depositional facies today.[34]

In the biblical framework of earth history, there is more than one episode capable of producing large regions of zoned metamorphic rocks. The formation of the dry land on Day Three of the Creation Week must have involved earth movements (tectonism), volcanism, magmatism, and the release of hydrothermal fluids, erosion of the emerging land surface due to the retreating waters, and deposition of sediments in the developing ocean basins. Such sedimentation could thus have been capable of producing zones of sediment with subtle differences in bulk chemistry and mineralogy that would be precursors for accompanying or subsequent regional metamorphism. The pre-Flood continental shelves and ocean basins would have continued to accumulate a variety of sediments with zonal patterns of different clay and other minerals, accompanied by sea floor hydrothermal activity associated with "the fountains of the great deep."[35]

At the outset of the Flood these pre-Flood zoned sediments would have experienced rapid burial and heat released as renewed volcanic and magmatic activity occurred sufficient to induce precursor transformations in those regional zones that would mimic conventional grades. The Flood event itself provided the greatest scope for regional metamorphism. Catastrophic sedimentation, deep burial of large volumes of fossil-bearing strata, vast outpourings of lavas on a global scale, ensuring the release of copious amounts of hydrothermal waters during sedimentation and interbedded volcanics, massive repeated intrusive magmatism, and the rapid deformation of catastrophic plate tectonics, would have ensured both elevated temperatures and pressures in thick sediment piles, as well as the potential for repeated cycles of sedimentation, metamorphism, and erosion in regions that overlapped as this catastrophic activity shifted geographically.[36] Add to this rapid plate movements with thermal runaway subduction, catastrophic rifting, and continent-continent collisions, as per conventional plate tectonics but during the year-long Flood, and various settings required for regional metamorphism are amply provided.

The range of induced pressures would have been short-lived, and the timescales would have only allowed for moderate temperatures to be reached. However, composition is the primary factor in regional metamorphism, and the zoning of index minerals found across regionally metamorphosed terrains is dependent

34 Snelling, 1994.

35 K. P. Wise, 2003, The hydrothermal biome: A pre-Flood environment, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 359-370.

36 D. J. Tyler, 1990, A tectonically-controlled rock cycle, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 293-301; S. A. Austin, J. R. Baumgardner, D. R. Humphreys, A. A. Snelling, L. Vardiman and K. P. Wise, 1994, Catastrophic plate tectonics: A global Flood model for earth history, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 609-621.

on the presence and compositions of precursor minerals. Sedimentary strata would not need to have been buried as deeply to reach the moderate temperatures needed for transformations of precursor minerals, due to catastrophic sediment accumulation and the increased heat flow from the mantle because of catastrophic plate tectonics. The waters trapped in the Flood sediments would have been warmer than waters being trapped in sediments today, so pore and hydrothermal fluids would have been another important factor in facilitating rapid regional metamorphism. Catastrophic erosion caused by the retreating Flood waters would also have exhumed these regionally metamorphosed rocks to expose them and their zones at the earth's surface today.

Because hydrothermal fluids are generated in water-saturated sedimentary rocks as they become deeply buried, helping to transform them into regional metamorphic complexes, it was predicted that such hydrothermal fluid transport through metamorphic minerals, containing inclusions of minerals such as zircons, would transport polonium from uranium decay in them to generate adjacent polonium radiohalos. This prediction has been vindicated with the discovery of plentiful polonium radiohalos in regionally metamorphosed rocks.[37] In further research, a test of this hydrothermal fluid transport model for polonium radiohalo formation was proposed in metamorphosed sandstones of the upper Precambrian Great Smoky Group near the Tennessee-North Carolina border. These regionally metamorphosed sandstones contain biotite flakes with zircon inclusions throughout, from the biotite zone through the garnet, staurolite and kyanite zones.[38] Furthermore, at the boundary between the garnet and staurolite zones, mineral transformations are supposed to occur that make biotite more abundant, staurolite to appear, and water to be released, which has been confirmed experimentally. It was thus predicted that, due to the presence of extra water at that boundary, samples of metamorphosed sandstones collected there would contain more polonium radiohalos.[39] This prediction was indeed confirmed in a dramatic way, there being more than five times the numbers of polonium radiohalos in samples across that boundary, than in samples from the other regional metamorphic zones. This confirms that hydrothermal fluids did indeed facilitate the formation of polonium radiohalos. Furthermore, since the polonium radiohalos have to be generated within days or a few weeks at most, this

---

37 A. A. Snelling and M. H. Armitage, 2003, Radiohalos—A tale of three granitic plutons, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 243-267; A. A. Snelling, 2005, Radiohalos in granites: Evidence for accelerated nuclear decay, in *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 101-207.

38 E. C. Allen and P. C. Ragland, 1972, Chemical and mineralogical variations during prograde metamorphism, Great Smoky Mountains, North Carolina and Tennessee, *Geological Society of America Bulletin*, 83: 1285-1298.

39 A. A. Snelling, 2005, Polonium radiohalos: The model for their formation tested and verified, *Acts & Facts*, 34 (8); A. A. Snelling, 2008, Testing the hydrothermal fluid transport model for polonium radiohalo formation: The Thunderhead Sandstone, Great Smoky Mountains, Tennessee-North Carolina, *Answers Research Journal*, 1: 53-64.

implies that these mineral transformations, which released the water to generate the polonium radiohalos, and therefore the regional metamorphism, had to have occurred within days to a few weeks.

Another confirmation for the rapid rate of metamorphism is further provided by polonium radiohalos within eclogite, a very high grade metamorphic rock, formed within shear zones by hot fluids repeatedly injected into them by earth movements.[40] Even the conventional view on the rate at which the precursor granulite in these shear zones was metamorphosed to eclogite has been radically revised.[41] Indeed, the presence of polonium radiohalos in biotite flakes within these eclogites in the shear zones confirms the rapid metamorphism of the granulite by hot fluids within weeks.[42]

Even further confirmation of rapid regional metamorphism, and melting of rocks to form granite, due to hydrothermal fluids is provided by the polonium radiohalos found in the regional metamorphic complex and its central granite at Cooma in southeastern Australia.[43] This regional metamorphic complex is regarded as a "textbook example" of the zones of increasing metamorphism resulting in partial melting of the metamorphic rocks at the highest grades in the centre of the complex to generate and intrude the granite.[44] The number of polonium radiohalos in these regionally metamorphosed rocks increase progressively from the biotite zone, through the andalusite and K-feldspar zones, but drop dramatically in the migmatite zone before increasing to their greatest numbers in the granodiorite. This is in keeping with expectations that increased quantities of hot fluids were both responsible for the progressively increasing metamorphism, and for generation of the granite. Furthermore, in the migmatite zone where partial melting occurred, the hot fluids both catalyzed the partial melting process and were "consumed" by the melt, reducing the volume of fluids

40 H. Austrheim and W. L. Griffin, 1985, Shear deformation and eclogite formation within granulite facies anorthosites of the Bergen Arcs, western Norway, *Chemical Geology*, 50: 267-281; B. Jamtveit, K. Bucher-Nurminen and H. Austrheim, 1990, Fluid controlled eclogitization of eclogites in deep crustal shear zones, Bergen Arcs, western Norway, *Contributions to Mineralogy and Petrology*, 104: 184-193; M. Bjornerud, H. Austrheim and M. G. Lund, 2002, Processes leading to eclogitization (densification) of subducted and tectonically buried crusts, *Journal of Geophysical Research*, 107(B10): 2252-2269.

41 A. Camacho, J. K. W. Lee, B. J. Hensen and J. Braun, 2005, Short-lived orogenic cycles and the eclogitization of cold crust by spasmodic hot fluids, *Nature*, 435: 1191-1196; S. Kelley, 2005, Hot fluid and cold crusts, *Nature*, 435: 1171.

42 A. A. Snelling, 2006, Confirmation of rapid metamorphism of rocks, *Acts & Facts*, 35 (2).

43 A. A. Snelling, 2008, Radiohalos in the Cooma metamorphic complex, NSW, Australia: The mode and rate of regional metamorphism, in *Proceedings of the Sixth International Conference on Creationism*, A. A. Snelling, ed., Pittsburgh, PA: Creation Science Fellowship and Dallas, TX: Institute for Creation Research, 371-387.

44 R. H. Flood and R. H. Vernon, 1978, The Cooma Granodiorite, Australia: An example of *in situ* crustal anatexis?, *Geology*, 6: 81-84; S. S. Johnson, R. H. Vernon and B. E. Hobbs, 1994, *Deformation and Metamorphism of the Cooma Complex, Southeastern Australia*, Specialist Group in Tectonics and Structural Geology Field Guide No. 4, Geological Society of Australia, Sydney; A. Hall, 1996, *Igneous Petrology*, second edition, Harlow, UK: Addison Wesley Longman.

so that the numbers of polonium radiohalos generated decreased.

These observations are totally consistent with both the hydrothermal fluid transport for the generation of polonium radiohalos, and the role of hot fluids in regional metamorphism and granite generation, both of which processes, based on the time constraints for the formation of polonium radiohalos, must have been exceedingly rapid, within weeks. Thus the rapid rate of these geological processes, contrary to conventional thinking and objections, can be accounted for within the biblical timescale for the Genesis Flood and earth history.

125

Ore and Mineral Deposits

The economies of the nations of the world, and the technological innovations of modern civilization, are not only fueled and driven by coal, oil, and gas, but are resourced by the mining and processing of ore and mineral deposits. Just as there are many geologists involved in the coal and oil industries, many geologists are employed to search for new ore and mineral deposits, and to develop and mine them. The mining and smelting of common and precious metals, as well as gems and minerals, has been part of human history, even being mentioned in the Scriptures prior to and after the Flood. Critics of the biblical timescale for the Flood and earth history have been quick to point out the paucity of treatment of this subject by those who accept the biblical timescale and that the Genesis Flood shaped the present world's geology, including the formation of ore and mineral deposits.[1]

Both the geochemical and geophysical techniques used in the search for new ore and mineral deposits do not require the application of conventional uniformitarian thinking on the formation of ore and mineral deposits, because they simply involve the collection and analysis of samples in the field and over prospects on the one hand, and instrument surveys on the other.[2] Once a decision has been made to explore in a particular area or region, then the geochemical and geophysical surveys are implemented and interpreted purely in scientific terms of observations and experiments, which are independent of the uniformitarian belief system. It is only at the earlier stage of deciding where to explore that uniformitarian ideas on the formation of ore and mineral deposits may have some bearing, but decisions are often on the basis of looking at geological maps to see what rock types are found in a particular region, and whether from past human history the target metals or minerals were found or mined in that region. In the words of a famous South African economic geologist:

1 A. N. Strahler, 1987, *Science and Earth History: The Evolution/Creation Controversy*, Buffalo, NY: Prometheus Books, 238-243.

2 A. W. Rose, H. E. Hawkes and J. S. Webb, 1979, *Geochemistry in Mineral Exploration*, second edition, London: Academic Press; W. M. Telford, L. P. Geldart, R. E. Sheriff and D. A. Keys, 1981, *Applied Geophysics*, London: Cambridge University Press.

> In the long ago, before men starting seeking minerals and money in the interior of Africa, the nomadic Bushmen had a saying: "If you want to hunt elephants, go to elephant country." If elephants and ore-bodies can be equated, then the fundamental problem of exploration geology is simply: where and how does one find the best elephant country![3]

Nevertheless, it is important to show that the formation of ore and mineral deposits can be explained within the context of the Genesis Flood, and the biblical framework and timescale of earth history.

It is now firmly established in conventional thinking that the ultimate sources of the metals in metalliferous ores are the magmas that produce igneous rocks, both intrusive and extrusive, and hydrothermal fluids produced by magmatism and volcanism are a primary, but not the only means, by which the metals are concentrated into economic ore deposits. With the advent of plate tectonics, ideas on the formation of ore and mineral deposits were unified within the new understanding of the working of global earth systems that formed and shaped the earth's crust through earth history.[4] Thus, the application of catastrophic plate tectonics within the biblical timescale and framework of earth history, particularly the Flood event, adequately accommodates the formation of ore and mineral deposits in the ways envisaged by conventional plate tectonics, but at catastrophic rates.[5]

As much as conventional plate tectonics is regarded as simply the uniformitarian extrapolation back into the past of the present occurrences and rates of geologic processes that are shaping the earth's crust, the scale of magmatic and volcanic activity in the past, for example, as preserved in the geologic record, defies any but a catastrophic explanation. Huge catastrophic outpourings of thick basalt lava flows on a continental scale, known as flood basalts, have no known counterpart in recent or present earth history. Nor do we have evidence among present-day geologic processes of the almost simultaneous generation and intrusion of hundreds of granite plutons to form batholiths, on the scale of the Coastal batholith of South America, the Sierra Nevada batholith and Pensinsular Ranges batholith from central California to Mexico, or the numerous granite batholiths of southeastern Australia. Furthermore, thermal runaway subduction is not

3 D. A. Pretorius, 1977, *The Strategy of Mineral Exploration in Southern Africa*, vol. 1, Earth Resources Foundation, The University of Sydney, 4.

4 B. F. Strong, ed., 1976, *Metallogeny and Plate Tectonics*, Geological Association of Canada Special Paper No. 14; F. J. Sawkins, 1984, *Metal Deposits in Relation to Plate Tectonics*, Berlin: Springer-Verlag; R. Kerrich, R. J. Goldfarb and J. P. Richards, 2005, Metallogenic provinces in an evolving geodynamic framework, in *Economic Geology: 100th Anniversary Volume*, J. W. Hedenquist, J. F. H. Thompson, R. J. Goldfarb and J. P. Richards, eds., Littleton, CO: Society of Economic Geologists, 1097-1136.

5 S. A. Austin, J. R. Baumgardner, D. R. Humphreys, A. A. Snelling, L. Vardiman and K. P. Wise, 1994, Catastrophic plate tectonics: A global Flood model of earth history, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 609-621.

now occurring, nor the accumulation of whole crustal slabs at the core-mantle boundary.[6] But where conventional plate tectonics cannot account for these and other major earth features and processes at uniformitarian rates, catastrophic plate tectonics can explain them at catastrophic rates and global scales, particularly within the year-long Genesis Flood event. Furthermore, objections to the catastrophic plate tectonics model for earth history within the biblical timescale, based on the claimed rates of granite magma generation, intrusion, and cooling, and the formation of regional metamorphic complexes, have been more than adequately answered here previously. Thus, the catastrophic plate tectonics model, and the catastrophic sedimentation, volcanism, magmatism, metamorphism, and ore-depositing hydrothermal fluid flows, can explain the catastrophic formation of ore and mineral deposits.

The study of ore deposits and how they form is a major branch of geology known as *economic geology*, and there is a voluminous extant literature available that documents more than a century of research into how the various styles and classes of ore deposits have formed.[7] Because conventional plate tectonics provides the framework in which models for the formation of ore deposits are understood, it is thus logical and justifiable to use the same ore deposit formation models, but applied at catastrophic rates within the catastrophic plate tectonics model and the biblical timescale and framework. Thus, for example, the formation of magmatic nickel and copper sulfide deposits[8] associated with vast outpourings of basaltic lavas (including flood basalts), due to mantle plumes, and platinum group element and chromium deposits associated with the intrusion of enormous

---

6 J. R. Baumgardner, 1986, Numerical simulation of the large-scale tectonic changes accompanying the Flood, in *Proceedings of the First International Conference on Creationism*, vol. 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 17-28; J. R. Baumgardner, 1990, 3-D finite element simulation of the global tectonic changes accompanying Noah's Flood, in *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. E. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship. 35-45; J. R. Baumgardner, 1994, Computer modeling of the large-scale tectonics associated with the Genesis Flood, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 49-62; J. R. Baumgardner, 1994, Runaway subduction as the driving mechanism for the Genesis Flood, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 63-75; J. R. Baumgardner, 2003, Catastrophic plate tectonics: The physics behind the Flood, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 113-126.

7 R. G. Roberts and P.A. Sheahan, eds., 1988, *Ore Deposit Models*, Geoscience Canada Reprint Series 3, The Geological Association of Canada; P. A. Sheahan and M. E. Cherry, eds., 1993, *Ore Deposit Models: Volume II*, Geoscience Canada Reprint Series 6, The Geological Association of Canada; R. V. Kirkham, W. B. Sinclair, R. I. Thorpe and A. M. Duke, eds., 1993, *Mineral Deposit Modeling*, Geological Association of Canada Special Paper 40; H. L. Barnes, ed., 1997, *Geochemistry of Hydrothermal Ore Deposits*, third edition, New York: John Wiley and Sons; J. W. Hedenquist, J. F. H. Thompson, R. J. Goldfarb, and J. P. Richards, eds., 2005, *Economic Geology: 100th Anniversary Volume*, Littleton, CO: Society of Economic Geologists.

8 N. T. Arndt, C. M. Lesher and G. K. Czamanske, 2005, Mantle-derived magmas and magmatic Ni-Cu-(PGE) deposits, in Hedenquist et al, eds., 5-23; S.-J. Barnes and P. C. Lightfoot, 2005, Formation of magmatic nickel sulfide deposits and processes affecting their copper and platinum group element contents, in Hedenquist et al, 179-213.

mafic and ultramafic magma bodies[9] are more easily conceivable and explained at catastrophic rates of mantle flow and heat generation to melt the required enormous quantities of the upper mantle as a result of catastrophic plate tectonics during the Genesis Flood. Perhaps these processes even occurred also during an earlier phase, during the middle of the Creation Week for those same ore deposits that formed earlier in earth history.

Similarly, the large porphyry copper (-molybdenum-gold) deposits associated with granitic plutons[10] can be better explained by the rapid generation and emplacement of these granitic plutons in belts of batholiths around the globe within the context of catastrophic plate tectonics, because such pluton emplacement and porphyry ore processes are not now currently operating over the timescales of conventional plate tectonics.[11] The heat rapidly dissipated from granite intrusions into their host wall-rocks, along with the convective outflows of hydrothermal fluids along fractures within the granites and in the surrounding host wall-rocks, resulted in a wide variety of skarn and other granite-related ore deposits.[12] The submarine hydrothermal systems on the present ocean floor that are slowly generating massive sulfide ore deposits in volcanic and related sediments[13] are miniscule in size compared with the many volcanic massive sulfide deposits found in the geologic record all around the globe, where they were generated by huge hydrothermal systems associated with catastrophic volcanic activity initiated by plate rifting or

9 A. J. MacDonald, 1988, The platinum group element deposits: Classification and genesis, in Roberts and Sheahan, eds., 117-131; J. M. Duke, 1988, Magmatic segregation deposits of chromite, in Roberts and Sheahan, 133-143; A. J. Naldrett, 1993, Models for the formation of strata-bound concentrations of platinum group elements in layered intrusions, in Kirkham et al, 373-387; R. G. Cawthorne, S. J. Barnes, C. Ballhaus and K. N. Malitch, 2005, Platinum group element, chromium and vanadium deposits in mafic and ultramafic rocks, in Hedenquist et al, 215-249.

10 W. J. McMillan and A. Panteleyev, 1988, Porphyry copper deposits, in Roberts and Sheahan, eds., 45-58; S. R. Titley, 1993, Characteristics of porphyry copper occurrence in the American Southwest, in Kirkham et al, 433-464; S. H. Sillitoe, 1993, Gold-rich porphyry copper deposits: Geological model and exploration implications, in Kirkham et al, eds., 465-478; R. B. Carten, W. H. White and H. J. Stein, 1993, High-grade granite-related molybdenum systems: Classification and origin, in Kirkham et al, 521-554; V. A. Candela and P. M. Piccoli, 2005, Magmatic processes in the development of porphyry-type ore systems, in Hedenquist et al, 25-37; M. T. Einaudi, L. Zurcher, W. J. A. Stavast, D. A. Johnson and M. D. Barton, 2005, Porphyry copper deposits: Characteristics and origin of the hypogene features, in Hedenquist et al, 251-298.

11 A. A. Snelling, 2006, Catastrophic granite formation: rapid melting of sedimentary and metamorphic rocks and rapid magma intrusion and cooling, in *Yosemite/Death Valley Guidebook*, Santee, CA: Institute for Creation Research, 17-28; A. A. Snelling, 2008, Catastrophic granite formation: Rapid melting of source rocks, and rapid magma intrusion and cooling, *Answers Research Journal*, 1: 11-25.

12 B. F. Strong, 1988, A model for granophile mineral deposits, in Roberts and Sheahan, 59-66; P. Cerny, 1993, Rare-element granitic pegmatites, Part I: Anatomy and internal evolution of pegmatite deposits, and Part II: Regional to global environments and petrogenesis, in Sheahan and Cherry, 29-47 and 49-62; L. D. Meinert, 1993, Skarns and skarn deposits, in Sheahan and Cherry, 117-134; L. D. Meinert, 1993, Igneous petrogenesis and skarn deposits, in Kirkham et al, 569-583; L. D. Meinert, G. M. Dipple and S. Nicolescu, 2005, World skarn deposits, in Hedenquist et al, 299-336; P. Cerny, P. L. Bleven, M. Cuney and D. London, 2005, Granite-related ore deposits, in Hedenquist et al, 337-370.

13 S. D. Scott, 1997, Submarine hydrothermal systems in deposits, in Barnes, ed., 797-875; M. D. Hannington, C. E. J. de Ronde and S. Petersen, 2005, Sea-floor tectonics and submarine hydrothermal systems, in Hedenquist et al, 111-141.

plate subduction in island-arc environments.[14]

Hydrothermal systems and fluid flows have been responsible for many other classes of ore deposits, either directly or remotely related to magmatic or volcanic activity. These deposits include: iron-oxide copper-gold deposits, primarily in large-scale granitic breccias; [15] gold and other metal deposits in veins generated as a result of deformation of sediments and in metamorphic terrains, where the gold and metals have been scavenged from various deep crustal sources during tectonics and associated metamorphism; and related gold deposits, where hydrothermal fluids have flowed from fractures to disseminate the gold and metals into conducive sedimentary units.[16] In every one of these ore deposit types, the hydrothermal systems involved in forming these ore deposits operated on a much larger scale than comparable geothermal systems today, so these deposits are more conceivably explained under catastrophic deformation, metamorphism, and hydrothermal fluid activity associated with magmatism and volcanism during catastrophic plate tectonics episodes.

Given that many of these lode and vein deposits occur in some of the earth's most ancient rocks, that clearly formed early in earth history, these would be attributable to the earlier catastrophic episode that occurred in the middle of the Creation Week, particularly when the dry land was formed on Day Three. These would have been among the metal and mineral deposits mentioned in the Scriptures as being utilized by the people in the pre-Flood world.

Many ore and mineral deposits are an intrinsic part of sedimentary strata sequences, and therefore accumulated during sedimentation, or sometimes after sedimentation, with the passage of hydrothermal and/or pore fluids transporting the metals into the sedimentary strata and depositing them where conducive geochemical conditions prevailed. The volcanogenic massive sulfide deposits are also related to simultaneous sedimentation, the sulfide minerals being deposited

14 J. W. Lydon, 1988, Volcanogenic massive sulphide deposits, Part 1: A descriptive model, and Part 2: Genetic models, in Roberts and Sheahan, 145-153 and 155-181; J. M. Franklin, 1993, Volcanic-associated massive sulphide deposits, in Kirkham et al, 315-334; J. M. Franklin, H. L. Gibson, I. R. Jonasson and A. G. Galley, 2005, Volcanogenic massive sulfide deposits, in Hedenquist et al, 523-560.

15 N. Oreskes and M.W. Hitzman, 1993, A model for the origin of Olympic Dam-type deposits, in Kirkham et al, 615-633; P. J. Williams, M. D. Barton, D. A. Johnson, L. Fontboté, A. deHaller, G. Mark, N. H. S. Oliver and R. Marschik, 2005, Iron oxide copper-gold deposits: Geology, space-time distribution and possible modes of origin, in Hedenquist et al, 371-405.

16 R. G. Roberts, 1988, Archean lode gold deposits, in Roberts and Sheahan, 1-19; A. Panteleyev, 1988, A Canadian cordilleran model for epithermal gold-silver deposits, in Roberts and Sheahan, 31-43; S. B. Romberger, 1993, A model for Bonanza gold deposits, in Sheahan and Cherry, 77-86; R. H. Sillitoe, 1993, Epithermal models: Genetic types, geometrical controls and shallow features, in Kirkham et al, 403-417; C. J. Hodgson, 1993, Mesothermal lode-gold deposits, in Kirkham et al, 635-678; S. F. Cox, 2005, Coupling between deformation, fluid pressures, and fluid flow in ore-producing hydrothermal systems at depth in the crust, in Hedenquist et al, 39-75; R. J. Goldfarb, E. Baker, B. Dubé, D. I. Groves, C. A. R. Hart and T. Gosselin, 2005, Distribution character, and genesis of gold deposits in metamorphic terranes, in Hedenquist et al, 407-450; S. F. Simmons, N. C. White and B. A. John, 2005, Geological characteristics of epithermal precious and base metal deposits, in Hedenquist et al, 485-522.

with volcanic units as sedimentation occurs adjacent to volcanic activity and associated hydrothermal systems.

Another enigmatic class of ore deposits is the iron ore deposits hosted by banded-iron formations.[17] These banded-iron formations only occur in a very restricted strata level early in the geologic record, only when conditions were obviously conducive for their deposition. It has now been recognized that at least some of these banded-iron formations are associated with vast outpourings of basalts and other volcanic rocks on a catastrophic regional scale. This volcanic activity delivered the enormous quantities of iron and silica to the ocean waters that couldn't hold these in solution and thus rapidly deposited them.[18] Being early in the geologic record, these banded-iron formations represent unique catastrophic conditions early in the earth's history associated with the geologic upheavals in the middle of the Creation Week. Subsequent geologic processes, such as fluid flow through these banded-iron formations, have concentrated a richer iron content to form the economic iron deposits that are today mined on a large scale.

The final classes of major ore deposits are the sediment-hosted and stratiform lead-zinc deposits,[19] the sediment-hosted and stratiform copper deposits,[20] the sediment-hosted and sedimentary basin-related uranium deposits,[21] and the limestone-hosted (Mississippi Valley-type) lead-zinc deposits.[22] These sediment-hosted ore deposits are believed to have been formed in one of two ways.

17 G. A. Gross, 1993, Industrial and genetic models for iron ore in iron-formations, in Kirkham et al, 151-170; J. M. F. Clout and B. M. Simonson, 2005, Precambrian iron formations and iron formation-hosted iron ore deposits, in Hedenquist et al, 643-679.

18 M. E. Barley, A. L. Pickard and P. J. Sylvester, 1997, Emplacement of a large igneous province as a possible cause of banded iron formation 2.45 billion years ago, *Nature*, 385: 55-58; T. S. Blake, R. Buick, S. J. A. Brown, and M. E. Barley, 2004, Geochronology of a late Archaean flood basalt province in the Pilbara Craton, Australia: Constraints on basin evolution, volcanic and sedimentary accumulation, and continental drift rates, *Precambrian Research*, 113: 143-173.

19 J. M. Morganti, 1988, Sedimentary-type stratiform ore deposits: Some models and a new classification, in Roberts and Sheahan, 67-78; W. D. Goodfellow, J. W. Lydon and R. J. W. Turner, 1993, Geology and genesis of stratiform sediment-hosted (SEDEX) zinc-lead-silver sulphide deposits, in Kirkham et al, 201-251; J. M. Parr and I. R. Plimer, 1993, Models for Broken Hill-type lead-zinc-silver deposits, in Kirkham et al, 253-288; D. L. Leach, D. F. Sangster, K. D. Kelley, R. R. Large, G. Garven, C. R. Allen, J. Gutzmer and S. Walters, 2005, Sediment-hosted lead-zinc deposits: A global perspective, in Hedenquist et al, 561-607.

20 R. W. Boyle, A. C. Brown, C. W. Jefferson, E. C. Jowett and R. V. Kirkham, eds., 1989, *Sediment-hosted Stratiform Copper Deposits*, Geological Association of Canada Special Paper 36; A. C. Brown, Sediment-hosted stratiform copper deposits, in Sheahan and Cherry, 1993, 99-115; M. Hitzman, R. Kirkham, D. Broughton, J. Thorson and D. Selley, 2005, The sediment-hosted stratiform copper ore system, in Hedenquist et al, 609-642.

21 J. E. Tilsley, 1988, Genetic considerations relating to some uranium ore, in Roberts and Sheahan, 91-102; S. Marmont, 1988, Unconformity-type uranium deposits, in Roberts and Sheahan, 103-115; V. Ruzicka, 1993, Unconformity-type uranium deposits, in Kirkham et al, 125-149.

22 G. M. Anderson and R. W. Macqueen, 1988, Mississippi Valley-type lead-zinc deposits, in Roberts and Sheahan, 79-90; D. L. Leach and D. F. Sangster, 1993, Mississippi-valley lead-zinc deposits, in Kirkham et al, 289-314; L. M. Cathles III and J. J. Adams, 2005, Fluid flow and petroleum and mineral resources in the upper (<28-km) continental crust, in Hedenquist et al, 77-110.

Metal-laden hydrothermal fluids were expelled through faults adjacent to where sedimentation was occurring, so the metals precipitated as the hydrothermal fluids mixed with the ocean waters that carried the sediments. Thus, the metals and sediments were deposited together. Alternately, after sedimentation had occurred, the ground waters trapped in the sediments were heated by burial, and perhaps even added to by hydrothermal fluids ascending along faults. In this way, large fluid flow cells developed in the sedimentary basins, scavenging metals from disseminated sources in the sediment piles, and then precipitating them where there were suitable, conducive, geochemical and structural traps to produce metal accumulations that became economic ore deposits.[23]

Depending on where in the rock record these ore deposits occur would determine whether they had been formed during the catastrophic sedimentation, magmatism, volcanism, tectonics, and fluid flows during the early-middle part of the Creation Week, or during the subsequent global Genesis Flood. Whereas in uniformitarian thinking the sedimentation, volcanism, fluid flow, and ore deposition processes were slow and gradual over millions of years, there are no known analogs in the present world on the same scale as the sedimentation and fluid flows that generated the ore deposits found in the geologic record. On the other hand, the global-scale catastrophic conditions that prevailed during the early part of the Creation Week, and during the year-long Genesis Flood, would have provided the ideal heat conditions under which these and many other ore deposits formed.

Two other types of ore deposits accumulated directly as a result of sedimentation, albeit catastrophically on a scale that is not now seen. These include the world's largest gold deposit, the gold and uranium in the conglomerate beds of the Witwatersrand Basin of South Africa, about which it has been argued also that it had its metal content upgraded by subsequent hydrothermal activity.[24] There are also similar placer or detrital deposits of numerous metals and minerals.[25] Many of these placer deposits were formed as the Flood waters catastrophically retreated, eroding and concentrating metal-bearing minerals and gems in beach sands and deltaic sediments. Of course, erosion also exposed earlier-formed metal-bearing

---

23 G. Garven and J. P. Raffensperger, 1997, Hydrogeology and geochemistry of ore genesis in sedimentary basins, in Barnes, 125-189; P. Landais and A. P. Gize, 1997, Organic matter in hydrothermal ore deposits, in Barnes, 613-655; L. M. Cathles III and J. J. Adams, 2005; R. R. Large, S. W. Bull, P. J. McGoldrick, S. Walters, G. M. Derrick and G. R. Carr, 2005, Stratiform and strata-bound Zn-Pb-Ag deposits in Proterozoic sedimentary basins, northern Australia, in Hedenquist et al, 931-963; D. Selley, B. Broughton, R. Scott, M. Hitzman, S. W. Bull, R. R. Large, P. J. McColdrick, M. Roaker, N. Pollington and F. Barra, 2005, A new look at the geology of Zambian Copperbelt in Hedenquist et al, 965-1000; D. L. Huston, B. Stevens, P. N. Southgate, P. Muhling and L. Wyborn, 2006, Australian Zn-Pb-Ag ore-forming systems: A review and analysis, *Economic Geology*, 101: 1117-1157.

24 S. M. Roscoe and W.L. Minter, 1993, Pyritic Paleoplacer gold and uranium deposits, in Kirkham et al, 103-124; H. E. Frimmel, D. I. Groves, K. Kirk, J. Ruiz, J. Chesley and W. E. L. Minter, 2005, The formation and preservation of the Witwatersrand gold fields, the world's largest gold province, in Hedenquist et al, 769-797; J. D. M. Law and G. N. Phillips, 2005, Hydrothermal replacement model for Witwatersrand gold, in Hedenquist et al, 799-811;.

25 R. H. T. Garnett and N. C. Bassett, 2005, Placer deposits, in Hedenquist et al, 813-843.

rocks and ore deposits to weathering and groundwater enrichment processes of the earth's surface, such processes being severer than today during the drying-out phase of the early post-Flood era.[26]

The only more detailed treatment of the formation of ore deposits within the biblical framework and timescale of earth history is that of the Mt. Isa orebodies in northern Australia.[27] Predictably, this catastrophic model for the formation of these massive lead-zinc orebodies was criticized by a uniformitarian detractor.[28] His objections to the catastrophic model were primarily due to his uniformitarian bias not being able to condone the extrapolation of geologic processes to catastrophic rates and volumes that clearly would have been the norm during the global upheavals of the early-middle part of the Creation Week and the year-long Genesis Flood, when the earth's crust was formed and totally reshaped respectively. However, ongoing research in the last two decades has, if anything, strengthened the case for the catastrophic formation of these massive lead-zinc orebodies.

Enormous outpourings of basalts and other volcanic rocks occurred prior to deposition of the sediments that host the orebodies, which together would have to have been catastrophic. The metals were then scavenged by the waters trapped in the sediments, that were heated up by the deep burial, to produce basin-wide fluid flows through faults and within the sediments which deposited the metals with the sediments in conducive geochemical traps (such as organic matter dispersed in the sediments), that rapidly concentrated the metals into the orebodies.[29] Significantly, present modeling of the processes of formation of these orebodies regard the necessary metal-bearing fluid-flow event to occupy an extremely narrow timeframe, virtually an instant in conventional geologic time, which is consistent with the uniform identical lead isotopic homogeneity throughout these massive orebodies over a total lateral distance of some 35 km,[30] an extraordinary

26 N. N. Gow and G. P. Lozeg, Bauxite, 1993, in Sheahan and Cherry, 135-142; Ph. Freyssinet, C. R. M. Butt, R. C. Morris and P. Piantone, 2005, Ore-forming processes related to lateritic weathering, in Hedenquist et al, 681-722; R. H. Sillitoe, 2005, Supergene oxidized and enriched porphyry copper and related deposits, in Hedenquist et al, 723-768.

27 A. A. Snelling, 1984, The recent, rapid formation of the Mt Isa ore bodies during Noah's Flood, *Ex Nihilo*, 6(3): 40-46.

28 Strahler, 1987, 242-243.

29 P. N. Southgate, T. K. Kyser, D. L. Scott, R. R. Large, S. D. Golding and P. A. Polito, 2006, A basin system and fluid-flow analysis of the Zn-Pb-Ag Mt Isa-type deposits of northern Australia: Identifying metal source, basinal brine reservoirs, times of fluid expulsion, and organic matter reactions, *Economic Geology*, 101(6): 1103-1115; P. A. Polito, T. K. Kyser, P. N. Southgate and M. J. Jackson, 2006, Sandstone diagenesis in the Mount Isa basin, an isotopic and fluid inclusion perspective in relationship to district-wide Zn, Pb, and Cu mineralization, *Economic Geology*, 101(6): 1159-1168; M. Glikson, S. D. Golding and P. N. Southgate, 2006, Thermal evolution of the ore-hosting Isa Superbasin, central and northern Lawn Hill platform, *Economic Geology*, 101(6): 1211-1229; J. Yang, R. R. Large, S. W. Bull and D. L. Scott, 2006, Basin-scale numerical modeling to test the role of buoyancy-driven fluid flow and heat transfer in the formation of stratiform Zn-Pb-Ag deposits in the northern Mt Isa basin, *Economic Geology*, 101(6): 1275-1292.

30 J. J. Richards, 1975, Lead isotope data on three north Australian galena localities, *Mineralium Deposita*, 10: 287-301.

circumstance if the lead in these orebodies had not been derived and deposited catastrophically.

The feasibility of the catastrophic formation of ore deposits is highlighted by the fact that, even in conventional geology, diamond deposits are said to have formed explosively and catastrophically.[31] Formed 200-400 km (125-250 miles) down in the earth's mantle, diamonds are brought to the earth's surface in gas-rich kimberlite and lamproite magmas that explosively rise through fractures to erupt at the earth's surface, leaving behind pipe-like bodies containing the diamonds. The rate at which these magmas explosively ascend from the mantle through the crust has been determined as around 4 meters per second, or between 10 and 30 km (6-19 miles) per hour.[32] Such a rapid ascent rate is crucial to the survival of the diamonds carried by these magmas because a slower ascent rate would result in the diamonds turning to graphite. At this ascent rate, it therefore only takes between 12 and 30 hours for the diamond-carrying magmas to travel from the source areas of the diamonds in the mantle up to erupt at the earth's surface. It is worth noting that even though the diamonds themselves yield old radioisotope "ages," dating them back to the early stages of earth history, the formation of the diamond deposits in the kimberlite and lamproite pipes at the earth's surface occurred much later in the earth's history, primarily late in the Flood event, and even early in the post-Flood era.[33]

In conclusion, therefore, it is staunchly maintained that catastrophic geological processes of erosion, sedimentation, magmatism, volcanism, hydrothermal fluid flows, and tectonics during the early-middle part of the Creation Week, and again during the year-long Genesis Flood, can more than adequately account for the formation of ore and mineral deposits during the biblical timescale for earth history.

31 R. H. Mitchell, 1993, Kimberlites and lamproites: Primary sources of diamond, in Sheahan and Cherry, eds., 13-28; A. A. Snelling, 1994, Diamonds: Evidence of explosive geological processes, *Creation Ex Nihilo*, 16(1): 42-45; J. J. Gurney, H. H. Helmstaedt, A. P. LeRoex, T. E. Nowicki, S. H. Richardson and K. J. Westerlund, 2005, Diamonds: Crustal distribution and formation processes in time and space and an integrated deposit model, in Hedenquist et al, 143-177.

32 E. H. Eggler, 1989, Kimberlites: How do they form? in *Kimberlites and Related Rocks*, J. Ross, A. L. Jacques, J. Ferguson, D. H. Green, S. Y. O'Reilly, R. V. Danchin and A. J. A. Janse, eds., Geological Society of Australia Special Publication No. 14 and Blackwell Scientific Publications Australia, vol. 1:. 489-504; S. P. Kelley and J.-A. Wartho, 2000, Rapid kimberlite ascent and significance of Ar-Ar ages in xenolith phlogopites, *Science*, 289, 609-611.

33 L. Hissink, 1993, Euhemerism and aboriginal myths, *The Australian Geologist*, 86: 6-7.

126

Earlier Ice Ages

As discussed in detail earlier (chapters 96-97), there is impeccable evidence for an Ice Age that affected the earth's surface after the Genesis Flood.[1] The Antarctic and Greenland ice sheets, and the many alpine glaciers, are today's remnants of that event. This so-called Pleistocene Ice Age produced distinctive landscape features and sedimentary deposits, such as *tillites* (angular pebbles and boulders cemented together in a large volume matrix of rock "flour"), and varves or *rhythmites* (very thinly bedded laminae of alternating mud and silt).

In their zeal to use uniformitarian dogma to interpret the formation of ancient sedimentary strata on the basis of present-day geological processes, sedimentary environments, and the sedimentary strata they produce, conventional geologists claim that there are ancient sedimentary strata identical to tillites and varves that, therefore, must have been deposited during ancient glaciations. Consequently, it has been claimed that in the past geologic "ages," the earth has experienced numerous ice ages, during which ice sheets covered large portions of the globe.[2] Thus, it is claimed that there were ice ages in the late Archean (the Huronian in Canada and elsewhere), the early Proterozoic, the late Proterozoic (now known as the Neoproterozoic), the late Ordovician-early Silurian, perhaps the late Devonian and early Carboniferous, but certainly in the late Carboniferous-Permian, and then possibly in the Eocene. Of these, the ice ages for which there is the most claimed evidence of a global nature are those in the late Archean, Neoproterozoic, and the late Carboniferous-Permian. The evidence not only includes claimed tillites and varves, but also striated bedrock where the boulders being carried at the base of ice sheets are supposed to have scratched the bedrock surfaces, leaving behind striations or grooves. Obviously, ancient ice ages, involving slow and gradual development of ice sheets and deposition of glacial sediments over millions of years, are incompatible with both the biblical timescale of earth history and the

1 M. J. Oard, 1990, *An Ice Age Cause by the Genesis Flood*, El Cajon, CA: Institute for Creation Research.

2 J. C. Crowell, 1983, Ice ages recorded on Gondwanan continents, *Transactions of the Geological Society of South Africa*, 86, 238-261; N. Eyles, 1993, Earth's glacial record and its tectonic setting, *Earth-Science Reviews*, 35: 1-248.

year-long Genesis Flood.[3] A full and adequate response to these claims of ancient ice ages from a young earth, global Flood perspective has already been published.[4]

It is, in fact, abundantly clear that the claimed evidence for these ancient ice ages is equivocal at best, because there is no way of proving the supposed tillites, varves, and striated bedrock were in fact due to glacial deposition and the passage of ice sheets respectively. As has been pointed out: "Identifying ancient glaciations is not easy."[5] The reality is that most, if not all, of the purported evidence for these ancient ice ages can be easily confused with, and interpreted as, the result of non-glacial sedimentation and activity. Perhaps the most crucial evidence, historically, for these ancient ice ages was the claimed tillites, which should have only ever been identified as diamictites, the general term for a non-sorted, or poorly-sorted at best, sedimentary rock containing all different grain sizes mixed up, particularly angular boulders and pebbles in a voluminous fine-grained matrix. The origin of these so-called tillites has long been challenged, being adequately demonstrated to represent the results of massive debris flows and related deposits, especially adjacent to tectonically active areas.[6] Geologists have slowly come to realize that massive debris flows can produce deposits that are indistinguishable from these ancient ice age diamictites.[7] One of the many important relevant properties of debris flows is the ability to transport surprisingly large boulders in laminar or non-turbulent flow.[8] Consequently, most of these so-called "tillites" are now recognized as containing abundant mass movement deposits,[9] but this has not curtailed the claims of them being associated with ancient ice ages. Indeed, it is now recognized that these diamictites can form in many non-glacial ways.

> Diamictites and conglomerates are dominantly the product of subaqueous mass flow and mixing of coarse and fine sediment populations (the term *mixtite* has been used in the past). These facies are not uniquely glacial and are produced regardless of climate and latitude.[10]

---

3 Strahler, 1987, 263-273.

4 M. J. Oard, 1997, *Ancient Ice Ages or Gigantic Submarine Landslides?*, Creation Research Society Monograph Series No. 6.

5 R. P. Sharp, 1988, *Living Ice: Understanding Glaciers and Glaciation*, Cambridge and New York: Cambridge University Press.

6 L. J. G. Schermerhorn, 1974, Late Precambrian mixtites: Glacial and/or non-glacial?, *American Journal of Science*, 74: 673-824; M. R. Rampino, 1993, Ancient "glacial" deposits are ejecta of large impacts: The Ice Age paradox explained, *EOS, Transactions of the American Geophysical Union*, 74(43): 99.

7 J. B. Anderson, E. D. Kurtz and F. M. Weaver, 1979, Sedimentation on the Antarctic continental slope, in *Geology of Continental Slopes*, L. J. Doyle and O. H. Pilkey, eds., Tulsa, OK: Society of Economic Paleontologists and Mineralogists Special Publication No. 27, 265-283.

8 T. Takahashi, 1981, Debris flow, *Annual Review of Fluid Mechanics*, 13: 57-77.

9 J. N. J. Visser, 1983, The problem of recognizing ancient subaqueous debris flow deposits in glacial sequences, *Transactions of the Geological Society of South Africa*, 86: 127-135.

10 N. Eyles and N. Januszczak, 2004, "Zipper-rift": A tectonic model for Neoproterozoic glaciations during the breakup of Rodinia after 750 Ma, *Earth-Science Reviews*, 65: 1-73 (p. 1).

It is therefore acknowledged that most diamictites are generated by mass flows (debris flows) on unstable slopes in tectonically active areas, such as in rift basins and subduction zones, on continental slopes, and on the margins of volcanoes and reefs.[11]

Nevertheless, these diamictites are still regarded as being indicative of ancient ice ages, even though such massive debris flow deposits are known to be relatively minor compared to the sedimentary deposits produced in the Pleistocene (post-Flood) Ice Age and associated with ice sheets today. It is because these ancient diamictites are claimed to have special features that are diagnostic of an ice age origin. The first of these are linear scratches or small grooves called striations on some of the boulders or pebbles in these diamictites, especially where the striations are on a flattened or faceted surface of the pebbles and boulders. However, striated pebbles and boulders have also been found in many conglomerates and debris flows, and even silt and fine sand grains can scratch such clasts, even in mudflows.[12] Indeed, any moving medium can potentially striate pebbles and boulders: "… nonglacial sedimentary and tectonic processes can produce pseudoglacial striated and faceted clasts."[13] Furthermore, "mass movement of material has long been known as an effective process of striating rock."[14] Indeed, uniform, massive debris flows are known to contain faceted clasts, the facets or flattened surfaces being caused by fracturing along joints, or bedding and metamorphic foliation surfaces.[15] Thus, when a claimed late Precambrian glacial diamictite in Namibia was re-examined, it was concluded that the striated and faceted clasts were only pseudofaceted, and the very rare random striations or scratches could have been received on the clasts when exposed at the present-day surface, so it was realized there was no evidence that this diamictite was of glacial origin.[16]

It has to be concluded, therefore, that striated and faceted rocks in a diamictite are not diagnostic of ancient glaciation, no matter whether the striations are parallel, random or crossing in organized sets, because all such features can be produced in massive debris flows and other non-glacial processes. Even though there have

11 G. Einsele, 2000, *Sedimentary Basins: Evolution, Facies, and Sediment Budget*, Berlin: Spring-Verlag.

12 E. L. Winterer and C.C. Von Der Borch, 1968, Striated pebbles in a mud flow deposit, South Australia, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 5: 205-211; D. H. Malone, 1995, Very large debris-avalanche deposit within the Eocene volcanic succession of the northeastern Absaroka Range, Wyoming, *Geology*, 23: 661-664.

13 L. J. G. Schermerhorn, 1975, Tectonic framework of Late Precambrian supposed glacials, in *Ice Ages: Ancient and Modern*, A. E. Wright and F. Moseley, eds., Liverpool, UK: Seel House Press, 241-274 (p. 253).

14 S. Judson and R. E. Barks, 1961, Microstriations on polished pebbles, *American Journal of Science*, 259: 371-381 (p. 377).

15 S. K. Acharyya, 1975, Tectonic framework of sedimentation of the eastern Himalayas, India, in *Gondwana Geology*, K. S. W. Campbell, ed., Canberra, Australia: Australian National University Press: 663-674.

16 H. Martin, H. Porada and O. H. Walliser, 1985, Mixtite deposits of the Damara Sequence, Namibia: Problems of interpretation, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 51: 159-196.

been claims that microtextural features on the surfaces of matrix grains, such as chattermarks, crescent-shaped shallow cracks perpendicular to the presumed motion of the abrasion of the grain's surface, exhaustive studies have concluded that the origin of such features is not necessarily environmentally controlled,[17] and that there are no unique glacial microtextures on matrix grains.[18]

The second claimed special feature of diamictites that is diagnostic of a glacial origin is striated bedrock surfaces. However, just as non-glacial mechanisms can scratch clasts, research has shown that the mass movements of debris flows, as well as tectonic shearing, can also striate and groove bedrock surfaces, even with two or more sets of crossing striations.[19] A related feature that is claimed to be even more diagnostic of glacial diamictites is boulder pavements, which is where there is a layer of boulders within the diamictite at its lower contact, the boulders being of similar composition but are striated.[20] While these boulder pavements are known in Pleistocene (post-Flood) Ice Age tills, they are especially rare in pre-Pleistocene diamictites. Unfortunately, the mechanism for forming these boulder payments is not understood,[21] which certainly diminishes their significance as a glaciogenic indicator. Indeed, at least five hypotheses have been advanced to explain the formation of these boulder pavements, yet all of them contain serious flaws![22] In any case, in a debris flow the larger clasts are observed to sink to the base of the debris flow to form a boulder pavement or traction carpet, where they are overridden and striated. Thus striated boulder pavements are also hardly a diagnostic feature of glacial diamictites.

The third major supposedly diagnostic feature used by geologists to conventionally identify pre-Pleistocene Ice Age deposits is varves or rhythmites containing

17 E. D. Orr and R. L. Folk, 1983, New scents on the chattermark trail: Weathering enhances obscure microfractures, *Journal of Sedimentary Petrology*, 53: 121-129.

18 Eyles, 1993, 82-83.

19 C. F. S. Sharpe, 1938, *Landslides and Related Phenomena—A Study of Mass-Movements of Soil and Rock*, New York, Columbia University Press; J. C. Crowell, 1957, Origin of pebbly mudstones, *Geological Society of America Bulletin*, 68: 993-1010; W. D. Harland, K. N. Herod and D.H. Krinsley, 1966, The definition and identification of tills and tillites, *Earth-Science Reviews*, 2: 225-256; H. J. Harrington, 1971, Glacial-like "striated floor" originated by debris-laden torrential water flows, *American Association of Petroleum Geologists Bulletin*, 55: 1344-1347; M. J. Hambrey and W. B. Harland, eds., 1981, *Earth's Pre-Pleistocene Glacial Record*, London: Cambridge University Press; J. P Petit, 1987, Criteria for the sense of movement on fault surfaces in brittle rocks, *Journal of Structural Geology*, 9: 597-608; D. R. Oberbeck, S. Hörz and T. Bunch, 1994, Impacts, tillites, and the breakup of Gondwanaland: A second reply, *Journal of Geology*, 102: 485-489.

20 S. R. Hicock, 1991, On subglacial stone pavements in till, *Journal of Geology*, 99: 607-619.

21 C. H. Eyles, 1994, Intertidal boulder pavements in the northeastern Gulf of Alaska and their geological significance, *Sedimentary Geology*, 88: 161-173.

22 P. U. Clark, 1991, Striated clast pavements: Products of deforming subglacial sediment?, *Geology*, 19: 530-533; P. U. Clark, 1992, Comments and reply on "Striated clast pavements: Products of deforming subglacial sediment?" reply, *Geology*, 20: 285-286; D. M. Mickelson, N. R. Ham, Jr., and L Ronnert, 1992, Comments and reply on "Striated clast pavements: Products of deforming subglacial sediment?" comment, *Geology*, 20: 285.

dropstones. Varves have been discussed previously (chapter 118), where it was shown that similar rhythmite deposits can be laid down by catastrophic flowing density or turbidity currents. Thus, rhythmites that look like varves are most definitely not diagnostic of glacial deposits. Dropstones, which are oversized clasts larger than the thickness of the silt/clay couplets in varves/rhythmites, however, are associated with Pleistocene varve deposits. They are believed to have been dropped from icebergs floating above where the varves were being deposited. Thus most geologists would regard the presence of these dropstones in ancient rhythmites to be instant "proof" of their glacial origin. However, not only can mass flows produce rhythmites that look like varves, but they can also produce "dropstones" that have, in fact, been carried laterally in the flow to be deposited in the rhythmite.[23] Indeed, cobbles and boulders up to 30-40 cm, or even a few meters, in diameter have been observed "floating" in the finer grain sediments above the turbidity current traction carpet.

> Many turbidites appear to contain floating megaclasts…reported examples include the deposits of inferred high-density turbidity currents that contain isolated, floating megaclasts up to a few decimetres or even a few metres in their longest dimension. [24]

In any case, if these large clasts had in fact been dropped into the varves/ rhythmites, the dropped stones should have disrupted the fine laminae and also pierced them. However, the reality is that the dropstones in pre-Pleistocene rhythmites are predominantly small, and are often isolated, compared with those in Pleistocene varves which are large and prolific.[25] Furthermore, very few dropstones pierced the laminations, instead slightly depressing them.[26] Otherwise, simple bending of rhythmite beds around a stone is best explained by compaction after lateral emplacement of the stone, so simple bending of the laminae around a clast is not diagnostic of a dropstone.

> Thus, clasts which show either symmetric or basally asymmetric bending of laminae around them cannot be regarded as diagnostic of drop.[27]

---

23 A. H. Bouma, 1964, Turbidites, in A. H. Bouma and A. Brouwer, eds., *Turbidites*, New York: Elsevier, 247-256; M. J. Hambrey and W. B. Harland, 1979, Analysis of pre-Pleistocene glaciogenic rocks: Aims and problems, in *Moraines and Varves*, Ch. Schlüchter, ed., A.A. Balkema, Rotterdam: 271-275; C. P. Gravenor, V. von Brunn and A. Dreimanis, 1984, Nature and classification of waterlain glaciogenic sediments, exemplified by Pleistocene, late Paleozoic and late Precambrian deposits, *Earth-Science Reviews*, 20: 105-166.

24 E. Postma, W. Nemec and K. L. Kleinspehn, 1988, Large floating clasts in turbidites: A mechanism for their emplacement, *Sedimentary Geology*, 58: 47-61.

25 G. M. Young, 1981, The early Proterozoic Gowganda Formation, Ontario, Canada, in *Earth's Pre-Pleistocene Glacial Record*, M. J. Hambrey, and W. E. Harland, eds., London: Cambridge University Press: 807-812.

26 W. Hamilton and D. Krinsley, 1967,Upper Paleozoic glacial deposits of South Africa and southern Australia, *Geological Society of America Bulletin*, 78: 783-800.

27 G. S. P. Thomas and R. J. Connell, 1985, Iceberg drop, dump, and grounding structures from

All of these so-called diagnostic features can readily be explained by debris flow deposition.

> An assemblage of arguments or indications separately of little diagnostic value as glacial criteria does not constitute collectively strong evidence for glaciation.[28]

It is the claimed late Precambrian or Neoproterozoic "Ice Age" that has been the subject of much recent discussion, with the claimed strong evidence for it becoming dogma.[29] The Neoproterozoic diamictites and other rocks claimed to be of glacial origin are only found in small areas but all over the world, usually at the bottom of thick sedimentary strata sequences in what were large sedimentary basins.[30] However, this postulated Neoproterozoic "snowball earth," as it is called, presents several vexing geological problems.

> …one of the major enigmas in contemporary Earth science, raising questions concerning the nature of the geomagnetic field, climatic zonation, and the Earth's rotational parameters in late Proterozoic time.[31]

Whereas it is freely admitted that these Neoproterozoic diamictites are dominantly the product of subaqueous mass flows and are related to nearby turbidites (rhythmites),[32] the enigmas are due to their close association with limestones, dolomites, "evaporites, stromatolites, iron formations and other unique rock types that are indicative of the warm climate and warm seawater at equatorial latitudes, confirmed by low paleomagnetic inclinations."[33] Indeed, much has been made of the "cap carbonates" that sit directly on top of the diamictites, but carbonate beds are also found below and within these diamictites.

Thus this Neoproterozoic Ice Age has been called the "snowball earth" hypothesis, because it is postulated that the ice sheets extended to sea level near the equator, yet it is admitted that this poses a paleoenvironmental conundrum! That model "is based on many longstanding assumptions of the character and origin of the

---

Pleistocene glacio-lacustrine sediments, Scotland, *Journal of Sedimentary Petrology*, 55: 243-249.

28 Schermerhorn, 1975, 675.

29 P. F. Hoffman, A. J. Kaufman, G. P. Halverson and D. P. Schrag, 1998, A Neoproterozoic snowball earth, *Science*, 281: 1342-1346; P. F. Hoffman and D. P. Schrag, 2002, The snowball earth hypothesis: Testing the limits of global change, *Terra Nova*, 14: 129-155.

30 Schermerhorn, 1974; Hambrey and Harland, 1981.

31 E. W. Schmidt, G. E. Williams and B. J. J. Embleton, 1991, Low palaeolatitude of late Proterozoic glaciation: Early timing of remanence in haematite of the Elatina Formation, South Australia, *Earth and Planetary Science Letters*, 105: 355-367 (p. 355).

32 Eyles and Januszczak, 2004.

33 L. A. Frakes, 1979, *Climates Throughout Geological Time*, Elsevier, New York; L. J. G. Schermerhorn, 1983, Late Proterozoic glaciation in the light of CO_2 depletion in the atmosphere, *Geological Society of America Memoir*, 161, Boulder, CO: 309-315; M. J. Hambrey, 1992, Secrets of a tropical Ice Age, *New Scientist*, 133(1804): 42-49; Hoffman and Schrag, 2002.

Neoproterozoic glacial record, in particular, 'tillites,' that are no longer valid."[34] Instead, it can be shown that these diamictites and conglomerates produced by mass flows are embedded with large olistostromes containing huge masses of carbonate debris derived from landsliding of fault scarps along rifted carbonate platforms at the time of the break-up of the supercontinent called Rodinia. Indeed, in some reconstructions of that supercontinent these diamictites and associated olistostromes are found to occur around its margins.

One of these submarine landslide deposits is the Kingston Peak Formation in southeastern California, which has been recognized as evidence for the catastrophic initiation of the Genesis Flood,[35] marking the pre-Flood/Flood boundary when the pre-Flood supercontinent (equated with Rodinia) was rifted and broken up by the initiation of the catastrophic plate tectonics of the Flood.[36]

Thus, the evidence for claimed ancient ice ages is consistent with the catastrophic Genesis Flood. The initiation of the Flood resulted in the collapse of the continental shelves surrounding the pre-Flood supercontinent, the debris collapsing in gigantic submarine landslides and debris flows into the deeper ocean basins, where the rising ocean waters sweeping landwards deposited over these diamictites the initial sediments of the cataclysm. This makes sense of all the evidence of the marine environment for these diamictites that have wrongly been interpreted as glacial deposits. Then, as the Flood event progressed, further gigantic debris and mass flows, in response to continuing rifting, catastrophic tectonics, and the earthquakes they generated, deposited diamictites and rhythmites higher in the strata record that also have been wrongly interpreted by uniformitarian geologists as subsequent ancient ice ages.[37] It should, therefore, now be firmly established that the biblical framework and timescale of earth history is both adequate and sufficient to explain and understand the evidence left in the geologic record of the earth's catastrophic past.

---

34 Eyles and Januszczak: 2004, 1.

35 R. Sigler and C. Van Wingerden, Submarine flow and slide deposits in the Kingston Peak Formation, Kingston Range, Mojave Desert, California: Evidence for catastrophic initiation of Noah's Flood, in *Proceedings of the Fourth International Conference on Creationism*, R. E. Walsh, ed., 1998, Pittsburgh, PA: Creation Science Fellowship, 487-501.

36 S. A. Austin and K. P. Wise, The pre-Flood/Flood boundary: As defined in Grand Canyon, Arizona and eastern Mojave Desert, California, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., 1994, Pittsburgh, Pa: Creation Science Fellowship, 37-47; S. A. Austin, J. R. Baumgardner, D. R. Humphreys, A. A. Snelling, L. Vardiman and K. P. Wise, 1994, Catastrophic plate tectonics: A global Flood model of earth history, in *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 609-621; C. Van Wingerden, 2003, Initial Flood deposits of the western Northern American Cordillera: California, Utah and Idaho, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 349-358.

37 Oard, 1997.

Concluding Challenges

Not even a detailed analysis of this size is able to present all the evidence, discuss all the objections, and solve all the difficulties in understanding the catastrophic past of our planet. Deriving a biblical framework and timescale for earth history using a literal reading and understanding of the Scriptures, and then applying that biblical model to the evidence left behind in the earth's rock record constitutes a serious attempt to select the most difficult problems for treatment, while acknowledging that this discussion has been limited by space constraints. Nevertheless, it is still hoped that the discussion of the evidence has shown that it is amenable to a satisfactory explanation in terms of biblical geology.

The Adequacy of the Biblical Framework of Earth History

Conventional geology, though today more accepting of catastrophism in explaining the accumulation of the geologic record, is still ultimately based on a uniformitarian framework for the earth's history. Of course, uniformitarianism requires long ages to enable the conception of the spontaneous generation of life, and the evolution of that life ultimately into today's plants and animals. However, because in most instances conventional geologists still believe present geologic processes operating at today's observed rates can account for the great bulk of the observable features of the earth's constitution and strata record, it has been necessary to show that the application of this uniformitarian belief to explain most of the important geologic phenomena is utterly inadequate. Even many conventional geologists have come to realize that the evidence in the rocks consistently and overwhelmingly indicates that many forms of catastrophism had to be involved in shaping the earth and forming its rock strata. The global evidences of geologic processes that in the past had to have operated violently at continental and global scales, compared to their local, quiet operation today—the rapid deposition of vast beds of sediments, the burial and fossilization of billions of plants and animals, volcanism and magmatism, the formation of coal, oil, and ore deposits, plate tectonics, earth movements, and regional metamorphism—overwhelmingly compel any reasonable observer to conclude that the dominant features of the earth's crust and surface had to be produced and shaped by global catastrophism. When this is recognized, along with the failure of the radioisotope "dating" of rocks to yield consistent "ages" for them, then it can be seen that even the supposed evidences of great geologic age are but the result of seeing them with a uniformitarian bias, when they can be easily reinterpreted to correlate well with the much more compelling evidences consistent with violent, rapid activity and formation.

Therefore, if present geologic processes and their rates of operation today cannot be used to deduce the earth's past history (and this conclusion is convincingly supported not only by the failure of the uniformitarian paradigm, but also by the impregnable laws of thermodynamics that describe without exception the conservation and deterioration of energy), then the only way we can have certain knowledge of the natural geologic processes and events on the earth, prior to the time when human historical records began, is by means of divine revelation. This is why the Bible's record of creation and the Flood immediately becomes absolutely essential to our understanding, not only of the early history of the earth, but also of the purpose and destiny of the universe and of man.

It has, therefore, been the purpose of this book to show how the outline of earth history provided by the early chapters of Genesis, as well as by the related passages from other parts of the Bible, actually provides a scientifically accurate model within which all the verifiable observations of field and experimental data in geology and geophysics fit robustly together remarkably well.

In the New Testament, Peter clearly states that there were two periods of earth history when God directly intervened in the operation of geological and geophysical processes to form and shape the earth and its crust (2 Peter 3:4-6). Thus, it is not only useless to interpret how the earth was formed and was shaped by the operation of geological and geophysical processes operating at today's rates, but also to interpret the appearance of the earth, its strata and formations, as indicating that they had a long geologic history and have a great geologic age. Instead, God's activities in the early part of the Creation Week established and shaped the earth, its foundations, deep crustal structure, and what are now its crystalline basement rocks, all in an unimaginably brief space of time measured in hours and days. Then, during the Flood cataclysm of Noah's day, God unleashed certain geological and geophysical processes that overturned the earth's surface and reshaped it. Thus, we cannot account for most of the earth's sedimentary strata that contain fossils, today's mountains ranges and volcanoes, the ocean basins, and other surface deposits and features, by those forces which are today only operating at a veritable snail's pace. The earth's climates have since returned to some semblance of normality after the upheavals during the Flood that initially resulted in a brief post-Flood Ice Age.

The reader may judge for himself whether the evidence presented here truly warrants this reorientation of our understanding of earth's geology from this biblical worldview. It is my hope, of course, that the evidence will be considered, and that the biblical understanding of earth's history will not simply be rejected because of the supposed authority of the "conventional" geologic community that not only disapproves of applying this biblical worldview to the geologic evidence, but rejects it without analysis.

An Unfinished Task

When Drs. John Whitcomb and Henry Morris teamed up to write their landmark book *The Genesis Flood: The Biblical Record and Its Scientific Implications*, first published in 1961, there were so few professional geologists with advanced degrees in geology, geophysics, and related fields, that they must have felt like lone voices standing for, and declaring, the literal truth of God's Word and its reliability in robustly explaining the earth's history and its geologic record. Nevertheless, the subsequent years have shown that God has honored their stand and used it to convince many Christians and convict many non-Christians that God's Word cannot only be trusted in matters of faith, but also in the details of the earth's history and geology as found in the strata record. The personal testimonies of some of these people, of the way that book challenged them, is now on the public record.[1]

Many of those convicted and convinced are either professional scientists or went on to become professional scientists. Furthermore, they and many others were inspired to take up the challenge to contend for the truth of God's Word and its reliability in understanding the earth's history and explaining the earth's strata record and features. Some chose to do this on a full-time basis, and so Christian organizations were established, staffed by professional scientists to research, write, and speak about this scientific evidence, not only in geology, but also in other fields, that resoundingly support the biblical account of our origins and the earth's history.[2] This book is unashamedly the result of the legacy of these pioneers.

However, it would be foolish to think that the task they inspired has been finished. The ranks of full-time and part-time creation scientists and Flood geologists are still meager and thin, and therefore brittle. Furthermore, the modern scientific enterprise has mushroomed, with veritably millions of professional scientists around the globe working in state-of-the-art laboratories with multi-billion dollar budgets to elucidate the workings of the earth and life on it, grounded in the belief that there was no Creator who instantly brought the earth and life on it into existence, but instead all that was needed was time plus chance! Nearly all the world's universities and places of higher learning are dominated by staff scientists and other intellectuals who teach this philosophy. By comparison, the creationist army, and its research and writing efforts, are but like David taking on Goliath. There are now so many fields of science and subdisciplines that require specialist training for their proponents to master, that for the creationist movement to research and write in all of these fields, to bring the evidences they provide under the scrutiny of God's Word, requires a whole army of scientific and other intellectual professionals with renewed vision and energy, plus a sizable budget, to expand and finish the task these pioneers began and this book expands upon.

Furthermore, the present generation of creation scientists and Flood geologists need to be able to pass on the torch, so that the message of the now mushrooming creation and Flood literature is not lost, but instead is built upon and expanded appropriately. I would therefore unashamedly issue a challenge, particularly to young readers who are at the formative stage of their careers, to heed God's call,

1 D. B. Sharp and J. Bergman (compilers), 2008, *Persuaded by the Evidence*, Green Forest, AR: Master Books.

2 H. M. Morris, 1984, *A History of Modern Creationism*, San Diego, CA: Master Books.

and use the intellectual gifts and abilities He has given you, to train in whatever fields of science or intellectual endeavor He may lead you into, so as to join the growing ranks of professional creation scientists and Flood geologists. And I challenge parents, grandparents, and Christians generally, to support our young people to take up the torch, and to dedicate their lives to God's service in every field of scientific and intellectual endeavor from a thoroughly biblical perspective, so that the light of God's Word will shine into every area of human knowledge for His glory.

As a result, Christians will be encouraged in their faith and be able to stand firm in their testimonies, equipped to defend their faith without compromise in any area of science and human endeavor. However, more importantly, the purpose of this task is to remove the stumbling blocks that would hinder people everywhere around the globe from listening and being convicted by the Gospel of our Lord Jesus Christ, so that they too can respond positively and accept the Gospel, and so be restored to fellowship with our Creator.

While this book is as comprehensive as space allows, there are clearly many more aspects of the geological evidences that require further study and research to elucidate them in light of the biblical framework and timescale of earth history. And even those evidences and details that were discussed still require further research so that every detail can be systematized rigorously. Thus, we need in our ranks many more young geologists, geophysicists, and other earth scientists with specialist training in every discipline and subdiscipline, so that all the interlocking pieces of the geological and geophysical puzzle can be elucidated. Only then can we produce the textbooks and curricula that can be used in schools, colleges, and universities for the ongoing training of future generations in the geological and related sciences within the biblical worldview.

POSTSCRIPT

An Eternal Challenge

Without a doubt, the central question of history must be: Who is Jesus Christ?

If there is indeed a Creator God, then He has an identity, and as His creation we all must subject ourselves to His rule. As we have seen throughout the pages of *Earth's Catastrophic Past*, the scientific and biblical evidences point unerringly to the *acts* of creation and the later Flood judgment upon the earth by the Creator, whom the Bible identifies as Jesus Christ.

Jesus the Word

The Bible states clearly that, whether they now recognize Him or not, all people must one day stand before God and answer that question. The apostle John laid the foundation for understanding Christ as Creator and Redeemer:

> In the beginning was the Word and the Word was with God, and the Word was God. The same was in the beginning with God. All things were made by him; and without him was not any thing made that was made ….And the Word was made flesh and dwelt among us (and we beheld his glory, the glory as of the only begotten of the Father,) full of grace and truth. (John 1:1-3, 14)

Paul also reminds us of this same truth, the central truth of history:

> For by him were all things created, that are in heaven, and that are in earth, visible and invisible, whether they be thrones or dominions, or principalities, or powers: all things were created by him and for him. And he is before all things and by him all things consist. (Colossians 1:16-17)

Jesus, the Word (Greek *logos*), the ultimate communication from God, is thus declared to have been, and still is, the Creator of the universe and everything in it.

Jesus the Creator

Yet when He came to this earth and laid aside His heavenly glory, He didn't lay aside His power. He was still fully human, because He suffered weariness and fell asleep in a boat, and pain on a Roman cross and when He was scourged. However, at the same time He never ceased to be the Creator during His earthly pilgrimage. We know this because of the miracles He performed that convinced men and women and children that He was whom He claimed to be, the Creator.

In Matthew 8:23-27 we read that Jesus calmed a raging storm on the Sea of Galilee. He simply stood up in a boat, and with a word of rebuke, there immediately was a great calm instead of a raging storm. His disciples, hardened fishermen, marveled: "What manner of man is this, that even winds and the sea obey him!" Of course, the wind and the sea had to obey Him instantly, because He created them. At a marriage feast Jesus turned water into wine (John 2:1-11). Water consists only of hydrogen and oxygen atoms, whereas wine consists of complex organic molecules. Thus, this was a miracle of creation, Jesus creating wine from just water instantly at His command. On two occasions, Jesus fed 5,000 people and 4,000 men, plus women and children, by simply breaking bread and fish so as to continually multiply them by creating more, as His disciples watched. In John 9:1-7, 32, Jesus healed a man born blind. But this required Jesus not only healing his eyes physically, but also programming his brain at the same time so that he could comprehend what he was physically seeing for the first time. On several occasions—for example, Jairus's daughter (Matthew 9:18-19, 23-26) and Lazarus (John 11:1-46)—Jesus, the Author and Creator of life, who thus had the power over life and death, brought individuals back to life again. Only the Creator of the universe, the earth, and everything in it could do these things.

Jesus the Truth

Jesus also spoke the truth, because He is the Truth. Jesus said: "I am the way, the truth and the life" (John 14:6). If He told us a lie, He couldn't be the Truth, and therefore He couldn't be the Way. In Mark 13:19, Jesus spoke of "the creation which God created." In Mark 10:6 and Matthew 19:4, He said: "From the beginning of the creation God made them male and female." He was in no doubt that everything had been created by God, and that God had created man at the beginning of history, not billions of years later. Jesus also spoke "of the days of Noah" in Matthew 24:37 and Luke 17:26-27, thus recognizing Noah as a real, literal man who lived. He spoke of Noah entering the Ark, and the Flood coming and taking them all away. So Jesus recognized the Flood, the Ark, and Genesis chapter 7 describing those events, as real, literal history. If Jesus was deluded or telling us lies, then He couldn't be the Creator, the Truth, and the Way to Life eternal with God our heavenly Father.

The accusation is often made that if the world is supposed to be young, but it looks old, then God has deceived us. However, Jesus didn't deceive anyone when He created wine from water, created more bread and fish, healed eyes, and raised people from the dead. There was always an eyewitness testimony. Indeed, the eyewitness account is crucial to our understanding of what happened in the past. Thus, if we view the evidence in the present with the wrong assumptions, it will lead us to the wrong interpretations, and the wrong conclusions. Unfortunately, this is exactly what so many people do today. They look at the world and say it looks old, so therefore the Bible is wrong and God has deceived us. Of course, God has not deceived us, because He has told us what happened at the beginning of history in *His* eyewitness account in Genesis. God saw what He had made and said it was very good. He was fully capable of recording and preserving for us His account in the Bible, so we would know what happened at creation with absolute certainty. We should see in the Gospel accounts Jesus' stamp of approval on Genesis as the historical record of the beginning of the earth and its early history. God's timetable for creation was that He spoke the earth into existence. However, if we use the wrong assumptions to interpret the evidence around us, we come to the wrong conclusion that the earth is old, because it has an appearance of age, when in fact God clearly says that the earth is young.

Furthermore, the rock strata may look old, because if we assume geologic processes have always been operating the way they do today, then of course it would have taken a long time to form the rock layers. However, as has been pointed out previously, the apostle Peter reminds us in 2 Peter 3 that latter-day scoffers will be "willingly ignorant that the present is not the key to the past." Indeed, they will be willingly ignorant that God created the earth during a period of six days, when all the processes we are familiar with today were suspended while God created. Then Peter says there was another period during which the rates of all today's processes were suspended again. These scoffers will also deliberately ignore the evidence for the Flood cataclysm. Not only was Jesus the Creator present and active during creation, but He was also present and active during the Flood. It was God who closed the door of the Ark, and God who started the Flood. God was in charge of everything that happened during the Flood. The evidence in the geologic record can be explained in terms of what happened during the Flood, but ultimately God was present in judgment overturning this world and destroying it, then restoring it with a new surface and a new biology afterwards.

Do these issues then matter ultimately, or are they just controversial and divisive? Jesus said in John 5:46-47: "For had ye believed Moses, you would have believed me, for he wrote of me. But if you believe not in his writings, how shall you believe my words?" Which book of the Bible, under the inspiration and direction of God's Holy Spirit, did Moses compile? It is Genesis! Jesus said, if you don't believe what Moses wrote in the book of Genesis, how are you going to believe what He told us. Jesus also said in John 3:12: "If I have told you earthly things, and you believe not, how shall you believe if I tell you of heavenly things?"

Jesus the Redeemer

Let me remind you of the reason why Jesus Christ came to the earth. He came, we are told in Genesis, because of what happened in the Garden of Eden, when man chose to rebel against God. God cursed the ground for man's sake, and as a result death and suffering came into the world. Many would say that Adam only died spiritually, but did Jesus come to just die spiritually? Paul reminds us in 1 Corinthians 15:21-22: "For since by man came death, by man came also the resurrection of the dead. For as in Adam all die, even so in Christ shall all be made alive." Jesus had to physically die, so Adam had to begin dying physically at the Fall (literally "dying you will die," Genesis 2:17).

Jesus died physically on the cross, demonstrating the love of God for us, His grace and mercy, which are so stupendous and mind-boggling, that none other than the Creator Himself, Jesus Christ, came to die for us. What greater measure of the love of God can there be? The Creator of the universe stepped down from heaven's glory to come and die for us (Philippians 2:5-8). In fact, the reason He could die for us was because He was (and is) the Creator. One man can die for one man (Romans 5:17), but only the Creator of the universe could die for all people, in all places, throughout all time. That's why we can be absolutely confident all our sin, our evil deeds and rebellion against God, were nailed to that cross with Him. Because He is the infinite Creator, He could die for all sin, in all places, throughout all time. Furthermore, as the Creator He has power over life and death, as He had demonstrated by His miracles. No man could take His life, so He laid it down willingly Himself. And then, because He had the power to lay it down, He had the power to take it up again. It was guaranteed that if He died, He would rise from the dead. If He wasn't the Creator, how could He do those things? Furthermore, because He is the Creator and rose from the dead, He can guarantee giving us what He has promised—eternal life in heaven with Him and God the Father.

Jesus the Author of Life

Now consider this. If the Creator Jesus Christ used the evolutionary process, as some Christians maintain, then it meant that He had to use death and destruction to bring man into existence, because evolution is said to have involved death and struggle over millions of years, "nature" red in tooth and claw, survival of the fittest. This would have meant He really didn't have the ultimate power over death. He would thus have had to allow death to happen so that He could finally evolve man after millions of years of the deaths of "misfits" and imperfect biological experiments! So how could the cosmic victories of Calvary's cross and the empty tomb then be accomplished? It just doesn't logically follow. If Jesus had the power to create instantly and power over death when He walked the streets of Israel, and He had power over death when He rose from the grave, then He didn't need to use the evolutionary process. Furthermore, Genesis tells us He didn't! Indeed, Adam and Eve weren't walking on a fossil graveyard in the Garden of Eden, because "God saw everything he had made, and, behold, it was very good" (Genesis 1:31). What God declares "very good" is measured against His own holiness, for as Jesus has said: "There is none good but one, that is, God" (Matthew 19:17; Luke 18:19). Death and violence came as a result of the Fall (Romans 5:12; Genesis 3:17-18; Romans 8:20-22), and the wholesale destruction of life by God in judgment came later at the time of the Flood (Genesis 7:21-23). It was sin, not evolution, which brought death into the world.

Jesus the Sovereign

Paul states in Romans 14:10 and 2 Corinthians 5:10 that we must all stand before the judgment seat of Christ. Paul is here speaking to Christians, not about a judgment for our sin, because if we are Christians we are no longer under condemnation because of Jesus paying the penalty for our sin on the cross. Rather, it's the same as in the parable Jesus told about the Master who returned and his servants had to then give an account for how they had faithfully served him in his absence (Matthew 25:14-30; Luke 19:12-24). So one day we are going to have to stand before Jesus and give an account of what we believe and what we have done in this life. It's all too easy to think about others, but what are we going to say when we stand before Jesus Christ? How would we respond to Jesus when He says to us: "You had my written and spoken Word, you had my life's testimony, so why didn't you believe? I declared plainly when I walked the streets of Israel that I was the Creator, and I spoke the truth. Why didn't you believe exactly what I told you in Genesis?"

An Eternal Choice

The challenge then to us is: Do we really, really believe who Jesus Christ is? When we really do believe that He is the all-knowing, all-powerful Creator of the universe, who can do whatever He chooses, when and where He chooses, it must revolutionize how we live, how we think, how we act, and how we understand this world around us. Of course, there are many scientific questions we cannot answer. We will never have all the answers in this life, because we are finite, fallible humans who are subject to mistakes, misunderstandings, and faulty reasoning. But when we go to the Creator Jesus Christ, and we accept that God's authoritative Word and the living *Logos* are His communication to us, then all those unanswered questions pale into insignificance when we recognize who Jesus Christ is.

The tragedy is that so many Christians still choose the "tree of knowledge" (Genesis 3:6) rather than obey the Word of God (Genesis 2:17). They fear man and man's knowledge, forgetting that "the fear of the Lord is the beginning of knowledge" (Proverbs 1:7), and "the fear of the Lord is the beginning of wisdom: and the knowledge of the holy is understanding" (Proverbs 9:10). As Jesus said: "Fear not them which kill the body, but are not able to kill the soul, but rather fear him which is able to destroy both soul and body in hell" (Matthew 10:28).

Indeed, what is the "everlasting Gospel"? "Fear God, and give glory to him; for the hour of his judgment is come: and worship him who made heaven, and earth, and the sea, and the fountains of waters" (Revelation 14:7).

Let's be clear about these issues. The Gospel message itself, the very issue of salvation, is predicated and built on the foundation of who Jesus Christ is, and on what happened back in the Garden of Eden as recorded in the historical account in Genesis. The one cannot be divorced from the other. To be sure, one doesn't have to believe in a literal Genesis to be saved, but one has to answer the question of who Jesus Christ is, and then acknowledge Him as the Lord of the universe, and our Savior and Redeemer.

To those who are not sure whether or not they are a Christian, I challenge you to consider carefully the person of Jesus Christ. Obtain a copy of the Bible, and turn to the book of John to read it from beginning to end. In John 20:30-31 we are told: "And many other signs truly did Jesus in the presence of his disciples which are not written in this book: but these are written, that ye might believe that Jesus is the Christ, the Son of God; and that believing ye might have life through his name."

It is my humble prayer that God will open your mind and heart to the truth of His Word, so that you will acknowledge your sin before a Holy God, who sent His Son, the Creator Jesus Christ, to die for your sin. If you ask for His forgiveness, in His grace and mercy He offers to give us new life, beginning with a new clean heart, so that we may walk in true fellowship once more with our Creator, now and for eternity.

Selected Bibliography

Selected Bibliography

Ager, D. V., 1973, *The Nature of the Stratigraphical Record,* London: MacMillan.

Ager, D. V., 1993, *The New Catastrophism: The Importance of the Rare Event in Geological History*, Cambridge: Cambridge University Press.

Albritton, C. C., 1967, Uniformity, the ambiguous principle, *Uniformity and Simplicity, a Symposium on the Principle on the Uniformity of Nature*, C. C. Albritton, ed., Geological Society of America Special Paper 89: 1-2.

Améglio, L., J.-L. Vigneresse and J. L. Bouchez, 1997, Granite pluton geometry and emplacement mode inferred from combined fabric and gravity data, *Granite: From Segregation of Melt to Emplacement Fabrics*, J. L. Bouchez, D. H. W. Hutton and W. E. Stephens, eds., Dordrecht, The Netherlands: Kluwer Academic Publishers, 199-214.

Arp, H. C., G. Burbidge, F. Hoyle, J. V. Narlikar and N. C. Wickramasinghe, 1990, The extragalactic Universe: an alternative view, *Nature*, 346: 810, 812.

Ashley, G. M. and I. J. Duncan, 1977, The Hawkesbury Sandstone: a critical review of proposed environmental models, *Journal of the Geological Society of Australia*, 24 (2): 117-119.

Austin, S. A., 1979, Uniformitarianism—a doctrine that needs rethinking, *Compass*, 56: 29-45.

Austin, S. A., 1980, Origin of limestone caves, *Acts & Facts*, 9 (1).

Austin, S. A. and D. R. Humphreys, 1990, The sea's missing salt: A dilemma for evolutionists, *Proceedings of the Second International Conference on Creationism*, Volume 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 17-33.

Austin, S. A., ed., 1994, *Grand Canyon, Monument to Catastrophe*, Santee, CA: Institute for Creation Research.

Austin, S. A., J. R. Baumgardner, D. R. Humphreys, A. A. Snelling, L. Vardiman and K. P. Wise, 1994, Catastrophic plate tectonics: A global Flood model of earth history, *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 609-621.

Austin, S. A., 1998, The Declining Power of Post-Flood Volcanoes, *Acts & Facts*, 27 (8).

Austin, S. A., 2000, The pre-Flood/Flood boundary: Correcting significant misunderstandings, *Creation Ex Nihilo Technical Journal*, 14 (2): 59-63.

Baillie, M. G. L., 1992, *Tree-ring Dating and Archaeology*, Chicago: The University of Chicago Press, Chicago.

Ball, M. M., E. A. Shinn and K. W. Stockman, 1967, The geologic effects of Hurricane Donna in south Florida, *Journal of Geology,* 75: 583-597.

Barnes, H. L., ed., 1997, *Geochemistry of Hydrothermal Ore Deposits*, 3rd ed., New York: John Wiley & Sons.

Barnes, T. G., 1971, Decay of the earth's magnetic field and the geochronological implications, *Creation Research Society Quarterly*, 8 (1): 24-29.

Bascom, W., 1959, Ocean waves, *Scientific American*, 201 (2): 80.

Baumgardner, J. R., 1986, Numerical simulation of the large-scale tectonic changes accompanying the Flood, *Proceedings of the First International Conference on Creationism*, vol. 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 17-30.

Baumgardner, J. R., 1990, 3-D finite element simulation of the global tectonic changes accompanying Noah's Flood, *Proceedings of the Second International Conference on Creationism*, vol. 2, R. E. Walsh and C. L. Brooks, eds., Pittsburgh, PA: Creation Science Fellowship, 35-45.

Baumgardner, J. R., 1994, Computer modeling of the large-scale tectonics associated with the Genesis Flood, *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, Pa: Creation Science Fellowship, 49-62.

Baumgardner, J. R. 1994, Runaway subduction as the driving mechanism for the Genesis Flood, *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 63-75.

Baumgardner, J. R., 2003, Catastrophic plate tectonics: the physics behind the Genesis Flood, *Proceedings of the Fifth International Conference on Creationism*, R. Ivey, ed., Pittsburgh, PA: Creation Science Fellowship, 113-126.

Baumgardner, J. R., A. A. Snelling, D. R. Humphreys and S. A. Austin, 2003, Measurable ^{14}C in fossilized organic materials: Confirming the young earth Creation-Flood model, *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 127-147.

Baumgardner, J. R., 2005, ^{14}C evidence for a recent global Flood and a young earth, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 587-630.

Berthault, G., 1986, Experiments on lamination of sediments resulting from a periodic graded-bedding subsequent to deposition—a contribution to the explanation of lamination of various sediments and sedimentary rocks, *Compte Rendus Académie des Sciences, Paris*, 303: 1569-1574.

Berthault, G., 1988, Sedimentation of a heterogranular mixture: experimental lamination in still and running water, *Compte Rendus Académie des Sciences, Paris*. 306: 717-724.

Beus, S. S. and M. Morales, ed., 2003, *Grand Canyon Geology*, 2nd ed., New York: Oxford University Press.

Blakey, R. C., 1979, Stratigraphy of the Supai Group (Pennsylvania-Permian), Mogollon Rim, Arizona, *Carboniferous Stratigraphy in the Grand Canyon Country, Northern Arizona and Southern Nevada*, S. S. Beus and R. R. Rawson, eds., Falls Church, VA: American Geological Institute, 102-108.

Blakey, R. C., 1990, Supai Group and Hermit Formation, *Grand Canyon Geology*, S. S. Beus and M. Morales, eds., New York: Oxford University Press, and Flagstaff: Museum of Northern Arizona Press, 167-168.

Boggs, Jr., S., 1995, *Principles of Sedimentary and Stratigraphy*, 2nd ed., Upper Saddle River, NJ: Prentice Hall.

Brand, L., 1997, *Faith, Reason and Earth History*, Berrien Springs, MI: Andrews University Press.

Brand, L. R. and J. Florence, 1982, Stratigraphic distribution of vertebrate fossil footprints compared with body fossils, *Origins*, 9: 67-74.

Brandon, A. D., T. Chacko and R. A. Creaser, 1996, Constraints on granitic magma transport from epidote dissolution kinetics, *Science*, 271: 1845-1848.

Briggs, D. E. G., D. H. Erwin and F. J. Collier, 1994, *The Fossils of the Burgess Shale*, Washington and London: Smithsonian Institution Press.

Broadhurst, F. M., 1964, Some aspects of the paleoecology of non-marine faunas and rates of sedimentation in the Lancashire coal measures, *American Journal of Science*, 262: 865.

Brooks, J. D. and J. W. Smith, 1969, The diagenesis of plant lipids during the formation of coal, petroleum and natural gas. II. Coalification and the formation of oil and gas in the Gippsland Basin, *Geochimica et Cosmochimica Acta*, 33: 1183-1194.

Brown, M. and T. Rushmer, 1997, The role of deformation in the movement of granitic melt: Views from the laboratory and the field, *Deformation-Enhanced Fluid Transport in the Earth's Crust and Mantle*, M. Holness, ed., London: Chapman and Hall, 111-144.

Bürgin, T., O. Rieppel, P. M. Sander and K. Tschanz, 1989, The fossils of Monte San Giorgio, *Scientific American*, 260 (6): 50-57.

Candela, P. A., 1991, Physics of aqueous phase evolution and plutonic environments, *American Mineralogist*, 76: 1081-1091.

Cathles III, L. M. and J. J. Adams, 2005, Fluid flow and petroleum and mineral resources in the upper (<28-km) continental crust, *Economic Geology: 100th Anniversary Volume*, J. W. Hedenquist, J. F. H. Thompson, R. J. Goldfarb, and J. P. Richards, eds., Littleton, CO: Society of Economic Geologists, 77-110.

Chapman, R. E., 1983, *Petroleum Geology*, Amsterdam: Elsevier.

Charlesworth, J. K., 1957, *The Quaternary Era*, London: Edward Arnold.

Chown, M., 1994, Birth of the universe, Inside Science 69: 1, *New Scientist*, 141 (1914).

Clemens, J. B. and C. K. Mawer, 1992, Granitic magma transport by fracture propagation, *Tectonophysics*, 204: 339-360.

Clemens, J. D., N. Petford and C. K. Mawer, 1997, Ascent mechanisms of granitic magmas: Causes and consequences, *Deformation-Enhanced Fluid Transport in the Earth's Crust and Mantle*, M. Holness, ed., London: Chapman and Hall, 145-172.

Clemens, J. D. and N. Petford, 1999, Granitic melt viscosity and silicic magma dynamics in contrasting tectonic settings, *Journal of the Geological Society*, London, 156: 1057-1060.

Clemens, J. D., 2005, Granites and granitic magmas: Strange phenomena and new perspectives on some old problems, *Proceedings of the Geologists' Association*, 116: 9-16.

Coffin, H. G., 1983, The Yellowstone Petrified "Forests," *Origins by Design*, Washington, DC: Review and Herald Publishing Association, 134-151.

Coffin, H. G., 1997, The Yellowstone Petrified "Forests," *Origins* (Geoscience Research Institute), 24 (1): 5-44.

Cohen, A. D., 1970, An allochthonous peat deposit from southern Florida, *Geological Society of America Bulletin*, 81: 2477-2482.

Conaghan, P. J., 1980, The Hawkesbury Sandstone: gross characteristics and depositional environment, *A Guide to the Sydney Basin*, C. Herbert and R. Helby, ed., Geological Survey of New South Wales, Bulletin 26, 188-253.

Conolly, J. R., 1969, Models for Triassic deposition in the Sydney Basin, *Special Publications of the Geological Society of Australia*, 2: 209-223.

Cowen, R., 1990, *History of Life*, Boston: Blackwell Scientific Publications.

Cruden, A. R., 1998, On the emplacement of tabular granites, *Journal of the Geological Society*, London, 155: 853-862.

David, T. W. E., 1907, The geology of the Hunter River coal measures, New South Wales, *Geological Survey of New South Wales, Memoir 4.*

Davidson, J., W. E. Reed, and P. M. Davis, 1997, *Exploring Earth: An Introduction to Physical Geology*, Upper Saddle River, NJ: Prentice Hall.

Davies, K., 1994, Distribution of supernova remnants in the galaxy, *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 175-184.

Davis, E. L., S. R. Hart and G. R. Tilton, 1968, Some effects of contact metamorphism on zircon ages, *Earth and Planetary Science Letters*, 5: 27-34.

Deevey, E. S., 1960, The human population, *Scientific American*, 203 (3): 194-204.

DePaolo, D. J., 1988, *Neodymium Isotope Geochemistry: An Introduction*, Berlin: Springer-Verlag.

Dickin, A. P., 2005, *Radiogenic Isotope Geology*, 2nd ed., Cambridge, UK: Cambridge University Press.

Dickson, B. L., B. L. Gulson and A. A. Snelling, 1985, Evaluation of lead isotopic methods for uranium exploration, Koongarra area, Northern Territory, Australia, *Journal of Geochemical Exploration*, 24: 81-102.

Dickson, B. L., B. L. Gulson and A. A. Snelling, 1987, Further assessment of stable lead isotope measurements for uranium exploration, Pine Creek Geosyncline, Northern Territory, Australia, *Journal of Geochemical Exploration*, 27: 63-75.

Diessel, C. F. K., 1992, *Coal-bearing Depositional Systems*, Berlin: Springer-Verlag.

Dill, R. F. and R. Steinen, 1988, Deposition of carbonate mud beds within high-energy subtidal sand dunes, Bahamas, *American Association of Petroleum Geologists Bulletin* 72: 178-179.

Dillow, J. C., 1981, *The Waters Above: Earth's Pre-Flood Vapor Canopy*, Chicago: Moody Press.

Eyles, N., 1993, Earth's glacial record and its tectonic setting, *Earth-Science Reviews*, 35: 1-248.

Eyles, N. and N. Januszczak, 2004, "Zipper-rift": A tectonic model for Neoproterozoic glaciations during the breakup of Rodinia after 750 Ma, *Earth-Science Reviews*, 65: 1-73.

Faure, G. and J. L. Powell, 1972, *Strontium Isotope Geology*, Berlin: Springer-Verlag.

Faure, G. and T. M. Mensing, 2005, *Isotopes: Principles and Applications*, 3rd ed., Hoboken, NJ: John Wiley & Sons.

Flint, R. F., 1957, *Glacial and Pleistocene Geology*, New York: John Wiley and Sons.

Flügel, H. W. and T. Faupl, eds., 1987, *Geodynamics of the Eastern Alps*, Vienna: Franz Deuticke.

Garner, P., 1996, Where is the Flood/post-Flood boundary? Implications of dinosaur nests in the Mesozoic, *Creation Ex Nihilo Technical Journal*, 10 (1): 101-106.

Garner, P., 1996, Continental Flood basalts indicate a pre-Mesozoic Flood/post-Flood boundary, *Creation Ex Nihilo Technical Journal*, 10 (1): 114-127.

Garton, M., 1996, The pattern of fossil tracks in the geological record, *Creation Ex Nihilo Technical Journal*, 10 (1): 82-100.

Gastaldo, R. A., 1999, Debates on autochthonous and allochthonous origin of coal: empirical science versus the diluvialists, *The Evolution-Creation Controversy II: Perspectives on Science, Religion, and Geological Education*, W.L. Manger, ed., The Palaeontological Society Papers, 5: 135-167.

Gentry, R. V., 1973, Radioactive halos, *Annual Review of Nuclear Science*, 23: 342-362.

Gentry, R. V., 1988, *Creation's Tiny Mystery*, Knoxville, TN: Earth Science Associates.

George, A. M., 1975, Brown coal lithotypes in the Latrobe Valley deposits, *State Electricity Commission of Victoria, Petrological Report,* 17: 32-35.

Giem, P., 2001, Carbon-14 content of fossil carbon, *Origins (Geoscience Research Institute)*, 51: 6-30.

Gould, S. J., 1965, Is uniformitarianism necessary? *American Journal of Science,* 263: 223-228.

Halliwell, J. J., 1991, Quantum cosmology and the creation of the universe, *Scientific American*, 265 (6): 28, 35.

Hambrey, M. J. and W. B. Harland, eds., 1981, *Earth's Pre-Pleistocene Glacial Record*, London: Cambridge University Press.

Hancock, J. M., 1975, The petrology of the chalk, *Proceedings of the Geologists' Association*, 86 (4): 499-535.

Harris, N., D. Vance and M. Ayres, 2000, From sediment to granite: Timescales of anatexis in the upper crust, *Chemical Geology*, 162: 155-167.

Harrison, T. M. and I. McDougall, 1980, Investigations of an intrusive contact, north-west Nelson, New Zealand—II. Diffusion of radiogenic and excess ^{40}Ar in hornblende revealed by ^{40}Ar/^{39}Ar age spectrum analysis, *Geochimica et Cosmochimica Acta*, 44: 2005-2030.

Hart, S. R., 1964, The petrology and isotopic-mineral age relations of a contact zone in the Front Range, Colorado, *Journal of Geology*, 72: 493-525.

Hedenquist, J. W., J. F. H. Thompson, R. J. Goldfarb, and J. P. Richards, eds., 2005, *Economic Geology: 100th Anniversary Volume*, Littleton, CO: Society of Economic Geologists.

Henwood, A., 1993, Still life in amber, *New Scientist,* 137 (1859): 31-34.

Hills, J. H. and J. R. Richards, 1976, Pitchblende and galena ages in the Alligator Rivers Region, Northern Territory, Australia, *Mineralium Deposita*, 11: 133-154.

Hoffman, P. F. and D. P. Schrag, 2002, The snowball earth hypothesis: Testing the limits of global change, *Terra Nova*, 14: 129-155.

Holmes, A., 1965, *Principles of Physical Geology*, 2nd ed., London: Thomas Nelson and Sons.

Holt, R. D., 1996, Evidence for a late Cainozoic Flood/post-Flood boundary, *Creation Ex Nihilo Technical Journal*, 10 (1): 128-167.

Hovland, M., H. G. Rueslåtten, H. K. Johnsen, B. Kvanne and T. Kuznetsova, 2006, Salt formation associated with sub-surface boiling and supercritical water, *Marine and Petroleum Geology*, 23: 855-869.

Hubbert, M. K., 1967, Critique of the principle of uniformity, *Uniformity and Simplicity, a Symposium on the Principle of the Uniformity of Nature*, C. C. Albritton, Jr, ed., Geological Society of America Special Paper 89: 3-33.

Humphreys, D. R., 1986, Reversal of the earth's magnetic field during the Genesis Flood, *Proceedings of the First International Conference on Creationism*, Volume 2, R. E. Walsh, C. L. Brooks and R. S. Crowell, eds., Pittsburgh, PA: Creation Science Fellowship, 113-126.

Humphreys, D. R., 2000, Accelerated nuclear decay: A viable hypothesis?, *Radioisotopes and the Age of the Earth: A Young Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 333-379.

Humphreys, D. R., 2005, Young helium diffusion age of zircons supports accelerated nuclear decay, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research, and Chino Valley, AZ: Creation Research Society, 25-100.

Hutton, D. H. W., 1988, Granite emplacement mechanisms and tectonic controls: Influences from deformation studies, *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 79: 245-255.

Karlstrom, K. E., S. A. Bowring, C. M. Dehler, A. H. Knoll, S. M. Porter, D. J. Des Marai, A. B. Weil, Z. D. Sharp, J. W. Geissman, M. A. Elrick, J. M. Timmons, L. J. Crossey and K. L. Davidek, 2000, Chuar Group of the Grand Canyon: Record of breakup of Rodinia, associated change in the global carbon cycle, and ecosystem expansion by 740 Ma, *Geology*, 28 (7): 619-622.

Kennett, J. P., R. E. Houtz, P. B. Andrews, A. R. Edwards, V. A. Gostin, M. Hajos, M. Hampton, D. G. Jenkins, S. V. Margolis, A. T. Ovenshine and K. Perch-Neilson, 1975, Site 284*, Initial Reports of the Deep Sea Drilling Project, 29*, J. P. Kennett et al, eds., Washington, DC: U.S. Government Printing Office, 403-445.

Kennett, J. P., 1982, *Marine Geology*, Englewood Cliffs, NJ: Prentice-Hall.

Kirkham, R. V., W. B. Sinclair, R. I. Thorpe and A. M. Duke, eds., 1993, *Mineral Deposit Modeling*, Geological Association of Canada Special Paper 40.

Knapp, R. B. and D. Norton, 1981, Preliminary numerical analysis of processes related to magma crystallization and stress evolution in cooling plutons environments, *American Journal of Science*, 281: 35-68.

Krauskopf, K. B., 1967, *Introduction to Geochemistry*, New York: McGraw-Hill.

Kröner, A., P. J. Jaeckel and I. S. Williams, 1994, Pb-loss patterns in zircons from a high-grade metamorphic terrain as revealed by different dating methods, U-Pb and Pb-Pb ages for igneous and metamorphic zircons from northern Sri Lanka, *Precambrian Research*, 66: 151-181.

Krumbein, W. C. and L. L. Sloss, 1963, *Stratigraphy and Sedimentation*, 2nd ed., San Francisco, CA: W. H. Freeman and Company.

Levorsen, A. I., 1967, *Geology of Petroleum*, 2nd ed., San Francisco, CA: W. H. Freeman and Company.

Lyell, C., 1844, On the upright fossil-trees found at different levels in the coal strata of Cumberland, Nova Scotia, *Annals and Magazine of Natural History, Companion: Botanical Magazine N.S.*, 17: 148-151.

Lyell, C., 1872, *Principles of Geology*, 11th ed., vol. 1, London: John Murray.

McCaffrey, K. J. W. and N. Petford, 1997, Are granitic intrusions scale invariant?, *Journal of the Geological Society*, London, 154: 1-4.

McCulloch, M. T. and B. W. Chappell, 1982, Nd isotopic characteristics of S- and I-type granites, *Earth and Planetary Science Letters*, 58: 51-64.

McKee, E. D. and R. G. Gutschick, 1969, History of the Redwall Limestone in northern Arizona, *Geological Society of America Memoir* 114.

McKee, E. D., 1979, Characteristics of the Supai Group in Grand Canyon, Arizona, *Carboniferous Stratigraphy in the Grand Canyon Country, Northern Arizona and Southern Nevada*, S. S. Beus and R. R. Rawson, eds., Falls Church, VA: American Geological Institute, 105-113.

McKee, E. D., 1982, *The Supai Group of Grand Canyon*, U.S. Geological Survey Professional Paper 1173: 1-504.

Middleton, L. T. and D. K. Elliott, 2003, Tonto Group, *Grand Canyon Geology*, 2nd ed., S. S. Beus and M. Morales, eds., New York: Oxford University Press, 90-106.

Miller, M. F. and C. W. Byers, 1984, Abundant and diverse early Paleozoic infauna indicated by the stratigraphical record, *Geology,* 12: 40-43.

Nadon, G. C., 1998, Magnitude and timing of peat-to-coal compaction, *Geology,* 26 (8): 727-730.

Neuendorf, K. K. E., J. P. Mehl Jr., and J. A. Jackson, eds., 2005, *Glossary of Geology*, 5th ed., Falls Church, Virginia: American Geological Institute.

Nisbet, E. G. and D. J. W. Piper, 1998, Giant submarine landslides, *Nature,* 392: 329-330.

Oard, M. J., 1990, *An Ice Age caused by the Genesis Flood*, El Cajon, CA: Institute for Creation Research.

Oard, M. J., 1997, *Ancient Ice Ages or Gigantic Submarine Landslides?*, Creation Research Society Monograph Series No. 6.

Palmer, A. N., 1991, Origin and morphology of limestone caves, *Geological Society of America Bulletin*, 103: 1-21.

Pant, D. D., 1977, The plant of *Glossopteris*, *The Journal of the Indian Botanical Society*, 56 (1): 1-23.

Patton, R. T., 1958, Fossil wood from Victorian brown coal, *Proceedings of the Royal Society of Victoria*, 70 (2): 129-143.

Petford, N., R. C. Kerr and J. R. Lister, 1993, Dike transport of granitoid magmas, *Geology*, 21: 845-848.

Petford, N. and J. D. Clemens, 2000, Granites are not diapiric!, *Geology Today*, 16 (5): 180-184.

Petford, N., A. R. Cruden, K. J. W. McCaffrey and J. L. Vigneresse, 2000, Granite magma formation, transport and emplacement in the earth's crust, *Nature*, 408: 669-673.

Pettijohn, F. J., 1957, *Sedimentary Rocks*, 2nd ed., New York: Harper & Row.

Pickles, C. S., S. P. Kelley, S. M. Reddy and J. Wheeler, 1997, Determination of high spatial resolution argon isotope variations in metamorphic biotites, *Geochimica et Cosmochimica Acta*, 61: 3809-3833.

Pitcher, W. S., 1993, *The Nature and Origin of Granites*, London: Blackie Academic and Professional.

Plimer, I. R., 1994, *Telling Lies for God*, Sydney, Australia: Random House.

Polyak, V. J., 1998, W. C. McIntosh, N. Güven and P. Provencio, Age and origin of Carlsbad Cavern and related caves from $^{40}Ar/^{39}Ar$ of alunite, *Science*, 279: 1919-1922.

Porfir'ev, V. B., 1974, Geology and genesis of salt formations, *American Association of Petroleum Geologists Bulletin*, 58: 2543-2544.

Roberts, R. G. and P. A. Sheahan, eds., 1988, *Ore Deposit Models*, Geoscience Canada, reprint series 3, Geological Association of Canada.

Robinson, S. J., 1996, Can Flood geology explain the fossil record?, *Creation Ex Nihilo Technical Journal*, 10 (1): 32-69.

Rollison, H., 1993, *Using Geochemical Data: Evaluation, Presentation, Interpretation*, Harlow, UK: Longman.

Roth, A. A., 1998, *Origins: Linking Science and Scripture*, Hagerstown, MD: Review and Herald Publishing Association.

Rouchy, J. M. and A. Caruso, 2006, The Messinian Salinity Crisis in the Mediterranean Basin: A reassessment of the data and an integrated scenario, *Sedimentary Geology*, 188-189: 35-67.

Rubin, D. M. and D. S. McCulloch, 1980, Single and superimposed bedforms: a synthesis of San Francisco Bay and flume observations, *Sedimentary Geology*, 26: 207-231.

Rupke, N. A., 1966, Prolegomena to a study of cataclysmal sedimentation, *Creation Research Society Quarterly*, 3: 16-37.

Sadler, P. M., 1981, Sediment accumulation rates and the completeness of stratigraphic sections, *Journal of Geology*, 89: 569-584.

Sawyer, E. W., 1991, Disequilibrium melting and rate of melt-residuum separation during migmatization of mafic rocks from Grenville Front, Quebec, *Journal of Petrology*, 32: 701-738.

Sayles, F. L., and P. C. Mangelsdorf, 1979, Cation-exchange characteristics of Amazon with a suspended sediment and its reaction with seawater, *Geochimica et Cosmochimica Acta*, 43: 767-779.

Schermerhorn, L. J. G., 1974, Late Precambrian mixtites: glacial and/or non-glacial? *American Journal of Science,* 74: 673-824.

Schermerhorn, L. J. G., 1975, Tectonic framework of Late Precambrian supposed glacials, *Ice Ages: Ancient and Modern*, A. E. Wright and F. Moseley, eds., Liverpool, UK: Seel House Press, 241-274.

Scheven, J., 1981, Floating forests on firm grounds: advances in Carboniferous research, *Biblical Creation*, 3 (9): 36-43.

Scheven, J., 1992, *Gleanings from Glossopteris*, Fifth European Creationist Congress, Biblical Creation Society and Creation Science Movement, England.

Scheven, J., 1996, The Carboniferous floating forest—an extinct pre-Flood ecosystem, *Creation Ex Nihilo Technical Journal*, 10 (1): 70-81.

Scott, A. C. and J. H. Calder, 1994, Carboniferous fossil forests, *Geology Today*, 10 (6): 213-217.

Selley, R. C., 1975, *Ancient Sedimentary Environments and Their Sub-Surface Diagnosis*, 3rd ed., Ithaca, NY: Cornell University Press.

Shackleton, J. J. and J. P. Kennett, 1975, Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: oxygen and carbon isotope analysis in DSDP sites 277, 279, and 281, *Initial Reports of the Deep Sea Drilling Project, 29*, J. P. Kennett et al eds., Washington, DC: U.S. Government Printing Office, 743-755.

Shea, J. H., 1982, Editorial: Uniformitarianism and sedimentology, *Journal of Sedimentary Petrology,* 52: 701-702.

Shea, J. H., 1982, Twelve fallacies of uniformitarianism, *Geology*, 10: 455-460.

Sheahan, P. A. and M. E. Cherry, eds., 1993, *Ore Deposit Models: Volume II*, Geoscience Canada Reprint Series 6, The Geological Association of Canada.

Shinn, E. A, R. P. Steinen, R. F. Dill and R. Major 1993, Lime-mud layers in high-energy tidal channels: a record of hurricane deposition, *Geology*, 21: 603-606.

Sigleo, A. C., 1978, Organic geochemistry of silicified wood, Petrified Forest National Park, Arizona, *Geochimica et Cosmochimica Acta*, 42: 1397-1405.

Snelling, A. A. and S. A. Austin, 1992, Startling evidence for Noah's Flood! Footprints and sand "dunes" in a Grand Canyon sandstone, *Creation Ex Nihilo*, 15 (1): 46-51.

Snelling, A. A., 1994, Towards a creationist explanation of regional metamorphism, *Creation Ex Nihilo Technical Journal*, 8 (1): 51-77.

Snelling, A. A., 1997, Radioactive "dating" in conflict! Fossil wood in ancient lava flows yields radiocarbon, *Creation Ex Nihilo*, 20 (1): 24-27.

Snelling, A. A., 1998, Stumping old-age dogma: Radiocarbon in an "ancient" fossil tree stump casts doubt on traditional rock/fossil dating, *Creation Ex*

Nihilo, 20 (4): 48-51.

Snelling, A. A., 1999, Dating dilemma: Fossil wood in "ancient" sandstone, *Creation Ex Nihilo*, 21 (3): 39-41.

Snelling, A. A., 2000, Conflicting "ages" of Tertiary basalt and contained fossilized wood, Crinum, central Queensland, Australia, *Creation Ex Nihilo Technical Journal*, 14 (2): 99-122.

Snelling, A. A., 2000, Geological conflict: Young radiocarbon dating for ancient fossil wood challenges fossil dating, *Creation Ex Nihilo*, 22 (2): 44-47.

Snelling, A. A., 2000, Radiohalos, *Radioisotopes and the Age of the Earth: A Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and St. Joseph, MO: Creation Research Society, 381-468.

Snelling, A. A. and M. H. Armitage, 2003, Radiohalos—A tale of three plutons, *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 243-267.

Snelling, A. A., S. A. Austin and W. A. Hoesch, 2003, Radioisotopes in the diabase sill (upper Precambrian) at Bass Rapids, Grand Canyon, Arizona: An application and test of the isochron dating method, in *Proceedings of the Fifth International Conference on Creationism*, R. L. Ivey, Jr., ed., Pittsburgh, PA: Creation Science Fellowship, 269-284.

Snelling, A. A., 2005, Fission tracks in zircons: Evidence for abundant nuclear decay, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 209-324.

Snelling, A. A., 2005, Isochron discordances and the role of inheritance and mixing of radioisotopes in the mantle and crust, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 393-524.

Snelling, A. A., 2005, Radiohalos in granites: Evidence for accelerated nuclear decay, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, L. Vardiman, A. A. Snelling and E. F. Chaffin, eds., El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society, 101-207.

Snelling, A. A., 2006. Confirmation of rapid metamorphism of rocks. *Acts & Facts*. (35) 2.

Snelling, A. A., 2008, Radiocarbon in "ancient" fossil wood, *Acts & Facts*, 37 (1): 10-13.

Snelling, A. A., 2008, Radiocarbon ages for fossil ammonites and wood in Cretaceous strata near Redding, California, *Answers Research Journal*, 1: 123-144.

Snelling, A. A., 2008, Significance of highly discordant radioisotope dates for Precambrian amphibolites in Grand Canyon, USA, in *Proceedings of the Sixth International Conference on Creationism*, A. A. Snelling, ed., Pittsburgh, PA: Creation Science Fellowship and Dallas, TX: Institute for Creation Research, 407-424.

Snelling, A. A., 2008, Testing the hydrothermal fluid transport model for polonium radiohalo formation: The Thunderhead Sandstone, Great Smoky Mountains, Tennessee-North Carolina, *Answers Research Journal*, 1: 53-64.

Sozansky, V. I., 1973, Origin of salt deposits in deep-water basins of the Atlantic Ocean, *American Association of Petroleum Geologists Bulletin*, 57 (3): 589-590.

Spera, F. J., 1982, Thermal evolution of plutons: A parameterized approach, *Science*, 207: 299-301.

Stach, E., M.-Th. Mackowsky, M. Teichmüller, G. H. Taylor, D. Chandra and R. Teichmüller, 1982, *Stachs' Textbook of Coal Petrology*, 3rd revised and enlarged ed., Berlin: Gebrüder Borntraeger.

Standard, J. C., 1969, Hawkesbury Sandstone, in The Geology of New South Wales, G. H. Packham, ed., *Journal of the Geological Society of Australia*, 16 (1): 407-417.

Stanton, R. L., and J. P. Vaughan, 1979, Facies of ore formation: A preliminary account of the Pegmont deposit as an example of potential relations between small 'iron formations' and stratiform sulphides ores, *Proceedings of the Australasian Institute of Mining and Metallurgy*, 270: 25-38.

Stanton, R. L., 1982, An alternative to the Barrovian interpretation? Evidence from stratiform ores, *Proceedings of the Australasian Institute of Mining and Metallurgy*, 282: 11-32.

Stanton, R. L., 1983, The direct derivation of sillimanite from a kaolinitic precursor: Evidence from the Geco Mine, Manitouwadge, Ontario, *Economic Geology*, 78: 422-437.

Stanton, R. L., 1989, The precursor principle and the possible significance of stratiform ores and related chemical sediments in the elucidation of processes of regional metamorphic mineral formation, *Philosophical Transactions of the Royal Society of London*, A328: 529-646.

Stearn, C. W. and R. L Carroll, 1989, *Paleontology: The Record of Life*, New York: John Wiley and Sons, Inc.

Steinen, R., 1978, On the diagenesis of lime mud: scanning electron microscopic observations of subsurface material from Barbados, W.I., *Journal of Sedimentary Petrology,* 48: 1140.

Strahler, E. N., 1987, *Science and Earth History—the Evolution/Creation Controversy*, Buffalo, NY: Prometheus Books.

Sujkowski, Z. L., 1958, Diagenesis, *Bulletin of the American Association of Petroleum Geologists*, 42: 2694.

Sun, S. S., 1980, Lead isotopic study of young volcanic rocks from mid-ocean ridges, ocean islands and island arcs, *Philosophical Transactions of the Royal Society of London*, A297: 409-445.

Thompson, A. B., 1999, Some time-space relationships for crustal melting and granitic intrusion at various depths, *Understanding Granites: Integrating New and Classical Techniques*, A. Castro, C. Fernández and J.-L. Vigneresse, eds., Special Publication 168, The Geological Society, London, 7-25.

Thornbury, W. D., 1969, *Principles of Geomorphology*, 2nd ed., New York: Wiley.

Tissot, B. P. and D. H. Welte, 1978, *Petroleum Formation and Occurrence: A New Approach to Oil and Gas Exploration*, Berlin: Springer-Verlag.

Tissot, B. P. and D. H. Welte, 1984, *Petroleum Formation and Occurrence*, 2nd ed., Berlin: Springer-Verlag.

Van Andel, T. H., 1981, Consider the incompleteness of the geological record, *Nature*, 294: 397-398.

Vardiman, L., 1993, *Ice Cores and the Age of the Earth*, El Cajon, CA: Institute for Creation Research.

Vardiman, L., 1994, An analytic young-earth flow model of ice sheet formation during the "Ice Age," *Proceedings of the Third International Conference on Creationism*, R. E. Walsh, ed., Pittsburgh, PA: Creation Science Fellowship, 561-579.

Vardiman, L., 1996, *Sea-Floor Sediment and the Age of the Earth*, El Cajon, CA: Institute for Creation Research.

Vardiman, L., A. A. Snelling and E. F. Chaffin, eds., 2000, *Radioisotopes and the Age of the Earth,* El Cajon, CA: Institute for Creation Research, and St Joseph, MO: Creation Research Society.

Vardiman, L., 2001, A vapor canopy model, *Climates Before and After the Flood: Numerical Models and their Implications,* El Cajon, CA: Institute for Creation Research.

Vardiman, L., A. A. Snelling and E. F. Chaffin, eds., 2005, *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*, El Cajon, CA: Institute for Creation Research and Chino Valley, AZ: Creation Research Society.

Visher, G. S., 1990, *Exploration Stratigraphy*, 2nd ed., Tulsa, OK: Penn Well Publishing Co..

Whitcomb J. C., and H. M. Morris, 1961, *The Genesis Flood: The Biblical Record and Its Scientific Implications*, Philadelphia, PA: Presbyterian and Reformed Publishing Company.

Whitcomb, Jr., J. C., 1986, *The Early Earth*, revised ed., Grand Rapids, MI: Baker Book House.

White, M. E., 1986, *The Greening of Gondwana*, Sydney: Reed Books.

Wiesner, M. G., Y. Wang and L. Zheng, 1995, Fallout of volcanic ash to the deep South China Sea induced by the 1991 eruption of Mount Pinatubo (Philippines), *Geology*, 23: 885-888.

Wilkins, R. W. T. and S. C. George, 2002, Coal as a source rock for oil: A review, *International Journal of Coal Geology*, 50: 317-361.

Williams, L. D., 1979, An energy balance model of potential glacierization of northern Canada, *Arctic and Alpine Research*, 11: 443-456.

Wingate, M. T. D. and W. Compston, 2000, Crystal orientation effects during ion microprobe, U-Pb analysis of baddeleyite, *Chemical Geology*, 168: 75-97.

Winkler, H. G. F., 1979, *Petrogenesis of Metamorphic Rocks*, 5th ed., New York: Springer-Verlag.

Wise, K. P., 2002, *Faith, Form, and Time*, Nashville, TN: Broadman and Holman Publishers.

Wise, K. P. and A. A. Snelling, 2005, A note on the pre-Flood/Flood boundary in the Grand Canyon, *Origins (Geoscience Research Institute)*, 58: 7-29.

Wonderly, D. E., 1977, *God's Time-Records in Ancient Sediments*, Flint, MI: Crystal Press.

Wonderly, D. E., 1987, *Neglect of Geologic Data: Sedimentary Strata Compared with Young-Earth Creationist Writings*, Hatfield, PA: Interdisciplinary Biblical Research Institute.

Woodmorappe, J., 2001, The rapid formation of granitic rocks: More evidence, *TJ*, 15 (2): 122-125.

Yoder, H. S., 1952, The MgO-Al_2O_3-SiO_2-H_2O system and related metamorphic facies, *American Journal of Science*, Bowen Volume: 569-627.

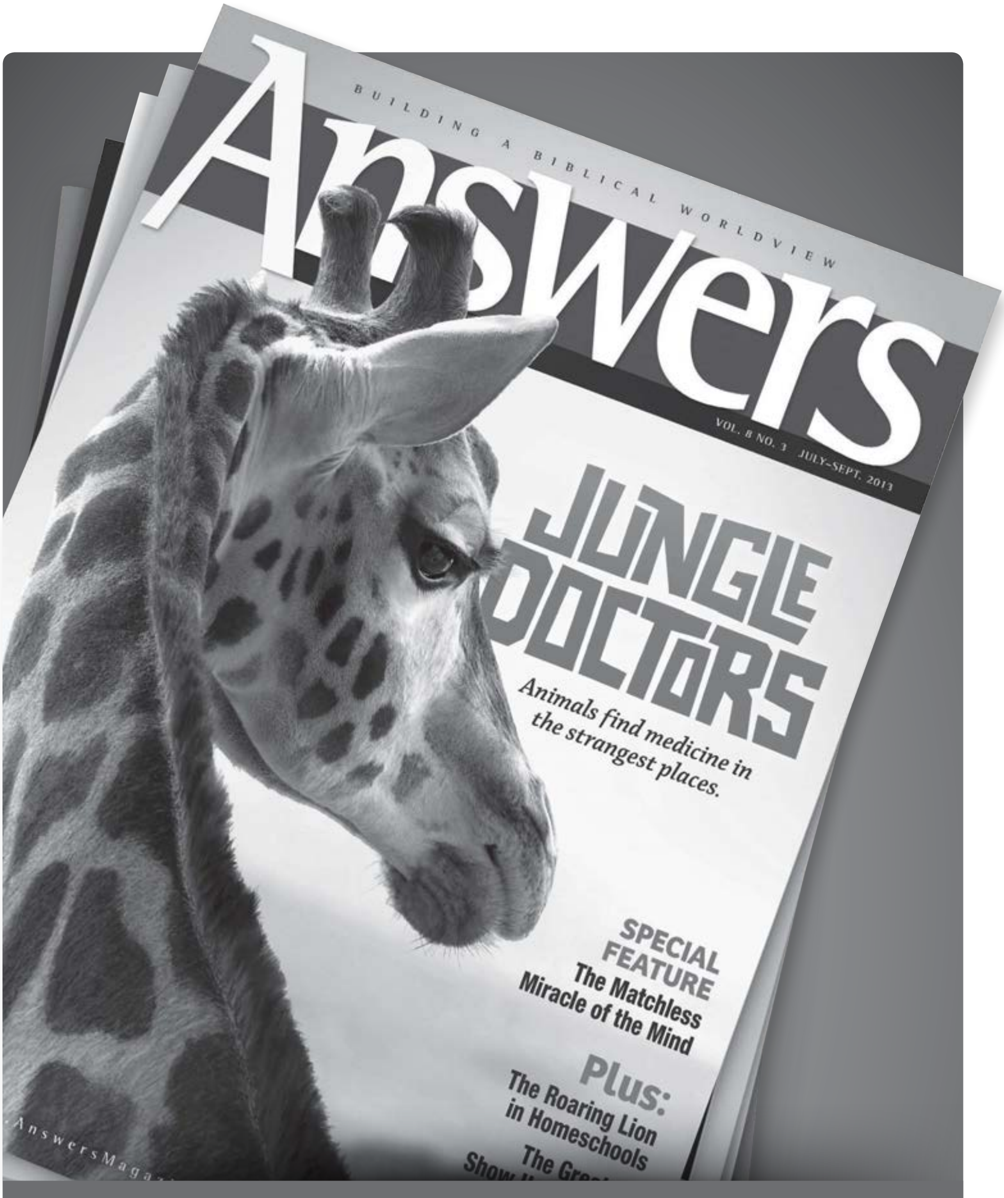
Young, D. A., 1990, The Discovery of Terrestrial History, *Portraits of Creation*, H. J. Van Till, R. E. Snow, J. H. Stek and D. A. Young, eds., Grand Rapids, MI: William B. Eerdmans.

Young, E. J., 1964, *Studies in Genesis 1*, Philadelphia, PA: Presbyterian and Reformed Publishing Company.

Zheng, Y.-F., 1989, Influences of the nature of the initial Rb-Sr system of isochron validity, *Chemical Geology*, 80: 1-16.

Topical Index

Topical Index


Answers
BUILDING A BIBLICAL WORLDVIEW
VOL. 8 NO. 3 JULY–SEPT. 2013
JUNGLE DOCTORS
Animals find medicine in the strangest places.
SPECIAL FEATURE
The Matchless Miracle of the Mind
Plus:
The Roaring Lion in Homeschools

Notes

Notes

Notes

Color Figures

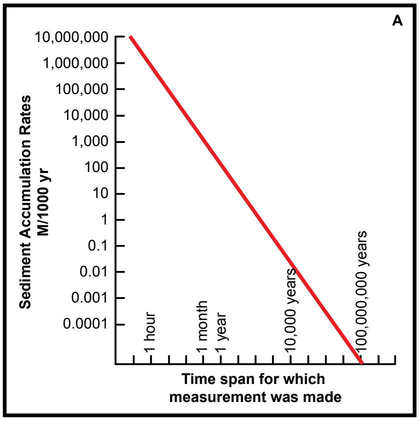


Figure 39. Relationship between sedimentation rates and the timespan over which the measurements were taken, showing average sedimentation rates on a log/log scale (after Sadler, 1981).

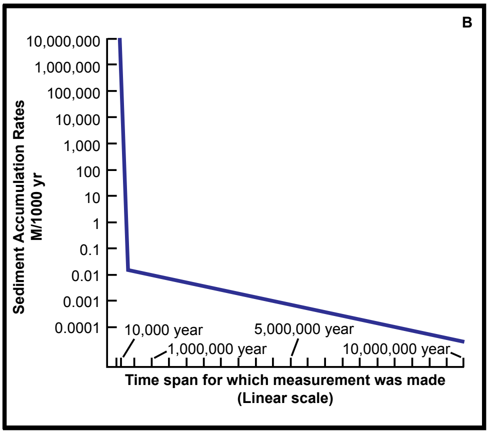


Figure 40. Relationship between sedimentation rates and the timespan over which the measurements were taken, showing the same data as in Figure 39, but with time plotted on a linear scale (after Sadler, 1981).

Figure 41. The Coconino Sandstone in the Grand Canyon is a horizontal sandstone layer up to 300 feet thick, but within it are these highly visible inclined beds called cross-beds.

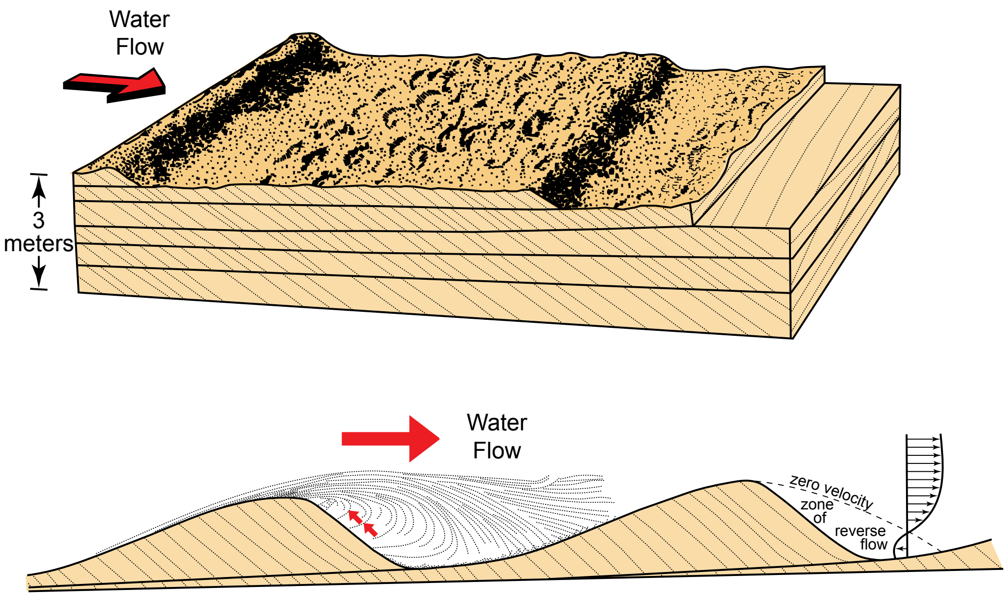


Figure 42. The formation of cross-beds on a sandy ocean floor, from the migration of sand waves (underwater sand dunes) in response to sustained water flow. Top: Block diagram showing the form of the small sand waves on the shallow ocean floor that produce tabular cross-beds beneath the sustained water flow by the down-current migration of the sand waves. Bottom: Cross-sectional diagram (with vertical exaggeration to show detail) of how a sand wave moves and accumulates. Erosion of sand occurs on the up-current surface of the sand wave, and the sand grains accumulate as inclined beds on the down-current surface of the sand wave in the "zone of reverse flow" (after Austin, 1994, 33, Figure 3.11).

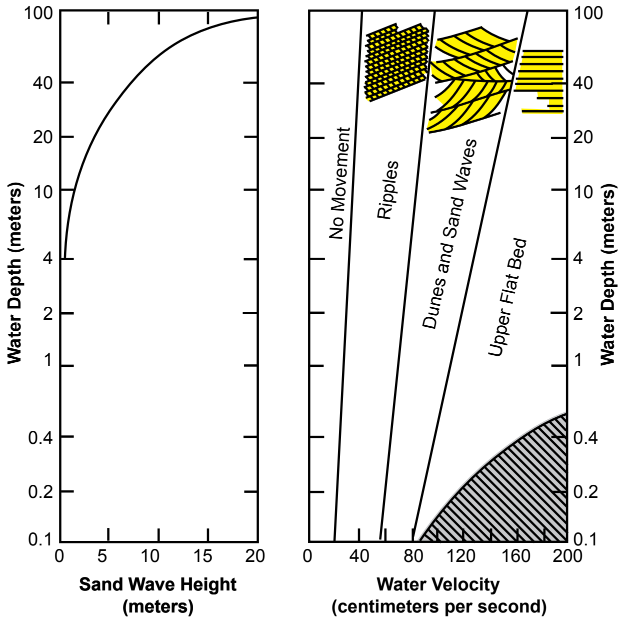


Figure 43. Graphs of water depth versus sand-wave height (left) and water depth versus water velocity (right), showing bedforms in fine sand expected under different water conditions. The thickness of cross-beds observed in fine-grained sandstone is used to estimate sand-wave height. Then, sand-wave height is plotted on the graph on the left to estimate the water depth where the sand wave formed. That water depth is then plotted on the right graph to estimate the minimum and maximum velocities of water for that specific water depth (after Austin, 1994, 34, Figure 3.12).

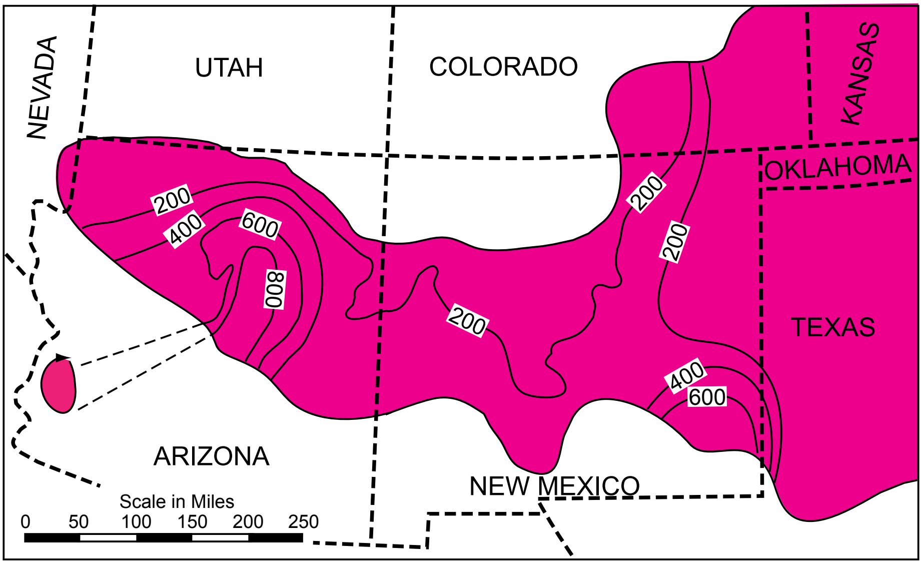


Figure 44. Sandstone thickness and distribution map for the Coconino Sandstone, which correlates with the Glorietta Sandstone (New Mexico and Texas), the Cedar Hills Sandstone (Colorado and Kansas), and the Duncan Sandstone (Oklahoma). The area of sandstone shown is 200,000 square miles, and the volume of sand is estimated at 10,000 cubic miles. Contour lines indicate sandstone thickness in feet (after Austin, 1994).

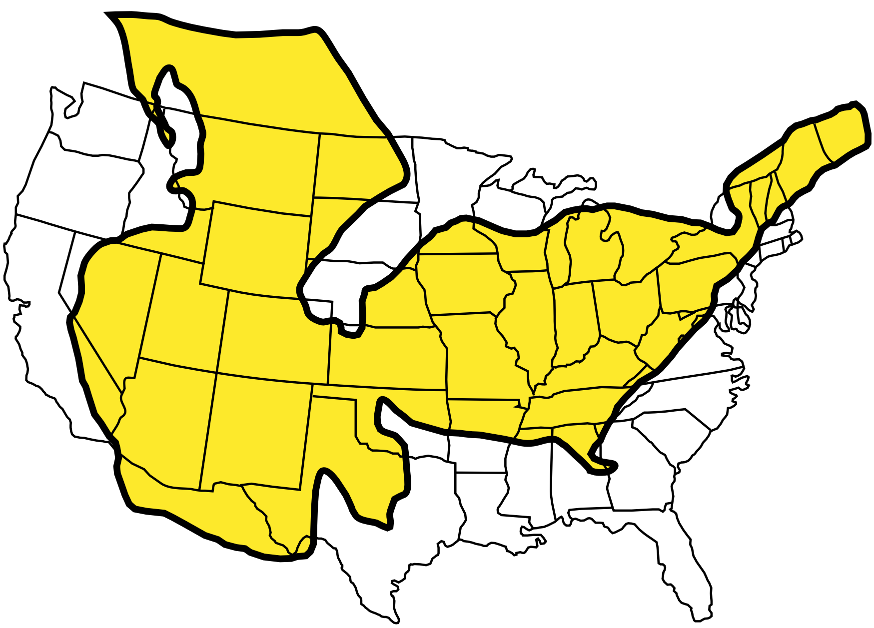


Figure 45. Map showing the distribution of the sandstone lithosome at the base of the Sauk Megasequence (the Tapeats Sandstone and its equivalents) across North America.

Figure 46. The Lower (bottom) and Upper (top) Pilot Seams exposed in an old quarry near Swansea Heads, Newcastle area, Australia. Note the two fossilized upright tree stumps on the lower seam, and the small upright tree stump on the top seam silhouetted against the sky. When first discovered more than 100 years ago, some of these upright tree stumps penetrated from the lower seam right through the volcanic ash beds between the seams and through the upper seam.

Figure 47. Two fossilized upright tree stumps in siltstone between coal seams at Redhead, Newcastle area, Australia. Note that the upper small tree stump sits directly on the broken-off top of the larger (lower) tree stump, and both tree stumps have had their roots broken off, indicating violent transport and rapid deposition.

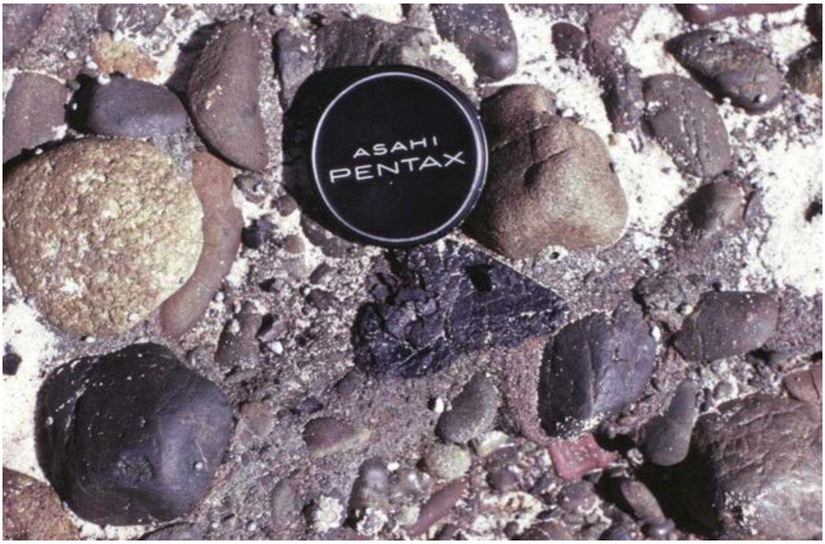


Figure 48. A large coal pebble among other pebbles in the Teralba Conglomerate, less than two feet above its contact with the underlying Great Northern Seam, Catherine Hill Bay, Australia.

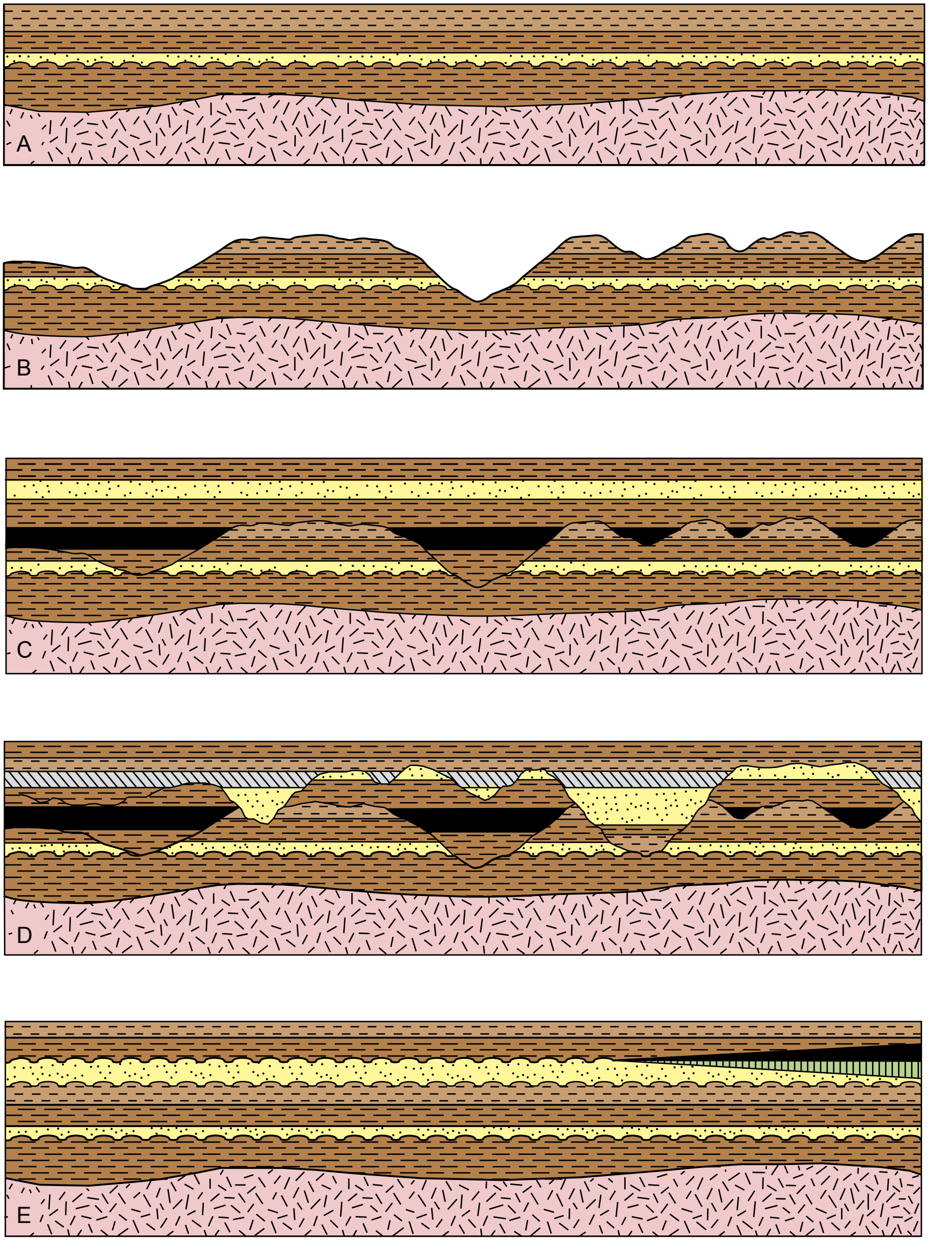


Figure 49. Hypothetical diagram of deposition-erosion patterns, with variable vertical exaggeration depending on erosional conditions. (A) Pattern of continuous deposition, where sediments are usually laid down in a flat, horizontal pattern. (B) Erosion. (C) Resumption of deposition, with the old erosion surface still visible. This pattern should be common within the earth's sedimentary layers wherever significant parts of the geologic column are missing. (D) A second cycle of erosion and deposition further complicates the pattern. (E) The more usual pattern seen. Significant erosion would be expected between the second and third layers from the top (left side) if extensive time was involved in the deposition of the two layers wedged in between them (right side) (after Roth, 1998).

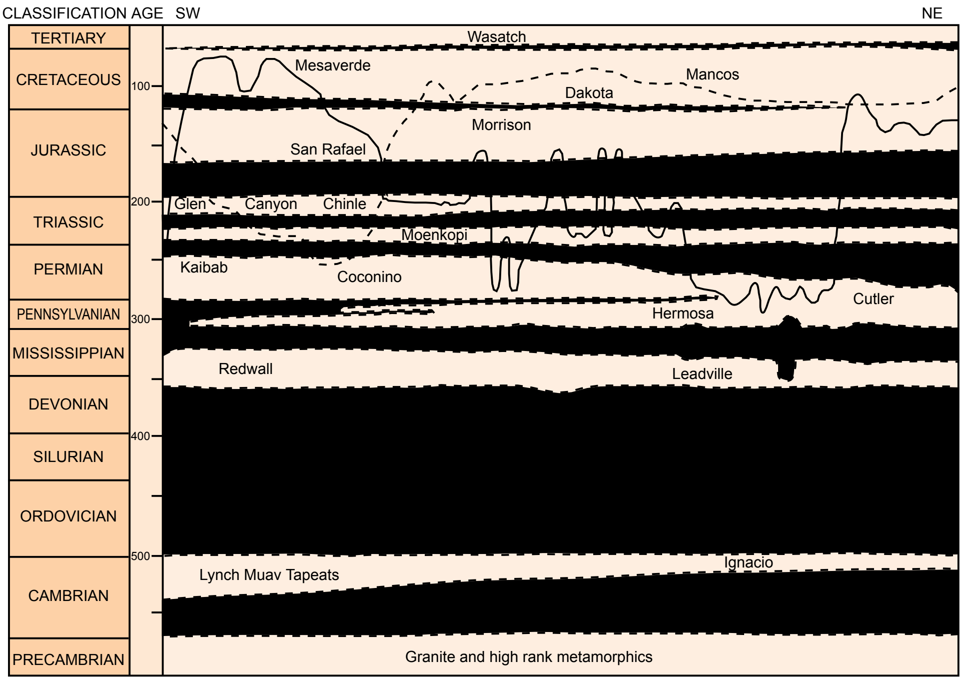


Figure 50. Representation of the sedimentary layers in eastern Utah across into western Colorado, based on the standard geologic timescale (instead of thickness, though the two are related). The clear (white) areas represent sedimentary rock layers, while the black areas represent the time for the main gaps (hiatuses) between layers where parts of the geologic column are missing in this region. The layers actually lie directly on top of each other with flat contact planes. The black areas stand for the postulated time between the sedimentary layers. The irregular dashed and continuous lines through the upper layers represent two examples of the present ground surface in the region. This provides evidence for the Flood model wherein the layers were deposited rapidly in sequence without much time for erosion between. Erosion toward the end of the Flood and afterward produced the irregular topography that exists today. If millions of years had elapsed between the layers (black areas) as postulated by the geologic timescale, we would expect patterns of erosion somewhat similar to the present surface pattern between the white layers. The vertical exaggeration is 16X, and the horizontal distance about 200 km, while the total thickness of the white layers is about 3.5 km (after Roth, 1998).

Figure 51. Folding of the Tapeats Sandstone at the East Kaibab Monocline in Carbon Canyon in the extreme eastern Grand Canyon. The view is to the south, and the upwarp on the right (west) side has caused the sandstone to be tightly folded into a vertical orientation without any major fracturing in the hinge zone, indicating the folding occurred soon after deposition. The people provide scale.

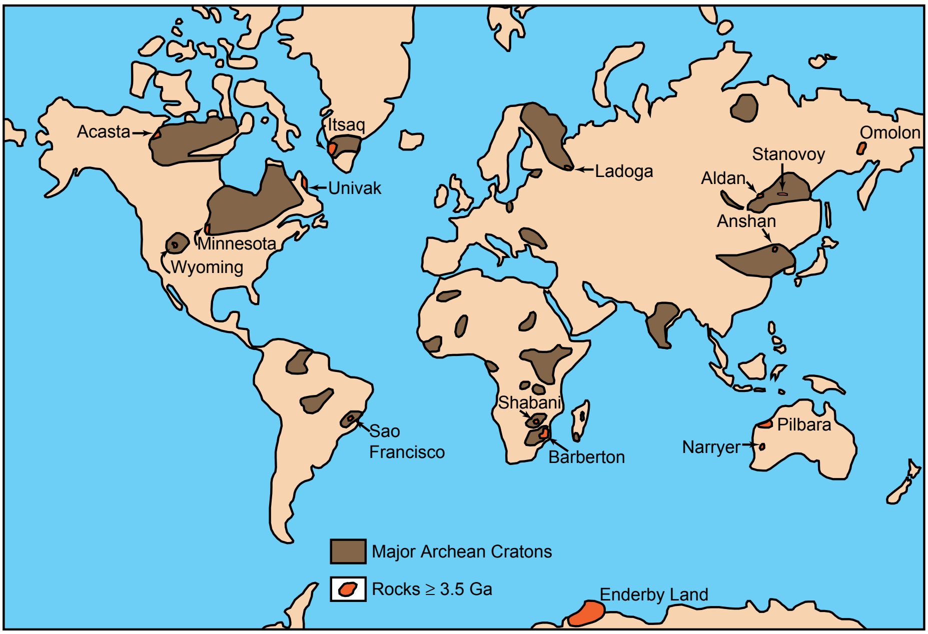


Figure 52. Map showing the distribution of the earth's oldest rocks.

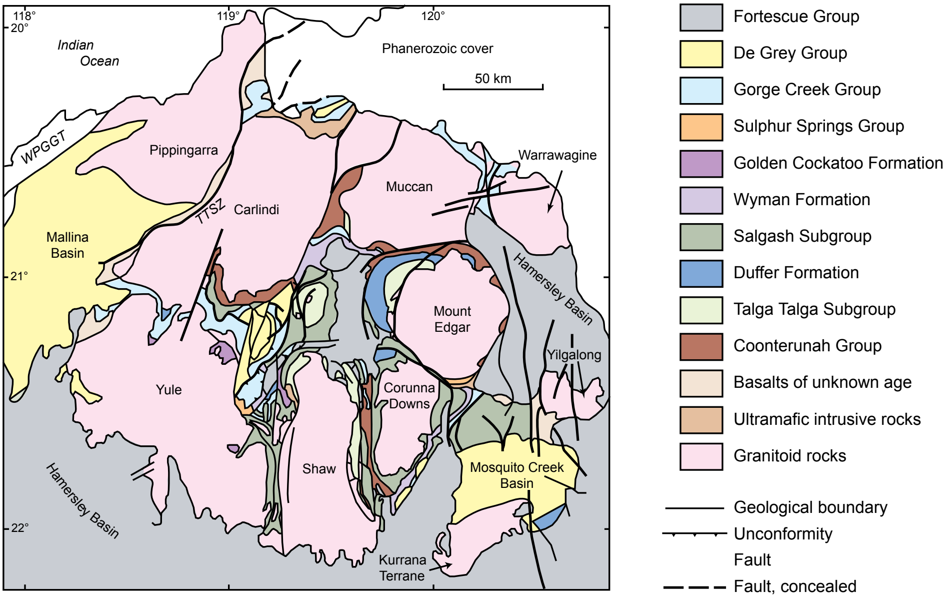


Figure 53. The Archean Pilbara Craton of Western Australia (including the granitoid domes and greenstone belts surrounding them with interbedded volcanics and sedimentary layers), showing the Proterozoic sedimentary basins marginal to it (compare with Figure 7, page 442).

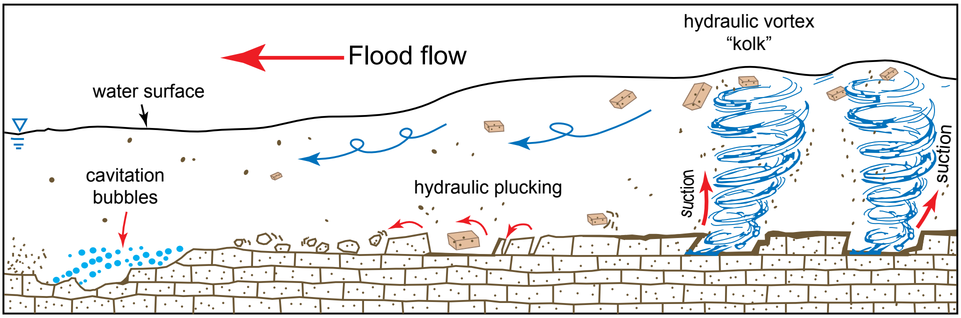


Figure 54. The major agents of erosion of solid bedrock during flood conditions. High-velocity flow produces cavitation downcurrent from an obstruction, as vacuum bubbles implode, inflicting hammer-like blows on the bedrock surface. Streaming flow impacts the bedrock surface, causing hydraulic plucking, especially along joints. Hydraulic vortex action causes a kolk, which exerts intense lifting force, removing blocks of bedrock (after Austin, 1994, 104, Figure 5.23).

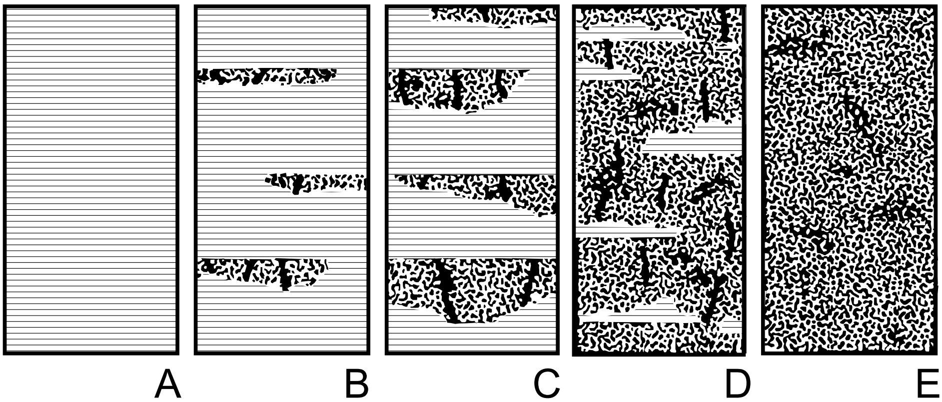


Figure 55. Relationship between bioturbation (animal traces) and sediments. In (A) the sediments were deposited rapidly with no time for bioturbation, or else erosion removed the tops of the sedimentary units, removing the traces. In (B) some time allowed for bioturbation after some of the units were deposited; (C) indicates more time after some units were deposited. Almost all of (D) and all of (E) have the original sedimentary structures removed by bioturbation, as would be expected if the deposits were produced slowly under conditions favorable to animal life (after Brand, 1997, 286, Figure 16.2).

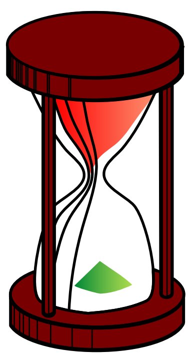


Figure 56. The analogy of an hourglass, which is useful for understanding the process involved and the assumptions in radioactive dating of rocks.

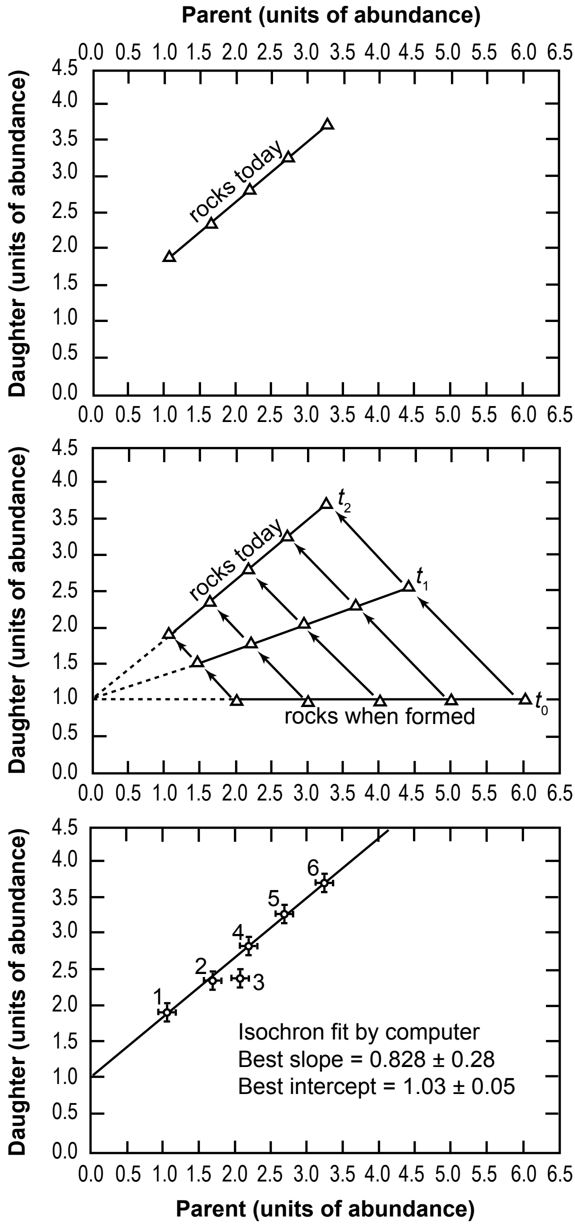


Figure 57. The assumptions and methods of isochron dating are illustrated by diagrams depicting samples from a hypothetical rock unit. (A) Study of five samples from the rock unit indicates that their daughter-versus-parent compositions plot today as a linear array having positive slope. (B) The isochron model suggests that the five samples, when the rock unit formed, all had the same abundance of daughter (1.0 "unit of abundance" in this case), but different abundances of parent. The compositions of the samples today are assumed to have been derived by significant radioactive decay of parent and accumulation of daughter. (C) Six isotopic analyses of the samples of this rock unit are plotted with error bars. A computer determines the "best-fit" line through the data points. The slope of the line can be used to estimate the "age" of this rock unit. The greater the slope, the greater the "age" (after Austin, 1994, 116, Figure 6.3).

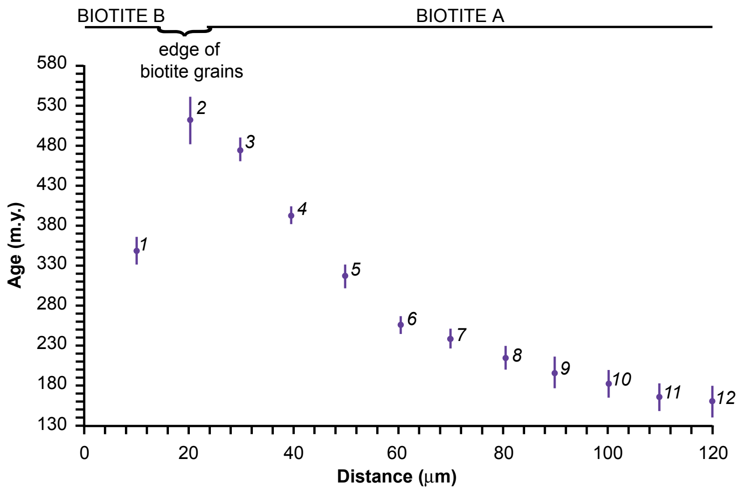


Figure 58. Apparent age versus distance profile across adjacent biotite grains in an amphibolite-granulite facies metamorphic rock from the Italian Alps (after Pickles et al, 1997—their profile 8 across sample 85370). The high spatial resolution profile is along a "trench" produced by an ultraviolet laser ablation microprobe which is parallel to the biotite cleavage and perpendicular to the grain boundary. Apparent ages range from 515+/-27 Ma at the edge of biotite A to 161+/-19 Ma 100 micron in from the edge of biotite A. The high apparent ages at the grain boundary cannot be attributed to alteration because scanning electron microscope (SEM) photographs discount it.

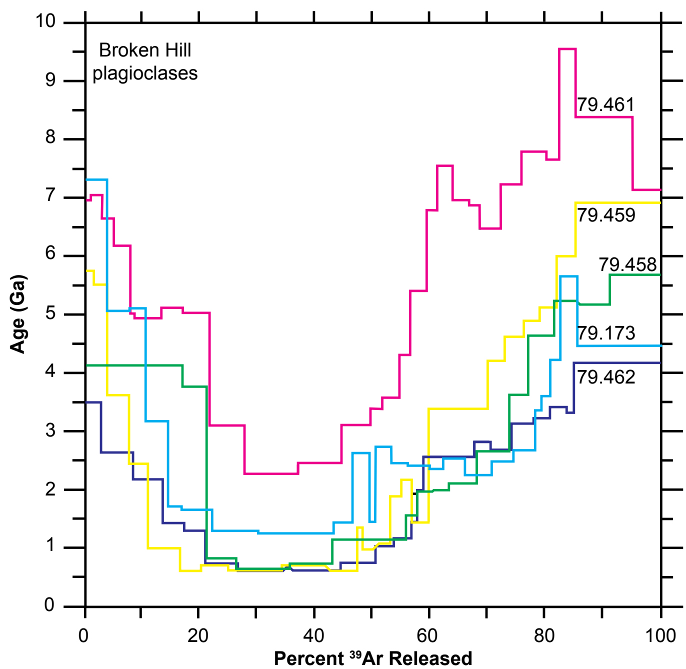


Figure 59. The ^{40}Ar-^{39}Ar "age" spectra for plagioclases from mafic granulites near the North Broken Hill mine and at Black Bluff (after Harrison and McDougall, 1980). All "age" spectra are characterized by a saddle-shape and each is labeled with its sample number. The plagioclase from sample 79.461 yields an apparent age of 9.588 Ga at over 80 percent ^{39}Ar released.

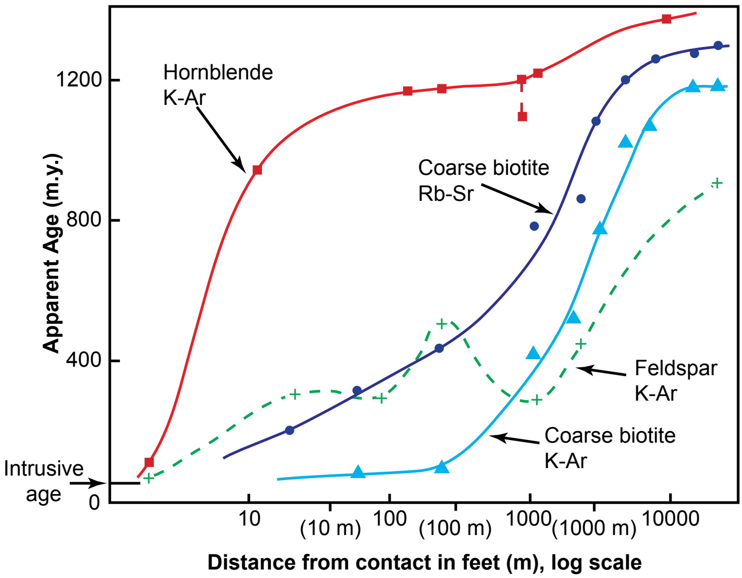


Figure 60. Plot of apparent mineral "ages" against outward distance from the contact of the Eldora stock, Colorado (after Hart, 1964).

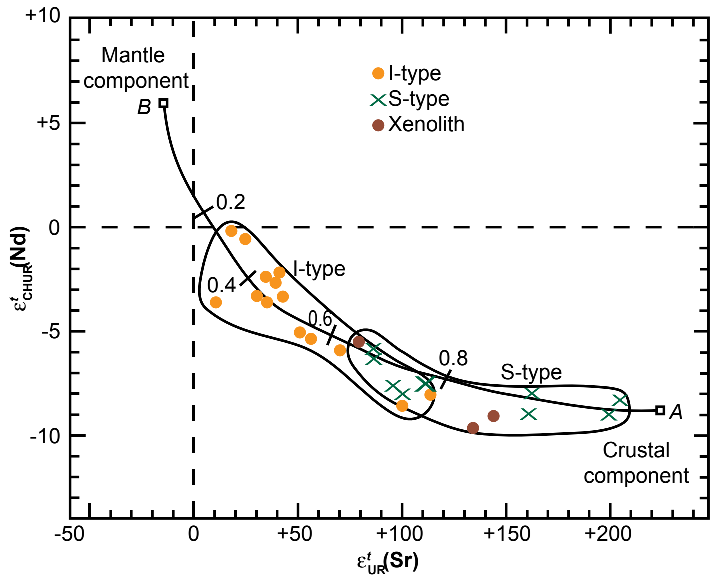


Figure 61. Epsilon values of Nd and Sr, corrected for decay, of granitic rocks and xenoliths from the Berridale and Kosciusko batholiths of southeastern Australia (after McCulloch and Chappell, 1982). Both I-type (igneous) and S-type (sedimentary) granitic rocks fit the same mixing line, indicating that both are mixtures of two components derived from "depleted" mantle and from the continental crust. The curve was fitted using the following end-member compositions: Crustal component *(A):* ε (Nd) = -9.0, Nd = 28.0 ppm, ε (Sr) = 227.2, Sr = 140 ppm; Mantle component *(B):* ε (Nd) = +6.0, Nd = 14.0 ppm, ε (Sr) = -14.20, Sr = 470 ppm.

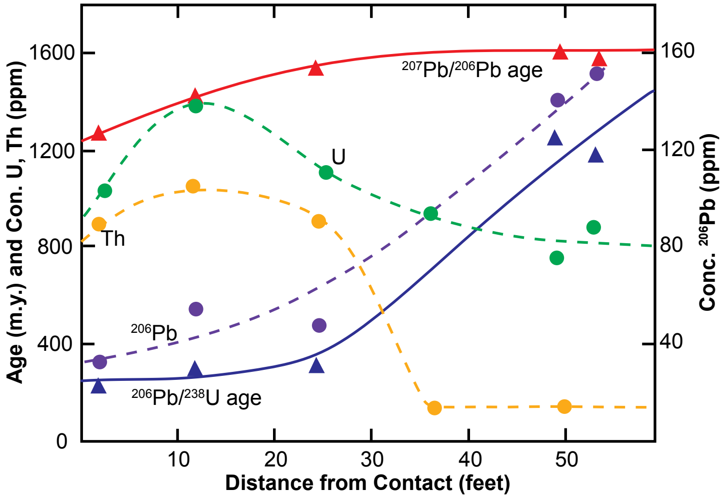


Figure 62. Change in $^{206}Pb/^{238}U$ and $^{207}Pb/^{206}Pb$ "ages" and in concentrations of U, Th and ^{206}Pb in zircons in Precambrian metasediments and metavolcanics as a function of distance from the contact with the Tertiary Eldora granite stock, Colorado (after Davis et al, 1968).

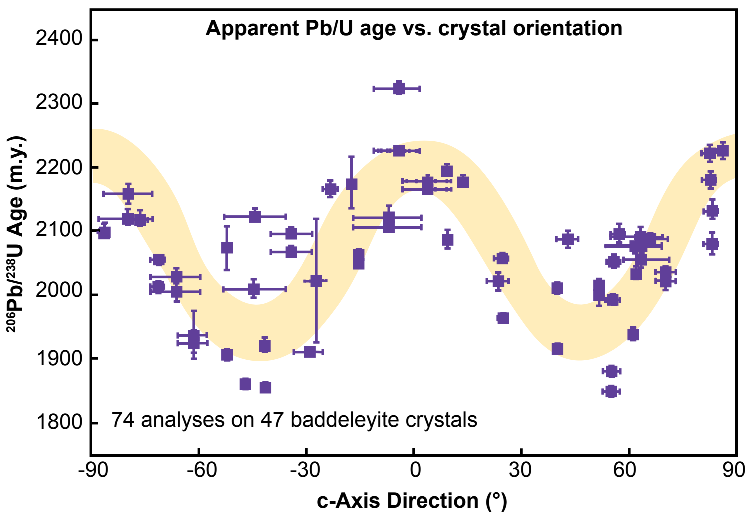


Figure 63. SHRIMP analytical results for baddeleyite, illustrating observed orientation effects (after Wingate and Compston, 2000). Variation of apparent $^{206}Pb/^{238}U$ "age" with orientation for (100) surfaces of 47 oriented baddeleyite crystals.

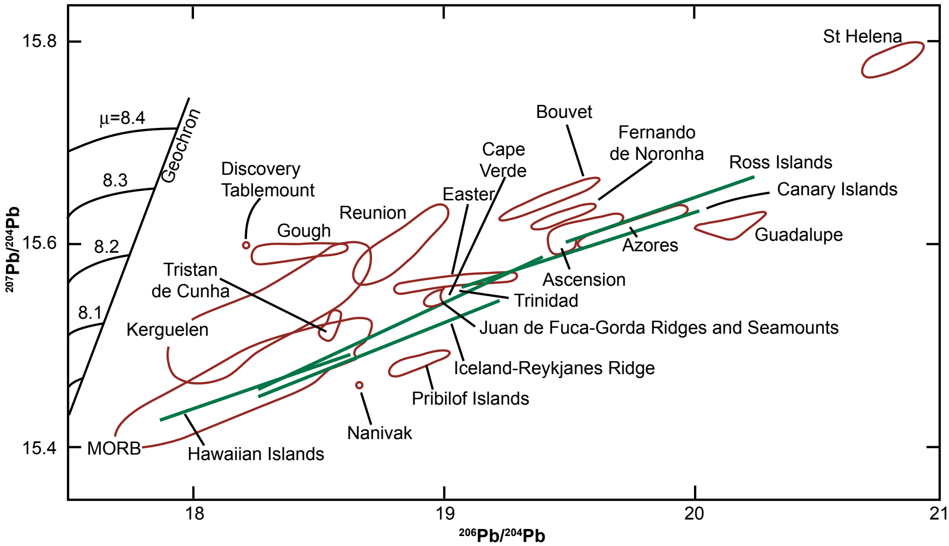


Figure 64. A Pb/Pb "isochron" diagram showing linear arrays of data defined by ocean island basalts (after Sun, 1980).

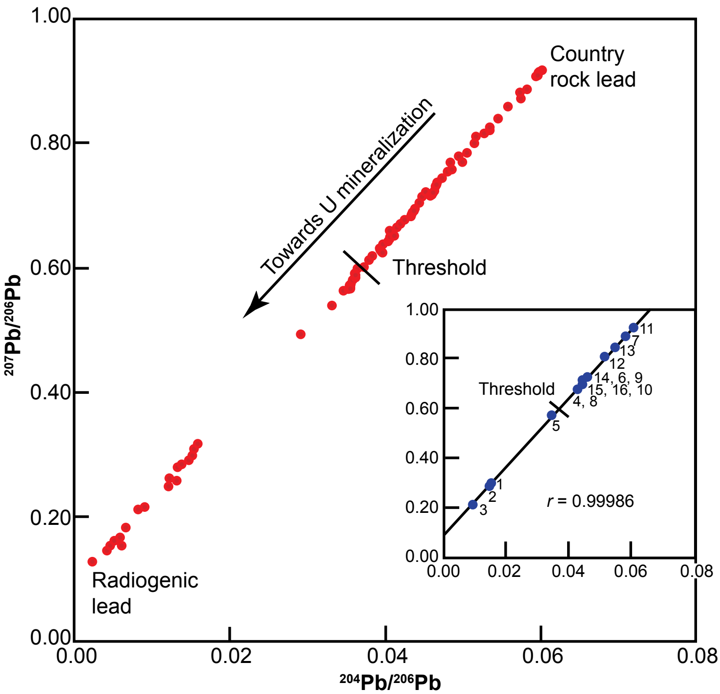


Figure 65. Plot of ^{207}Pb/^{206}Pb for the combined data sets of Dickson et al, 1985 and 1987, of Pb isotopic ratios in soils from the area around the Koongarra uranium orebody, Northern Territory, Australia, indicating the high correlation (r = 0.99986) between the two variables. Inset shows data collected in the later Dickson et al, 1987, study plotted on the fitted regression line.

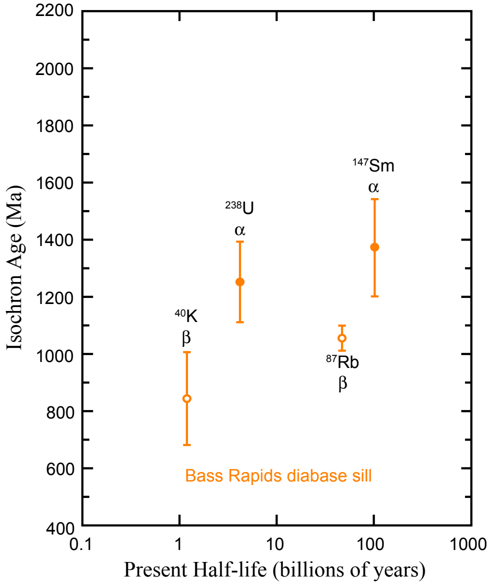


Figure 66. The isochron "ages" yielded by four radioisotope systems for the Bass Rapids diabase sill, Grand Canyon, plotted against the present half-lives of the parent radioisotopes according to their mode of decay (after Snelling et al, 2003).

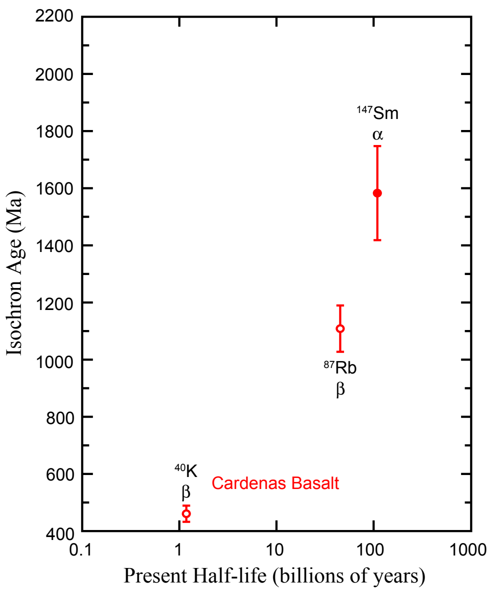


Figure 67. The isochron "ages" yielded by three radioisotope systems for the Cardenas Basalt, Grand Canyon, plotted against the present half-lives of the parent radioisotopes according to their mode of decay (after Snelling, 2005, Isochron discordances, 393-524).

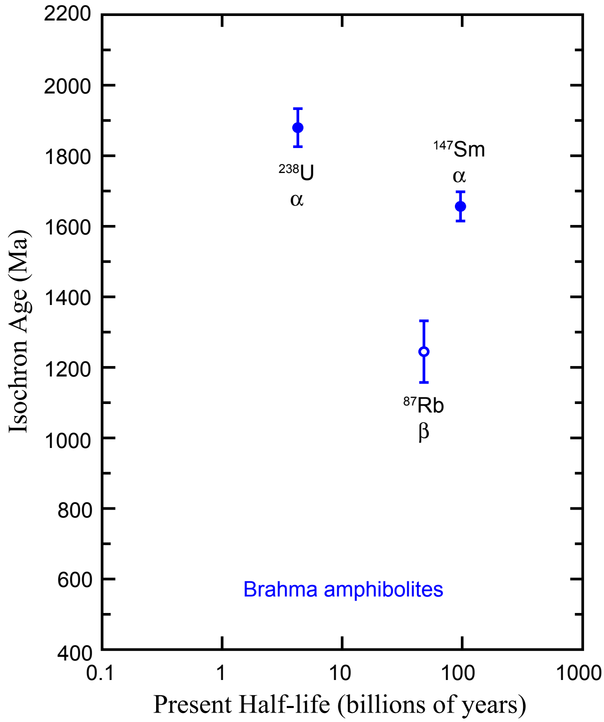


Figure 68. The isochron "ages" yielded by three radioisotope systems for the Brahma amphibolites, Grand Canyon, plotted against the present half-lives of the parent radioisotopes according to their mode of decay (after Snelling, 2005, Isochron discordances, 393-524; Snelling, 2008, Significance of highly discordant radioisotope dates, 407-424).

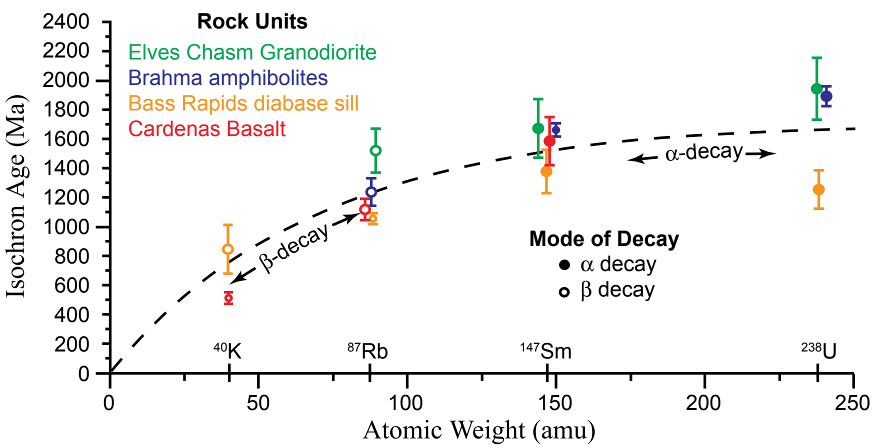


Figure 69. Composite plot of isochron "age" versus atomic weight for four radioisotope pairs and four Precambrian rock units in Grand Canyon (after Snelling, 2005, Isochron discordances, 393-524; Snelling, 2008, Significance of highly discordant radioisotope dates, 407-424).

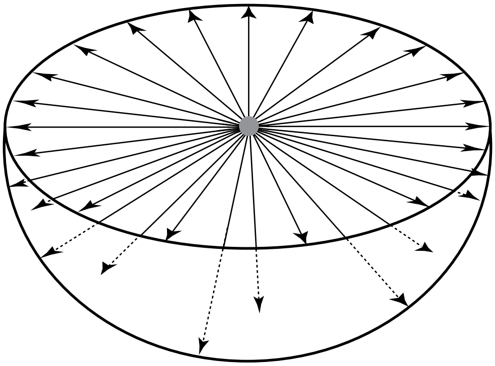


Figure 70a. Sunburst effect of alpha (α)-damage trails. The sunburst pattern of α-damage trails produces a spherically colored shell around the halo center. Each arrow represents approximately 5 million α-particles emitted from the center. Halo coloration initially develops after about 100 million α-decays, becomes darker after about 500 million, and very dark after about 1 billion (after Gentry, 1988).

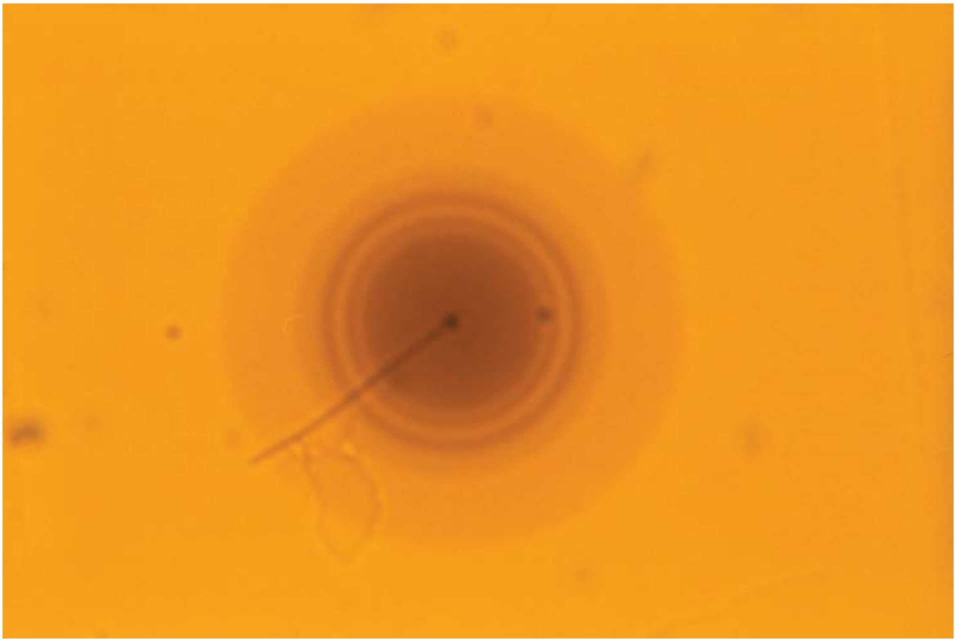


Figure 70b. A fully-developed ^{238}U radiohalo in biotite, with all eight rings visible (courtesy of Mark Armitage).

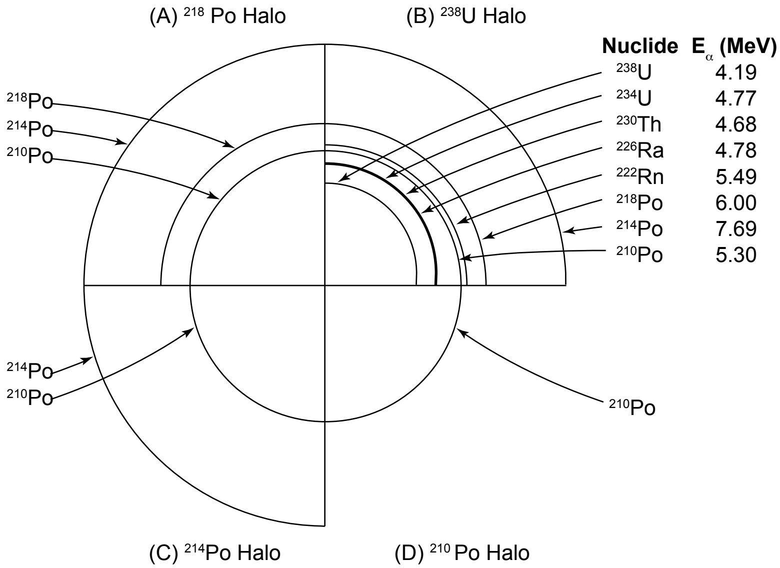


Figure 71. Composite schematic drawing of (A) a ^{218}Po halo, (B) a ^{238}U halo, (C) a ^{214}Po halo, and (D) a ^{210}Po halo with radii proportional to the ranges of α-particles in air. The nuclides responsible for the α-particles and their energies are listed for the different halo rings (after Gentry, 1973).

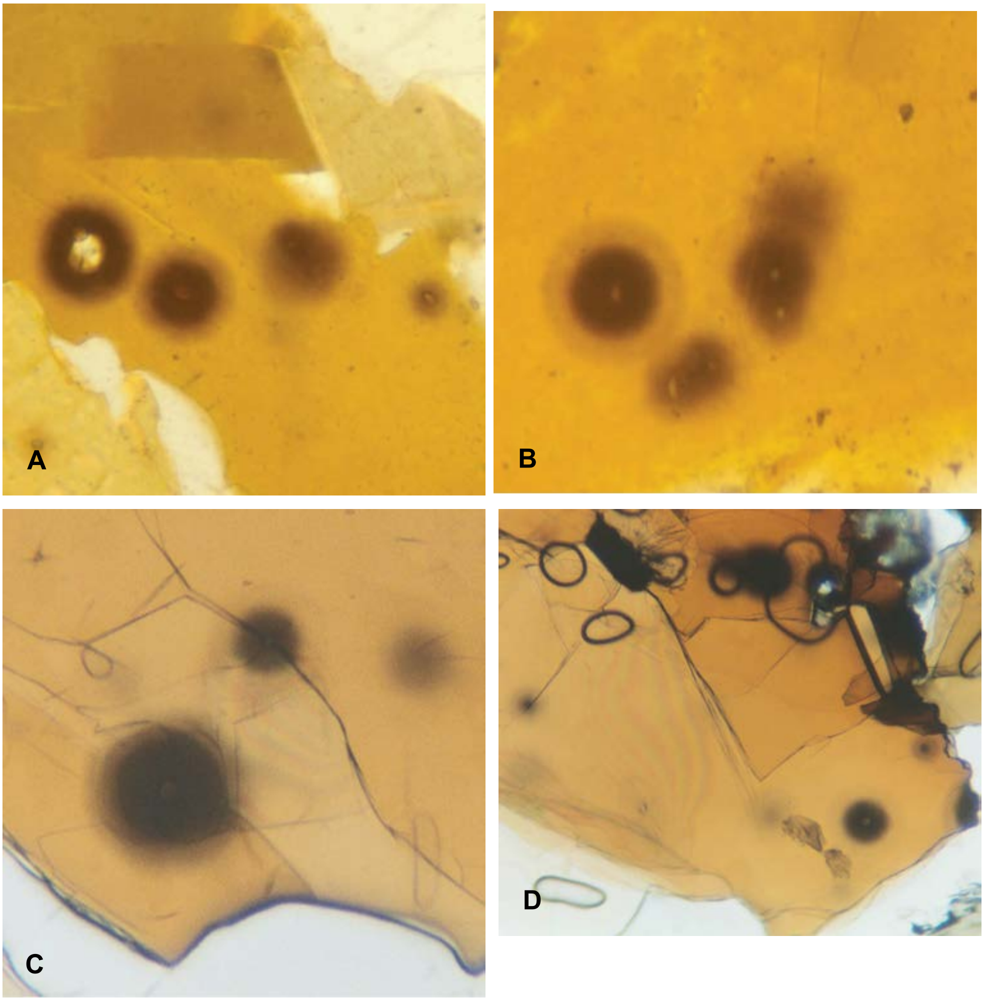


Figure 72. Some typical radiohalos in biotites. (A) An overexposed ^{238}U radiohalo (left) and a ^{210}Po radiohalo (right). (B) Adjacent overexposed ^{238}U radiohalos with overlapping and adjacent ^{210}Po radiohalos. (C) An overexposed ^{238}U radiohalo (lower left) and a ^{214}Po radiohalo (above right). (D) An overexposed ^{238}U radiohalo (upper center), a ^{214}Po radiohalo (lower right), and a ^{210}Po radiohalo (right center).

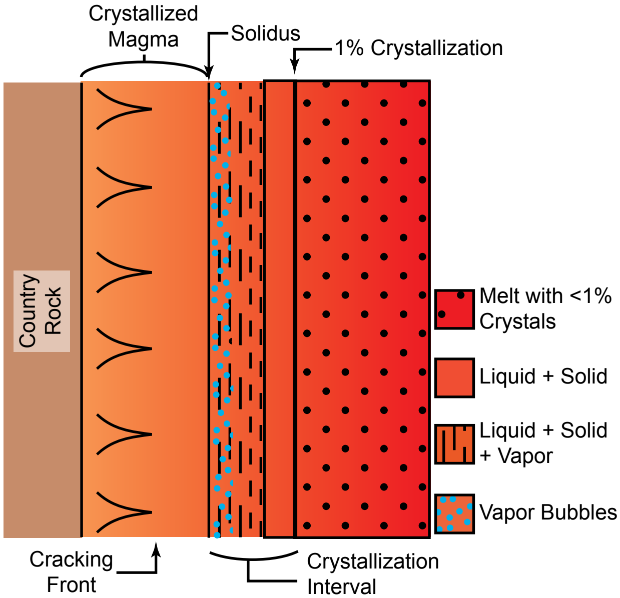


Figure 73. Cross-section through the margin of a magma chamber traversing (from left to right): country rock, cracked pluton, uncracked pluton, solidus, crystallization interval, and bulk melt (adapted from Candela, 1991).

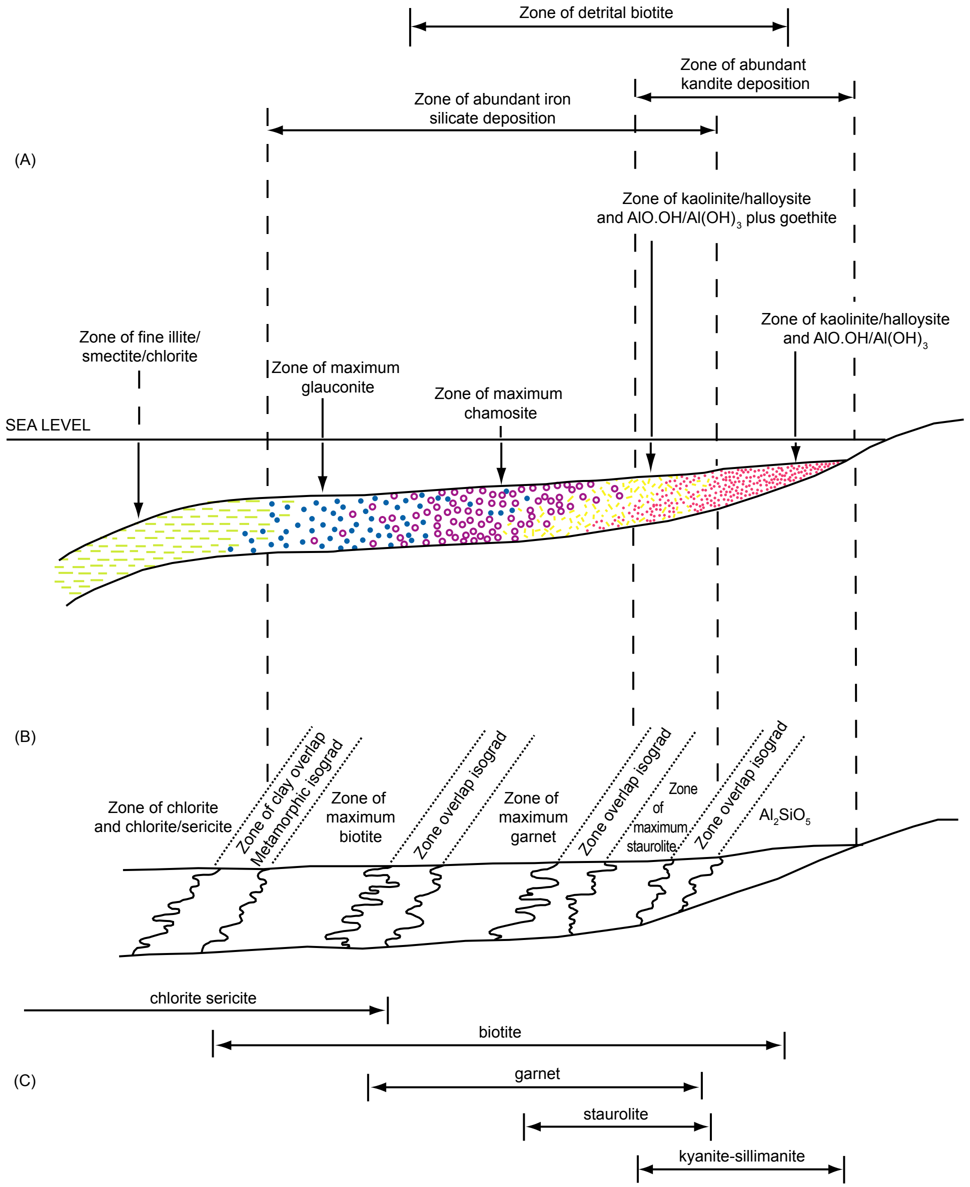


Figure 74. (A) Idealized representation of a pattern of notably aluminum- and iron-rich clays and clay-type minerals that might develop in the warm waters of a tropical shelf to which seaboard calc-alkaline volcanic and hydrothermal activity were contributing. (B), (C) Similarly idealized representation of metamorphic mineral zones that might result from essentially isochemical regional metamorphism, with concomitant precursor to metamorphic mineral transformation, of the original pattern of detrital, sedimentary, and diagenetic clays, as in (A). Note that the original clay mineral facies boundaries and their derived metamorphic zones cut across bedding, and hence would be transgressive to later fold structures (adapted from Stanton, 1982).