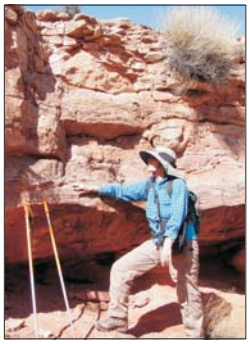
Article

Flood Geology and the Grand Canyon: A Critique

Carol A. Hill and Stephen O. Moshier



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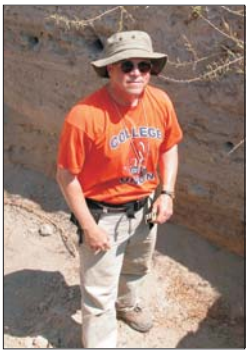

Stephen O. Moshier

Four claims of Flood Geology—as they are related to the Grand Canyon and specifically to the book Grand Canyon: A Different View *—are evaluated by directly addressing Young Earth Creationist arguments, by showing rock features that belie these claims, and by presenting the most up-to-date scientific theories on the origin of the Grand Canyon. We conclude that Young Earth Creationism promotes an erroneous and misleading interpretation of the geology of the Grand Canyon. We also conclude that the claim that all (or almost all) of the sedimentary rock in the Grand Canyon and on planet Earth was formed during Noah's Flood is not supported by the Bible.*

About four million people each year visit Grand Canyon National Park to witness one of the most well-known and spectacular geologic features on planet Earth. Visitors typically ask questions like: "How old is the canyon?" or "How did it form?" Explanations for the natural history of the canyon are found on interpretive signs and in books available for purchase at concessions in the park. Official park signage and most books on the topic present the "mainstream geology" position that the rocks exposed by the canyon are hundreds of millions to a billion or so years old, while the canyon itself—carved into these rocks—is millions of years old. In this vein, *Carving Grand Canyon—Evidence, Theories, and Mystery* by geologist Wayne Ranney examines the evidence for the history of the Colorado River and the formation of the canyon, while *Grand Canyon Geology* edited by Stanley Beus and Michael Morales contains chapters written by geoscientists on the origin of the rocks that are exposed in the canyon.[1]

Another book sold at the park—one that has garnered much attention in the media[2]—presents an entirely different age and origin for the canyon and its rocks. *Grand Canyon: A Different View*, consisting of over twenty section authors and compiled by Tom Vail,[3] rejects the idea of a millions-of-years-old canyon and proposes instead an approximately 4500-year-old canyon, wherein the mile-deep sequence of sedimentary rocks formed during the one-year-long Noah's Flood, and with the entire canyon being excavated since that flood event. This position is known as "Flood Geology," which is an essential component of Young Earth Creationism (YEC).

Carol A. Hill *is an adjunct professor at the University of New Mexico and has been working in the Grand Canyon for the last ten years. She has recently published some of her results in* Science and Geomorphology. *Carol is also a Fellow of the ASA and has published a number of articles in* PSCF *on the Garden of Eden, Noah's Flood, the Numbers of Genesis, and the Worldview Approach to scriptural interpretation. She resides in Albuquerque, New Mexico, with her husband of almost fifty years and attends Heights Cumberland Presbyterian Church. She can be contacted at carolannhill@aol.com.*

Stephen Oakley Moshier *is an associate professor of geology, Wheaton College, Illinois. He studied geology at Virginia Tech (BS, 1977), SUNY Binghamton (MA, 1980) and Louisiana State University (PhD, 1987). Previous professional experience included working in the petroleum industry and a faculty position at the University of Kentucky. Moshier's teaching responsibilities cover areas of general geology, earth history, stratigraphy, sedimentary petrology, biogeology, and geoarchaeology. From 2000 to 2007, he served as team geologist for the Tell el-Borg excavation in the NW Sinai, Egypt, and in 2008, he joined the Harvard University-Leon Levy Expedition to Ashkelon, Israel. He is a member of several professional societies and past president of the Kentucky Geological Society.*

Article

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Critical differences between "Flood Geology" and "Mainstream Geology" that are relevant to the Grand Canyon are listed in Box 1. The "Young-Earth Creationist" position is popular with fundamentalist Christians and has been defended by a number of authors of that persuasion.[4] YEC proponents believe that scientific details of the Earth's creation and early history are evident in the Bible and that examination of the geological record can support a literal biblical narrative. However, other Christians—including many theologically conservative, evangelical Christians—hold the "Old-Earth Creationist" (OEC) position that accepts the mainstream view of geological history.[5] Our purpose in this article is to evaluate Flood Geology claims as they relate to the Grand Canyon, and more specifically to evaluate some of the ideas presented in the YEC book *Grand Canyon: A Different View* and references therein. It is our position that the contributors of this book present misleading information about the geology of the Grand Canyon to support a theological position that is not demanded or even supported by the Bible.

Flood Geology and the Bible

First, we examine how flood geologists, as represented in *A Different View,* come to their position of a young Earth and of sedimentary rock having formed in Noah's Flood. The most significant passages in Scripture bearing on Earth origin and natural history, as understood and applied by flood geologists, are reviewed below.

Age of the Earth and Date of the Flood

The Earth was created approximately 6,000 years ago based on a 24-hour day/six days of creation (Genesis 1) plus the chronologies of Genesis 5 and 11. The Flood is understood to have happened about 4500–5000 years ago (2500–3000 BC).

Changes in Nature after the Fall

Before Adam sinned and ate of the fruit of the tree (Gen. 3:6), a world of perfect harmony existed on planet Earth. Perfection is implied from the declaration by God that his creation was "good" (Gen. 1:25, 31). In this perfect world, there was no death, not even the death of animals. Since no animals died, all animals (created as distinct species in Genesis 1) had to have been herbivores before Adam's fall. Adam's "original sin" brought about a violent imperfect world where both humans and animals died and where some animals became carnivores. This violence is illustrated by the avenging line of Cain (Gen. 4:23–24).

The long ages of the patriarchs before the Flood (Genesis 5) signify decay from a state of perfection in the Garden of Eden to a maximum 120-year life span for humans after the Flood (Gen. 6:3). A vapor

Young Earth Creationist (Flood Geology)	Old Earth Creationist (Mainstream Geology)
• Earth is about 6,000 years old	• Earth is about 4.6 billion years old
• Radiometric methods for the dating of geological materials are flawed	• Radiometric dating methods yield reliable absolute dates on geological materials
• Noah's Flood occurred about 4,500 years ago and was universal over planet Earth	• Noah's Flood was limited to the Mesopotamian hydrology basin
• It never rained on Earth before Noah's Flood	• Abundant evidence exists for its having rained throughout Earth's geologic history
• Fossils in sedimentary rocks represent the "all flesh" of Genesis 7:21	• Fossils in sedimentary rocks are plant and animal remains that died and were buried and solidified as sediments turned into rock over millions of years
• Fossil-bearing sedimentary rock on Earth formed during Noah's Flood in only one year's time	• Sedimentary rock has formed over hundreds of millions of years by the process of sedimentation and compaction
• A vapor canopy and/or fountains of the deep supplied all of the water for a universal flood	• The Colorado River and Grand Canyon have a complex history that is still being investigated, but the canyon's erosion involved millions of years rather than thousands of years
• The Grand Canyon and Colorado River formed as water from the flood retreated from the land	• The Garden of Eden is described in Genesis as a modern landscape overlying sedimentary rock
• No death of animals before Adam sinned; all animals were herbivores	
• By implication, all pre-flood land was covered by flood deposits, including the four rivers of Eden	

Box 1. Young Earth versus Old Earth Creationist Positions Relevant to the Grand Canyon

canopy may have shielded humans from harmful radiation so that they lived longer in pre-flood days. The violence had become so pervasive by Noah's time that only one man was considered "good" by God and that man was Noah (Gen. 6:9). Consequently, God instructed Noah to build an ark and prepare for a flood, wherein all men and animals and birds would be destroyed from off "the face of the earth" (planet Earth) (Gen. 6:7).

Source of Flood Water

No rain fell on the "earth" (interpreted to be "planet Earth" rather than "ground") before Noah's Flood (Gen. 2:5). Rather, a "mist" (Gen. 2:6) served to moisten the ground from creation to the time of Noah's Flood. Since supposedly it had never rained on planet Earth before the flood, no (or very little) sedimentary rock could have formed before this time, and pre-flood locations (like the Garden of Eden) had to have existed on a crystalline rock basement devoid of sedimentary rock or on a thin cover of sedimentary rock deposited between the Creation week and the Flood.

Some flood geologists—especially those in the middle- to late-twentieth century—have proposed that the mist of Gen. 2:6 refers to a dense vapor canopy that shrouded the earth before the time of Noah's Flood. However, in recent years there has been a growing skepticism among flood geologists of this concept.[6] Genesis 7:11 states that the windows of heaven were opened and all the fountains of the great deep were broken up. From the perspective of most flood geologists who still adhere to the Vapor Canopy hypothesis, this verse is interpreted to mean that all of the water in their proposed vapor canopy fell as rain and that a great amount of water in the Earth's crust was expelled along faults and volcanoes.

Global Extent and Geological Results of the Flood

Since the Bible says that "all the earth" was flooded, with even the mountains being covered to a depth of fifteen cubits (Gen. 7:19–20), and that "all flesh" died (Gen. 7:21), this must mean that Noah's Flood left an immense record of itself in the form of sedimentary rock containing fossils. In addition to being subjected to a worldwide deluge, Earth's tectonic forces must have caused continents to move ("plate tectonics") and mountains to heave upwards because sedimentary rock is found today on the highest mountain peaks (e.g., the summit of Mount Everest is composed of marine limestone). The separation of continental plates (e.g., South America and Africa) was rapid, happening in only one year during Noah's Flood.

Since even the highest mountains were covered, the ark would have landed on the highest peak of the Middle East region, Mount Ararat (elevation 16,803 ft). After landing on Mount Ararat, the floodwaters decreased rapidly due to evaporation (Gen. 8:1), and also because they "*returned from off the earth continually*" (Gen. 8:3) to low elevations relative to mountains raised during the Flood. Exactly one year (365 days) after the Flood started, the post-flood landscape where Noah landed was dry (Gen. 8:14), and the topography of planet Earth was completely changed from its pre-flood landscape.

Critique of Biblical Basis for Flood Geology

The authors of *Grand Canyon: A Different View* affirm the inerrancy of God's Word in its original form as the "one basic premise" informing their understanding of creation history (p. 7). For flood geologists, biblical inerrancy means that words in the Bible are taken literally with little or no regard to how those words may have held different meanings at the time and in the culture when they were written—a position that is contradictory to the Chicago Statement on Biblical Inerrancy, which does not affirm ironclad biblical literalism that disrespects ancient cultural contexts, literary forms, and phenomenological language never meant to convey modern scientific information.[7]

In *A Different View,* readers are warned that nonliteral interpretations of words and phrases like "day" and "all the land" or "all flesh" are compromises to accommodate evolutionary ideas about creation that are in violation of biblical admonitions such as Deut. 4:2: "*You shall not add to the Word which I am commanding you*." However, it is not unusual for flood geologists to make dramatic leaps of meaning from the text to modern scientific concepts, such as in the way Ps. 104:8 is quoted in *A Different View*: "*The mountains rose, the valleys* [ocean basins] *sank down to the place which You established for them*" (p. 5). John Whitcomb, the author of this section of the book, feels free to interpret "valleys" to mean "ocean basins" even though this is not a literal trans-

lation and thus is contrary to the book's stated "one basic premise."

Numerous scholars with orthodox or conservative credentials have addressed problems with literal hermeneutics applied to Creation scriptures.[8] They have questioned attempts to fix the date of Creation, establish direct harmony between biblical and scientific descriptions of Creation, or draw conclusions about changes in nature after the Fall beyond what is written in the text. The issue of the age of the Earth and how to interpret Genesis 1–3, 5 and 10 with respect to the numbers contained in these chapters is beyond the scope of this article and readers are referred to the cited reference.[9] The issue of "no animal death before the Fall" is probably most pertinent to Grand Canyon geology because of the YEC claim that fossils buried in the strata could only have perished after the Curse introduced death to all creatures. Not only is it *not* obvious from Genesis 3 that the Curse introduced death to all creatures, the Apostle Paul offers contrary commentary on the matter in Rom. 5:12, 13 (NIV): "*Therefore, just as sin entered the world through one man, and death through sin, and in this way death came to all men, because all sinned—for before the law was given, sin was in the world.*" Here, Paul is specific that death from sin applies to all humans and he does not consider the death of animals as consequential or relevant to his doctrinal point.

Flood geologists have also drawn geological and paleontological conclusions about the extent of the Genesis Flood from many Bible verses without consideration of valid alternative and nonliteral understandings of their meaning. For example, Old Testament scholar John Walton has pointed out that the description in Gen. 7:20 (NIV) that floodwater "*covered the mountains to a depth of more than twenty feet*" could as well be understood, in the context of other applications of the same words elsewhere in the Old Testament, to mean that the mountains were "drenched" and that water rose to a depth of twenty feet against the mountain.[10] Walton also provides examples from the Old Testament and other literature of its time (i.e., Akkadian texts) where the expressions of "all" or "every" could never have been understood as universal. For example, when in Gen. 41:57, "*all the countries came to Egypt to buy grain from Joseph, because the famine was severe in all the world,*" Walton quips that no one believes that the Eskimos were included. Similarly, the senior author of this article has considered that the ancients used expressions like "all," "every," and "under heaven" to describe regional, but non-universal, events.[11] Hill also considered the word "earth" (*eretz*) to mean ground or dry land, rather than the planet Earth, arguing that the misinterpretation of this word in particular has led to the erroneous conclusion that "all the earth" means a worldwide, universal flood.

The Bible and Sedimentary Rock

Does the Bible really claim that all of the sedimentary rock on Earth, such as is exposed in the Grand Canyon, formed in Noah's Flood? Nowhere does it even mention sedimentary rock and it is highly unlikely that the ancient biblical authors distinguished rock types by their origins since this is a modern concept developed only over the last 150 years or so. That the Bible does *not* claim all sedimentary rock formed in Noah's Flood can be deduced from the Genesis text (Gen. 2:10–14) where it describes the pre-flood Garden of Eden as being located near the confluence of the four rivers of Mesopotamia near the Persian Gulf. This mention of rivers raises the first red flag on a flood geology interpretation of the universal nature of "earth" (*eretz*) because if it had never rained over the entire planet Earth before Noah's Flood, then where did the four rivers of Eden receive their water?

Genesis 2:10–14 specifically identifies the four rivers of Eden as being the Euphrates, Hiddekel (Tigris), Pishon, and Gihon. The Euphrates and Tigris are rivers that still exist by those names in Mesopotamia today (modern-day Iraq). The identification of the other two rivers, Pishon and Gihon, is somewhat problematic. Hill identified the Pishon River with what is now the dried-up Wadi Batin, tracing this wadi westward into Arabia (the "land of Havilah") where all three of the commodities identified by the Genesis text—gold, onyx, and bdellium—are found (Fig. 1).[12] The Gihon River was identified as today's river Karun, which takes a zigzagging, circuitous course through the great folded structures of Iran's Zagros Mountains. In the case of the Tigris River, Gen. 2:14 identifies it as "that which goeth toward the east of Assyria." The Tigris was the great river of ancient Assyria, and on its banks stood many of the cities mentioned in the Bible, including Ashur (Fig. 1). The Tigris does (and did) flow east of ancient Ashur (now the mound of

Ashur), in perfect concordance with Gen. 2:14 *if* a *modern landscape* is assumed rather than a pre-Flood landscape. What we mean by this is a landscape that can still be recognized as being the same landscape as the ancient biblical author was identifying for his readership.

Another important biblical clue that fixes a modern landscape for the southern Mesopotamian area in pre-Flood time is Gen. 6:14, "*Make thee an ark of gopher wood; rooms shalt thou make in the ark, and shalt pitch it within and without with pitch*." Pitch (or bitumen) is a thick, tarry, oil product composed of a mixture of hydrocarbons of variable color, hardness, and volatility. Bitumen was used extensively by the ancient peoples of Mesopotamia for every type of adhesive-construction need, including the waterproofing of boats and mortar for buildings (e.g., the "slime" of Gen. 11:3). The center of bitumen production in Noah's time was (and still is) at Hit (Fig. 1), located along the Euphrates River about 80 miles west of Baghdad. The Hit bitumen occurs in "lakes" where a line of hot springs is upwelling along deep faults.[13] These faults connect the surface with the source of hydrocarbons at depth—the source being *sedimentary rock* (Fig. 1). In southern Iraq oil and gas are produced from the limestone and sandstone sedimentary rocks of the Jurassic Najmah Formation; the Cretaceous Yamama, Zubair, Nahr Umr, Mishrif, and Hartha Formations; and the Miocene (Tertiary) Fars and Ghar Formations.[14] The essential point of the above discussion is this: How could Noah have obtained pitch from sedimentary rock for building his ark, if (as claimed by flood geologists) little or no sedimentary rock existed before the Flood?

The biblical author's placement of the Garden of Eden on a *modern landscape* presents a major conflict between Genesis and Flood Geology. There are *six miles* of sedimentary rock *beneath* the Garden of Eden as it is described in the Bible (Fig. 1). Geologists know that six miles of sedimentary rock exist there because this area has been extensively drilled for oil down to the Precambrian basement. The six miles of sedimentary rock below the Garden of Eden area include (downward) Tertiary, Cretaceous, Jurassic, Triassic, and Paleozoic rock to a

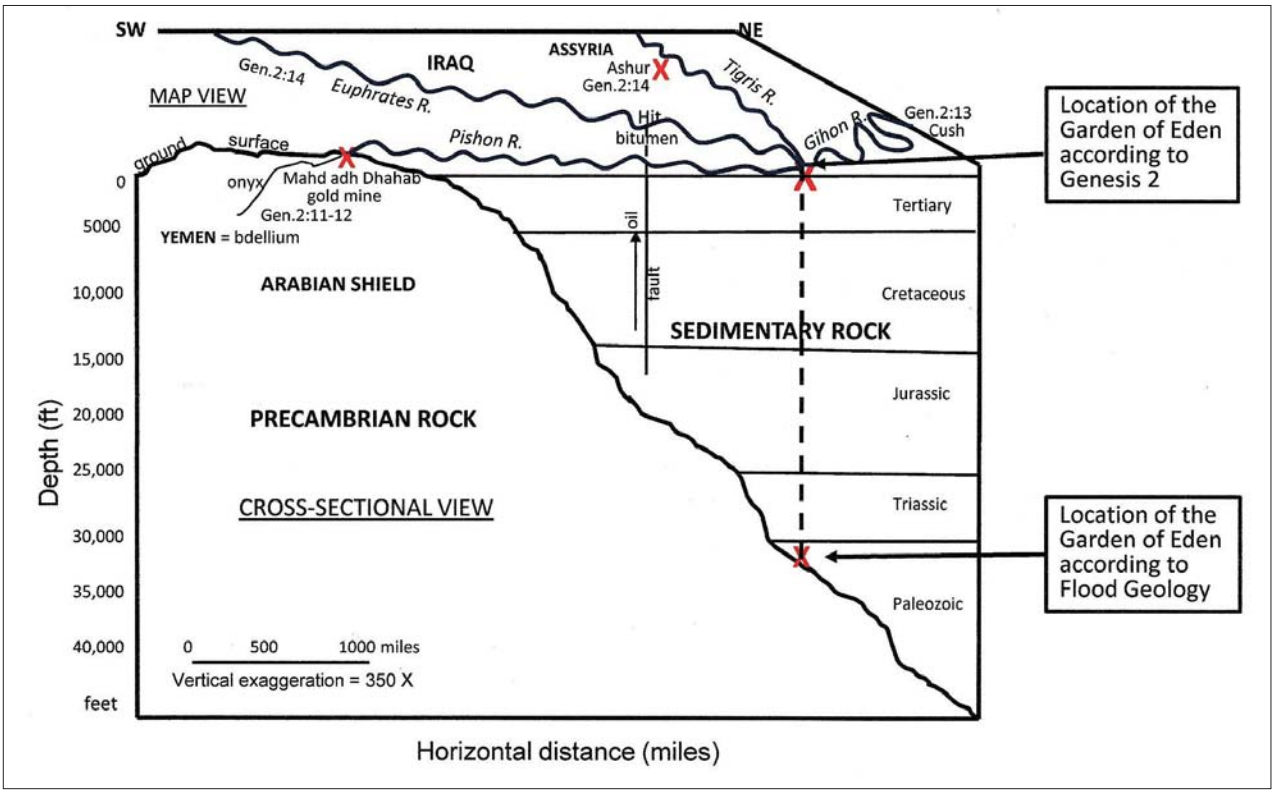

Figure 1. Schematic block diagram of the surface rivers, and cross-section of the subsurface geology, of the Persian Gulf/Garden of Eden area. If all sedimentary rock formed at the time of Noah's Flood, as claimed by flood geologists, then the Garden of Eden would have had to exist on Precambrian basement rock 32,000 feet (six miles) below where the Bible says it was located. Vertical exaggeration is approximately 350 times.

depth of about 32,000 feet before the Precambrian basement is reached.[15] The question then becomes: How could Eden, which existed in *pre-flood* times, be located *over* six miles of sedimentary rock supposedly deposited later *during* Noah's Flood? What flood geologists are implying is that the Garden of Eden existed on a crystalline basement and then Noah's Flood covered up the Garden of Eden with six miles of sedimentary rock. But this is not what the Bible says. It states that Eden was located where the four rivers existed on a modern landscape, which happens to be *on top of* six miles of sedimentary rock. Thus, these sedimentary rocks must have existed in pre-Flood times.

Grand Canyon Geology

The flood geology view of the Grand Canyon, as presented in books such as *Grand Canyon: A Different View,* is appealing to many Christians because it offers a scientific explanation that (1) does not exclude God, and (2) corresponds with what the Bible seems to reveal about Creation history. In this article we evaluate four major claims about the geology of the Grand Canyon made by flood geologists in their literature and videos:

1. *Evidence of Rapid Burial*. Sedimentary rocks contain features that are best explained by rapid deposition by deep, swift currents.

2. *No Time Gaps between Formations*. Contacts between formations lack evidence of protracted, subaerial exposure, such as would be consistent with deposition over hundreds of millions of years.

3. *Massive Tectonic Upheaval*. Deformation of the oldest sedimentary rocks in the Grand Canyon coincides with the initiation of the Flood. Uplift of the Colorado Plateau and deformation of strata in the canyon section (faulting and folding) occurred as the floodwaters receded and before sediment solidified into rock.

4. *Rapid Erosion*. The nature of the canyon and landscape of the Colorado Plateau is consistent with rapid erosion by receding floodwater.

We evaluate these four claims by not only directly addressing YEC arguments, but by also showing rock

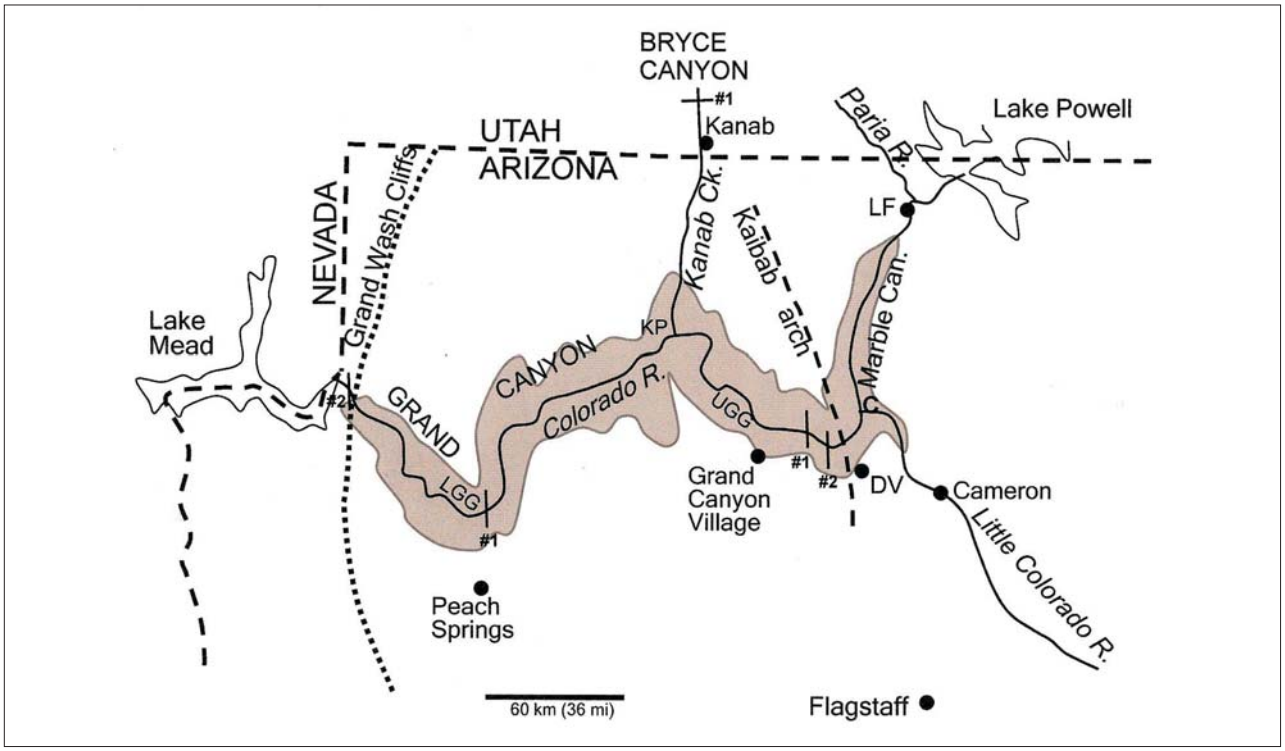

Figure 2. Grand Canyon of northern Arizona, USA. LF = Lees Ferry, C = Confluence, DV = Desert View, UGG = Upper Granite Gorge, KP = Kanab Point, LGG = Lower Granite Gorge. Laramide-age, proto-canyon drainage in the central part of today's Grand Canyon (the extent of which is marked by the three #1 symbols) would have flowed north to the Bryce Canyon area. The western Grand Canyon (the extent of which is marked by the two #2 symbols) would have existed from 16 to 6 million years ago and would have extended from the west side of the Kaibab arch to the Grand Wash Cliffs. East of the Kaibab arch is the eastern Grand Canyon, which is thought to have connected to a western Grand Canyon about six million years ago thus forming an integrated canyon along which the Colorado River flowed from Colorado to the Gulf of California.

features that belie these claims and by presenting the most up-to-date scientific theories on the origin of the canyon. A location map illustrating some of the geographic features of the Grand Canyon is shown in Figure 2, and the stratigraphic sequence of rocks exposed by the Grand Canyon is illustrated in Figure 3. An introduction to the basic rock types in the Grand Canyon is provided in Box 2. Flood geology literature contains many critiques of radiometric dating, which we feel have been capably evaluated by others,[16] and thus this topic will not be covered by us.

Remember in the following discussion what YEC are really claiming for the origin of the Grand Canyon (and for that matter the whole planet Earth): (1) that all (or almost all) of the sediments comprising the canyon's sedimentary rock was deposited by the floodwater of a worldwide Noachian Flood that took place some 4500 to 5000 years ago, (2) that these sediments were compacted into hard rock, and (3) that recession of this floodwater carved the Grand Canyon into this rock. Since Genesis 8 claims that dry land appeared after one year's time, this implies that at least (1) and (2) had to have occurred within a one-year time span, with the carving of the entire Grand Canyon (3) occurring in the last 4500 years or so since Noah's Flood.

Claim #1: Evidence of Rapid Burial

Flood geologist Steven Austin has applied the principle of hydrodynamic sorting to the Tonto Group at the base of the Grand Canyon sedimentary sequence.[17] The Tonto Group consists of, from the base, the Tapeats Sandstone, Bright Angel Shale, and Muav Limestone (Fig. 3). The Tapeats Formation overlies the Precambrian metamorphic and igneous rocks exposed at river level in the Inner Gorge. Austin argues that rising floodwater scoured the igneous and metamorphic bedrock to produce a cover of gravel and coarse sand, corresponding to the Tapeats Formation. As the water deepened in the area, fine sediment settled from suspension, corresponding to the Bright Angel Shale. Then lastly, the overlying Muav Limestone represents the introduction of fine calcareous sediment from an unknown source of eroded limestone bedrock.

Austin's model of hydrodynamic sorting raises a number of questions, the most pertinent one being: Does this model adequately explain the lithologic

Igneous Rock forms from melted material (magma). Igneous rock can form quickly when magma erupts onto the surface of the earth, either as volcanic lava flows or as explosive material. An example of such a volcanic rock is basalt. Other igneous rocks form very slowly when magma cools beneath the Earth's surface, and an example of this type is granite. The Zoroaster Granite is found at the base of the canyon in the Inner Gorge and has been radiometrically dated at between 1.4 and 1.5 billion years. The inner part of the western Grand Canyon contains many volcanic flows and cinder cones, such as Vulcan's Throne. These basaltic rocks have been radiometrically dated from about 20 million years to less than one-half million years.

Sedimentary Rock forms from sediments deposited mainly by water and to a lesser extent by wind. Sediments are eroded off the land, blown by the wind, carried to the oceans by rivers, deposited on the ocean floors, and then slowly compacted into rock. Sediments can also be derived from the shells and exoskeletons of marine invertebrate animals. The Grand Canyon contains an almost-one-mile-thick sequence of sedimentary rocks. These rocks include limestones (e.g., the Redwall Limestone), shales (e.g., the Hermit Shale), sandstones (e.g., the Coconino Sandstone), and evaporites (e.g., gypsum beds in the Toroweap Formation). Sedimentary rocks in the Grand Canyon include the Precambrian Unkar and Chuar Groups, which contain some of the earliest fossils in the sedimentary record anywhere on Earth.

Metamorphic Rock forms when igneous and sedimentary rocks are buried to great depths and are subjected to high temperatures and/or pressures over a long period of time. These processes cause these rocks to undergo a metamorphosis and become new rocks with different minerals, appearance, and structure that are compatible with their new pressure-temperature environment. Examples of metamorphic rock are marble and schist. Metamorphic rocks are found mainly as Precambrian (>570 million year) basement rocks. The metamorphic rocks of the Grand Canyon lie at the base (Inner Gorge) of the canyon and represent the core of a very ancient mountain range. These rocks are sometimes referred to as the "crystalline basement" or "crystalline rock." The crystalline metamorphic rocks in the Grand Canyon have been dated from about 2 billion to 1.5 billion years ago. Crystalline rocks are exposed in the Inner Gorge as the Vishnu Schist (metamorphic rock derived from precursor sedimentary rock) and the Brahma Schist (a metamorphosed basalt), which represents volcanic rock that was originally interbedded with sediments of the Vishnu.

Box 2. Three Different Basic Rock Types Occurring in the Grand Canyon

transitions in Grand Canyon rock involving sandstone, shale, and limestone sequences, such as occur in the Tonto Group and in rocks overlying the Tonto Group up to the rim of the canyon? It certainly does not explain the lithologic transition between the Hermit *Shale* and overlying Coconino *Sandstone*; i.e., this sequence of mud underlying sand is opposite to that expected for hydrodynamic sorting. Furthermore, how could the calcareous sediment for the Muav Limestone have come from a pre-flood source of "eroded limestone bedrock" if there was no (or very little) sedimentary rock such as limestone existing prior to the Flood?

Mainstream geologists agree with flood geologists that the Tonto Group was deposited by rising seawater, the difference being that in the Old Earth view the sea rose over a period of tens of millions of years. The rock at the base of the Tapeats Formation is a conglomerate (pebbles, cobbles and some boulders), such as would be deposited along a rocky coastline with aggressive waves and frequent violent storms eroding the pre-existing Precambrian metamorphic and igneous rocks down to a nearly flat surface. This nearly flat surface between Precambrian rock (age = 1.75 billion years) and the above lying Tapeats Formation (age = 525 million

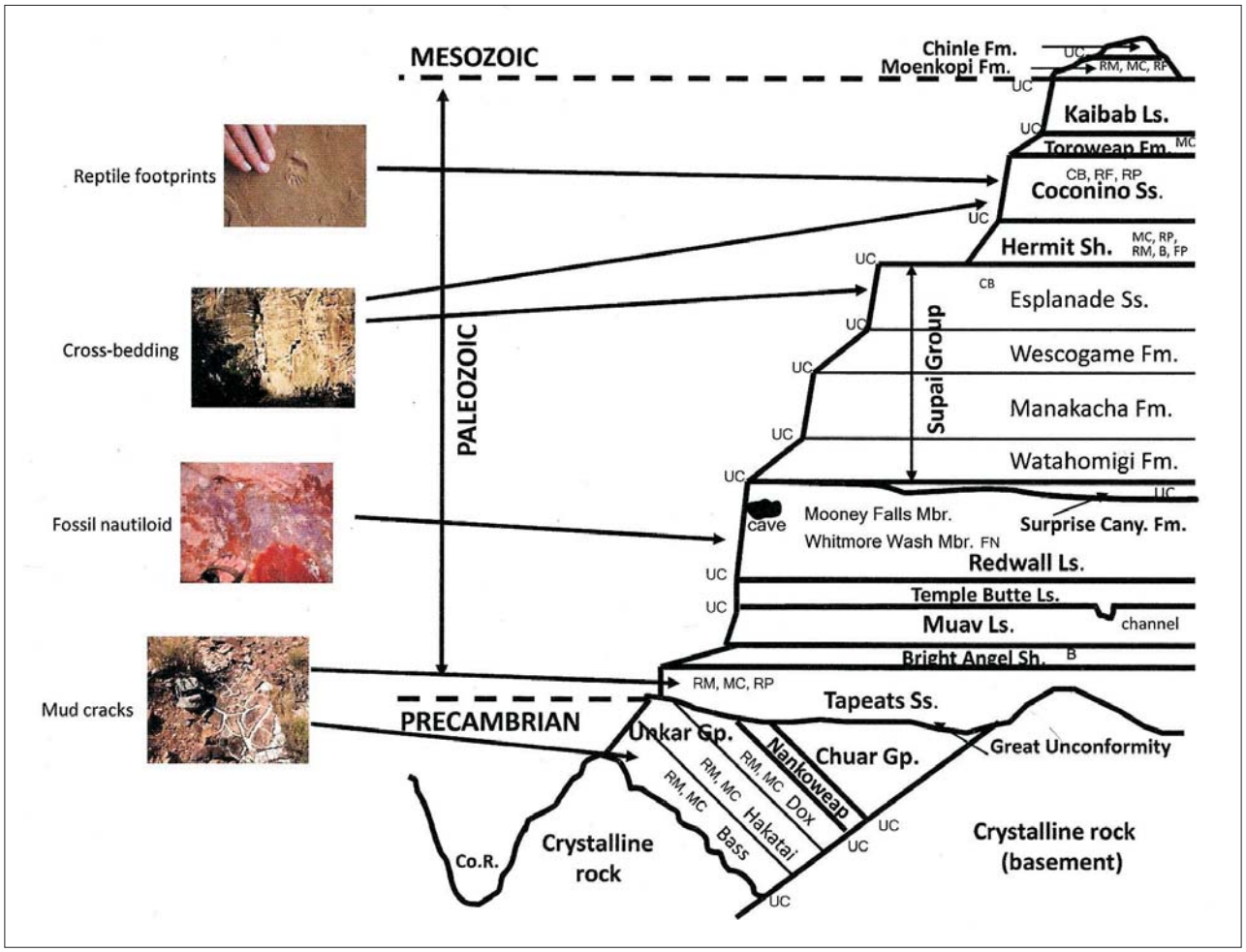

Figure 3. Simplified stratigraphic section of the Grand Canyon of Arizona, USA, showing the approximately 5,000 ft thick sequence of sedimentary and crystalline (igneous and metamorphic) rock. Each of the named layers is a rock division called a member, a formation, or group of formations. The age of this rock ranges from about 2 billion years (Precambrian crystalline rock) to about 200 million years (Mesozoic Chinle Formation). The rim of the canyon is usually capped by the Kaibab Limestone, which is about 260 million years old. The four photos show the location of some of the sedimentary features in the rock. Ss. = sandstone; Sh. = shale; Ls. = limestone; Fm. = formation. UC = unconformities, CB = cross bedding, RF = reptile footprints (tracks), RP = raindrop prints, B = burrows, FP = fossil plants, FN = fossil nautiloids, RM = ripple marks, MC = mud cracks. Many modern caves are developed along an old Mississippian-age paleokarst horizon in the Mooney Falls Member of the Redwall Limestone (black area marked "cave"). Vertically exaggerated about 18 times.

years) is called "The Great Unconformity" by geologists, and represents up to 1.225 billion years of missing geologic time. During this great expanse of time Precambrian crystalline basement rocks, which represent the core of a very ancient mountain range, were being eroded to an almost flat surface before rising seawater inundated this surface and deposited the Cambrian Tapeats Formation.

Above the basal conglomerate of the Tapeats, the rest of the formation is composed of sand about 200 feet thick, with bedding containing sedimentary structures typical of tidal flat, beach, and shallow-shore environments that include ripple marks, mud cracks, and raindrop prints (Fig. 3, RM, MC, RP). The overlying Bright Angel Shale is a mudstone that was deposited in an offshore, low-energy (not high-energy) environment.[18] Fossil animal burrows in the Bright Angel Shale attest to the continuous reworking of fine-grained sediment on the seafloor under slow (not rapid) burial conditions (Fig. 4).

Figure 4. Fossil animal burrows and grazing trails in the Cambrian Bright Angel Shale, Grand Canyon. Photo shows the top of a typical bedding plane decorated with interlaced tubes produced by deposit-feeding invertebrates. Photo by Steve Moshier.

Further offshore, the shallow sea bottom was home to many lime-secreting organisms such as brachiopods, trilobites, and algae—normal marine organisms that also cannot survive under rapid-burial conditions. All of these structures in the Tonto Group do *not* support "rapid deposition by deep, swift currents" as proposed by Austin. Rather, these features in the Tonto—and also in the entire Grand Canyon sedimentary rock sequence above the Tonto Group—indicate deposition in an alternating subaqueous (under water) and subaerial (under air) environment where the sea advanced (transgressed) over the land and then retreated (regressed) time and time again. The reason geologists know the past environments under which these sedimentary structures formed in Grand Canyon rocks is because we can *witness* how these features form today.

Sedimentary Structures in Grand Canyon Rocks

Sedimentary structures—including fossils and tracks—tell geologists about the conditions under which rocks form, such as under shallow-water or deep-water conditions or under subaerial or sand-dune conditions:

Raindrop prints. Raindrop prints are made when droplets of pounding rain impact wet mud, silt, or sand, thus creating imprints of those drops in the sediment. This can only happen when wet sediment is exposed to the atmosphere, because if the sediment is underwater it cannot be impacted by rain drops. In other words, this feature could not have formed in a rapidly rising floodwater environment as proposed by Austin—or even in a body of water greater than a few inches deep. Raindrop prints have been reported as occurring in the Tapeats, Coconino, and Hermit Formations (Fig. 3, RP).

Ripple marks. Ripple marks are typically generated by currents moving in one direction or by the to-and-fro motion of waves in shallow water to depths of a few tens of feet at the most. Figure 5 shows some ripple marks that formed along the bank of the Colorado River in Grand Canyon in September 2004 compared to ripple marks that formed in the Tapeats Formation 525 million years ago (Fig. 3, RM). Ripples have been photographed on the sea floor in very deep

Figure 5. *Left:* Mud cracks and ripple marks formed in 2004 by wave action along the banks of the Colorado River. Photo by Bob Buecher.
Right: Ripple marks preserved in the 525-million-year-old Cambrian Tapeats Sandstone. Photo by Alan Hill.

water, where these features are probably caused by density-driven currents. However, it is unlikely that such delicate ripple marks could have formed and been preserved under conditions of extremely rapid sediment burial at a scale imagined by flood geologists.

Mud cracks. Mud cracks are sedimentary structures that form by the shrinkage of wet mud when it dries out. Usually the mud cracks are preserved by being filled with sediment that covers the mud-cracked layer or by calcite crystals that fill the cracks after deposition. Invariably mud cracks imply baking under the sun (that is, they form under subaerial conditions). Figure 6 shows mud cracks forming today in the Grand Canyon along the Colorado River near its confluence with the Little Colorado River compared with ancient mud cracks formed in the 525-million-year-old Tapeats Formation (Fig. 3, MC).

Figure 6. *Left:* Mud cracks forming today in wet mud along the Little Colorado River near its confluence with the Colorado River in the Grand Canyon. Photo by Bob Buecher.
Right: Mud cracks in the 525-million-year-old Tapeats Sandstone; over geologic time these mud cracks filled with white calcite material. Photo by Doug Powell.

Cross-bedding. Cross-bedding is a feature in sedimentary rock in which strata include internal sets of layers that are inclined at an angle to the original horizontal bedding of the rock unit as a whole (Fig. 7). Cross-bedding usually occurs in sandstone but also sometimes in limestone. In the Grand Canyon the Coconino Sandstone (and some units of the Supai Formation) characteristically display cross-bedded layers of sandstone composed of frosted sand grains (Fig. 3, CB). The angle of repose for loose sand in a sand dune is about 33° to the horizontal, and if

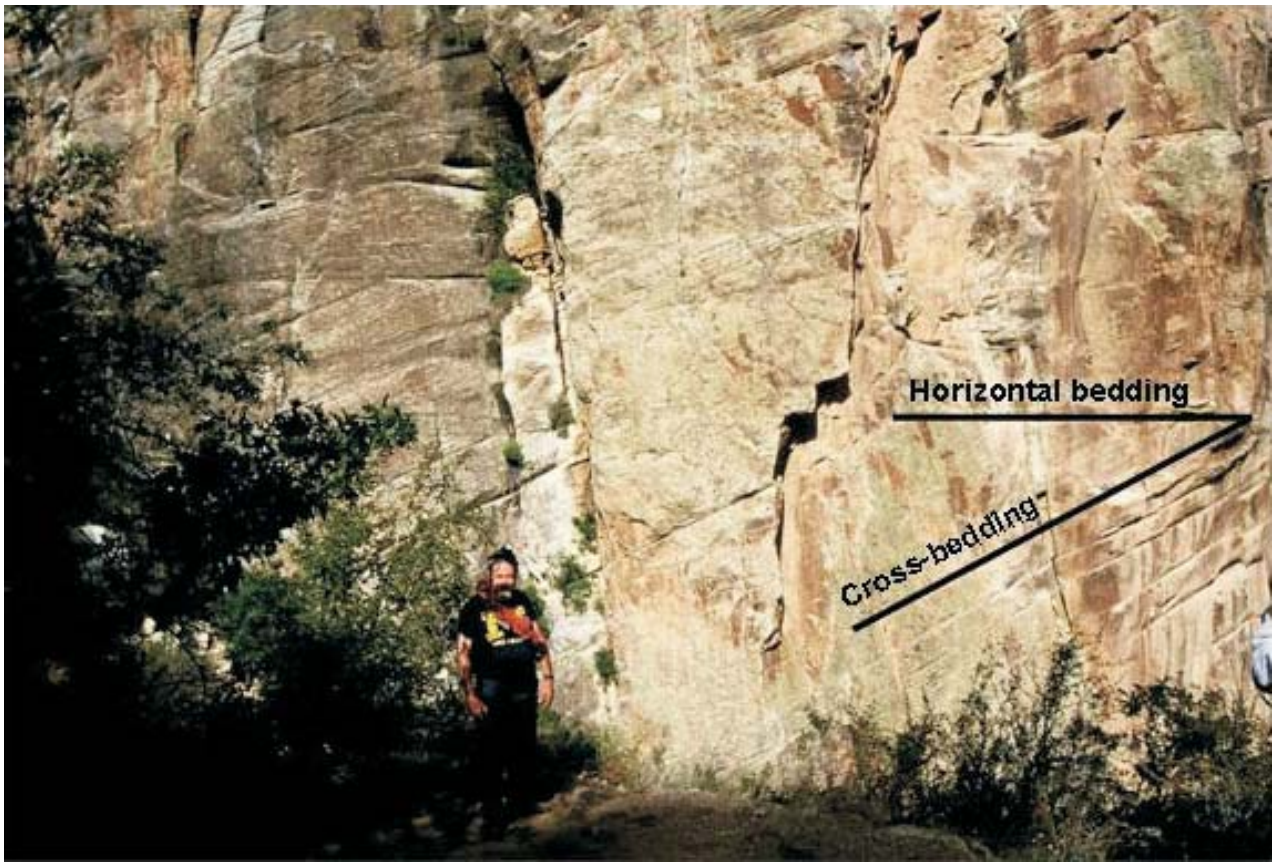

Figure 7. Cross-bedding in the Coconino Sandstone, Hermit Trail, Grand Canyon. Note the wedge-shaped lines in the rock; this is what is referred to as "cross-bedding. The cross-bedding is at an angle to the horizontal bedding, both of which are marked with lines and labels on the photo for clarity. Photo by Carol Hill.

sand is piled any steeper than this, it will avalanche downhill. The cross-beds in the Coconino have been measured between 29–31°. "Frosted" texture in sand grains is caused by the cracking of these grains as they collide when blown about by the wind (natural sand blasting). From all of this evidence geologists have inferred that the Coconino Sandstone originally formed as sand dunes that later became compacted and hardened into rock. These sand dunes likely formed in a vast coastal desert, possibly similar to the Namib Desert of West Africa today.

Flood geologist Steve Austin has proposed an alternative interpretation that cross-bedding in the Coconino Formation was produced by the migration of underwater dunes moving at velocities of three to five meters per second at depths of about 100 meters.[19] These flow and depth parameters were extrapolated from published experimental data produced by observing sand moving in laboratory sediment flumes. In defense of this interpretation, Austin cites a mainstream geologist who also proposed that the Coconino dunes were formed underwater and that the size distribution of Coconino sands is comparable to sands being deposited in the estuary of the Altamaha River along the coast of Georgia. However, that mainstream geologist never envisioned the catastrophic conditions of high-velocity flow prescribed by Austin. Such high velocities cannot possibly account for the preservation of delicate reptile footprints and raindrop prints found in the Coconino Sandstone (Fig. 3, RF, RP).

Tracks. Tracks are impressions left in soft mud or wet sand by the feet of birds, reptiles, or other animals.

Figure 8. Close-up of a footprint (track) made by a small reptile as it made its way up a rain-moistened dune surface in the sands of what was later to become the Coconino Sandstone, Bright Angel trail area, Grand Canyon. Note the tiny, delicate claw marks. Photo by Cyndi Mosch.

Reptile footprints are common in the Coconino Sandstone. These reptile tracks were made by small (lizard-size) to large (Komodo dragon-size) reptiles that crossed the sand dunes about 275 million years ago. These tracks preserve even delicate features such as claw marks (Fig. 8). Incredibly, flood geologists envision these land animals walking on dunes that they propose were moving under currents of 3 m/sec (or more) beneath about 100 m of water!

Burrows. The 500 ft (150 m) thick Bright Angel Shale contains abundant fossils including brachiopods, trilobites, and worm tracks and burrows (Fig. 4). The abundance of worm burrows shows that the accumulating mud was constantly being reworked by these animals at or just below the seafloor surface. A close look at this rock reveals that almost every particle of sediment was ingested and re-deposited by these burrowing and grazing organisms. Flood geologists have suggested that these burrows represent vertical escape trails or structures for organisms that were made during rapid sediment deposition.[20] But marine biologists and geologists know the difference between grazing trails on a normal seafloor (which is what we see in the Bright Angel Shale) and escape trails created under the duress of escaping rapid sediment deposition. Flood geologists must also explain how invertebrate organisms, including soft-bodied types such as worms, could have survived long-distance transport in their postulated turbulent, sediment-loaded currents, where the entire 5,000 ft sequence of Grand Canyon sedimentary rocks was being deposited in only one year's time in a raging flood.

Fossils. Flood geologist Steve Austin in *Grand Canyon: A Different View* concludes that certain fossils found in the Grand Canyon are evidence of "deposits from a flood of truly catastrophic proportions" (p. 53)—presumably Noah's Flood. The fossils being referred to are orthocone nautiloids, *Rayonnoceras sp.*, that occur in the top ten feet or so of the Whitmore Wash Member of the Redwall Limestone in Nautiloid Canyon and elsewhere in the Grand Canyon region (Fig. 3, FN).[21] From the scenario illustrated in the Institute for Creation Research's video *Geologic Evidences for Very Rapid Strata Deposition in the Grand Canyon*, Austin speculates that a catastrophic ocean-floor collapse swept the swimming creatures across the seafloor at velocities of four to five meters per second. Remarkably for such a scenario, the skeletons of these creatures are in excellent condition, not

showing evidence of breakage or abrasion (Fig. 9). While it may be true that this *ten-foot-thick* layer of the Whitmore Wash Member containing *Rayonnoceras* fossils represents some kind of debris-flow-type deposit, this in no way implies a worldwide cataclysmic flood affecting the entire *5,000-foot-thick* suite of sedimentary rocks exposed in the Grand Canyon! Rather, most of the limestones exposed by incision of the canyon display delicate invertebrate fossils preserved in a manner typical of normal marine conditions.

Figure 9. Orthocone nautiloid fossil in the Whitmore Wash Member of the Redwall Limestone, Nautiloid Canyon. This nautiloid (and other nautiloids in the same vicinity) are not broken up but look perfectly preserved. Photo by Doug Powell.

Why are all of the above-mentioned sedimentary structures in Grand Canyon rocks pertinent to a discussion of flood geology? Because they occur throughout the entire sedimentary rock sequence, from the earliest Precambrian sedimentary rocks up to the canyon rim (Fig. 3). Ripple marks and mud cracks are preserved in the Precambrian Bass, Hakatai, Dox, and Nankoweap Formations. Ripple marks, mud cracks, and raindrop prints can be seen in the Cambrian Tapeats Sandstone. Further up in the stratigraphic sequence, Supai and Hermit rocks display mud cracks, ripple marks, and reptile tracks. The above-lying cross-bedded Coconino Sandstone represents lithified sand dunes that also display reptile tracks. Well-developed mud cracks (polygons 6 inches or more in diameter) have also been observed in the overlying Toroweap Formation, and marine fossils typical of normal marine conditions occur in the Muav, Redwall, and Kaibab Limestones.

Considering all the above evidence, certain critical questions can be asked: If all of the sedimentary rock in the Grand Canyon was deposited in a miles-deep universal flood lasting one year, then why do the sedimentary structures in these rocks indicate a long depositional series of marine to shallow-water to subaerial to sand-dune-forming environments? Why don't *all* of the formations and their fossils throughout the canyon's 5000-foot sedimentary sequence reflect rapid deposition in deep water? How could tiny claw marks in the footprints of reptiles (Fig. 8) have been made and then preserved under turbulent flood conditions? Evidence such as this has convinced mainstream geologists that a Flood Geology interpretation of Grand Canyon rocks is not valid.

Claim #2: No Time Gaps between Formations

Let us now examine the flood geologist's tenet that there was uninterrupted deposition during the year of Noah's Flood and their claim that contacts between formational units do not show evidence of time gaps—or "unconformities" as geologists call these gaps. An *unconformity* in the rock record represents the time that transpires between the erosion of an underlying lithified (changed to rock) unit and the deposition of overlying unlithified sediment. Many such unconformities exist between the major formations in the Grand Canyon (Fig. 3, UC): in fact, they are the rule rather than the exception. However, John Morris in his section of *Grand Canyon: A Different View* uses as his example the contact between the Coconino Sandstone and the Hermit Shale to illustrate his belief that time gaps do *not* exist in the rocks of the Grand Canyon. On pages 42–43, Morris states

> the Coconino … originated in a completely different environment than the Hermit, and according to evolution, was separated in time by about 10 million years. If the Coconino represents a desert … then the ocean bottom which accumulated the Hermit material had to be uplifted, out of the water, to an elevation high enough and dry enough to be a desert.

In a photo on page 43, Morris shows a flat contact between the Coconino Formation and overlying Toroweap Formation and says,

> The existence of the sharp, knife-edge contact between these two beds argues against the passage of long periods of time between their deposition.

How do mainstream geologists interpret the unconformities related to the Hermit, Coconino, and Toroweap Formations? First of all, the contact between the Coconino and Toroweap Formations is *not* unconformable (i.e., on Fig. 3 there is no UC between the Coconino Ss and Toroweap Fm). Or, as it says in *Grand Canyon Geology*: "The boundary (between the Coconino and overlying Toroweap) is conformable in most locations … or the Coconino intertongues with the Toroweap" (p. 207).[22] Second, the Hermit Shale did not form on the "ocean bottom." The Hermit contains mud cracks, raindrop prints, and ripple marks indicative of shallow-water deposition. It formed under sluggish, meandering-stream conditions on a broad, low-lying, arid coastal plain. These fluvial red beds exhibit tracks, fossil-plant remains, and even perhaps the wing impression of a large dragon-fly-like insect—hardly evidence for an "ocean bottom" environment! Over this arid coastal plain, eolian (wind-blown) sands of the Coconino spread southward and accumulated in great dune fields directly overlying the Hermit fluvial deposits. For an excellent book that features colored paleogeographic maps of the Grand Canyon-Four Corners area, showing paleoenvironmental conditions under which sediments were deposited over time from the Precambrian to the present, refer to the newly-released *Ancient Landscapes of the Colorado Plateau* by Ronald Blakey and Wayne Ranney.[23]

In addition to the discussion of the Hermit-Coconino-Toroweap unconformities by Morris, the discussion and photos (on p. 44) by Alex Lalomov of the Great Unconformity in *A Different View* are also misleading. While in this and many other stratigraphic locations the unconformity marks a relatively flat surface over eroded Precambrian crystalline rock, in other places the vertical extent of the Great Unconformity is striking—such as between the Precambrian Shinumo Sandstone and Cambrian Tapeats Sandstone, where remnant ridges of up to 800 ft (240 m) high exist.

Two other types of contact surfaces also demonstrate that long periods of time must have occurred between different formations: channeled surfaces and karstic surfaces. Channeled surfaces exist along the Muav-Temple Butte contact where the Temple Butte Formation fills depressions (old river channels) in the Muav Limestone (Fig. 3, "channel"). A regional karst surface, characterized by sinkholes and caves, and similar to the one forming near sea level today on the Yucatan Peninsula, exists near the top of the Redwall Limestone where the Surprise Canyon Formation has filled ancient (paleo) sinkholes and caves. Prior to the sea advancing in Surprise Canyon time (Fig. 3, UC, Surprise Canyon Formation), karst valleys and sinkholes formed near the top of the Redwall Limestone as the Redwall became exposed to a long period of erosion and karstification—a scenario that begs the question: "How could these karst features have formed in soft sediment in one year's time in the middle of a flood?" Modern caves have developed along this same Mississippian-age (330 million years ago) paleokarst horizon in the Mooney Falls Member because groundwater readily dissolves caves as it moves more freely along this permeable horizon (Fig. 3, black area = cave). All of this is evidence against the YEC claim that there are no time gaps between formations in Grand Canyon rocks.

Claim #3: Massive Tectonic Upheaval

Young Earth Creationists maintain that deformation (tilting) of the oldest sedimentary rocks in the Grand Canyon (the Unkar and Chuar Groups; Fig. 3) coincided with the initiation of Noah's Flood.[24] Or, in other words, all of the sedimentary rock of the Unkar and Chuar Groups had to have been deposited *before* the Flood in order to have been tilted during the initiation of the Flood. However, this claim contradicts one of the basic premises of YEC: that all (or almost all) of the sedimentary rock on planet Earth formed *in* Noah's Flood. The Unkar and Chuar Groups of rock (together comprising the Grand Canyon Supergroup) consist of almost 12,000 ft (3600 m) of sedimentary rock—hardly an insignificant amount of rock to have accumulated between the time of Adam (who, according to YEC lived about 6,000 years ago) and Noah's Flood (about 4,500–5,000 years ago)—especially without any rain being involved in its deposition!

What about a "massive tectonic upheaval" that supposedly took place on the Colorado Plateau as the floodwaters receded? Exactly what this upheaval was, and when it supposedly happened, is unclear from YEC literature. There was compression in the Grand Canyon region during the Laramide orogeny (~60–40 million years ago), and this was the time when the Colorado Plateau was uplifted almost to its present elevation and when most

folding occurred. Then there was Basin and Range age extension (starting about 20 million years ago), during which time the Colorado Plateau Province separated from the Basin and Range Province by down-faulting of the Basin and Range along the Grand Wash Cliffs (Fig. 2).

It is presumed that the "massive tectonic upheaval" as hypothesized by YEC occurred during the latter stage of Basin and Range tectonism since supposedly it represents a time when the flood-waters receded. Henry Morris, on p. 4 of *A Different View* describes how the Grand Canyon was carved during this time:

> … a great dammed-up lake full of water from the Flood suddenly broke and a mighty hydraulic monster roared toward the sea, digging deeply into the path it had chosen along the way.

The lake being referred to is Lake Bidahochi, and the work referred to is the "Lake Overflow Model."[25] This model—while popular with some geologists at the moment—is unsubstantiated by the evidence that Lake Bidahochi remained a very shallow lake/playa throughout its history—especially during the time when lake overflow supposedly occurred.[26]

Flood geologists also try to explain tectonic faulting and folding in the Grand Canyon from their position of a very rapid, one-year-long, Noah's Flood. With regard to folding, one (unidentified) contributor to *A Different View* (pp. 32–3) claims that sedimentary layers must have been still soft during episodes of deformation, as evidenced by the tight folds seen along the Butte fault in the Tapeats Formation in Carbon Canyon (Fig. 10). The logic behind this claim is that to account for rocks deforming very rapidly, it is assumed that these rocks were unlithified (still in a wet state) when folding occurred. However, evidence from field studies and rock deformation experiments demonstrate that solid rocks behave in a ductile manner if deformed slowly under great stress. The strata "bend" by microscopic re-orientations of mineral grains and by changes in bedding thickness along the fold. Thus, the tight folds in the Tapeats Sandstone can be explained by mechanical crowding at the synclinal hinge of the East Kaibab monocline.[27] With regard to faulting, it is extremely puzzling to visualize how thousands of feet of offset along Grand Canyon faults could have been achieved in sediments that were still soft! In addition, how could slickensides (polished and smoothed striations made in hard rock by fault action), fault gouge and breccias (pieces of angular rock and earthy material along faults), and the sharply offset rock layers along faults (rather than layers slumping into faults) have formed in rock that was still soft?

Figure 10. Beds upturned along the Butte Fault, Carbon Creek area, Grand Canyon. The once-horizontal beds of the Tapeats Formation have been folded upwards to a vertical position along the fault zone. Photo by Bob Buecher.

Claim #4: Rapid Erosion

The matter of carving the Grand Canyon into the canyon's sedimentary rocks is covered on pages 30–1 of *Grand Canyon: A Different View*. Essentially, this discussion leads up to the question of "Where did all of the sediment go to that was excavated to form the canyon over the last 70 million years?" "Math calculations" show that "during those 70 million years the river should have eroded a layer more than five miles thick off the top of the entire 137,800 square-mile drainage area of the Colorado River. This massive amount of material is nowhere to be found between the Canyon and the sea, as we would expect." The comments made on these two pages show a lack of knowledge about the geological findings on the Grand Canyon obtained over the last two decades—especially since the Grand Canyon Symposium was held at Grand Canyon Village in 2000.[28] The senior author of this article participated in that symposium and since that time has published a number of articles on the origin of the canyon.[29] The following is a brief summary of her ideas and the ideas of other geologists regarding the most recent geological findings.

(1) From two independent lines of evidence,[30] it has been proposed that a relatively shallow central "proto" Grand Canyon formed during the Laramide orogeny (mountain-building episode 40 to 50 million years ago) when water flowed northward into a broad shallow lake in the Bryce Canyon area (Fig. 2, the proto-canyon existed in the area between the three #1 symbols). This proto-canyon was not nearly as deep or extensive as the Grand Canyon is today.

(2) Basin and Range faulting began along the Grand Wash Cliffs just west of the Grand Canyon about 16 million years ago. This down-to-the-west faulting and lowering of terrain in the Basin and Range Province caused drainage to begin flowing to the west. The canyon at this time (from about 16 to 6 million years ago) occupied the area west of the Kaibab arch (Fig. 2, the area between the two #2 symbols).[31]

(3) At 6 million years ago, the part of the Grand Canyon east of the Kaibab arch "hooked up" with the earlier western canyon to finally become the Grand Canyon traversed by the Colorado River that we see today.[32]

(4) While the above three recent theories are still controversial, it is known from many lines of evidence that the Colorado River has only flowed through the Grand Canyon from Colorado to the Gulf of California over the last six million years.[33]

With respect to the erosion discussion on pages 30–1 of *A Different View*, we have the following three comments to make considering these newer geologic findings:

1. The (unidentified) author of these pages makes the statement that "some geologists claim that the canyon carved by the Colorado River is 70 million years old." But only the central part of the canyon could possibly be this old, and during this time drainage flowed to the north, not to the west as it does today.

2. The math calculations based on a presumed 70 million year old age for the canyon and on the erosion rates and sediment load of today's (pre-Glen Canyon Dam) Colorado River are inapplicable because there was *no* Colorado River flowing through the Grand Canyon before about 6 million years ago. Furthermore, in contrast to the unsubstantiated incision rates used in these math calculations, actual measured incision rates are *too low* (not too high) to explain the carving of the entire Grand Canyon over the last 6 million years.[34] Thus, this "missing mass" must be accounted for by either invoking earlier canyon-erosion episodes (such as a Laramide proto-Grand Canyon) or accelerated erosion rates over the last 6 million years.

3. Therefore, regarding the question asked on page 30 of *A Different View*: "Where did all of the material go to that was eroded from the canyon?" it depends on what time frame one is talking about. Since the Colorado River is implied in the question on page 30, we will consider only the last six million years of erosion. In this time frame geologists know exactly where the Colorado River deposited its sediment load. These sediments are in the Bouse Formation southwest of the canyon (deposited in the time frame of 5.5 to 5.3 million years ago); in the Imperial Formation (of the Imperial Valley in California) deposited in the time frame of 5.3 to 2.8 million years ago; and since 2.8 million years ago, the Colorado River has been depositing its sediments in the Gulf of California.[35]

Conclusion

In this article we have addressed four of the main YEC claims concerning the geology of the Grand Canyon, sometimes specifically using examples from their book: *Grand Canyon: A Different View*. While the Grand Canyon is the "geologic showcase of the world," similar long and complex histories are also written in the rest of Earth's rocks. This consistent and planet-wide evidence is what has convinced geologists over the course of almost two hundred years that Earth's sedimentary rocks are *not* the product of a year-long biblical flood.

If Earth's sedimentary rocks were not deposited in a universal flood, as demanded by flood geologists, should this undermine one's faith in the Bible as God's inspired word? No, because the Bible *never* claims that all sedimentary rock formed in Noah's Flood! Rather, it describes a pre-Flood world that is consistent with a modern landscape overlying sedimentary rock. In our opinion, despite their good intentions, Young Earth Creationists promote an erroneous and misleading interpretation of the geology of the Grand Canyon, if not of the entire planet Earth.

Acknowledgments

We thank the three anonymous reviewers who made this manuscript much better, and we acknowledge the thousands of geologists over the last one hundred fifty years who founded the geologic framework of the Grand Canyon upon which our work is based.

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