GENESIS AND GEOLOGY

ON THE

COLORADO PLATEAU

SCHEDULE

THEOX FIELD CONFERENCE
SUMMER 2007, WESTERN US
(Subject to modification)

MONDAY, July 30, 2007. Travel by bus, Loma Linda to Flagstaff
Mostly a travel day. We will go directly beyond Flagstaff to view Meteor Crater, then back to Flagstaff.

7:30: am	Bus leaves
Noon:	Box lunch @ City Park in Kingman, AZ
6:00 pm	Dinner: Salsa Bravo @ Flagstaff (Directly from Meteor Crater)
Early evening	Check in to Days Inn
8:00 pm	Evening meeting. Ken Hart (Hotel Conference Room)

Lodging: Days Inn Phone (928) 774-5221

TUESDAY, July 31. Travel to Grand Canyon and back to Flagstaff
View: Soft sediment at a time gap, Little Colorado Gorge, fault caused slickensides, Grand Canyon strata, carving of the Grand Canyon.

8:00 am	Bus leaves
Noon:	Box lunch @ Buggeln Picnic Area
3:30 pm	I-Max Theater Grand Canyon
6:00 pm	Dinner: Delhi Palace @ Flagstaff (Directly from Grand Canyon)
8:00 pm	Evening meeting, Ken Hart (Hotel Conference Room)

Lodging: Days Inn Phone (928) 774-5221

WEDNESDAY, August 1. Travel to Albuquerque
View: Petrified Forest National Park (north end only), fossil "termite nests" near Gallup, gaps in the stratigraphic record

8:00 am Bus leaves
Noon: **(Mountain daylight time)** Lunch, Golden Coral @ Gallup, NM

6:00 pm	Dinner: Barry's Oasis Albuquerque (Directly from Gallup)
Early evening	Check in to Country Inn & Suites
8:00 pm	Evening meeting, Ken Hart (Hotel Conference Room):

Lodging: Country Inn & Suites Phone (505) 823-1300

THURSDAY, August 2. Travel to Durango
View: Rio Grande rift, San Juan basin sediments, Chaco Culture National Historic Park, Aztec Ruins National Monument, ball and pillow sediments in Durango

8:00 am	Bus leaves
Noon:	Box lunch @ Chaco Canyon
Early evening	Check in to Quality Inn
6:30 pm	Dinner: Historic Strator Hotel, Durango

Free evening in Durango.
9:00 pm Bus returns from downtown Strator to Quality Inn
Lodging: Quality Inn & Suites Phone (970) 259-7900

SCHEDULE (continued)

FRIDAY, August 3. Travel to Moab

View: Mesa Verde National Park, Blanding Dinosaur Museum, Wilson Arch, Moab Valley salt tectonics and erosion.

8:00 am	Bus leaves
Noon	Box lunch @ Mesa Verde
Early evening	Check in to Moab Valley Inn
6:30 pm	Dinner: Day Star Academy
7:30 pm	Evening Meeting, Ken Hart, Day Star Academy Chapel

Lodging: Moab Valley Inn Phone (435) 259-4419

SABBATH, August 4. Meetings at Moab SDA Church

9:00 am	Bus leaves for Moab SDA Church
	Sabbath School: Paul Giem – Why it All Matters
	Worship: Ken Hart
12:30 pm	Hay Stack lunch provided by the church Family
2:30 pm	Paul Giem - Carbon 14 Dating
3:30 pm	Ken Hart
6:00 pm	Dinner: Day Star Academy
8:00 pm	'Canyonlands by Night' boat tour

Lodging: Moab Valley Inn Phone (435) 259-4419

SUNDAY, August 5. Survey of some geologic features around Moab

View: Soft sediment features in Arches National Park, Double Arch, fossils in the Upper Hermosa Formation, Dead Horse Point State Park panorama, Grand View in Canyonlands National Park, Upheaval Dome in Canyonlands, Ottinger's fossils.

8:00 am	Bus leaves
Noon:	Box Lunch @ Dead Horse Point State Park
6:00 pm	Dinner: Day Star Academy
7:30 pm	Evening Meeting, Ken Hart, Day Star Academy Chapel

Lodging: Moab Valley Inn Phone (435) 259-4419

MONDAY, August 6. Travel to Torrey

View: Turbidites and ball and pillow features at Hatch Mesa (3 mile roundtrip walk), extremely widespread sediment units of the Book Cliffs, Powell Museum in Green River, Buckhorn Conglomerate, San Rafael Swell, the old Wolverton gold mining mill, fossils in Dakota Formation, soft sediment contact in Capitol Reef National Park.

8:00 am	Bus leaves
11:45am	Lunch: Tamarisk Restaurant @ Green River
Early evening	Check in to Wonderland Inn
6:30 pm	Dinner: Wonderland Inn & Restaurant

8:00 pm Evening Meeting: Paul Giem: Radiometric dating
Lodging: Wonderland Inn & Restaurant Phone (435) 425-3775

SCHEDULE (continued)

TUESDAY, August 7. Travel to Price

View: Cleveland-Lloyd dinosaur quarry (gravel road), Hiawatha ball and pillow, foundering of Ferron Sandstone (gravel road), Price Prehistoric Museum, Hiawatha ball and pillow

8:00 am	Bus leaves
Noon:	Lunch: Ricardo's in the Greenwell Inn, Price, UT
Early evening	Check in to Holiday Inn
6:00 pm	Buffet Dinner in Hotel Conference Room
7:30 pm	Evening Meeting: Ken Hart, Conference Room

Lodging: Holiday Inn Hotel & Suites Phone (435) 637-8880

WEDNESDAY, August 8. Travel to Vernal

View: Coal seams at Castle Gate, worm tubes in Panther Tongue, fire caused klinker in Blackhawk Formation, Utah Field House of Natural History, dinosaur bones at Dinosaur National Monument, Split Mountain erosion enigma.

8:00 am	Bus leaves
Noon:	Lunch: Stockman's Inn
Early evening	Check in to Dinosaur Inn
6:00 pm	Dinner: Twilliger's Restaurant at Dinosaur Inn
7:30 pm	Evening Meeting: Ken Hart, in the restaurant

Lodging: Best Western Dinosaur Inn Phone (435) 789-2660

THURSDAY, August 9. Travel to Richfield

View: Uinta stratigraphic drive through the ages, fossil in Curtis, Red Canyon overlook, widespread formations

8:00 am	Bus leaves
Noon:	Lunch: Golden Coral, Vernal UT
Early evening	Check in to Quality Inn
6:30 pm	Buffet Dinner in Conference Room adjacent to hotel
7:30 pm	Evening Meeting: Ken Hart, Conference Room

Lodging: Quality Inn Phone (435) 896-5465

FRIDAY, August 10. Travel to Loma Linda

Mostly all day travel

8:00 am Bus leaves

Noon **(Pacific daylight time)** Lunch Buffet, Gold Strike Casino, Jean, NV

4:00 pm Home at last!

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AN INTRODUCTION TO SOME

GEOLOGICALLY SIGNIFICANT

LOCALITIES OF THE

COLORADO PLATEAU

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For
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Field Conference

2007

This digital version adapted from the original printed copy

CONTENTS

INTRODUCTION

The western region of the United States is well known for its dramatic scenery and an unusual abundance of National and State Parks. The region has the additional benefit of a sparse vegetation cover that provides extensive exposure of the colorful geological layers. These exposures are accentuated by dramatic fault scarps, elongated monoclines and deep canyons such as the Grand Canyon. Furthermore, the colorful geological sequence of the region is quite simple and serves as an easy preamble to the study of geology, which can at times be very complex. There are few places, if any, on the surface of our planet where one can get a better introduction to the geologic past of our Earth.

You will encounter many new terms in this brief treatise. In order to facilitate your reading, we have provided: 1) a glossary of geological terms; 2) a listing and description of the important geologic formations of the region; 3) a standard stratigraphic column to help you identify which part of the geologic column you are in; and 4) a brief introduction to petrology (the study of rocks) to give you some idea of the nature of the rocks encountered. You will find these resources appended at the end of the descriptive section of this guide. You should refer to these whenever you run into an unknown term. It is suggested that these four study aids be examined carefully ahead of time so that you will know where to turn for help.

For two centuries there has been an ongoing conflict between science and the Bible. This has been one of the greatest intellectual battles of all time. The Bible, with its recent creation by God in six days a few thousand years ago, and science with its theory of evolutionary development over billions of years, stand in stark contrast to each other. The Bible, with a publication record which is 17 times that of any secular book, is highly respected. Science, with dramatic accomplishments such as space exploration and genetic engineering, is also highly respected and many are perplexed as to which is correct. This field guide addresses itself especially to issues related to both sides of this controversy.

Very pertinent to the Biblical account of beginnings is the Genesis flood, which reconciles the geologic layers of the Earth and their enclosed fossils to a recent creation by God. Without a worldwide flood, as described in Genesis, it is not possible to explain the fossiliferous geologic layers found on all the continents of the Earth in the context of Biblical history. Without that flood one cannot reconcile the uniqueness of the various fossiliferous layers of the Earth with the six day creation event given by God in the fourth commandment and in the Genesis account of beginnings. At stake here are questions about the integrity of Scripture. This is not a question that can be easily dismissed. The question of the Genesis flood is paramount to the question of the integrity of the Biblical model of origins and of the Bible as a whole. Hence special attention will be given in this treatise to geologic questions about that horrendous event.

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1. THE COLORADO PLATEAU

GENERAL FEATURES

The geology of the United States has been divided into a number of geographical provinces based on structure and perceived geologic history. Much of the area to be considered in this guide is in what is known as the Colorado Plateau Geological Province. This plateau radiates out from the Four Corners region, the only place in the United States where you can stand on four different states at the same time. It covers major portions of Utah, Arizona, Colorado and New Mexico. The Plateau is not named after the State of Colorado, but after the Colorado River, which courses from the northeast to the southwest of this region.

The varied topography of the Colorado Plateau exposes many easily recognizable, widely distributed and distinctive rock formations. The Plateau is surrounded by major regions of volcanic activity including the high plateaus of central Utah, the San Francisco Mountains of central Arizona, the Datil region of western New Mexico, and the San Juan Mountains of southwestern Colorado. The Colorado Plateau itself is dominated by smaller plateaus, mesas, and buttes that expose a rich array of sedimentary rocks. Volcanic peaks and mountains formed by the intrusion of molten rock between the sedimentary layers can be seen here and there; some form mushroom-shaped bodies called laccoliths. The La Salle, Abaho, Ute, and Carrizo Mountains around the Four Corners area are all such mountains. In the more central part of Utah are the Henry Mountains, where G. K. Gilbert first described and named the laccolith intrusion feature. Other intrusions of molten rock include several well-known residual volcanic necks such as Shiprock, and Cabazon Peak in New Mexico.

The Grand Canyon is one of the most instructive and intriguing features of the Colorado Plateau. The Canyon cuts right through a broad uplifted area with the Kaibab Plateau to the north and the Coconino Plateau to the south. It exposes the Paleozoic layers of the region as well as Precambrian sedimentary, igneous and metamorphic rocks (consult the Glossary, Rock Classification, and the Geologic Column at the end of this guide for explanations of these terms).

THE STANDARD, SLOW, LONG-AGES INTERPRETATION OF THE GEOLOGIC HISTORY OF THE COLORADO PLATEAU

The account begins with the low Precambrian (see Geologic Column in the Reference section at the end of this guide for location in column) rocks which can be seen in the depths of the Grand Canyon. Here rocks of various types, assumed to be in the billion year range, are free of all but the simplest kinds of fossils, and the rare, often poorly preserved examples have sometimes been reinterpreted as not being fossils at all. Rocks that have been metamorphosed by heat and/or pressure can also be seen in the form of dark schists (see: Introduction to Introductory Petrology: The Five Minute Rock Course in the reference section in back for explanation of what a schist is). Thick Precambrian layers of sedimentary deposits are seen especially in the eastern end of the Grand Canyon and there are Precambrian intrusions of molten rock magma into both the metamorphic and sedimentary rocks of the region. All of this suggests a harsh environment devoid of most of the life forms we are familiar with.

The Precambrian period was followed by a time (Cambrian to Mississippian, 550 to 300 million years ago) during which the Colorado Plateau was mainly an ocean, providing a rich marine environment. The deposits we now see are widespread layers of limestone and shale with marine fossils which are locally abundant. Following this period several parts of the Colorado Plateau were moderately uplifted. This facilitated their erosion into the lower sedimentary basins between. This was followed by a period when many of the colorful, bright red or green, iron rich deposits of the region were laid down. This period, which lasted from Permian up to the Jurassic (consult your geologic stratigraphic column in the Reference section), is thought to have lasted around 180 million years.

Subsequently uplifts in the east and west served as sources of sediments for the plateau area, which had broad north-south marine troughs in the middle. This combination of factors, which lasted through the Cretaceous (about 70 million years ago) produced wide-spread interfingering marine and land types of deposits. Much of the coal of the region is found in these layers.

A major uplift of the Colorado Plateau, of as much as 3 to 5 kilometers, took place in the late Cretaceous to early Tertiary. This uplift, called the Laramide Orogeny, dramatically modified the landscape. The Grand Canyon region was probably also uplifted at that time and other plateaus and basins were delineated by these events. Many of the notable elongated monoclines of the region, such as Capitol Reef, were formed then. The more recent events include volcanic activity, especially around the edges of the Plateau. The abundant faulting which characterizes the Basin and Range Province which is found to the south and west of the Colorado Plateau had little effect on the Colorado Plateau itself. The faulting did produce major features such as the Rio Grande Rift to the southeast, which cradles the Rio Grande River on its way to the Gulf of Mexico.

Evidence for slow geologic changes, evolutionary time requirements, and radiometric dating are used to support this long ages model.

A CREATION-FLOOD PERSPECTIVE

The following is an example of the history of the Colorado Plateau within the context of the Biblical historical record. It is subject to revision as new information is assimilated.

The Precambrian rocks seen in the deepest rocks of the Grand Canyon represent the geological history of the Earth before the flood and possibly before the six days of creation described in Genesis. This is the Earth "without form and void" of Genesis 1:2, which is dark and covered with water (see

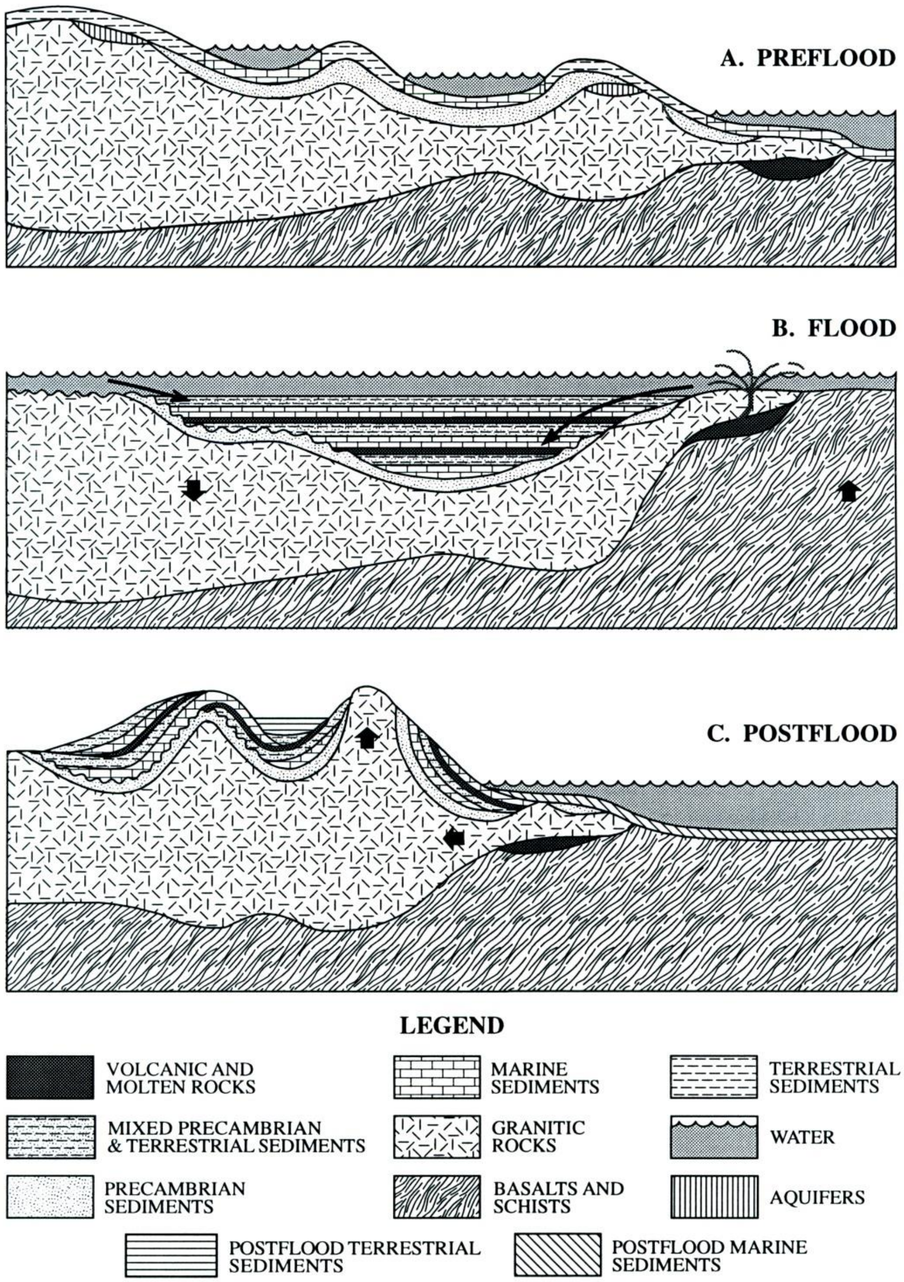

FIGURE 1. An example of a flood model. The diagrams represent cross sections of part of a continent and an ocean before, during, and after the Genesis Flood.

also Job 38:9 and II Peter 3:5). Intrusions of molten rock magma, metamorphism of rocks, and the formation of sedimentary layers, would take place before the light appears on the first day of creation week. The microscopic fossils found in these rocks represent microbial life that has infiltrated after the creation of life during creation week. Infiltration could occur before, during, or after the Genesis flood.

The Cambrian through Mississippian layers, with many marine fossils, represent in its lowest parts an epeiric sea over part of a continent. As the continents sank down and the ocean floor rose up to bring about the Genesis flood (Fig. 1) marine deposits and organisms were transported from preflood seas to the continents to form the extensive lower Paleozoic marine layers of the region.

Erosion of the lower land areas of the preflood continents would bring about deposition of Upper Paleozoic land-derived (terrestrial) sediments and organisms. The sedimentary layers of the Plateau alternate many times between marine and land-derived sources as one ascends the geologic column of the area. This would have been brought about by alternation of land and ocean sources for the sediments (Fig. 1B). Erosion of the land-derived source areas would reach well down into uplifted Precambrian sediments. Towards the end of the flood, there would be an abundance of fine sediments suspended in the flood waters. These would serve as a source for the abundant shales found in the region near the top of the geologic column.

As is the case for the long geologic ages model, there would be local uplifts here and there, and there would be the major Laramide Uplift of the Plateau during the late Cretaceous and early Tertiary part of the geologic column. As the continents rose towards the end of the flood, the receding waters which covered the Earth would erode major portions of the flood sediments, leaving great denuded areas and smaller eroded canyons, such as those seen around Bryce, Zion, and the Grand Canyon. The major flood events would have taken about one year, but the lingering effects of this major catastrophe would have lasted for many centuries or for millennia thereafter.

The above is presented only as a suggestion. Several alternative flood models have been proposed. Nevertheless, regardless of the flood model being considered, a significant number of geologic features are difficult to explain if one adopts the usual explanations of billions of years for the formation of the crust of the Earth. Some of these features will be discussed in the following pages.

2. THE GRAND CANYON

INTRODUCTION

The Grand Canyon of the Colorado River (Figs. 1-3), referred to below as "the Canyon," has been described as one of the world's grandest natural architectural masterpieces. President Theodore Roosevelt, who helped establish the United States National Park System, of which the Canyon is a part, declared that the Canyon is "the one great sight which every American should see." Some have not been that impressed, calling it just a bad case of soil erosion, or commenting that, once you get there, there is nothing to do but turn around and go back. These latter comments belie the fact that over four million people visit the Canyon every year. No one can stand on its edge and not be at least awed by its size. Pictures are but a poor substitute for the experience of actually seeing it.

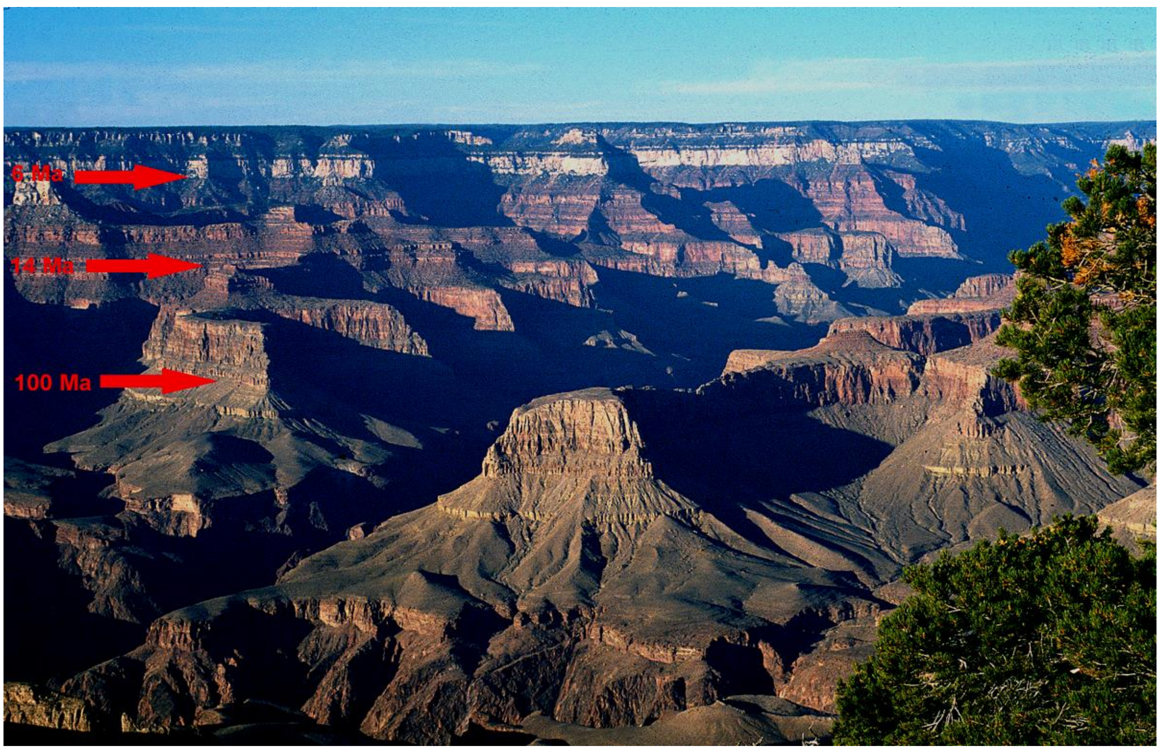

FIGURE 1. View of the Grand Canyon looking north from the South Rim. The three arrows designate where major portions of the geologic column are missing between the layers. From top to bottom they represent assumed gaps of approximately 6, 14, and 100 million years (Ma). The Colorado River, which is not visible here, runs diagonally towards the lower left of the picture in the deep Inner Gorge seen through the middle of the picture.

The Colorado River winds its way for 446 kilometers through the region of the Canyon, dropping about 610 meters in the process. The Canyon is much deeper in the mid region where the river cuts through a broad dome, scores of kilometers wide, called the Kaibab-Coconino Uplift. Here the Canyon reaches a depth of 1.8 kilometers from rim to river, and a maximum width of nearly 30 kilometers. The size is impressive, although some of the transverse gorges of the Himalayas reach nearly three times the depth of the Grand Canyon (Wadia 1975, p 27). However, what is especially important about the Canyon is how well it so openly displays many important geologic features beneath its rim. Rightfully it has been identified as the geologic showcase of the world.

FIGURE 2. View to the north of the Grand Canyon. The rock units below the tip of the arrow are Precambrian, while the parallel layers above are Phanerozoic. Note the extensive erosion to the north of the little river which is hidden in the small dark gorge in the foreground.

The size of the Canyon is most arresting, but, once one gets over that, one is duly impressed with the extremely parallel nature of the rock layers, and how small the Colorado River is as it courses its way through this huge canyon (Fig. 3). Two main aspects of this landscape are important to the study of the past: 1) How did the layers get there? And 2) how was the canyon cut? Many mysteries still lie hidden in the rocks of the Canyon, but there is a significant amount of available data that bears on these questions.

THE CREATIONISTIC INTERPRETATION OF THE GRAND CANYON

Most of the widespread layers of rock that we see in the Canyon are composed of various sediments, hence are called sedimentary rocks. They sometimes contain fossils that are occasionally quite abundant. The sediments that produce sedimentary rocks are most often transported by water. However, not all of the layers of sedimentary rock that one sees in the Canyon are interpreted by those scientists who believe in creation as originating during the flood. In the lowest portions of the Canyon, especially towards the eastern end, we find thick layers of sedimentary rocks that have very few or questionable fossils in them. These are part of the lower rock layers we call Precambrian and are seen in Figure 2 as the layers below the arrow. Precambrian layers are usually considered by flood geologists to have been there before the biblical flood. The layers above the Precambrian are designated as Phanerozoic. They contain many more fossils and in the Canyon region are strikingly parallel in arrangement (Figs. 1, 2). Only the lower half of the Phanerozoic is represented in the Grand Canyon. Just beyond the Grand Canyon, especially to the north and east are thick sedimentary layers that lie above the rock layer that forms the rim of the Canyon. These thick layers represent a significant portion of the upper part of the Phanerozoic. Most of the Phanerozoic is considered by flood geologists to have been deposited during the biblical worldwide flood. Creationists believe the Canyon was cut by the receding waters of the flood.

FIGURE 3. The Colorado River entrenched in the Inner Gorge of the Grand Canyon.

THE STANDARD GEOLOGIC INTERPRETATION FOR THE FORMATION OF THE GRAND CANYON ROCK LAYERS

Most geologists believe that the rock layers of the Grand Canyon, and most other major sedimentary layers of the Earth were formed over many millions of years. For instance, the strikingly horizontal layers of the Phanerozoic of the Canyon are commonly represented as having taken more than 300 million years for their formation. These layers have been extensively studied and the geologic literature covering them is vast. Three useful recent summaries are the publications by Beus and Billingsley (1989), Beus and Morales (1990, p 83-245), and Ford (1994).

Various ancient environments are postulated for the deposition of these layers. The lowest (just above the arrow in Fig. 2) is considered to represent a combination of shallow marine and river deposits, although there is evidence of this having occurred in deeper water (Kennedy, Kablanow and Chadwick 1996, McKee and Resser 1945). The Layers above this, up to well past the middle of the Canyon wall, are interpreted as having been deposited mainly in a marine environment with seas repeatedly advancing and retreating over the area, while occasionally rivers deposited sediments in the environment. In this portion of the layers there is an upward trend towards less marine and more terrestrial environments.

One of the most striking rock units of the Canyon is the light-colored Coconino Sandstone found near the top of the Canyon (just above the top arrow in Fig. 1). This has traditionally been interpreted as an ancient desert dune environment, although questions about this have been raised (Brand 1978, Brand and Tang 1991). From the top of the Coconino Sandstone to the rim of the Canyon the layers are thought to have been deposited over millions of years in a marine or near marine type of environment. According to standard geologic interpretation the Canyon itself was cut by slow erosional processes over millions of years.

QUESTIONS ABOUT THE BIBLICAL FLOOD INTERPRETATION OF THE GRAND CANYON

1. **The abundance of sediments.** In the context of the biblical flood, one of the most obvious questions to be asked when viewing the Canyon is how all these thick sedimentary layers could be deposited in a single event such as the Genesis flood which took only about a year. Also, as referred to above, beyond the Canyon region, there are layers of sediment, thicker than the horizontal ones seen in the Canyon itself, that lie above the layers we see in the Canyon. This is a lot of sediment to account for in a one-year flood. However, one needs to keep in mind that: 1) under rapid catastrophic conditions sediments can be deposited at the rate of meters per minutes or even faster; 2) the lowest sedimentary layers seen in the Grand Canyon are not considered to have been deposited during the flood; 3) in terms of thickness of sediments the Canyon region is not at all typical. Here the layers are several times as thick as the average over the earth. Some regions of Earth have virtually no sediments at all. Actually, the average thickness of the sedimentary layers resulting from the flood would form only a very thin veneer (a few hundred meters) on Earth's surface. Proportionately on an ordinary 30-cm globe, the thickness would be less than 1/4 that of an ordinary sheet of paper! It is still a lot of sediment.

2. **Karst surfaces.** Another question which has been posed for those who believe in a recent creation relates to the top of the Redwall Limestone which forms a prominent reddish vertical cliff in the mid-region of the layers of the Canyon (just above the lowest arrow in Fig. 1). In places the top surface of that limestone is irregular. It is interpreted as an ancient "karst" surface that would normally require many years for erosion (see Jennings 1983). The term karst comes from the Karst region of the Adriatic coast where the limestone has been eroded into a characteristic irregular surface. Limestone is quite easily dissolved; that is why we often_find cavities (Fig. 4), and even very large caves in it. One of the ancient erosional channels found in the Redwall Limestone is 122 meters deep, and there are many smaller grooves and cavities near the top of the Redwall (Billingsley and McKee 1982, Billingsly and Beus 1985, Beus 1986). How could these irregularities form if the layers of the Grand Canyon had to be all laid down

during a one-year flood, as suggested by the biblical model? Two things need to be kept in mind. 1) During a worldwide flood there would have been plenty of water activity to cut a few channels in the top of the Redwall Limestone which may not even have been very hard then. 2) Also it appears that some of these irregularities developed after the layers that lie over the limestone had already been laid down. Hence they could have formed during the thousands of years since the flood. The evidence for this is that in places we find blocks from the layers above the limestone that have collapsed into the cavities dissolved out of the Redwall Limestone (Fig. 5). If the cavities had formed before the layers above had been laid down, as is assumed for a real karst surface, the cavities would have been first filled in with sediments, but not with hard blocks of rock from the layers above which would not yet have been formed. It appears that at least some cavities formed after the layers above the Redwall Limestone had been laid down (Eberz 1995).

FIGURE 4. An example of a cavity dissolved in limestone (the Edwards Limestone) in central Texas. Note that the roof of the cavity, which is about a meter across, has not yet collapsed.

The traditional karst interpretation for a similar situation to the north of the Canyon region, but at the same location in the geologic column, has been challenged by a traditional geologist (Bridges 1982). He states: "In my opinion, the late Mississippian karst story in the Rocky Mountains is completely fallacious." He is of the opinion that the so-called karst features developed much later. Such a sequence of events would not require that much time be required for laying down of the Canyon layers. The interpretation of ancient karst surfaces is subject to reevaluation.

FIGURE 5. A collapsed area (collapsed breccia; dark red rocks in center, around the red pen) at the top of the Redwall Limestone in the Grand Canyon. The light-colored rocks are from the Redwall Limestone, while the darker ones are from the overlying Watahomigi Formation. The presence of blocks of Watahomigi suggests that the Watahomigi was laid down before solution of the limestone and collapse took place.

QUESTIONS ABOUT THE STANDARD, LONG-AGE INTERPRETATION OF THE GRAND CANYON ROCK LAYERS

1. Widespread sedimentary layers. The layers of rock exposed by the Canyon seem unusually widespread and horizontal (Fig. 3). In some cases this widespread pattern is more than meets the eye. For instance, on the basis of fossils and other characteristics, the Redwall Limestone, which forms the single steep cliff mentioned above, is commonly divided into four units lying one above the other. Many of the other major rock units are subdivided into widespread subunits. Over a century ago, Clarence Dutton, one of the leading pioneers of geology in the United States, studied the Canyon district and commented on this:

> *The strata of each and every age were remarkably uniform over very large areas, and were deposited very nearly horizontally. Nowhere have we found thus far what may be called local deposits, or such as are restricted to a narrow belt or contracted area* (Dutton 1882, p 208-209).

Some local deposits such as those mentioned above found at the top of the Redwall Limestone have been described since Dutton's original survey, but these are small. This would be more consistent with rapid widespread catastrophic flood deposition, than with slow deposition over hundreds of millions of years. During such long periods, changing conditions such as the postulated movements of the continent, including the uplift and subsidence (Dickinson 1981), which would bring about the many advances and retreats of the sea postulated for the area, would seem to favor more local deposition.

2. **Cracks at the top of the Hermit Shale.** The dark-colored formation called the Hermit Shale lies just below the light-colored Coconino Sandstone referred to above. The contact between the two is indicated by the top arrow in Figure 1. Over the Canyon region one finds fine elongated

FIGURE 6. Cracks in the dark Hermit Shale of the Grand Canyon (arrows) filled in with sand from the lighter-colored overlying Coconino Sandstone seen in the top of the picture. Note that the white sandstone in the crack to the left has caused some discoloration of the surrounding rock. Only part of a filled crack can be seen towards the right. The cracks are over a meter deep.

vertical cracks in the Hermit Shale that are filled with sand grains from the Coconino (Fig. 6). Some of the cracks are as much as 7 meters deep. One might wonder if the presence of these cracks in the Hermit Shale does not require that the Hermit Shale had first dried out before the Coconino was laid down, thus posing a problem for a flood model. This is not necessarily the case, since cracks can form underwater in soft mud due to the cohesion of clays as the process of dewatering (removing the water) takes place. The presence of the cracks actually seems to pose a problem for the long-geological-ages model, especially since it is assumed that there is a gap of several million years between the Hermit and the Coconino (Fig. 1 in Blakey 1990a, and Figs. 4 and 16 in Blakey 1990b would suggest around 6 million years). How could the cracks in the Hermit remain open for millions of years until the Coconino was laid down? Any rain or strong winds carrying sediments during that time would tend to fill them up. What we have here seems to fit well with rapid action. A possible scenario is that the Hermit was covered with Coconino very soon after it was laid down, then the shrinkage cracks formed due to dewatering of the Hermit, and the still-soft Coconino sediments filled the cracks as they formed.

3. The scarcity of erosion where significant parts of the geologic column are missing. When looking at the flat-lying Phanerozoic layers of the Grand Canyon, one does not realize that according to the standard geologic interpretation, major parts of the geologic column, representing millions of years, are missing between some of these layers. The way one tells that there is a gap is that the missing parts (layers) of the geologic column, which contain the appropriate fossils, are found in other parts of the world. During those assumed gaps of millions of years when there was no deposition, one would expect a lot of erosion forming gullies, valleys, and canyons (Roth 1988). There is no place on the surface of the Earth where we would not expect either erosion or deposition over these long periods of time. If there is deposition, then there would be no gap in the geologic column. But if there is no deposition, we would expect significant erosion over such long periods of time, and the layers of the Grand Canyon should not appear so parallel. The Canyon itself well illustrates the dramatic effects of erosion. The three arrows in Figure 1 point at significant gaps in the layers estimated from top to bottom at approximately 6, 4, and 100 million years; yet, as can be seen, the underlying layers appear essentially free of erosion. The top arrow points to the gap between the Coconino and Hermit discussed above (see also Fig. 6). In referring to the gap at the middle arrow, a geologist (Beus and Morales 1990, p 158) comments: "Contrary to the implications of McKee's work, the locations of the boundary between the Manakacha and Wescogame formations [where the gap is] can be difficult to determine, both from a distance and from close range." In referring to some localities of the very long lower gap, another geologist (p 111, Beus and Morales 1990) states: "Here, the unconformity [gap], even though representing more than 100 million years, may be difficult to locate." Over these very long assumed periods of time a lot of weathering and erosion of the rock layers would be expected, but this is not what we see.

Average present rates of erosion for the region around the Grand Canyon would erode a layer as thick as the Canyon is deep in less than 12 million years. This means that, according to the standard geologic time scale, the Canyon and the rock layers that form it should have been eroded long ago (Roth 1986). While there is considerable disagreement as to how the Grand Canyon itself was eroded, the geologist Lucchitta (1984) suggests that "most of the canyon cutting occurred in the phenomenally short time of 4 to 5 million years." The discrepancy between the expected erosion over the postulated millions of years, where parts of the geologic column are missing, and what is seen, suggests that those millions of years never took place. What is seen seems to favor the rapid deposition expected during the biblical flood.

4. The lack of food for animals in the Coconino Sandstone. In the lower half of the Coconino Sandstone, hundreds of well-defined animal footprint trackways are found. These trackways were probably made by amphibians or reptiles. The surprising thing is that no plants appear to have been present. Aside from the footprints, the only other fossils that have been reported are those of a few worm tubes and invertebrate trackways (Middleton, Elliott and Morales 1990; Spamer 1984). If the Coconino had been deposited over millions of years as is assumed for the standard geologic interpretation, what nourishment was available for the animals who made all these trackways? There is no evidence for the presence of plant food. If simple footprints are well preserved, one would also expect to find the imprints or casts of roots, stems, and leaves of plants, if they were ever present (Roth 1994).

Almost all of the trackways in the Coconino indicate that the animals were going uphill. Furthermore, there is good evidence that these trackways were formed underwater, instead of the usual interpretation that they were made on desert dunes (Brand 1978, Brand and Tang 1991). Is it possible that all these uphill trackways were formed by animals seeking to escape the waters of the flood? The bodies of the animals could have been swept away by flood activity. That may be why we don't find them. On the other hand, in the context of the standard interpretation of slow geologic processes, we would expect to find at least the imprint of the roots of the plants on which the animals had to feed, but these appear to be absent.

HOW WAS THE GRAND CANYON CUT?

The simple question of the cutting of the Canyon turns out to be very complex. Although geologists have been intensely studying this matter for over a century, no simple answer or consensus seems in sight. The details of the discussions are beyond the scope of our brief survey, but are well summarized in the professional geologic literature (Brown 2000; Beus and Morales 1990; Babenroth and Strahler 1945; Breed 1969; Elston and Young 1989; Graf et al. 1987; Hunt 1976; Longwell 1946; Lucchitta 1990, 1984, 1972; Perkins 2000; Rice 1983). Recent interpretations suggest much shorter times and catastrophic activities for the carving of the Canyon. These trends are in the direction of a creation interpretation. However, to most geologists the cutting of the Canyon is an unsolved mystery sometimes referred to as the "Canyon conundrum" (Rice 1983).

Among the vexing problems which the Canyon poses is the fact that the Colorado River, which courses through the Canyon, cuts right through a broad dome, instead of going around it. One would not expect that any "intelligent" river would go up over a dome instead of around it.

Another problem is the question of the past location and age of the river. Was it present before the dome formed? Evidence for an ancient Colorado River is notoriously sparse, especially west of the Canyon. Some have suggested that in the past on the east side of the dome the river came from the northeast to the edge of the dome and then went to the southeast towards the Gulf of Mexico without ever traversing through the dome itself. It has also been suggested that the dome was eventually eroded from the west to join the Colorado River from the east, but without much of a source of water to cut a deep gorge through the dome, this seems unlikely. On the west side, it has been suggested that the river may have left the Canyon region, going to the northwest before eventually changing its course and going to the southwest where it is now found. Also puzzling are the huge side canyons found especially on the north side of the Canyon (Fig. 1, 2 far side). These side canyons which end up in the high region of the dome have virtually no streams to erode them.

The Canyon is huge. Some 4000 cubic kilometers of sediment have been eroded to form the Canyon. Yet this is but a fraction of the erosion evident in the region for the layers mentioned earlier that must have been above those exposed in the Canyon (Dumitru, Duddy, and Green 1994). The erosion of these layers forms a broad valley, more than 200 kilometers wide, that lies above the Canyon. Probably 15 to 30 times as much sediment was removed to form the broad valley above the Canyon as was involved in the carving of the Canyon itself. Dutton (1882 p 61-77) called the erosion of this broad valley "the great denudation." According to standard geologic interpretations this great denudation would be considered to be a slow process of broadening of the valley over time as the valley walls retreated laterally as they were slowly eroded. But this does not seem to be the case. The sides of the broad valley do not have active talus (debris) at the base of the cliffs as would be expected for a slow process. The sides of the broad valley are clean as though the valley had been catastrophically washed out. Clean edges are more like what you would expect from the runoff of the waters of the flood than from a slow gradual weathering process. Besides, if the valley was the result of a slow weathering process, one has to explain why all the weathering and washout took place in the broad valley while the sides of the valley are left uneroded.

How did the Canyon get cut? We don't know for sure. We do know that the standard slow model poses a number of questions. It is also of interest that the lore of local Indian tribes reflects more rapid action. One writer, in referring to this comments that: "The Navajo, the Hualapai and the Havasupai still believe that the river is the runoff from a great flood that once covered the earth" (Wallace 1973, p 99). Some scientists who believe in the biblical account of beginnings also suggest that the carving of the Canyon and the surrounding region is the result of the runoff of the waters of the worldwide biblical flood. One model (Austin 1994, p 92-107) proposes that at the end of the flood a lot of water was ponded to the east of the Grand Canyon region. A natural dam on the west side of the ponded water was breached and a great volume of water flowed to the west cutting the Canyon. A second model proposes that the Canyon was cut under water, that is below the surface of the flood waters, as these were retreating to the west. This model may explain the origin of the many side canyons to the Canyon. Although we don't see it, underwater erosion in the ocean is a common thing. We have many underwater canyons cut along the edge of our continental shelves. A submarine canyon, the Monterey Canyon, which lies off the coast of California, is as deep and as wide as the Grand Canyon. We may not know how the Grand Canyon was carved, but the action of the receding waters of the biblical flood present some interesting possibilities.

CONCLUSIONS

The Grand Canyon has much to say about the past history of life on Earth. This fascinating display of rocks has been interpreted in a variety of ways. Most scientists propose that one to many millions of years were involved in its formation. However, a number of questions about this interpretation can be raised when specific details are considered. The biblical model implying rapid formation of the rock layers and of the cutting of the Canyon provides some resolution to some of the questions posed by the standard model. While the Grand Canyon still hides many mysteries, and we still have much to learn about it, it also provides strong evidence that supports the truthfulness of the biblical account of beginnings.

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3. PURPORTED FOSSIL "TERMITE NESTS" IN THE JURASSIC MORRISON FORMATION

NOTE: In the field guide prepared for the conference participants, this topic was presented as eight pages of text and illustrations. However, as a precaution, due to possible publication and copyright conflicts, distribution of that version is being temporarily restricted. A report that has already been published and that gives the salient results of the research on these intriguing structures is provided below. It is published in: Geological Society of America. 2006. Abstracts with Programs, Volume 38(6): p 7. GPS for the locality is 35.5579 and 108.6007.

COMPLEX CONCRETIONS IN THE JURASSIC MORRISON FORMATION

(Ariel A. Roth, Tom Zoutewelle, and Dwight Hornbacher)

Complex concretions found in bedded sandstones of the Recapture Member of the Morrison Formation near Church Rock, NM are often large, resistant to erosion, and frequently display an abundance of 4-10 mm diameter branches. A common form is a vertical cylinder in the meter range, protruding and/or imbedded in the country rock, which consists of a hard core that often encloses an internal soft core. Frequently branches protrude from the hard core into the country rock and/or form irregular complexes. Cores or branches may be missing, and simple to compound bizarre shapes abound, including rare horizontal cylinders of core with small protruding branches.

On a microscopic scale the contact between concretions and country rock is dominantly irregular and gradational. Thin section point count comparisons of eight concretions with eight samples of country rock show significantly more cement ($P < 0.001$) and fewer primary pores ($P < 0.001$) in the concretions; also significantly fewer grains and more IGV ($P = 0.014$ for both) in the concretions. SEM of the concretions shows dominant pore-filling microcrystalline quartz, including intergrowth with illite/smectite. The country rock shows variable amounts of pore linings and local pore fillings composed of chlorite, kaolinite, illite/smectite, hematite, and microcrystalline quartz. Comparisons by XRF shows significantly more Si ($P < 0.001$) and less Al, Fe, Na, K, Mn, and Mg ($P \leq 0.003$) in the concretions. NA shows significantly less Na, Fe, Rb, Sb, and La ($P \leq 0.007$) in the concretions; Si and Al were not tested by NA. These data suggest that silica is added to the country rock to form the concretions.

Petrographic analysis seems to invalidate the suggestion of a fulgurite origin. Thus far, we have not found a convincing termite nest architecture or termites, and this brings into question the fossil termite nest interpretation. The rhizoconcretion interpretation also appears to be problematic due to general morphological factors and a paucity of ramifications. It may be that the concretionary process follows in part the pattern of the abundant "tubes," of organic or inorganic origin, that are already present in the country rock. It is hoped that the data presented above will help elucidate the origin of these intriguing structures.

Rocky Mountain Section-58th Annual Meeting (17-19 May 2006)

Session No. 4--Booth# 4
Stratigraphy and Sedimentology (Posters)
Western State College: Kebler West Ballroom and Red Mountain Lounge
8:00 AM-11:40 AM, Wednesday, 17 May 2006

Geological Society of America *Abstracts with Programs*, Vol. 38, No.6, p. 7

4. PARACONFORMITIES

LOCATION

Paraconformities (and closely related similar features called disconformities) are found in many places in the sedimentary layers of the world. The specific location of the various paraconformities discussed below is provided with the legends of the illustrations.

DESCRIPTION

Paraconformities are widespread gaps in the geologic layers where there is essentially no irregular erosion of the surface at the gaps, hence the sedimentary layers below and above the gaps are parallel. As you consider paraconformities keep in mind two characteristics: a **gap** and **parallel layers**. Dead Horse Point in Utah gives a good introduction. Good paraconformities are also mentioned in the Grand Canyon (Section 2) of this guide. The red arrows in Figure 1 point at two gaps in the geologic layers of some 10 and 20 million years (Ma) each, and the layers just below and above the gaps are parallel, hence here you have two paraconformities.

FIGURE 1. Valley of the Colorado River as seen from Dead Horse Point, Utah. Top arrow points to an assumed 10-12 million year (Ma) depositional (time) gap. Lower arrow points to a 15-20 million year gap. Note the striking contrast between the flat depositional patterns of the layers at these 10 and 20 million year hiatuses and the deep irregular erosion of the canyon by the Colorado River.

FIGURE 2. View to the south from E of the town of Hurricane, Utah. The arrow points to the paraconformity between the Shinarump that forms the thin caprock and the Moenkopi below. Between the two there is an assumed gap (Middle Triassic missing) representing 10-12 million years (Ma) of geologic time. The lack of erosion during such extended time challenges the validity of the geological time scale.

These paraconformities can be very widespread. The arrow in Figure 2 points to the same paraconformity designated by the upper arrow in Figure 1, yet these localities are 200 miles (320 km) from each other. The 10 million year gap lies between the Shinarump Conglomerate that is found at the base of the Chinle Formation, and the Moenkopi Formation below. To find a description of these units look towards the back of this guide in the Stratigraphic Section. There you will find them in the Triassic portion of the Mesozoic.

Keep in mind that we are dealing here with **paraconformities** where parts of the geologic column are missing and the layers above and below the gap are parallel. These localities are hard to detect because (1) the layers representing the gap are missing, so there is nothing there; and (2) the layers above and below the gaps are parallel as is the case for many sedimentary deposits. The way paraconformities are identified is by noting that a part of the standard geologic column is missing between the layers below and above the gaps. In other words where we find these gaps, there are parts of the geologic column in other parts of the world that represent the missing layers. Identification of the layers is based mainly on their fossil content, however the kind of rocks associated with them is also important. Rarely, radiometric dating is used.

The sequence outlined below for Dead Horse Point is assumed to have taken some 60 million years. See the "Geologic Column" in the References Section for details. The listing, in the order they appear, given below illustrates the details of the gaps at Dead Horse Point.

MESOZOIC

Jurassic

Navajo Sandstone

Triassic

Kayenta Formation

Wingate-Moenave Sandstone

Chinle Group

Shinarump Conglomerate of Chinle

(Paraconformity of about 10-12 million years, middle Triassic missing)

Moenkopi Formation

PALEOZOIC

Permian

(Paraconformity of about 15-20 million years, upper part of Permian missing)

Kaibab near Hurricane, Utah and Cutler Group (top is White Rim Sandstone) at Dead Horse Point

The lower gap in Figure 1 is also present at the locality of Figure 2, however it is difficult to see there, being visible only in parts of the Virgin River Gorge.

A CREATION-FLOOD PERSPECTIVE

Paraconformities present a challenge to the long geologic ages that are generally accepted for the sedimentary layers of the earth because we don't see the expected effects that time should produce at these gaps. Those effects include weathering and especially erosion (Figures 3 and 7). The contrast between the amount and irregularities of erosion by the Colorado River at Dead Horse Point and the flatness of the sedimentary layers in the region is instructive. Between some of these layers, significant parts of the geologic column are missing. That is supposed to represent lots of time. However, if lots of time occurred between the deposition of some of the layers, one would expect evidence of this in the form of lots of irregular erosion, as the huge canyon cut by the Colorado River ably demonstrates. Yet where there are gaps (paraconformities), the layers we see lie flat (on top of each other) indicating that the long ages suggested for the significant missing parts of the geologic column, did not occur.

It also needs to be kept in mind that the present average rate of erosion of the continents of the earth is way too fast to fit into the standard geologic time scale (See Roth 1998 p 263-266 for references). Our present continents are being eroded at the rate of 61 mm per thousand years. This may seem slow, but according to that rate, including correcting for the present accelerating effects of agriculture, our present continents should have been eroded to sea level over 100 times during their proposed geologic ages of billions of years. The average amount of erosion expected at the flat paraconformities is very significant. At a 10 million year gap, one would expect about 1000 feet (300 m) of erosion, and at a 100 million year gap one would expect 10,000 feet (3 km) of erosion. Occasionally one sees a little erosion, but the contacts are usually nearly flat, indicating that the long geologic ages never took place. The lack of irregular erosion that would be expected at the surface of (Go to page 27.)

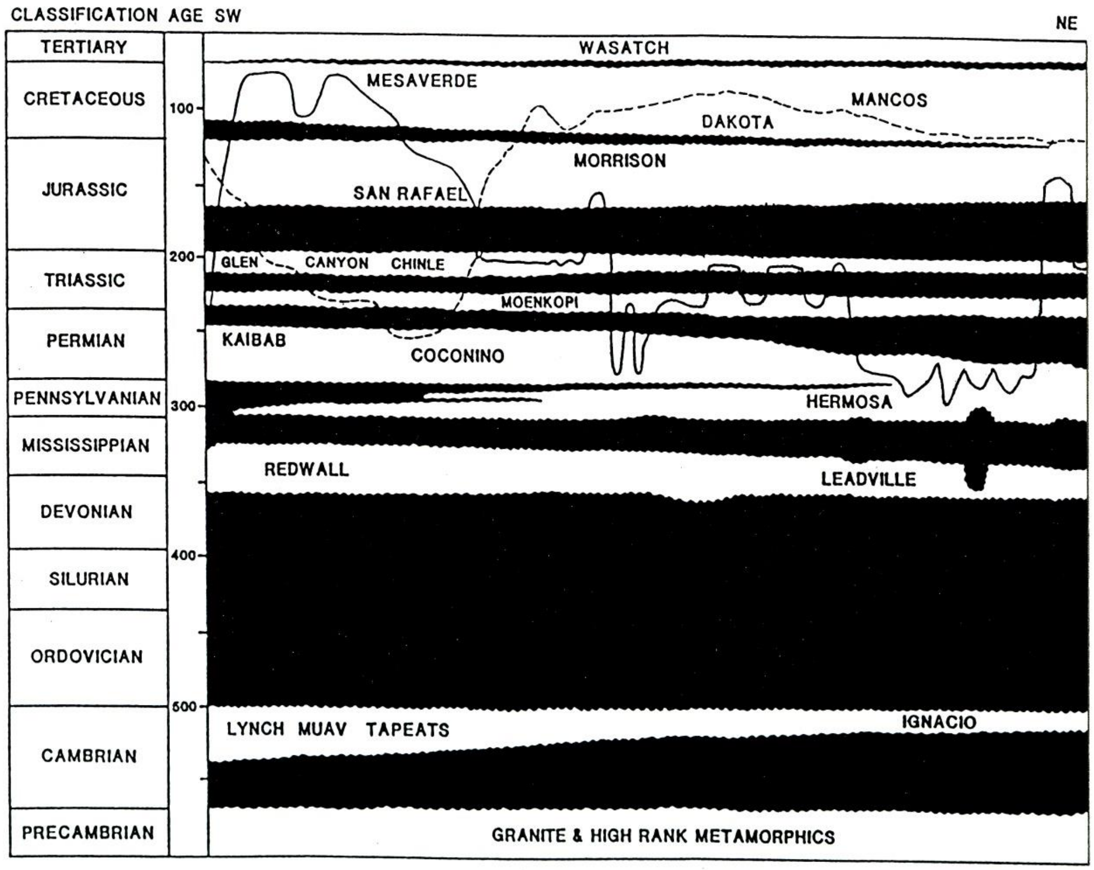

FIGURE 3. Representation of the sedimentary layers in eastern Utah, based on the standard geologic timescale (instead of thickness, although the two are related). The clear (white) areas represent sedimentary rock layers, while the black areas represent the time for the main gaps (hiatuses, paraconformities) between layers where parts of the geologic column are missing in this region. The layers (white areas) 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 as carved by erosion. The dashed line (- -) represents one of the flattest surfaces of the region as found along Interstate 70, while the smooth line (--) is in the hills farther south. This provides evidence for a flood model wherein the layers (white areas) 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 (dashed and continuous lines). 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 (dashed and continuous lines) between the white layers. The main divisions of the geologic column are given in the left column, followed by their putative age in millions of years. Names in the sedimentary units represent only the major formation or groups. Vertical exaggeration is about 14x. The horizontal distance represents about 133 kilometers while the total thickness of the layers (white part) is about 3½ kilometers. (Based on references for Figure 3 given in References below.)

FIGURE 4. Location: View to the N, from near Whipple Point in Petrified Forest National Park. The red, gray and white layers below the tip of the red arrow are the Triassic Chinlee Formation or Group. The gray layer just above is the Pliocene Bidahochi Formation. The line separating the two, right at the top of the red layer, represents a major paraconformity of some 190 million years (Ma).

FIGIRE 5. Location: At the intersection of Interstate 40 and the Continental Divide in New Mexico. The thin tan layer just above the tip of the red arrow is the Cretaceous Dakota Sandstone or Dakota Formation. Just below it is the Jurassic Morrison Formation. A significant part of the Lower Cretaceous is missing here representing a gap of some 40-50 million years (Ma), yet the Dakota lies very flat on top of the Morrison. This relatively flat contact can be followed for 150 miles (240 km) along Interstate 40.

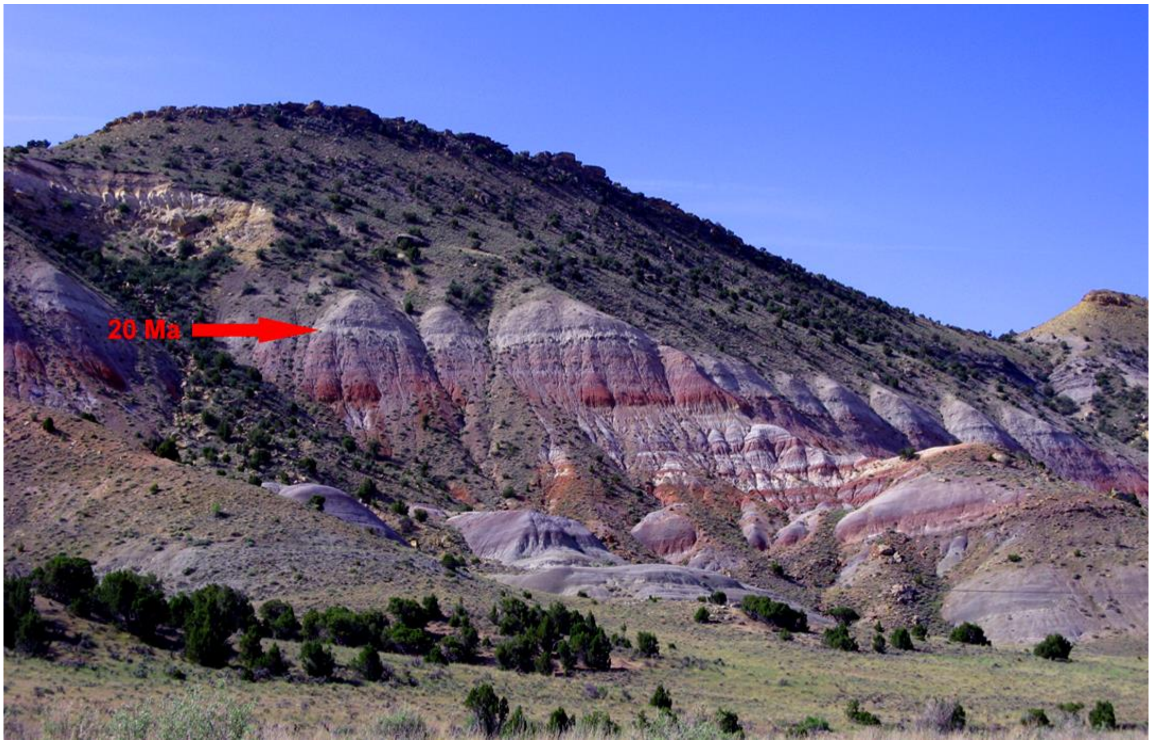

FIGURE 6. Location: View E from U.S. Highway 191, N of Steinaker Reservoir and Vernal, Utah. The Cretaceous Cedar Mountain Formation lies just above the tip of the red arrow; below the tip is the Jurassic Morrison Formation. Between the two is a paraconformity of some 20 million years (Ma). The lower part of the Lower Cretaceous is missing over a wide area. The Dakota Formation forms the light tan scarp some distance above the red arrow.

the lower layer at these gaps over time challenges the millions of years that are proposed for the standard geologic time scale.

The difficulty with the extended time proposed for these gaps is that one cannot have deposition, nor can one see much erosion. With deposition, there is no gap, because sedimentation continues, and fossils would be preserved. With erosion, one would expect abundant channeling and the formation of deep gullies, canyons and valleys; yet, the contacts are usually flat or nearly flat. Over the long periods of time envisioned for these processes, erosion would erode the underlying layers and all the rest of the continents. One has difficulty envisioning little or nothing at all happening for millions of years over such widespread areas on the surface of our planet.

This is not an isolated situation (Roth. 1988; 1998, pp. 222-229; 2003). Figure 3 illustrates the missing layers towards the middle of the Colorado Plateau and contrasts the flat sedimentary layers with the present topography illustrated by the dashed and dotted lines superimposed on the diagram. Figures 4-6 illustrate other paraconformities on the Colorado Plateau. Figure 7 contrasts what would be expected from slow and rapid deposition. What we see in the rocks favors rapid deposition as expected for the Biblical model of origins.

As one travels over the Colorado plateau, one is struck with the irregular topography of the present surface of the land, as contrasted to the flatness of the sedimentary layers. This is well illustrated in Figure 3 (study the legend), and most anywhere you look on the Colorado Plateau. When you realize that according to the standard geologic time scale there are substantial parts of the geologic column, representing lots of time, that are missing (paraconformities) between some of the layers, one has to wonder if the proposed millions of years ever occurred; because what we see is more like Figure 7 A, E and not like Figure 7 C, D (study the legend) as we would expect over the millions of years postulated. What we see speaks of a very different kind of world with rapid, widespread deposition and little time between the depositions of the layers. This is just what we would expect from the Genesis Flood.

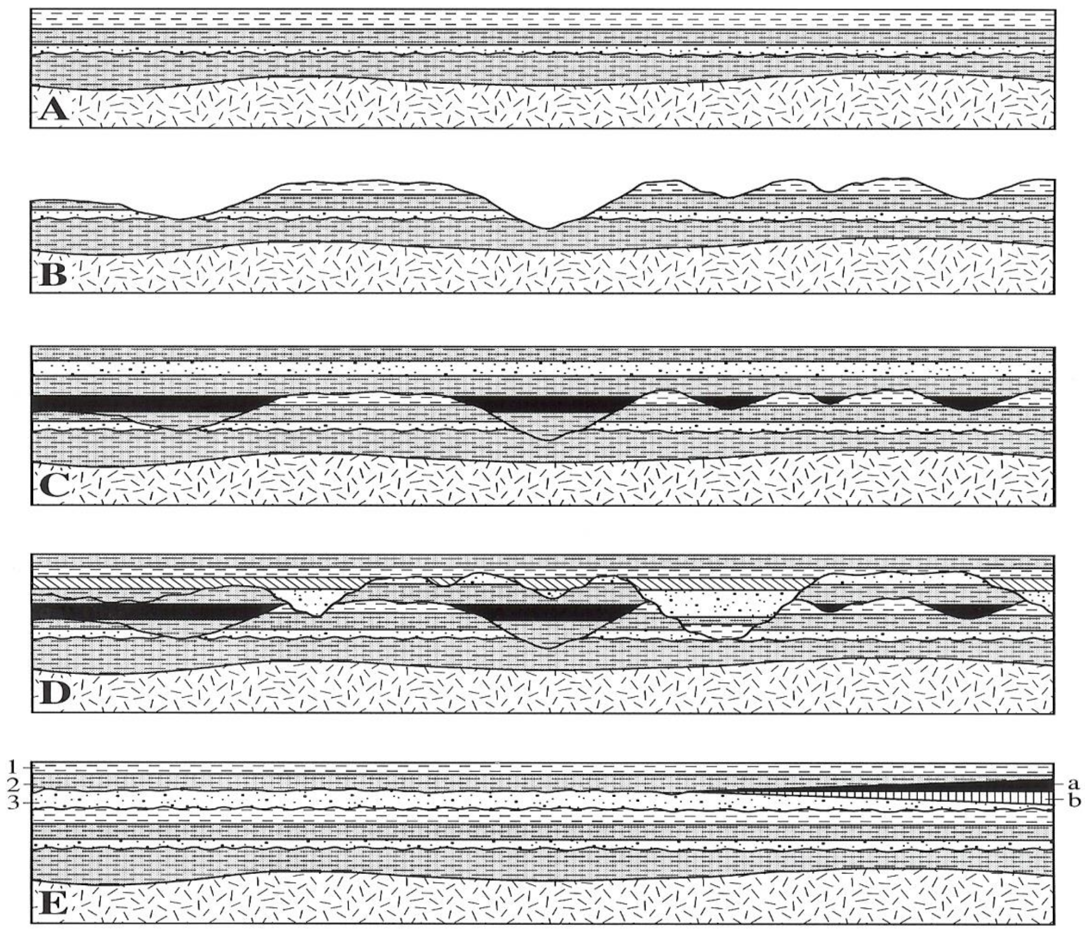

Figure 7. Deposition-erosion patterns. (A) Pattern of continuous deposition. Sediments are usually laid down in a flat, horizontal pattern as shown. (B) Erosion. (C) Resumption of sedimentation. The old erosion surface is still visible. This pattern should be common within the earth's sedimentary layers whenever significant parts of the geologic column are missing. (D) A second cycle of erosion and deposition further complicates the pattern. (E) The more normal pattern seen. In E we would expect significant erosion between layers 2 and 3 (left side), if extensive time was involved in depositing layers a and b wedged in on the right.

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5. MOAB VALLEY

LOCATION

The Moab Valley is an elongated valley that runs in a northwest to southeast direction in eastern Utah. It is located mainly to the south of the town of Moab and can easily be seen as high cliffs on either side as one drives along U.S. Highway 191 through the Moab region.

DESCRIPTION

The Moab Valley (Fig. 1) is one of six to eight (depending on subdivision) elongated parallel valleys that run in a northwest-southeast direction in western Colorado and eastern Utah. These valleys are all anticlines (layers convex upward) whose central portions subsided and have been eroded, leaving valleys between opposing cliffs (Baars and Doelling 1987, Chenoweth 1987). These anticlines were formed by the migration of salt (also called an *evaporite*) to the region below the valleys, mainly along fault lines. Upward migration of the salt caused uplift of the valley regions prior to erosion. The salt, which has a lower density than the surrounding rock, migrated up below the developing valleys along zones of least confining pressure.

FIGURE 1. View from the south end of the Moab Valley looking north. The valley was formed by the migration of salt, faulting, and by erosion. The gray Cedar Mountain-Burrow Canyon (Cretaceous) layers in the center and right foreground (red arrow) of the valley used to be much higher above the level of the reddish to tan layers (Jurassic Triassic) forming the sides of the valley. These Cretaceous gray layers, which are stratigraphically higher than the reddish-tan layers, collapsed down due to dissolving of the salt below the floor of the valley and other factors including possible lateral expansion (rifting).

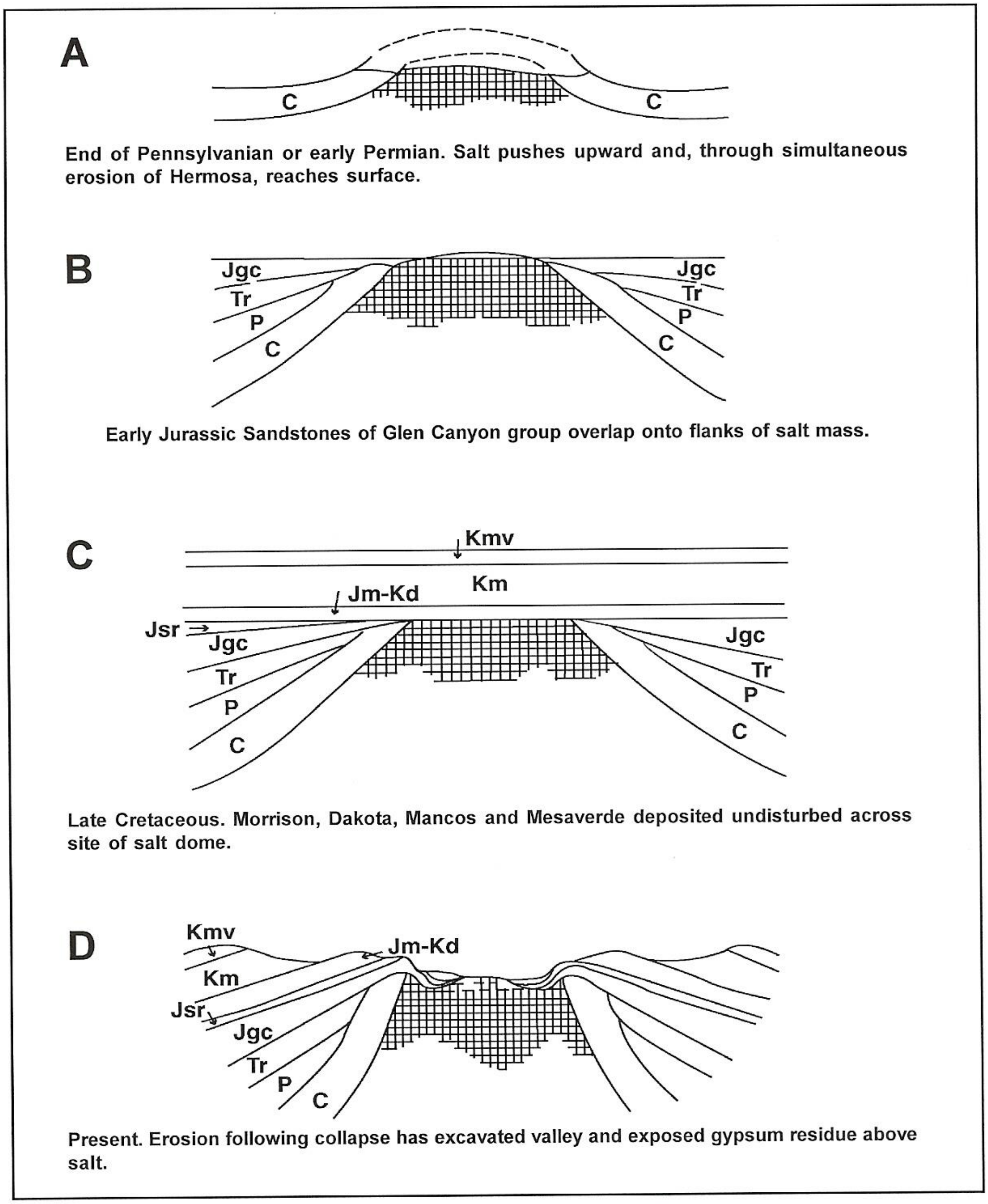

FIGURE 2. Postulated sequence in the formation of salt valleys. Hatched pattern -- salt; C – Carboniferous (Pennsylvanian); P – Permian; Tr – Triassic; Jgc – Jurassic Glen Canyon Group; Jsr– Jurassic San Rafael Group; Jm-Kd – Jurassic-Cretaceous Morrison to Dakota; Km – Cretaceous Mancos Shale; Kmv – Cretaceous Mesa Verda Group. Modified from Thornbury (1965) p. 432.

Movement of the salt occurred mainly from Pennsylvanian through Triassic time (Figure 2). A little more salt migration may have occurred during the Laramide Orogeny late Cretaceous and early Tertiary time. As the valley regions moved up, it appears that deposition of surrounding formations was restricted over the rising ridges, but this is a disputed point. In the late Cretaceous the Mancos Shale completely covered the region (Fig. 2 C). This was followed by further accentuation of the anticlines by west-to-east compressional pressure, but some also argue for extension (Ge 1996). Solution of the salt caused collapse of the valley floor, and occasionally the Burrow Canyon can be seen much lower (Fig. 1) than the stratigraphically lower valley walls. Erosion of sediments in the central part of the valley accentuated the topography. The Moab Fault on the southwest side of the valley is an apparently normal fault, suggesting expansion of the valley, with a down drop of as much as 2600 feet of the northeast side.

The Paradox salt layer, that migrated up and eventually caused the valleys to form, is not pure and contains significant clay, gypsum, and limestone. It is from 2,000 to 6,000 feet thick in the surrounding region, but reaches up to 12,000 feet under the Moab Valley and 15,000 feet under the Paradox Valley to the east. There is no salt exposed on the floor of the Moab Valley but there are associated gypsum outcrops along the southwest side of the valley.

Up to 29 cycles of evaporation have been proposed for the Paradox salts. It would require the evaporation of many kilometers of depth of sea water to produce one cycle; hence a reflux model with repeated addition of sea water in a barred basin is proposed. It would require many reflux cycles of replacement to produce one of the 29 cycles of the Paradox salts. The sequence of precipitation of various salts from sea water is sometimes normal and sometimes reversed, and various reflux systems have been proposed to accommodate this (Hite 1973).

One of the baffling features of the region is that major rivers cut almost perpendicularly across the long valleys. The Colorado River cuts across the Fisher and Moab Valleys, and the Dolores River cuts across the Paradox Valley. Another question is why are the centers of these elongated anticlines cleaned out while the sides remain? The paradox of rivers flowing perpendicularly to the valleys is the reason for the names: Paradox Valley, the Paradox Formation, which is the source of the salt, and the Paradox sedimentary basin of the region. Several explanations have been proposed and will be considered later in connection with erosion of the Uinta Mountains. This paradox is also seen in the Grand Canyon region.

A CREATION-FLOOD PERSPECTIVE

The traditional view that the salt of the Paradox Formation formed as a result of the evaporation of sea water does not fit easily with the concept of the deposition of most of the Phanerozoic sediments in a one year flood. On the other hand, one can postulate “original” preflood salt deposits getting involved in these sediments, as the crust of the Earth broke up at the time of the flood. Uplift and erosion of the salt valleys would take place during and after the flood.

The traditional slow evaporation model for the formation of salt is not without serious problems. It would take a thickness of around 25 miles of sea water to produce 2000 feet of Paradox salt. And when you evaporate sea water calcium and gypsum precipitate out first. Repeatedly replenishing an evaporation basin with sea water by a reflux-barrier system is the usual long-age explanation, but requires special fortuitous conditions for a very long time. Because of many difficulties a number of other models for the formation of evaporite salts have been proposed such as volcanic activity (e.g. Rode 1944).

The very few natural salt deposits now being formed by evaporation on our Earth are extremely minute compared to the huge salt deposits found in the sedimentary record of the past. Past conditions seem definitely different from present ones. There are no thick evaporites forming anywhere on earth today!

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6. RAPID SEDIMENTATION

INTRODUCTION

Time is a major difference between the Biblical model of a recent creation by God and the billions of years proposed for evolutionary development. Time is probably the most contentious topic in the ongoing battle between the Bible and science. The improbabilities of evolution need a lot more time than the billions of years proposed, while the God of the Bible does not need any. Some of the sedimentary layers of the earth have something to say about time.

There are many localities in the Colorado Plateau that give evidence of rapid sedimentation. A lot of this evidence is at the contacts between two sedimentary layers. Some data indicate that both the layer below and the one above the plane of contact between the two were soft. This is usually interpreted by geologists to indicate that they were deposited at about the same time, because sediments tend to harden over time, and it doesn't take very long for a mud layer to gain some physical competence as water migrates out of it.

Some of this evidence is at major gaps between units and gives evidence that the proposed long time between the layers never occurred. For instance two geologists (Roca-Argeim and Nadon, 2003) propose that the Buckhorn Conglomerate which is at the base of the Cedar Mountain Formation is part of the Brushy Basin Member of the Morrison Formation that lies just below it. They come to this conclusion because the Brushy Basin shows numerous mud injections into the Buckhorn, indicating that both were soft. The significance of this and the problem for the traditional geological time scale here is that there is supposed to be some 20 million years between the Brushy Basin and the Buckhorn. It appears that those 20 million years never occurred!

One must be cautious and keep in mind that a time problem in one locality does not invalidate the whole geologic time scale of itself. On the other hand there is significant evidence for soft sediments, in many instances not at major time gaps, but of themselves evidence of rapid deposition as expected during the Genesis Flood. Every locality is part of the total picture.

We also mention *turbidites* (Figure 6), that are a persistent interpretation of many sedimentary deposits, (e.g. Carvajal and Steel 2006); and a significant factor in the rapid sedimentation picture. Turbidites are deposited quite instantaneously; they form as sediments flow underwater, and are just what one would expect during the Genesis Flood. They produce many layers in one depositional event. Unfortunately their identification is usually difficult. Figure 10 illustrates the various parts of an ideal turbidite. In their process of deposition, first only the lower parts of the ideal sequence, i.e. A, B, is deposited, in the middle all parts may be deposited, while towards the end only the higher units of the ideal sequence, i.e. C, D, are deposited. When forming, turbidity currents can travel at 100 kilometers per hour and can deposit a layer as much as 200 meters thick. Most are much thinner. A recent turbidite in the North Atlantic deposited some 100 cubic kilometers of sediment.

DESCRIPTION AND INTERPRETATION

Below, several soft sediment localities are illustrated and briefly discussed. We will visit most of them.

FIGURE 1. Location: Mile marker 461 on US highway 89, S of Cameron, AZ. Contact between the Triassic Moenkopi Formation, dark brown (red arrow) and the lighter colored Shinarump Conglomerate. The Moenkopi intrudes into the Shinarump rock indicating it was still soft when the Shinarump was laid down, yet the Moenkopi is supposed to be around 10 million years older than the Shinarump.

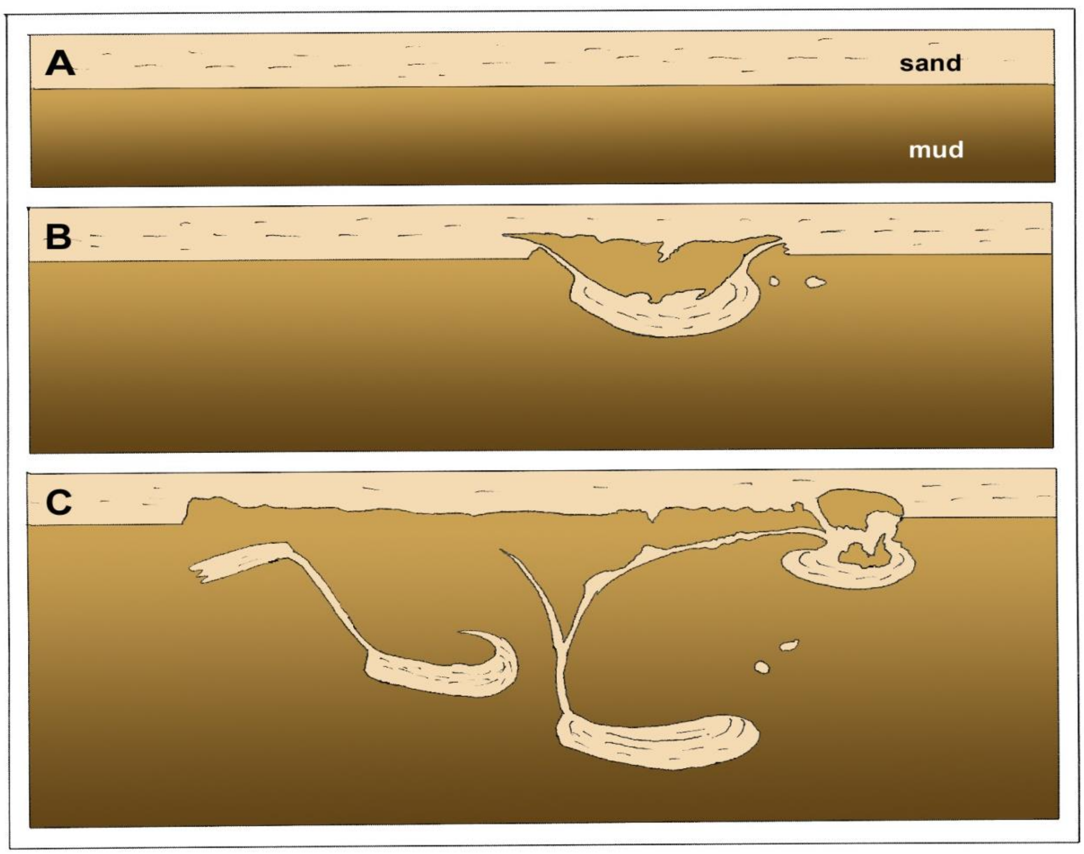
FIGURE 2. Location: On main road into Arches NP, 1.6 miles W of junction to Windows Section. Top massive layer is Jurassic Entrada, bottom red layers are Jurassic Dewey Bridge (Carmel). Note major foundering and penetration of middle grayish layer into the Dewey Bridge (of Entrada or the Carmel Formation). You would not expect this from slow gradual deposition.

BALL-AND-PILLOW FEATURES

We will have a chance to see several ball-and-pillow localities that are illustrated in subsequent figures. A few introductory comments should help you understand these fascinating structures. While the cumbersome term ball-and-pillow is highly descriptive, some geologists opt to just call them pillows, although some are very much ball like and the term pillow is used for other geologic structures.

These structures form in unconsolidated sediments, usually with a sandy layer, which can have a density of 2, overlying a muddy layer with a density of 1.5. Plumes of mud arising between units of sand can isolate the sand into ball like structures, or flatter pillows can form by sinking into the mud. The mud has to be quite fluid for this to occur.

Ball-and-pillow structures are interpreted by most geologists as representing rapid action (Figure 3). A good supply of sand has to cover the mud before it consolidates, so both the mud and the sand have to accumulate quite rapidly. The term *foundering* is often used in describing the breakdown of the original sedimentary system into balls and pillows. These structures do not necessarily prove the Genesis Flood, but they lend good support to the concept because they are the kind of activity expected during that flood in contrast to the slow accumulation rates of sediments usually going on now on our earth.



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IGURE 3. Laboratory experiment producing pillows. (A) Sand is laid over mud in a tank; (B) tank is shaken to simulate an earthquake thus producing a pillow; (C) more shaking, more pillows. Based on Howard and Lohrengel (1969) reporting on Kunnen's classic experiments in The Netherlands.

FIGURE 4. Location: Horse Gulch path, at the E end of 3rd Street, N side , at the gate to the path, in Durango, Colorado. Note the three prominent balls at the base of the overlying tan Cretaceous Point Lookout Sandstone. Note the flat tan sandstone pillows below, imbedded in the black Cretaceous Mancos Shale. Their emplacement must have taken place before the Mancos was consolidated. (Dunbar 1992, Lucas 1997).

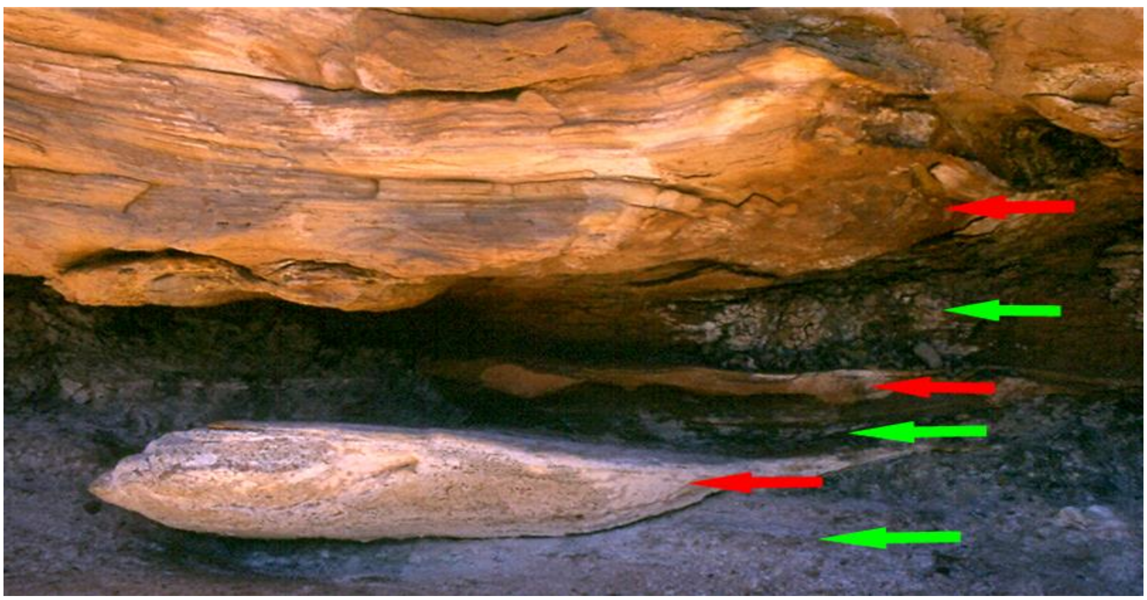

FIGURE 5. Location: Near the S end of the main paved Scenic Drive road in Capitol Reef NP, Utah. View is on the E side of a wash E of the road just before the road turns sharply to the E to go to the Capitol Gorge parking area. In the figure above, the red arrows point to the Upper Triassic Shinarump Conglomerate, and the green arrows points to the Lower Triassic Moenkopi Formation found between and below the Shinarump. The Middle Triassic, that represents some 10-12 million years, is missing between these two formations. It is very doubtful that the Moenkopi would remain soft for 10 million years so as to facilitate this kind of deposition. Height of the total view is about one meter (3 feet).

FIGURE 6. Location: Start on E end of Green River, UT. Go 9.5 miles east on Old Highway, turn N on dirt road just before a small bridge, go to railroad tracks, walk N towards end of small canyon. Features are high on W side. This is in the Kenilworth member of the Cretaceous Blackhawk Formation. The two thick sandstone units above the shale are interpreted as turbidites (Pattison 2005). Picture above is of the lower one and shows details of two ball structures with soft mud that went up between the two (arrow), suggesting rapid deposition.

FIGURE 7. Location: This is just S of Hiawatha, UT. Follow State Highway 122 W to the railroad track, the features can be seen for a mile to the west along the tracks. This is Cretaceous Panther Sandstone. Howard and Lohrengel (1969) have reported on these pillows. They propose that originally there was a thick mud layer between the pillow layer and the thinner sandstone layer below. The tip of the red arrow is where the mud layer was. That layer flowed up between the pillows thus forming them and placing the pillows directly over the thinner sandstone layer that is only moderately deformed. This all occurred as one event in soft sediments.

FIGURE 8. Location: South of Wellington, UT. Go S on 100 East Street for 5.7 miles, turn E and go 3.6 miles on a dirt road that veers S. The features are in the top of the cliff to the west. The resistant cap rock is the widespread Cretaceous Ferron Sandstone. Below is Mancos Shale. This locality highlights the foundering of the Ferron into soft mud. Note the curvature of the layers in the balls and the squeeze up of mud between large balls.

FIGURE 9. Location: Up Spring Canyon Road W of Price, UT, drive up into the coal seams and look. Contact is between black coal and light colored overlying sediments. Note that the coal intrudes in several places into the sediment or vice versa, indicating that both must have been soft when coal forming vegetation was covered up by the sediments. Foundering of the sediment suggests rapid action; however, here geologists do not propose any major time period between the deposition of these two units. View is about half a meter (1.5 feet) across.

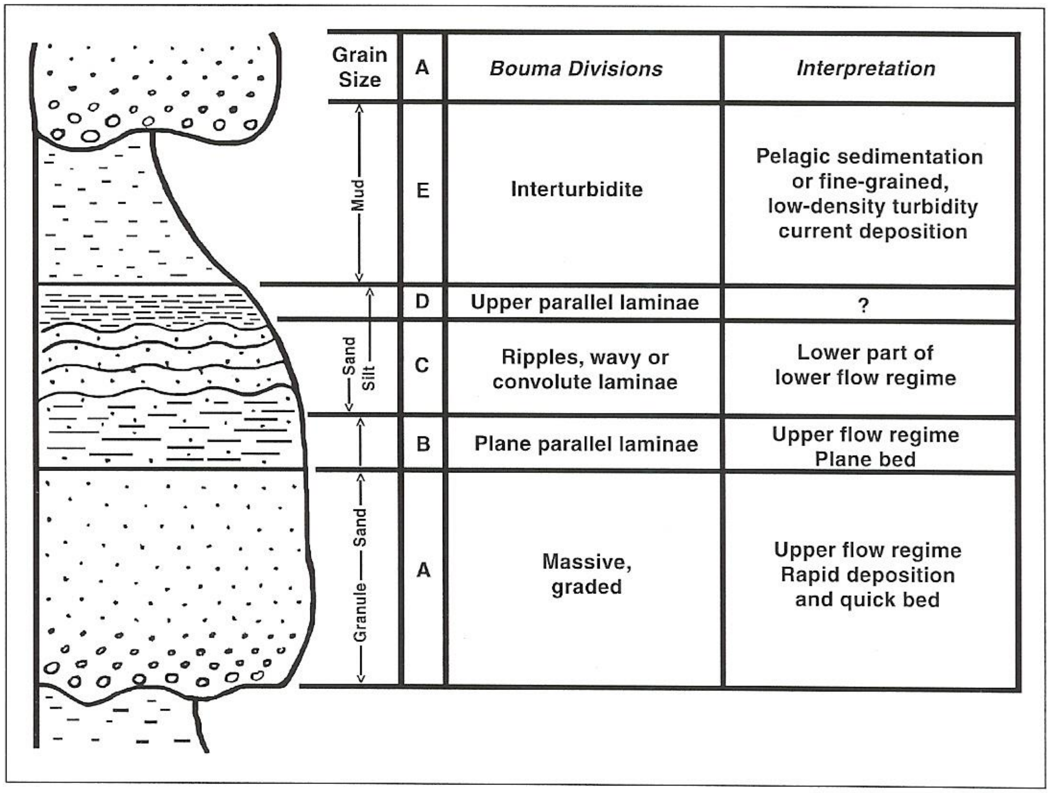

FIGURE 10. Sediment characteristics of an ideal turbidite (Bouma sequence). Units A, B, C, D, are all laid down at about the same time, very rapidly, by the turbidity current. Unit E, the interturbidite is laid down between turbidite deposition events and is not necessarily present.

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7. "WORM TUBES"

LOCATION

The "worm tubes" being considered here are located on the west side of a little north-south directed canyon that opens onto the south side of US Highway 6, just a little east of the highway truck weighing station at Castle Gate, Utah. This is east of the junction of US Highways 191 and 6 west of Helper, Utah. The worm tubes can be easily seen at the entrance of the canyon in blocks that have fallen down from the layers of the well bedded Panther Sandstone Member of the Cretaceous Star Point Formation (Figure 1) that is exposed on the west side of the canyon.

FIGURE 1. The parallel layers of sediment to the left and middle of the upper part of the figure are the Panther Tongue of the Cretaceous Star Point Formation. Some of the upper layers have abundant "worm tubes," especially in their top portions.

DESCRIPTION

The Book Cliffs area around Price, Utah, is a Mecca for trace fossils (tracks, tubes, etc., left by organisms). In the sandstones of this region numerous tube-like structures ("worm tubes") left by organisms are found. These have been thoroughly studied (e.g., Frey and Howard 1985, 1990). It is strange that though the tubular structures are abundant, little is known about the kinds of organisms that produced them: "Body fossils are virtually non-existent" (Frey and Howard 1990.) Over a score of different kinds of trace fossils ("tubes") have been identified in this area.

A CREATION-FLOOD PERSPECTIVE

The presence of "worm tubes" is considered to be a problem for a flood model. In a worldwide flood, one would not expect organisms to be producing "tubes." This is considered to require time.

One suggestion as an answer to this objection is that these tubes really do not represent structures made by organisms. After all, organisms are essentially absent. This may be the case for some; however, for others a biological origin seems almost certain, since a regular pattern of biological activity is reflected in the wall and sometimes the content of the tubes. This is especially conspicuous in the *Ophiomorpha* group, which has a pellet-wall pattern.

An alternative answer lies in the question of the amount of time required by these organisms to produce these tubes. The flood described in Genesis took over a year for its various phases. Could organisms build these tubes within the constraints of that time? During the year of the flood, many things could happen, including tube burrowing. In order to disprove the flood, only events that take longer than the time available should be considered valid. Since the known rate of formation of these tubes can be quite rapid, they may not represent a firm challenge to a flood model after all.

Studies by Kranz (1974) indicate that bivalves burrow between 0.16 and 153.15 cm/hr under an increasing overburden of sediments (anastrophic events). Under normal conditions, rates between 1.84 and 1000 cm/hr are reported by Stanley (1970; also see Table 4 in Kranz 1974). Investigations by Howard and Elders (1970) on small (1 mm diameter burrow) crustacea from Sapelo Island, Georgia, indicate burrowing rates of 0.7 to 4.6 cm/hr.

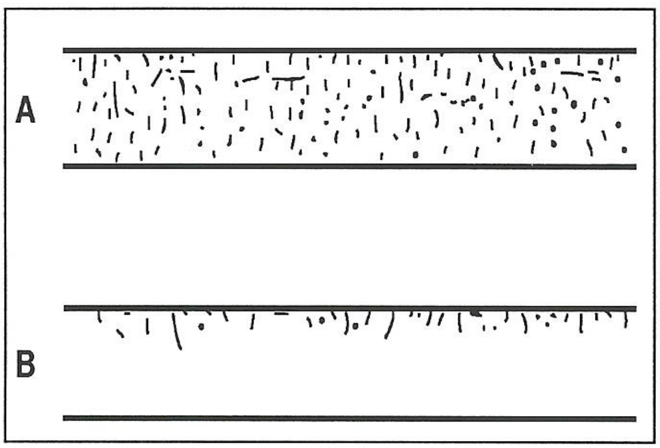

FIGURE 2. Sedimentary layer with trace fossils illustrated as vertical-oblique lines. A = pattern expected under a slow process of accumulation; B = pattern expected under rapid deposition.

Interestingly, Signor (1982) found that fat turritelliform (elongated, pointed) snails buried themselves much faster in sand (about 100 sec.) than thinner ones (about 600 sec.). The faster ones were assumed to have a more efficient burrowing apparatus. The substrate also affects the rate of burrowing (Alexander 1988).

The Blackhawk and related formations of the Price, Utah region are interpreted as a shoreline-type location. The sea was to the east, coarse sediments came from the west. Lagoons, deltas, flood plains, bars, and rivers are assumed to have formed a complex in which “rafted organic material” (Marley 1978) served as the source for coal. Trace fossils (“worm tubes”) are found at many levels in this complex. Some sediments are assumed to have accumulated slowly (Frey and Howard 1985), while storm deposits are the interpretation for slightly hummocky beds (Frey 1990). The picture is generally similar around the Cretaceous Cliff House Formation sediments of Horse Gulch in Durango, Colorado.

Another suggestion within a flood model is that these “worm tubes” represent escape burrows as sediments accumulated episodically and trapped organisms during the later stages of the flood. Some of the same organisms might even be responsible for escape burrows at various levels as they were repeatedly trapped and escaped. This might help explain the virtual absence of body fossils in these tubes. Brandt (1980) proposes the same kind of process for successions of burrows in the Upper Ordovician around Cincinnati, Ohio.

Many of the units in the region show a preponderance of both horizontal and vertical trace fossils (burrows?) near the tops of the units. Such a pattern is interpreted as instantaneous deposition (Seilacher

1962; Frey and Pemberton 1984). Rapidly deposited turbidites are specifically suggested by Seilacher. This kind of evidence is an argument for rapid action.

FIGURE 3. Block of Panther Tongue showing a top surface with many pits that represent "worm tube" fossils. Red pen for scale is 135 mm long.

The argument is that if the layers accumulated slowly, one would expect a more-or-less even distribution of "worm tubes" throughout a rock unit, as shown in Figure 2A. If accumulation was rapid, tubes would be formed mainly in the tops of the units, as illustrated in Figure 2B. There would not be enough time for the formation of worm tubes throughout the unit during "instantaneous" deposition.

The presence of these "worm tubes" (bioturbation) in the tops of the sedimentary units is also reported by Pattison (2005, p 485) in the Cretaceous Blackhawk Formation north of Green River Utah, and in the Cretaceous Point Lookout Sandstone in the Horse Gulch area near Durango, Utah (Lucas et al. 1997, p 28).

The question of rate of formation of sedimentary units also raises the question of preservation of sedimentary surfaces in the presence of organisms which can destroy such surfaces by "stirring" them up. The term "bioturbation" is used for this process. The main organisms involved in bioturbation in marine environments are fish, crabs, clams, snails, and worms that persistently forage on the bottom of ocean and lakes. Clifton and Hunter (1973) have reported on this process in the US Virgin Islands. They found that sand ripples are totally destroyed in 2-4 weeks. Layering in the upper 2 cm is largely obliterated in the same period of time. These data suggest that in the presence of bioturbating organisms, burial of layers has to be rapid if their structure is to be preserved at all, and the presence of these layers may signify rapid burial. I have noted myself, while living underwater in the ocean for several days, that the ripple marks left in the sediments produced by a storm completely disappeared after three days as a result of the action of foraging organisms.

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8. WIDESPREAD DEPOSITIONAL PATTERNS

LOCATION

The five formations designated in the illustration below are widespread and can be viewed from many localities in the western United States. Figure 1 below is from the eastern shore of Steinaker Reservoir north of Vernal, Utah.

FIGURE 1. Five formations viewed above the eastern shore of Steinaker Reservoir. The lowest is the top part of the Jurassic Morrison Formation; the four formations lying above are Cretaceous.

DESCRIPTION

Some formations are small and local in geographical extent. On the other hand some are huge and extremely widespread. The five formations illustrated above are in the medium to very large range and all are examples of unusually widespread distribution.

MORRISON FORMATION

The Upper Jurassic Morrison Formation is most famous for its dinosaur remains. Its variegated (multicolored) mudstones and white, tan, and gray sandstones are characteristic. It can reach up to 450 m (1500') in thickness, although through most of its expanse it is more like 100 m (300') thick. It is spread over 1,000,000 km^2 (400,000 mi^2) (Fig.2). It has been divided into lateral and vertical subunits

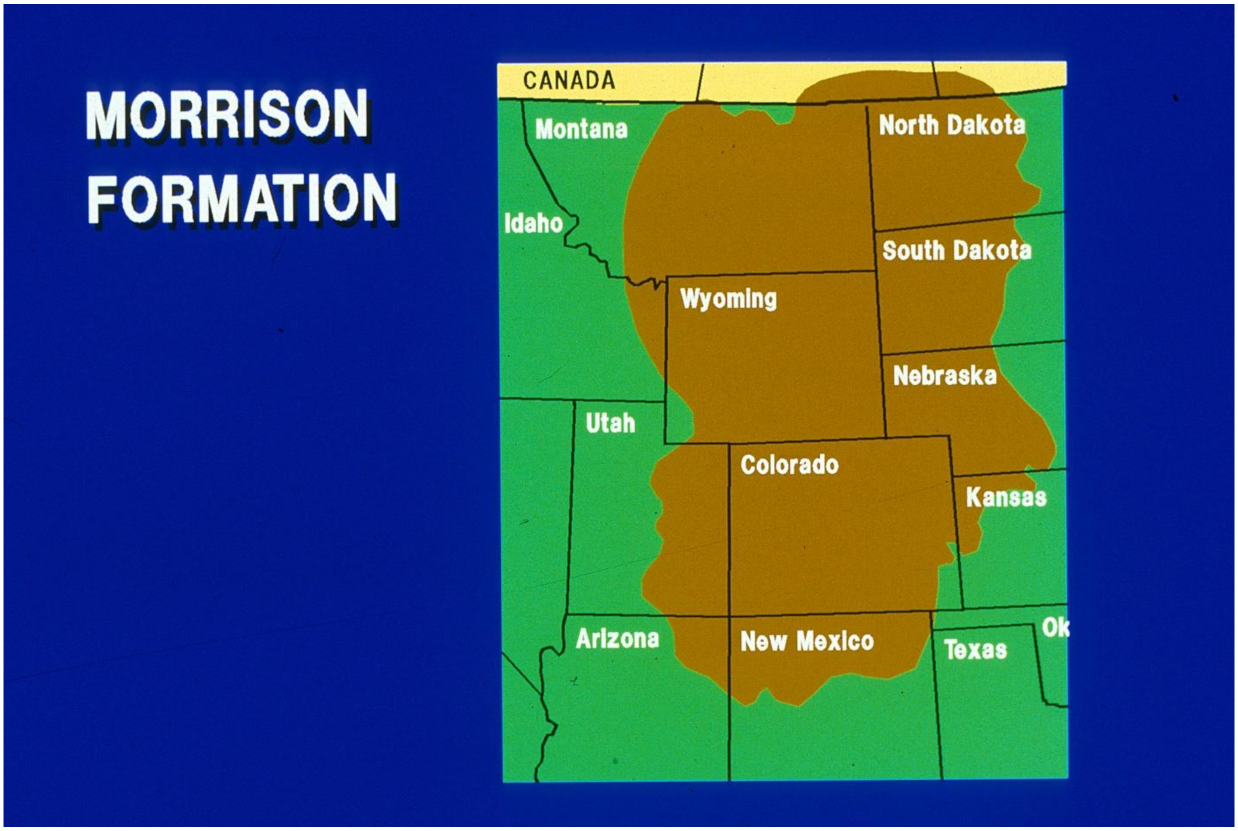

Figure 2. Distribution of the Morrison Formation.

(Craig et al. 1956, Peterson and Roylance 1982, Peterson and Turner-Peterson 1987).

Fossils are rare in the Morrison. Dinosaur bones are found in localized massed accumulations mainly in some 20 localities such as the Cleveland Lloyd Quarry and Dinosaur National Monument. Other animal fossils include: crocodiles, turtles, fishes (primarily lungfish), frogs, salamanders, ostracods, snails, clams, and small primitive mammals. Plants are also rare and include large conifers (mainly logs) and small plant fragments. Palynomorphs (pollen and spores), which are also rare, suggest gingkos, ferns, lycopsids, and algae.

The Morrison is considered to represent a past environment of rivers and floodplains with possibly an increased tendency toward more lakes and deltas in later periods (Peterson and Roylance 1982). Some deposit by wind has also been suggested. There is no agreement as to whether there was a humid, dry, or varied climate in Morrison time (Dodson et al. 1980). Source of sediments for the Morrison is generally considered to have come from hills in the west, which included a volcanic arc. On the other hand, Yingling and Heller (1987) suggest a southwest source.

THE CEDAR MOUNTAIN AND BURROW CANYON FORMATIONS

Stokes (1944) proposed formational status to the Lower Cretaceous Buckhorn Conglomerate and also the Cedar Mountain Formation which are similar to the Morrison, and lie between the Morrison and the Dakota in the central-western part of the formation. To the east, formational status has been proposed for a Burrow Canyon Formation that is very similar to the Cedar Mountain Formation, and also lies between the Morrison and Dakota, but the difference between the two has been disputed. However, see Tschudy, Tschudy and Craig, 1984 for pollen differences.

From the standpoint of the depositional pattern we will consider these two similar deposits as one unit. They cover some 130,000 km^2 kilometers (50,000 mi^2). Thickness varies, but averages less than 60 m (200').

The Cedar Mountain-Burrow Canyon complex is considered to have been deposited by rivers. Fossils are rare and include snails, ostracods, dinosaurs, mammals, and a few plants, etc.

THE DAKOTA SANDSTONE (Formation or Group)

This Lower Cretaceous formation is very thin, often around 30 m (100') thick, with a maximum up to 220 m (700'). It is very widespread (Fig. 3), extending from Iowa to Arizona and

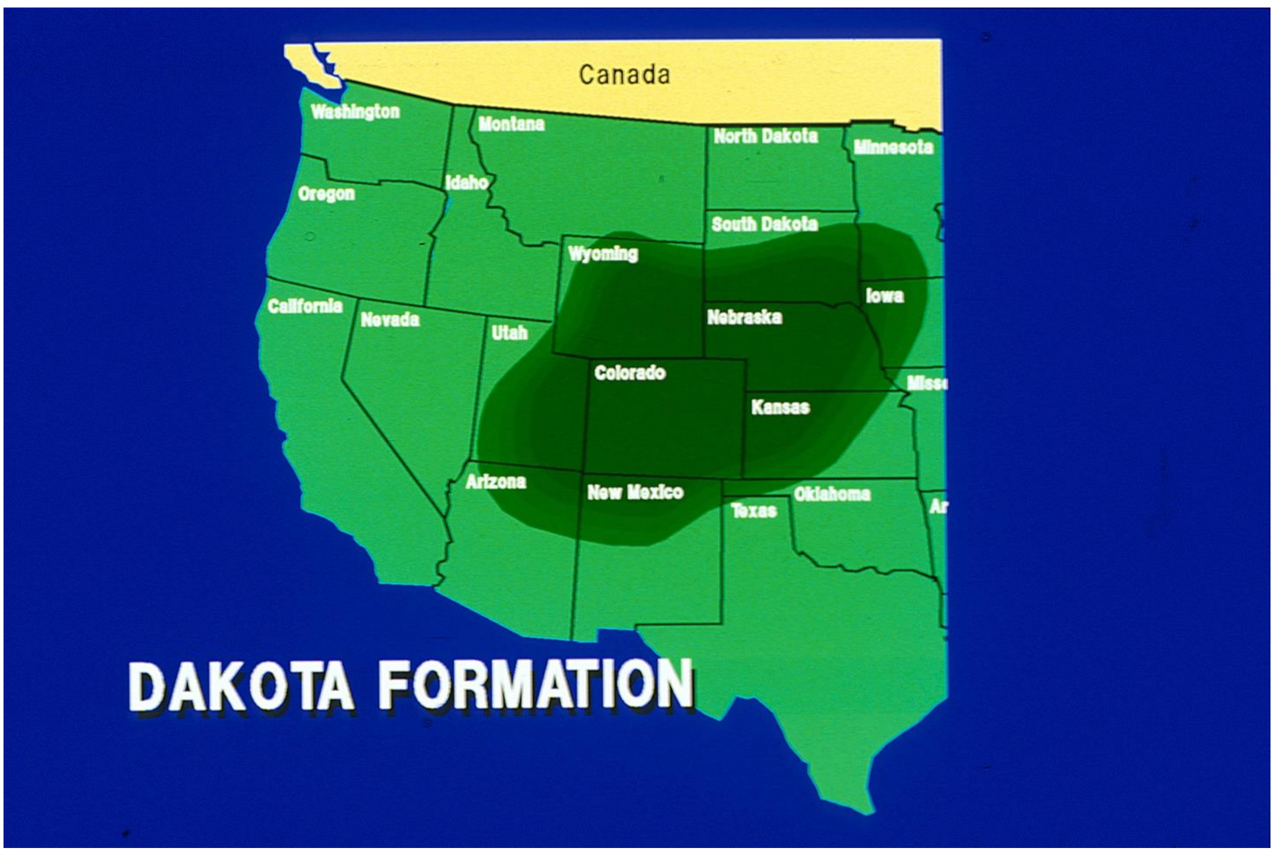

FIGURE 3. Distribution of the Dakota Formation.

from Montana to New Mexico, covering some 815,000 km^2 (315,000 mi^2). It is a mixed marine-and-land formation containing a great variety of fossil types such as leaves, coal, wood, dinosaurs, mammals, sharks and invertebrates.

The Dakota Formation is assumed to have been deposited in a variety of environments such as transgressive sea, river, lagoonal, and tidal environments. In the southwest it tends to consist of three units, a shale layer between two sandstone layers. It is a very thin layer and represents unusually flat depositional environments. Unusual energy levels may be necessary for such widespread distribution.

THE MOWRY SHALE

This Lower Cretaceous formation is characterized as a silver gray to tan shale that contains an abundance of fish scales. It is spread over much of Wyoming and beyond, covering some 250,000 km^2 (90,000 mi^2). Thickness varies from 10-300 m (30-1070') (Keroher et al. 1966, p. 2644-2646).

Fossils include fish, ammonites, foraminifera, worm tubes, marine reptiles, ferns. The Mowry is interpreted as having been deposited in an ancient sea associated with a large seaway to the east. It is part of the vast group of Cretaceous black shales now found on both continents and ocean floors that suggests a "Cretaceous anoxic event." It has also been proposed that the sandstone layers may have been deposited during sea level falls (Davis 1987).

FRONTIER FORMATION

This Upper Cretaceous formation consists of large tan sandstone units separated by gray shale units. It is up to 3000 m (10,000') thick, but mostly only a few hundred meters thick. It is spread over much of Wyoming, eastern Idaho, and beyond, covering some 300,000 km^2 (100,000 mi^2). Fossils include many marine invertebrates, and sharks' teeth; commercial coal beds in the eastern part reflect abundant plant material. It is interpreted as having been deposited in beach, near-shore marine, and coastal swamp environments. Deltas and proximal volcanic sources are also postulated. Marine sediments increase to the east. Its thinness and widespread distribution pattern represent an unusually flat environment unlike our usual continental deposits.

A CREATION-FLOOD PERSPECTIVE

The Morrison poses a number of puzzles which would be alleviated by a catastrophic flood model. These include:

1. For a unique continental (land) deposit the Morrison is very widespread (Figure 2). Could local deposition produce such a special thin, widespread formation? This seems very unlikely. Dodson et al. (1980) point out:

> *The enormous area covered by the Morrison sediments and the general thinness of the sedimentary sheet (being in most areas less than 100 m in thickness) indicate that the sediments were distributed by widespread flowing water.*

While the authors do not entertain the suggestion of a worldwide flood, their mode of spread reflects the type of activity expected for such an event.

2. Ancient channels of *major* rivers, which would help distribute the sediments over a wide area, have not been found in the formation.

3.The Morrison Formation appears to represent a vast but incomplete ecological system. It has been one of the world's richest sources of dinosaur fossils, yet plants are rare, especially in the vicinity of dinosaur remains (Dodson et al. 1980). What did the behemoths eat? The paleontologist Theodore White (1964) comments that "although the Morrison plain was an area of reasonably rapid accumulation of sediment, identifiable plant fossils are practically nonexistent." He further muses that by comparison to an elephant an apatosaurus dinosaur "would consume 3 ½ tons of green fodder daily." If dinosaurs were living there for millions of years, what did they eat if plants were so rare? Other investigators (Herendeen et al. 1994, Peterson and Roylance 1982, Peterson and Turner-Peterson 1987) have also commented on this lack of plant fossils. Brown (1946) states that the Morrison in Montana "is practically barren of plant fossils throughout most of its sequence," and others (Dodson et al. 1980) comment that the absence of evidence for abundant plant life in the form of coal beds and organic-rich clays in much of the Morrison Formation is puzzling." These investigators also express their "frustration" because 10 of 12 samples studied microscopically were essentially barren of the "palynomorphs" (pollen and spores) produced by plants. With such a sparse source of energy, one wonders how the large dinosaurs could survive the assumed millions of years while the Morrison Formation was being deposited.

4. To explain the dilemma, some have suggested that plants existed but did not get fossilized. This idea does not seem valid, since a number of animals and a few plants are well preserved. Perhaps the Morrison was not a place where dinosaurs lived. Instead, it might have been a flood-created dinosaur burial ground with plants sorted and transported by water elsewhere.

Paleontologists (Factovsky et al. 1997) report a similar situation for the dinosaur Protoceratops found in the central Gobi Desert of Mongolia. These investigators, studying various aspects of these Cretaceous deposits, conclude that "the abundance of unambiguous herbivore (protoceratops) and a rich trace fossil fauna [probably tubes made by insects] reflect a region of high productivity. The absence of evidence of well-developed plant colonization is, therefore, anomalous and baffling."

5. Also puzzling for a long ages model is the general absence of fish remains and diverse molluscan assemblages in deposits interpreted as "clearly lacustrine [lake] in origin" (Dodson et al. 1980).

A model of a worldwide flood with gradually rising and receding waters provides some answers to these questions. The flood-waters provided the widespread distribution of the sediments, and the animals did not live in the inhospitable environment inferred from the fossil picture.

It is difficult to appreciate how widespread these formations are compared to their thickness. The Morrison and the Dakota are especially intriguing. This can be illustrated by noting that proportionately for the maps of Figures 2 and 3, each formation would average less that 1/8 the thickness of the sheet of paper the map is printed on. Such incredibly thin layers, spread over such a wide area seem to indicate "widespread flowing water" as suggested by Dodson et al. (1980) for the Morrison. Also on a long-ages model for Earth, one has difficulty thinking of such a stable (flat) environment for the millions of years postulated to accommodate the deposition of these formations. During that time continents would be moving, and uplift and subsidence is suggested around the region to provide a source of sediment for the deposits and varied environments of final deposition. Also, one wonders if over many millions of years some erosion through these layers would not tend to break the widespread continuity and sequence we see for these five formations. Furthermore, laying such relatively thin and widespread layers requires incredibly flat topography to begin with, the likes of which we do not find anywhere on our present continents. Here we see evidence of activity of a different nature and scale than is common at present. High-energy factors and rapid action seem to have been involved in such widespread distribution of thin, unique sedimentary units.

A few geologists recognize the problem. Carlton Brett (2000), who believes in long geologic ages, states that "beds may persist over areas of many hundreds to thousands of square kilometers precisely because they are the record of truly extraordinary, oversized events. … The accumulation of the permanent stratigraphic record in many cases involves processes that have not been, or cannot be observed in modern environments. … there are the extreme events … with magnitudes so large and devastating that they have not, and probably could not be observed scientifically." This is specifically the kind of activity we would expect during the Genesis Flood.

COAL PARTINGS

Another widespread geologic feature, however on a much smaller scale, is coal partings. An example is the thin light colored layer at the tip of the red arrow in Figure 4. These partings are thin layers of grainy sediment that are found in the midst of much thicker coal seams. These coal partings challenge the commonly held view that our coal beds come from vegetation that grew where the coal is found. This is in contrast to the view that coal comes from transported vegetation. This latter interpretation is what would be expected during the Genesis Flood. One would not expect that our coal seams, and the coal partings we find therein, should have such horizontal continuity if the coal came from locally growing vegetation.

Steve Austin (1979) reports on how widespread these coal partings can be. In some of the coal mines in Kentucky, he reports on six coal partings that extend over 1,500 km^2 (580 mi^2). The widespread distribution of such thin layers requires extreme conditions such as we would expect during the Genesis flood.

FIGURE 4. Coal parting, i.e. the fine gray layer at the tip of the red arrow within the thicker dark coal seam. The coal seam is about 40 centimeters (16 inches) thick.

FIGURE 5. Pebbles in a coarse portion of the Shinarump Conglomerate. The largest pebbles are in the 2 centimeter (1 inch) range.

THE EXTREMELY WIDESPREAD DISTRIBUTION OF SOME COARSE DEPOSITS

Also very anomalous are coarse deposits that would require extremely powerful forces to distribute them over the very wide areas we find. The Triassic Shinarump Conglomerate (sometimes called a member or formation) of the southwestern United States is an outstanding example. It covers over 250,000 km^2 (100,000 mi^2). Figure 5 illustrates some of the coarse pebbles one finds in the Shinarump, but it needs to be kept in mind that in some places it consists of only coarse sand. How did such a coarse deposit get distributed over such a wide area? The pebbles would have to be transported many hundreds of miles. Geologists usually state that the Shinarump was formed by rivers and streams, but how are rivers or streams going to carry pebbles over hundreds of miles when you have very little gradient. The Shinarump is usually less than 30 meters (100 feet) thick suggesting a very smooth topography over a very wide area. It appears that you are going to have to have catastrophic conditions to spread the Shinarump Conglomerate over such a wide area.

Other problematic deposits include the Buckhorn Conglomerate, the basal conglomerate of the Cloverly Formation in Wyoming and the Dakota Sandstone (Dakota Formation) which has a more varied lithology than the Shinarump, but is much more widespread. The geologist William Stokes (1960) has addressed this problem and suggests that these deposits may represent pediments. Pediments are the coarse deposits that accumulate at the base of mountains as debris from the mountains accumulates over time. This is no solution. The tiny pediments that we normally find at the base of mountains are no match for the extremely flat thin widespread coarse sedimentary units we find in the sedimentary record. Catastrophic activity, such as we might expect during the Genesis Flood is a more likely explanation.

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9. DRAINAGE PATTERNS

(A discussion)

Streams and rivers often follow unexpected patterns that do not seem to reflect topography. In the Middle Rocky Mountains, major rivers such as the Green River cut through the Uinta Mountains instead of going around their end only a few dozen miles to the east. Any intelligent river would be expected to go around, and not "over" the Uintas. That is not what the Green River has done. It has cut a gorge over 600 m (2000ft) deep through the Uintas. The Colorado River has cut perpendicularly through the Fisher and Moab Valleys and then it cuts a mile down through the Kaibab Upwarp to form the Grand Canyon. This pattern is also well represented in other continents of the Earth. Several models have been used to explain these unusual features. Some pertinent concepts will help you understand proposed models.

A river system that follows a normal downhill pattern along a pre-existing land surface is said to be **consequent** (the consequence of original slope). This pattern can be altered by mountain uplift, erosion around resistant rock units, etc. When altered, this is called **subsequent** (subsequent to the original pattern). Occasionally a river may erode its bed into the path of another and capture it. This is called **stream capture** or **piracy**. When this happens, the downstream portion of the captured river dries up and is said to be **beheaded**.

The case of rivers cutting right through mountain ranges is especially intriguing. Two models have been given serious consideration. The first, called **antecedent**, postulates that the river has stayed more or less in its original position as slow uplift of the region has taken place (compare Diagrams A and B under "Antecedent" in Fig. 21). As long as uplift is slower than the erosional capability of a river, the river can maintain its normal position and grade (slope) across uplifting regions. Its position being antecedent to uplift, the sequence is appropriately referred to as antecedent drainage. The river Arun, which crosses the Himalayas a few dozen km east of Mount Everest through deep and almost impassable gorges, is considered to be antecedent (Sparks 1986, pp. 157-159).

The second model to explain rivers cutting through mountain ranges is called **superposed**, a contraction of "superimposed." In this model the pattern of a river from a higher level is superimposed on the present topography. The mountain ranges are assumed to have already been there but buried in sediments (see Fig. 21, Diagram A, under "Superposed"), and the rivers flow on the surface of the sediments that cover these ranges. The sedimentary layers over and around the mountain ranges are then eroded with time, and the river cuts down through them including the buried ranges (see Diagram B under "Superposed", which is the same as Diagram B under "Antecedent'). With either model one ends up with the same final result. This makes it more difficult to tell which really occurred.

Early geologists studying the Middle Rocky Mountains thought the rivers were antecedent. Later workers, finding remnants of former alluvium (stream deposition) high on mountain sides, have given preference to the superposed model (Bloom 1978, p. 275). In general superposition is given preference over antecedence, the latter being considered a "last resort" (Sparks 1986, p. 156) because of difficulty in authentication. On the other hand, one has some difficulty in envisioning enough of a sedimentary volume to fill up all the space between mountain ranges as suggested for superposition.

The superposed model can be fit into a flood model just as easily as the antecedent one, or even more so. Major sediment removal accompanied the receding "superimposed" flood waters, and rivers entrenched themselves even through mountain ranges as the drainage of the continents continued.

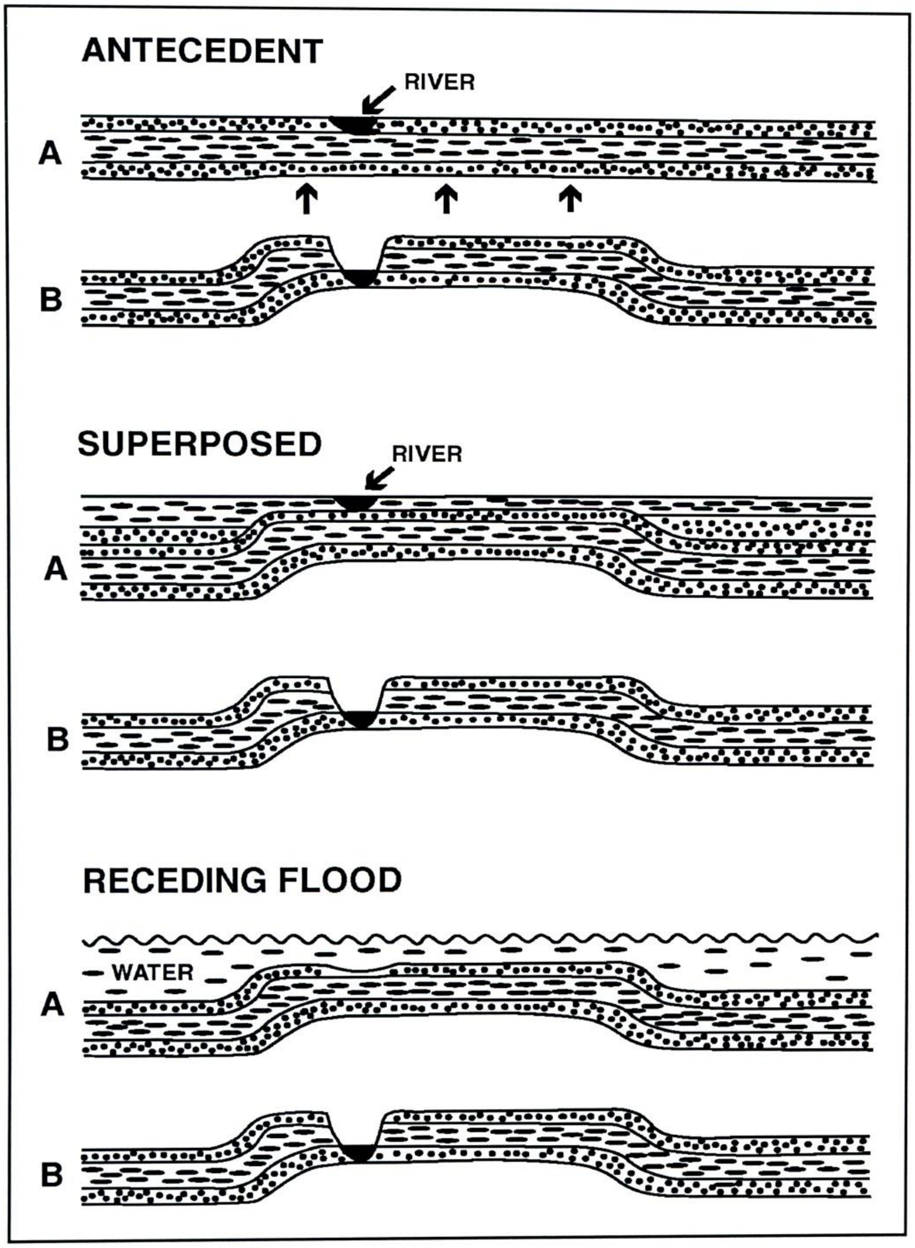

FIGURE 1. Drainage patterns.

In the context of a creation-flood perspective a third pattern can also be considered, namely that the overlying flood waters could cut through these mountains as they drained a particular region (Fig. 21, receding flood pattern). The rapidly flowing waters of a receding flood could rapidly cut deep gorges through mountain ranges as these waters sought lower elevations. In varied situations, especially when under water, it would be easier for the overlying waters to proceed through an incipient gorge and deepen it than to go all the way around a range. Such a pattern could mitigate the problems of the slow uplift required for the antecedent model and the necessity of sediments to support a high river bed in the superposed model. In the context of a creation-flood model, all three patterns and others could be involved. The receding flood pattern can explain the enigma of the huge side canyons, especially on the north side of the Grand Canyon, that have no source of water to erode them.

Under the conditions expected during the receding of the waters of the Genesis Flood, the assumed time imposition that uplift has to be slower than the expected erosional capability of a river is not very restrictive. Rapid erosion could take place as raging waters would drain off the continents. Of interest is the increase in transporting capacity of rivers as their velocity increases. Holmes (1965, p. 512) points out:

> *The transporting capacity of a stream rises very rapidly as the discharge and velocity increase. Experiments show that with debris of mixed shapes and sizes, the maximum load that can be carried is proportional to something between the third and fourth power of the velocity.*

This means that if the velocity (speed) of the river is increased ten times, it can carry between 1000 and 10,000 times as much sediment.

The abundance of rivers that cut through mountain ranges over the earth strongly suggests a past quite different from the present. The receding waters of the Genesis Flood provide a reasonable and simple explanation for this.

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10. FOSSILS AND THE GENESIS FLOOD[1]

Why did those terrible dinosaurs become extinct? Many ideas have been proposed. One scientific article lists 40 possible reasons ranging from stupidity to changes in the gravitational constant.[2] More recently consideration has been given to the possibility that a huge asteroid, rich in the element iridium, struck the Earth, causing a gigantic catastrophe that destroyed dinosaurs and many other forms of life. This arresting idea is especially popular with the public media and geophysicists, but comparable groups of other scientist, especially the paleontologists who study fossils, think that other factors, such as heat or volcanoes, caused the extinction of the dinosaurs.[3]

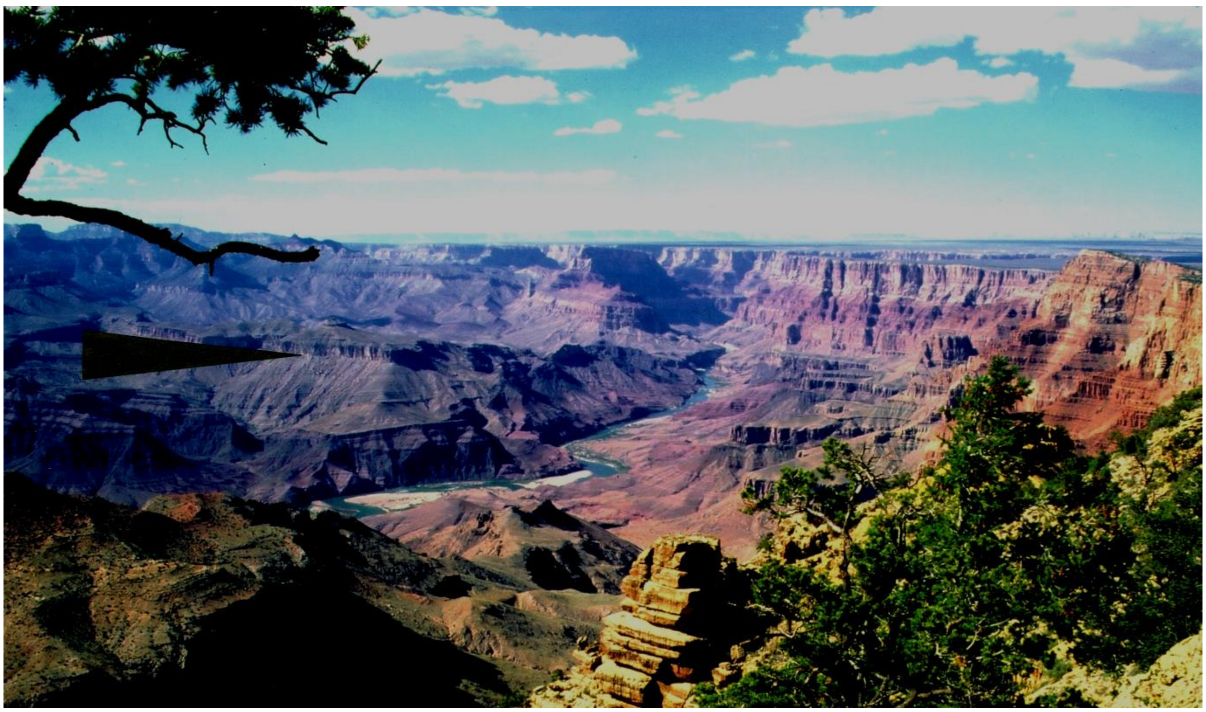

FIGURE 1. View of the Grand Canyon of the Colorado River. The Precambrian is exposed in the layers just below the tip of the black arrow at the left, the Cambrian Explosion and the Phanerozoic in the layers just above.

Scientists who believe the Bible is the Word of God interpret the past history of life on Earth differently. They see the worldwide flood described in the book of Genesis,[4] as the horrendous event that would have destroyed the dinosaurs and deposited the main fossil bearing layers of the crust of the Earth. Such a view is not accepted at present in scientific circles, although it very much was in the past. The variety of ideas about the demise of the dinosaurs warns us to be cautious in interpreting a past we cannot now observe.[5]

A CRUCIAL QUESTION

Which is true, science or the Bible? The differences between the scientific evolutionary model and the biblical creation model are striking, and could hardly be more different. This is not just about dinosaurs dying. The evolution model proposes that life originated thousands of millions of years ago by itself, and then evolved into more and more advanced forms eventually producing man. The creation model, as given in the Bible, proposes that God created the main forms of life, including man, a few thousand years ago. Because of man's wickedness, that creation was destroyed by a worldwide flood. How we interpret the arrangement of the fossils in what we call the *geologic column* has much to say about these two models.[6] More importantly, these models can profoundly affect our world-view. Are we here only as a result of a prolonged meaningless mechanistic evolutionary process, or were we created in

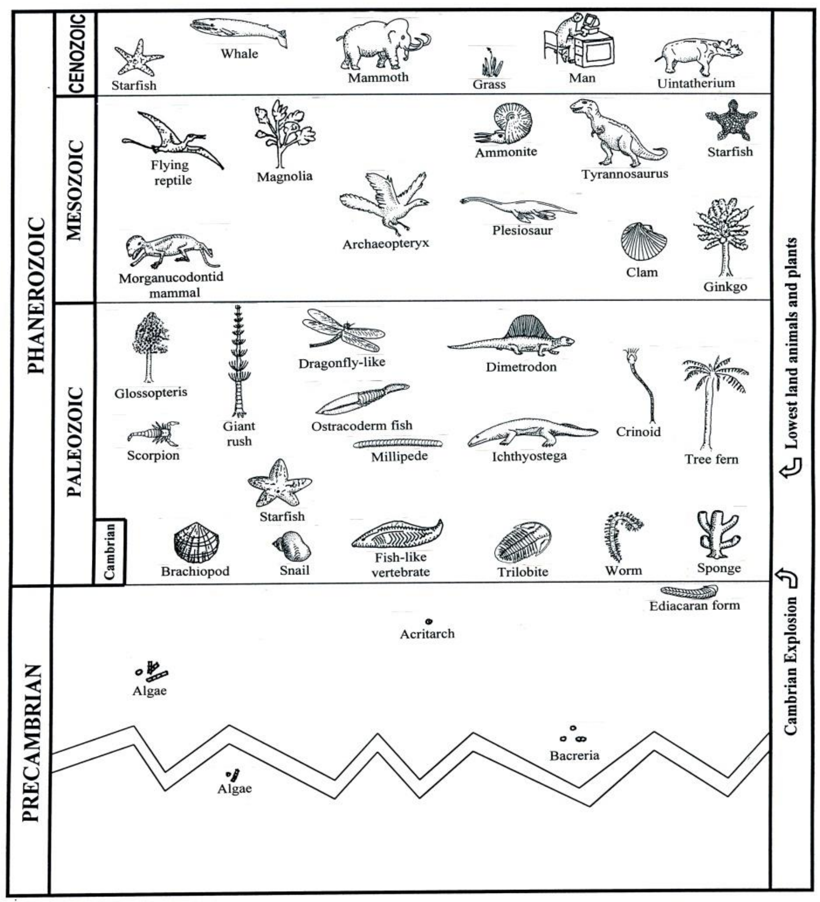

FIGURE 2. Major divisions of the geologic column and examples of some representative organisms.

the image of God, with purpose, responsibility, and hope for future eternal life, as indicated in the Bible? Many have struggled over these questions, and many will continue to struggle.

THE GEOLOGIC COLUMN—WHAT IS IT?

There is no place in the rock layers that form the crust of the Earth where you can go and find the geologic column. The geologic column is more like a map. It is a column-like representation of the general order of the rock layers over the surface of the Earth. The lowest layers, that would have been deposited first, are at the bottom of the column, and the most recent are at the top as we find them in nature. When you look at deeply eroded places like the Grand Canyon in Arizona (Figure 1), you are seeing a significant part of the Geologic column represented by layers that are exceptionally thick in that locality. You can think of the geological column as a slice of a layered cake. The slice represents the various layers in the order found in the cake. Likewise if you would cut a thin vertical slice through layers forming the wall of the Grand Canyon, you would have a geologic column of the area.

As is usual in the study of nature the picture is complicated. Often in many parts of the Earth, some layers of the geologic column are missing. We can tell they are missing because we find them in other places. There is no place on the surface of the Earth where we can find a complete geologic column. In a few places the major divisions are all well represented. The complete geologic column is the ideal where all the layers are represented in the expected order as we go up or down through the layers of the crust of the Earth. The geologic column was patiently put together as paleontologist compared the fossil sequence in the geologic column of one locality with another. It was noted that certain kinds of fossils, like crab-like trilobites, were below dinosaurs, and dinosaurs below elephants. A sample of a few characteristic organisms found in the main parts of the geologic column is illustrated in Figure 2. The column shows a striking difference between the Precambrian part, where fossils are very rare, and essentially microscopic in size, in contrast to the higher Phanerozoic where the fossils are comparatively abundant and represent a variety of much larger organisms. Very scarce and very odd (Ediacaran) types of larger organisms are found immediately below the Phanerozoic.

HOW RELIABLE IS THE GEOLOGIC COLUMN?

When you look at the Grand Canyon (Figure 1), you are not aware that major parts of the geologic column are missing. While the Cambrian period is represented (layers just above the arrow at the left in Figure 1), the Ordovician and Silurian periods are absent. Furthermore the Mesozoic and Cenozoic eras (see Figure 2 for terminology) are not there either, as they comprise layers that lie just above the Canyon wall. Since the geologic column is put together from sequences in different localities, and since parts of the column are often missing, can we trust the sequence that has been put together? Furthermore there are a few places where normally lower parts of the geologic column lie *above* higher parts, but these are disturbed areas where lower layers have been thrust over younger ones. In spite of these weaknesses, in most areas of the world, the geologic column is generally in the right order and remarkably reliable.

THE GEOLOGIC COLUMN AND EVOLUTION

The geologic column provides one of the strongest arguments for evolution. Simple life is believed to have evolved 3,500 million years ago and we find evidence of simple life forms in the lower Precambrian layers (Figure 2). Above this, in the lower part of the Paleozoic, one finds more complex marine animals like sponges. Just above these in the upper Paleozoic and Mesozoic are more advanced land animals and plants like tree ferns and dinosaurs. In the uppermost Cenozoic we find the most advanced organisms like elephants and flowering trees. In general, simpler organisms are also found in the higher layers but advanced organisms are not found in the lower ones. The general trend of some advancement as one goes up the geologic column is considered to represent evolutionary advancement over eons of time as the layers were gradually laid down, trapping organisms that became fossilized.

EXPLANATIONS FOR THE GEOLOGIC COLUMN IN THE CONTEXT OF THE BIBLICAL MODEL OF ORIGINS

The advancement of life, seen as one ascends the geologic column, has been explained in several ways that fit with the Biblical model of a recent creation. Crucial to these explanations is the worldwide Genesis Flood as the event that caused the deposition of most of the Phanerozoic layers. Explanations include: (1) During the Flood, the larger more advanced animals could escape to higher levels. This can explain some sequences of advancement that we see in animal fossils, but it is very unlikely that it can explain the whole geologic column. On the other hand exceptional organisms like whales would be expected to escape. (2) Some experiments show that the carcasses of more advanced forms like mammals and birds float for weeks, while less advanced animals like reptiles float for a shorter period, and simpler amphibians for only days.[7] These lengths of time fit well with those of the Flood events and this may be a significant contributing factor. (3) The most comprehensive explanation is the *Ecological Zonation Theory*.[8] This model proposes that the distribution of organisms before the flood (Figure 3) is responsible

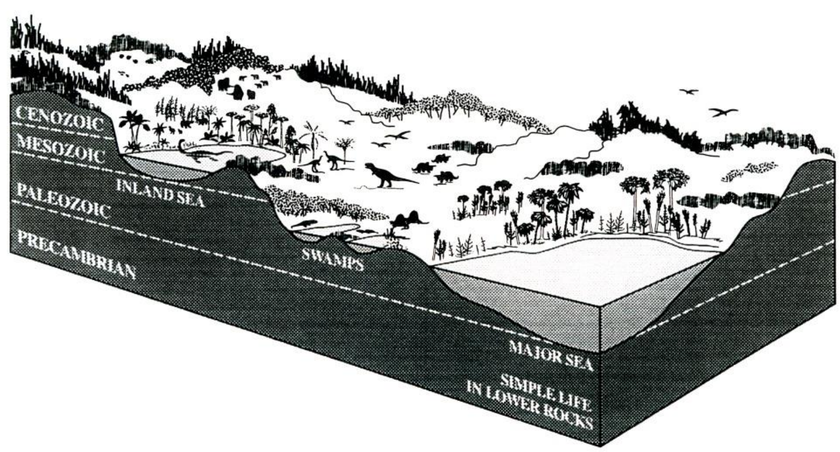

FIGURE 3. Proposed distribution of organisms before the Genesis Flood. The Ecological Zonation Theory suggests that the gradual destruction of these environments by the rising waters of the flood would produce the fossil sequence we now find in the geologic column.

for the distribution of organisms in the geologic column. The organisms living in the lowest regions of the world before the flood represent the lowest part of the geologic column, and those in the highest, the top of the column.

The suggested mechanism for the Ecological Zonation Theory is that as the surface of the Earth was broken up and the waters of the flood rose *gradually*; the various landscapes before the flood were destroyed as waves eroded them. The waters would erode and carry the sediments and organisms away from low lying areas first and deposit them in still lower regions

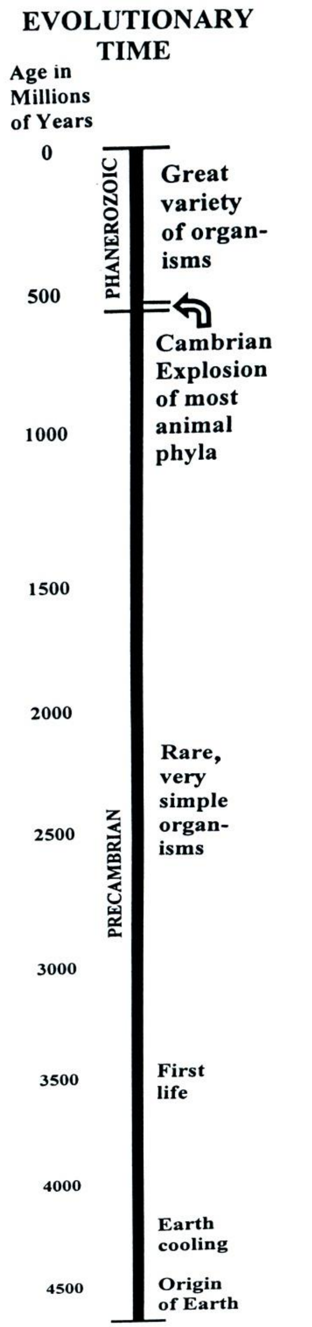

FIGURE 4. The evolutionary time scale. The Cambrian Explosion took only about 20 million years. Proposed ages not endorsed by the author.

(sedimentary basins). Higher and higher areas would then gradually be eroded and deposited in order in large sedimentary basins where a geologic column would form. The process was placid enough that the deposited layers were not significantly disturbed and remained in order as we see them now (Figure 1).

SOME QUESTIONS

While the general distribution of organisms on the Earth now fits the general distribution in the geologic column (see below), this is not the case in certain important details. These are considered to be the most serious objections to the ecological zonation theory. For instance, in the geologic column we find mammals and flowering plants mainly in the upper parts (Figure 2).

This would have been high up in the terrestrial landscapes before the flood, while on Earth now we find these organisms way down to seashore level. To accommodate these and other objections it is proposed that the ecological distribution of organisms before the flood was somewhat different from the present. A worldwide Flood would be expected to cause some differences. The distribution of organisms before the Flood may have been more restricted and orderly than at present, and there probably were seas at different levels (Figure 3). Note the similar distribution of organisms in Figures 2 and 3.

Questions also arise as to why, thus far, convincing examples of fossil man are found only near the very top of the geologic column. Explanations include: (1) Before the flood man and mammals resided in only higher cooler regions. (2) During the flood, intelligent man escaped to the highest regions where the chance of burial and preservation by sediments was slim. (3) There may not have been that many humans before the flood hence chances of finding them are meager. The biblical record indicates much slower reproductive rates before the flood. For instance, Noah had only three sons in six hundred years.[9]

EVIDENCE FROM THE GEOLOGIC COLUMN THAT SUPPORTS THE BIBLICAL MODEL OF ORIGINS

The presence of fossils of simple microscopic organisms throughout the Precambrian fits better with the biblical model than the evolutionary one. These fossils would come from the recently discovered microbes of various types, including algae[10] that live in deep rocks. For the evolutionary model these microscopic fossils mean that virtually no advancement takes place here for 3,000 million years (Figure 4), and this represents 5/6 of all evolutionary time. The Precambrian does not look at all like gradual progressive evolutionary development.

All of a sudden, just above this, in what evolutionists call the *Cambrian Explosion*, almost all your basic animal types (Phyla) appear (Figures 2 and 4).[11] This looks more like creation than a gradual evolutionary process. Evolution needs all the time it can muster to accommodate all the virtually impossible events necessary for producing complex life forms, but the geologic column does not allow for much. Evolutionists speak of only 5 to 20 million years for the Cambrian Explosion![12] That is less than one percent of all evolutionary time. Samuel Bowring of the Massachusetts Institute of Technology, whose specialty is dating rocks, comments: “And what I like to ask some of my biologists friends is, How fast can evolution get before they start feeling uncomfortable?”[13] The black arrow at the left in Figure 1 indicates the location of the Cambrian Explosion in the Grand Canyon. The Cambrian Explosion fits very well with the Ecological Zonation Theory. This represents the lowest seas (Figure 3) before the Flood that harbored a great variety of marine animals as found in present seas.

As you go further up the geologic column, you encounter marine (ocean) types of organisms until you reach the middle of the Paleozoic. There a great variety of land (terrestrial) organisms begins to appear (Figures 2 and 3), including fungi, mosses, rushes (horsetails), ferns, insects, millipedes, spiders and amphibians.[14] Evolution has to answer why so many different kinds of land organisms evolved at about the same time. For the ecological zonation theory this would represent, as expected, the lowest dry land regions before the flood.

Further up the column you find, according to the evolutionary scenario, that most of the orders of mammals appeared in only 12 million years, and living orders of birds in 5-10 million years. Some evolutionists characterize such rapid rates as "clearly preposterous."[15] Fossil species are thought to last several million years each, and you need a great number of species generations for any significant evolutionary changes.

Another serious problem for evolution revealed by the geologic column is the notorious absence of fossil intermediates especially between the major groups of both plants and animals. This is specifically where you would expect the greatest number. A few have been described, but where there should be hundreds or thousands, such as just below the Cambrian Explosion, virtually nothing applicable is there. It does not look as if evolution has occurred.

THE VERDICT

Many evolutionists feel that the general progression of life forms as one ascends the geologic column is compelling evidence for their model. However, a closer look reveals rather severe problems; especially lack of time and fossil intermediates. In a biblical context one would also expect some general progression of life forms as the Genesis Flood contributed to the geologic column. A worldwide flood on our present Earth would also produce a geologic column with a general increase in complexity. Lowest would be the simple microorganisms that live in the deep rocks, next would be the marine organisms of the oceans, and highest the advanced land organisms of the continents. Furthermore, if the landscapes of the Earth before the Flood were as pictured in Figure 3, and they were gradually buried in order by that Flood, you would get the geologic column as we see it. Evidence such as the presence of microscopic life in the deep rocks, the Cambrian Explosion, and the same level of appearance of a number of terrestrial organisms, provide strong evidence for the Ecological Zonation Theory and the biblical Flood explanation for the geologic column.

ENDNOTES

[1] Modified from: Roth AA 2003. Genesis and the geologic column. Dialogue 15:9-18.
[2] Jepsen GL. 1964. Riddles of the terrible lizards. American Scientist 52:227-246.
[3] Hallam A. 1989. Great geological controversies. Second edition. Oxford: Oxford University Press, p 185-215; Dobb E. 2002. What wiped out the dinosaurs? Discover 23(6):35-43.
[4] Genesis 6-8.
[5] For further cautionary considerations see: Kerr RA. 2002. Reversals reveal pitfalls in spotting ancient and E.T. life. Science 296:1384-1385; Roth AA. 1996. False fossils. Origins 23:110-124.

[6] There are some views like progressive creation and theistic evolution etc., that are intermediate between creation and evolution. For an evaluation see: Roth AA. 1998. Origins: Linking science and Scripture. Hagerstown, Maryland: Review and Herald Publishing Association, p 339-354.
[7] For some details see: Roth AA. 1998. Origins: Linking science and Scripture. Hagerstown, Maryland: Review and Herald Publishing Association, p 169.
[8] Clark HW. 1946. The new diluvialism. Angwin, California: Science Publications, p 37-93; Roth AA. 1998 Origins: Linking science and Scripture. Hagerstown, Maryland: Review and Herald Publishing Association, p 162-177.
[9] Genesis 5-7.
[10] The presence of algae in deep rocks is unexpected. For further discussion see: Roth A. 1992. Life in the deep rocks and the deep fossil record. Origins 19:93-104; Sinclair JL, Ghiorse WC. 1989. Distribution of aerobic bacteria, protozoa, algae, and fungi in deep subsurface sediments. Geomicrobiology Journal 7:15-31.
[11] Valentine JW. 1995. Why no new phyla after the Cambrian? Genome and ecospace hypotheses revisited. Palaios 10:190-194; Thomas RDK, Shearman RM, Stewart GW. 2000. Evolutionary exploitation of design option by the first animals with hard skeletons. Science 288:1239-1242.
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[13] As quoted by: Nash M. 1995. When life exploded. Time 146(23):66-74.
[14] For a comprehensive illustration see: Roth AA. 1998. Origins: Linking science and Scripture. Hagerstown, Maryland: Review and Herald Publishing Association, Figure 10.1, p 165.
[15] Stanley SM. 1981. The new evolutionary timetable: Fossils, genes and the origin of species. New York: Basic Books, p 93.

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THE GEOLOGIC COLUMN

	ERA	SYSTEM OR PERIOD	SERIES OR EPOCH	STANDARD TIME SCALE*
Phanerozoic	Cenozoic	Quaternary	Holocene (Recent)	0.01
			Pleistocene	2.5
		Tertiary: Neogene	Pliocene	7
			Miocene	26
		Tertiary: Paleogene	Oligocene	38
			Eocene	54
			Paleocene	65
	Mesozoic	Cretaceous	Upper, Lower	136
		Jurassic	Upper, Middle, Lower	190
		Triassic	Upper, Middle, Lower	225
	Paleozoic	Permian		280
		Carboniferous		
		Pennsylvanian	Upper, Middle, Lower	325
		Mississippian	Upper, Lower	345
		Devonian	Upper, Middle, Lower	395
		Silurian	Upper, Middle, Lower	430
		Ordovician	Upper, Middle, Lower	500
		Cambrian	Upper, Middle, Lower	550
	Precambrian		Upper, Middle, Lower	4600

*Represents millions of years; not endorsed by the author.

Cenozoic	Eocene	Wasatch (Claron) Formation
Cenozoic	Eocene	San Jose Formation
Cenozoic	Paleocene	Nacimiento Formation
Mesozoic	Cretaceous	Ojo Alamo Sandstone
Mesozoic	Cretaceous	Cliff House Sandstone
Mesozoic	Cretaceous	Menefee Formation
Mesozoic	Cretaceous	Point Lookout Sandstone
Mesozoic	Cretaceous	Castlegate Sandstone
Mesozoic	Cretaceous	Blackhawk Formation
Mesozoic	Cretaceous	Starpoint Sandstone
Mesozoic	Cretaceous	Mancos shale
Mesozoic	Cretaceous	Dakota Formation
Mesozoic	Cretaceous	Cedar Mountain Formation
Mesozoic	Cretaceous	XXXXXX Major hiatus
Mesozoic	Jurassic	Morrison Formation
Mesozoic	Jurassic	Summerville Formation
Mesozoic	Jurassic	Curtis Formation
Mesozoic	Jurassic	Entrada Sandstone
Mesozoic	Jurassic	Carmel Formation
Mesozoic	Triassic	Navajo Sandstone
Mesozoic	Triassic	Kayenta Formation
Mesozoic	Triassic	Wingate Sandstone
Mesozoic	Triassic	Chinle Formation
Mesozoic	Triassic	Shinarump Conglomerate
Mesozoic	Triassic	XXXXXX Major hiatus
Mesozoic	Triassic	Moenkopi Formation
Mesozoic	Triassic	XXXXXX Major hiatus
Paleozoic	Permian	Kaibab Limestone
Paleozoic	Permian	Toroweap Formation
Paleozoic	Permian	Coconino Sandstone
Paleozoic	Permian	XXXXXX Major hiatus
Paleozoic	Pennsylvanian	Supai Group
Paleozoic	Mississippian	Redwall Limestone
Paleozoic	Devonian	Temple Butte Limestone
Paleozoic	Cambrian	XXXXXX Major hiatus
Paleozoic	Cambrian	Muav Limestone
Paleozoic	Cambrian	Bright Angel Shale
Paleozoic	Cambrian	Tapeats Sandstone
Precambrian	Proterozoic	Sediments, schists and granites

INTRODUCTION TO INTRODUCTORY PETROLOGY

"THE FIVE MINUTE ROCK COURSE"

Petrology is the study of rocks. Rocks are aggregates of minerals of varying size, composition, physical characteristics and origin. This latter factor is especially important in present classification schemes.

The minerals which form rocks are composed of atoms that are organized into highly defined substances with more or less constant physical and chemical properties. Examples of minerals include diamond, rock salt, graphite, quartz, etc.

A rock, on the other hand, is not so well defined; it can consist of a single or many minerals mixed in various proportions, sizes, etc. The important features of a rock can tell us much about its past history, and this is particularly important as one considers the past history of Earth.

There are three major groups of rocks — igneous, sedimentary, and metamorphic. Their major features will be described below.

IGNEOUS ROCKS

These rocks are formed by the congealing of hot molten material called magma. The hardening of a molten volcanic flow would be an example. Hardening can take place either below or above Earth's surface. Some identifying characteristics of igneous rocks are:

Usually not in layers, at least, not fine layers

Hard and massive

Interlocking mineral crystals

EXAMPLES

Basalt — fine crystals, dark in color from the more rapid cooling of magma.

Granite — consisting of coarse, light and dark interlocking crystals, not in layers, often from slow cooling of magma, but can also be of metamorphic origin.

Ophiolite — group of medium to dark igneous rocks including basalt, derived in part by metamorphism and associated with the development of a geosyncline.

Volcanic breccia — hardened coarse, angular particulate products of volcanoes.

SEDIMENTARY ROCKS

These rocks are formed by the cementing together of fragments aggregated together by various transport mechanisms such as moving water, wind, flowing ice, etc. An example would be the cementing together by minerals of sand particles on a beach to form beachrock or sandstone. Some identifying characteristics of sedimentary rocks include:

Layering

Particulates often rounded by transport

Sorted according to size by transport

EXAMPLES

Anhydrite — hard whitish rock composed of anhydrous calcium sulfate.

Claystone — massive, indurated clay particles.

Conglomerate — cemented round to subround pebbles in a finer matrix.

Dolomite — carbonaceous sedimentary rock, often greyish-tan in color, with a dominance of the mineral dolomite which is a calcium-magnesium carbonate.

Evaporite — composed primarily of minerals such as rock salt, gypsum, anhydrite, thought to have originated by the evaporation of saline solutions.

Gypsum— soft whitish rock composed of hydrous calcium sulfate.

Limestone — usually massive calcium carbonate, often white to grayish, produced by precipitation of lime from seawater either inorganically or by living organisms.

Marl — usually composed of fine impure calcium carbonate with some clay. An ill-defined term.

Sandstone— cemented sand.

Sedimentary breccia — composed of coarse angular clasts and originating from a sedimentary process.

Shale — cementing of fine particles, finely laminar.

METAMORPHIC ROCKS

These rocks originate from igneous, sedimentary, or other metamorphic rocks. They are altered physically or chemically or both, producing a new kind of rock. These changes occur essentially in the solid state and can be either minor or of such a nature as to completely change the characteristics of the original rock. An example would be the changing of a shale into a slate by shearing pressure. Characteristics of metamorphic rocks are:

Generally laminated

Original structures out of shape, hard to identify

Contains mineral assemblages characteristic of metamorphic changes

EXAMPLES

Gneiss — foliated rocks with alternating mineral bands, usually formed from coarser grained rocks, layer greater than 1 mm in thickness.

Granite— coarsely crystalline rock, consisting of light and dark (usually) minerals, sometimes derived by the metamorphism of sedimentary rocks, also of igneous origin.

Marble — from limestone, usually not in layers, altered and bent carbonate crystals.

Mylonite — compact, fine-grained rock produced by extreme mechanical granulation and shearing during metamorphism.

Phyllite — compact, fine grained, usually intermediate between a slate and a schist. Does not cleave as perfectly as a slate.

Schist — strongly foliated crystalline rock, easily split, originating from fine-grained rocks, layers 1 mm or less in thickness.

Serpentine— rock with a black to green, greasy luster, soapy feel, derived from metamorphism, magnesium-rich rocks.

Slate — compact, fine grained, very fine layers, can be split into slabs and plates, usually from shale.

STRATIGRAPHIC SECTION: COLORADO PLATEAU

This is a selected list from the most important formations. Depositional environments given are those implied in the standard literature.

CENOZOIC

QUATERNARY

Various alluvial (recent stream, flood, and lake deposits) and eolian (wind-blown) deposits.

TERTIARY

Sevier River Formation (probably Pliocene)

Grey, partly consolidated, coarse conglomerate with volcanic debris. Thickness to 250 m. Fluvial (river) deposit.

Brianhead Formation (Eocene to Miocene? Probably Eocene)

Grey, consolidated ash flow. Thickness to 300 m, usually thinner. Fossils? Volcanic origin.

Wasatch Formation (also called Claron in S)

Pink, white limestone and calcareous sandstone, soft, conglomeratic at base. Invertebrate and plant (angiosperms) fossils. Thickness up to 1100 m; usually 150 m. Considered to be a freshwater deposit; fluvial (river), paludal (swamp), and lacustrine (lake) environments described.

San Jose Formation (Eocene)

Buff, grey, etc., mudrock with interbedded sandstones. Cuba member is prominent at base. Thickness up to 630 m. Was called Wasath in north before formation worked out. Has yielded one of the most diverse Eocene vertebrate fauna. Deposited by rivers (fluvial), includes flood plain and sheet sandstone deposit. Paleocurrent data indicates high-energy streams from the north.

Naciamento Formation (Paleocene)

Grey to variegated (multicolored) black and white mudstones and sandstones. Thickness up to 525 m. The formation is famous for its Paleocene vertebrate fossils, especially early mammals. E.D. Cope reported about these. Fluvial (river) and lacustrine (lake) paleoenvironment

MESOZOIC

CRETACEOUS

Ojo Alamo Sandstone (Cretaceous from vertebrate evidence, but Tertiary from few plant fragments). Thickness up to 35 m. Vertebrate and plant fossils. Continental (land) paleoenvironment.

Kirtland Shale and Fruitland Formation

Grey to variegated (multicolored) sandstones, shale and coal. Upper Kirtland with more shale. Both with thicknesses up to 500 m. Many vertebrates, fish to mammals, including dinosaurs, crocodiles, turtles, invertebrates and plants. Important coal source. Fluvial (river) deltaic, paludal (swamp), coastal paleoenvironment.

Pictured Cliffs Sandstone (Upper Cretaceous)

"Salt and pepper" sandstone. Thickness up to 60 m. Deposited in a regressive marine offlap of a littoral (intertidal) marine environment. Named for the thousands of "fantastic figures" engraved on the massive sandstone exposed along the San Juan River.

Lewis Shale (Upper Cretaceous)

Dark-grey to drab-grey sandy shale with clay and sandstone and calcareous concretions, and thin white-to-grey sandstone layers. Thickness up to 600 m. Marine fossils include bivalves and ammonites. Marine paleoenvironment. Extends from New Mexico to Montana

MESAVERDE GROUP

Forms a variety of outcrops in different localities. In general it consists of buff, bedded sandstone layers with interbedded shale members, many of which are carbonaceous. Coal seams common, dinosaur tracks, upright trees; marine fossil layers also common. Intertongues with Mancos Shale. Thickness up to 1500 m.

In the Mesaverde region, the group includes the following three formations:

Cliff House Sandstone (Upper Cretaceous)

Thin-bedded to massive buff sandstone with shale partings. Thickness up to 250 m. Deposited in a transgressive (inundating sea) marine paleoenvironment.

Menefee Formation (Upper Cretaceous)

Interbedded grey-buff sandstones, grey shales, and coal seams. Thickness up to 700 m. Fossils include fish, turtles, crocodiles and many plants. Nonmarine, fluvial (river) and coastal paleoenvironment, possibly some marine deposits.

Point Lookout Sandstone (Upper Cretaceous)

Massive, light-grey to yellow sandstone. Thickness up to 100 m. Littoral regressive (receding sea), marine paleoenvironment, sediments supplied by rivers, in part fluvial (river) - deltaic, strand (shore) plane, and barrier beach deposit.

In eastern-central Utah the group includes the following four formations:

Price River Formation (shale; piedmont environment)

Castlegate Sandstone (floodplain environment)

Blackhawk Formation (coal and sandstone; lagoonal environment)

Star Point Sandstone (littoral — intertidal — marine environment)

Mancos Shale

Evenly bedded, light- to medium-dark grey, calcareous, marine shale which weathers yellowish grey. Limestone and sandstone members present. Intertongues with Mesaverde Group above and Dakota Group below. Some marine vertebrates and invertebrates and coal at several levels. Thickness 15-1500 m. Depositional environment: coastal marine, swamp, barrier bar, delta.

Kaiparowits Formation

Grey-blue, arkosic sandstone and shale, forms slopes and badland topography. Fossils include various reptiles, non-marine invertebrates, and plants. Thickness 180-360 m. Considered to be mainly a fluvial (river) deposit.

Wahweap Sandstone

Yellowish-grey sandstone and mudstone layers. Fossils very rare, include reptiles, invertebrates, and leaves. Thickness up to 360 m; usually 180-200 m. Depositional environment: fluvial (river).

Straight Cliffs Sandstone

Yellowish-grey, massive sandstone layers and mudstone. Land fossils (terrestrial vertebrates) rare in top part, marine and brackish water fossils in lower part. Thickness to 300 m. Depositional environments: fluvial (river) and coastal marine.

Tropic Formation

Grey shale with many buff-yellow sandstone beds, especially in lower part. Fossils include coal derived from plants as well as freshwater and marine invertebrates. Thickness to 380 m. Depositional environment considered to be marine.

Dakota Formation (Dakota Sandstone)

Yellow to white, brown to buff sandstone and darker carbonaceous shale and coal, partly conglomeratic. Fossils include coal, petrified trees, marine and freshwater invertebrates. Thickness to 30 m. Depositional environment: marginal marine, fluvial (river).

Cedar Mountain Formation

Grey to dark-grey shale with coarse Buckhorns basal conglomerate. Fluvial (river) and flood-plain paleoenvironment.

JURASSIC

Morrison Formation

Variegated mudstones, siltstone and yellowish grey-brown sandstones. Fossil dinosaurs, plants and freshwater invertebrates, fish, crocodiles, and primitive mammals present. Usually around 100 m thick, may reach 450 m. Depositional environment: fluvial (river), lacustrine (lake), floodplains, deltas.

Cow Springs Sandstone

Fine-grained quartz (mostly) sandstone, greenish carbonate cement. White to light-green, grey or buff in color, difficult to distinguish from Entrada. Fossils (none?). Thickness up to 200 m. Depositional environment: eolian (wind).

Summerville Formation

Crinkled, banded, or massive silty sandstone with some shaley members. Usually tan, grey, orange-red or buff in color. Fossils (none?). Thickness up to 100 m. Depositional environment: tidal flat, possibly some eolian (wind) deposits(?).

SAN RAFAEL GROUP (INCLUDES FIRST 4 FORMATIONS BELOW)

Todilto Formation

Cliff-forming grey limestone, shale, mudstone, and gypsum. Thickness up to 75 m. A few invertebrate fossils and fish. Commercial source of gypsum. Correlated with Curtis in Utah and Pony Express in Colorado. Was considered to be of marine origin, but now thought to represent evaporation in a salina (salt flat) with limited access to the sea.

Curtis Formation

Grey to white, roughly bedded limestone and thick gypsum. Marine fossils. Thickness usually 15 -75 m, up to 220 m. Depositional environment: marine, evaporite.

Entrada Sandstone

Light-red with white bands and reddish-orange, fine-bedded sandstone shale and gypsum. Fossils? Thickness usually 30-60 m, up to 180 m. Depositional environment: mainly fluvial (river) and eolian (wind).

Carmel Formation

Grey to buff limestone in beds alternating with softer, red, shaley layers, etc., some gypsum. More marine to the W. Marine fossils, vertebrates and algae. Thickness usually 30-60 m, up to 180 m. Depositional environment: generally considered to be marine, especially in W.

GLEN CANYON GROUP (INCLUDES FIRST 4 FORMATIONS BELOW)

Navajo Sandstone

Red, pink, orange, buff, grey, white, intensely cross-bedded sandstone. Occasionally with a thin layer of cherty limestone. Virtually no fossils except for a few tracks of dinosaurs, terrestrial reptiles, and plant remains. Thickness usually 30m, up to 670 m. Lower part has been considered Triassic. Depositional environment: mainly eolian (wind) and lacustrine (lake).

TRIASSIC

Kayenta Formation

Red-maroon, cross-bedded sandstone beds, with grey limestone and brown shale layers between. Fossils very rare, some freshwater invertebrates, wood, and vertebrate tracks. Trend is towards considering it Jurassic. Thickness usually less than 60 m, up to 365 m. Depositional environment: fluvial (river) and eolian (wind).

Moenave Sandstone

White to reddish-brown, cross-bedded sandstone and mudstone usually a massive cliff. Fossils include fish and crocodiles, very rare, vertebrate (dinosaur and other reptile) tracks. Thickness to 120 m. Depositional environment: eolian (wind) and fluvial (river).

Wingate Sandstone

Reddish, cliff-forming sandstone. Fossils very rare, some reptile tracks and remains reported. Thickness up to 200 m. Depositional environment: eolian (wind).

Chinle Group

Variegated mudstones, siltstones, sandstones, conglomerates and limestones. Several members including a prominent basal conglomerate called the Shinarump, which has a thickness of 20-40 m. Fossils include petrified wood (locally abundant as in Petrified Forest National Park), other plant remains, reptiles, etc. Thickness usually from 300-600 m. Depositional environment: fluvial (river) and lacustrine (lake). Was considered a formation, but the trend is to divide it into several formations.

Moenkopi Formation

Chocolate-brown to grey, gypsiferous sandstone and shale with gypsiferous and marine limestone members. Fossils include marine invertebrates and some tracks of land animals in other layers. Thickness up to 600 m. Depositional environment: marine, fluvial (river), tidal flat.

PALEOZOIC

PERMIAN

Kaibab Limestone

Grey-white, buff, dense-bedded limestone and dolomite, also with some sand and gypsum. Abundant variety of marine fossils including: fish, trilobites, sponges, brachiopods, rugose coral, gastropods, and scaphopods. Thickness 100 m at central part of Grand Canyon, up to 600 m elsewhere. Depositional environment considered to be an open and restricted ancient seaway.

Toroweap Limestone

Buff, reddish-grey limestone and sandstone with some gypsum layers, marine fossils as for Kaibab. Thickness 85 m at central part of Grand Canyon. Depositional environment assumed to be tidal flat, eolian (wind), marine, evaporite.

Coconino Sandstone

Buff, grey, cross-stratified sandstone. Fossils include locally abundant, mostly uphill, trackways of vertebrates and invertebrates. Thickness 100 m at central part of Grand Canyon, up to 300 m elsewhere. Depositional environment assumed to be a desert. Some data challenge this.

Hermit Formation

Deep-red, thin-bedded, shaly siltstone. Cracks to 5 m deep at top. Scarce fossils include some plants, trackways and insects. Thickness 70 m at central part of Grand Canyon, up to 300 m elsewhere. Correlates with Supai Fm. to the SW. Depositional environment: stream, dunes, coastal plain.

SUPAI GROUP (INCLUDES FIRST 4 FORMATIONS BELOW)

Esplanade Sandstone

Cross-stratified, reddish-brown sandstone units with thickness of 2-15 m, with mudstone or limestones between. Thickness 60-250 m. Some marine fossils, vertebrate tracks, and plant fragments. Assumed to have been deposited in a complex shoreline environment, including a fluvial (river) environment.

PENNSYLVANIAN

Wescogame Formation

Alternating quartz sandstone and intercalated red mudstone and some limestone that increases to the W. Has a lower cliff unit and an upper slope unit. Contact with the Manakacha below (hiatus — most of Middle Pennsylvanian absent) difficult to determine. Thickness about 30-200 m. Marine fossils mostly in limestones include fusulinids, pelecypods, and gastropods; also vertebrate trackways but no skeletal remains; some plant fragments. Depositional environment not well-defined, but assumed to have been by the sea but largely non-marine.

Manakacha Formation

Quartz sandstone and intercalated, red mudstone with great increase in carbonate content to the NW. Thickness 45-100 m; thickest in Grand Canyon region. Sparse fossils include plant fragments, brachiopods, bryozoans, pelecypods, gastropods, trilobites, and coral. The formation is assumed to have been deposited in a tidally influenced marine environment.

Watahomigi Formation

Consists mainly of red mudstone and siltstone and grey limestone and dolomite. Thickness in Grand Canyon from 30 m in E to 100 m in W. Fossils more abundant than in Manakacha include: brachiopods, gastropods, pelecypods, echinoderms, trilobites, sharks, forams, conodonts, corals, and plant fragments. The formation is assumed to have probably been deposited in a marine and adjacent-to-marine environment.

MISSISSIPPIAN

Surprise Canyon Formation

Appears as isolated lens-shaped exposures. It sometimes consists of a lower, dark-grey to red-brown clastic, terrigenous cherty deposit, and an upper, grey to brown-red marine carbonate. Best represented in the W part of the Grand Canyon. Thickness usually a few dozen meters, but up to 120 m. Fossils include: plants, coral, brachiopods, echinoderms, bivalves, cephalopods, trilobites, sharks teeth, and foraminifers. The formation is assumed to have been deposited in an ancient estuarine-stream valley system with a marine shoreline to the W.

Redwall Limestone

Grey to yellow limestone usually stained red from overlying layers. A large variety of marine fossils present including fish. Thickness 150 m in central part of Grand Canyon; slightly thicker elsewhere. Formation divided into 4 members in the Grand Canyon region. Depositional environment: shallow epeiric sea.

DEVONIAN

Temple Butte Limestone

Purplish limestone and dolomite. No clearly identifiable invertebrate fossils found (McKee 1976, p 53), possibly crinoids, corals, stromatoporoids and conodonts. Some fish discoveries made. Thickness 0-300 m. In central part of Grand Canyon, limited to small channels in Bright Angel Shale. Thickens W-ward. Depositional environment: tidal channels, subtidal and open marine.

CAMBRIAN

Muav Limestone

Grey limestone units with layers of mudstone, etc., between. Marine fossils not common, and include some brachiopods and trilobites. Thickness 30 m at central part of Grand Canyon, up to 250 m elsewhere. Depositional environment: shallow marine, intertidal and subtidal.

Bright Angel Shale

Greenish, shaley mudstone and fine-grained sandstone. Fossil brachiopods locally common, trilobites present. Thickness about 170 m at central part of Grand Canyon. Depositional environment: shallow marine, offshore.

Tapeats Sandstone

Brown-grey, coarse to medium cross-bedded sandstone forming a cliff. Fossils include trilobite trails and numerous "problematical worm borings" (McKee 1976, p 47). Thickness 70 m at central part of Grand Canyon, up to 180 m elsewhere. Depositional environment: shallow subtidal.

PRECAMBRIAN

In the Grand Canyon area, various layers of sedimentary deposits totaling 3600 m lie unconformably below the Cambrian. Fossils very rare, many questionable. Below these layers are igneous and metamorphic rocks.

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GLOSSARY OF SOME GEOLOGICAL TERMS

(Consult the "Introduction to Introductory Petrology" and the "Geologic Column" for rock and stratigraphic terms)

ALLOCHTHONOUS — originating from elsewhere, transported.

ANTECEDENT — pertaining to a stream that maintains its original course.

ANTICLINE — a fold which is convex upward.

AUTOCHTHONOUS — indicates no transport, in situ.

BACK REEF — the area between a reef and the mainland.

BALL AND PILLOW —a primary sedimentary structure characterized by hemisphere and kidneyshaped masses usually attributed to foundering.

BENTHONIC — said of an organism living on the ocean bottom, fixed or free.

BOUMA SEQUENCE — the characteristic sequence of complex sedimentary structures deposited by a turbidity current.

CARBONATE — a mineral formed in part using carbonate ions. Limestone is a common example, consisting of calcium carbonate.

CARBONATE COMPENSATION DEPTH — the depth in the ocean where the solution of carbonate exceeds the rate of deposition. Presently this is usually several thousand meters below sea level.

CATASTROPHISM — theory in which phenomena outside our present experience of nature have greatly modified Earth's crust by violent, sudden, but short-lived, events more or less worldwide.

CIRQUE — a steep-walled semicircular recess situated high on a mountain and produced by glacial erosion. It is commonly at the head of a glacial valley.

CLAST — the individual constituent of a sedimentary rock. It can be from clay size to boulder size.

CLASTIC — pertaining to rocks formed of clasts.

COLUMNAR JOINTING — forms parallel prismatic columns as a result of the cooling of magma.

CONCRETION — a hard compact mass of mineral matter in a sedimentary rock.

CONVOLUTE — wavy, disorganized, crumpled sedimentary layers, often occurring between parallel layers.

CORALLINE — pertaining to corals and related features of coral, such as reefs, etc.

CORDILLERA — an assemblage of mountain ranges with a general parallel arrangement.

CYCLOTHEM — a term applied to the repeat unit of a cyclic sedimentary sequence.

DEBRIS FLOW — a moving mass of a mixture of rock and mud with a dominance of the clasts being larger than sand size.

DENUDATION — erosion on a broad scale that results in uncovering the bedrock or a designated rock formation through erosion of overlying material.

DETRITUS — transported fragmental material derived from the breakdown of rocks.

DIAPIR — a dome or anticlinal fold, the overlying rocks of which have been ruptured by the squeezing out of the plastic core material. Diapirs in sedimentary strata usually contain cores of salt or shale; igneous intrusions may also show diapiric structure.

DISCONFORMITY — an unconformity where the bedding planes above and below the gap in deposition are essentially parallel.

ECOLOGICAL ZONATION THEORY — the theory that the sequence of fossils found in the geologic column is due to the ecological distribution of the organisms before the Genesis flood. The preflood ecological zones were destroyed in sequence by the gradually rising waters of the flood. The preflood ecology is assumed to have been different from present ecology.

EOLIAN — pertaining to the action or effect of wind.

EPEIRIC SEA — a sea within a continent or on the continental shelf.

EPIDERMIS FOLDING — folding of the epidermis (sedimentary layers or superficial cover layers) in contrast to a more stable basement which is not so involved in the folding.

EUSTATIC — changes in sea level that are worldwide, not local.

EVAPORITE — a nonclastic sedimentary rock composed primarily of minerals produced from a saline solution that became concentrated by evaporation of the solvent. Examples include gypsum, anhydrite, rock salt, chemically precipitated limestone, primary dolomite, and various rare nitrates and borates.

FACIES — the characteristic textures of a particular rock unit. May refer to rock type, fossil content, etc.

FAULT — a fracture plane in a geologic unit in which there is some observable displacement.

FLUVIAL — pertaining to, or produced by, a river or stream.

FLYSCH — a sedimentary deposit of thin units of marls, sandstones, conglomerate, graded deposits, often alternating in nature. May include turbidites.

FOLD — a bend in an originally planar rock structure.

FOLIATION — the planar structural features of a rock that result from the flattening of the constituent grains in the metamorphic process.

FORELAND — the stable area next to an orogenic belt towards which the belt was thrust. See Hinterland.

FORE REEF — the seaward side of a reef.

FORMATION — a group of rock strata or a body of igneous or metamorphic rock that has certain unique characteristics common to the unit and differing from adjacent units, usually of mappable size.

FOSSILS — any trace, imprint, natural cast or remains of a living organism preserved in sediments.

GEOLOGIC COLUMN — a composite diagram showing in one column a sequence of rocks corresponding to a chronological scale made according to the evolution of the fossils found in these rocks.

GEOSYNCLINE — an extensive elongated downwarped region of Earth's surface in which sediments and volcanic rocks have accumulated to great thicknesses.

GRABEN — an elongated trough bounded on both sides by high-angle normal faults dipping to the inside.

GRADED BED — a sedimentary layer which has the coarsest material at the base and becoming finer as one proceeds towards the top.

HIATUS — gap, missing layers in a sedimentary structure.

HINTERLAND — the area on the side of an orogenic belt away from the direction of the thrust. See Foreland.

HORST — an elongated block bounded on both sides by normal faults dipping to the outside.

INDEX FOSSIL — fossil used to date and to identify the strata in which it is found; a good index fossil is a species having a broad geographic range, a restricted stratigraphic range, a distinctive morphology and a relatively common occurrence.

ISOCLINE — a fold whose limbs are parallel.

JOINT — a fracture in a rock without displacement. It is often planar.

KARST — a type of topography formed on limestone due to dissolution forming sinkholes and caves.

KLIPPE — a transported block of rock that is isolated from its source either by sliding or by erosion of the thrust sheet from which it originated.

LACCOLITH — an intrusion of igneous rock with a convex upward roof and a flat floor.

LACUSTRINE — belonging to, or produced by, lakes.

LAMINA — very thin sedimentary layer, commonly in the mm range or thinner.

LITHOLOGY — physical character of a rock: color, mineralogic composition, grain size, etc.

LITTORAL — pertaining to the region between low water and high water, i.e., intertidal.

LOAD CAST — the bulbous projection of an overlying layer into the one below due to unequal loading.

MAGMA — molten fluid within Earth's interior formed from the melting of rock.

MATRIX — the finer-grained material filling the space between larger particles or fossils, etc.

MOLASSE — an extensive mixed sedimentary deposit resulting from the early erosion of a mountain range such as north of the Alps.

MONOCLINE — a local steepening of more horizontal sedimentary deposits.

MORAINE — accumulation of larger aggregates of unsorted glacial drift by the action of a glacier.

NAPPE — an extensive body of rock that has moved by recumbent folding or overthrusting.

NORMAL FAULT — fault in which the depressed block is above the fault surface, and the hanging wall has been depressed relatively to the footwall.

OOLITH (OOLITHIC) — a small (0.25 to 2 mm diameter) sphere whose center is usually a debris and whose shell is formed by concentric thin layers, usually of calcium carbonate.

ORGANIC REEF — a wave-resistant ridge or mound built by sedentary organisms showing relief above the surroundings.

OROGENY — the process of mountain formation.

OVERTHRUST — a near-horizontal thrust fault of wide extent usually many km2.

PALEOGEOGRAPHIC DOMAIN — the location of a particular geologic area at a particular time in the past.

PALUDAL — pertaining to a marsh.

PALYNOMORPHS — a resistant, microscopic, organic body such as pollen, spores, acritarchs, etc.

PARACONFORMITY — an unconformity in which there is no erosional surface and the beds below and above are parallel, a non-sequence.

PARAUTOCHTHONOUS — not transported very far, intermediate between autochthonous and allochthonous.

PELAGIC — pertaining to the open sea but not the sea floor.

PENEPLAIN — a widespread featureless (flat) land surface presumably produced by long, continuous subaerial erosion.

PETROLOGY — the study of rocks.

PLATE TECTONICS — theory in which Earth's surface (lithosphere) is formed of rigid plates floating on the aesthenosphere. The different plates interact with one another at their boundaries, causing seismic and tectonic activity.

PROGRADATION — the outward or basinward migration of a shoreline and accompanying basinward sedimentation.

PSEUDO-OOLITHIC ROCK — rock composed of small spherical pseudo-ooliths (ooliths without the defining internal structure). Sometimes with ill-defined outlines.

RECUMBENT FOLD — an overturned fold as in a nappe or other geologic unit.

REEF — a projecting outcrop of rocks.

REGRESSION — retreat of the sea from land areas.

RELIEF — unevenness of Earth's surface.

RETROGRADATION — the landward migration of a shoreline and its accompanying landward sedimentation.

REVERSE FAULT — fault in which the raised block is above the fault surface.

RIFT — a long, narrow continental trough bounded by normal faults; a graben.

RIPPLE MARKS — finely detritic sedimentary structures formed of sub-parallel elongated ripples, 1 to 5 cm high; produced by wind, water currents or wave action.

ROCHE MOUTONNEE — smoothed off, mounded rock usually a few meters in size, produced by the action of glaciers.

SACCHAROIDAL — a rock texture term used for rocks having a sugary appearance.

SALINA — an area in which deposits of salt are found or formed.

SEDIMENTARY — formed by precipitation from solution, or as a result of transport by water.

SEDIMENTATION — processes leading to the formation of sediments: separation of rock particles, transport, deposition and finally consolidation of the particles in a new rock.

SEDIMENTS — any particles (of any size), laid down after some transportation by water, wind or ice.

SHEET — a large, widespread tabular mass of rock.

STRAND PLAIN — a prograded shore built seaward by waves and currents.

STRATA — plural of stratum, a stratigraphic unit. A stratum (or bed, layer) is a layer of sediments limited by two surfaces approximately parallel featuring sharp variations (visually obvious) in the structure of the sediments.

STRATIGRAPHY — science of the strata of Earth's crust, dealing especially with the characteristics, sequence of layers, and the time factors of this sequence.

SUBSIDENCE — gradual or sudden sinking of a large portion of Earth's crust.

SUPERPOSED — pertaining to a stream that maintained its course as it was established on a new lower surface.

SYNCLINE — a fold which is concave upward.

TALUS — rock fragments at the base of a steep slope or an extensive slope of such fragments.

TECTONIC — related to structural or orogenic features of Earth's crust.

TERRIGENOUS — originating from land surfaces in contrast to a marine origin.

THRUST FAULT — a fault whose surface is more horizontal than vertical and in which the direction of movement of the two parts is compressional.

TILL — heterogeneous mixture of clay-boulder clasts resulting from the action of glaciers.

TRANSGRESSION — extension of the sea over land.

TURBIDITE — a sedimentary rock deposited by a turbidity current.

TURBIDITY CURRENT — a downhill, underwater density current consisting of a suspension of sediments. The current has a greater density than water, flows with a characteristic pattern, leaving a characteristic deposit.

UNCONFORMITY — an interruption in deposition in a sedimentary sequence. A gap in the stratigraphic record.

UNIFORMITARIANISM — theory stating that geologic processes operating today acted the same way and at the same speed in the past. This theory does not exclude some local catastrophes.

VARIEGATED — showing irregular variations in color.

VARVE — layer of sediment usually consisting of a coarse and fine portion, and thought to have been deposited during one year.

VERGENCE — the direction of inclination or overturning of a fold.

WILDFLYSCH — a kind of flysch characterized by large, usually unsorted blocks and contorted beds.

WRENCH FAULT — a lateral fault with a more or less vertical fault surface.

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THEOX 2007 GEOLOGY FIELD CONFERENCE: SUMMARY AND IMPLICATIONS

(References refer to field guide)

METEOR CRATER. For many years D. M. Barringer resisted the broadly accepted opinion of G. K. Gilbert and other geologists that Meteor Crater was due to volcanic activity. It turns out that Barringer was right. This is an illustration of a strong sociological component in the scientific community.

INTRUSIONS OF MOENKOPI AND SHINARUMP INTO EACH OTHER (Ch. 6, Fig. 1). Since both formations appear to have been soft, the ten million year gap between the age of the two formations appears invalid.

LITTLE COLORADO RIVER OVERLOOOK. This kind of deep gorge is atypical of the ancient topography we find within the old geologic layers, suggesting a different past for the geologic layers than for present conditions.

GRAND CANYON: DEPOSITION OF LAYERS. Several factors suggest rapid deposition including extreme lateral continuity of sedimentary units; paucity of erosion where major parts of the geologic column are missing (Ch. 2, Fig. 1); and the incongruity of cracks in the top of the Hermit Shale not filled until after an assumed six million years later (Ch. 2, Fig 6).

GRAND CANYON: CUTTING OF THE CANYON. Cutting the Canyon is probably a minor problem compared to removal of the Mesozoic and Cenozoic layers (The Great Denudation) that were above the Canyon rim. Many models are proposed for cutting the Canyon. Both the geologic community and flood geologists are in disagreement among themselves as to how the canyon was cut. The necessity for a major water source to cut the numerous side canyons of the Grand Canyon, and the need for sediment erosion above the Canyon rim, favors the receding of the flood waters as the cause for the erosion of the Grand Canyon.

TERMITE NESTS. Data indicates that what is interpreted as termite nests in the Morrison Formation (Ch. 3) are concretions formed by the addition of microcrystalline quartz. Too often speculation is rampant in paleontology.

PARACONFORMITY – 1. The 40 million year gap between the Morrison and Dakota formation, followed for 150 miles from Lupton, AZ and Albuquerque, NM (Ch. 4, Fig. 5) along I-40, is a severe challenge to the validity of the geologic time scale. How could any area remain that flat for that long a time on any part of the earth.

CHACO CULTURE NATIONAL HISTORIC PARK, AZTEC RUINS, AND MESA VERDE NATIONAL PARK. These three habitats of ancient man well illustrate

that man tends to leave solid evidence of his presence; and raises the question as to whether man has really been around for half a million years, or much longer as commonly believed. If man has been around that long, why is the good evidence for his presence, such as archaeology, written language, and reproductive potential; all indicative of just a few thousand years?

BALL AND PILLOW. Such features as illustrated in Ch. 6, Figs. 3,4, (also Figs. 5-9); illustrate rapid deposition for both the underlying shale and the overlying sandstone. This is the kind of activity expected during the Genesis Flood, but it must be kept in mind that here we are dealing with only a limited part of the geologic column. Long-ages geologists recognize these as very rapid activity, but place long ages between such events, thus preserving the millions of years in the geologic column. The Hiawatha pillows (Ch. 6, Fig. 7) are another example of rapid action involving many layers, and this is well recognized by the geologic community.

MOAB VALLEY SALT DEPOSITS. These salt deposits that consist of many thousands of feet of salt are usually attributed to the slow evaporation of sea water. There are many problems with this model, including the fact that nowhere on the surface of our earth do we find any salt deposits being formed on a scale remotely approaching the size of these huge deposits. Redepositon of original salt by movements associated with volcanic and orogenic activity during the Genesis Flood is proposed as a more reasonable alternative.

PARACONFORMITIES – 2. Dead Horse Point (Ch. 4, Fig. 1; see also Figs. 2-7) and Canyonlands National Park offer exceptional views of the widespread nature of the sediments on the Colorado Plateau. The lack or paucity of erosion where major parts of the geologic column are missing offer convincing evidence of rapid deposition of the sedimentary layers and of the invalidity of the geologic time scale.

UPHEAVAL DOME. While Upheaval Dome presents lots of evidence of soft sediment deformation, one must keep in mind that the apparent softness of the sediments could be due to acoustic fluidization. Further evaluation is necessary.

TURBIDITES AT HATCH MESSA. These rapidly deposited sandstone layers (Ch. 6, Fig. 6) illustrate the trend towards catastrophism that is now acceptable in geological interpretations.

"WORM TUBES." The numerous trace fossils found could be produced rapidly during the Genesis Flood. A 1.7 cm clam can travel through soft sediment at the rate of 10 meters per hour. When the "tubes" are found only in the tops of the sedimentary units, this suggests rapid deposition as is the case for turbidites.

EROSIONAL PATTERNS. We find many peculiar river drainage patterns (Ch. 9). The stream capture, antecedent and superposed models have serious problems. It may well be that the rapid receding waters of the Genesis Flood present the best

explanation for the very unusual erosional features seen in the Grand Canyon, Moab Valley, Split Mountain, and the northern Uinta Mountains.

EXTREMELY WIDESPREAD SEDIMENTARY LAYERS. Whether we are dealing with thin coal partings, basal conglomerates, or major formations; extremely widespread sedimentary deposits are found (Ch. 8). This is precisely what we would expect from the Genesis Flood. Furthermore the highly irregular erosional surface that we find on the surface of our present continents, completely precludes the present deposition of such thin widespread layers. We are dealing with a past that is very different from the present and the major differences we find are what we would expect from the Genesis Flood.

THE FOSSIL RECORD. The pattern of distribution of fossils (Ch. 10) presents some evidence that seems to support evolution while at the same time it provides strong evidence that severely challenges that concept. There is a very general increase in complexity of organisms as one ascends the geologic column as expected for evolution. On the other hand, the Cambrian explosion; paucity of intermediates; a defined appearance of terrestrialization; and total lack of time for the improbabilities required for complex evolutionary changes; indicate that evolution never occurred. The slight increase in complexity noted fits in general with present ecologic distribution of organisms, but in the context of the ecological zonation theory, creationists need to postulate a more orderly and restricted ecologic distribution pattern before the Genesis Flood than seen at present in order to explain the uniqueness of sorting found in the fossil record. However the broad general fossil pattern we find fits very well with the expectations of the biblical creation-flood model.

CONCLUSIONS. There is a lot of scientific evidence that authenticates the Biblical model of beginnings. Furthermore, paraconformities and extremely widespread sedimentary deposits are very difficult to explain unless you believe in that model.

The authentication for the biblical model of origins found in the rocks affirms the truthfulness of the Bible and of the wonderful loving and forgiving God presented therein. We should do all we can to help others learn about this God.

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