Steve Austin's 1988 Grand Canyon Guidebook – No Grand Lake. No breached dam explanation.

Institute for Creation Research

# GRAND CANYON

## FIELD STUDY TOUR GUIDEBOOK

### APRIL 9-16, 1988

Raft Trip on Colorado River
Bus Tour of Northern Arizona & Southern Utah
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## SUMMARY OF THOUGHTS ON EROSION OF THE GRAND CANYON

by Steven A. Austin

**Note: This short article is a plain English condensation of the more technical article "Erosion of the Grand Canyon--A Geologist's Personal Reflections" which appears immediately after this summary.**

Twenty-five years ago I stood on the rim of the Grand Canyon contemplating the forces of erosion that had produced that awesome spectacle. Two observations came to my attention: First, I recognized that an enormous amount of material had been removed to create the 217-mile-long form of the canyon. (My simple calculation estimated just under one thousand cubic miles of strata had been excavated.) How was the material removed and where did it go?

Second, I noticed that the plateau through which the Grand Canyon occurs is much higher than the region on the west and east. Most interesting was the observation that the Colorado River is positioned flowing from east to west through the elevated plateau acting like a "river that flows uphill". Why did the Colorado River select its location through the more elevated area of northern Arizona, rather than around that plateau? Rivers, I know, like to take the easiest path.

As I contemplated the magnitude of Grand Canyon erosion and the improbability of the Colorado River being positioned where it is, I tried to devise an explanation consistent with evolutionary theories of geology which I had taught in school. I imagined that the ancestral Colorado River was located across northern Arizona as it is today, but that there was no elevated plateau. The whole area was low, I supposed, until uplift of the plateau caused the river to erode into the slowly rising land. That uplift I had been taught occurred from fifty to seventy million years ago. I concluded that the Grand Canyon was a long enduring feature which had evolved by the slow down cutting of the Colorado River.

The theory for the Grand Canyon I had favored was simple and elegant. It even conformed with evolutionary theory. It explained things in terms of processes that I know and observe. All I had to do was imagine how the slow rise of the land was balanced by continuous erosion by the ancestral Colorado River during periods of tens of millions of years.

The more I considered the theory that the Colorado River eroded the Grand Canyon, the more problems I had. Chief among these was the nagging question, "Where did all the sediment go?" To the west of the Grand Canyon there ought to be an enormous deposit of silt, sand and gravel deposited by the ancestral Colorado River. Not just one thousand cubic miles of eroded Grand Canyon strata, but an enormous quantity of sediment should be found from seventy million years of erosion of the entire drainage basin. My simple calculation showed that the muddy waters of the Colorado River now carry enough sediment to total one million cubic miles if erosion operated slowly over seventy million years. No colossal delta of silt, sand or gravel has been found! Instead, immediately west of the Grand Canyon occurs a thick limestone layer, where there ought to be silt, sand and gravel.

I began to entertain a notion that could be regarded as geologic heresy: the Colorado River did not erode the Grand Canyon! Soon I found comfort knowing that many other geologists also had dismissed the ancient ancestral river theory. For several years I tried to devise an alternate way to leave the plateau uplifted and uneroded for millions of years, then repositioning the Colorado River across it just recently. I imagined that a long, straight, and deep gully began to erode eastward from northwestern Arizona through the plateau and the present location of the Grand Canyon. The original Colorado River, I supposed, was diverted through the enormous gully. I freely admitted that I was attributing the Grand Canyon to one of the world's most unusual natural accidents. My mind could no longer continue to think that way.

As I evaluated the progress of my thinking on the Grand Canyon, I began to ask myself if I was laboring with a concept of geologic time which really did not exist. Could the Grand Canyon instead be the result of rapid erosion and the plateau in northern Arizona a young geologic feature? I was no longer thinking like an evolutionist and uniformitarian, but like a creationist and catastrophist. The concept I was entertaining resembled the account of Noah's Flood and the legend of the Havasupai Indians (who live in the Grand Canyon today and tell a story very similar to the Bible).

Lately I've begun supposing that the plateau land in northern Arizona was uplifted rapidly and that the Grand Canyon basin upstream was blocked by the plateau. That elevated plateau

... plateau would have formed a gigantic natural dam with a lake east of the present Grand Canyon. Thin sedimentary deposits from the lake occur east of the canyon. Modern experience with man-made dams shows that when they fail, they fail catastrophically. I supposed that the northern Arizona dam also failed rapidly allowing the impounded lake to drain westward over the plateau causing significant erosion to the Grand Canyon.

A catastrophic drainage model for the origin of the Grand Canyon needs to be supported by geologic evidence. Several evidences suggest that the landscape is a relict feature, not forming slowly by modern agents of erosion. Many elements of northern Arizona appear to be stagnant landforms, left over from ancient water erosion on an immense scale. The plateau land around the Grand Canyon has a flat surface which appears to have been beveled by sheet flooding. The Grand Canyon, itself, has amphitheater-headed side canyons and a meandering course which resemble the system of canyons formed rapidly by breaching of a dam at Mount St. Helens by mudflows on March 19, 1982. Slopes of the canyon are usually covered with a red or brown coating of minerals which argue that its slopes are in an arrested stage of development, not continually evolving.

The Grand Canyon continues to astound and amaze. I have found that Scriptures, while they do not discuss the Grand Canyon specifically, do give an excellent model within which to interpret the data. Furthermore, the creation/catastrophe model provides more satisfying answers than the evolution/uniformity model.

# EROSION OF THE GRAND CANYON--
# A GEOLOGIST'S PERSONAL REFLECTIONS

by Steven A. Austin

Grand Canyon, the world's most awesome erosional wonder, captures my attention and causes me to contemplate the forces of nature which have excavated it. As I stand on the south rim I see only a fraction of its true dimension. The Grand Canyon is 217 miles long, not counting 60 miles of Marble Canyon upstream on the Colorado River. The depth of the Grand Canyon varies between 3,000 and 6,000 feet and the width from rim to rim between 4 and 18 miles. At my observation post on the south rim near Grand Canyon Village, I am standing on the Coconino Plateau which has an elevation of nearly 7,000 feet above sea level. The north rim, which is the southern part of the adjacent Kaibab Plateau, has an elevation of 8,000 feet, while the Colorado River below has an elevation of 2,400 feet.

## AN ENORMOUS AMOUNT OF EROSION

My mind is drawn first to the colossal quantity of material which has been removed. Figure 2.4 shows the entire drainage basin of the Colorado River. Sedimentary strata, the major rocks forming the surface of the broad area known as the Colorado Plateau, have been deeply incised destroying the original continuity of the strata. In the Grand Canyon I see the breached remnants of once continuous strata. My simple calculation of the volume of the Grand Canyon shows that almost 1,000 cubic miles (4,000 cubic kilometers) of sediment was removed from northern Arizona to form just the topographic form of the canyon itself.

But this is not all the erosion. Beside the road just 16 miles south of Grand Canyon Village rises Red Butte, a prominent conical hill standing 1,000 feet above the present surface of the Coconino Plateau (see Figure 2.5). Red Butte is composed of shale of the Moenkopi Formation overlain by Shinarump Conglomerate of the Chinle Formation (the same formation outcropping at the Petrified Forest). This small butte stands on top of the Kaibab Limestone which forms the present Coconino Plateau.

The top of Red Butte is capped by a lava flow which has protected the underlying shale and conglomerate from erosion. (I asked myself how a lava flow could cover a butte, since lava does not usually flow over hills but around them. The answer is found by postulating that the lava flowed over a vast plain that existed 1,000 feet above the present south rim of Grand Canyon, and that the Moenkopi and Chinle formations covered the entire surface of the present Coconino Plateau above the Kaibab Limestone! Red Butte is simply an erosional remnant providing evidence of broad, sheetlike erosion of the Coconino Plateau.)

The Coconino Plateau appears to have been buried even deeper than the 1,000 feet indicated by Red Butte. There is evidence above the Moenkopi and Chinle formations, which have now been eroded off the south rim, that the Glen Canyon Group (Navajo Sandstone, Kayenta Formation, Moenave Formation and Windgate Sandstone), another 2,000 feet of strata, were present as well. My


Figure 2.4 The drainage basin of the Colorado River (after map of C. R. Longwell, 1946)


Figure 2.5 Possible routes of the primeval Colorado River with locations of geologic features important to theories on how the Grand Canyon was eroded. (from R. J. Rice, 1983, The Canyon Conundrum, p. 291)

mind is staggered in its attempt to imagine not just the 1,000 cubic miles of canyon erosion, but many times that volume indicated by thousands of feet of erosion off the plateaus surround the Grand Canyon.

## THE GRAND CANYON CUTS THROUGH THE PLATEAU

My second observation is even more startling than the first: the Grand Canyon cuts through, not around, a great plateau land. The well developed drainage basin of the Colorado River (see Figure 2.4) has its headwaters in elevated areas, as all rivers do, but unlike most rivers, it has high plateaus adjacent to it one third of its total length from the sea. Most rivers have broad lowland areas that close to the sea. I would expect the Colorado River to have established its course around, not through such an elevated area standing in its path to the sea.

Observation of the extreme eastern portion of the Grand Canyon shows the magnitude of this river location problem. At Grandview Point and Desert View Tower I observe the Colorado Plateau north and east of Grand Canyon. The plateau with its surface of Kaibab Limestone, to my astonishment, rises from an elevation of 5,000 feet near Glen Canyon Dam on Lake Powell to 7,400 feet at Grandview Point on the south rim. The north rim of the Grand Canyon across the Colorado River is the southern portion of the Kaibab Plateau (also the upper surface of the Kaibab Limestone) which has an elevation over 8,000 feet above sea level. The rise in the plateau land is caused by a north-south trending geologic fold structure called a monocline which flexes up the Grand Canyon strata and the plateau almost 3,000 feet on the west relative to the east. This fold structure forms the eastern flank of the Kaibab and Coconino Plateaus.

I expected that the Colorado River would have flowed southeast from its present entrance to Grand Canyon onto the lower terrain of Painted Desert in east-central Arizona. From there the Colorado River could have proceeded southeast to join the Rio Grande emptying into the Gulf of Mexico, or cut back toward the west through central Arizona to join the Gila River emptying eventually into the Pacific Ocean. The Colorado River, to my astonishment, does neither. Instead, the river is directed to the west straight through the plateau lands of northern Arizona to take a more direct route to the Pacific Ocean!

## THE ANTECEDENT RIVER THEORY

When I first studied the Grand Canyon twenty five years ago, my pattern of thinking was uniformitarian. I conceived of great ages for strata and river basins, and I believed that erosion continued for millions of years at imperceptably slow rates to excavate canyons. During my education I was told that the uplift of the Colorado Plateau occurred during the Laramide Orogeny (70 to 50 million years ago in the standard way of thinking). As I observed the Colorado River drainage basin, I made the logically simple conclusion that the river was older than the plateau uplift and that the Grand Canyon is an enormously old feature that evolved directly from the uplift.

Figure 2.6 shows the theory that I had in my mind. The present course of the Colorado River was inherited from the location it had before the plateau land was uplifted. Very slow uplift on the Kaibab Upwarp beginning in late

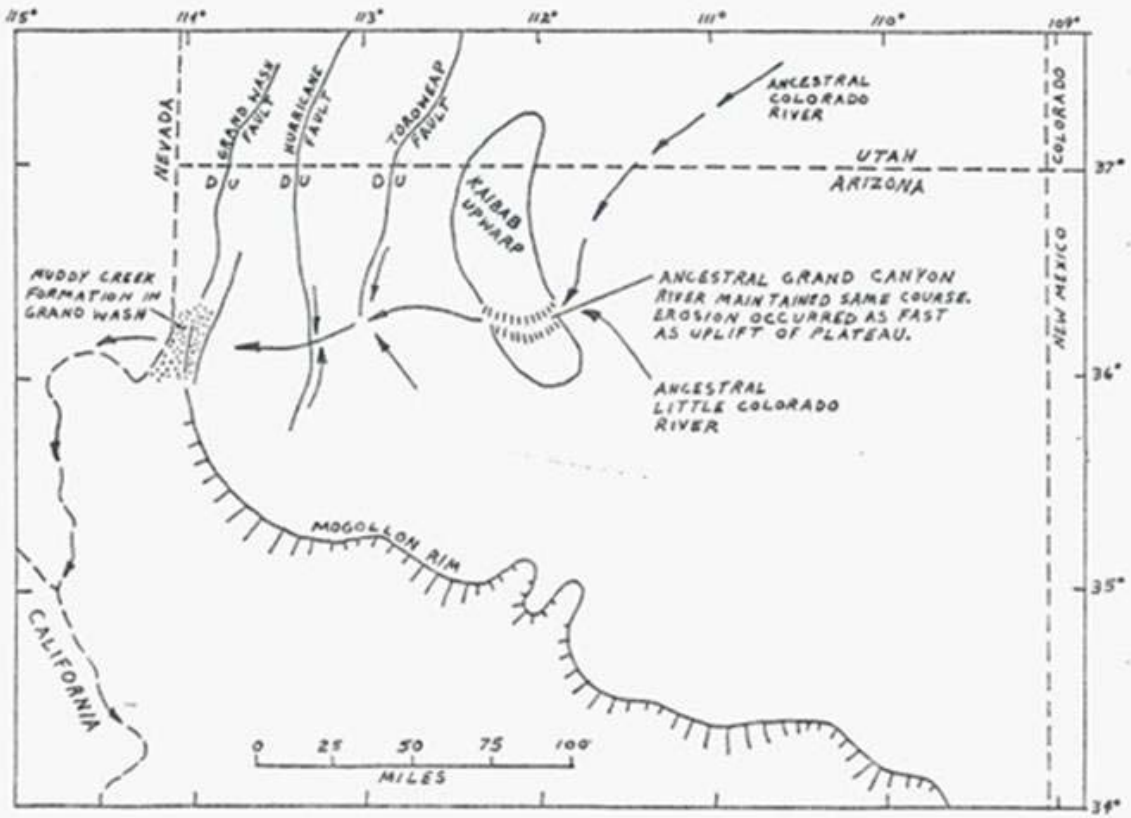


Figure 2.6 Explanation of how the Grand Canyon was eroded according to the antecedent river theory. Before the Kaibab Upwarp occurred seventy million years ago, the ancestral Colorado River was flowing westward through northern Arizona. The Grand Canyon was eroded by slow downcutting by the Colorado River as the Kaibab Upwarp occurred. The present course of the Colorado River was inherited from the ancestral river after tens of millions of years of uplift and erosion.

Cretaceous time was accompanied by equally slow erosion. Because the rate of uplift was precisely balanced by the rate of downcutting, the Colorado River was not diverted toward the southeast, but maintained its course as the Grand Canyon was eroded as the Kaibab Upwarp occurred. What I had in mind was a theory where the Colorado River location was antecedent to the uplift structure.

I learned that this theory had great explanatory power, and that many other geologists, including John Wesley Powell, had favored it. The antecedent river theory, for example, was able to explain the sheetlike erosion to the top of the plateau! I supposed that before the Kaibab Upwarp occurred the entire Colorado Plateau was near sea level. The primeval Colorado River would have been a slow, sluggish, meandering river in the Cretaceous Period which could have beveled the surface nearly down to sea level. The planation I conceived in my mind was what other geologists had called a "peneplain," the end product of many millions of years of erosion.

The antecedent river theory was extraordinary in its simplicity. It explained things rationally and reasonably in terms of processes which I could see and understand going on today. It was totally consistent with my education. All I had to do was assume that the canyon evolved slowly as uplift began 70 million years ago and had achieved its major form visible today just 50 million years ago. It was an elegant theory!

## THREE MAJOR PROBLEMS WITH THE ANTECEDENT RIVER THEORY

My notion of an antecedent river had some fatal flaws. I could not allow my mind to rationally explain real and concrete data without contriving imaginary scenes which drew me away from what I actually saw. Among these problems were the following three.

### Problem 1--Where has all the sediment gone?

The cutting of the Grand Canyon by the Colorado River would have produced vast quantities of clastic sediments. I expected these would be deposited just beyond the western end of the Grand Canyon near Pierce Ferry (see Figure 2.5). No great mass of gravel, sand, silt and clay is found there! Instead, at Pierce Ferry is found a relatively pure limestone bed (the Hualapai Limestone) 600 feet thick showing that no prolific supply of gravel, sand, silt and clay such as the Colorado River was situated nearby when the enlarged head of the Gulf of California was located over southern Nevada.

I tried to imagine how the extreme western end of Grand Canyon could be young allowing for deposition of limestone and lack of sand and gravel. I supposed that the ancestral Colorado River could have departed its present path southwest from Peach Springs or northwest from near Toroweap (see Figure 2.5) but such thinking required an "antigravity waterfall" which my mind found offensive.

### Problem 2--Could the Colorado River erode for 70 million years?

My theory of antecedency required that the Grand Canyon is a long-enduring feature left over from Cretaceous uplift of the Colorado Plateau, but

present rates of erosion would seem to prevent this from enduring! I made some calculations which show the order of magnitude of this problem.

Before the construction of Glen Canyon Dam, scientists noted that an average of 500,000 tons of sediment were being carried per day past any point in the Grand Canyon by the muddy waters of the Colorado River. This weight of sediment is equivalent to 0.00004 cubic mile per day of eroded rock or 0.015 cubic mile per year of erosion. During a flood in 1927 the river was carrying 55 times its average load or 0.0022 cubic miles per day (equivalent to 0.83 cubic mile per year of erosion). How long would it take to erode the 1000 cubic miles of material from the Grand Canyon? At the average daily rate:

1000 cubic miles ÷ 0.015 cubic mile per year = 67,000 years

At the 1927 high water flood rate:

1000 cubic miles ÷ 0.83 cubic mile per year = 1,200 years.

This illustrates the potential for just modern slow erosion when accumulated over just thousands of years. (Actually, most of the present erosion is occurring in the headwaters of the Colorado River, not on the present slopes of the Grand Canyon. The Grand Canyon, accordingly, can be viewed as a pipe transmitting most of its sediment delivered at its east end to its west end.) If the Colorado River drainage basin above the Grand Canyon is eroding at 0.015 cubic mile per year, a simple calculation shows that in 70 million years the river could erode one million cubic miles of rock, a volume far in excess of erosion that has really occurred. When I considered present rates of erosion, I found it very difficult to believe that the Colorado River drainage basin, the Colorado Plateau and Grand Canyon have an age of 70 million years.

**Problem 3--Do radiometric methods of dating support a very old canyon?**

Twenty five years ago, when I began my investigations of the Grand Canyon, I believed that analysis of radioactive components of minerals gave accurate "dates" of millions of years for rocks. It was with interest that I investigated rocks around the Grand Canyon. I learned that even radiometric methods gave "ages" far younger than (my theory of river antecedency) allowed. For example, a volcanic ash bed in the Hualapai Limestone at the western terminus of the Grand Canyon dated at 8.7 million years, indicating that river sediment had not begun to go through the canyon until after that time. Even more disturbing was a date of 9 million years for the lava flow remnant capping Red Butte south of Grand Canyon Village. I had supposed that the sheetlike erosion surface which overlay the present Coconino Plateau was older than the uplift of the plateau, dating back over 70 million years! When it came to (my theory of river antecedency) and my opinions regarding radiometric dating, I learned that I could not have my cake and eat it too!

## THE PRECOCIOUS GULLY THEORY

The demise of the antecedent river theory caused some distress in my mind. But, I found comfort in knowing that other geologists were experiencing similar difficulty with antecedency and were suggesting an alternative. The alternative theory would have to explain how the upstream segment of the

Colorado River could have the appearance of being long established in its drainage basin, while the Grand Canyon segment of the river would appear to be very young. I would have to postulate a major adjustment in the course of the Colorado River to allow it to erode the Grand Canyon in less than 8.7 million years before the present. I would also have to explain how the Kaibab and Coconino Plateaus could endure in uplifted configuration for over 70 million years without having great canyons resembling the Grand Canyon.

My dispute with the antecedent river theory caused me to question a simple and elegant notion favored by geologists for 100 years. I was ready to commit what would appear to be geologic heresy. In a deliberate way I was supposing that the Grand Canyon was not eroded by the Colorado River!

The theory I next came to accept involved major repositioning of the Colorado River by accidental capture of the drainage. It has been referred to as the "precocious gully theory," somewhat disparagingly even by its advocates, because it is difficult to visualize and accept. This theory, or something very similar to it, seems to be required if millions of years of river history are to be assumed.

Figure 2.7 shows three block diagrams depicting how, according to the theory, the Colorado River became established through northern Arizona. Originally (block diagram A), the primeval Colorado River drained southward from Utah to the eastern Grand Canyon area, but continued to flow southeast along the present course of the Little Colorado River east of the Kaibab and Coconino plateaus. Erosion of the Kaibab and Coconino plateaus began just a few million years ago and a westward flowing stream eroded the Hualapai drainage system (block diagram B). The drainage extended eastward through what is today the Grand Canyon. Because of energetic erosion, the Hualapai stream was somehow able to cut down the plateau enough to make an enormous gully almost the size of the present Grand Canyon. Finally (block diagram C), the Hualapai gully was able to "capture" the drainage of the Colorado River and divert it through the gigantic gully, adding some finishing touches with further downcutting to complete the Grand Canyon.

## PROBLEMS WITH THE "PRECOCIOUS GULLY THEORY"

As I thought about the possibility that a greatly enlarged gully could capture the drainage of an entire river, I realized that I had abandoned my logical theory for an illogical one. Three problems came to my attention.

**Problem 1--Have I devised an elaborate scheme simply to circumvent the inadequacies of my first theory?**

True, this new theory avoided problems encountered with the antecedent river theory. However, the explanation I offered appeared to create more problems than it sought to answer. Chief among these was my lingering doubt about whether assigning the major excavation of Grand Canyon to enlarged gully erosion was possible. I instinctively realized that I was arguing a special case. There are many elevated plateaus in the world, but none of them have Grand Canyon gullys through them. By arguing for the gully I knew I was attributing the Grand Canyon to one of the world's most remarkable accidents. Furthermore, I knew of no major structural reason why the enlarged drainage should have been situated where the Grand Canyon is today. There is,

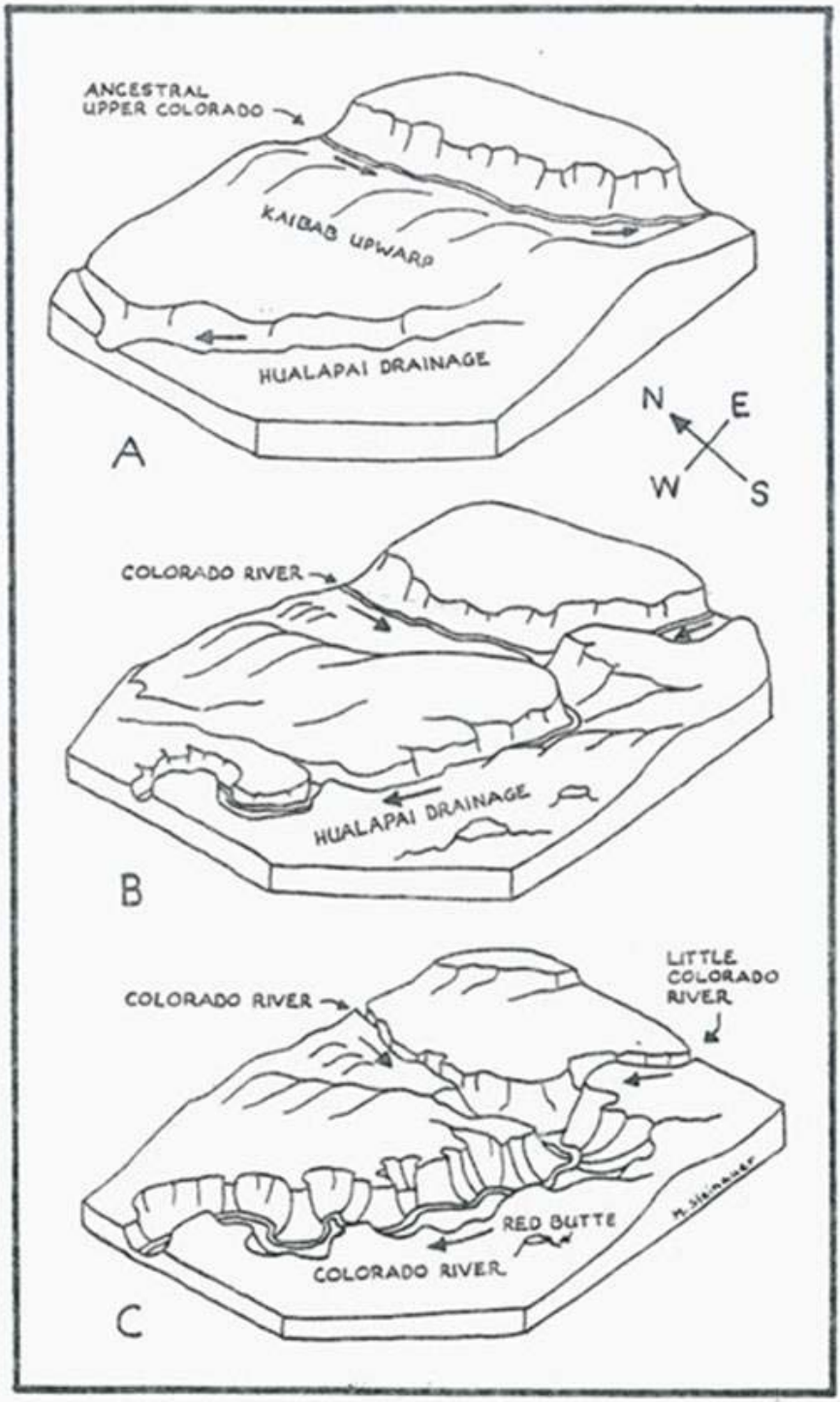


Figure 2.7 Block diagrams showing three steps supposing how the Grand Canyon formed according to the "Precocious Gully Theory." The repositioning of the Colorado River through the Kaibab Upwarp is supposed to have been achieved by a westward-flowing drainage which cut back and captured the south-flowing Colorado River.

for example, no east-west trending fault or zone of rock weakness to guide the gully as it enlarged and no trough-like sag in the plateau to straighten or direct the gully. Furthermore, the drainage must have been very long, straight and deep without much branching, all features I knew are not characteristic of enlarged gullys. Last, the gully must enlarge to the east through a sloping plateau which has drainage to the south.

A well-intentioned geologist friend of mine recognized the problems I was having conceptualizing the gully. He proposed that I visualize the capture of the Colorado River through the Grand Canyon area not by a gully, but by a cave. Could a cave have diverted the original drainage of the Colorado River? If so, the present Grand Canyon could have formed by the collapse of that cave. We both smiled and shook our heads when we considered the direction our speculations had led us.

**Problem 2--Could the plateaus in Northern Arizona endure as an uplifted landscape for 70 million years?**

Although this new theory did not require the Grand Canyon to be several tens of millions of years old, I was still supposing that the Colorado River and the Laramide uplift of the plateau dated back 70 million years. As mentioned previously, 70 million years of erosion should severely alter the uplifted plateau. There should have been intense erosion generally to the plateau lands, not just deep erosion in one enlarged gully. My theory left this problem unexplained.

**Problem 3--Where are the evidences of the long-continued operation of the ancestral upper Colorado River?**

Because I still assumed that the Kaibab Upwarp occurred 70 million years ago while the amazing stream capture was completed less than 9 million years ago, I was obligated to have the ancestral upper Colorado River located east of the Kaibab Upwarp for 60 million years. I would expect significant erosional and depositional features would be obvious. No obvious abandoned channel for my postulated river can be found southeast of the Grand Canyon. If the upper Colorado River eroded as it does today, I would expect it to have generated nearly one million cubic miles of sediment. Although some thin alluvial sediments are found in eastern Arizona (the Bidahochi Formation), no colossal quantity needed by long continued erosion occurs east of Grand Canyon.

## THE CATASTROPHIC DRAINAGE THEORY

My thinking regarding the Grand Canyon went through two very significant modifications. First, I learned that the Colorado River acting incessantly during 70 million years could not carve the canyon. Second, I also came to realize that attributing the canyon to stream capture from a much-enlarged gully required mental gymnastics that my brain could not accomplish. Both theories assumed the ancestral Colorado River to have operated for 70 million years, but ultimately that assumption worked contrary to forming the very geologic structures I was trying to explain. Could it be that I was laboring with a concept of geologic time that really did not exist? Twenty years ago I became skeptical of the millions of years conventionally assigned to rocks by radiometric dating and began to consider catastrophist explanations for

geologic data. I learned of a third theory which explains the erosion of the Grand Canyon, a theory which supposes it to be a geologic relict, a landform which has survived decay and disintegration being left behind by catastrophic drainage which is not now operating.

I was amazed to learn that the catastrophic drainage theory is contained in legend and is the oldest explanation for the origin of the Grand Canyon. According to the Havasupai Indians, who still tell the story in their villages within the Grand Canyon, the immense chasm formed after the world was covered by a great flood. Pu-keh-eh, daughter of the good god Tochapa, was placed in a hollowed out trunk of a tree and survived when the evil god Hokomata caused the waters to rise so severely that the earth was covered. When the flood retreated, mountain peaks emerged and rivers were produced. One of these great gushing rivers cut the Grand Canyon. From the mortal children of Pu-keh-eh came all the people of the earth including the Havasupai, which Tochapa commanded to live at peace within the Grand Canyon.

The Havasupai legend is immediately recognizable as one of hundreds of flood traditions which are known worldwide, of which the Biblical account of Noah's Flood is the most detailed and accurate. If the Flood was involved in forming the Grand Canyon, then it would be a relict feature formed from erosive processes which had operated at rate and scale far greater than today. The Grand Canyon would be a largely dead monument to the action of intense ancient processes, not a constantly evolving landform in equilibrium with slow, modern, erosive processes as I had earlier assumed.

My mind began again to consider the geologic evidence at Grand Canyon. As explained before, it seems certain that the Kaibab Upwarp was established before the Colorado River was positioned across northern Arizona. Could the uplift of the plateau have created a drainage basin east of Grand Canyon which completely filled with flood water? Could the large dam created by the Kaibab Upwarp have been breached allowing the "lake" behind it to drain over the plateau through northern Arizona initiating the erosion of Grand Canyon?

There is evidence that an impounded mass of water existed on the east side of the Kaibab Upwarp. Geologists call the sedimentary deposits restricted to the east of Grand Canyon the Bidahochi Formation. They contain regular layers of silt and sand which look like lake deposits which would have been deposited from accelerated erosion in the drainage basin now occupied by the upper Colorado River. These are thin strata that represent a short time geologically (classed as Pliocene by many geologists). The Bidahochi Formation does not provide evidence of impoundment of the ancestral upper Colorado River for tens of millions of years as my theories once required.

I know of several dams which have been breached catastrophically producing significant canyon erosion. In fact, it seems that dams do not fail slowly, but catastrophically. My favorite example is the erosion on the North Fork of the Toutle River in Washington after the recent eruptions of Mount St. Helens. The valley of the North Fork of the Toutle River had been blocked by up to 600 feet of landslide debris and volcanic ash on May 18, 1980. Then on March 19, 1982, mud and water rapidly breached the blockage to the valley creating an elaborate canyon system resembling the Grand Canyon, but at one-fortieth scale. Figures 2.8 and 2.9 show the new canyon next to Mount St. Helens.

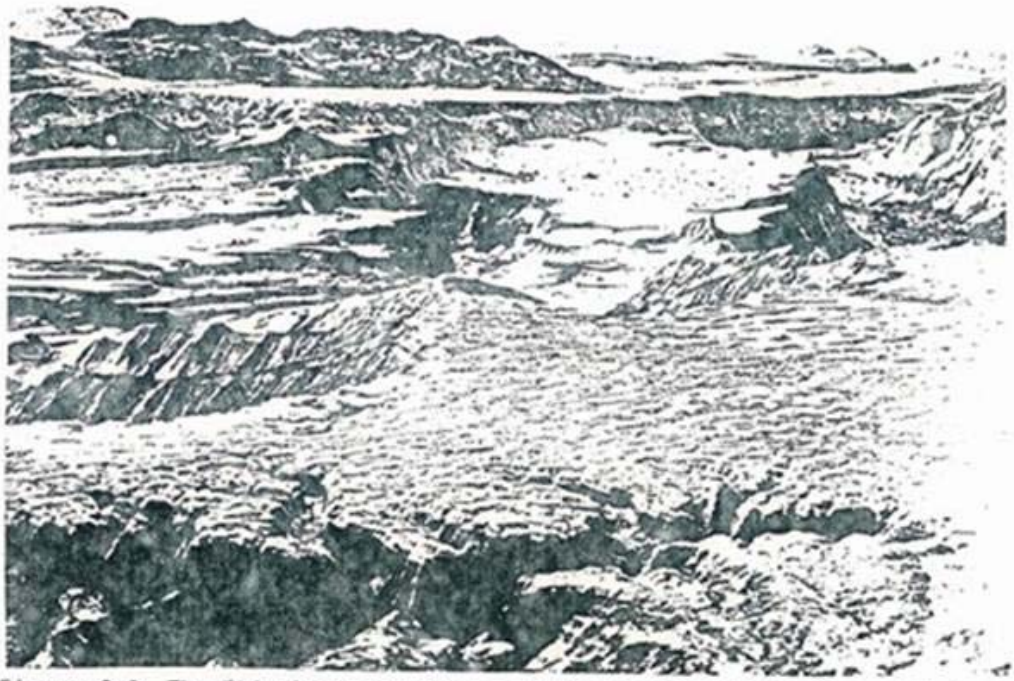

Figure 2.8 The "Little Grand Canyon of the Toutle River" is a relict canyon system on North Fork of the Toutle River just north of Mount St. Helen's volcano. The rockslide and pumice deposits from the 1980 eruptions had been breached by mudflow on March 19, 1982, to form a dendritic system of canyons up to 140 feet deep. (Photo by Steven A. Austin)

Figure 2.9 Detail of one of the relict canyons at Mount St. Helens. The volcanic deposits had been eroded over 100 feet deep to form this canyon within two years. The small stream in this canyon did not erode this canyon. (Photo by Steven A. Austin)

## EVIDENCES FOR RELICT LANDSCAPE AND YOUTHFUL CANYON

If the Grand Canyon was eroded largely by catastrophic drainage of impounded water behind the uplifted plateau, I would expect the landscape to show marks of erosion by energetic agents. My attention is drawn to many features which appear to be stagnant, not evolving. The prominent slopes of the canyon are dominantly in an arrested stage of development. An excellent example is the cliff of Redwall Limestone which has an accretionary reddish coating derived from overlying Supai redbeds dominating its exposure. This cliff is not now slowly eroding back through a major extent of the canyon. Another example is the Vishnu Schist of the inner gorge which is dominated by an accretionary coating of desert varnish, another chemically attached residue on to the rock surface.

I also notice that the very low relief surface of the plateaus which form the north and south rims of the Grand Canyon are landforms which are not now evolving. When I favored the antecedent river and precocious gully theories, I had to apologize for the plateaus assigning them to pre-Laramide erosion by sluggish rivers near sea level. I marvelled at how such landforms could endure as elevated features for tens of million years. The catastrophic drainage theory I now favor easily accomplishes the plateau erosion by sheet flow of the flood waters over the plateau surface before the water became channelized to erode the canyon. I no longer need to explain why the plateaus have endured millions of years, because I no longer regard them as that old, but recent features, which could be thousands of years old.

Hundreds of smaller side canyons branch off from the Colorado River in the Grand Canyon. What is interesting is that these side canyons are typically short, rather wide, quite deep and have bowl-shaped heads ("amphitheatre" heads). These side canyons of this shape are not typical of enlarged gullys which usually have narrow V-shaped heads. I could not conceive of a very old river canyon having such short and wide features. Instead, such amphitheater-headed side canyons remind me of collapse features formed where water oozes out of wet sediment causing the supporting layers of sediment or rock to be removed so collapse occurs. Technically, this process is known as "sapping" and would have been an important process as greatly enlarged flow through the main canyon down cut and caused poorly consolidated sediment marginal to the canyon to dewater and slump into the main canyon. These amphitheater-headed canyons today rarely have springs at their heads, and, therefore, can be recognized to be relict features. They resemble some of the side canyons formed by catastrophic erosion on the North Fork of the Toutle River in 1982 after the eruptions of Mount St. Helens.

Evidences can be found for increased water flow in the past on the Colorado River. Just upstream from Grand Canyon in Marble Gorge, the channel of the Colorado River forms incised meanders. Laboratory experiments indicate that these elaborate meandering canyons could not have formed by the continued action of the present river. Greater water flow was required. Thus, the present Colorado River can be considered "underfit" relative to its canyon.

Another evidence of increased water flow in the past comes from consideration of cliffs near the Colorado River, especially upstream from Grand Canyon where broad flat benches of shale occur below sandstone and

limestone cliffs. If such cliffs are the result of continuous slow erosion over hundreds of thousands of years, we might expect a progressive increase in the decomposition of talus on the benches away from cliffs. Such boulder aging has not been demonstrated. Instead, we see shale benches which appear to have been swept clean of larger rocks by large flooding. Then after significant flood modification, a recent talus has accumulated.

When I favored the antecedent river and precocious gully theories, I had the problem of explaining where the products of 70 million years of river erosion went. I could not find appropriate erosional or depositional features to the west or east of the Grand Canyon which would have been produced by the long-continued action of the primeval Colorado River, and I knew that such incessant river action would erode and deposit one million cubic miles of material. With the catastrophic drainage theory there is no requirement for the Colorado River to erode for tens of millions of years because the river only needs to be thousands of years old. The lack of features which would be produced by an old river is an argument for a young river. The vast erosion off the plateaus could be produced by sheet flooding when the flood water retreated off the plateaus. It would have removed the sediment far from the plateaus. We would expect no stream deposits adjacent to the plateau. Then, after the Kaibab Upwarp occurred, impounded water behind the plateau was released by catastrophic breaching and drainage. The Grand Canyon and the establishment of the Colorado River through northern Arizona would be very recent geologic features. This explains why the products of the Colorado River's erosion and sedimentation are confined to near-surface sedimentary layers.

## CONCLUSION

There will need to be more investigations of how the Grand Canyon was eroded. The notion that the Colorado River carved the canyon, as the antecedent river theory assumes, over millions of years is untennable and now recognized so by most geologists. The concept of Grand Canyon erosion from stream capture by enlargement of a gully involves an accident of incredible improbability. The explanation of recent erosion of the canyon in association with catastrophic drainage from a great flood seems to integrate and coordinate a great number of facts in believable fashion. I found that the statements of Scripture provide an acceptable framework for interpreting the erosion of the Grand Canyon.

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