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ARTICLE

When Was Grand Canyon Carved—Millions of Years Ago or Thousands of Years Ago? How Do We Know?

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Introduction

Grand Canyon (Figure 1) is one of the most impressive erosional features on planet Earth. Within the dramatic exposures of its scorching rocks, generations of geoscientists have labored to find out how this section of the vast Colorado River system came to be and how fast it eroded. Young-earth creationists (YECs) also flock to Grand Canyon, but with a very different agenda than scientists. For YECs, Grand Canyon is a prime target for promotion of their idea that the Earth is only a few thousand years old. While geoscientists know that

Figure 1. *Map of Arizona–Utah area showing Grand Canyon, nearby plateaus, the Colorado River, and its tributaries. Map reprinted with permission from Bronze Black.*

the most ancient rocks of Grand Canyon are nearly two billion years old, and many are in the range of half to a quarter billion years old, these dates are irreconcilable with the YEC view of a young Earth. In their view, most of the rocks of Grand Canyon were deposited in just one year in the wake of Noah's Flood, about 4363 years ago (Wright 2012).

So who's right—and how do we know? This article examines these questions by focusing on ways geoscientists measure rates of erosion in Grand Canyon. As we will see, the YEC view of the age of Grand Canyon finds no support in the rocks themselves.

A testable hypothesis

Was the amount of erosion produced by the Colorado River accomplished in the last 4363 years following the supposed worldwide Noah's Flood or was a much longer time required? Fortunately, there are at least two kinds of scientific tools that can be used to determine the rates at which the Colorado River cut into the sedimentary rocks, and these can be used to test the YEC hypothesis. The first is the mineral apatite, and the second is the analysis of river terraces in the Colorado River and its tributaries.

1. Apatite crystals

Apatite is a common mineral in igneous and metamorphic rocks. As rocks break down, crystals of apatite are released to become grains within sandstones and conglomerates (two common types of sedimentary rock). Apatite usually contains traces of uranium, which, as it radioactively breaks down, creates noticeable "fission tracks" in the apatite.

These fission tracks can be very useful because they are sensitive to temperature. When the rocks are above 120°C, tracks do not form and any existing tracks are destroyed. When a rock is deeply buried, temperatures above 120°C are common. But now consider what happens when a river carves into the ground and exposes the apatite crystals within sediments: the cooling "starts a clock" of track formation.

Because the uranium breakdown has a predictable rate, we can judge how long the process has been occurring by observing the number of fission tracks. Simply stated, an apatite crystal that has been cooled below 120°C for a long time will have many tracks; an apatite crystal that has been cooled below 120°C for a short time will have few tracks; and an apatite crystal that has never been cooled below 120°C will have no tracks.

Apatite has a second heat-related trick. When the uranium within it breaks down, it emits helium. If temperatures are above 70°C, then the helium escapes; below that threshold, helium is trapped and accumulates. When rocks are eroded and exposed on the surface by the cutting of a river, they're going to be much cooler than 70°C. So by examining helium, we have a second way to judge when Grand Canyon was cut.

By analyzing Grand Canyon apatite crystals for fission tracks and the presence of helium, we can recognize two important time periods in which these rocks were exposed: 50–70 million years ago, and 5–6 million years ago (Karlstrom and others 2014). Both time ranges show that the YEC interpretation of Grand Canyon being a few thousand years old is way off.

How have YECs responded to the apatite data? Unsurprisingly, YECs would rather not mention apatite. One of the major creationists involved with Grand Canyon, Andrew Snelling, avoids talking about fission tracks directly (Snelling 2007), instead proposing: “[T]he large quantity of nuclear decay must have occurred at much faster rates than those measured today.” Snelling adds, “There is evidence that nuclear decay rates were grossly accelerated during a recent catastrophic episode or episodes.”

Except there isn’t such evidence. On the contrary, all evidence points to the clockwork-like regularity of atomic decay. Creationists have to make an ad hoc argument like this, claiming that decay rates could have somehow been faster in the past, because to concede what the apatite evidence shows is to concede the issue of the age of Grand Canyon, not to mention the age of Earth.

Although some YECs believe that there is scientific evidence that radioactive decay happened faster in the early history of Earth, there is no scientific evidence that radioactive decay happened faster during the brief period in which YECs claim Noah’s Flood happened. Thus, the YEC model that a *worldwide* Noah’s Flood occurred about 4363 years ago (Wright 2012) is not supported.

2. River terraces

Sediments left on river terraces are another method for assessing the timing of Grand Canyon’s carving. When a river initially cuts into Earth’s crust, it generally forms a steep **V**-shaped canyon. But if the river jumps out of its channel, it can cut laterally, forming a horizontal flood plain. Flood plains get their name because when the river spills out, it deposits sediment on the plain. As a river evolves, this cycle repeats over and over again. As the river cuts lower, it picks up and drops off new sediment layers on the floodplains. River terrace gravels—a mix of clay, silt, sand, and pebbles found on these flood plains—can yield evidence about how and when the river cut the canyon.

Creationists know about this, of course, but like the apatite crystal problem, they tend to ignore the issue. Steve Austin, a creationist geologist, mentions these river terrace gravels as evidence for the drainage of lakes following Noah’s Flood (Austin 1994) but does not address the fact that these deposits can be dated.

There are two ways we can assign ages to the sediment left on river terraces: cosmogenic radionuclide dating (CRN) and optically stimulated luminescence (OSL).

Cosmogenic Radionuclide Dating (CRN)

When the steady flux of cosmic rays strike rocks at the surface of Earth, the energy of these rays produces unique chemical signatures. (Specifically, rays interact with ^{18}O isotopes in quartz to produce beryllium [^{10}Be] atoms and with ^{32}Si isotopes in quartz to produce aluminum [^{26}Al] atoms.) The quantity of these chemical signatures can be measured with a mass spectrometer and used to estimate how long the rock surfaces have been exposed: the greater the amount of time of exposure, the greater numbers of these nuclide atoms are formed.

What can this tell us about Grand Canyon? Terraces along the Colorado River near Lee’s Ferry in Utah south of Lake Powell (upper right corner of Figure 1) show that the CRN ages are 124000 years (124 ka) at the oldest and highest terrace and 38000 (38 ka) at the lowest and youngest terrace (Figure 2; Pederson and others 2013). Because similar age relationships have been obtained from hundreds of analyses at many other different places along the length of the Colorado River and its tributaries (Pederson, personal communication), these ages are unlikely to be accidental but instead represent real values of chronological age. All of these ages are far older than what the creationists claim for Grand Canyon.

Optically Stimulated Luminescence (OSL)

A second method of dating river terraces involves measuring a phenomenon that occurs when radioactive elements decay inside crystals. This radioactive decay emits energy inside the crystals, but if those crystals are exposed to sunlight, then this energy dissipates. However, if those sediments are buried by other sediments and cut off from sunlight, then a "clock" begins and the energy accumulates. By collecting such buried samples in opaque sealed cores, geologists are able to measure the energy released and thus estimate how long the sediment has been buried.

What can this tell us about Grand Canyon? The oldest OSL age is 142 ka in a high level terrace near Lee's Ferry and the youngest is 23 ka in a terrace near the bottom of the canyon (Figure 2; Pederson and others 2013). The OSL ages are not exactly the same as the CRN ages because both the samples and exact sample locations differed in each set of measurements, but both methods produce ages that are complementary and consistent with the relative positions of the terraces.

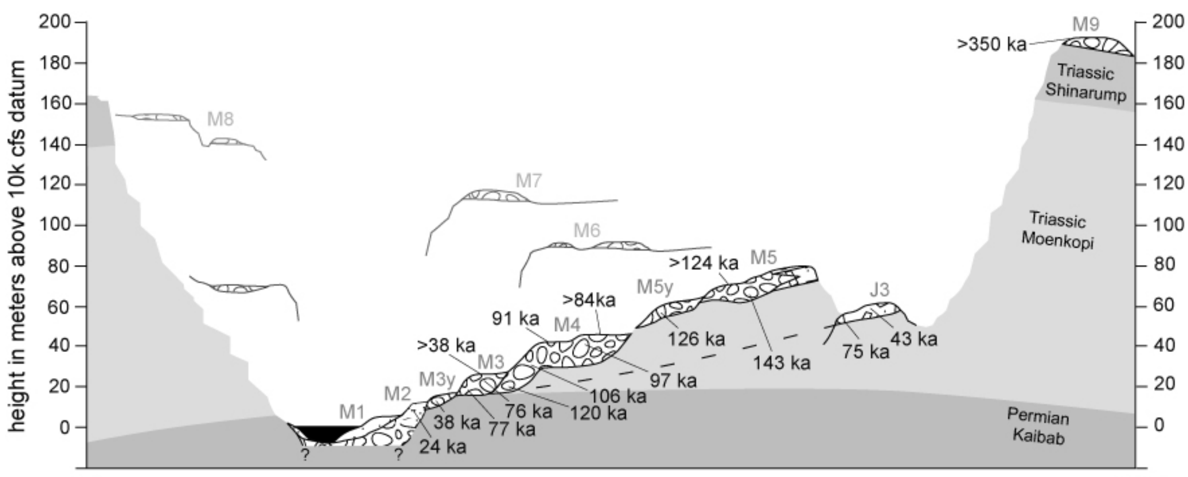

FIGURE 2. *Schematic profile of the terrace stratigraphy at Lee's Ferry, Arizona, with central age results from cosmogenic radionuclide values (CRN, labeled above deposits) and optically stimulated luminescence (OSL, labeled below deposits). View is not to scale horizontally and is looking downstream, with higher terrace remnants preserved in that direction shown in gray. Terraces are on Triassic Shinarump and Moenkopi Formations and Permian Kaibab Formation (speckled gray). Figure from Pederson and others 2013, included here with permission.*

Significantly, these ages are much older than the 4363-year age that is proposed by YECs for Grand Canyon (Wright 2012). Noah's Flood could not have deposited these formations here 4363 years ago.

Differing rates of incision

The creationist model posits that Grand Canyon was carved rapidly, on the scale of days or weeks, by the flow toward the seas of impounded lakes left over from Noah's Flood. In this model, the drainage cut into flat, soft sediment layers; there should not be different rates of incision in different areas because the layers were horizontal.

However, geologists know that significant warping of these sedimentary rocks occurred as the carving happened, and this uplift is reflected in erosional rate variation along different areas of the Colorado River.

Different rates of incision can be observed in many places along the river. An example is shown in Figure 3 (data collected near Lee's Ferry as shown in Figure 4) where the rate of incision is calculated to be 350 meters per million years (m/My). Moreover, in at least one place in Utah along the Colorado River, the rates of incision change from low values of 80 m/My southwest of Lee's Ferry, then northward to 450 m/My, and finally decrease farther northward to 130 m/My.

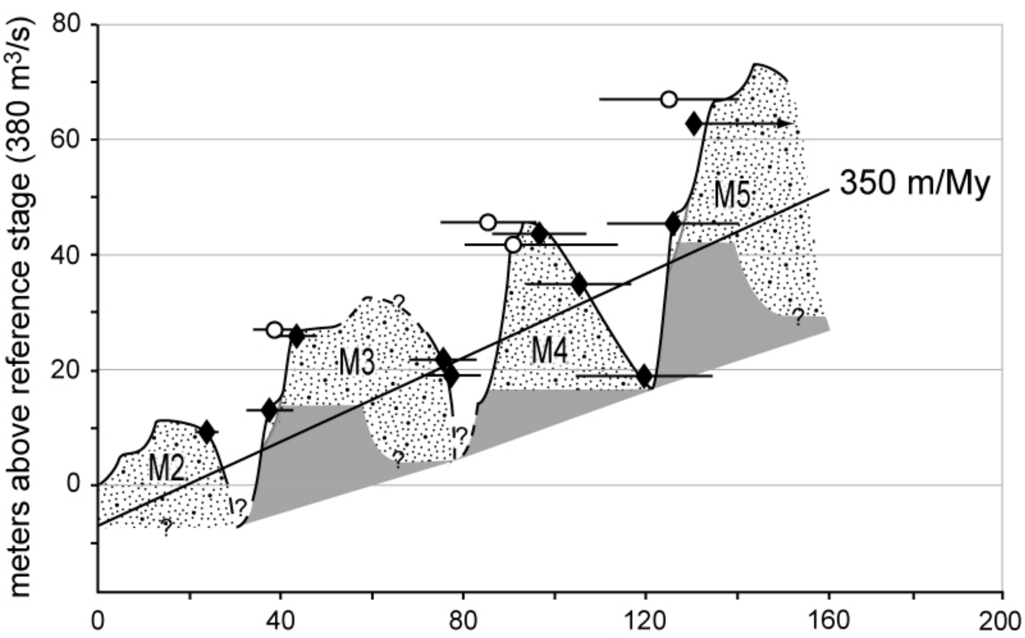

FIGURE 3. *Curve representing the height of the Colorado River channel bed through time constrained by survey and geochronological data (diamonds = optically stimulated luminescence; circles = cosmogenic radionuclide), tracing cycles of aggradation then incision through fill (stippled) and bedrock (gray). The base-level-driven rate of incision integrated through these cycles is ~350 m/My. Figure from Pederson and others 2013, included here with permission.*

These rates can be contoured in a "bull's eye" shape (Figure 4), with the center near modern-day Cataract Canyon. In this area as much as 3 km of overlying rock was removed, unloading the crust and causing it to rise, just as an iceberg rises when the upper portions melt. The Colorado River flowing across this area had to erode this area rapidly to keep up with the uplift. The slower rate of erosion southwest of Lee's Ferry of 80 m/My (Figure 4)

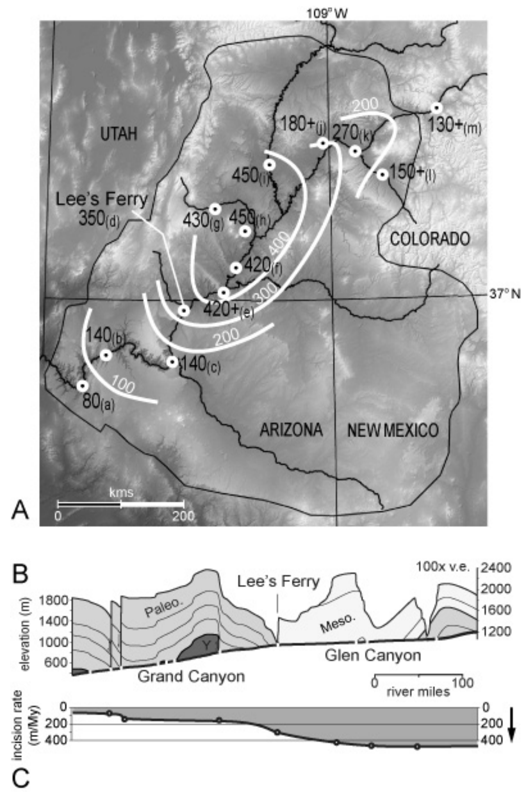

FIGURE 4. *Bull's-eye pattern of comparable late Pleistocene incision rates in m/My along trunk drainages in the Colorado Plateau, with 100 m/My contours. Figure from Pederson and others 2013, included here with permission.*

probably is because the eroded canyon here is in the harder Paleozoic sedimentary rocks of the Grand Canyon whereas the faster rates, as much as 450 m/My, are in a region underlain by softer Mesozoic sedimentary rocks (Figure 4; Pederson and others 2013).

The point is that we find the Colorado River incising the canyon at different rates in different places, and this variation corresponds to the uplift patterns in the region. We would not expect this pattern to emerge from what creationists claim happened. Once again, the geologic reality provides no support for this area being carved in the wake of Noah's Flood.

Further considerations

Incision rates of erosion in the Grand Canyon vary along the Colorado River in this part of its drainage system, but 150 m/My would be the best "average" rate in the main eastern part of the canyon (Pederson and others 2002; Pederson personal communication). If that rate was steady over geologic time during the Pleistocene, it would take 10 million years to cut the canyon because it is 1 500 meters deep. However, 10 million years is a bit too long because that rate likely has not stayed constant over that time period. Greater rates of erosion have been estimated, as high as 700 m/My (Machette and Rosholt 1991), and such rates likely occurred when huge volumes of water were released from melting glaciers that were in the Rocky Mountains during the Pleistocene ice ages, when the climate was colder and wetter. Moreover, parts of today's canyon had already been cut by precursor drainages (Pederson and others 2013; Karlstrom and others 2014; Hill and Polyak 2014). That is, the

Colorado River did not need to cut the full 1500 meters all on its own and took advantage of the erosion that was produced in pre-existing canyons (Ranney 2005; Pederson and others 2013).

Conclusions

The evolution of the landscape in both Arizona and Utah reveals the complex history of the Colorado River in the Grand Canyon and in its upstream tributaries. If science is used instead of an interpretation of Genesis for establishing the age of the erosion by this river, then there is no support for the YEC model that Noah's Flood was an event 4363 years ago (Wright 2012).

In science, all data must be considered and not just those cherry-picked data that fit a preferred model. In their claims, YECs either ignore the data summarized here in this article or fail to perform due diligence in research. Several different scientific methods establish, neither fortuitously nor arbitrarily, the same 5 to 6 million-year age of the youngest erosion by the Colorado River and its upstream tributaries. Creationists make outlandish claims about a very young Grand Canyon, but when one examines the rocks, these claims simply do not hold up.

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