



The Grand Canyon and the Colorado River from Lipan Point

*Photo Paul Fretheim*

## **Geology of the Grand Canyon**

by Paul Fretheim

When Garcia Lopez de Cardenas, the first European explorer to see the Grand Canyon, found himself at the canyon rim in September of 1540 he exclaimed, "*¿Que pasa aqui?*" ("What happened here?")

Over the intervening centuries millions of visitors have wondered the same thing as they have gazed upon the magnificent spectacle of the Grand Canyon of the Colorado.

### **The Story Has Two Parts**

Two things impress the eye upon seeing the canyon for the first time: A huge gash has been carved into the Earth's surface; The



- KAIBAB LIMESTONE
- TOROWEAP FORMATION
- COCONINO SANDSTONE
- HERMIT SHALE
- SUPAI GROUP
- REDWALL LIMESTONE
- MAUV LIMESTONE
- BRIGHT ANGEL SHALE
- TAPEATS SANDSTONE
- VISHNU SCHIST

The layers of the Grand Canyon.  
*Photo Paul Fretheim*

canyon walls have multi-colored horizontal bands of rock that are strikingly uniform and symmetrical.

These two aforementioned phenomena are representative of the two threads in the story of the geology of the Grand Canyon.

The first part of the story is that of the recent events, geologically speaking, of the last few million years that carved the canyon.

The second part of the story is that of the much longer period of time over which the layers of rock into which the canyon was carved were formed.

### **Uplift and Erosion Result in Canyon Topography**

The Colorado River has flowed westward from the Rocky Mountains to the Pacific Ocean for at least the past 80 million years.

The part of the North American continent centered on the Four Corners, east of the Great Basin and west of the Rocky Mountains is known as the Colorado Plateau. Click on the link below to bring up the USGS web page on the Colorado Plateau.

<http://geology.wr.usgs.gov/docs/parks/province/coloplat.html>

This part of North America began to be uplifted by tectonic forces some 5 - 10 million years ago. The Colorado River at this time was already flowing westward across the Colorado Plateau. For the past 60 million years, at least, the gradient of the river from the highlands of the Rockies to the Pacific has always been quite steep. Because of this the water in the Colorado River has always flowed swiftly. Fast flowing streams can carry exponentially more sediment than slower flowing streams and have tremendous power to erode away the rock of the riverbed. Because of these factors, the Colorado has always been capable of cutting its way down to "base level."

The Colorado Plateau has been being uplifted for the past few million years. Some geologist place the date for the beginning of the uplift as recently as three million years ago, others date the start of the uplift as long as ten million years ago. As the Colorado Plateau has been rising, the Colorado River has been able to cut its way down through the bedrock of the plateau as fast as it has been rising up in the river's path.

So, expressed most accurately, the Colorado River did not cut down into the Earth's surface to create the Grand Canyon, but, rather, the rock of the Colorado Plateau rose beneath the river and the river cut its way through the rock to maintain its level nearly constant despite the nearly 2000 meters of uplift which the Colorado Plateau has undergone over the past few million years.

### **The First Geologists**

Geology, the study of the structure and prehistoric past of the Earth, had begun a generation or two before the exploration of the Grand Canyon region. The first scientists to make an organized study of the Earth's past began their work in England. Charles Lyell and Charles Darwin are two of the most famous of those early geologists.

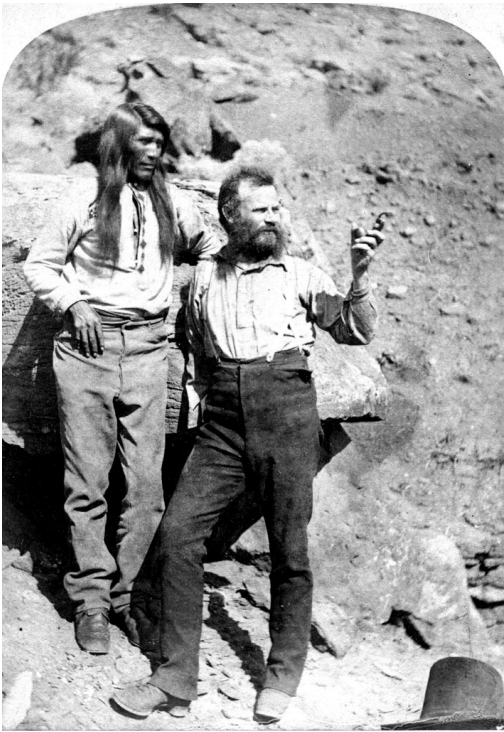
Lyell, who was a generation older than Darwin and a mentor of his, was among the first to systematically study fossilized life forms. He noticed that the rocks of the Earth's surface seemed to occur in distinct layers. After a period of time studying the fossilized life forms, he noticed that below a certain rock formation the number of fossils dropped off dramatically. Lyell understood that the layer of rock where a large number of fossils first appeared marked the time when complex life first appeared on the Earth.

Since Lyell found this layer of rock near Cambridge he named it "Cambrian."

Many of the names we still use today when describing rock formations which correspond to a specific time in Earth's geological past come from this era of early study in 19th century England. As another distinct rock formation was identified it was given a name corresponding to the area where that layer was found. For example, the Devonian was first identified in Devonshire County, England.

### **Early Study of Grand Canyon Geology**

To early geologists the Grand Canyon appeared to be "an open book" to the geology of the Earth's past. They believed that surely such a deep canyon exposed rocks from the very beginning of time. Actually, the oldest rocks of the Inner Gorge are about 1.7 billion years old, which is only about one third as old as the Earth itself,



John Wesley Powell and Tau-Gu, Chief of the  
Paiutes overlooking the Virgin River. 1873.  
GRCA 13806

which has been dated by measuring the ratios of isotopes of uranium as being about 4.6 billion years old.

After his widely hailed trips of exploration down the previously unknown Colorado River, John Wesley Powell parleyed his well earned fame to become director of the United States Geological Survey. As director he continued in his efforts to uncover the scientific secrets of the Colorado Plateau, and in 1880 he sent a party which included geologist Clarence E. Dutton to map and study the geology of the Grand Canyon district.

Upon his return to civilization in 1881, Dutton published the results of his findings under the title "[The Physical Geology of the Grand Canyon District.](#)" The completeness and accuracy of this geological treatise are really quite astounding considering that it was written in the latter part of the 19th century. This work is considered by many to contain, even to this day, the most colorful and best descriptive prose of the Grand Canyon ever written.

At the close of his monograph on the Geology of the Grand Canyon District Dutton wrote:

No doubt the question will often be asked, how long has been the time occupied in the excavation of the Grand Cañon. Unfortunately there is no mystery more inscrutable than the duration of geological time. On this point geologists have obtained no satisfactory results in any part of the world. Whatever periods may have been assigned to the antiquity of past events have been assigned provisionally only, and the inferences are almost purely hypothetical. In the Plateau country, Nature has, in some respects, been far more communicative than in other regions, and has answered many questions far more fully and graciously. But here, as elsewhere, whenever we interrogate her about time other than relative, her lips are sternly closed, and her face becomes as the face of the Sphinx.

The most significant addition to the understanding of the Geology of the Grand Canyon District since Dutton's time has been the ability of geologists to add absolute dating to the relative dating that was largely worked out by Dutton in 1880 - 1881. Absolute dates, that is, when, in years an event or series of events took place in the past, has been worked out in the last 50 years. This achievement has been accomplished by geologists utilizing dating techniques based upon the ratios of different radioactive isotopes of a various elements found in rock formations.

### **Tectonic Forces and Periods of Erosion and Deposition**

Except for the basement metamorphic and igneous rocks of the Inner Gorge, which are as much as 1.7 billion years old, nearly all the rock formations of the Grand Canyon are from the period of time geologists call the Paleozoic. This name means "old life" in English.

There have been at least two major events in Earth's past that resulted in extinctions of a large percentage of the species which existed at the time of the extinctions. That is to say, that at two points in the fossil record, one 250 million years ago and one 65 million years ago, the number of different species drops off suddenly and many of the species whose fossils are found in rocks older than those dates do not appear after those times.

The life forms that lived after the first flowering of species during the Cambrian up until the first great extinction are the life forms that geologists are referring to when they use the term Paleozoic.

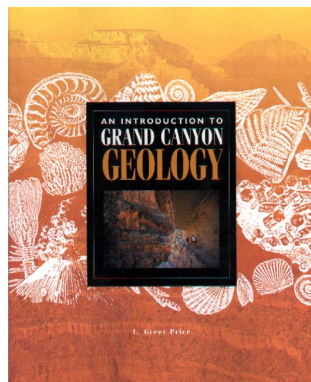
This time period, the Paleozoic, stretches for about 230 million years, from the emergence of complex multi-cellular life on the planet during the Cambrian, some 580 million years ago, until about 250 million years ago, the time of the first great extinction.

It was during this time, the Paleozoic, that the landmass that today embodies the Colorado Plateau was intermittently submerged under seas of varying depth. The sediments that comprise today's colored layer rock formations of the Grand Canyon collected at the bottom of these seas that covered the Colorado Plateau during Paleozoic times. ( See: [Colorado Plateau Through Geologic Time](#))

Most areas of the Earth's surface have been subjected to folding and other distortions of the original horizontal orientation of their sedimentary layers of rock. One of the unique features of Grand Canyon geology and of the Colorado Plateau in general is the lack of deformation of the rock formations over an extensive area. This retention of the formations organization gives the Grand Canyon its strikingly uniform multi-hued layered character.

In the time since the Colorado Plateau rose above the sea some 250 million years ago, the forces of erosion have been at work and have removed over 2000 meters of rock from the surface over the general area of the Colorado Plateau. Dutton referred to this as "The Great Denudation." We know now that it was not the result of any single cataclysmic event, but was the product of the accumulated effects of erosional forces over a very long period of time.

This article was meant to give the reader only the most brief overview of Grand Canyon geology. For further reading see *An Introduction to Grand Canyon Geology* by L. Greer Price, which is great little book and is available from the Grand Canyon Association at a very reasonable price. You can contact the Grand Canyon Association via their on-line bookstore at:



<http://www.grandcanyon.org/bookstore>