Geologic Map of the Grand Canyon
Geology of the Grand Canyon

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Experience

- Completed 5 privately permitted trips through the Grand Canyon from 1989-2011. Logged 1250 river miles and 90 days in the bottom of the Grand Canyon.
Powell was the second Director of the USGS from 1881-1894 and was the principal force in expanding geologic studies and topographic mapping throughout the country and in stimulating investigations of soil, ground water, rivers, flood control, and irrigation.
Major John Wesley Powell

- Geologist famous for the 1869 Powell Geographic Expedition, a three-month river trip down the Green and Colorado rivers that included the first known passage through the Grand Canyon.
- The one-armed Major explored and mapped the “blank spot” on the map where the Grand Canyon is located.
- He published written accounts and observations from the expeditions.
- Great reading material!!
Located in the Colorado Plateau Physiographic Province of Northern Arizona
Grand Canyon

• Contains one of the most complete rock sequences on earth.
• Over 40 sedimentary rock units and many metamorphic/igneous units have been mapped and named in the Grand Canyon.
• Rock units range in age from the fairly recent Quaternary sediments and volcanics to the nearly 1.7 billion year old Vishnu Schist.
• Geologic history includes at least three separate episodes of uplift followed by erosion.
Generalized Cross-Section

- Kaibab Plateau
- Coconino Sandstone
- Hermit Shale
- Supai Group
- Redwall Limestone
- Muav Limestone
- Bright Angel Shale
- Tapeats Sandstone
- Unkar Group
- Tonto Group
- Angular unconformity
- Disconformity
- Vishnu Schist
- Zoroaster Granite
- Inner Gorge
- Colorado River

- Permian
- Pennsylvanian
- Mississippian
- Devonian
- Cambrian
- Precambrian
How did the Grand Canyon Form?

- 2 to 1.8 billion years ago (BYA). Sediments accumulated to unknown thicknesses.

**Step 1** 2 to 1.8 billion years ago. Sand and mud accumulate to unknown thickness. Heat and pressure will later turn them into Vishnu Schist, gneiss, and Zoroaster Granite.
1.8 to 1.2 BYA. Mountain building events uplifted the sediments and turned them into the basement rocks we see today (Vishnu Schist and Zoroaster Granite).

**Step 2** 1.8 to 1.2 billion years ago. Earlier formations now become high mountains intruded by thin white dikes of coarse pegmatite and thick pink granite.
1.2 BYA to 900 million years ago (MYA). Erosion of the mountain range and deposition of more sediments (Grand Canyon Supergroup) on top of the eroded basement rocks.
800 MYA. Tilting and faulting changes the Grand Canyon Supergroup formations into a series of mountains and valleys.
545 MYA. The Grand Canyon Supergroup mountains and valleys are eroded to a low flat plain, allowing the first invasion of Paleozoic seas.

**Step 5** 545 million years ago. Erosion has created a flat lowland plain allowing the first invasion of Paleozoic seas. Resulting deposition creates Great Unconformity (see blue line above).
250 MYA. Nearly 300 million years of deposition lays down the sedimentary Paleozoic formations seen today as horizontal layers (Kaibab-Tapeats).
70 MYA. Additional deposition in lowland environments builds approximately 2000 feet of Mesozoic sediments on top of the exposed Grand Canyon units.

**Step 7** 70 million years ago. Deposition in lowland environments during the Mesozoic Era build about 2,000 feet of sediment. Later, these “Dinosaur Age” deposits eroded away except for remnants like the Vermilion Cliffs near Lee’s Ferry.
70 to 40 MYA. The Colorado Plateau rises and the present erosional period begins. Most of these Mesozoic deposits have eroded away and are only seen in a few places in the Grand Canyon. Some of the Mesozoic units that are missing from the Grand Canyon are the ones most geologists know (Navaho Sandstone – Zion NP, Chinle Formation – Petrified Forest, Morrison Formation – Dinosaurs).

**Step 8** 70 to 40 million years ago. Colorado Plateau rises, present erosional period begins. Grand Canyon begins to form.
6 MYA to Present. Continued erosion forms the modern Grand Canyon. Tertiary-Quaternary volcanic activity creates widespread basaltic lava flows.
Cross Section of the Grand Staircase

GEOLeGIC CROSS SECTION OF THE CEDAR BREAKS - ZION - GRAND CANYON REGION
A Trip Through Time

The next part of this presentation will be a brief tour through the Grand Canyon, starting at the top near Glen Canyon Dam and traveling down river and down section, through the geologic units to the bottom and oldest units of the Grand Canyon, highlighting interesting features along the way.
Cenozoic (Quaternary) age rocks are found throughout the Grand Canyon. The Cenozoic deposits are much more recent and are generally deposited on top of the Quaternary erosional surfaces of all the other formations found in the area. Two that are interesting are the travertine cemented debris flows/river gravels and the abundant lava flows and formations.
Travertine Deposits and Cemented Debris Flows

- Quaternary age travertine cemented talus and river gravels at Mile 60. Contain rocks from above units.
- Evidence of a much wetter climate when formed.
Lava Flows

- Quaternary lava flow are present throughout the Grand Canyon area. These lava flows have dammed the Colorado River at least 13 times, with some of the lava dams being nearly 2000 feet high and creating lakes over 100 miles long.

- The largest rapid in the Grand Canyon (Lava Falls) is the remnant of one of these lava dams.
Major John Wesley Powell observed many lava flows and wrote the following in his journal:

August 25, 1869 - What a conflict of water and fire there must have been here! Just imagine a river of molten rock running down into a river of melted snow. What a seething and boiling of the waters; what clouds of steam rolled into the heavens."
Mesozoic Units

View from Lee’s Ferry, AZ at Mile 0. Mesozoic sedimentary units can be seen dipping upriver. This is the only place in the Grand Canyon where Mesozoic units are present. Units shown are the Chinle Formation (Petrified Forest and Shinarump Members - Triassic) and the Moenkopi Formation (Triassic). The lighter units near the river are the Paleozoic (Permian) Kiabab Limestone.
Paleozoic Units

- The Mississippian Redwall Limestone is one of the most distinctive units in the canyon. First encountered at Mile 23.
- Forms massive vertical cliffs, 400-800 feet thick.
- Not red, a brown to bluish gray limestone and dolomite, surfaces are stained red from the iron containing formations located above.
Muav Limestone
The Grand Canyon Supergroup consists of nine sedimentary units that were deposited in a shallow sea between 1.2 BYA and 900 MYA. The units were uplifted, tilted, and faulted approximately 800 MYA. Then by about 545 MYA the Grand Canyon Supergroup was eroded into a low flat plain, where flat lying Paleozoic sediments were deposited on top.

In many areas of the canyon, the Grand Canyon Supergroup is missing or partially missing due to several long erosional periods represented by several large unconformities.

Photo taken from River Mile 108.
The Great Unconformity

- This nonconformity is where the bedded Paleozoic and/or Proterozoic rocks are located on top of igneous or metamorphic rocks.
- The time gap represented by this erosional period ranges from 300 MY to over 1.2 BY in the Grand Canyon.
- At this spot the Grand Canyon Supergroup units are missing and the Tapeats Sandstone (Early Cambrian) lies directly on top of the 1.7 BY old Vishnu Schist.
The Great Unconformity

- Major John Wesley Powell observed this contact and named it “The Great Unconformity”. That day he wrote the following in his journal:

- August 14, 1869 - At daybreak we walk down the bank of the river, on a little sandy beach, to take a view of a new feature in the canyon. Heretofore hard rocks have given us bad river; soft rocks, smooth water; and a series of rocks harder than any we have experienced sets in. The river enters the gneiss! We can see but a little way into the granite gorge, but it looks threatening.
Generalized Cross-Section
Early Proterozoic Units

- The Vishnu Schist and Zoroaster Granite has been dated as being formed 1.7 BYA. The Vishnu Schist formed from sediments in an ancient sea. The sediments were buried nearly 12 miles deep and metamorphosed into a schist.
- Three episodes of granitic intrusions created the Zoroaster Granite that is seen throughout the Vishnu Schist.
- Both units were then uplifted into a mountain range that was 5-6 miles high.
- Subsequent erosion reduced them to a low plain that was only 10’s to 100’s of feet high.
- The later Proterozoic Grand Canyon Supergroup was then deposited as sediments on top of the eroded metamorphic and igneous basement rocks.
Man-Made Geologic Processes

- Beach erosion has been a problem in the Grand Canyon river corridor since Glen Canyon Dam was built in 1963. The rapidly rising and falling water levels due to hydroelectric operations at the dam have scoured the river corridor beaches that support native wildlife. Pre-dam floods transported tremendous amounts of sediment down the river, and the dam has prevented floods and new sediment from entering the canyon to replenish the beaches.

- A series of man-made floods was completed as part of a study to determine if beaches could be replenished by increasing river flows to pre-dam levels.

- The test floods were successful in replenishing the beaches and as a result, the current environmental management plans for the Colorado River in the Grand Canyon were updated to include moderation of the rapid water level changes and periodic beach replenishment flood events.
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