The Grand Canyon

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Nothing could have prepared me for my first sight of the Grand Canyon though I have seen photos of it of course. The sheer scale is difficult to take in. The Colorado River was quite hard to spot at first, a mile below us at the South Rim. At this point the North Rim was some 10 miles from us. It was like looking at a painted back-drop. Everything was so still and majestic and unreal!

What fascinated me, though, was the sequence of the strata, the variations in colour and texture and thickness. I wanted to understand what changes in the paleoenvironment caused these rocks to be laid down.

When you gaze down into the Grand Canyon you find yourself looking at a representation in rock of two billion years of earth history. Every geological age from the Precambrian to the Permian is recorded with the exception of the Silurian and Ordovician. These may have existed but have since been completely eroded away.

The oldest formation, the Precambrian metamorphic Vishnu schist, is all that remains of the roots of a mountain range which was once taller than the Himalayas. These schists were originally sedimentary rocks and arc volcanics which were metamorphosed in an orogenic event at approximately 1.7 Ga.

Above this crystalline basement in the eastern part of the canyon can be seen the Grand Canyon Supergroup, a 12,000 feet thick angled sequence of layered sedimentary rocks (sandstones, shale, red beds and conglomerates) with interbedded thick basaltic sequences dated at approximately 1.25 Ga. This sequence has been associated with the breakup of the supercontinent Rodinia and is not exposed on the western part of the canyon. It was eroded to form a horizontal surface prior to the deposition of the Cambrian Tapeats sandstone, the oldest Paleozoic unit in the sequence.

The Tapeats sits with unconformity on the basement rock and marks the position of the inner gorge. As the Cambrian sea advanced onto the rifted edge of the former supercontinent it formed this shallow marine passive margin unit close to the shore. The 100-300 feet thick sandstone was probably formed from coastal dunes.

The overlying 250-450 feet thick Bright Angel Shale represents the deepening of the advancing sea and the deposition of offshore muddy sediments. It is composed of green mudstones with some fine-grained sandstones and contains fossils of trilobites, brachiopods, and worms. This layer forms a gradual transition to the 150-800 feet thick Muav formation above. This youngest Cambrian unit is composed of limestone with green micaceous siltstones and represents the continued transgression and deepening of the sea resulting in carbonate deposition in clear offshore waters.

On top of the Muav limestone are deeply eroded channels which have been infilled with a Devonian carbonate unit called the Temple Butte limestone.

The next formation is a bluish grey limestone with chert nodules laid down in a retreating shallow tropical sea near the equator in the early to middle Mississippian (Lower Carboniferous). This is the 500 foot Redwall Limestone distinctive because of its thickness and the formation of steep (often vertical) rock faces. It marks the continuation of the offshore clear water deposition of the passive margin. It contains abundant fossil evidence of crinoids, brachiopods and bryozoans typical of a warm, shallow clear ocean. The top of this limestone has a karst erosion surface.

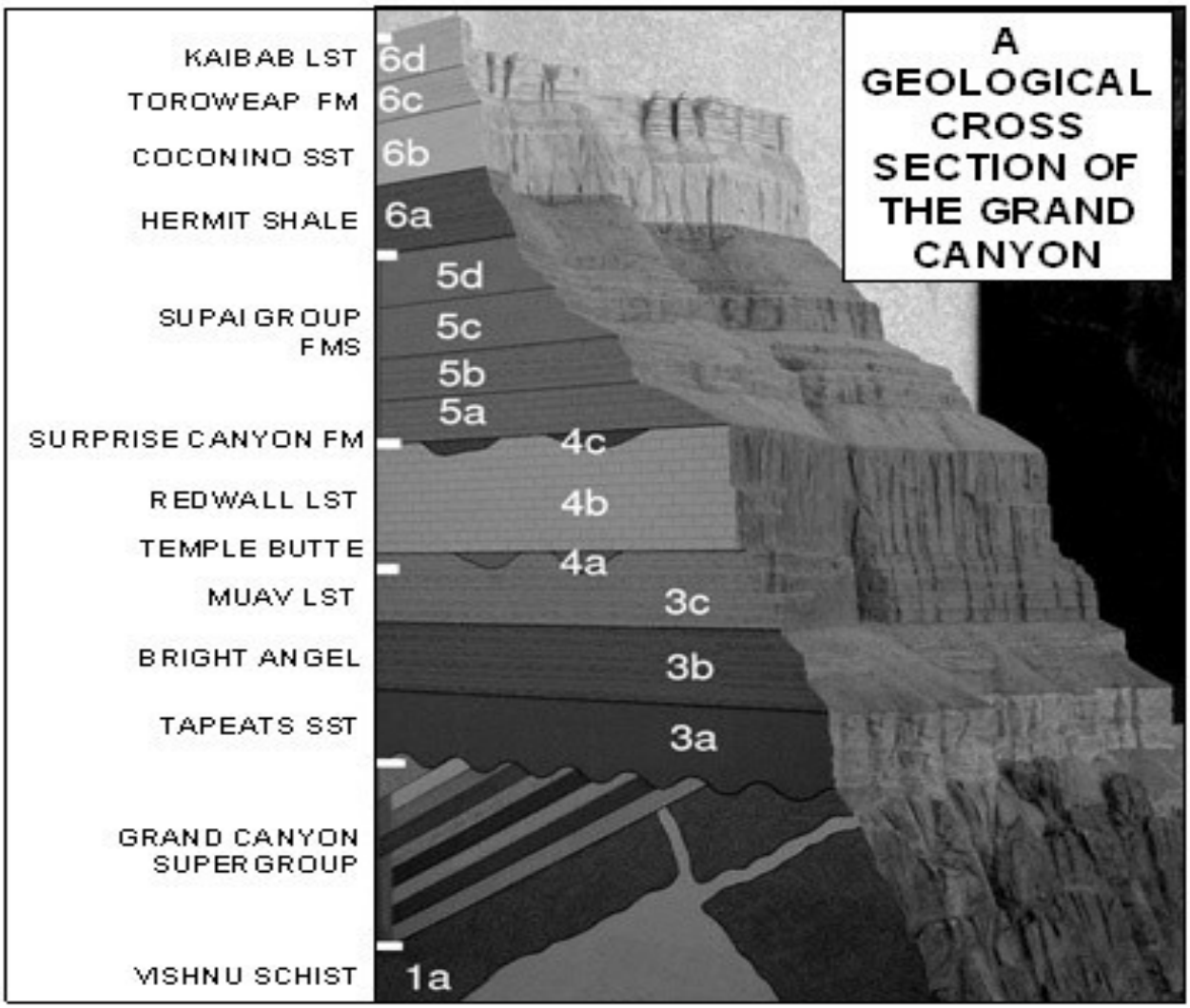

Fig 1, *A geological Cross Section of the Grand Canyon*

The upper Mississippian marks the beginning of the change from a passive margin dominated succession into sequences reflecting a gradual development of subduction zones along the western US coast and associated uplift. The arc volcanoes above the subduction zone provided a new and massive source of detrital input into the former passive margin. This change is recorded in the Supai Group which is of Pennsylvanian (Upper Carboniferous) and

early Permian age and forms the slopes above the Redwall limestone.

This 600-700 feet thick group consists of a very varied range of sediments with siltstone, sandstone, conglomerates, mudstones, marls and limestones representing a range of depositional environments from near shore tributary and brackish to fluvial and dune type sedimentation. Plant fossils indicate a depositional environment that was low and swampy and there is abundant evidence of cross bedding.

The main Permian sequence consists of three main formations: the Hermit shale, the Coconino sandstone and the Toroweap formation.

The 300 feet thick Hermit shale is a typical red-bed unit and represents alluvial fans and floodplain deposits that covered Northern Arizona during the Permian 280 Ma. It consists of siltstones formed from deposits in swamps and lagoons.

The overlying Coconino Sandstone is an

aeolian dune deposit representing an arid desert that extended across the area 270 Ma. This formation is distinctive because of the dune cross-bedding of its exposures. There are also numerous reptile tracks preserved in the sandstone. The thickness of this layer varies between 50 and 300 feet and forms prominent white cliffs near the top of the Grand Canyon.

The 200 feet thick Toroweap Formation consists of red and yellow sandstones and shaly limestone interbedded with gypsum. These were deposited 260 Ma in a warm shallow sea as its shoreline transgressed and regressed over the land.

And finally we come to the Kaibab, a massive 300 feet thick limestone forming a prominent cliff and the top of the Grand Canyon succession. This represents the deeper parts of the advancing warm, shallow sea that deposited the underlying Toroweap Formation. Fossils here include molluscs, crinoids and brachiopods. The Kaibab forms the plateau region covering most of Northern Arizona.

Mesozoic rocks would have been deposited on top of the Palaeozoic but have subsequently been eroded away.

The end of the Mesozoic is marked by the Larimide orogeny which gave rise to the Cordilleran Mountain Chain. The Colorado plateau reacted by developing large scale monoclinal folding and extensive uplift from an estimated 1000 feet to approximately 9000 feet. In the mid Tertiary crustal extension led to widespread volcanic activity that continues to the present day. The origin of the canyon has been attributed to the opening of the Gulf of California at about 5 Ma, resulting in a lowering of the river base level and reversing the flow of the proto-Colorado towards the rifting region, causing the river to cut through the sequences of the Kaibab plateau.

Fig 2, *Contact of the Coconino Sandstone and The Hermit Shale*

Fig 3 *Standing on the Kaibab at South Rim*

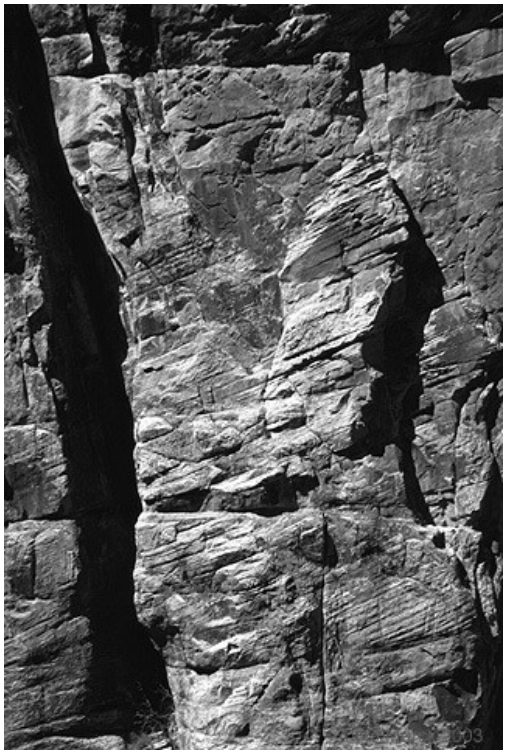

Fig 4, *Aeolian cross-bedding in the Coconino Sandstone*