**Grand Canyon 3**

1. The first great transgression ends as worldwide sea levels fall in response to the first of several collision orogenies that will culminate in the formation of Pangaea. Remember that orogeny decreases continent area and the corresponding increase in ocean area initially lowers sea level.
2. But as the mountains erode, sea level slowly increases due to sediment transfer into the oceans. Whether or not this transgression deposited any sediment in the Grand Canyon area is unknown, for there is no Ordovician or Silurian strata in the canyon. It may have never deposited, …
3. … or perhaps it was completely eroded when sea levels plummeted as a second collision orogeny adds another chunk of land to the growing supercontinent of Pangaea.
4. Slower sea floor spreading rates may also have contributed to the low sea levels at the beginning of the Devonian. Importantly, this graph shows only global sea level variations. Local sea level will also be affected by any uplift or subsidence of the land in that area. Thus, if the Grand Canyon area had underwent more uplift during the Ordovician and Silurian than the synchronous global rise in sea level, a *regression* could have actually occurred in the area. We simply don’t know whether there was a transgression or regression in the Grand Canyon area during the 165 million year interval that spans the Ordovician and Silurian periods.
5. We do have a record, albeit spotty, of Devonian transgression in the canyon, which may once again have been the result of sediment transfer into the oceans following orogeny and erosion.
6. Although this transgression may or may not have been the third in the area, we will nonetheless call it the second, because it is the second time transgression left any sedimentary record in the canyon.
7. The unit deposited during this transgression is the Devonian Temple Butte Limestone and it corresponds to “Truly” in our handy mnemonic.
8. During the Devonian Period the region was again awash in shallow seas which now covered an eroded Muav Limestone sea floor.
9. In the eastern part of the canyon the Temple Butte Limestone generally outcrops as thin lenses that terminate against the sides of former stream and tidal channels carved into the Muav Limestone.
10. In the western part of the canyon, which was farther offshore during the Devonian, the Temple Butte’s thickness increases markedly. Here we see the “type locality” for the Temple Butte Limestone.
11. Now back to the eastern section for a moment where we see another lens within the Temple Butte. If the sea transgressed over the Muav Limestone, why don’t we see sandstone and shale deposited before the Temple Butte Limestone? Remember that the Tapeats Sandstone and Bright Angle Shale were deposited before the Muav Limestone. Pause the presentation and see if you can come up with an explanation. When you think you have one, resume.
12. Well, unlike the Cambrian transgression which occurred on an eroded Proterozoic basement of largely silicate rocks, the Devonian transgression occurred on soluble carbonates, which largely dissolved upon erosion and therefore produced very little insoluble sand and mud.
13. A relatively brief regression followed the deposition of the Temple Butte Limestone, but by the middle of the Mississippian period, a third transgression was in full force.
14. The unit deposited during this transgression is the Mississippian Redwall Limestone and corresponds to the word “Rocks” in our mnemonic.
15. The combination of global sea level rise and subsiding land led to a profound transgression that covered even more of the western states with shallow seas than did the previous transgression. With the shoreline even farther from the Grand Canyon during the deposition of the Redwall than it was during the deposition of either the Temple Butte or Muav Limestones, …
16. … the sea water here was extremely clear and the Redwall Limestone is therefore almost entirely pure calcium carbonate formed from accumulated shell material. Typical fossils include crinoids, bryozoa, brachiopods, coral, and cephalopods.
17. As one of the most conspicuous cliff formers in the Grand Canyon and thoroughly red-stained from iron oxidizing in the units above it, the Redwall Limestone is aptly named.
18. Where the river has washed away the iron staining, the true blue-grey color of the Redwall Limestone is visible.
19. At Redwall Cavern, the river has completely dissolved the Redwall Limestone - a dramatic example of its high solubility.
20. The giant cavern is a popular stop with raft trips.
21. A rather profound recession followed the deposition of the Redwall Limestone, during which time it was uplifted and eroded.
22. Caverns developed in the soluble Redwall at this time, many of which can be seen along the river.
23. Some of these provide conduits for modern groundwater flow.
24. The extensive cave system at Vasey’s Paradise with over 2 miles of passageways, indicates that the Mississippian erosional period was quite significant. Of course the Redwall Limestone is exposed to erosion today, so there are modern caves that have developed in the Redwall as well. Some of the modern Redwall caves have speleothems that must form just below the water table and thus indicate that the canyon was at least partly eroded at the time they formed.
25. By dating such speleothems, known as cave mammillaries, the age of Grand Canyon formation has been pushed back to 16-17 million years ago. Centered in the photo is a broken-open mammillary exposing the Redwall Limestone beneath the mammillary crust (m).
26. That mammillary stuff is cool, I know, but we need to get back to the Mississippian regression, which not only resulted in cave formation, but also, ….
27. … in a similar manner to what happened in Florida during intervals when sea level dropped, …
28. … runoff carved stream channels across the carbonate platform.
29. In the Grand Canyon region similar channels later filled with reworked carbonate debris to become …
30. … the Surprise Canyon Formation. This mode of occurrence is similar to the Temple Butte Limestone, but the Surprise Canyon Formation only outcrops in remote areas of the canyon and was not discovered until 1985. Accordingly we will attach little significance to it and move on to …
31. … the Fourth Transgression.
32. The final Transgression recorded in the Grand Canyon occurred during the Pennsylvanian and Permian periods. At this time orogeny associated with the final stages in the assemblage of Pangaea will generate a lot of clastic sediment that will greatly diversify the kinds of sediment accumulating in the Grand Canyon area.
33. Accordingly, there are five distinctly different units deposited during this interval – the Kaibab, Toroweap, Coconino, Hermit and Supai, or in our mnemonic: “Know The Canyon’s History Study”!
34. Pennsylvanian deposition begins with the Supai Group – a unit so variable that it contains four distinct geologic formations (don’t worry about their names). The various layers represent a variety of changing environments, …
35. … including marginal marine (delta, estuary, lagoon and tidal flat) and shallow marine, similar to the Texas Gulf today. This scene attempts to interpret these marginal marine environments with scant vegetation (ferns and calamities- giant horsetails) and animal tracks of an unknown species. Red colored sediments, or “red beds” as geologists usually call them, almost always indicate that the sediments where exposed above sea level, where highly oxygenated rain water could oxidize iron-bearing minerals derived from the erosion of distant mountains.
36. It is primarily the Supai Group which provided the iron oxide which colored the Redwall Limestone below.
37. Above the variable beds of the Supai Group lay the soft, vivid red slopes of the Hermit shale. The color of these siltstones and mudstones absolutely screams oxygen!
38. It should therefore be of no surprise that the Hermit Shale represents a coastal lowland environment, probably a lagoon on the edge of a tropical sea, where extensive rain thoroughly oxidized the sediments. Some layers are rich with plant fossils (see inset), indicating occasional swampy conditions. The animal in this scene is a Dimetridon and more of a lizard than a dinosaur. True dinosaurs won’t appear until the Triassic period. The trees are conifers similar to the trees responsible for the petrified wood in the Petrified Forest southwest of the Grand Canyon. Giant Horsetails and ferns fill out the scene. The lush world of the Hermit Shale will almost completely dry out as several factors will join forces towards the middle of the Permian to make much of North America a desert.
39. First on the drying list is the precipitous fall in sea level that accompanied orogeny associated with the final assemblage of Pangaea. Notice that this is the lowest global sea level of the entire Paleozoic. As sea levels fall, continental area increases and larger continents tend to be more arid.
40. The largeness of Pangaea itself also contributed to the aridity as did the location of much of North America which lay in the typically dry sub-tropical latitudes.
41. Climatic conditions at this time where similar to modern Saharan Africa, and vast dune fields spread across Permian North America.
42. The conspicuous light-colored cliff near the top of the canyon is the Coconino Sandstone and represents this time period.
43. The high angle cross-beds which are characteristic of this formation are visible from some distance and are indicative of its windblown origin.
44. On closer inspection you can see that the cross-beds slope in different directions because changes in wind direction reshaped the dunes. The light color indicates very mature sand with few ferromagnesian minerals. Individual sand grains have a “frosted” surface, imparted by countless impacts with other grains.
45. Also indicative of the Sahara-like Coconino landscape are the sporadic reptile tracks found throughout the formation (see inset). Vegetation was minimal.
46. The dune field represented by the Coconino Sandstone covered a vast area …
47. … stretching from Mexico to Montana. The mountain ranges built during the formation of Pangaea …
48. … will eventually erode, add sediment to the ocean and …
49. … once again raise sea level, although just barely above average.
50. Nonetheless the slight rise in sea level was enough to cover the Coconino dune fields with shallow seas because they were only slightly above sea level to begin with. Two units deposited at this time - the Kaibab Limestone and Toroweap Formation. Both deposited in a shallow, warm tropical seas in which marine invertebrates flourished. The scene here includes a shark, sponges, brachiopods, crinoids, bryozoa, rugose corals and a coiled cephalopod. Not surprisingly, these conditions once again led to the deposition of carbonates so both units are mostly limestone.
51. The Kaibab Limestone forms the rim of the Grand Canyon and is easily recognized as the irregular gray cliff which stretches from the rim to the largely tree-covered slope of the Toroweap Formation below. Since the Toroweap Formation deposited on the shifting sands of the Coconino, the limestone is interbedded with sandy layers. There are even a few gypsum layers in the Toroweap indicating local evaporitic conditions. The variability of the Toroweap requires that it be called a “formation”, whereas the regularity of the Kaibab Limestone requires no such designation. There is an unconformity between the two units indicating yet another drop in sea level, …
52. … but when the sea returned to deposit the Kaibab Limestone, the dunes had been sealed and stabilized by Toroweap carbonates, so shorelines were less shifty during Kaibab time. Thus the Kaibab Limestone contains virtually no clastic material and is almost entirely made of skeletal remains.
53. Like most limestones, the Kaibab is susceptible to solution, so potholes and…
54. … sinkholes are not uncommon. This one has filled with pond sediments. Well we’ve reached the top of the canyon now, but some of the best parts of the story still lie ahead.