

Six thousand feet below the surrounding surface of northwestern Arizona, ancient rocks (1840 million years old, give or take a million) resist the continuous cutting of the Colorado River in its Grand Canyon. Shorelines were different back then and these basement rocks, at present 300 miles from the nearest ocean, were formed beneath the sea. They started as granite, lava, ash, and shale, under and around a volcanic island archipelago at the edge of Laurentia, the early continent that would become North America. Over the course of 50 million years the islands slowly slammed into Laurentia as the oceanic crust they rode was dragged down into the molten mantle under the continental plate margin. This collision was slow but powerful, partially melting and deforming the mythically-named rocks -- the Elves Chasm Pluton, and the Brahma, Rama, and Vishnu Schists -- metamorphosing them from their original forms into recrystallized bands that demonstrate which way they were squeezed and how hot they got. Then they sat, now a permanent part of a continent, for 300 million years.

This was the first chapter in the tale of the Proterozoic Rocks (Protero = former; zoic = life) of the Grand Canyon, as told by Trevor Waldien, a doctoral student in Earth and Planetary Sciences at UC Davis. Proto-Doctor Waldien studies how faults develop in response to tectonic plate motion, and currently works on the Denali fault system in Alaska. Some of the same processes that formed the Proterozoic rocks of the Grand Canyon were at play in Alaska much more recently: 80-150 million years ago. When he's not finding fragments of faults formed at different depths, now exposed at the surface in the uplifted Alaska Range, he teaches at UC Davis. He's been a TA every quarter since 2013, teaching mineralogy in the fall, structural geology in the winter, and then field geology in the spring and summer. And this March he'll drop down into the Grand Canyon on a raft, riding the river backwards in time, across the Great Unconformity, into the Proterozoic heart of our continent.

But we're ahead of ourselves, and the story has gaps. During those 300 million years, after the mythic metamorphic rocks stuck on to Laurentia, whatever lay on top of them eroded away. The basement rocks were once again, 1300 million years ago, on the bottom of a nearly lifeless ocean. New rocks began forming underwater, on top of the old rocks, with a 300 million-year gap (an unconformity) between them. But this isn't the Great Unconformity, not yet. This is the beginning of the Grand Canyon Supergroup, a 13,000-foot-thick sequence of sedimentary and volcanic layers deposited between 1300 and 740 million years ago. We can see 13,000 feet of layers in a 6,000-foot-deep canyon because the whole Grand Canyon Supergroup is tilted, up to 60 degrees. So in addition to travelling back in time by going deeper into the canyon, we also time-travel by moving across tilted layers. And the layers of the Supergroup are in their original state, not metamorphosed, except of course for the tilt. The limestones, shales, sandstones and lavas were all originally deposited horizontally, on an ocean floor or coastal plain. Uplift caused the tilting, but didn't otherwise deform or melt the original rock, and initiated the erosional period of the Great Unconformity. But there I go skipping ahead again.

The rocks of the Supergroup were formed in very different ocean depths: shale in the deep ocean, limestone in warmer, shallower seas (from the carbonate skeletal fragments of tiny marine organisms), and sandstone near shore. Several layers of lava and conglomerate contain features that indicate they were deposited on land. The late Proterozoic, on the patch of continent that is now the Grand Canyon, was a time of wide fluctuations in water depth. Some of this deepening and shallowing is related to some close neighbors that Laurentia had, but lost. The continents that are now Australia and Antarctica abutted the western side of Laurentia (nearest the Grand Canyon). Along with most of the other large landmasses of the day these formed the supercontinent of Rodinia. The sediments of the Supergroup were deposited on the edge of this supercontinent. Many of the changes in water depth and depositional environment were caused when Antarctica and Australia broke away from Laurentia, disbanding the supercontinent.

The last rocks at the top of the Supergroup record a transition from deep marine deposition to a shallow marine or terrestrial environment. Then nothing. At last we've reached the Great Unconformity. Here's where the rocks of the Proterozoic must have been tilted up, perhaps in an uplift event related to that last recorded drop in water depth. The Supergroup, tipped and thrust up above the water, would have been exposed to erosion. And for 250 million years those rocks that formed in the mostly-lifeless sea wore away. And when new rocks were made on top of them, just above the Great Unconformity, the tracks and shells of creatures were everywhere! This was the Cambrian Explosion. The Former Life was over and Old Life (the Paleozoic) was just beginning, with a bang.