Chapter 20 WHEN LIFE CLEANSED THE SKY Mile 137-167

We emerged two days ago from our traverse through the inner gorge of ancient schist and granite. The confining walls of the canyon stepped back, and the rapids decreased in frequency and ferocity. After leaving Garnet Canyon, the river turned and carried us generally northward before making a smooth turn to the northwest and then almost west into its narrowest width just before Deer Creek Falls. This morning at Poncho's Kitchen camp, we board the boats and depart in the deep morning shadows of the steep wall behind us. Several small humps of schist make a last appearance below the Tapeats on our left side—tiny islands in the Cambrian Sea that got buried rather than eroded flat. It is the last time we will see the schist on this trip before we reach the helipad where helicopters will lift the passengers up to an airstrip on the North Rim. Looking back on the right we can see the old, pre-slide channel cut down through the Tapeats that is now filled with the landslide breccia. It astounds me to recognize that the old channel apparently filled catastrophically in a matter of seconds. The major geological narratives on these great walls are not all about events in deep time. We are now on the river back in its original channel. For the past several miles, we had been on a river detour around and down through the landslide rubble. I look up and wonder if the collapsed north wall ahead might suddenly drop down upon us. It certainly has happened in the past.

Now downstream from the great landslide, JP points out strands of imbricated gravels perched high up on the walls. These obviously formed in a raging flow after the landslide dam was breached. There is little time to visualize the almighty torrents flowing wildly over these boulders and cobbles that were hopelessly trying to choke the flow here. Even after all these years, these few still lie on narrow ridges tens of feet above the current flow—but alarm! Here comes 139.1 Mile Rapid. We plow through it easily, so I continue to scan both shadowed walls for more imbricated gravels from the great dam breach. There are none easily visible now, and I lose interest because the character of the walls has become very different. Both walls stand almost vertical leaving us in deep shadows. Both are dark and close together as far ahead as the eye can see. The extreme narrowness and great height of the walls so close to the river is something new. No wonder a wall collapse could choke the canyon as happened just behind us.

The strata must be tilted slightly downward away from us because we are going ever so slowly upward through the stratigraphy as the river flows downhill. The first several days, they were slanted down toward us, so we descended through the stratigraphy much faster than the river was taking us downward in elevation. We now pass upward through the Tapeats and Bright Angel and are then surrounded by the Muav Limestone lying above both those units. Once in the Muav, the tilt of the tectonic block must become more horizontal because we often travel along the same horizon in the Muav even though the river is taking us downhill. The Muav has also become dramatically thicker than when we first encountered it at Buck Farm Canyon about 100 river miles behind us. For the rest of the day, we will motor entirely within this unit. Indeed, all the lower Paleozoic strata thicken westward of the Grand Canyon--especially these marine carbonate units. The western edge of the continent in early Paleozoic time was sagging more and more in this direction. Production of seashell debris here was on a colossal scale in those earliest days of marine animal life. The shell debris apparently piled up as fast as subsidence progressed to keep sea level here more or less the same. The shallow waters were apparently an optimal environment for animals that secreted carbonate shells. Layer upon layer of shell debris was converted to dolomite--probably by vast sabkhas that sent evaporatively concentrated waters back through the coastal slush or in places where build-up of seashell debris reached sea level and local brine ponds remained after tidal flooding. This could be a stunning example of my old colleague Clyde Moore's idea that primary production of shells slows as they pile up to near sea level. Then, the piles are eroded until subsidence allows the sea to return and the cycle to begin again. Now we are immersed between huge walls of a great stack going from river level 3,000 ft upward to the top of the Redwall Limestone that we glimpse from time to time up toward the baby blue morning sky.

We pass the mouth of imposing Kanab Canyon--a long, meandering, intermittent stream bed entering from the north as a scenic route that hikers with lots of time and scrambling ability could exit or enter along. Today, it is not flowing, but the exceptionally long rapid here tells of repeated times when debris flows dumped their loads across the path of the river. We are now in what is called "Muav Gorge." It is dark and deep with confining, gray walls and rough-textured surfaces. Precipitous side canyons enter from both sides but seem to plunge steeply to the river without an entrance to walk into. Cold mists fly up over us in the deep shade at every little rapid or riffle and provoke unease regarding this strange, narrow stretch of the river.

We round a slight bend to see a narrow shaft of sunlight streaming in to brilliantly illuminate a small cottonwood tree (Fig. 20.1).

Fig. 20.1. Morning apparition in Muav Gorge at mouth of Olo Canyon.

This resplendent green apparition in the dark gloom has often been one of my favorite moments on a raft trip. The little cottonwood tree sits on a pile of debris thrust out the mouth of Olo Canyon. It is my favorite tree in the whole world. In moments of dejection, I recall this sight to boost my spirits. I am always a bit apprehensive approaching this location because once on a previous trip we rounded the bend in the morning darkness and saw nothing. The shaft of sunlight was without joy. The tree was gone. We landed and discovered only a pile of beautiful white logs and branches with ends chewed into cones by beavers. It was sad as sad can be, although the little waterfall in a small alcove was enjoyed by the others while I went out to pay my respects (Fig. 20.2).

Fig. 20.2. Here lie the ruins of the noblest tree that ever lived (Fig. 20.1). Beavers got it. Fortunately, it or its progeny grew back within several years.

Unbeknownst to me, several friends smuggled out a chewed-on branch and gave it to me at an after-trip party. A little gold plate was affixed that said “River Memories” along with the date. I look at it often in my study with joy knowing that it or one of its descendants grew back-- a testimony to the stubborn resilience of life—or to the speed with which cottonwood trees can grow. Its joyful welcome will hopefully continue to greet morning river runners in Muav Gorge as it does for us today.

Within three miles on the left, we approach a slot canyon that is easily but rarely missed because there are usually boats sticking out its mouth. It is spectacular Matkatamiba Canyon that is a favorite for those with time to climb up its steep walls or go straight up the slot with arched bodies propping hands on one wall, feet on the other. A group of boats today indeed clogs the narrow entrance forcing us to continue without stopping. I only get a quick glance into this place which holds such uplifting memories (Fig 20.3).

Fig. 20.3. Patio area high up in Matkatamiba Canyon. Always in shade and always a place to calm the soul.

This is not the loss it seems because we will be able to see much of the same thing in National Canyon tomorrow at the end of an easy hike. In both places, the Muav Limestone is on display with extensive bench exposures of its fretted layers. The gnarly texture is caused by weathering of crisscrossing seafloor burrows. Standing on one of these benches with the burrows etched out in relief, I am reminded of how I once stood on a modern example and watched the action. I had waded out ankle deep into a tide pool on Andros Island in the Bahamas with sand-sized shell fragments squishing up through my toes. Holding still, the stirred-up gray cloud settled, and I could see innumerable small snails burrowing around. Their crisscrossing trails were at the same scale of those often visible in the Muav Dolostone (Figs 20.4 and 20.5).

Fig. 20.4. Burrows in the Muav Limestone etched out by weathering on a flat surface. Each cubic centimeter of the original sea floor shell debris probably went through the guts of an animal many times while rucking around for bits of organic matter to feed on.

Fig. 20.5. Modern example of burrowing in seashell debris washed in during high tides on northwest Andros Island in the Bahamas. This photo was taken looking straight down through ankle-deep water. The tracks and trails are from gastropods (snails) in coiled shells about an inch long.

Geologists always say the present is the key to the past. It is thus easy to imagine the burrowing creatures once here in the shallow water deposits of the Cambrian Sea, although the organisms were undoubtedly different. The ocean floor here was bustling with life. Fossils are rare because everything was eating everything else and leaving only crushed shell fragments behind. It is estimated that every cubic centimeter of carbonate like this went through the guts of a lugworm or some other creature at least ten times before it was buried and converted into hard rock. This churning and rearrangement of lose sediment by organisms is called "bioturbation." It is a distinctive texture doubtless present in every carbonate layer here from river to sky. It all signals ancient life –abundant, thriving life in the blue waters of the Cambrian seas. Yes, there is gloom in Muav gorge, but it can be thought of as a celebration of life that evolved into us.

After two miles, the river bends sharply to the left and roaring Upset Rapid appears before us. This short rapid contains a mound of water moving at the speed of light right over a big rock in the center of the channel. The current plunges into a seething hole and then erupts as a terrifying wave breaking right back over the flow. Many small boats flip trying to go around this deathtrap. Sticking close to the right bank usually avoids trouble, but that is not easy to do with a large boat like ours. Revered Hatch boatman Shorty Burton flipped and drowned here in 1967. Famous for the pies he cooked on the river, he is memorialized here with an unofficial pie tin nailed to the north wall. The Park Service regularly removes it, and it is regularly replaced. While our now bigger boats would be difficult to flip here, a direct hit on the big rock under that initial mound of water can induce an almost instantaneous stop that can throw passengers off their seats no matter how tight the grip and almost certainly inflict serious damage to the boat and/or motor. I once experienced just that when a trainee drifted too far out and slammed into this obstacle. He went headfirst into the motor well and got pulled up holding the broken-off motor handle with blood streaming down his terrified face. Until that point, he had been doing a superb job and developing confidence. It did not help his self-esteem that two groups of private boaters recovering from their own troubles were watching from the north bank. He decided to never drive again. This was a pity because he would have done well with a little more experience. I hate violent rapids.

There is a small grotto here that the incoming side stream flows through that is a magical swimming hole if there have been recent rains. We pass up the opportunity this time and shoot through the rapid without incident or comment while my mind swims in various memories good and bad about this place. I still have recurring dreams about swimming refreshed in that shaded grotto on a hot day. It has evolved so much in my confused dreams that I would probably be disappointed to visit it again. A raft trip is always eventful and can leave indelible marks on the subconscious.

A beautiful set of ledges of the Muav Limestone shortly rises up the lower north wall straight out of the river. A small waterfall of rivulets drips and streams over green fuzz on a giant, fallen travertine block. There is no beach, but this is a wonderful campsite known as "The Ledges" adequate for a group smaller than ours. Boats can simply tie up and everyone step out. Find your own ledge and note you can take a shower in that dripping waterfall slightly downstream. Do not believe any boatman who sincerely repeats the legend that this is a place never touched directly by light of the full moon. While once camped here on a previous trip, an alarm went off out on one of the boats at 1:00 am. Everyone blinked awake to see the whole area bathed in the magical light of the full moon. I heard a voice from one of the crew sleeping out there say, “we lost” as they groaned and went back to sleep. I had just won two sixpacks of beer with a bet that the full moon would clear the right side of the vertical wall directly across the river shortly after midnight. It is rare to win a bet with an experienced Hatch crew, but they should never bet against an amateur astronomer about where the moon is going to be during the night.

The midday sun today clears that same wall and turns the gloom into a solar blast that quickly loses its welcome. We pull in against a shaded wall of ledges on the left side and break out lunch. A wall stretching vertically upward to an inconceivable height stands on the other side of the of the river as it does down the entire length of the Muav Gorge (Figs 20.6 and 20.7).

Fig. 20.6. Immense thickness of carbonate stretching from the river to the sky in the Muav Gorge.

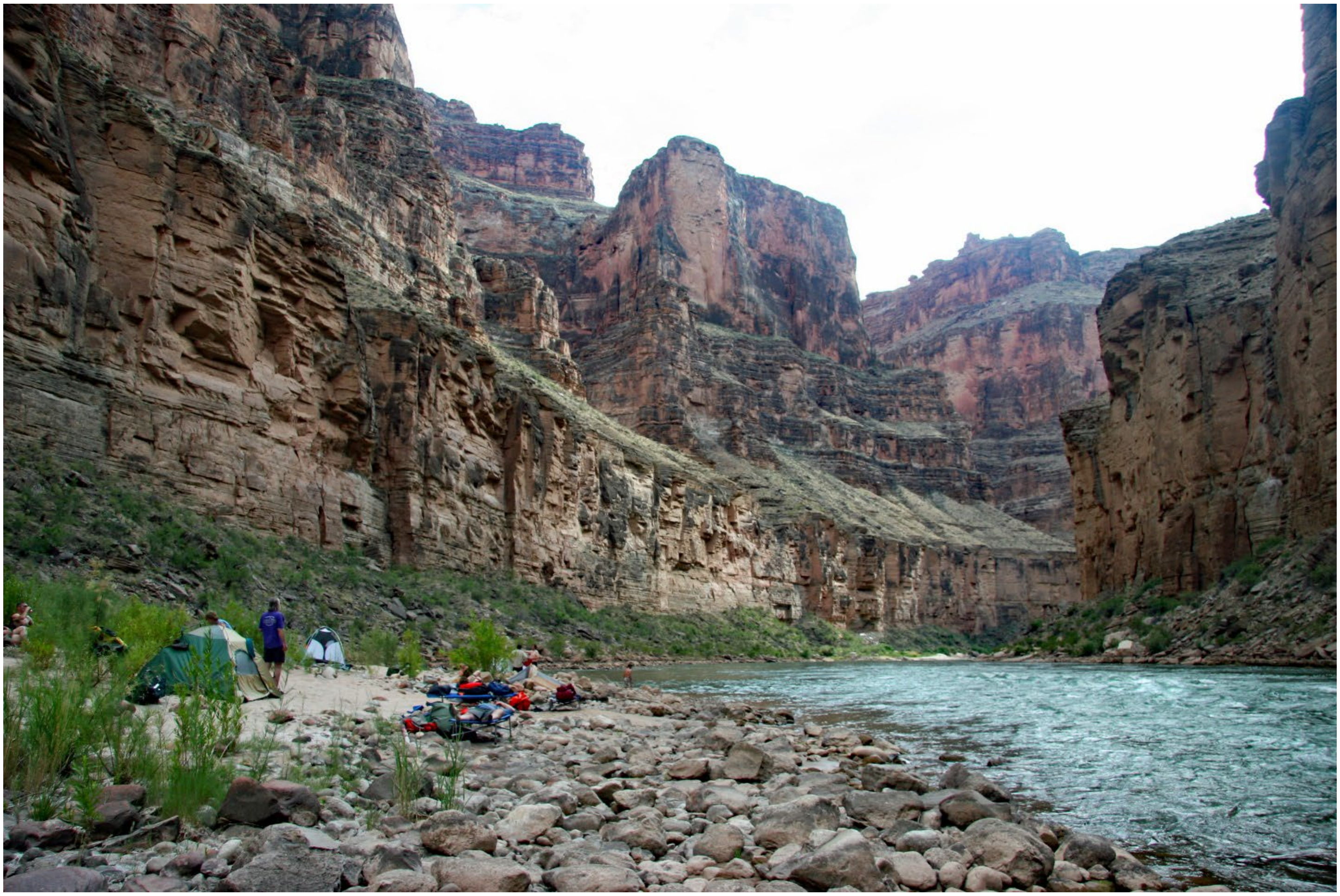

Fig. 20.7. In the Muav Gorge near its western end at Tuckup Canyon. All the layers visible here are carbonates (limestone and dolostone).

It is a unique setting that puts to shame the dwarfing a human-built forest of skyscrapers can inflict on pedestrians in big cities. Almost all the Paleozoic layers stacked up to the sky here are carbonate. Layer upon layer of once loose shell debris that accumulated over sagging continental crust like that which we saw in the inner gorge and at Garnet Canyon. To me it is breathtaking until I reflect that out to the west and on into the Death Valley area, these carbonate strata are up to three times thicker yet. The carbonate wasn't washed in and dumped; it materialized right here straight out of seawater. What a colossal amount of carbonate that was once dissolved as calcium and carbon dioxide in the ocean has been taken out and stored over hundreds of millions of years in these layers!

Our shady view of the river is framed by the jutting edges of giant fallen blocks amidst which we assemble for lunch. The emerald water flowing smoothly along with a surface as flat as a tabletop seems to be mesmerizing some of the group--including me. In shadowed desert heat and lunchtime wonder, the scene prompts me to confess prejudices regarding climate change over Earth history. It is something I worked on throughout my long professional career. Not just recent changes, but the big picture going back to the beginning of geologic time. Several others in hearing range wander over. This surprises me because it is late in the trip now, and canyon magic has transitioned into a captive euphoria that can diminish interest in science-- anything serious for that matter. I nevertheless rally loose a bit of chemistry with a summary of results and interpretations I rush through before the anticipated calls for lunch. It is an:

Impromptu technical seminar regarding climate change over geologic time

Carbon dioxide in the atmosphere dissolves into raindrops and directly into the ocean to form carbonic acid ($CO_2+H_2O=H_2CO_3$). The subsequent molecular dance of these atomic combinations (molecules) within this water is virtually instantaneous but somewhat variable depending upon temperature and other environmental conditions. The clumsy H_2CO_3 molecule disintegrates into the chemical ions H^+ and HCO_3^-. The HCO_3^- further breaks into more H^+ and CO_3^{-2} as well. High H^+ is what makes all rainwater slightly acidic. What started as CO_2 in the air and H_2O in the fluid has now rapidly become a group of six atomic associations that combine and break apart back and forth until an equilibrium mixture prevails. Meanwhile, abundant calcium dissolved in the water can snatch CO_3^{-2} assemblies to form the mineral calcite ($Ca^{+2} + CO_3^{-2}= CaCO_3$). Marine animals take advantage of this chemistry to make the seashells that get reconstituted during early burial into limestone. The organisms essentially take CO_2 out of the air and lock it up with an endless supply of calcium released from crustal rocks during uplift and weathering. Today's atmosphere contains far less than 1% CO_2. If we could just accelerate growth of calcite shells in the ocean today, the CO_2 we are putting into the atmosphere at an alarming rate would diminish concomitantly. It is a solution to the global warming issue caused by increasing CO_2 produced from burning fossil fuels. So far, no one has proposed a way to do this on a large scale.

Another important aspect of carbonate geochemistry is that it is the acidic nature of rainwater that causes it to attack common silicate minerals like feldspar and mica and convert them into tiny crystals of clay minerals (mud). If the amount of CO_2 in the atmosphere increases, then the rate of acidic weathering of rocks like granite, basalt lavas, and schist increases. This draws down CO_2. If too little, weathering decreases allowing CO_2 in the atmosphere to rise. Rock weathering has thus been proposed by modelers as a "thermostat" that keeps climatic temperatures and CO_2 levels constant over long time periods. This model predicts that climatic temperatures have not changed over geologic time. Alas, burning of fossil fuels injects huge amounts of CO_2 into the atmosphere much faster than the proposed weathering thermostat can handle. Accelerated weathering of silicate rocks thus cannot help us much on the short range where it is really needed. Indeed, some geochemists are skeptical that the proposed thermostat works at all due to so many other variables involving weathering. The Himalaya Mountains were uplifted to be the highest mountains on Earth mostly in the past several million years. We should therefore find geochemical evidence in the streams there if all that freshly exposed rock was weathering at the rate necessary for the proposed thermostat to regulate climate over million-year time intervals. The streams were extensively studied, but the results were unclear. The theoretical thermostat remains questionable. However, removal by enhanced growth of seashells on a subsiding ocean floor is a surefire way to lower CO_2 in the atmosphere.

So here is this enormous wall of carbonate indicating that staggering amounts of CO_2 were removed from the atmosphere over geologic time. It seems like there shouldn't be any left in the atmosphere at all! But volcanoes emit CO_2 gas. Sometimes lots of it. Measurements of gases so emitted are difficult, and it is still not clear exactly how much volcanoes are emitting today--or did in the past. An army of brave modelers nevertheless studies the "carbon cycle" wherein inputs and outputs of CO_2 and C in other forms are identified and quantified to the extent possible. It has turned out to be horribly complicated. Rather strong statements are made by various research groups that often agree but often do not.

Modeling with equations has become a dominant force in science today. By making measurements and understanding processes, it is often possible to come up with equations that model reality and allow predictions of what might happen in the future. It is a wonderful intellectual challenge to do this. Assumptions are used to fill in variables in the equations such that the model yields results that fit the data. When processes are understood and there is a strong basis for the assumptions, it is possible to come up with theoretical models of great utility in our attempt to understand how nature works.

Some theoretical models attempt to explain unknown aspects Earth history. For example, assume that the amount of CO_2 emitted by the volcanoes equals the amount that gets locked up in shells. Then atmospheric levels of CO_2 don't change much over geologic time. Combine that assumption with the model astronomers use for the evolution of stars as they burn their hydrogen fuel over time, and it is then possible to use what we know about the atmospheric Greenhouse Effect to model the history of the Earth's surface temperature going back billions of years. The astronomical model is that the sun has become progressively more luminous over time at a known rate, so surface temperatures can be calculated to have been much lower in deep time back when the sun was cooler—even at the time these carbonates formed. The models predict the Earth's surface was so cold about 3.5 billion years ago that the oceans should have been frozen. However, compelling evidence from sedimentary rocks indicates that oceans were widely present back then. Something must be wrong with the model or the assumptions used to apply it. The astronomers are adamant about their evolution of solar luminosity over time and the geologists are adamant there were marine sediments. All this is known as "the faint young sun problem."

Some modelers have used claims from geochemical studies of possible 3.5-billion-year-old fossil soils to argue that atmospheric CO_2 two billion years ago was at the same low level as today. If so, the climate then must have been very cold. Having seen in Australia the prime example of a paleosol so used, I am skeptical. What they called a paleosol on an ancient basalt lava flow looked to me like nothing more than an ash deposit from an explosive volcano much richer in SiO_2. Furthermore, the published chemistry and mineralogy even matched that. There is just no demonstrated way to currently extract reliable estimates of atmospheric CO_2 levels from ancient rocks. So, what can we say about ancient climatic temperatures? Have they been constant which might imply that the thermostat does actually work and that climates have always been similar to that of today? What is known from the rock record about past climatic temperatures? This is an important issue that could have shaped the evolutionary history of life.

Trying to determine the temperature history of the Earth over geologic time as recorded in the rock record has been the major focus of my research career since graduate school days at Caltech in 1966-1972. Over time, I built laboratories with numerous vacuum lines and mass spectrometers to determine oxygen isotope ratios in cherts. This ratio is temperature dependent, so I went all over the world for decades to find and collect the kinds of cherts holding field evidence indicating they formed prior to compaction of the host sediments. Cherts form during burial of sediment, so it is important to find those that display such evidence in the field. A chert temperature so determined would approximate the yearly average climatic temperature. From the analyses, I have authored and co-authored many papers in which isotope data were used to argue that climatic temperatures in the earliest history of the rock record were not just warm enough to have liquid water, but much warmer—possibly as high as 80°C about 3.5 billion years ago (compared with today's global average of about 13°C). There is a thus a huge conflict between the isotope results and those of the modelers with their assumptions about low CO_2 in the early atmosphere. To me, it is obvious that the early atmosphere was loaded with much more CO_2 to generate the greenhouse warming necessary for water to exist under the faint young sun. Rather than engage in the intricacies of carbon cycle theories, I have demanded that the speculative models fit the data. The modelers assuming constant CO_2 have argued that my data must be wrong or misinterpreted and that the models are better indicators of past conditions. Those are fighting words, and I was almost ready to do that once at a NASA-sponsored conference on the "Faint Young Sun Problem." I had some allies there who favor my interpretations, so the rather heated public exchanges between me and a young modeler I met there must have been entertaining to those not having a dog in the fight. The take-home message in this technical seminar on the river is that this enormous accumulation of carbonate exposed by the Muav Gorge has an important message. It is not just peculiar scenery. It is speaking (at least to me) the following conclusion.

Shelled organisms came on the scene less than 550 million years ago on an Earth formed 4,500 million years ago. Layers of carbonate from bacterial slime show up when the first long-lived continental platforms developed 2.5 billion years ago. As more and more limestone got piled up on flooded continental platforms, the high atmospheric CO_2 of the early Earth should have been progressively drawn down. It must have really started to decline when animals appeared in the sea and started making these extraordinarily thick carbonate walls we see before us. Animal life in the sea was cleansing the atmosphere of carbon dioxide. It is possible that the flurry of unprecedented ice ages during the last 14 million years is a result of the ever-increasing abundance of calcite shelled organisms that has lowered CO_2 to its currently very low levels. Our unstoppable practice now of burning buried carbon to increase CO_2 in the atmosphere may destroy us, but life itself will not die from the level getting so low that the Earth freezes over. The enormous, magnificent carbonate walls of the Muav Gorge section of the Grand Canyon thus trigger big questions and big thoughts about major issues and events in Earth history. How many eyes see this? Maybe a few now after my blathering, but all bets are off because a lunch call reverberates off the narrow canyon walls here.

Seminar over. Onward

At mile 157.2, we come to Havasu Canyon, a major tributary that flows with gorgeous spring fed, light blue, clear water. It splashes, crashes, and surges sequentially down through a series of breached travertine dams. It divides and rejoins around huge boulders fallen from the dolostone ledges above. This is usually a mandatory swimming stop for all raft trips, so we are not surprised to find a gaggle of row boats clogging the opening. A long, low, and loud rapid erupts at the confluence. It is flowing too fast for row boats to tie up on the wall just past the gaggle of boats, but downstream that wall with a nice set of benches rises high above the water. It is possible for us to turn the boats around and crawl along the wall against the raging current here. We ease toward it amidst the strange sensation of motoring full throttle while bobbing up and down but barely moving relative to the swirling turbulence of the current we fight against. Once tied up, people are directed to climb out and scamper up ledges to walk back to the mouth of Havasu Creek (Fig. 20.8).

Fig. 20.8. Tying up to the wall in the rapid just downstream of the mouth of Havasu Creek. The first boat is secure and the passengers have departed. The second boat has tied to the first, and its passengers will come over the first to step up onto the bench of Muav dolostone. Both boats are bobbing in current, so all this must be done carefully and with life jackets on.

We are still in the Muav Limestone, so there is no new geology to examine. This is purely a recreation stop to hike up the creek and go swimming in this glorious water. The walls along the creek at its mouth are steep, so we must climb up and over to drop back down into the lowing stream water (Fig 20.9).

Fig. 20.9. Looking down on Havasu Creek just above where it joins the Colorado River. The trail descending benches is visible on the wall to the right. Two hikers to the right of center have reached the creek, will wade across, and take a trail going along the base of the wall to numerous swimming places farther upstream.

The trail is a little scary, but hard, gnarly, travertine is all around to provide handholds. The group wades across the creek and follows a trail through lush greenery upstream several hundred yards to travertine pools. These are some of the finest swimming holes on this side of paradise (Fig. 20.10).

Fig. 20.10. One of many swimming holes in Havasu Creek.

Along the way, I duck out from the hiker train into one of my special spots amidst the greenery. A couple of deer are grazing indifferently in this lush splendor and slowly move away as I walk through chest high broad-leafed bushes and shady cottonwoods now growing rapidly after a flash flood scoured through here several years ago (Fig. 20.11).

Fig. 20.11. Lush cottonwood trees grow in places along Havasu creek. They are periodically washed out by debris flows but grow back rapidly.

An hour of solitude in the deep shade of cottonwoods beside azure, blue water pouring over travertine obstacles is heaven (Fig. 20.12).

Fig. 20.12. Havasu Creek paradise.

The water here is loaded with billions of microscopic calcite crystals just like what we played in a few days ago at the Little Colorado River. The sunlight bounces around the tiny crystals along paths long enough for the true, beautiful color of water to be seen. As they settle or get trapped in the abundant green algae, the bottom becomes a white ooze. The green algae get coated and entombed by this sludge very rapidly. The transition from green to white along surfaces getting so coated is apparent everywhere you look (Fig. 20.13).

Fig. 20.13. The waters of Havasu Creek spill over numerous travertine dams. Algae and mosses growing on them trap microscopic crystals of white calcite precipitated as a floc when the source springs about 11 miles upstream erupt from the Redwall Limestone. The tiny crystals rapidly amalgamate and embed the growing plant material. This is fossilization in action.

Little stick fragments and leaves with their forms perfectly preserved thus become coated and buried. With time, all these tiny calcite crystals will meld into limestone. This is fossilization in action. This trapping of suspended calcite crystals is a likely way carbonates formed in coastal oceans of the Precambrian long before shelled animals had evolved. I could just as well be watching mound-like stromatolites forming here like the “brain rocks” we saw at Chuar camp. Indeed, travertine stromatolites line the walls on the trail we just hiked up and clearly formed when the stream here was at much higher level (Fig 20.14).

Fig. 20.14. Travertine precipitates as tiny layers one upon the other to form stromatolites like those formed ubiquitously in the Precambrian seas. They rapidly harden into resistant mounds. Here a stromatolite that formed during high water flows of the creek is plastered on the wall. A United States quarter for scale is partially obscured by shadow.

I once saw a plastic comb partially embedded in travertine along the banks here (Fig. 20.15). Fossilization is not always a slow process.

Fig. 20.15. A plastic comb along with numerous twigs that got covered and embedded by travertine along the banks of the creek. This vividly demonstrates how rapidly fossilization can occur in carbonate rocks.

The travertine laminae and mounds forming here before my eyes are limestone in the making--but different from the great walls of the ancient Paleozoic carbonate all around us. They both start as loose grains ranging from microscopic in the case of the travertine to sand-size for the walls. They are different because the particles in Havasu Creek are a floc that precipitated almost immediately after spring water upstream drained out of fractured Redwall Limestone into the creek channel while the vast Paleozoic accumulations exposed in the walls are carbonate that originally precipitated as shells in the ocean. The dissolved parent carbonate in those oceans was derived from CO_2 dissolved in water and calcium atoms released from silicate minerals during weathering. The oceans today are generally so saturated with the dissolved constituents necessary to precipitate calcite that any chemist would tell you it should be precipitating out of surface sea water everywhere. Every ship bottom and pier pole should be coated with a white calcite crust, but it doesn't happen. The surface waters of the oceans today are "threefold supersaturated" with respect to calcite--and yet it doesn't happen! This is a mystery that geochemists still haven't explained. Make a beaker full of threefold supersaturated water in the lab and calcite will form in a matter of hours. So why not in sea water? Sub-microscopic crystals may start to form, but growth of anything larger ceases. Most ideas have it that atoms of something dissolved in the ocean attach on the faces of these baby crystal "nuclei" and poison further growth. It isn't sodium or chlorine atoms, so magnesium atoms, phosphate molecules, organic molecules, and others (perhaps acting together) have been suggested. It is so mysterious that people don't like to talk about it. Modelers run from the issue because all their models depend on the laws of equilibrium chemistry in dilute solutions which predict something that isn't happening. You won't find this discussed in geology textbooks or even in sedimentology texts. I wonder if our current global warming crisis could be solved by figuring out why calcite is so reluctant to precipitate in the calcite supersaturated shallow waters of the world. The crystal poison might be neutralized by addition of something harmless or some bacterial organism that could be cheaply introduced into vast areas to cause an explosion of calcite precipitation. The white flocs making the water so blue here in Havasu Creek are in fresh water which apparently doesn't have the mystery crystal poison that today's sea water is loaded with.

All this starts bothering my otherwise peaceful mind this morning because more than half of these vertical walls to the sky are made not just of calcite, but dolomite which is even more supersaturated in the oceans today than even calcite! Fivefold, in fact. I wade out into the sludge and start thrashing the water and grumbling wherefore I know not. I think it is frustration at these important geochemical problems and because so few of my colleagues apparently know or care about this geological embarrassment. It is not like people haven't agonized over these things and offered suggestions. But how can we be writing papers on the significance of isotopes, trace elements, and other aspects of limestones and dolostones without understanding literally the first step in the sequence of processes that produced this material? I always thought we would soon know. But no! The field remains a big mess. Ah, well.

I calm down and start washing off the sludge. I was going to daydream about the Precambrian Sea when shells didn't exist and flocs like this may have been settling out on the ocean floor to form the stromatolite layers we see everywhere in those old carbonates. Memories of long campfire conversations with my research colleague Bob Horodyski about the origin of Precambrian stromatolites flood over me. Something in the cell walls of marine animals apparently filters out the atomic or molecular poisons that stop calcite crystal growth. Did the microbes that thrived as green slime back then also precipitate carbonate like the shells do today, or did the slime simply trap tiny crystals like I see happening here in Havasu Creek? Apparently, some types of microbes grown in the lab can make calcite, so there is a spreading prejudice that Precambrian stromatolites were carbonate factories. Alas, the issue will always persist because we weren't there to observe the goings-on.

A distraction from geological daydreams lies all around in the sands here. Numerous conical depressions clearly made by some critter living here are all around me. The critters are the tiny larvae of flying insects known as lacewings. They are long enough to barely fit across a fingernail and easily scrape out a steeply sloping conical trap (Fig 20.16).

Fig. 20.16. Conical depressions caused by "ant lions." These are dug out by the larvae of lacewings, a flying insect. A larva has buried itself just under the pit and instantly pounces on ants that wander in and can't get out. These pits are common in overbank deposits of the river usually near or under an overhanging wall.

They larvae themselves near the bottom and patiently wait. Ants who wander in slip and slide to the bottom where the larva flits out and pounces. There are a few ants scurrying around like every other place in temperate climates, so I watch for nature's cruelty in action. They all seem to miss the pits, so I lose interest. The encounter does trigger thoughts about how much else is going on in the Grand Canyon than geology. A botanist or wildlife biologist could just as readily describe and ponder the other wonders of natural history down here. Some have, but my ignorance of so much in this world knows no bounds. This would be a pleasant place to talk about some of these things with my fellow river runners, but I accept that the senses can only take so much stimulation before knowledge and understanding seem somewhat picayune. Ecstatic from their swim in magical waters, the group starts noisily funneling back past my secluded spot. Soon we carefully step out into the boats ready to continue onward through these now endless walls of Muav limestone.

JP returns from consulting with the groups that were tied up at the mouth and along the wall, including several that arrived behind us. Most of the private groups hope to camp at one of the two large campsites at wonderful National Canyon about ten miles ahead. They won't have time to make it there this day, but groups that departed earlier might. A motorized commercial group will be slightly behind us. Chances seem good that we can snag one of these sites if we motor hard. The race is on. We shoot past Tuckup Canyon which has a wonderful camp site that triggers many memories. It is a scenic slot canyon beautiful near its mouth (Fig. 20.17) and magnificent farther up for those with a rope willing to scale a blocking wall (Fig. 20.18).

Fig. 20.17. The entrance to Tuckup Canyon going up from the river is a magical place in the early morning or late afternoon.

Fig. 20.18. A short hike up Tuckup Canyon ends at this dry waterfall. If someone climbs the wall and throws down a rope, it is possible to get over this cliff and explore the canyon further. Here, river runner Donna Benson offers encouragement.

We eventually arrive at huge National Canyon breaching the massive wall on the left. Both camp spaces are open. Hallelujah, because alternatives for large groups like ours farther downriver are scarce. One site is just past the mouth, and the other is toward the downstream end of a huge pile of vegetated gravel piled up from repeated debris flows that spilled out during past rainy seasons. JP chooses the downstream space which has a better pull-in for our large boats. This long side canyon to the south is an easy hike with only a trickle of water that normally flows mostly underground in its loose gravels.

A huge shadow from the far wall slowly inches across the river as we set up camp and finally become immersed in blessed shade. Tomorrow is our last day, and we will have time in the morning to take a group hike up this side canyon to where it is a slot with pools in beautifully smoothed dolostone. There, people can waddle sideways above the pools if they stretch out with feet on one side and flat hands on the other (Fig 20.19).

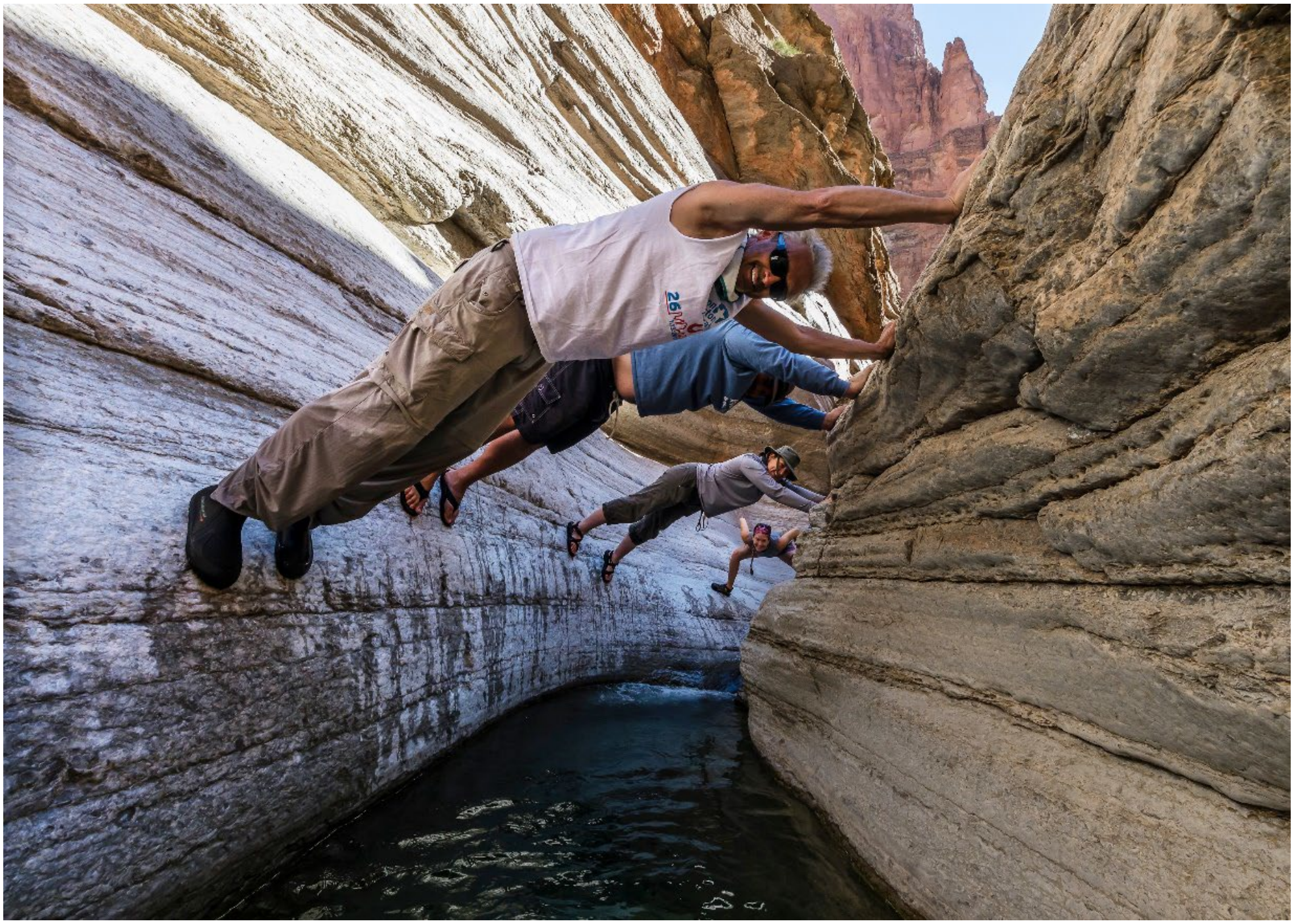

Fig. 20.19. A hike up National Canyon turns into this. To proceed, a different hiking technique is required to keep feet dry. (Photo by Michael Nolan)

It is always a lot of fun. For now, we'll set up camp, relax, and watch the incredible patterns of shade and sunset-tinged color swath over the high walls facing us. With lots of time before dark, a huge chair circle forms and people swap exaggerated stories about almost everything but politics and religion. By this time on a raft trip, an impressive amount of camaraderie, friendship, and goodwill ushers forth from almost everyone. A trip like this works magic on the human spirit. Everyone alive has interesting stories in their soul, and I am continually amazed at what comes out of people toward the end of the trip. The banter becomes giddy by consumption of distillments fetched from daytime storage in the hold of one of the boats.

Boat companies do not like people to hike unless accompanied by a guide carrying a first-aid kit and knowledge about routes in this dangerous country. But I know this side canyon like the back of my hand, so I sneak out to wander up it aware that late day magic awaits. The sound of the rapid fades and the crunch-crunch-crunch of my steps on gravels is balm for the soul. Every step seems to be taking me deeper into a magic kingdom full of dark shadows and brilliant walls rising straight up toward the blue sky. The smooth, rounded gravels of Muav dolostone are almost entirely light gray with a pale blue tinge. The late afternoon shadows are jet black. Here and there where the blinding sun hits them, smooth walls are theater screens slanted this way and that. The green tangled branches of mesquite thickets in front are black silhouettes intricately pierced by light from the theater screens. It is an incomparable display of light, shadow, detail, and unique grandeur. I climb over some big boulders and walk in the deepening shadows now inching up the giant walls. Every view is changing constantly. I look back toward the river and see high walls on the other side of the river developing a red glow. Shimmering colors reflect off the wet gravels and rivulets of water snaking through the chaotic stream gravels.

Here in the magnificence between these high noble walls, I sense in splash and solitude the ravages of time steadily tearing down all that stands. Relentless. Unstoppable. Surprisingly, I feel no insignificance in the grand scheme of things here. I am a consciousness stood up and now being torn down by time's incessant gnawing. Out of all this long and ongoing history, this small part of the universe somehow became conscious of itself in a mortal coil. In me and you for sure and maybe in other ways on other worlds that we can't fathom. In this brief time and place I rejoice over what a privilege it is to be able to experience this consciousness in an animal life at the top of the Earth's savage food chain. How wonderful that I had an opportunity to get a scientific view about what these walls are, what their history tells, and what the future may hold! I know these thoughts and this consciousness are generated by electronic configurations in my brain, but is there more to it than that? No point fretting about that; we just cannot know.

These lifeless walls that started out as accumulations of shell debris of animals on an ancient sea floor are now reconstituted into layers upon layers of dense stone, each fragment created by a little life that flashed and is now gone. I can put my hand on any spot and there was an ancient ocean teeming with life that evolved for over 500 million years toward conscious organisms like this one now standing amidst the wreckage of its evolutionary ancestors. I am a conscious organism able to trace the history of my atomic constituents back to outer space in times before the Earth was born. And yet, here it is the colors, the majesty, the infinity of shadows, and the inner glow generated by six previous days experiencing it all that captures my soul. Anyone could stand here and admire the beauty as many river runners have done before. Is the experience enhanced to know science, geology, and all this history? Yes, but maybe that part isn't so important. Right now, there seems again to be something eluding me that is more significant. Once again, there are no answers to the deepest aspects here despite an overwhelming longing for some kind of revelation. No wonder that primitive peoples everywhere invoke invisible spirits and such when these very human feelings arise. Is it compulsory to invoke the supernatural? No--I am content to keep longing, searching, and staying rooted in science and reality. This pilgrimage through natural history is still in its early stages.

But now the lighting is beginning to fade. If I get back too late, I might miss dinner. Is there really time to linger here for deep thoughts? Yes, there is time. Everything seems to be going to sleep--or rather returning to darkness. Each speck of surface on these walls started out as dissolved molecules in the ocean. Early animals in the history of life then involuntarily assembled them to form shells or other such encrustations. Sunlight, starlight, and moonlight flashed off them in the coastal waves and swirling seas before they were reduced to sand by munching predators or pounding surf. Then they descended into burial darkness for over 500 million years. They basked today again in sunlight. Tonight, photons from distant stars will once again impact and vibrate molecules on their newly exposed surfaces. This re-exposure to the daily light of the sun and the nighttime light of the stars will go on for days, years, or centuries before pieces of rock fall off and get washed down this side canyon into the river where they will dissolve or get buried as sediment back into darkness again. Darkness to light to darkness to light to darkness again… "creeps in this petty pace from day to day to the last syllable of recorded time." Ha…I wonder what Shakespeare would have written about nature if he could have gone on a raft trip through Grand Canyon. But wait. I don't have a flashlight with me. It is time to set aside deep thoughts and skedaddle back while I can still see where my feet should step (Fig. 20.20).

Fig. 20.20. National Canyon darkens prior to sunset. It is a place of incomparable beauty at these times. It is also a place to see one of the thickest exposures of Paleozoic limestone and dolostone layers in the world. To the west in southern California, the thickness is three times larger, but all is broken into tilted mountain blocks produced by tectonic mayhem nowhere present in the Grand Canyon.

In the darkness after dinner, I assemble the people for a camp meeting--the first of the trip because people usually do not like night sessions. "Had this assembly been here on August 24, 1869, and looking upstream, we would have seen three boats holding nine desperate, bedraggled, starving men round the corner and go past indifferent to whatever interest National Canyon had to offer. Look, can you see them right now out on the river passing us desperate and unaware we are here? The group was organized by one-armed civil war veteran John Wesley Powell and began as an exciting first-ever traverse of this region on the Colorado River. It launched with enthusiasm in Wyoming and was meant to go all the way to the Gulf of California. By the time it passed this spot, the group was just trying to get out alive." And so, I tell the story of Powell's earlier life, how this trip came about, what happened during and after the trip, and give my view of how Powell helped change the way we look at the American west. He has always been a controversial figure in American history, but his impact was great. Involving some pitiful theater, we conjure up his tormented spirit to appear so we can grant him relief. The meeting has a surprise ending if all goes well. More memorable for me tonight is how this shtick was once interrupted on a previous trip by breakout of an epic water war in which young and old adults went at each other with water guns, plunger cannons, buckets, pots, and even battery-powered hoses used to rinse mud off sitting areas in the boats. Adults on the river will be kids, but all goes well tonight. I retreat to my cot hidden way off in the darkness before the group takes revenge regarding the surprise ending about which nothing should ever be revealed or written.

The next morning, we walk up National Canyon in the morning shadows to where the lower layers form a slot that people can traverse arms stretched to one wall from feet on the other. The more widely spaced walls near the start of the walk have perplexing, gnarly, fist-sized cavities aligned in discontinuous rows along the bedding planes of the Muav (Fig. 20.21).

Fig. 20.21. Layers in the walls of National Canyon have peculiar divots along their sides called "Tafoni." This is where a small chunk of rock falls out. The cavity left behind gets enlarged to allow water to stand and decompose the rock. Why this develops in some exposures and not others is a mystery.

A curious few of the hikers ask what caused these peculiar divots in certain layers of the walls. Some geologists call it "tafoni," although purists may retain that term for larger examples or special shapes in gravelly layers. These kinds of flat bottom, weathered-out cavities can even occur in solid granite. For most tafoni, the idea is that a small chunk of something falls out which allows rainwater streaming down the cliff face to enter and form a pool. The enhanced water rots the rock which causes the cavity to enlarge as weathered chips get washed or blown out by high winds. This allows even more water to collect which allows more weathering which allows more water which allows……you get the idea. In the end, I'm not sure that tafoni is really understood or even forms the same way in the different rock types. It is not one of the grand themes and the curious are now being left way behind staying here with me. I turn them loose to go catch up. Having been to those destination slots many times and not needed, I slip off to the side where I can climb up through a mesquite thicket to the base of the east wall where I can be alone amidst big angular blocks that fell off the walls and now rest in deep morning shade.

I have sneaked off the back end of the hiker train on many previous trips to this same spot. The tangle of mesquite branches keeps getting thicker, but once I push through them, there is my little place in a small clearing against the wall. I lie down atop a big, flat block and stare up at the sky and the walls rising straight up into it. Almost directly above me is a block the size and shape of a mattress ready to drop straight down (Fig. 20.22).

Fig. 20.22. Mattress-sized block of highly burrowed Muav Limestone ready to drop off side of National Canyon.

What is holding it up? No noise here from the rapid--only the occasional song or rustling of a bird. Over the years, the sweet sound of the Canyon Wrens seems to have vanished. This cannot be good, but all is changing always in the Grand Canyon. Sensing endless change amidst silence and solitude is another strange experience. I am always exhausted toward the end of a raft trip. My wife says it is because I am always on call. As usual, I fall completely asleep like a stone on this flat-topped stone. As also usual, voices of people and the crunching of gravels in the creek bed on the other side of the mesquite thicket awaken me. A blink was almost an hour. I crash out through the thicket and soon find I am the last person to arrive back at the boats. We have less than a day on the river left together, but the walls are about to change into something altogether new. The Grand Canyon is full of never-ending surprises.