Ch 10 **VANISHED WORLDS** Mile 33-41

Motoring out from the deep shade of Redwall Cavern is a bit jolting not because of the sudden blast of bright sunlight but because the river corridor here is narrow and tight. Vertical walls rise straight up from the riverbanks toward a wide slot of blue sky. The top edge of the Redwall is the skyline. Before the river cut down into this sharp bend, it was carving out all the layers above sequentially from the Kaibab down through the Supai. Those layers were reamed out at the bend one by one leaving them stair stepping up the walls of the widened canyon above and now largely out of sight from the river. The walls of the Redwall held as the river sliced straight down into it. The river apparently reached a more erodible layer and is now carving laterally into the wall at the bend where it makes Redwall Cavern. An alternative possibility is that rapid downcutting halted at some point due to reduced flow or higher sea level at the mouth and allowed the river a longer time to dig its way around this prominent bend. Whatever, this undercutting will allow the overlying wall to collapse at any time. I am relieved to have survived another lunch in there.

Many fracture-bounded blocks have eroded out at this stratigraphic level leaving overhangs with water dripping out from cracks. As we cruise along, water weeps out through clusters of ferns over a few conical tongues of smooth travertine with drips directly into the river (Fig. 10.1).

Fig. 10.1. Travertine building out a wet hollow cone from river wall of Redwall Limestone. Spring water issues from behind the greenery, slides down the walls of a growing cone, and audibly drips down its open innards. A small hole on the left side is large enough to put a cup in for those hoping this is the fountain of youth.

We pull up to a hollow cone with an opening big enough to stick a cup in. I announce this is the "famous" fountain of youth accessible only to people on a raft trip. We fill cups to pass around for those who want to try it. I chug one down, although I secretly fear diarrhea. This is our first introduction to travertine that we will encounter later in the trip coating entire walls of the canyon. We are familiar with travertine in our daily lives as floor tiles, countertops, and decorative building stones. It forms where ground water becomes saturated with dissolved limestone and bleeds out into the air as drips, springs, or gushing outflows. Water saturated with dissolved limestone is "hard" water that tastes normal but refuses to froth up into suds and bubbles. If you have hard water at home, your water supply has been in contact with a lot of limestone before it got to your tap. That is most places on Earth and certainly true of springs emerging from the Redwall Limestone. Travertine is simply the dissolved calcite forming back into a solid.

Some Geochemistry

But why does travertine precipitate so immediately as it emerges into the air? A geochemist with integrity answers this with difficulty because carbonate chemistry is a very complex subject. It ultimately involves only three components: calcium derived from rock weathering, carbon dioxide, and water. These participate in six simple chemical reactions that operate simultaneously at different speeds depending upon important environmental variables such as temperature, pressure, exposure to the atmosphere, and other chemical reactions going on in the system. Fortunately, surface conditions of present aqueous environments on Earth vary within typical ranges such that geologists use some "rules of thumb" to roughly predict or understand what those six simultaneous reactions will likely yield. Travertine forms from water already loaded with dissolved limestone and is one of the simplest to interpret. I attempt to explain it as people sip water that they pretend will keep them young for at least the rest of the day.

Ground water is usually deep enough to be insensitive to seasonal variations of climatic temperatures. The climate does impart heat or cold downward, but yearly variations largely dampen out by depths of about twenty feet. Water in the shallow subsurface is thus usually at about the yearly average temperature of an area. It will always be cooler than the air in the summer, so ground water emerging from an aquifer can undergo rapid warming. This is especially so if it weeps out like these drips rather than gushing out like at Vasey's Paradise. Put those six equations together in most natural situations and you find that warm water cannot hold as much dissolved calcite as can cold water. So, it is no wonder that calcite might precipitate to form slimy travertine around a spring. Do not worry about those equations, just remember how heating "hard" water in a pot will produce a white film. If you think about it, this seems crazy. Sugar, like most soluble things, dissolves faster in hot tea than in iced tea. But calcite dissolves faster in cold water than in hot water! There is no justice.

The four “rules of thumb” to keep in mind are that calcite tends to precipitate from hard water upon heating, loss of dissolved CO_2 gas, increasing pH, and depressurizing. Deep ocean water today thus dissolves a lot of calcite because it is cold, at high pressure, and contains a lot of dissolved CO_2 from decay of organic matter that settles there. There is no carbonate in deep sea muds because the rain of tiny shells from floating organism dissolve as they fall deeper and deeper. When the deep ocean water wells up over a shallow bank like the Bahamas, it rapidly warms, depressurizes, and the dissolved CO_2 escapes to the atmosphere. Calcite is thus primed to precipitate from the chemistry alone. Organisms making calcite shells have an easy time in that environment and thrive. Grand Canyon travertine precipitates similarly when cold spring water emerges, warms rapidly, depressurizes, and releases CO_2 that has built up underground from decaying organic matter.

The Pilgrim rants about “Creation science”

The obvious river lie about this fountain of youth is appropriate along here because we immediately pass a place of infamy as far as I am concerned. Some nice exposures to our left just above river level in angular shady alcoves contain abundant nautiloid fossils. These are shaped like tiny dunce hats and are easy to spot when exposed by erosion along a bedding plane. A small octopus-shaped animal wore this mineral hat and darted around in the Mississippian sea. A side canyon just downriver from here known as Nautiloid Canyon is a favorite campsite or stopping place where people can climb up a slightly perilous cliff and see nautiloid fossils on a stream-polished surface (Fig 10.2).

Fig. 10.2. Nautiloid fossil on narrow floor of Nautiloid Canyon. This is an almost perfect cross section of a gently tapering cone defined by dark zones that were likely once aragonite, a crystal variety of calcite ($CaCO_3$). All the empty innards were filled with gray carbonate mud after the organism died and became buried. The wide, lower end was the living chamber that housed an octopus-like creature complete with tentacles, eye, and mouth. The other chambers were filled with air that made the heavy shell buoyant. A central tube connecting all together is well displayed. This was a ferocious predator that jetted around in the Mississippian seas unlike most shelled invertebrates which are immobile, crawl slowly, or drift with currents. Upon death, the shell likely floated before sinking. During early burial, it filled with the carbonate mud and sand made of tiny shell fragments. All then transformed via in situ dissolution/reprecipitation into coarser crystals of dolomite.

The layer just above river level here is at the same stratigraphic position and was one of many relieved of some of its nautiloid treasure by a creation scientist who wanted to do analyses on it. While driving toward the river two days ago, the first ominous trouble began that there are uncertainties in science that interfere with using it unquestioned to amplify encounters with the natural world into something more transcendental. That amplification is at the root of my journey, and here it takes a hit from another direction.

The National Parks and public lands contain some of our greatest scientific treasures. It is commonly necessary to take samples back to labs for analyses that cannot be done in the field. I myself have personally collected numerous samples from public lands because it was essential for the project I was researching. National Parks require samplers to get a permit, and this was once a straightforward process. I even got one in 1970 at Big Bend National Park just by visiting the chief naturalist on the spot at park headquarters and filling out a form. The Park personnel fully support research that generates new knowledge that can be highlighted in interpretive displays and programs or that simply advances America's scientific endeavor.

Here a chap from some creationist operation used the bureaucratic procedure to obtain numerous samples of nautiloids and the surrounding rocks to do "scientific" research. He believed a nautiloid concentration along this bedding plane was some kind of catastrophe in the sea at the time and wanted data to prove it. The creationists interpret the strata of the Grand Canyon to have been deposited during Noah's flood. His catastrophe idea fit into that somehow, but he apparently kept that out of the application. I later stumbled by his poster booth at a meeting of the Geological Society of America in New Orleans where he was presenting his chemical data and arguing that conditions at this time had gone crazy and induced a mass killing of the nautiloids. Several creationists with PhDs were striving at that time to give presentations at scientific meetings and to get papers published in professional, peer-reviewed scientific journels. Their strategy was that they would then achieve credibility as objective scientists with serious evidence. Direct mention of the flood was avoided.

His Redwall data had concentrations of elements that might look peculiar for seashells or limestone made from them. Like all chemical data on fossils, the analyst is not dealing with the shell material as it precipitated out of the ancient ocean. All such data relate to the early burial transformation event that converts the original microcrystals into interlocking crystals of calcite or dolomite. This typically involves pore fluids that are not pristine sea water but mixed fluids that have moved into the sediment, often from considerable distances away. The chemistry of shell fossils thus may or may not have anything to do with sea water compositions. In this case, the nautiloids were likely composed of aragonite like their modern descendants. This is a metastable crystal variety of $CaCO_3$ commonly precipitated by numerous other organisms in the ocean today. The Redwall clearly contains many horizons that underwent exposure when sea level fell and rose again. The metals and such that he was seeing in his limestone analyses may well have been just part of insoluble residues brought in with the migrating pore fluids. The creation evangelist apparently was unaware of published work regarding how original carbonate sediment is converted in limestone or dolostone. He

may have been willfully blind to it because creationists insist that deposition from bottom to top of the Grand Canyon strata was continuous as Noah's Sea rose and retreated to wherever it went. Depositional hiatuses do not exist in their story. After I pressed him a bit about not considering alternative interpretations, he turned away saying he would think about it. To my knowledge, no paper by him on this was ever accepted by a professional, peer-reviewed journal.

So here as elsewhere, wonderful specimens were removed from a National Park so that superstitious investigators could promote mythological stories. Examples of some of the best Precambrian bacterial mounds in Glacier National Park tragically experienced the same fate. The Park Service eventually woke up and implemented a rigorous application procedure to ensure that credible scientists can sample. Of course, the creationists starting with Bible stories insist they are credible scientists and are probably willing to go to the courts to get their permits. The result is that the application procedure takes months to process. In recent years, I could not suggest some great projects in the Grand Canyon to my M.S. degree students because they only have 18 months to do a project, and it could take about nine of those just to get permission to sample. The Park Service basically had to throw out the baby with the bathwater. That still cannot stop the creationists from doing their damage.

The Pilgrim rants about Paradigm Locks and NASA Mars Science

The issue is deeper and more difficult than it seems because it touches on the fundamental question of how we investigate nature. Obviously, the creationists are starting with a result they already think they know and want only to gather scientific evidence to sell their belief to others. This means they are especially prone to selectively pick, ignore, and even distort observations and data that refute their preconceived conclusion. Creation "science" is easily refuted by more logical explanations or interpretations not requiring a deity. So, one test of whether one is doing science is to examine whether investigators are just trying to bolster or further develop a "belief." But... alas, it appears to me that maybe half of all scientific investigations in geology are doing just that! It is framed differently and starts with the idea of "testing a hypothesis" or getting evidence to "prove" this or that theory or confirmation of a computer model. Some philosophers of science note that fields get into "paradigm locks" where new observations are force-fitted into existing "beliefs" common to the scientific community and where alternative interpretations are shoved aside. Quite often, the new data become so blatantly force fitted that the wheels come off the paradigm and people must finally rethink the whole business. Otherwise, all gets worked into textbooks and further investigations are abandoned because something is "already known."

An example to make the point is with the first rover that landed on Mars in 2009. Orbital images had been interpreted by credible planetary geologists to indicate there had been water flood deposits there on a scale that was hundreds to thousands of times larger than any ever observed on Earth. One example seemed to flow right into 100-mile-wide Gusev crater.

Mission planners who targeted this site for the first landing were convinced the smooth floor would be covered with lake deposits. Paintings were publicized showing carbonate mounds that might be evidence of life present at the time of the lake. Two experts familiar with microbial deposits in ancient carbonate rocks on Earth rocks were even assigned to the small team designated to provide interpretations to the public and the scientific community even though carbonate rocks had not then been detected from orbital remote sensing. NASA's motto to find evidence of extraterrestrial life had become "Follow the Water" and here it was. Alas, upon arrival the floor of the crater turned out to be just another boulder field of impact shattered basalt lava flows.

Not to let go of the new "paradigm" that water had flowed in huge amounts on Mars and specifically into this big crater, the NASA team's interpretation became that the lake sediments must had been covered by later lava flows. No problem here. Several years later, a team member found subtle evidence of carbonate minerals amidst impact rubble on hills within the crater by deconvoluting wiggly readings in a spectrometer, something only he and his colleagues could do. You had to trust them. They then announced that a lake had indeed filled the crater and that "where there was water, there could have been life." Of course, there are several other more likely ways to make little carbonate particles in impact rubble on Mars without invoking a lake, but these were not presented or discussed. Basically, the wheels had come off the story that the massive flood deposits were water floods, but no Mars NASA scientist I know will yet admit that publicly even though many are now skeptical. Not all geologists familiar with Earth rocks had accepted that story in the first place. Many had noted the similarity of the apparent martian flood deposits to vast floods of lava observed on Earth and the Moon. NASA lost interest in that crater as claims about vast water floods on Mars faded.

So, looking at the pillaged nautiloid site, all this rushes through my mind to cloud my pilgrimage meant to use science to see in nature the grand themes of geology and their significance. How much of the science I trust and practice is actually itself erroneous, however highly promoted and "accepted?" However, I move on encouraged realizing that geological science has many eyes and brains chewing on how best to interpret what we see. More will come. If there is a major blunder, it cannot survive withering criticism indefinitely like it does in the smaller, tightly controlled NASA community. The creationist story can be easily countered with basic geology unless our whole science is wrong. Their arguments against science do not hold up and cannot get through critical peer review in the professional literature however erratic that process may be. To protect scenic resources, the Park now requires you to return your samples but has no way to enforce it. Meanwhile, bona fide science is being impeded. All this might sour a raft trip, so we pass by the nautiloid site without me commenting. Aside from this business, there is only one more sour spot ahead today; the rest is glorious.

The Pilgrimage continues

For the next four miles, we pass down and down through the Redwall. It is not only the thickest layer we have encountered but also the most homogenous and certainly the narrowest gorge since launching. Finally, it starts widening a bit. After we pass the famous Nautiloid Canyon with its campsite probably occupied every night during raft trip season, we note a small open cavern the size of a closet high up the right wall that is filled with giant crystals of calcite. These might be in a museum if they could be reached (Fig. 10.3).

Fig. 10.3 Giant calcite crystals growing in a small cave. The largest ones here are about a foot long.

The answer to why they are here and not in every cave demonstrates another important principle of geochemistry. Ground water can dissolve limestone until it is so full of dissolved carbonate that it can't dissolve more. Chemists say it is then "saturated with respect to calcite." This is the standard condition of small cavities in limestone unless the flow is constantly being supplied with fresh ground water before it reaches saturation. The cavity slowly enlarges as more and more of the wall rock dissolves into the throughgoing ground water. If the flow is slow enough, the water in a cavity becomes saturated from wall rock

dissolution. At that point, the rate of dissolution equals the rate of precipitation. The cavity will cease enlarging and calcite crystals will grow. Some will become bigger than others. They cannot dissolve as fast as the small ones and start dominating as sites of precipitation. Big crystals grow at the expense of smaller ones, including the small ones in the limestone itself. That is what happened here. Part of the wall fell off here and exposed a cavity that had very little ground water flow through it. These big crystals were happily growing in it until the spall off the wall drained it.

After marveling at these crystals, we next encounter oval-shaped caverns standing side by side amidst ragged, highly weathered limestone. To the right of this striking part of the Redwall, caverns have connected leaving only an arch spanning a small side canyon. The famous Kolb brothers on one of the earliest trips through Grand Canyon named it the "Bridge of Sighs" because it reminded them of that famous arch in Venice (Fig 10.4).

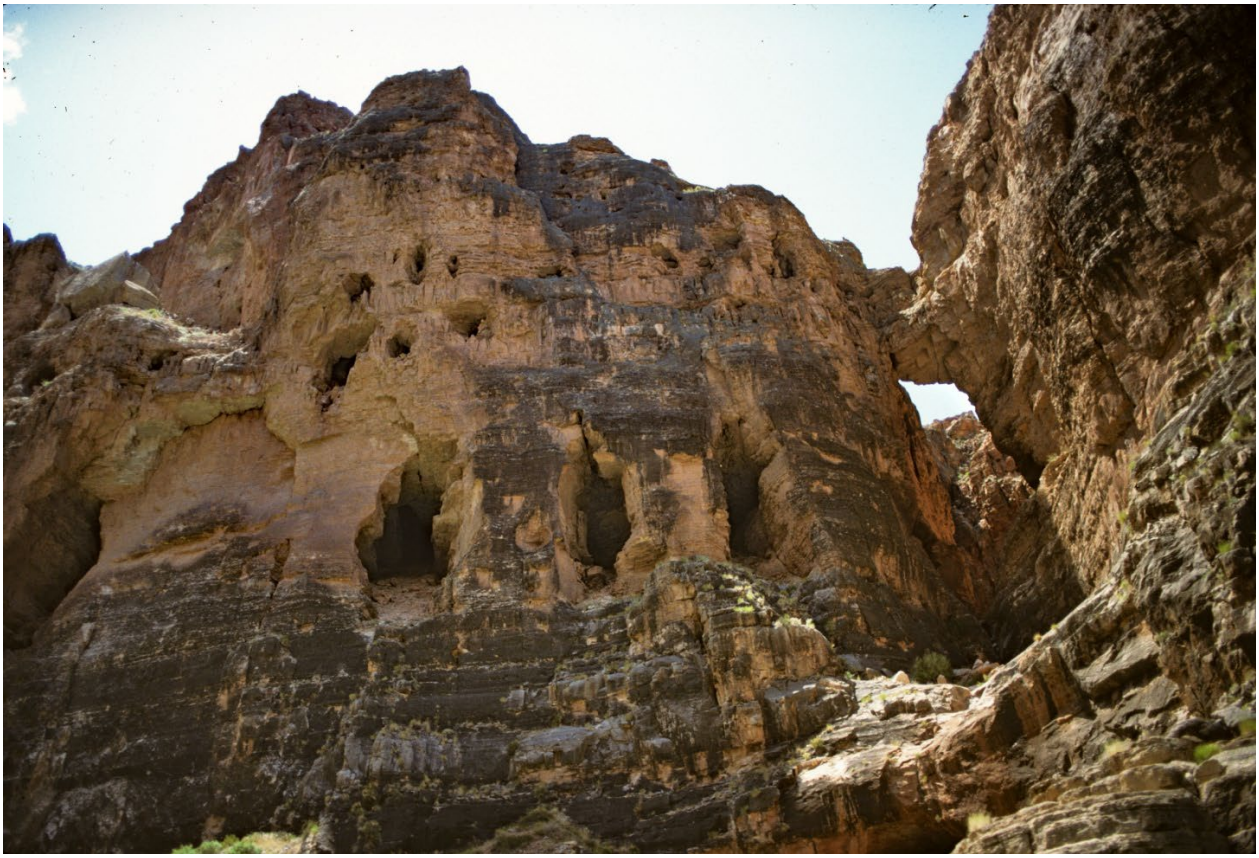

Fig. 10.4. Caves in the Redwall Limestone and the "Bridge of Sighs." An aquifer once filled these caves and drained out after the river cut down through them. The original cave network could date back to the great sea level drop at the end of the Mississippian. Some have argued that the river itself helped dissolve out the caverns while others suggest ground water flow was enhanced by more extensive fracturing in this area. Erosion has stripped away over 2,000' of strata in a small area above the Redwall Limestone here. Another cave like those in the center was under where the bridge is now. It extended far back behind the cliff face. A small gulley had developed directly above this cave. The cave roof collapsed about 100 yards behind the wall causing runoff to funnel down into the cave and then via cascading waterfalls into the river. The bridge is the last roof remnant.

All this dissolution internal to the Redwall signifies an exhumed, drained limestone aquifer now being unroofed for all the world to see. What enormous amounts of ground water flowed through here before the river breached downward and drained these subterranean water courses!

We are in hot afternoon sunshine here, and the rapids are mere riffles that throw very little cold water up to cool us. It is easy in the blinding light to miss the appearance just above river level here of some resistant gray ledges. They comprise an altogether different geologic unit underneath the Redwall and are now making a slow, silent appearance. Unlike the Redwall which is mostly limestone, these are beds of dolomite now emerging. I do not say anything here about the new layers because a shady amphitheater awaits us just downriver. A remarkable lens shaped patch of gnarly, chewed up rock about half a football field long now appears on the left wall sandwiched between the familiar Redwall and this new layer. A few people notice and start asking. Good, because along this stretch an example of one of the greatest themes in geology presents itself like a diagram in a textbook. A mile more and we pull in on the right and climb up into the best shade spot in the Grand Canyon.

Until this place at mile 39.2 called “Redbud Alcove,” we have been descending through a stack of layers that were deposited almost continuously one upon the other. Yes, there was a major emergence of the Redwall at the end of its deposition before the seas returned to deposit the Supai. And then, there are the Coconino desert or coastal sands which signify an interruption to the great, overall subsidence of this entire region that yielded the Redwall, Supai, Hermit, Coconino, Toroweap, and Kaibab formations we just descended through. The scenery has not changed that much with the arrival of these new dolostone beds. Indeed, without someone pointing out the geologic sleuthing that has been done here, you would just assume it is some strange aspect of the Redwall. A person travelling on a recreational raft trip might not even notice. However, with knowledge of a few technical details and the regional geology, one can float along here aware of vanished worlds.

The dolomite of the little ledges peeping out under the Redwall about a mile back reappear and become vastly thicker and more homogeneous farther downstream as a major unit known as the Muav Formation. Fossils in it are decidedly Cambrian age! This is astonishing, because fossil correlations worldwide indicate that the Cambrian in this area is older than 500 million years while the Mississippian Redwall Limestone is no older than about 350 million years. Passing immediately down into the Muav Formation is thus a step in time of about 150 million years, an immense interval of time far longer than any we have encountered so far in our layer-by-layer descent into the Earth. It puzzles us more as we climb up into the amphitheater with its welcoming, cool shade. For here, sandwiched between this old Muav Formation and the younger Redwall is a wedge of carbonate like the gnarly one we just saw in the canyon wall to the left. Ledges of this indescribable formation in this amphitheater make convenient classroom seats. The overhanging alcove is a slot of deep blue sky splitting the cathedral dome into two sections. Small clumps of deliciously green redbud trees sweeten the view and contrast with the layered chaos we are sitting on. The smooth gray Redwall cliff reaches down

from the sky and passes with sharp discontinuity into this convoluted layer that is so fraught with chaotic, clay-filled honeycomb-like features (Fig 10.5).

Fig 10.5 Peculiar layer of Devonian Temple Butte Limestone in Redbud Alcove at mile 39.2. Note person sitting on ledge in lower right for scale. The base of the Redwall Limestone stretches across the topmost part of the image. The peculiar nature of the top of the Temple Butte may have developed here during episodes of deep weathering of several layers shortly after they were individually deposited, an underappreciated process common throughout the original deposition of many Grand Canyon strata.

The ledges we are sitting on are a mottled confusion of gray, purple, and white swirls. It is mostly dolostone, but plenty of rusty iron-bearing clay minerals are embedded in the muddle.

I am expected to explain the crazy goings on here, including what redbud trees are doing in the arid Grand Canyon. Clearly, this cool retreat never gets the blazing sun, and the water trickling down one of the walls shows that it rarely dries out here. But how did these trees characteristic of cooler climes get here? The guidebook story is that they became established during the last ice age when it was wetter and cooler here and then held out in this protected refuge when the climate became warmer and drier. Sounds good, but an alternative possibility is that pollen travels great distances in high winds and some derived

from far elsewhere could have fallen in and thrived here. Redbud trees grow in other side canyons not too far away. However, I am more concerned with the bizarre sedimentary layer before us.

The guidebooks note that this is the same material as found in the large, lens-shaped rocks we saw on the walls of the river as we arrived here and will see for the next mile or two. Channels, they say, that were cut into the Muav Formation. They sure look like it. But what is the age? Alas, there is little chance for fossils in this jumbled layer that looks like it got churned by a mix-master. However, isolated lenses of this turn into a continuous layer that thickens as it extends westward. It will be too high up on the walls once we leave here for us to examine, but at the west end of the Grand Canyon it is exposed at the Grand Wash Cliffs in road cuts you can drive a Mercedes through. There it is a great-looking limestone called the Temple Butte Formation with nice Devonian-aged fossils. This is the period immediately preceding that of the Redwall, so seeing it here directly under the Redwall makes sense. But under the Devonian elsewhere in the world, we find strata of Ordovician and Silurian age. To the west in California and to the east in New Mexico, the whole buffet is present in a nicely stacked sequence: Cambrian overlain by Ordovician overlain by Silurian overlain by Devonian overlain by Mississippian. So why not here in northern Arizona? It is not actually that rare for this to happen. The contact where missing strata occur is called a “disconformity” or “unconformity.” The awkward term distracts from the profound significance which suits it. It is like peeking into the pages of a thick dictionary lying on its side and discovering that sections for letters L to P are missing. Is it a printing goof where they were simply left out, or did someone tear them out? A simple answer here is that unlike California or New Mexico, northern Arizona was pushed up from below at the end of the Cambrian and was a land area throughout the Ordovician and Silurian---printing goof. Or maybe both were deposited and then the local region was uplifted which allowed them to be eroded away---pages torn out. Just looking at a spot where the Redwall lies on the Muav, there is no way to readily choose based on what we see. But here in our shady classroom, what about the appearance of this wedge of Devonian that will only thicken and turn into a normal looking limestone farther to the west?

The stratigraphic goings on here are like those observed in many places around the world. The simple interpretation any geologist would make is that Ordovician and Silurian strata were likely deposited here at the same time they were accumulating in New Mexico to the east and California to the west on top of a crustal region that had been subsiding since the beginning of the Cambrian. After whatever Silurian strata had been deposited, a tectonic block underlying northern Arizona tilted eastern side up. As the land rose east to west, it was eroded down into the underlying Cambrian Muav formation. The tilting ceased and subsidence resumed allowing the Devonian Sea to encroach west to east again over the slightly tilted erosion surface. The river here has cut down into a section where the sea was filling river valleys cut into the uppermost Cambrian strata during transgression of the Devonian Sea.

The missing interval here tells us a story of past uplift, erosion, and vanished worlds. The story may be even more complicated. To the southeast of this place about 150 miles, Pennsylvanian strata are deposited directly on Precambrian rocks at Christopher Mountain located 17 miles east of Payson. My field school mapped where the strata butted up against it and confirmed that this was a mountain in the Paleozoic Sea at least through Pennsylvanian time. The sea ate at it from several directions to leave a nice apron of stacked Cambrian through Pennsylvanian seashore deposits. It is a mountain of 1.7 billion-year-old quartzite, one of the toughest rocks in nature. It finally got buried by Permian sediments. It stands today in the sunshine again while the strata that lapped up against it are being stripped away by modern erosion following regional uplifts that started about 55 million years ago. It used to stand like a monument over the summer field geology school I taught for 16 years along its northwestern flanks. Is it the oldest mountain in the world--one that stood, got buried, and rose into the sunshine again? Maybe. I think about it as I look at these Devonian channel-fills we just floated past. It may mean that there are similar remnants protruding up through the Paleozoic only isolated and behind the walls of the present canyon. Or not. There are not enough deep river gorges, drill holes, or seismic surveys to know. There probably never will be. West of here the Ordovician and Silurian are clearly missing along the river course all the way to where it bends south to flow toward the Gulf of California. On the walls at this spot, we see with startling clarity the recorded interplay between interrupted subsidence, tectonic uplift, and renewed subsidence that then lasted 150 million years. This area of the continental crust bobbed down, up, and back down again during the Paleozoic time interval in which the strata before us were deposited. Recognizing that the speed of all this is no faster than fingernails grow yields feelings of what “deep time” means. So here in the cool shade people listen and some look at the diagrams in our river guidebook struggling to make sense of it. A few geologist participants seem nonplussed, but I do see a few people talking and pointing and staring in wonder. Maybe they are sensing the enormity of time that only something like this can provoke? I too get a few chills when witnessing such direct evidence of past tectonic events. Then someone rightly breaks the spell and asks, “So what about the crazy jumbled nature of this thin sliver of Temple Butte channel-fill we are sitting on? Are these current deposits in an ancient channel?” I point out that they show no obvious crossbeds or other evidence of having been deposited in the strong currents of a channel.

JP Running is sitting up high on a ledge above and behind everyone listening to my spiel. During his several hundred trips down the river, he has heard many geologists expound on this. It seems most of them talk about the Temple Butte and the missing time and struggle to explain the honeycombed, variegated textures all around us. But some do, so I ask him to tell us all what various stories he has heard here. Some of them sound pretty good, but after each I point out some aspect that I suggest remains unexplained by it. At last, I must confess I do not know either but that I would be willing to bet this is a limestone that was deposited and then subjected to deep weathering--yet another paleokarst. We know that sea level rise and fall over a coastline is not likely to be a continuous process, so we can expect interspersed

retreats where what was deposited was then exposed to the ravages of rains and runoff. I offer that the Temple Butte was laid in here onto an eroded landscape and then weathered. Not once, but in several transgression-regression events before the final transgression that deposited the Redwall. These layers were once soupy marls penetrated by roots that left the honeycomb appearance at various levels. Indeed, the strange appearance of these layers is markedly like the exposure at the top of the Kaibab Limestone where I sat in upper Cathedral Wash 3 days ago. Others are free to suggest that these are lungfish burrows, channel deposits, or whatever. Let multiple hypotheses thrive. Unfortunately, the only time anyone can study this peculiar deposit is on brief stops on trips like this. So, we must leave it at that at get on to a campsite.

Before leaving, I tell the story of how we once came into this amphitheater and found a group of Buddhist Monks making deep, continuous, resonant "Om" sounds. When a certain frequency of Om was sustained in this particularly acoustic, a rock or two would vibrate off and bounce down one of the steep rock walls. People think I am pulling their leg, so I challenge everyone to join in a synchronous Om. I conduct the affair like Herbert Von Karajan and try through gestures to adjust the frequency. Suddenly a hand-sized rock comes cascading down the wall from higher up and not far from where JP is sitting--and looking like the cat that ate the canary. See!! It works. People laugh, moan, and accuse me and JP of fraud. It is a difficult accusation to refute.

As people file back to the boats, I am left reflecting that we have been going downward through a series of layers that accumulated pretty much as continuously as strata can accumulate. This area of Arizona was tectonically sagging downward for about 200 million years without much interruption. But now we have descended to stratigraphic horizons predating this mostly continuous sag. Here, the crust was probably bobbing over tens of millions of years like a tectonic cork on the hot chaos deeper down. The Cambrian aged Muav Formation is now emerging out of the river for us and will be our close friend for the rest of the trip. After it was deposited, newer layers were deposited, uplifted, and eroded until the Temple Butte was deposited. If you think about it enough, the missing intervals can inflict a sense of immense time that you can experience no other way. Alas, the strata associated with all this look very similar to the untrained eye. Even to me, the impact is not sustained or deafening. I decide to leave it alone because in few days we will visit a locality where you can walk up a canyon to an exposure where the immensity and complexity of geologic time does impact everyone. There, we will dwell on the issue and reflect on the broader consequences this can have on the deepest levels of the human psyche.

Every mile floating down the river, we descend into deeper levels of the great sedimentary basin that once subsided here. Now it is Cambrian Muav Limestone at the base of the enormous cliffs of Redwall Limestone. Ragged lenses of Temple Butte Limestone appear here and there along the contact, but all three are gray carbonate walls stained red with mud that has washed down from above. At some point going west, the Temple Butte becomes a discrete layer, but the difference in appearance between it and the Redwall is difficult for me

to see, much less point out to anyone interested in tracking the separate layers as we float along.

Although we are now racing to secure a good campsite, the boatmen suddenly kill the engines to float silently amidst shadows now filling the entire gorge. Each begins to narrate the alarming story of how a giant dam was almost built in this stretch right here just upriver from Buck Farm canyon. Several small gray debris tongues issue from the mouths of clearly manmade holes drilled in the walls and drape over the natural talus piles. Engineers spent months in the 1950's drilling here and probing the nature of the rock walls that the dam would fit against. Three or more dams were planned by the Bureau of Reclamation to tame the river and make a series of lakes that would accumulate water to supply the growing population and to generate hydroelectric power. There were even proposals to dig an enormous tunnel from here all the way to the west end of the Canyon that would shoot high pressure water through turbines to spin out vast amounts of electricity. A public relations campaign was mounted showing bikini clad damsels water skiing in the Grand Canyon. It was the uninformed days of "Man against Nature" where the land was to be used to the maximum extent possible for economic development and nothing else. Yes, the walls of the canyon are pervasively fractured and much of the water behind a dam would simply disappear into the ground to become unused ground water seeping northward down the slope of the strata under the Colorado Plateau. Nothing mattered except getting it built. Few people were even aware of the scenic and spiritual treasures that would be forever lost.

Hearing about this is shocking enough, but to hear about it while immersed in this late afternoon splendor casts a pall over our little group. How close we came to never being able to see all this harrows up our souls. Then we hear the story of how David Brower and the Sierra Club mounted one of the first-ever battles to preserve a national treasure under attack from developers. The highly effective claim that a lake would allow everyone to see up close the walls that were now impossible to access was countered by an extraordinary ad in the New York Times and Washington Post asking if we should flood the Sistine Chapel so people could float around to look closer at Michelangelo's immortal paintings on the ceiling (Fig. 10.6).

SHOULD WE ALSO FLOOD THE SISTINE CHAPEL SO TOURISTS CAN GET NEARER THE CEILING?

EARTH began four billion years ago and Man two million. The Age of Technology, on the other hand, is hardly a hundred years old, and on our time chart we have been generous to give it even the little line we have.

It seems to us hasty, therefore, during this blip of time, for Man to think of directing his fascinating new tools toward altering irrevocably the forces which made him. Nonetheless, in these few brief years among four billion, wilderness has all but disappeared. And now these:

1) There are proposals *still* before Congress to "improve" Grand Canyon. If they succeed, two dams could back up artificial lakes into 93 miles of canyon gorge. This would benefit tourists in power boats, it is argued, who would enjoy viewing the canyon wall more closely. (See headline.) Submerged underneath the tourists would be part of the most revealing single page of earth's history. The lakes would be as deep as 600 feet (deeper for example, than all but a handful of New York buildings are high) but in a century, silting would have replaced the water with that much mud, wall to wall.

There is no part of the wild Colorado River, the Grand Canyon's sculptor, that would not be maimed.

Tourist recreation, as a reason for the dams, is in fact an afterthought. The Bureau of Reclamation, which has backed them, calls the dams "cash registers." It expects they'll make money by sale of commercial power.

They will not provide anyone with water.

2) In Northern California, during only the last 115 years, nearly *all* the private virgin redwood forests have been cut down.

Where nature's tallest living things have stood silently since the age of the dinosaurs, there is, incredibly, argument against a proposed park at Redwood Creek which would save a mere 2% of the virgin growth that was once there. For, having cut so much and taken the rest for granted, the lumber companies are eager to get on with business. They see little reason why they should not.

The companies have said tourists want only enough roadside trees for the snapping of photos. They offered to spare trees for this purpose, and not much more. The result would remind you of the places on your face you missed while you were shaving.

3) And up the Hudson, there are plans for a power complex —a plant, transmission lines, and a reservoir near and on Storm King Mountain—effectively destroying one of the last wild and high and beautiful spots near New York City.

4) A proposal to flood a region in Alaska as large as Lake Erie would eliminate at once the breeding grounds of more wildlife than conservationists have preserved in history.

5) In San Francisco, real estate interests have for years been filling a bay that made the city famous, putting tract houses over the fill; and now there's a new idea—still more fill, enough for an air cargo terminal as big as Manhattan.

There exists today a mentality which can conceive such destruction, giving commerce as ample reason. For 74 years, the Sierra Club (now with 48,000 members) has opposed that mentality. But now, when even Grand Canyon is endangered, we are at a critical moment in time.

This generation will decide if something untrammelled and free remains, as testimony we had love for those who follow.

We have been taking ads, therefore, asking people to write their Congressmen and Senators; Secretary of the Interior Stewart Udall; The President; and to send us funds to continue the battle. Thousands *have* written, but meanwhile, Grand Canyon legislation *still* stands a chance of passage. More letters are needed and much more money, to help fight the notion that Man no longer needs nature.*

David Brower, Executive Director
Sierra Club
Mills Tower, San Francisco

- ☐ Please send me more details on how I may help.
- ☐ Here is a donation of $_____ to continue your effort to keep the public informed.
- ☐ Send me "Time and the River Flowing," famous four color book which tells the complete story of Grand Canyon, and why T. Roosevelt said, "leave it as it is." ($25.00)
- ☐ Send me "The Last Redwoods" which tells the complete story of the opportunity as well as the destruction in the redwoods. ($17.50)
- ☐ I would like to be a member of the Sierra Club. Enclosed is $14.00 for entrance and first year's dues.

Name_____

Address_____

City_____ State_____ Zip_____

*The Sierra Club, founded in 1892 by John Muir, is nonprofit, supported by people who, like Thoreau, believe "In wildness is the preservation of the world." The club's program is nationwide, includes wilderness trips, books and films—as well as such efforts as this to protect the remnant of wilderness in the Americas. There are now twenty chapters, branch offices in New York (Biltmore Hotel), Washington (Dupont Circle Building), Los Angeles (Auditorium Building), Albuquerque, Seattle, and main office in San Francisco.

(Our previous ads, urging that readers exercise a constitutional right of petition to save Grand Canyon from two dams which would have flooded it, produced an unprecedented reaction by the Internal Revenue Service threatening our tax deductible status. IRS called the ads a "substantial" effort to "influence legislation." Undefined, these terms leave organizations like ours at the mercy of administrative whim. [The question has not been raised with organizations that favor Grand Canyon dams.] So we cannot now promise that contributions you send us are deductible—pending result of what may be a long legal battle.)

Fig. 10.6. One of several ads run in the New York Times and the Washington Post in June, 1966 to mount public support for the Sierra Club's campaign to stop the dam planned for Mile 40.5.

The campaign cost the Sierra Club its tax exemption but was remarkably successful. A general uproar started to stop the dam builders before all was lost. The upstream Glen Canyon dam could not be stopped, but the menacing Marble Canyon Dam at this spot did not happen. Plans to build a third, the so called "Bridge Canyon" dam farther downstream, were shelved but not abandoned. As recently as the early 1980's the dam builders pushed it again to no avail. It will come up again as the water demand grows, but every raft trip pauses at this spot with its drill holes, rusty cables, and piles of steel junk to remind us that the threat is never ending. And it is no longer just dams—now noisy helicopter rides, airplane rides, skywalks, gondola rides, and who knows what may erupt at any time, including on the Indian Reservations that border so much of the river and need revenue.

We pull in for camp at fully shaded Buck Farm Canyon at mile 41. People quickly find places to pitch tents because a strong upriver wind has started blowing. Someone jokes that this is happening because upriver Utah sucks. I am a little apprehensive and follow one of the hacked-out pathways going into an immense thicket of intergrown tamarisk trees to look for a wind-protected sleeping spot. Before long, this entire camp area is going to be choked out of existence as this non-native vegetation spreads like wildfire along the riverbanks. Several sites downstream that we used to camp at are now completely overgrown. With likely unintended consequences, a species of beetle that feeds on the leaves was introduced to turn the thickets into dead clumps that will eventually decay away. This clump is still thriving, and I quickly find a cubby hole someone hacked out deep in the middle of the tangle. The floor is a nest of interwoven roots, and I am a little nervous about lying amidst this surely snake inhabited spot. I pitch my little tent which has a nice floor, screen sides, and a great rainfly. I will be in a snake resistant cocoon if the winds pick up. And do they ever later that evening!

Meanwhile, several of us scamper over some big rocks carried down Buck Farm side canyon by past debris flows and walk along narrowing ledges of Muav Limestone projecting out from the walls. Unlike the Redwall, the Muav ledges are very knobby and mottled from innumerable burrowing organisms that seemed to have digested and excreted the whole sea floor repeatedly. The side canyon narrows, the ledges get smaller, and we find ourselves finally threading along the sides of an ever narrowing slit with a deep drop below us (Fig 10.7).

Fig. 10.7. An easy hike up Buck Farm Canyon finally comes to this. Time to do dangerous side-stepping or sit on ledges of the Cambrian Muav Formation and have your picture taken.

People take photos of themselves in explorer poses that look more dangerous than they are. Well, maybe they really are dangerous. We return to camp to study a most splendid exposure we noted casually as we pulled in to camp. It is a Temple Butte lens on the far wall of the river sandwiched between our knobby Muav layer and the smooth walls of the Redwall Limestone above (Fig 10.8).

Fig. 10.8. Canyon wall across from mouth of Buck Farm Canyon showing right side of small valley or channel in top of the Muav Limestone filled with thin layers of Devonian Temple Butte Formation draping down from the right. The massive Redwall Limestone sits above both. The difference in age here between the Muav and the Redwall is about 150 million years. The time interval between Temple Butte and Redwall is vastly shorter but not confidently known here.

A giant boulder of Redwall with rows of gorgeous agate-like chert nodules lies along the shoreline. Several of us take off our footwear before it--not in homage but to feel the soothing wet cool sand squish through our toes as we admire the beauty of the shiny chert and discuss more deeply the origin of chert in limestone. The Grand Canyon is full of unusual classrooms.

Wind gusts pick up alarmingly shortly after dinner. Everyone hunkers down in various wind shadows around camp to consider options where there are none. As twilight and clouds set in, there is no magic this evening. A dome tent suddenly goes tumbling along in a blast of sand. People scramble to retrieve this quivering hut as it bounces along. Others run off to put more rocks into their tents. I retreat in this gusty gloaming into my little cubbyhole, climb into my welcoming tent, and stretch out on a spongy pad. The roar of the increasing wind thrashing through the tops of the tamarisk while my tent walls barely ripple generates such a cozy feeling I start to fall asleep fully clothed. It is heavenly music. A phrase from Bunyan's Pilgrim's Progress floats through my fading brain, "…. music in heaven, for joy that I am here." I zonk out until the noisy grinding together of big branches in what must be a hurricane around the thicket awakens me in the darkness. In the background I hear peals of distant laughter from a group that has apparently gone out onto the back of the boats with the crew to carouse in sand-free winds. All must be good, so I just waft off again into curtained sleep. All is not good, however.

At first light, I am up and walk down for coffee in a dead calm. Camp gear is scattered all about with rocks piled on anything that might move. Very few people are awake yet. They were tormented by the flapping, popping, and bending over of their tents for much of the night. I can see a few people climbing out of sand loaded tents trying to brush off every place sand could possibly collect on a human body. I feel guilty because I slept like a baby through the whole furor. Remarkably, spirits are high because it is such a beautiful sun-shiny calm cool morning. Everyone has survived what JP later tells us is the most ferocious windstorm he ever encountered or heard about in all his years on the river. Now all have a great memory and story to tell about the Great Buck Farm Windstorm. But alas, a giant tarp used to cover the duffel pile has simply vanished. We cannot find it anywhere and conclude it has blown into the river and sunk. For the rest of the trip, one boat motors on without the final tarp that covers the duffel pile. It all turns into a great story when a Hatch boat later in the day finds a Hatch tarp swirling in a back eddy vortex downstream of Buck Farm. Of course, we are by then well down river and there is no communication between boats. The tarp finders become alarmed at the appearance because it gives a primordial impression that the boat sunk in a whirlpool leaving only the tarp behind. However, the windstorm happened all along the river, so the initially concerned discoverers correctly surmised what happened when no additional debris was spotted. For me personally, falling into blissful sleep in a tamarisk thicket during such a storm was no big deal. To experience the profundities of geology and the history of the Earth, it is imperative to get thyself into the field where adventures are inevitable. A tamarisk thicket can be a good thing.

Travelling downward into the Muav Limestone opens a great new chapter in the history of life. The mottled, knobby pattern of the Muav formed as sea floor organisms burrowed, dug, munched, and pushed through shell debris to a degree greater than anything we have seen so far. The area was absolutely seething with life, yet fossils rarely survive this eat-and-get-eaten lifestyle. Any shell or shell fragment is quickly torn apart and gobbled up. The organic goodies

get digested, and any shell residue gets excreted and eaten again. Thus, although we do not see shells, the intense burrowing is strong evidence of abundant life in the sea at that time. Rare fossils in the Muav that have been found correlate with Cambrian aged fossils elsewhere on the planet. We started our raft journey descending through the Kaibab Limestone, the youngest of the Paleozoic group of strata and on day 3 have now already cut down 2,700' into the top of the lowest age group. That the river has only dropped 300' is testimony of how tilted toward us the stack of layers is despite us not noticing it. This will continue for the rest of the day as we float downward through the three distinctly different Cambrian layers beneath us. The story of life in the Cambrian is unique in Earth history. I am itching to call everyone together in this morning shade to start the story about what we think was going on in those days. But soft me now; everyone is getting reorganized, getting high on morning coffee, and trading stories of how they survived a night of rampaging nature. Besides, the story I want to share is not for ears filled with sand. I do not know it as we depart, but this pilgrim is about to stare into blackness this day and become a traumatized time traveler.