Chapter 5 **PAST WORLDS ONE BEFORE ANOTHER** *Lees Ferry to mile 7.5*

Hatch River Expeditions boatman John Paul Running is leaning back against the silver front of one of the two giant, pontoon boats beached on the gravelly launch ramp at Lees Ferry. He is instructing 27 attentive people about where it is safe to ride and what they "probably don't want to do on the boat" while floating down the river for the next eight days. His modest demeanor cannot conceal the tremendous authority, experience, good will, and wisdom he will demonstrate throughout this adventure of a lifetime for the eager participants (Fig. 5.1).

Fig. 5.1. Living legend, John Paul Running. Masterful boatman and river guide for Hatch River Expeditions. All who take commercial, charter, and research trips on rafts through the Grand Canyon are dependent on and grateful for the extraordinary skills, knowledge, experience, and hard work of river guides like "JP." Commercial boat companies make it possible for about 22,000 people a year to safely have the unique, fun, inspirational, and often life-changing experience a raft trip can offer.

Of the 31 previous raft trips I have done with Hatch River Expeditions, JP has been my head boatman for at least 26 of them. I have watched him develop for three decades into a river legend amidst crises and situations most of us would be helpless in. Tough is an inadequate word to describe him when the going gets rough, but he is also an inexhaustible fount of humor and serious knowledge about the Canyon. Some people learn semi-real geology from

books and professors strutting their hour upon the stage; JP has learned the real deal mostly from keen and relentless observation.

I know the orientation speech in all its variations by heart, so I size up the group standing there so cleanly shaven, in fresh new clothes, new river sandals, excited, and somewhat apprehensive. They are the usual mix of adults of all ages and walks. Every one of them has an amazing story, and I often find it out after they loosen up amidst the spell of the Canyon. My group met last night in the Hatch Warehouse about 15 miles to the west. Everyone introduced themselves and confessed what brought them to this trip--sort of like what probably goes on at a group therapy session. I always try to infuse a culture that we will learn something about the history of nature while enjoying and safely experiencing the adventure of a whitewater raft trip. I did not tell them that while this is going to be my 32nd public outreach trip for Arizona State University, it is my first trip where I am going to release internally and try to recognize, immerse, exult, and articulate on the Mount Everest summit of messages the Grand Canyon delivers. As always, I will still try to open their minds to what the canyon walls are saying about the actual history of nature. This time I do not care if my own yearnings and passions spill out. For now, the participants have set aside their daily grinds and cares and are lined up for a new kind of experience. I love all these people. Talk about politics, prejudices, or ugliness is always superseded by River Wonderment, an existential condition Sartre never wrote on.

With all the anticipation and excitement about going rafting, this is not the time to point out the amazing geologic story here at Lees Ferry. On several previous of my charter trips, those interested could come up a day early to look around here with me and then drive up to tour the Glen Canyon Dam. The big monocline encountered on the drive here at Cedar Ridge comes right through this spot; its bending down of the strata is why the boat launch is here. Looking west, the Vermillion Cliffs form the northern skyline. The colorful strata are the Chinle Formation with the thick beds of the Navajo Sandstone on top. Between those cliffs and the Echo Cliffs is a huge expanse of strata that was eroded away by the Colorado River. The layers are currently being washed down numerous side canyons to the river and carried toward the Gulf of California and the Pacific Ocean. Rising immediately just northwest of the parking area is a steep gray ramp most river runners ignore because of the tension and excitement of their upcoming adventure. Those with time to kill can go over and walk up it over a layer of naturally cemented-together river cobbles. These cobbles have nothing to do with the current river but are fast-moving channel deposits that existed here during the Triassic about 230 million years ago. They actually form a sheet that extends over much of northeastern Arizona and the whole Four Corners area (junction of Arizona, Utah, Colorado, and New Mexico). It is at or near the base of the Chinle Formation and is called the “Shinarump Conglomerate” famous for its uranium deposits that were much prospected for to build atomic bombs after WWII. Exactly how conglomerate channel deposits assemble into a regional sheet is not easy to understand. Migration of meander loops of a huge ancient river can do this, or the area may have been a

huge plain of channels all braided together as they accumulated from long mountain fronts that retreated as they were worn away. This is happening on a smaller scale along mountain fronts in Death Valley today. Figure 5.2 is a view of the boat launch area coupled with Figure 5.3 that gives labels for the Shinarump Conglomerate and an indication of the monocline that goes through the boat launch area.

Fig. 5.2. Looking west over Lees Ferry area. The Navajo Sandstone makes up most of the cliff forming the skyline. The lower brown cliff more toward the foreground and running horizontally across just above center is part of "The chocolate Cliffs" capped with the Shinarump Conglomerate overlying the Moenkopi Shale. The boat launch area from which all raft trips start is immediately to the right of the center. See Fig. 5.3 for a few labels.

Fig 5.3. Lees Ferry area same as Fig. 5.2 but featuring the Shinarump Conglomerate (S) that the river slices down through here. The arrows indicate how all the strata begin plunging downward just west of the boat launch. The rightmost arrow lies on top of the Shinarump ramp as it plunges down eastward. A cross section of this monocline just to the left of the image is shown in the lower left corner of Fig. 4.3. After a mile downstream, the strata are largely west of the monoclinal fold but appear almost horizontal when viewed from the river. Strata in this region not folded into monoclines slope gently to the northeast up to about 10 degrees.

The arrows show how this almost horizontal layer plunges downward as it passes west to east through the boat launch area. The fold axis of this second great monocline coming east off the Kaibab Uplift runs right through the Lees Ferry area. Strata to the east of here were brought structurally downward and the fold axis is being eroded out to make this vast open area—which is why it is possible to drive down to the river here. We will encounter another example of such erosion in a few days when our generally westward journey crosses the great monocline that defines the eastern side of the Kaibab Uplift.

Our two boats launch, and we immediately start motoring down into the top of the great pancake stack of Paleozoic sedimentary layers illustrated on the bandana (Fig. 3.3). The nearly horizontal strata west of this locality are actually slightly toward us. We thus progress down through them at a much more rapid rate than would occur if we were relying only on the

descending elevation of the riverbed as it cuts down through the layers and into the underlying tilted layers and "crystalline rocks." In fact, we will descend only 1,500 feet in elevation while traversing through 10,000 feet of rock layers and back over a billion years into deep time. The tilt is not very noticeable, and progressively older layers seem to rise imperceptibly out of the river as we cruise along. A reverie is to be had about a seashore environment or landscape that once existed right here in Northern Arizona for every new layer or protruding ledge that so appears. There are past worlds ahead, many with an astounding array of organisms that once lived and flourished and then died out with their lineages never to be seen again. For these participants, I will try to tease the extinct organisms back to life through the wonders of geologic science and human imagination. For myself, I will ponder it all in the context of a consciousness that arose out of life's long evolutionary progression and is now wondering what to make of it on this bank and shoal of time. All must be inferred from degraded tracks, trails, and fossils supplemented with inferences from mineralogy, geochemistry, and regional geology. This raft trip is an opportunity to look closely at the wake left by this historical ship of reality, make some deductions, and get jostled around in modern turbulence. The first opportunity whizzes by as we pass an extraordinary close-up of the almost white paleokarst at the top of the Kaibab Limestone overlain by the dark brown Moenkopi muds (Fig 5.4).

Fig 5.4. Contact between the light gray Kaibab and reddish-brown Moenkopi Formations on south side of the Colorado River ¾ mile downstream of the raft trip boat launch at Lees Ferry. The strata are very noticeably tilted upstream because the river is here cutting down through the axis of the Echo Cliffs Monocline (Fig 4.3). The sloping Kaibab ramps up and becomes almost level within 2 miles downstream. It then rises again to top the Kaibab Uplift visible along the skyline over 30 miles to the west. The white, fretted topmost zone of the Kaibab layers here is consolidated paleokarst rubble. The great End-Permian mass extinction occurred in the time interval between and possibly during formation of the paleokarst. The Moenkopi has been eroded off the Kaibab over much of the Grand Canyon making this an exceptional exposure.

There is no chance to bring this one to life for the group; we will not see it again because the Kaibab quickly rises to form the skyline for the rest of our raft trip.

Exhilarated screams erupt as cold water splashes up during our swift, bouncy traverse of the Pariah rapid. Well…er… the Pariah *riffle*--but let us not disclose the cold-water splashes to come when we encounter the REAL rapids. The boatmen point out the vanishing wagon road cut into the south wall by Mormon settlers in the 19th and early 20th centuries. People strain to

see graffiti on the rocks made by the Saints as they waited for the rope-powered ferry raft to cross the river. Meanwhile, the epoch of the dinosaurs is way above us now. Goodbye dinosaurs and Mormon settlers; we are plunging into bottomless time as we start our descent through the 250-million-year-old Kaibab Limestone.

After floating for less than three miles, I ask for the boats to pull in on the right bank at Cathedral Wash, the first notable side canyon. It is the very one whose upper reach I sat in yesterday atop the Kaibab Limestone, but now here we are near the bottom of this thick gray layer. We have descended through the numerous rough-edged ledges of nearly horizontal internal layers emerging as the river claws at the channel walls. All along, the walls are fractured into quite geometric blocks separated by thin vertical openings. Here at Cathedral Wash, rain runoff from the north has funneled down one of these cracks causing it to widen. Blocks and chunks of the torn-off wall rocks have been flung through the gash and out into the river by flash floods from monstrous rainstorms. Being insignificant against the force of the river, most have already washed away. The water surface erupts into small standing waves as it flows over the diminishing boulder pile. Subsequent rains have sent enough water down the slot to carve right across the big pile of rubble along the shoreline where the debris flows exited. We land just downstream of this mound and hike back up over it and down onto the carved-out gravelly floor of this remarkable side canyon.

Within a few steps, we encounter a telling sight where recent erosion has cut down between the bedrock wall and the heap of rubble that piled up against it. On our left side, we see a cross section of the sand and rubble. We will later pass innumerable piles of this same kind of material on both sides of the river, so it is good to have this one right off the bat displaying its jumbled innards for all to see. The most striking feature is the set of long roots that grow not just straight down but in long horizontal vines emerging and reentering from the wall eroding to our left. They hang down like slack ropes. People do not get to see root networks partially hanging in the air very often, so the tangle is surprising. A cross section of the hard, ancient Kaibab Limestone bedrock stands on the other side of the slot we are entering. Rain and heavy surges of runoff have exposed a thing of wonder in this otherwise drab and unexciting rock wall. It is a pattern of intertwined rock fingers and stringers once lost in the matrix of the rock mass but now eroding out such that you can run fingers along and feel them. They look exactly like many of the modern roots sticking out and running along the other side of the wash, but these are solid features etching out of the stone itself! It does not take much reasoning after comparing both sides of the wash to deduce that these are fossil root patterns of plants that once grew here as the original limestone was being deposited. They grew here 250 million years ago and left hollows in limy sand after they decomposed. By analogy with roots growing today on islands in the Bahamas, decaying roots become infilled with finer particles and the whole lot transforms into stone during burial. Here, modern dissolution of the limestone wall surface in rainwater is preferentially removing the slightly

more soluble portions and revealing the original pattern of these 250-million-year-old roots! Rotating your head sideways from the modern example in the rubble just across the narrow wash back to the ghostlike fossilized version is something you will never experience in a textbook or panoramic photograph. It is a confrontation with how geologists use the present to infer the past. It is a tangible confrontation with Earth history. Here are fossils of a surprising sort—fossil roots. An eyeball view up toward the sky from the modern roots shows greenery above projected into white, baby morning clouds fluffing up into a deep blue sky. A mind's eyeball looking upward from the stone ledge on the other side envisions a Permian version of the same thing--only the plants are different, and the clouds can be anything you want. I envision a billowing thunderhead about to unleash a torrent on my 250-million-year-old fantasy plants. But the reverie I try to transmit to the group must end because people are now confused about whether this is an ocean deposit or a land deposit. Well, it is both, so I lead them up the wash for an explanation in the shade after we do a bit of boulder climbing. This rock scrambling will also calibrate me on who can do what on the rest of the trip. I note who and how many had to struggle as we gather up in the deep shade under overhanging rock ledges of this deep slot canyon.

This short hike is more than a calibration. These troops signed onto a geology trip, so it is time to introduce the remarkable story of the carbonate rocks here and those we will encounter ahead. We are now immersed within the rock body itself with all its internal layers and peculiar features freshly exposed by recent flash floods that scoured the walls and kept clean by rainwater streaming down their nearly vertical walls. We are deep below the top surface that was so profoundly weathered and dissolved during the end-Permian karst event that I pondered so intensely yesterday at the Desert View vista point. This will be my first geology talk of many to come on this raft trip. The group gathers up where the slot canyon is widened a bit and most sit on rock ledges sticking out or on the somewhat flat tops of big boulders lying on the dry streambed. It is like the first day of class where the students go silent at once and stare at you wondering what they are in for. I am a bit nervous myself because I do not want to sound too know-it-all and dogmatic about what we will witness on this trip. Most things we will see require a great deal of background knowledge to appreciate, and much of it is highly interpretive and not well understood. The challenge is to emphasize something important that might fire the imagination from what they can actually see. A raft trip through the Grand Canyon is a once-in-a-lifetime experience for most who do one. Handling the interpretative side of a coveted raft trip through the scenic splendors of the Grand Canyon year after year is a tough job—but someone has to do it. So here goes my latest effort. The point of this stop is to encapsulate within 20 minutes how this particular layer of dolostone formed and how it fits into the bigger picture of Earth history. They will see layers of sandstone, mudstone, and carbonate over the next several days. Although each has a unique story and significance, the processes that created the Kaibab Dolostone are illustrative of how carbonate layers form

and how they can vary depending upon their geographic location, climate, and types of organisms present at the time. The story must also illustrate how interpretative geology is. We do not know for certain what happened here, but I can at least propose a reasoned interpretation based on what is known about how carbonate layers form today insofar as we understand it. The analysis will summarize much of what I contemplated in more detail yesterday at Desert View regarding how the Kaibab formed. I begin with the filter feeders and how their calcite shell debris can spread out and often form sand layers or get heaped up into islands by high tides and/or storms (Fig. 5.5).

Fig. 5.5. View of shallow water carbonate deposits forming on the Great Bahama Bank that extends over 81,000 square miles. Vast areas that looked like this extended over Arizona and vast areas of all continents during high sea-level stands of the past. Currents and storms pile up shoals just a few feet deep and into islands that get flooded during large storms. The islands are vegetated and collect rainwater that seeps into the subsurface as it flows back to the seas. Brine pools are left after storm flooding of vast flat areas and also sink downward through the washed-in sediment. If the platform upon which all this accumulates is subsiding, limestone and dolostone like that found in the Grand Canyon can form during burial. The fluids in which shallow water "marine carbonates" form should never be assumed to have been only ocean water!

Then, I explain how that sand can get washed up along coastlines and large islands in vast sheets called “sabkhas.” These dry out in equatorial areas to leave percolating sea water strongly enriched by evaporation in sea water magnesium and sulfate. Stewing in such concentrated fluids often diluted by rains and percolating ground waters moving offshore from islands or land areas, gypsum precipitates as blebs, stringers, and masses shaped like cauliflowers. The calcite sand gets incrementally but pervasively converted in place into dolomite. I pick up some chert nodules eroded off the walls and point out that these are microcrystalline quartz replacements of the original sand and gypsum during this early period of burial. I point to some “cauliflower cherts” on the walls that dramatically illustrate quartz replacement of gypsum (Fig. 5.6).

Fig 5.6. Cauliflower cherts in Cathedral Wash slot canyon. Gypsum blebs and nodules were dissolved, replaced, and infilled with microscopic quartz crystals in the burial slush of a sabkha.

To a geologist, suddenly spotting a cauliflower chert is like getting hit in the face with a wet monkey! Bingo, this was a sabkha with all its paleoenvironmental implications for coastal

accumulation of filter feeder fragments washed in and stewing in sinking pore fluids from evaporating sea water. Look you! This is how you use geologic observations to deduce the past. It is sometimes obvious and easy. Above all, remember that what you see here is hard rock that formed during early burial transformation of loose carbonate sands. It is not a rock layer that formed directly from or in unaltered sea water! Here I could rant pent-up frustrations with certain geochemists and geologists who ignore how chemically and mineralogically changed these rocks are from the original shell material that formed directly in sea water. They repeatedly and regrettably make dubious claims about past ocean chemistry from sophisticated machine analyses of small chips they collected off walls like these or obtained through the mail. But I hold my tongue knowing that disputes and problems with the scientific endeavor can emerge slowly over the next week. Reason and science are the great hopes of humanity, so it is enough to emphasize the most reasonable interpretation while pointing at features easily seen from here. I do conclude with the remarkable story of the great extinction event at the top of the unit which was so gloriously exposed on the left wall as we went screaming through the Pariah riffle. The goal in this slot canyon is to visualize, feel, and hear the ancient ocean waves washing over the reefs, lapping on the shorelines, and washing sand up onto vast sabkhas where it will get transformed into dolomite, gypsum, and chert. Yep, I try to condense and simplify a whole course in carbonate sedimentology into 20 minutes--or less if too many heads with eyes curtained by dark glasses start to droop. Geology talks rarely sink in the way a presenter desires, so much of all this will have to be repeated in different ways when appropriate at future stops. As explained to me when I began my teaching career, “You are pouring water onto dry ground; do not pour so fast that it just runs off.”

The crowd listens to all this with respectful attention. I stand back as people return toward the boat to resume the raft trip they had anticipated. At least one thinks I was passionate about it when she tells me, “I’m not sure I understood all that, but I know it must be wonderful.” I find myself way back bringing up the rear and totally lost in a reverie as I boulder hop past gray ledges with all their subtle features simply shouting out the story. I am not here; I am walking on a Permian sabkha adjacent to a huge expanse of ocean water under a deep blue sky. I go offshore and snorkel amidst colorful fish to look at the fantastic carbonate factory studded with jagged corals, waving forests of white crinoids, and juicy sponges. Tiny shell fragments fall off as sand or get temporarily suspended in the clear water as waves crash over tops of reefs and predators crunch away or peck at the carbonate castles. I emerge back on the beach under a blistering sun and glop through hot slush making up the flat coastal sabkha. White gypsum goo squishes up between my toes. Tiny, hair-thin needles of opal from disaggregated sponges stick in my feet and form an opalescent halo of reflected sunlight. This is a scientifically informed vision of what was likely here in those days. I feel it and exult. However, I suddenly realize that the heat is real because I am now walking over hot sand back toward the boat. The modern sun is already heating up this grand chasm.

As we float along down through the rest of the Kaibab and through the underlying Toroweap dolostone layers that are here almost indistinguishable from the Kaibab dolostone, I have dream after dream passing the thin and thick dolostone layers within these two formations. This was once a long-lived sabkha environment about 250 million years ago here in northern Arizona while it was slowly subsiding. I think back to the vision at Desert View yesterday of the seas progressively pulling off the continent west to east. The shallow water platform environments around the emerging continents were shrinking. Competition between organisms was becoming fierce. Whole ecosystems were getting altered or collapsing altogether. A tipping point was approaching for a probable mass extinction. All this history is around me and palpable as a scientific vision. The uncertainty about whether extinction finally happened from shrinking habitats, volcanoes, an asteroidal impact, a surge of brine back into the sea from some immense inland basin, or some other slow or rapid but catastrophic event hounds me. I am now on the river slowly going backward in time, but the great Permian/Triassic extinction still has me engrossed and perplexed.

"How deep is the river here?" someone asks. I look at the depth sounder that happens to be in JP's motor well for this trip and respond, "13 feet." So lost in deep thought, I almost say, "As deep as our scientifically informed imagination will allow." That could be misconstrued, and nobody likes a smart-ass. The trip is young, and I have a lot of pontificating yet to impose on this group. Meanwhile, the layers are alive in my own mind's eye as never before—but so also is that looming trouble that plagues all who try to deduce natural history. We can never know, so everything I have been thinking and saying about all this could be wrong. Nevertheless, there is truth in nature. We must constantly struggle with our observations and reasoning to deduce it as best we can. Geology is about observing, interpreting, and then dreaming.

We float along under the two big bridges where Highway 89A crosses the canyon. I can see people looking down from the one I walked out on yesterday. This is one of only two places on the raft trip where development and civilization intrude into the Canyon "wilderness." I realize what a distraction such intrusions are when I hope that no one will throw something at us or drop a watermelon. Condors perched on structural beams underneath the bridges stare down on our silver boats as we pass underneath. Do they recognize the appearance of the different-looking rock layer just above river level now appearing to us passengers on the boats? Probably not, but neither do the people on the trip.

The appearance of this new layer indicates our trip has already cut down entirely through the Kaibab and Toroweap dolostone layers into something altogether different. The boatmen point out this layer with thin beds cross slatted across their considerable thickness and tell us it is named the Coconino Sandstone. The slatted beds initially formed on the downwind side of large sand dunes that slowly moved over this spot when it was a land surface or ocean floor prior to deposition of the overlying Toroweap Formation. Sand on the ocean

floor can get piled up into great dunes this size by strong steady currents as found today on the floor of the English Channel, but they are rare. On the other hand, large dunes like these are commonly formed by blowing winds along coastlines and in arid land regions like the Sahara Desert. The deposits above that we have just floated down through were huge accumulations of seashell fragments washed around by a vast shallow sea. So, we might be tempted to argue that our first encounter with a sandstone layer is a place where large amounts of sand were first washed into the area like the English Channel dunes and then got layered over with seashell sands as northern Arizona slowly subsided. However, everywhere in northern Arizona where we get to peek under or drill through the carbonate layers, we find these giant Coconino cross bedded dune sands. This seems too vast an area to invoke an English Channel like depositional environment. An easier interpretation is that the overlying Toroweap/Kaibab sea flooded over a vast desert. Think if the Mediterranean Sea along the north coast of Africa was a shallow-water bank encrusted with coral reefs and their white sand aprons and that sea level rose and flooded the Sahara Desert to the south. We would have what we just observed, namely the Kaibab/Toroweap deposited over the Coconino. The whole area was slowly subsiding, but the rate of subsidence either increased or something caused sea level to rise over the region. Either explains it, but relative sea level rise is the logical explanation in either case. There we have it. The sea most likely rose over a desert covered with dunes of windblown quartz sand. A very arid climate that persisted from Coconino time to Kaibab time accounts for the big cross beds here and the gypsum sabkha above that we saw in our first stop at Cathedral Wash. If this interpretation is correct, the rocks are telling us about the depositional environments and something about the climate here about 270 million years ago.

It seems therefore probable that this place in northern Arizona was once a vast desert of sand dunes whipped by relentless high winds. Sand was blown up the more gently sloping windward side of a dune and then avalanched down the lee side. Dune climbed over dune and left this layer of strongly “cross bedded” sand. The top of the dune being overrun is eroded off during this process, so the internal slatted pattern of the avalanche surface lower down is all that is preserved. Avalanche moves over avalanche leaving a set of slatted, inclined beds that we see. The dune shapes were highly irregular, so progressive beds piled over the ones below avalanching down from different directions. We are seeing a two-dimensional slice through a three-dimensional dune, so it is not exactly clear whether a given rock face is holding sands that were sliding toward us or away from us. But the cross beds here almost all slant up roughly in a mostly upriver direction telling us that the prevailing winds around here in those days were blowing generally to the east in our upriver direction. We turn off the motors and float along listening to birdsong and gurgles as the river lazily churns along. The sound of the wind blowing over the water and the rustling of tamarisk thickets lining the banks gives way in my own mind to hot, howling winds in an imaginary landscape of desert sands. I let the blue sky and blazing sun go away and imagine it is deep night with Milky Way and stars arrayed into

constellations that I don't recognize. The brightest stars we see in the night sky are mostly the large young ones prodigiously burning their atomic fuel at a rate that will exhaust itself in a few million years. My midnight desert landscape is over 250 million years old so most of the bright stars that were there are now long gone. Plus, stars are slowly moving in the night sky as they and the sun orbit around the core of our galaxy. Measurements suggest that our solar system orbits around once about every 250 million years--which is slightly younger in cosmic time than the approximate age of these strata. So, my desert at midnight reverie is taking place coming up on a galactic birthday of sorts when the sun is back where it was in its orbit around the galaxy 250 million years ago. JP points out that the direction of the prevailing winds inferred from the slatted angle of the Coconino crossbeds is different from those of the prevailing winds today. He relates the turnaround to the idea that continents drift around on the globe on hundred million-year timescales and that our continent may have migrated up through different prevailing wind directions associated with various latitudes. I'm not sure we have enough rock exposure here to establish the statistics of ancient wind directions, but it sounds good and is an interesting possibility. The motor fires up and we are back descending through the historical record of deep time. I remember that all my geologic reveries are just interpretations that can change as we learn more. The daydreams of a geologist floating along here 100 years from now may be different. It does not matter. It is good for the soul to mix up daydreams guided by science with the more normal fantasies that get us through life's daily slings and arrows.

The Coconino desert deposit is observed throughout the length of the Grand Canyon and extends south mostly in the subsurface across the northeastern half of Arizona. Fractures develop down the slanting cross beds now turned into rock. Together with the orthogonal uplift cracks I will soon explain to the group, these fracture openings help make this a superb aquifer rock for much of northern Arizona. Here, the layer is about as thin as it gets and doesn't really stand out. It will take us about a half hour to float through it after which it will rise higher and higher above us and become a distinctive, almost white, horizontal band high up the walls for the rest of the trip.

Before losing contact with this unusual rock layer, we stop on the left to look at a jumble of inclined slabs that fell a short distance off the wall. Several of them have numerous tracks that some kind of small 4-legged creatures left on the faces of one of the fossilized dunes (Figs. 5.7 and 5.8).

Fig. 5.7 Slab of fallen Coconino Sandstone covered with impressions of animal tracks scurrying around on sand dunes about 275 million years ago.

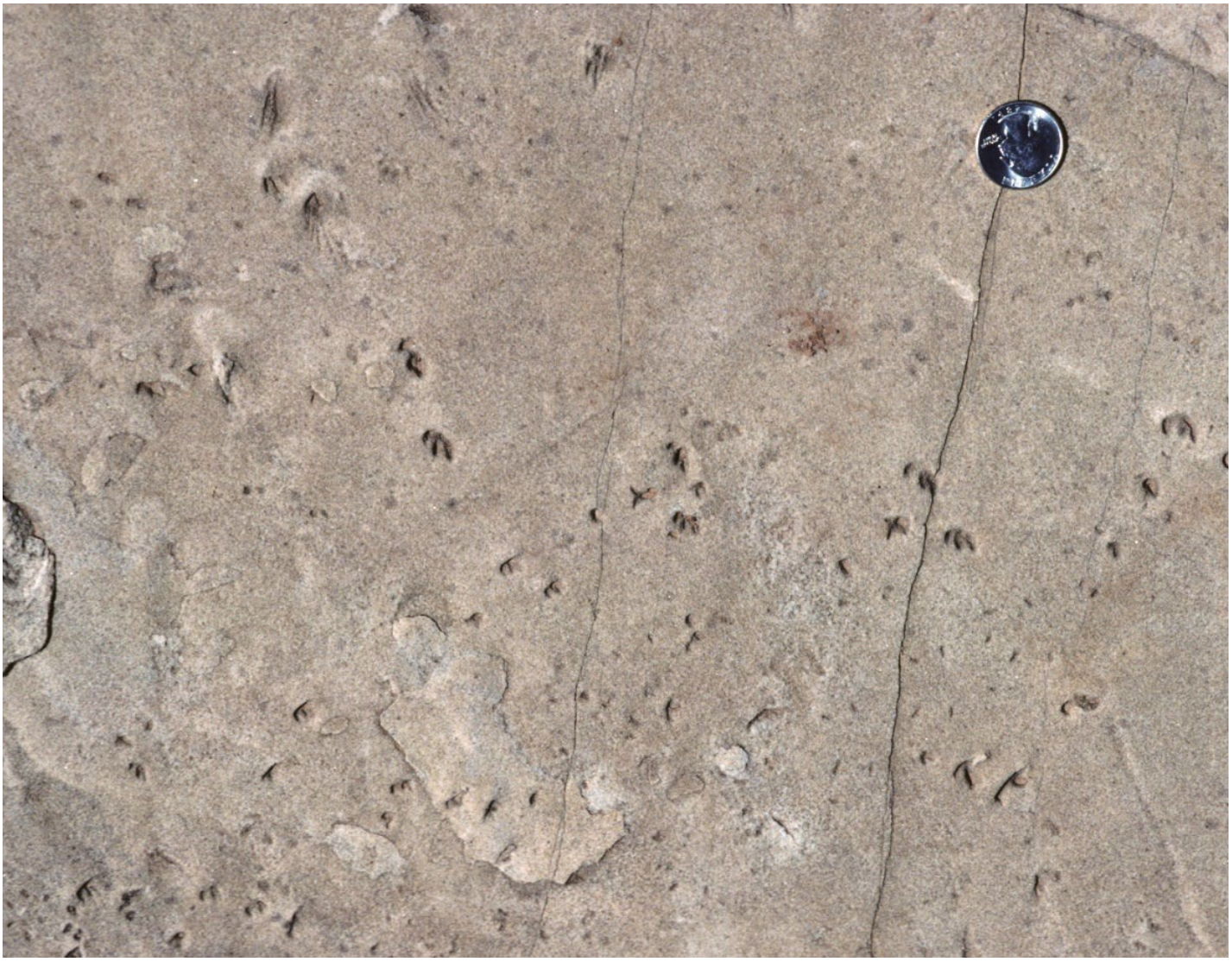

Fig. 5.8. Close up of tracks on slab shown in Fig. 5.4.

Such tracks are actually common on Coconino slabs. One photogenic example of larger tracks near Badger rapid has remnants of plaster where someone took an impression (Fig 5.9).

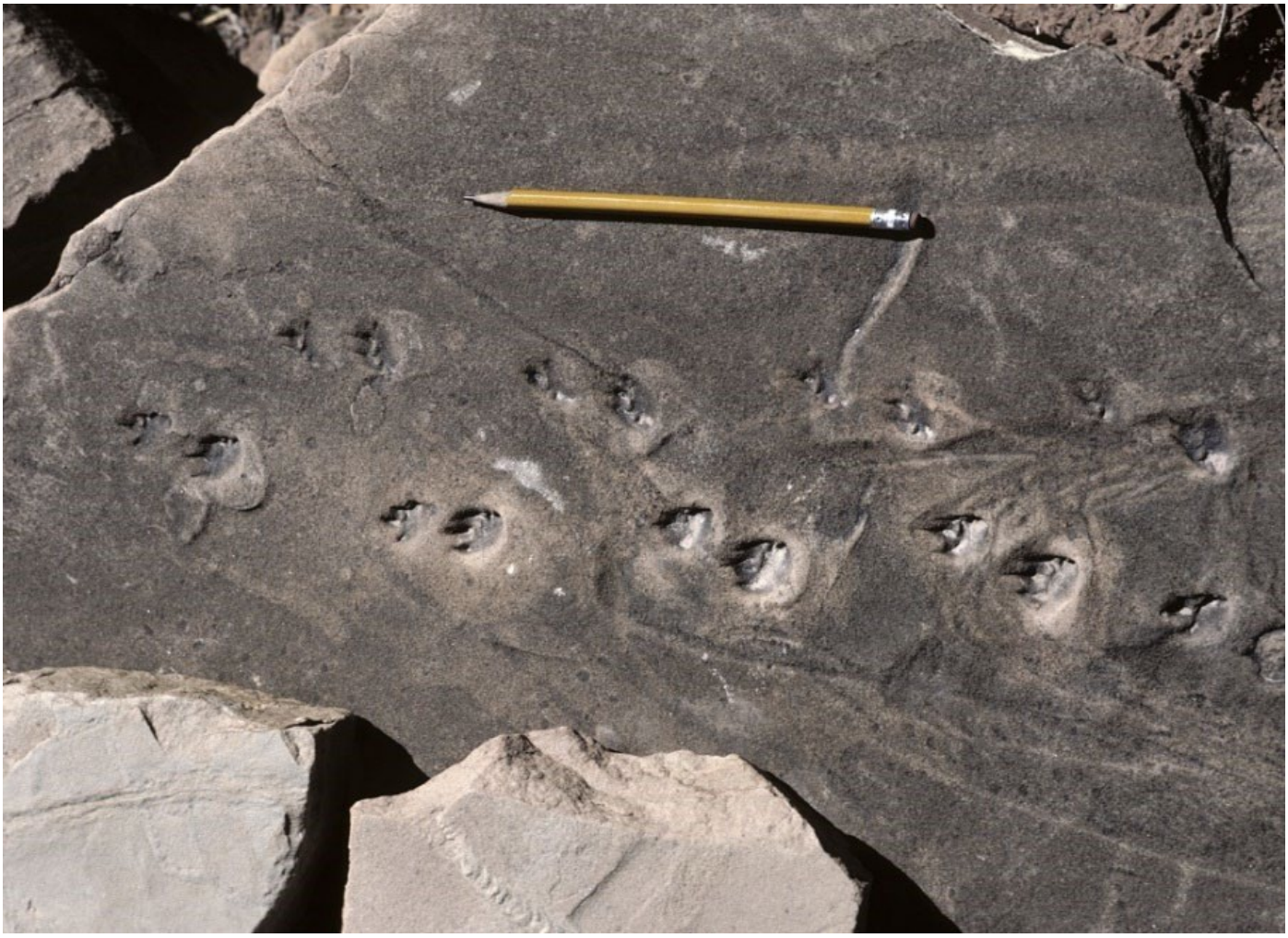

Fig 5.9. Frequently visited vertebrate tracks on slab of 275-million-year-old Coconino Sandstone where Jackass Creek meets Badger Rapid. White stains and remnants of plaster remain from someone who took a souvenir impression.

The slabs at our slightly upstream river stop are larger and crisscrossed with smaller and less photogenic footprints, but they haven't been defaced with remnant plaster. This makes them easier to emotionally connect with. Based on fossils of the kinds of creatures that lived during this time elsewhere, these were probably reptiles climbing around the dunes after a rain. The more cohesive wet sand with the tracks was then covered over with new avalanches of sand when the wind blew again. When this big block fell off the wall, a slab of that covering layer split off to leave this smooth surface that was once the top of a large sand dune. After about 275 million years, the footprints are in the sunshine again. They are strikingly well-preserved and even show how the claw tips dug in with every step. Hiking up a sand dune face is for us humans three steps up, slide back one, and go at it again. Those little claw tips show these little creatures were grasping loose sand as they were struggling upward. I am able here to feel their effort as well as see the result. Little did the creatures know that their footprints would be

marveled at by evolved alien-like creatures in a future world. Immortal tracks? No. Soon the hosting sandstone will disaggregate and itself wash down the river. I stand mesmerized and seem to hear the ghosts of these ancient amphibians lamenting the imminent and inevitable destruction of their tracks and consoling with the eternal message, “All is transitory.” But some footprints do last longer than others.