**Chapter 21** **MAKING LEMONADE OUT OF LEMONS** Mile 167-187.5

Shortly after the morning sun clears the high eastern cliff, we leave National Canyon and motor to a gem of a side canyon known as Fern Glen. The rapid at the constriction caused by the debris delta at its mouth has been historically mild even though flash floods derived from the higher North Rim are frequent. Probably more flash floods have been filmed here by river runners and posted on social media than for any other side canyon. Maybe it is because it so directly drains off the west slopes of the high country of the North Rim where prevailing air masses are lifted to cause more abundant rain and snow than over the South Rim. We land on a big sand beach on the downriver side and troop up into a slot canyon that always has deep shade even if you arrive at noon (Fig. 21.1).

*Fig. 21.1. Morning in Fern Glen Canyon.*

We scamper over some big boulders into the shady slot but can't go in very far without encountering a stagnant pool with a tall pile of big blocks on the other side. Those who slop through the pool and climb over the rocks encounter a slightly wider slot with abundant ferns. Some trips make this a must-see place because if it is Fern Glen, the ferns must be seen. Hikes up deep and narrow slot canyons this close to the river are usually choked with big debris piles or waterfalls, but Fern Glen is an attractive stop because hikers can get into deep shade without having to climb or scramble very much.

We are already running late now for our last day, so we stop at the pool, enjoy the shade, and note how few overhangs there are in this tall and narrow slot. Then we gather for a short talk back near the opening amid a great jumble of giant blocks that fell off the steep walls. Looking out toward the river, a giant column resembling an Egyptian obelisk is leaning against the west wall (Fig. 21.2).

*Fig. 21.2. "The Leaning Pillar of Fern Glen" viewed southwest from the mouth of that famous slot canyon. A huge pillar of Muav Limestone defined by more than four fracture surfaces has dropped off the wall and "heeled out" over the Bright Angel Shale. This is a stunning example of how erosion in the Grand Canyon initiates not grain-by-grain but rather block-by-block.*

Here is an important lesson emphasizing the process of erosion of uplifted layers in the Grand Canyon. As we previously appreciated, rectilinear jointing causes all this country to resemble a stack of blocks fitted together tightly. When water flowing down a slot canyon encounters a layer of more easily eroded material like shale, it reems that layer out rapidly. This can create thin indents in the walls where the shale layers are thin, but it can wreak erosional havoc on the walls if it cuts down into a shale layer of considerable thickness. As it sluices that shale away, it can remove the foundation upon which millions of tons of wall rock are standing. The blocks making up the walls of Jericho can come tumbling down. Here, a column of rock typical of the Muav detached and started sliding out at the bottom over the Bright Angel Shale. Unlike most blocks and pillars that do this, here sits one that did not shatter internally as its base slid away from the wall---for now. Someday, the pillar will fall apart and become just another talus pile.

This pillar has facets like a giant quartz crystal. Higher up in the Paleozoic stratigraphy, weathering along fractures produces blocks with two sets of vertical fractures at right angles to each other. The Muav splits along those directions as well, but it has additional vertical fractures apparently from an earlier uplift event. Cliff faces of the Muav tend to weather out not so much as rectilinear blocks but rather as faceted pillars like this—albeit most edges get rapidly smoothed by weathering. It is a remarkable sight even amid all the other remarkable sites. It is one of my favorites, but time will not be nice to it. Someday, there will be a crashing sound as it falls apart to become a pile of angular blocks. No one should ever crawl under it and sneeze.

The underlying Bright Angel Shale shines bright green in the morning sun. It is so beautiful that I must resist reminding everyone that the green color may be from the iron silicate mineral glauconite that forms in the burial pore fluids around fecal pellets in this highly burrowed shale. The organisms themselves are long gone, but their partially fossilized excrement remains. Individual grains of the beautiful glauconite minerals are typically visible in a hand lens. This is the geologist's indispensable little magnifier that you hold against your eye while you move the rock close to your face to bring it into focus. Everyone seems relieved that we do not have hand lenses to bring a rock rich in fossil excrement near their face. Glauconite is actually a beautiful mineral, particularly in a petrographic microscope. How iron silicate comes to replace little microturds has never been satisfactorily explained. It also may be more abundant in sedimentary rocks of specific ages. It seems to me to be more common in Cambrian strata near the beginning of the Paleozoic, in the Mississippian near the end of the Paleozoic, and in Tertiary-age sandstones. Burrowing, excreting organisms have thrived in ocean sediments throughout the history of life, and the chemistry and mineralogy of the host sediments is common to all. There is no known reason it should form more abundantly at certain times, so this is just speculation.

The canyon is going to start opening wider from here on. The Muav Gorge is nearing its end. The reason, I suspect, is that the walls have been slipping out on the Bright Angel shale which will be with us for the rest of the day. It may also have something to do with antiquity of erosion along various segments of the river which are not necessarily the same. Some have argued that the modern Colorado River is a stitched-together path across terranes with

different erosion histories. It is something that can't be assessed by standing on the river, so I don't bring up the large question of how the Colorado became one of only two great rivers flowing in the American west. More importantly, this is a distraction when we are about to enter between walls that are totally different from any we have seen before.

Travelling through the Muav Gorge, the walls are so vertical and starkly uniform that river runners usually fail to note that cacti and other vegetation characteristic of the Sonoran and Mojave deserts have become more prominent on step-backs atop cliff faces. Now that such step-backs are a bit more abundant lower down, thorny branches of the ocotillo plant radiating outward in big, curved loops become common. Prickly pear and other cacti seem to be growing in denser clumps. Whatever the statistics might show about desert plant populations, the mile by mile widening of the canyon has generated a subtle new desert ambience. Then a wondrous sight appears to our right around mile 175. As it has been for the past 40 river miles, the immediate skyline as seen from the river is the top of the Redwall Limestone. Along this stretch, the rock layers above the Redwall have been disproportionately and unevenly stripped back to leave a resistant layer in the Supai Formation called the Esplanade Sandstone exposed for at least a mile on both sides of the river. Both sides of Kanab Creek coming in from the north are stripped back up to three miles on each side. The six-mile expanse of the red Esplanade catches the attention of the low flying scenic airline flights and will be seen by some of our group on the flight back tomorrow to Cliff Dwellers where they started the trip. What we see now coming into view is a one-mile breach of the right-side near-skyline that goes up to near the top of the Redwall. It extends back a half mile from the river and is filled with rubble covered over for the most part with landslide rubble and talus. The Muav, overlying Temple Butte Limestone, and at least part of the Redwall Limestone that have heretofore formed cliffs bounding the river appear to have collapsed and become covered with rubble. All is being deeply gullied now to leave several ridges of rubble coming from high all the way down to the river. This is by far the largest pile of talus we have passed. High up near the contact of the rubble ridges with the lower part of the Redwall Limestone is something unlike anything we have seen so far on the trip. It looks like a forest of red pillars. It is! Through binoculars, a telephoto lens, or a climb up one of the rubble ridges, the pillars are seen to be made of red rock rubble, each capped by a large angular boulder (Fig. 21.3).

*Fig. 21.3. Forest of rock pillars at the top of Red Slide. Each is a column of rock rubble capped with a large boulder.*

The boulder cap apparently protects the underlying material from falling rain while adjacent material is washed downhill. Such rock forests are called “hoodoos.” Altogether, this vast deposit of cliff debris mantled with red rock rubble is called “Red Slide.” It is said to be a mini version of the great Deer Creek Landslide. But there is plenty about it that looks different—so different that it warrants close examination of the kind most raft trips don’t have time for.

When viewed from the river, the “slide” seems like it is mostly a stack of rubble layers lying parallel to the slope that goes up to the base of the Redwall. If so, it formed by numerous small landslides that stacked up one over the other—unlike the Deer Creek slide in which a whole segment of the wall broke off and slid somewhat coherently down feet first. These instead seem like “angle of repose” landslides. This is the term when the slope is as steep as it can get without a displaced rock tumbling down it. The most recent slides that cap the earlier slides are composed predominantly of red sandstone blocks from the Supai Formation which now is out of sight stepped back high above the Redwall Limestone. It looks like the Supai is collapsing above the Redwall and its debris is sliding over its edge and down into the slump pile where the Muav and Temple Butte cliffs used to be. Why this unusual type of lower cliff failure occurred here is not clear. Up near the top where the slope is not so steep, rainwater and runoff sluicing downward through the red rubble has created the Hoodoos. There is a geologic story here that involved some kind of stepwise cliff collapse that is uncommon if not unique in the river corridor. Aerial and satellite views show how the Esplanade platform in the Supai Formation becomes more dominant going from the Kaibab Uplift westward. This probably, but not necessarily, indicates that erosion has been acting longer on the landscape

going west to east. It is an issue relating to controversies over the erosional history that created the Grand Canyon. How Red Slide fits into this is not clear.

**Diversion on the evil of "Snag Boats"**

The origin of Red Slide troubles me and once provoked a scary climb I talked JP and the crew of an early trip into doing. Everytime we pass since then, JP and I look up, exchange odd glances, and silently think how crazy it was to do that. What in the world happened here to create this strange sight? And, at the top is that amazing rock forest that I long to wander in. Usually, like today, we just exchange glances and drive past trying to get to our final campsite at or near the helipad where a tag team of helicopters will lift us out tomorrow along with almost all the commercial river traffic that is now less than a day behind us. But once, there was a special opportunity to confront Red Slide because of an unfortunate (and now forbidden) practice by certain groups determined to get the campsites they desire at all cost.

Private river runners participate in a lottery to get a permit to launch their own rafts and try to get through the huge canyon rapids without injury or death. They depart in a group of a few small boats almost always rowed by enthusiasts that have little or no prior river experience in the Grand Canyon. The attraction is a chance to go at a leisurely pace for two weeks, explore many side canyons, be on their own without motor noise. and test their courage on the fastest white water in North America. That last aspect is often the chief attraction that has fueled many interesting books, stories, and videos about conquering their fears and achieving their personal best. There are amazing tales of how they almost died, and numerous online videos of them in their row boats getting car-washed in a rapid or tumbled as in a clothes washer. Stories of great hikes and dangerous hikes up some of the side canyons abound. The stories and writings make camping at certain side canyons something they passionately dream of, long for, and plan on for years. A two-night camp at some places allows a full day to explore up long side canyons. Camping at certain spots thus becomes something they are understandably determined to do. It is this that inadvertently caused most of us on one of my earlier three-boat trips to climb Red Slide one very hot morning.

Private groups are small and can camp at any size campsite, but commercial trips are large and need to take the larger camps so that people aren't sleeping elbow to elbow. Until the Park Service cracked down on the practice, it was common for the small private groups to send a "snag boat" ahead to secure a desired campsite. One person in one boat would leave early and row as fast as possible to secure the desired campsite. A claim would be established by sitting in a chair on the beach under an umbrella while reading a book or getting high until the rest of the party arrived much later. Sharing campsites is unusual and up to the discretion of those who arrive first. In stretches of the river where good sandy beaches are rare or where there are desirable side canyon hikes, snag boats would arrive by 2 pm or even earlier. The situation is first-come first-served, so it is a sneaky way to win the campsite competition.

For us, the day we travel to our final camp (usually at the helipad itself) is through wide open stretches with essentially no shade--not even in the accessible side canyons. It is the hottest day of the trip, so the idea is to make it a long day on the water, vector through every

rapid in the wettest way possible to stay cool, and not arrive at our exposed final camp until the hot sun is sinking behind the far side wall. Arrive there earlier, and you roast. The idea is to have one cool early morning hike that last day on the river, at either Havasu, National, or Fern Glen. We will encounter the monster rapid known as "Lava Falls" mid-afternoon where everyone is guaranteed an ice water drenching. This special day means that we will need a big camp the night before that allows a morning hike before a full day drive to the end. There are only four such sites that can comfortably accommodate a two-boat commercial trip--one at Tuckup Canyon, two at National Canyon, and one at Fern Glen. So, one year there were snag boats at every one of those sites. A single person sitting under an umbrella was at each and holding the site for groups that would not arrive for many hours.

JP stays concentrated and doesn't show much emotion when things get tough. Encountering those snag boats on that trip broke my heart for him. We passed the first one at Tuckup Canyon above Havasu and there goes the hike up Havasu possibility. Then one at the first camp at National. Then another at the second camp there, which is huge. There goes National Canyon and its morning hike. At this point, we are in possible trouble, so JP pulls in and goes over to ask the chap if we can share this gigantic campsite--even give his small group ice, dinner, and beer. It is understandable that a small private group would not want a large commercial group to crash in on them. But this really is an enormous camp, and the guy is a snagger after all. JP is rudely dismissed and comes back visibly concerned. He is a peaceful soul and says we should keep our fingers crossed for the last chance, Fern Glen. Sure enough, we round the corner and see a boat on the huge sand beach with the usual reader under an umbrella. JP pulls in again and asks but no luck from this pestilent fellow either. So, in fading light we pull away. We are thus forced to drive two more miles to Stairway Canyon where there is a beautiful sandy and empty campsite waiting in the late twilight. With no shady stops on the upcoming stretch of river from here, we might arrive tomorrow at our last campsite in the morning where we will roast in the hot afternoon sun. The group has no idea the trouble we are in. While people are scampering around in great spirits setting up their cots and such, JP and I have a beer on the back of his boat sticking out in the river. What are we going to do tomorrow? We can't even sleep late and hang out here because the sun will hit this site shortly after it rises. There are a few tamarisk trees, but no shade. We need to get on the water early. Lava Falls will appear within an hour tomorrow morning. We can hang out under some shady ledges just downstream, but not for most of the day.

Then it occurs to me that we could climb up to the hoodoos at Red Slide. We have three boats (as allowed in those days) and most of the participants would be up to it. We'll go up along with one of other boatmen, the always upbeat, master outdoorsman Dave Kashinski. The indefatigable Jimmy Grissom can take the non-climbers on a gentle, short hike up Mohawk Canyon where there will be at least a little morning shade. I am excited because I want to get up into the hoodoo forest and take a closer look at the nature of the landslide and what it might mean. JP says we are trying to make lemonade out of lemons but yields to my plan against his better judgment.

**Red Slide Story**

After a great Powell night, we pull away from camp the next morning just as it starts turning into a hot hellhole. Arriving at Red Slide, about 28 of us start up the steep slope like an expedition going up Mt Everest. Climbing the main ridge line of rubble sloping down from the wall isn't too difficult after all, but this is not the kind of thing people on a commercial raft trip usually do. A great view of the adjacent ridge to the west demonstrates in detail that these are simply angle of repose landslides—one after another (Fig. 21.4).

Fig. 21.4. Most of Red Slide is angle of repose landslides representing many different events. This is completely different than the Deer Creek Landslide which happened mostly at once.

Comparison with the Deer Creek Landslide(s) is indeed not appropriate. Many excited about this impromptu climbing adventure quickly fall away and return slowly to the boats. Pretty soon, it is only about eight of us crawling up a narrowing ridgeline that ends as a little flat area standing at the base of a 15-foot wall of jointed limestone. The forest of rock pillars beckons above, but it means going up that scary wall starting here so high above the river that the people near the boats look like ants. To the right, we notice that it would have been easier to come up an adjacent drainage and will certainly be much easier to go down that way. All but three now decide it is too risky to go up that wall. I decide I really do not need to get into the

hoodoos; the sight up close above that wall is wonder enough for me. I stop and easily persuade those still in the climb that we are getting an amazing view here and do not need to climb that scary little wall. And look how much easier that descent down the drainage will be! Meanwhile, a young chap from Switzerland scampers up the wall with ease. Then my friend, the unstoppable Bill Lieske scampers up. Then, gazelle-like Jeanne Calhoun goes up it as if she does this every day. She would later become Director of Environmental and Natural Resources at Grand Canyon National Park, but here she was pioneering an exploration of the Red Slide hoodoos. The three can be heard celebrating their triumph while sitting amid these strange pillars of rock debris. I get my picture (Fig. 21.5) and turn around to join the group now starting carefully down the drainage back to the boats.

*Fig. 21.5. Close-up of the rock forest at the top of Red Slide. The pillars here are over 20 feet high.*

But wait! Look at this. Water sluicing vertically downward through the ridge of landslide rubble we just hiked up is starting to create hoodoos right here where we are (Fig. 21.6).

*Fig. 21.6. Looking down from near the top of Red Slide on top of one of the angle of repose landslides. Rainwater sluicing downward is etching out pillars, most of which eventually fall off the sides. A pillar in the making is on the left side of the photo.*

Kashinski is waiting for me to start down. Being an indefatigable climber, he is having the time of his life but insists he needs to accompany all of us for safety. I feel a little bad, because I know he would love to go up into that rock forest. But having JP and him near in case of trouble is comforting. JP stays behind until the three conquerors of Red Slide come back down that wall safely. Going down that drainage is surprisingly easy and a great relief.

Pulling away in the boats, the three that got into the hoodoos are ecstatic. Everyone back safe and sound, JP is now a new man. I can tell this is something he is NEVER going to allow again. It was unexpectedly strenuous and a bit risky. To me, it was about as risky as the hike thousands of people take at Deer Creek Falls and along the heavily travelled path to Havasu Creek. However, there is no trail, so people scrambling up the slope might disturb loose rocks. Commercial trips nowadays pretty much limit hiking to established trails or the floors of commonly travelled side canyons. More important to me was the chance to look up close at cross sections through the rubble deposit. While unlike the Deer Creek Landslide, those who argue for earthquake triggers could suggest that was a cause for the lower cliff collapse(s) that created a place for Supai slope debris to accumulate.

Red Slide and the immediate areas around it are rare and possibly unique features in the Grand Canyon. It thus warrants further attention and geologic investigation even if it isn't

one of science's greatest problems. Going past it on this trip today triggers vivid memories of this unusual adventure and the usual exchange of strange facial expressions with JP who would probably rather forget that day. I don't know of anyone else who has ever climbed up to the hoodoos. No one on a raft trip should do it. It looks on satellite photos that it might be accessible via a trail coming in from the west high above. The Tuckup Trail coming from the west might offer a great view from above of the whole area. I am still not sure why this unusual feature formed here or what it means.

**Lava Flows and the Biggest Rapid**

Reminiscences pass quickly because we soon spot a horizontal black band running horizontally along the face of the south wall not far above the river. It comes and goes along the wall. It is a horizontal belt of black basaltic lava not cropping out, but rather stuck on the surface of the wall. We have reached a place where volcanoes high up on the rim erupted and poured lava over the sides and down into the canyon. Along this stretch we are now in, whatever lava that was once present in the channel itself has eroded away save these isolated remnants.

On about my fourth river trip through the Grand Canyon, I was about to fall asleep about two miles after a Havasu Canyon hike but blinked wide awake at the sight of something I couldn't believe. A vertical joint on the north wall was filled with something black looking for sure like an intrusive dike of basalt. It was a stringer less than a foot wide and it rose on the wall out of the river and got lost in the jointed surface above (Fig. 21.7).

*Fig. 21.7. Thin dike of black basaltic lava going up fracture in Muav Limestone at Mile 159. There are several here, each less than 12" wide.*

It was pretty obvious. Then another appeared and then another. Then no more. Wow, there are basaltic dikes cutting up through the Muav almost 20 miles upstream before lava first appears attached to the walls! I thought I had discovered something new, but the "159-mile dikes" are actually well known. I guess there are around a half dozen of them, and researchers have tried to radiometrically age-date them to possibly assess how long the gorge has been here. The idea was that the dikes were surely already there when the river cut into them. Alas, the once molten material was incorporating little pieces of the wall rock when it squeezed up into the fractures and contaminated the geochemistry in such a way as to make radiometric age dating unreliable. Besides, a dike is a vertical sheet, not a tube or finger of molten material. Moving up sheetlike, the lava could have just extruded into the river and been quickly eroded away after solidification. So, it is not clear what an age-date of these dikes

would mean for the age of the river gorge itself. It is possible that claims of uncontaminated samples yielding an age less than 1 million years are correct, but it is a lot to ask a of molten lava being squeezed upward through thousands of feet of jagged rock to remain pure. In any case, those who spot these dikes get an early warning that within 20 miles huge amounts of lava erupted up through the Colorado Plateau and poured out in great floods that spilled over the walls which then flowed down the channel itself. The black band on the south side we pass now is the most upstream remnant of the volcanic upheaval and a harbinger of what will soon come into view.

JP starts pointing out jet black lava on both sides at various levels above or in the river. A black fretted knob known as "Vulcan's Forge" appears ahead in the middle of the river (Fig. 21.8).

*Fig. 21.8. "Vulcan's Forge." Is it erupting lava that solidified in a vent fortuitously located in the river channel, or is it a boulder that fell off surface flows higher up on the walls?*

We go around it slowly and up close. Several cylindrical holes are just above river level where someone drilled out scientific specimens. The sudden defacement jolts us all, and I am reminded how insensitive some of my geology colleagues can be when they sample rocks. I have done my own shameful rock busting that left scars for others to encounter. I tuned in late in my geology career that we often work and deface remote areas that later become popular

tourist sites. One of my colleagues chastised me after I whacked off a rock in western Australia, and it taught me a lesson. A famous and aggressive South African researcher created a scandal by leaving numerous cylindrical drill holes in an area that subsequently became a National Park. All this floods my mind instead of assessing possible vertical flow banding in Vulcan's Forge which many claim indicates this is a volcanic neck itself instead of something that fell off the lava flows higher up on the rim.

Black lava is now visible all around. A better-than-textbook intrusive sill of black lava on the right has squeezed horizontally into the strata near the base of the Muav (Fig. 21.9).

*Fig 21.9. Sill of black basaltic lava near the base of the cliff that intruded along a bedding plane of the Muav Limestone.*

Black boulders and black blocks now dominate the talus aprons and cover a wide flat space to the left. We start circling in placid waters while JP advises that Lava Falls is ahead and that we may want to suit up into rain gear. This is the biggest rapid in the Grand Canyon. "Vulcan's Throne," a classic volcanic cone lies high up and back far enough that we cannot see it from the river at all. However, an unnamed peak with that distinctive, almost triangular shape someone might sketch if you asked them to draw a cross section of a volcanic cone sits high up

the skyline to our left. It is on the west side of wide Prospect Canyon coming in from the south. It is indeed the western half of a giant volcanic cone. Its eastern half was eaten away by cliff collapse thus allowing us to see it in cross section. This would be such an amazing geology stop, but we are now moving toward the right side of the river. JP is carefully positioning the boat for entry into this fearsome rapid. The roar becomes louder, and jets of foaming water shoot up from the other side of the smooth flat end of the river as it goes over the entry lip--the start of a 13-foot drop that will occur over 150 yards. We imagine from its name and the surroundings that the rapid is a waterfall over a hard dam of subsurface lava like that all around us. It is actually just another giant rubble pile brought in by debris flows coming in via Prospect Canyon from the left—a rapid formed like most all the others. But it is the biggest and fastest rapid on the Colorado River. A gaggle of private row boats are tied up on the right just above the rapid, and we see people have climbed up to a high perch to scout what they must soon traverse. They are trying to figure out a route that might get them through upright. We will have an audience as they try to learn something from the route we take.

JP doesn't scout Lava Falls; he is devoid of fear in this matter. Except he isn't. He confessed to me once that he is so used to Lava Falls Rapid and has run it so many times without incident, even in little row boats and during high water floods, that he is afraid he might become complacent and get trounced by the river gods for his hubris. After making sure everyone is secure and ready, he stands high for an announcement. "Ladies and gentlemen, we are about to enter the fastest white water in North America. Open your eyes and witness the power and glory of Lava Falls. Someday, I too hope to open MY eyes and witness the power and glory of Lava Falls. Hang on tight and have a nice day." Who else could say it with such panache!

We fully attuned riders are too scared to chuckle because the boat begins rapidly accelerating downward into a steep chute of water streaming directly toward a furious confusion of waves 137,000 feet high. We hit the first and are thrown violently forward, backward, sideways, up, down, and then all ways at the same time. Blinding sprays and firehose blasts hit us from all directions. People scream louder than any sound they ever made in their lives. A wall of water comes over the boat like a tsunami --then another--and another. Blinding curtains of water suddenly clear and we see straight ahead an enormous black rock sticking out from the bank with a frothing whirlpool at its base. JP motors the boat hard to the left and we shoot by it into more chaos that begins tapering off into powerful bobbing, bouncing, and plowing through whitecaps as we move across the river toward the left bank. Everyone is still screaming with a mixture of primordial fear, thrill, excitement, yahoo-yelling, and just plain going wild. JP swings the boat around such that we are pointing upstream and motors hard. We seem to be creeping against the current along the riverbank now on our right side with the mayhem of the main current we just traversed still raging past on our left side. People try standing as we pitch up and down and right and left. They are trying to let water inside their rain suits drain out. No one knows quite what is happening now, but all quickly sit before falling down. JP is powering along the back eddy toward the start of the rapid while the main current rages and shoots past the left side of our bucking bronco boat. We suddenly spot our second boat entering the top of the rapid. It drops out of sight as it plummets into

white water bedlam. I somehow pull out a camera just in time. The boat explodes out the front of frenzied waves with riders screaming and thrashing amid barrages of water blasting over them from all sides (Fig. 21.10).

*Fig 21.10. Crashing through Lava Falls Rapid.*

Great pics--but quick! Everyone sit back down! We are going to power out into the current for a second ride through the impossible tumult developed just downstream of the initial drop. JP yells, “You can ride the side tubes if you want!” Delirious and sopping-wet riders fly out onto the tubes and here we go again. The front of the boat catches the current and swings hard to the left. All is pandemonium as we go crashing through the lower 80% of the rapid for the second time (Fig. 21.11).

*Fig. 21.11. Riding the side tubes through part of Lava Falls Rapid. This is too dangerous to do near the beginning of the rapid, but it is possible to motor back up toward the entry on a back eddy and swing out into the main current. (Photo courtesy Michael Nolan)*

The screaming, cheering, and yelling sound different from the terror of the first run. It is now pure ecstasy. We emerge utterly and completely drenched. Drowned. But here we are again in the back eddy going back up toward the start again. It is ride number three through Lava Falls ready to start in just seconds! The exulting resumes but is noticeably less delirious this time. Everyone is now frozen, especially considering that the strong afternoon upriver wind has turned us into arctic explorers. We finally exit the violent white water with an opportunity now to dry out, stop trembling, and warm up-- so we think. Please no, please no—and then comes "Lower Lava Falls." This one is a short thumper that drops 14 feet in about 50 yards. We get thoroughly sloshed again. I want to yell, "Enough already!" But I refrain fearing that certain parts of me are so cold that I may have become a soprano. We emerge onto the normal flow and a freezing headwind. We are now desperate for the hot sunshine we tried to avoid on most of the previous days.

The running Lava Falls phenomenon is somewhat unfortunate for the kind of trips I lead, and especially for me on this one because it upstages one of the most spectacular geologic spectacles in the Canyon—or anywhere for that matter. Even after having already run so many ferocious rapids, everyone is shocked when they see and feel the boat hurtle through the

churning chaos of Lava Falls. Emerging exhilarated, there is closure and a sense of fulfillment that the major challenges of a raft trip have been overcome. Everyone is giddy, feeling like a veteran, and thinking only about how soon they can dry out and be warm again. The strong head wind throws noisy spray over a group now strongly bonded and free of uncertainties over what the rest of the trip may bring. We come to one last rapid through which people are encouraged to ride the side pontoons seated backwards. There is no hope of pulling over for a geology talk right now. People don't even notice the strange character of the walls here. All around us is a display of black lava rock in a setting that may be unique.

Within this half mile, the black walls return to the lighter color of the Tapeats Sandstone which we have descended to. Black boulders being tumbled downriver by the current still line the banks, but the lava itself is high up and set back from the lower walls. Then the black lava reappears as the wall rock for another 3 miles until the lower Paleozoic strata reassert themselves. A view from above shows that this three-mile stretch is where lava from many cinder cones to the north coalesced and poured over the walls (Fig. 21.12).

*Fig. 21.12. Aerial view of black lava from multiple vents pouring over the walls. Vulcan's Throne, a classic cinder cone, is located in the upper right just beneath the wing strut.*

It filled the canyon to heights possibly 2,000 feet above the current river level so that the channel is here thoroughly walled within this black lava. This stretch is where classic studies by Kenneth Hamblin of Brigham Young University documented evidence of more than

150 flows that poured into the canyon between about one and two million years ago. He presented evidence that these flows piled up into dams 13 times--sufficient to stop river flow altogether. He estimated that the duration of times intermittent lakes developed behind these dams added up to 250,000 years. He concluded that the half cinder cone we saw high up to our left before entering Lava Falls was part of a dam that crossed the river and made a lake that extended back up the river channel all the way to Utah! Had we been here about 1.8 million years ago, we would have seen a waterfall or series of waterfalls falling cumulatively almost 2,000 feet. That is 14 times as tall as Niagara Falls and would have had more than twice the amount of falling water. Hamblin's monumental publication, "Late Cenozoic Lava Dams in the Western Grand Canyon" includes a fold-out geologic map in which all the various flows and dams are identified along this stretch we are now zooming through. Several days of a raft trip could be spent examining these amazing features. The scenes we could reconstruct in our mind's eye! Alas, our trip is almost done, and nobody wants to talk geology right now.

At just under 4 miles downstream from the big rapid, a steep side canyon in the strata on the north side is filled with a tongue of black lava that looks as if it were flowing yesterday and just stopped in place (Fig. 21.13).

*Fig. 21.13. View from the river of black lava (to the right) that came down a drainage on the north wall. Some that coated the wall near the center has been subsequently eroded away.*

It did! It solidified from a molten state into a rock as it was flowed down this steep side canyon. Shelly's great poem about ice falls in the Alps runs through my mind wherein I can replace just two words and have an exact description (lava for ice and canyon for mountain).

*Ye lava falls,*
*Ye that from the canyon's brow*
*Down enormous ravines slopes amain,*
*Torrents methinks, that heard a mighty voice*
*And stopped at once amidst their maddest plunge.*

I can easily visualize it as a red flow visible through the clouds of steam as rhapsodized by John Wesley Powell: "What a conflict of water and fire there must have been here! Just imagine a river of molten rock, running down into a river of melted snow. What a seething and boiling of the waters; what clouds of steam rolled into the heavens!"

Exactly! Right on Major Powell! I wish you could ride with us in comfort unlike the tortuous trip you made through here, and that we could hear you sing your verses. There is no stretch of the river where the distant past comes to life with such clarity as amid these flows of lava down the walls and then down the channel. Hot basaltic lava can flow almost like water until broken plates and chunks of its cooling crust get wrapped in to turn it into a slower moving, more viscous fluid. Remnants of in-place lava that flowed in the channel have been found 83 miles downstream from here. There was a million-year interval where the canyon was intermittently turned into a lava funnel.

I add to Powell's rhapsody with visions of many-fingered waterfalls cascading over dams and solidified flows as the river ripped down the lava constructs. But was Hamblin right? Did the dams build up and form immense lakes as recently as a million years ago? His evidence and interpretations were carefully and clearly laid out in print and illustrations. Nevertheless, there are some skeptics who are bothered by the scanty evidence in the form of lake sediments upstream. And where are the thick carbonate crusts that should have formed on the walls when the lakes drained? Could the lavas that crack extensively when they cool really make effective dams? Were individual flows really so thick that they couldn't be ripped apart by this huge river before the next lava came in? Hamblin reasonably interpreted what could be lake sediments up some of the side canyons and even near Lees Ferry. A million years is a long time, and it is not unreasonable that unconsolidated lake sediments would get washed away. If lava piles up fast enough, maybe it could make tight dams. Hamblin's work is so impressive that it is easy to get convinced reading his masterpiece. Like so much else in science, there is no proof that all this happened this way. If there are reasonable ways to interpret the evidence differently, we cannot know for sure. I do not find this uncertainty a burden. That it is a reasonable interpretation is good enough for me to generate reveries and exciting visions of what this place once looked like. Such is the joy of geology.

What catches everyone's attention no matter how wet, cold, ecstatic, or otherwise distracted are the fantastic crack patterns in the black lavas whenever we catch an erosional

cross section glistening in late afternoon sun. These formed during cooling and slight shrinking of the brittle, solidified mass. They occur worldwide in solidified lavas and have fascinated volcanologists since the beginning of the geological sciences. Some are like stacks of hexagonal logs, pillars, or posts (Fig. 21.14).

*Fig 21.14. Shrinkage during cooling of the solidified lava caused it to crack here into hexagonal pillars.*

Some arrays in Europe standing vertically got the science of geology off to an erroneous start when they were interpreted as giant crystals that developed in the deep oceans. Others seen in cross sections plume up and out and are so named “plumose” fractures (21.15).

*Fig 21.15. "Plumose" fractures in basalt lava that flowed into the channel. Shrinkage cracks radiate away from a central axis here slanting upper right to lower left.*

And there are many more. Who can imagine such fantastic patterns resulting from simple shrinkage processes? They look contradictory, like chaos evolved systematically from order or maybe order evolved systematically from chaos. They have been classified and mathematically modeled probably beyond what is warranted for any practical reason-- such is their power to intrigue. A quiet-spoken French geologist little prone to drawing attention on one of my early trips stood up here "with eyes in a fine frenzy rolling" from one magnificent display of fractures to another while uncontrollably exulting "Magnifique!! …Magnifique!!" It is how I feel about this, but our brains are now sensually overloaded. There is no hope of gathering up here to talk geology.

Once we HAD to gather up right after running lava falls. One of our boats went into the vortex in front of that deadly big rock on the right side and couldn't get out. I was in JP's boat that had already gone through. The second didn't come, but we could see its nose bobbing out behind that rock. JP motored up a back eddy toward the backside of the rock yelling, "Watch for people!" The danger was that one side was going to push up the sloping surface of the rock, flip, and dump everyone into the river. As we approached the rock, our amazing cook

Sammy Pappas jumped off our front bow with one end of a rope in hand. The idea was to drop into the imprisoned boat, tie an end to the bow, and send a loop wave back that would arc it around the rock. JP could then nose our boat out into the current which would pull the stranded boat out into the current before it flipped. Just as Sammy got to the top of the rock, our colleagues popped out around its side and back into the current before we could take credit for a rescue. After that, we all landed at the first sand beach to the right, a place where many a raft trip has gathered up to treat injuries, upright their flipped boats, and/or just celebrate a successful run of this notorious rapid. While our group got their wits together, I walked out alone into a sunlit, black boulder field to warm up and look at the basalt. There before my eyes was a big chunk of lava with green nodules the size of golf balls made mostly of the high temperature mineral olivine (Fig. 21.16).

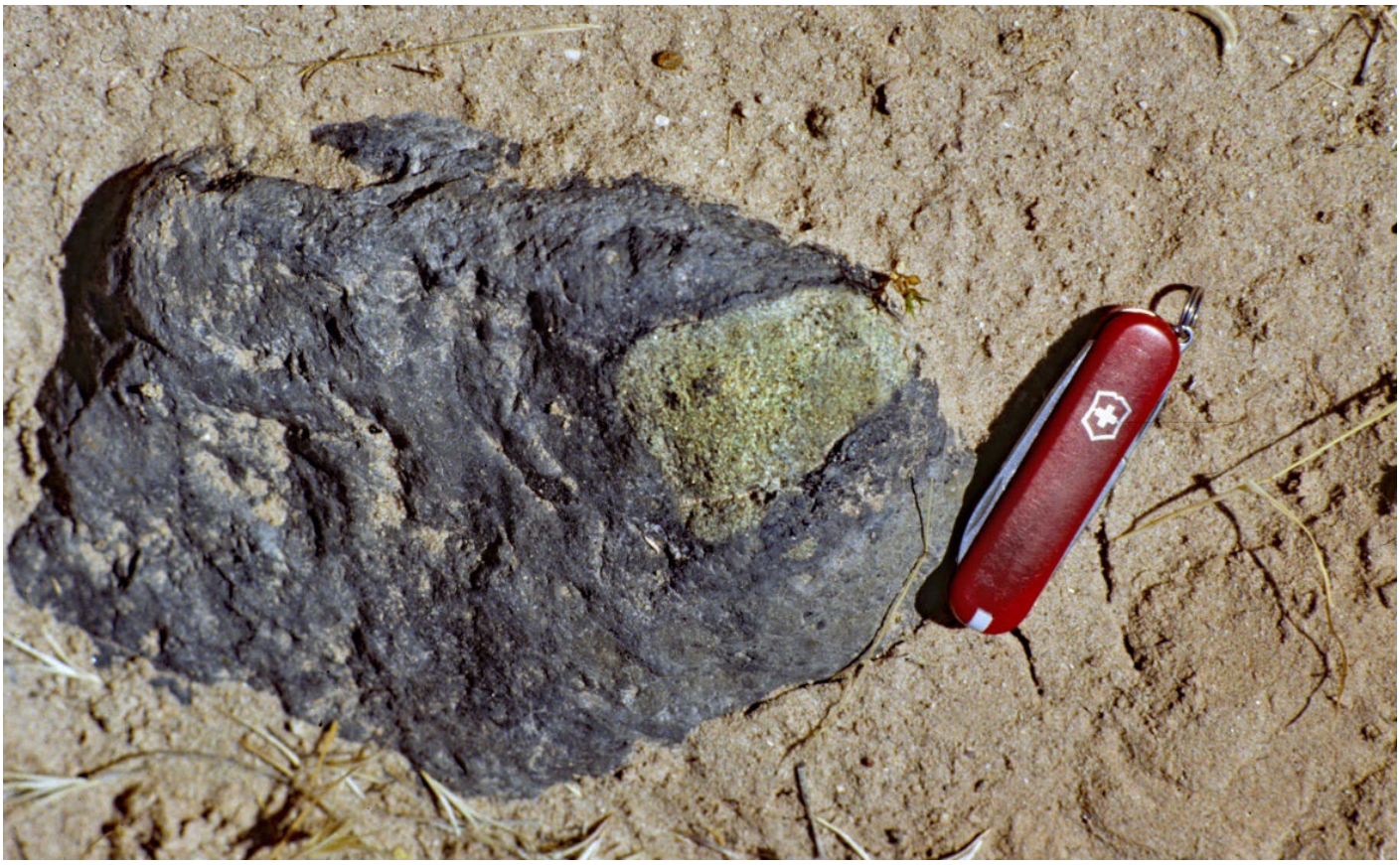

*Fig. 21.16. Green peridotite nodule in lava chunk that fell off a wall. This is a piece of the Earth's mantle ripped off the walls along the path of the ascending molten rock.*

This is called "Peridotite," although purists have a variety of terms depending upon what other minerals are present. It was torn off the wall of a magma chamber deep below in the mantle of the Earth. Here it sits after getting delivered up with the lava. There were several other small boulders with peridotite nodules of various sizes. All had recently broken off the solidified flows and were now in the first stages of getting pushed and tumbled along by strong currents during flood stage. I thought I had made a noteworthy discovery not in any guidebooks but later learned that others have noted peridotite nodules in lavas near the rapid.

It would be great to land there every trip and talk about how you can hold a piece of the Earth's mantle from probably at least a hundred kilometers straight down. This boulder field is entirely in sunshine, so looking around in it while trying to dry out from Lava Falls might work. The problem is that Lava Falls is a tough act for a soprano geologist to follow.

Basalt volcanoes have magma that came up from deep below the crust, so they often have such pieces of the mantle in them. There is a place not far from here in the Hopi Buttes Volcanic Field of northeastern Arizona where a fellow grad student at Caltech while I was there systematically collected such inclusions radially away from the known vent of an explosive eruption. He was able to put together a vertical cross section of the Earth's crust and upper mantle and calculated that the gas-driven eruption had reached speeds faster than sound moves in rocks. Such "diatremes" are not common, but it is in those rock types that diamonds are brought to the surface. No diamonds here, but as I stared at those inclusions, I spread out my arms and said, "Magnifique"

Shortly after passing Shelly's mighty-voice-that-stopped-a-plunging-lava-flow, we pass a sand beach that comes and goes with major changes in the river discharge. It can be enormous following high flows of the river. It is then an attractive campsite if there is no wind. Sitting in a chair on that sandy expanse and watching the sunset pageant on an imposing wall directly across from it is one of life's great experiences (Figs. 21.17 and 21.18).

*Fig. 12.17. Giant sand bar that often forms at mile 185.*

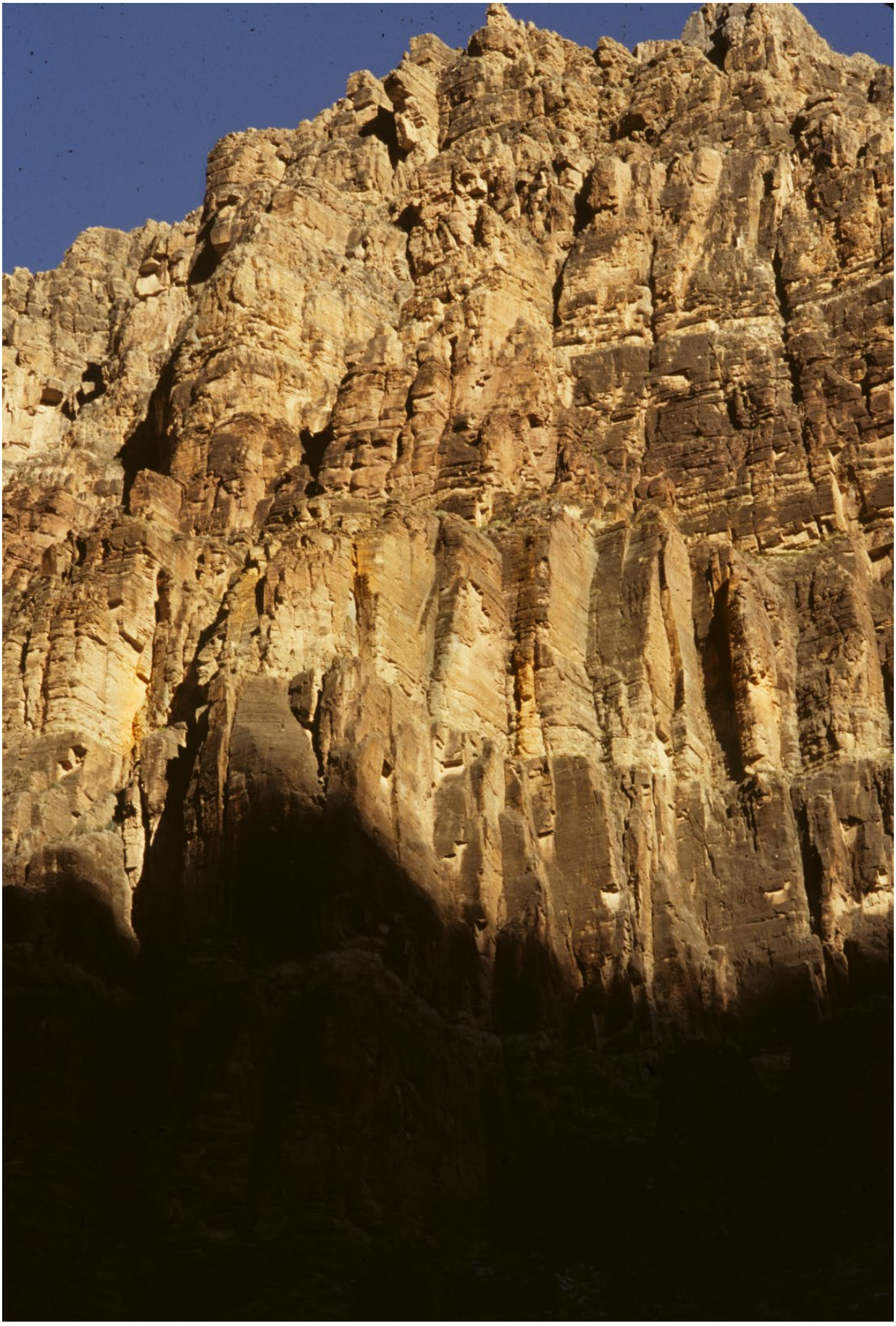

*Fig 21.18.  Sunset on wall at Mile 185.*

Sand banks near it display a sedimentary structure called “climbing ripples” (Figs. 21.19, 21.20).

*Fig. 21.19. Sand deposited during flood stage is here being eroded back into the river. As sand collapses off the bank, the internal structure of the deposit can be examined on the small vertical cliffs. At this place, it is possible to see better-than-textbook examples of “climbing ripples.”*

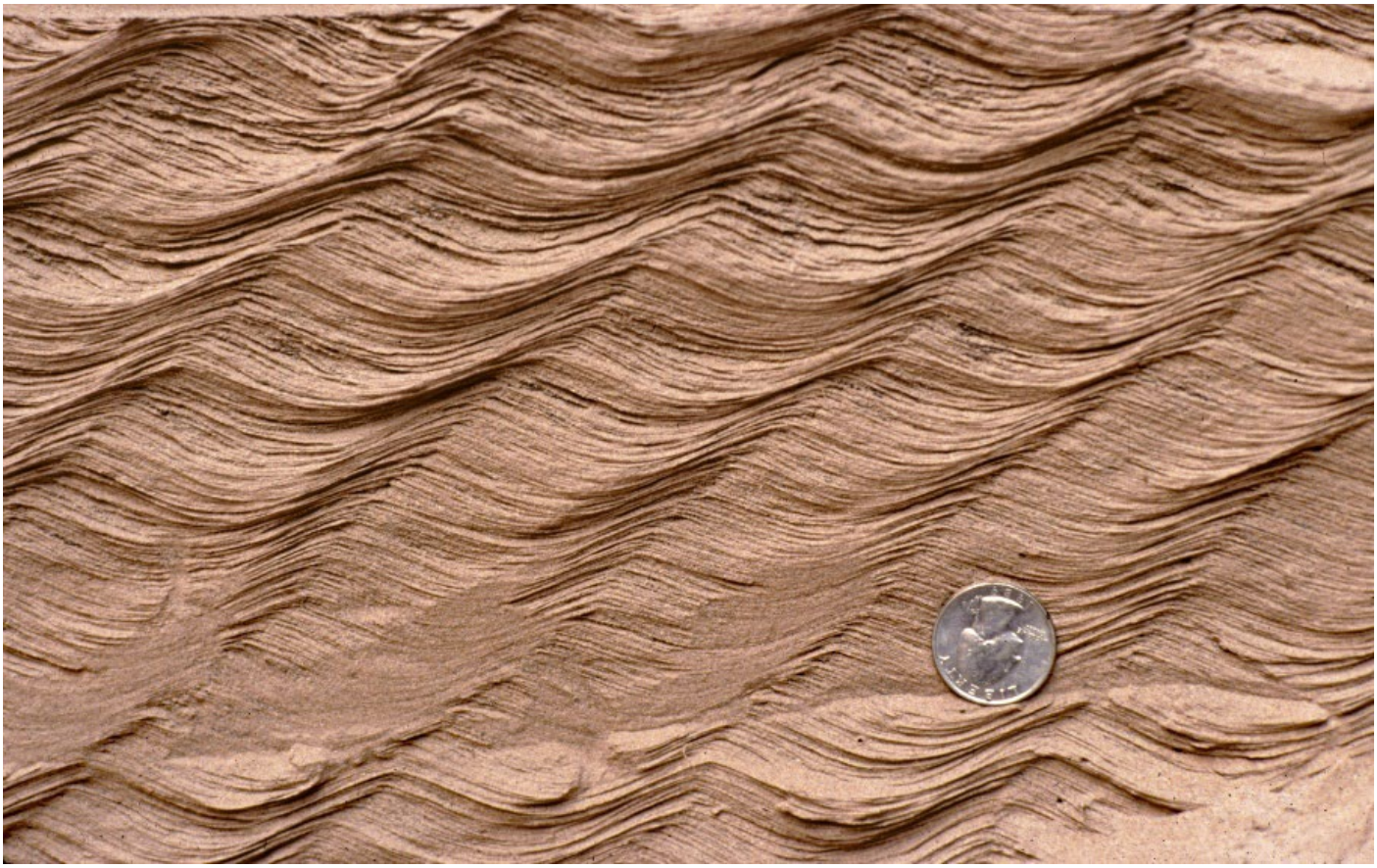

*Fig. 21.20. Climbing ripples in sand over-bank deposit. During a flood, rippled sand being pushed along the floor of the channel comes over the bank and piles up faster than the current can move it. The rippled surface grows upward. Here, the current was flowing left to right, so the ripple crests built upward lower left to upper right. The more closely spaced laminae define the upstream side of the ripple. Cross sections of ripples are common in ancient sedimentary rocks and can be used to infer the current direction at the time of deposition.*

I showed color slides of this beautiful example for over three decades in my sedimentology classes at ASU. They indicate rapid sedimentation and the direction of a slowing current. Coming across an example in an ancient sedimentary rock is almost as if the rock is speaking aloud. Here we can understand how they formed as water overflowed the bank and slowed down. The upriver current direction as read from the climbing ripples indicates that this was deposition in a back eddy rather than on a riverbank next to the main flow. We get to see here how geologists deduce past events from certain patterns observed in sedimentary rocks. The great sandbar beach is not present today, so we motor on and go past another large campsite called “Chock in the Rock.” This one has a large chockstone nearby lodged between two huge masses of jet black fractured basalt. The spot is quite concealed, so the crew usually puts a porta-potty there (Fig.20.21).

*Fig. 21.21. Chockstone that fell into a fissure in lavas at the popular “Chock in The Rock” campsite about a mile upstream from the riverside helipad. For obvious reasons, the spectacular fractures and great chockstone can only be examined privately and individually. No geology lectures allowed.*

Both camp sites are about a mile from the helipad ahead. If staying at one, the task is to get up early and get down to the pad by 7am sharp when the first helicopter will arrive. JP decides it best that we get along to the helipad and camp right there for our last night. The sky has now clouded over and looks a little threatening. I get a little nervous because we certainly do not want stormy weather tomorrow morning that could delay the helicopter exits. A gasoline generator and water hose suddenly appear between the bushes on our left side. This is used to wet down potentially blowing sand and dust at the small helipad out of sight above the vegetation. It is startling how something so artificial catches attention after the natural sights we have become accustomed to. We turn into a little embayment and land on a small beach that is our last campsite. It is the end of another of my many public outreach raft trips on behalf of Arizona State University. Everyone is alive and unhurt. I look up into the blue sky between clouds and do an exhale for the ages. Before morning, however, this will become the most terrifying night of my life.