Ch 16 **RAPIDS WITHOUT END** Mile 75-108

The increasingly thick clouds appear to extend from horizon to horizon, although the high walls here actually prevent us river runners from being able to see what kind of weather is coming our way. This can yield interesting weather adventures if thunderstorms are in the area. A pitter patter rain can turn into a deluge with almost no warning. This isn't the season, but the lack of a warm sun for what is going to be a very wet day in cold water is a bit concerning. We suit up in rain gear for our entry into the string of endless rapids ahead with apprehensions enhanced by the ominous sky. We climb aboard and both boats push off. JP explains to us that there may be times that the boat swings around and he drives backwards so that he can spot and dodge big rocks lurking just below the surface. They are recognizable because smooth fast water pouring over them creates a big hole on the other side and then an enormous wave. Going over all that sideways can flip even a big boat like ours. Going over it at any angle can cause us to get stuck on the rock. Upcoming Hance rapid is long, ferocious, and exceptionally rocky. Smaller boats regularly flip over in it, and big boats have gotten terminally stuck on rocks out in the middle of the current. More than once, passengers have been helicoptered off a stuck boat before the frame eventually broke up. This is not a situation we want, so we are all ears as we listen to JP's directions. Hang on tight and follow instructions if something goes awry.

Anticipated fears contradict the placid water we are slowly motoring over. We are in something resembling a small lake now with water piled up behind rock-choked Hance Rapid still out of sight around a slight bend ahead. In this anticipatory atmosphere, no one notices that the slanting huge cliff of Shinumo sandstone has risen way up the walls and that we are now floating past a deep red crumbly layer that lies stratigraphically below it. Straight ahead, this beautifully colored layer known as the Hakatai Shale suddenly fires up in a momentary shaft of morning sunshine where the river bends out of sight to the right. I had never noticed before how fiery red it can be from down here in the gorge, but a morning sunshine view down onto it from the South Rim high above is always breathtaking (Fig.16.1).

Fig 16.1. View down to the bright red Hakatai Shale from Moran Point on the South Rim. Morning sunshine shows how much redder it is than the Redwall Limestone along the left margin of the image. The source of such hematite-rich shale is unknown, but it could have come from weathered basalt on top of the older Mescal Limestone to the south.

So much redder than the Redwall Limestone, it just seems unreal. Part of it down here by the river is dulled a bit by jet-black dikes of lava that solidified while squeezing along some of its bedding planes. It is possible to land at this spot and contemplate these once-molten intrusions and the extraordinary red color of this Precambrian sedimentary layer (Fig. 16.2).

Fig 16.2. Ground view of Hakatai Shale on south side of entry into Hance Rapid. Molten basalt intruded laterally along bedding planes to form the dark bands in this otherwise red silt and shale.

Where did all that red hematite come from as it washed in here along with the sands and silts over a billion years ago? One likely source is about 150 miles to the south in the Sierra Ancha Mountains. There, basalt lava flowed repeatedly over an area of the yet older Mescal Limestone that was undergoing extreme karsting in a humid climate. They were weathered to the maximum extent possible and almost dissolved away. Hematite (iron oxide) residual soils developed over heavily silicified karst rubble of the Mescal (silica dissolved out of the basalt). I suspect it was that widespread red hematite soil that washed into lower areas to the north where the Hakatai sands and silts were accumulating at that time. Interestingly, the hematite soils in the source area converted to iron ore during burial metamorphism and were mined in World War I (Fig. 16.3).

Fig 16.3. A two-meter-thick bed of iron oxide residue of ultra-weathered basalt flow lying on the 1.1-billion-year-old Mescal paleokarst rubble exposed on the south side of Shell Mountain in the Sierra Ancha mountains 150 miles south of the Grand Canyon. The skyline knobs are the Chediski Quartzite, the stratigraphic equivalent of the Shinumo Quartzite complete with convoluted bedding somewhat like that in Fig 15.10. Several miles away, this basalt residue is 10 times thicker and was mined for iron in World War 1.

There is a lot of geology to contemplate here, but the increasingly loud roar of Hance Rapid draws attention to the bend we are turning to the right on--only to discover it turns sharply left again. This is but a jag, and then we will go into the great rapid. Froth and high squirts

shoot up from behind the smooth lip hiding the 30-foot drop along the ¾ mile length of this nasty rapid. JP is all concentration because a screw-up here can be a trip-ender.

What a pity this scary rapid is here. Rising on our right is a towering cliff showing the Hakatai Shale capped by the Shinimo Quartzite. And slashing up through the red shale is an eye-catching, black, basaltic dike (Fig. 16.4).

Fig. 16.4. The great dike of formerly molten basalt ramping up through the Hakatai Shale at the beginning of Hance Rapid. It was diverted to the right as it approached the base of the overlying Shinumo Quartzite. This dike is a planar feature seen here in cross section. It once extended straight out toward the viewer before the river cut down through it. A second, thicker dike intrudes from the left center margin and squeezes up and then along the base of the Shinumo.

Outstanding! The ancient molten lava squeezing up this crack hit an uncracked section of the bottom of the hard Shinimo, and caused it to move laterally until it found a zone of weakness to continue upward in. The red shale, the dike, and its deflection here are one of the most photographed geologic features in the Grand Canyon. A major but unmaintained trail comes down from the South Rim, and backpackers regularly camp here at the head of Hance Rapid. It is possible to circle around in our boats in the calm water just above the rapid to look at things, but that would have to be a special-purpose trip because here comes the rapid.

As we shoot through this white-water maelstrom, we pass quickly right down through the red Hakatai shale bed, the dolostone layers of the Bass Limestone that lie under it, the rounded cobbles of the thin Hotauta Conglomerate layer and then into the new world of the schists and granites of the inner gorge. What a pity we can't explore these lowest sedimentary layers in the Grand Canyon--but break my heart--there is no stopping in a rapid. Even if we could, it would be difficult to see the rock units in context from river-level in the gorge. While rising through the red Hakatai, that black basalt was also squeezing sideways as a sheet right through the Bass Limestone. The best view of the Bass with this sheet intruded laterally into it along with the overlying Hakatai and the Shinumo above it is from a vantage point on a cliff higher up on the south side of the river (Fig. 16.5).

Fig 16.5. Beginning of the inner gorge of the Grand Canyon. The Vishnu Schist extends upward from the river (seen to the lower right) to an erosion surface upon which the Bass Limestone was deposited. An intrusion of molten basaltic lava intruded as a sheet along the lowest layers of the Bass to form the black bed ramping up from the lower right with the white band above it. This band is asbestos created when heat from the molten rock caused chert to react with its carbonate host rock. The Bass is the collection of thin layers making up the cliff directly above the asbestos layer. The red Hakatai is the red slope above the Bass.

The Bass Limestone is full of stromatolites of a type not common in younger Precambrian sedimentary rocks. Units just like it occur in West Texas north of Van Horn (the Alamore Formation), east of Phoenix in the Sierra Ancha Mountains (Mescal Limestone), and in the Death Valley region of California (Crystal Springs Formation). The diabase dikes and sheets present in all four areas yield radiometric age dates of about 1.1 billion years. The Bass was likely deposited in shallow waters that covered a large continental platform extending from west Texas to California. However, there are reasons to think that while generally the same age, the four areas are not tightly coeval. The intrusive diabase may be another story, and that could emerge as more radiometric ages are determined. There are reasonable scenarios invoking modern plate tectonics that have these intrusions occurring in continental rifts associated with a huge subduction zone far to the east, the so-called “Grenville Orogeny.”

Many assumptions geologists can question are required for this interpretation, so there is still much to investigate here. Whatever, none of the geologic evidence can be examined while traveling through Hance Rapid.

I must content myself with not being able to stop and talk here by quickly and irresistibly remembering the time in 1979 that Bob Horodyski, field assistant Pat Lowry, and I were dropped off just above the rapid by a Hatch boat so that we could spend a couple of days collecting samples from the Bass Limestone. We hiked along a cliff on the south side of the river to Mineral Canyon where there are magnificent exposures of the Bass and where for one of two times in my life, I felt the flapping of the wings of the Angel of Death. The mountain bar sticking up from my rigid Kelty backpack caught an overhang as I was carefully walking along a narrow rock ledge sticking out from a high wall. I was suddenly swung out toward a 50' drop and for a second teetered between life and death. I remember this every time to ameliorate fears going into Hance Rapid—this is really nothing compared to that scare so long ago.

Suddenly, I notice we are jerking back and forth and left and right because the boat is traveling sideways through all this turmoil! What? I look back and JP is not there in his usual position hanging on to a strap with one arm and the other extended backward to the tiller handle on the outboard motor. The back of the boat heaves up and I see the top of his head down in the motor well with him wildly cranking the starter rope for dear life. The motor has gone out and we are suddenly at the mercy of violent white water. He starts popping up and down between cranks to see what is ahead—or rather off to the side in the direction we are speeding. Suddenly, he rises high and yells as loud as I ever heard him, "HANG ON TIGHT!!!" We are indeed going sideways on smooth supercritical water flow over a big rock into a famous hole known fearfully as the "Big Kahuna." As one side of the boat tilts downward toward the base of the far wall wave, it looks like the end of the world. Bam! We hit mid ship and almost stop as we go into and across the hole. Water explodes over the whole length of the left side simultaneously with an enormous jolt that knocks several of us off our padded bench seats onto the floor of the "tearoom"—and we were indeed hanging on tight with white knuckles. Didn't help, but I guess that kept us from catapulting into the river. Yay for big pontoon boats because we emerge upright and see JP again driving the boat under renewed power into a more reasonable part of the current. Who says small boats have all the fun! I hate rapids.

Almost immediately, we are through Hance and turned around motoring hard against the current to stay put so we can see if our second boat is going to get through without kissing the Big Kahuna. This sentry action is to pick up anyone that may have fallen overboard if the second boat flips. We see it plowing through the waves on a beautiful, perfect run. Now, two boatloads of people are whooping, yelling, and clapping. JP is not miffed that he got nailed and that his less experienced colleague did not. You can do everything right, and the River Gods get you anyway. Motors go out in the violence of rapids all the time. Propellers break off on rocks. Random swirls deflect your course. Any run that gets you through right side up is good

enough. Trouble of any kind with JP driving is rare. The second boat passes, and we move out to reunite in the swift but now linear current.

A big, tilted block of rock with a knobby surface was immediately to our right while we were turned around and motoring hard to watch the second boat come through. The knobs are ancient beach gravels that got preserved when the sea flooded this area about 1.1 billion years ago. The cobbles now cemented together by deep burial were derived from the then adjacent highlands. They are a collection of rocks unlike any we have seen so far on the trip. It is possible to tie up here and exit the bouncing, bobbing boat and climb around to look at this interesting rock collection. We skip it this trip because this is a very noisy place and from now on today, we will be within the very rocks that shed those gravels before the sea submerged them. We might as well look at what was eroding instead of what was derived from it. I suspect that the gravels also contain interesting cobbles derived from more distant highlands to the south but viewing them again will have to be on another day.

As we join the other boat, everyone is shaking off water, especially those on our boat. Now you discover if the rain gear you bought is really water “proof” as claimed on the label or only water “resistant” as most of it actually is (not). You may also find that the rain pants you cinched around your ankles are bulging pantaloons full of water--or worse. Anything that can fill with cold water just did, including that hood on your raincoat that you forgot to pull up. Rain gear or no, river runners get very wet. Once all that is straightened out and some of the rejoicing and laughing has died down, everyone looks around and realizes that the layers are gone. We have entered the strange new world of the Vishnu Schist. (Fig. 16.6).

Fig. 16.6. The Vishnu Schist as seen from its contact with the overlying Bass Limestone on the south side at Hance Rapid. The Vishnu is mainly 1.7 billion-year-old old pressure-cooked ocean mud but is extensively intruded by stringers of granite somewhat pinkish in color.

This black shiny rock is interpreted as ancient ocean mud that got deeply buried and pressure-cooked into an array of new minerals that we have not seen before. The former muds are now dominantly black biotite, feldspar, white mica, quartz, chlorite, garnet, and other metamorphic minerals. Somewhere along the way down or up during its burial history, all was folded, sheared, and faulted. At temperatures glowing cherry red, everything became as malleable and deformable as paste. In places, it was stretched out like taffy and bent into tight folds (Fig. 16.7).

Fig. 16.7. Tight folds in the Vishnu Schist exposed on the vertical wall of a stream bed. Here are two small ones mashed together like folds in an accordion. Location near mile 96.6 on south side of the river. The bush in the lower right corner is about 4 ft high.

We will encounter formerly molten masses of sticky granite that squeezed upwards and solidified in place as pods, sheets, and stringers. In some cases, the intruded masses were large and widespread, so we will see examples of granite and schist in various amounts in various places on both walls (Fig 16.8).

Fig 16.8. Vertical wall of mixed granite and schist, a common occurrence. The vertical banding is mostly due to shearing and not compositional variations in the schist. The horizontal bed is the Tapeats Sandstone deposited directly on the schist.

The geologic history is long and endlessly complicated. We will be immersed in it for the next several days. There is no urgency to force a geology stop now. An unusual but significant metamorphic mineral occurs loosely mantling the steep gullies on the north side near where the rapid ends. It is asbestos, and it comes not from the schist but from the younger Bass Limestone on the cliffs high above it. Loose asbestos! Yikes! Hold your breath because asbestos causes lung cancer. Commercial trips thus do not stop here to look at the beautiful green fibers that we can pull out of world class chunks of this dangerous mineral. Imagine the liability if someone subsequently develops lung cancer and decides to sue the boat company or the National Park service. They might win a court case--such is the concern associated with this mineral.

Asbestos used to be a valuable mineral. Its fibers could be woven together to make fire-proof stage curtains, especially back when theaters illuminated with candles would frequently burn down. Asbestos was used extensively in brake linings, insulation, and anything requiring extreme heat and fire resistance. But it was the theater curtain market that induced old John Hance to have a try at mining it here. He came down the trail now bearing his name sometime around 1900 and crossed the river to open a mine in the Bass Limestone. A filing he made claimed a cable was set up 1200 ft above the river to transfer asbestos, but there is no evidence this was ever done. We look up and see the mine as a tongue of greenish white tailings spilled out of a dark hole on the side of the cliff now making the skyline (Fig 16.9).

Fig 16.9. Close-up of one of Hance's diggings looking at eye-level from Mineral Canyon on the south side of the gorge. He had stripped off the weathered surface of the asbestos at the top of the white band to reveal the blue-green shimmering color of the asbestos. Another large digging is down near the river off to the lower right.

A prominent mine hole is dug into a shimmering blue-green layer just above a horizon of black lava that squeezed along a bedding plane in the Bass Limestone while it was deeply buried. Heat from this intrusive molten mass baked the areas above and below enough to cause chert nodules to react with their host rock dolomite to form the mineral asbestos. This zone of heat-driven mineral transformations localized around intrusive magma is called "contact metamorphism." Considering the molten intrusion was white hot, it is striking how thin the contact metamorphic aureole is. But it was thick enough for old John Hance to possibly cart several loads of asbestos out on the backs of mules. The scar associated with any unlikely profit he made is left today and will be around for another thousand years. It is the story of mining all over the west. Profits were made on relatively few of the horrendous scars left on the landscape for future generations. Hance quickly abandoned mining life to become a legendary teller of entrancing lies at resorts atop the South Rim. Meanwhile, most of the

asbestos-rich rock he mined out has subsequently washed down gullies in the canyon wall and dropped into the river.

On a trip many years ago, I was able to look at some accessible piles of the mining debris. There were wondrous big crystals with bundles of greenish fibers of the mineral chrysotile asbestos that you could peel off one by one (Fig. 16.10).

Fig 16.10. Beautiful fibrous crysotile asbestos at the digging near river level. The spike from the mining activity in 1910 is ¾" wide.

Some claim that chrysotile asbestos that forms in this manner has never been specifically implicated as a cause of lung cancer. In one study, a town in Canada where the population lived amidst huge piles from local chrysotile asbestos mines surprisingly had lower incidences of lung cancer than normal. The asbestos scare originated from a likely carcinogen called crocidolite, a blue mineral that forms in an altogether different way in an altogether different geologic setting. The biggest mine of this "blue asbestos" was in Australia, where it was used for pipe insulation and fire control in ships during World War II. The miners there were indeed savaged with lung cancer, but one wonders how much heavy smoking added to the lung damage. In the United States, a mine in Butte Montana also produced crocidolite on a large

scale, but it closed long ago and is currently being mitigated. Because lawmakers do not distinguish between harmful crocidolite and possibly benign chrysotile, there is now a multibillion asbestos removal business, never mind much of which may be to remove chrysotile. It is widespread in old linoleum, pipe insulation, and a thousand other items that must be removed by people in bunny suits at great cost to the public. Whether justified or not, the expensive train left the station on this issue long ago. Lawyers will likely induce a settlement for anyone aggrieved by fear that their health problems were caused by "asbestos."

The assumed dangers associated with Hance's asbestos mine provoke bigger thoughts. Many scientists often justify their research by thinking it will lead to new knowledge that will "inform decision makers" and thereby benefit society. You would thus think the medical studies and regulations would be more specific to the type of asbestos. My experience is that most decision makers in the public arena are not guided by science when they make decisions. Other factors involving politics, fear of lawsuits, and greed triumph all too frequently. My pilgrimage involving how science affects our outlooks and collective psyche here runs into more troubles--asbestos troubles. If science is so great, how can it be so readily and willfully ignored? I just wish we could stop here and look at the beautiful crystals of chrysotile that old John Hance inadvertently shuffled down the slopes.

In a few minutes, we find ourselves deeper in the schist and oblivious to everything above it. Indeed, it now defines a close-in skyline for us in this narrow stretch of the river. Everyone notices a certain banding defined not so much by composition changes but rather by shear zones lifting jagged spires dramatically up toward the leaden gray sky. Unlike the nearly horizontal layering before, these thin ledges go straight up and are often twisted and contorted like rocks few eyes have ever seen (Fig. 16.11).

Fig 16.11. Intense deformation is common in the tortured Vishnu Schist.

The schist is black and beautifully polished at river level. Higher up, it is splintered and broken into piles of jagged debris lodged in gullies and perched precariously on any ledge breaking the slope of the steep walls. All piles are typically at the "angle of repose." That is the angle of a steep slope upon which any disturbance will cause a fragment to tumble downward. These are rock piles not to be walked on. There is no such temptation because they are usually high up on or at the base of an unclimbable wall. White quartz veins crisscross the shiny walls with varieties appearing straight to wildly convoluted. Quartz veins are almost always sheetlike features that only appear "vein-like" because of how topography is cut into them (Fig. 16.12).

Fig 16.12. Quartz-rich vein in the Vishnu Schist. These resulted from fluid circulation during deep burial. This cliff is about 150 feet high. The white vein is actually a sheetlike feature slanting down from upper right to lower left and cut into by modern erosion. Quartz veins are almost aways sheetlike features but appear in fantastic shapes depending on how the local topography is cut into them. This particular one divided into two sheets for a small distance to create a planar quartz vein sandwich holding a small slab of country-rock near the center of the photo.

Pink granite pods, lenses, and masses appear unpredictably. This is all so different--and together with everything so dark and jagged--somewhat spooky under this kind of ominous sky and in this swift swirly current. We have now cut into the core of the Kaibab Uplift. We are in the oldest rocks in the Grand Canyon and at its deepest depth. Deep in time--the innards of the Earth, sea floor buried, tortured, and billions of years later uplifted into jagged fingers silhouetted against portentous dark clouds. Wow! But no time to think about it. We see high walls of schist closing in to cause the frothy mayhem known as Sockdolager Rapid. There is no obstructing pile of rocks or sudden drop; it is the funneling effect of the narrowing canyon walls that creates this fury of nature. I have had my worst experiences in this one. The first time through it, I was already very alarmed about rapids in the inner gorge. Sure enough, the motor went out just as we entered the wall-to-wall white-water chaos. Out of control, the big pontoon boat started rotating and crashing repeatedly into the left wall all the way through. Being helpless amidst dangerous convulsions of great power is not a great experience. On a subsequent trip, I was riding defiantly out on a side pontoon when a million-ton wall of water slammed into me sideways and knocked me off hard into the duffle pile in the center of the boat. I remember the impact as a brief blackout, a real sockdolager indeed. JP is devoid of fear here and takes us right down the middle with everyone screaming for joy.

Blue sky suddenly drifts in over the south wall allowing sunlight to fill the gorge. Everyone is shivering, so JP pulls over on a little sand beach where we can spread out rain gear, get dry, and empty bladders. Maybe this will be a good time to talk about the schist. People shed their rain gear and have a love affair with the sun for the first time on the trip. We break out some fruit while all around us, the silent schist in sunshine is just as spectacular and mysterious--if not more so. This pressure-cooked ocean mud is slaty, jagged, and studded with tiny crystals of dark garnet. I look at a piece with a hand lens and want so much to start talking about all that has gone on here to make this fabulous, shiny rock. Alas, I sense that the troops are not hungry for it now. The sun is really baking this little beach, and the sand is already too hot to stand on. The geologic story can wait because an even better place to engage with the schist is only a couple of river miles ahead after people will have had time to adjust to this strange new world.

We climb aboard and people now feeling the sun's heat stuff their rain gear into small duffle bags. The fragrant smell of sunburn goo seems incongruous with the setting but makes perfect sense. Grapevine Rapid ahead quickly provides a cold shock to those wanting now to get sloshed a bit. Then hot again. I ask JP if I can take the group up Clear Creek, a babbling creek flowing down a narrow side canyon cut deeply into the dark schist. Here we can splash up through sparse but welcome greenery to a small, complex waterfall that shoots water forcefully out sideways as well as falls hard from above. People can immerse in it for a soap-free shower in water not warm but vastly warmer than that which has been soaking them in the rapids. The mouth of the creek appears on the right behind a protruding wall such that anyone looking straight ahead is likely to miss it altogether. The river is flowing swiftly across

the mouth, so only at low water and slow flows can a boat nudge into the slot where passengers can climb out over the bow. Not today, so JP pulls in above the mouth against a river-smoothed wall projecting out into the current. We tie up on some big knobby protrusions and now need only climb this wall and work our way through a cleft down into the stream. There are cracks for handholds, but all is somewhat smooth and slippery. Some marvel that they are doing this, but none hesitates (Fig 16.13).

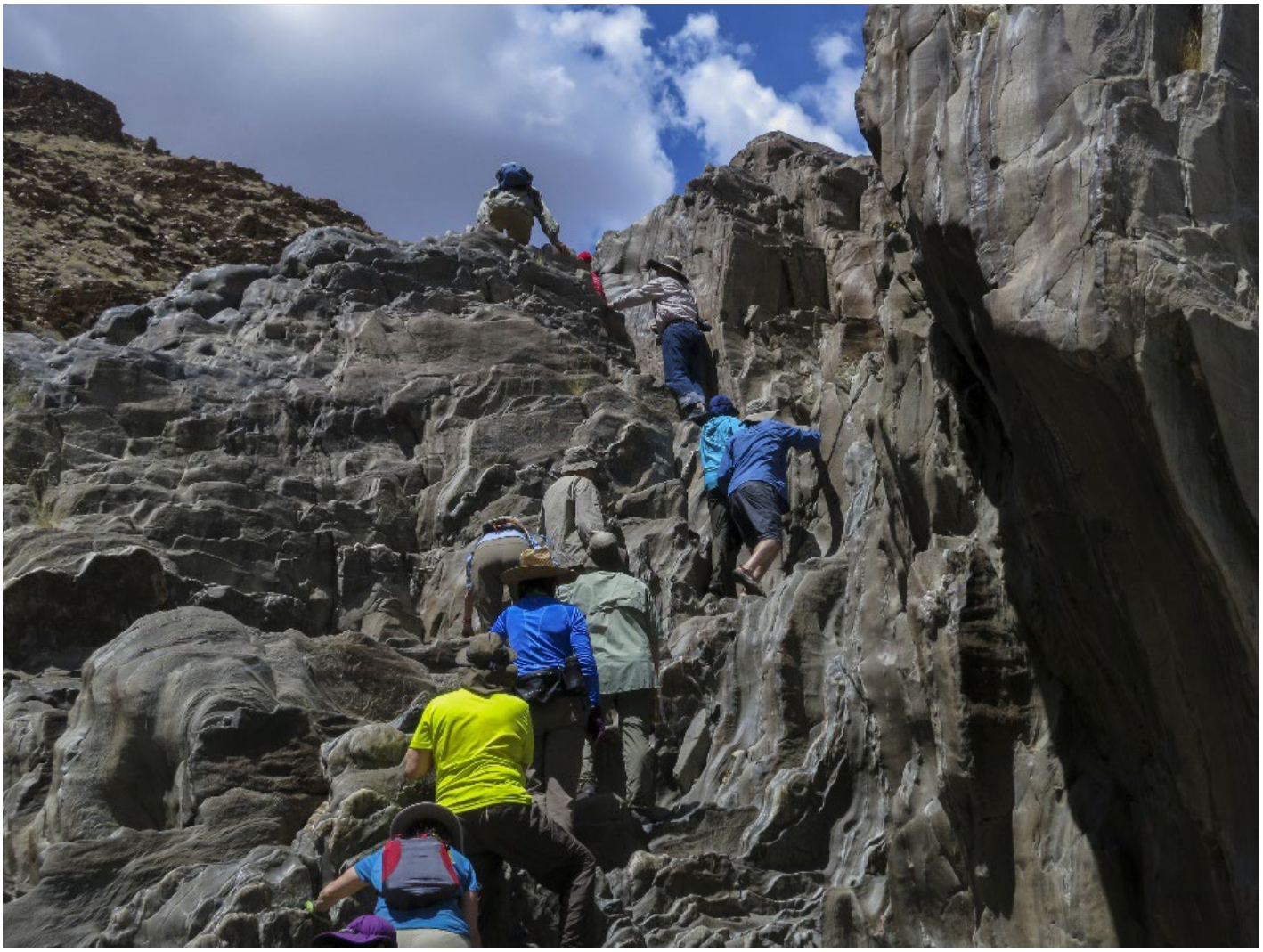

Fig 16.13. Climbing the wall to get into Clear Creek

The second boat comes in against us for people to climb aboard and follow the group. Everyone makes it and we soon form a scattered line of people splashing up the creek while marveling at the fantastic scenery so deep in this narrow gap (Fig. 16.14).

Fig 16.14. Walking up Clear Creek during high water.

Walking on slick rocks against a shallow but fast current in places, we turn a corner and gather near the splash pool of the resounding little waterfall (Fig. 16.15).

Fig. 16.15. The complex carwash in Clear Creek created by fallen blocks trying to impede the flow. The horizontal blast is strong enough to knock people over, but everyone usually tries to see how far they can get into it. Visitors to the deepest part of the Grand Canyon in the heart of the Kaibab Uplift can take a memorable shower here.

I lurk back near a cliff a short distance away that has one of my favorite outcrops in the Grand Canyon. After some frolicking and picture taking in the car wash, waterfall-cleaned groups now free of sand from last night splash back toward me. I feel somewhat like the ancient mariner in Coleridge's famous poem who accosts a chap on his way to a wedding feast and tells him a story that shakes him up. That is my design here. It is a small wall panel that illustrates vividly the extreme conditions some horizontal layers of sea floor mud went through during deep burial, deformation, and then uplift. Here the layers were mashed and heated to the consistency of putty and then shredded apart sideways to allow intervening material to squish between breaks (Fig 16.16).

Fig 16.16. Compositional layers in the schist that were ripped apart and squished together during deep burial metamorphism. At high temperatures and pressures, the buried ocean mud has the consistency of toothpaste. Regional deformation folded the originally horizontal layers into tight vertical folds.

A more dramatic demonstration of metamorphic conditions I have never seen. You can almost feel the heat, the enormous pressure, and the slow-motion distortions inflicted on this material then glowing cherry red. It started off as particles settling into an ancient sea and was subsequently transfigured over 1,700 million years ago. What could cause this history? Imagine the energy to forge such rocks from mud. The micas, feldspar, quartz, and even a few

garnets are new minerals created from tiny particles—all happening in the solid state without melting. This is a process we cannot visualize in terms of our everyday experiences. All happened at the higher temperatures and pressures characteristic of deep burial, a domain we can never adequately visualize. I repeat the story with each of the several clumps of returning waders as they arrive, listen, stare a bit, and head back to the boat. Not too much! Just see what goes on deep down in the Earth. This was once just ocean sediment but look at it now! Nay, you can even feel it.

After the last small group to endure my increasingly emotional discourse disappears around the corner, I stare at it myself and try to achieve the state I wanted them to achieve. While not apparent to the group yet, I know that we are now travelling in a terrane mangled at depth into tight vertical bends resembling the folds of a giant accordion. Trace this banding up toward the sky and it folds over, comes back down, and then folds up again. Over and over. Rips and faults tore into the whole accordion during its tectonic trip to great depth and then back up to expose its sides to the sky. Constant erosion by rains and rivers then beveled it down to sea level as it began sinking downward again. The Bass Limestone, Hakatai Shale, Shinumo Quartzite and Dox Sandstone accumulated from billion-year-old seas above and then all got shaken by a tectonic orogeny that moved great blocks of the whole package sideways, like a stack of dominos tilting side by side on their ends. The jagged tops of the dominos leaning over got smoothed down by erosion to allow the Cambrian Sea and its subsequent strata to deposit horizontally across it all. Little pockets of the Precambrian strata remain preserved in the deeper parts between the jagged domino tops. Those are what we passed through yesterday and this morning. Directly above us, the Cambrian Tapeats is here deposited horizontally right on the Vishnu Schist with all its faults and folds. The souvenir bandanna illustrates the result (Fig. 3.3), so I will be pulling mine out and showing it several times to individuals and groups on the two days we will be in the schist. But here I am alone in the deepest part of the Grand Canyon looking at what was halfway down in the continental crust. This pilgrimage started somewhere out in the universe and has brought me to this inverted Mt. Everest summit in the core of the Kaibab Uplift. But this summit is not something few human eyes have seen. One involving the same kinds of rocks of the same age and similar history is an actual mountain summit right in the middle of Phoenix! Yes! It is Piestewa Peak, the mountain just north of downtown that thousands of hikers walk up and down every week. Central Arizona once probably had all the strata above it that we see in Grand Canyon, but the north half of the state was tectonically uplifted while simultaneously rotating down to the northeast--all starting about 70 million years ago. The uplift brought the basement rocks, the Vishnu Shist equivalents in Phoenix, right up toward the surface and higher. All that was above has now become sand that eroded off and deposited in the adjacent desert valleys. Similar peaks of schist and granite with their adjacent erosional debris also occur elsewhere in the southwestern half of the state. But this is something not to tell until we have travelled more into this domain where natural history can be so viscerally felt in all its context. Besides, the remainder of the day will be furious with thought-executing rapids.

It is now approaching noon, and the sun is starting to turn the inner gorge into something of a furnace. Within two miles we pass Cremation Camp, possibly so named because you will feel like you are being cremated if you stay there during a summer day. It is now used almost exclusively by boat trips that plan to arrive late and travel early the next morning downriver just a mile to the Bright Angel trail. There, passengers taking only a half trip can hike out from the deepest part of the Grand Canyon and be exchanged with those who hiked down to take a half trip to the end. The river is still frigid even after leaving the bottom of Lake Powell, now some 100 miles upstream. By the end of our trip, it will only have warmed up to about 50 deg F, such is the capacity of water to resist rapid temperature changes. Air moving over the cold water or us moving through the air over cold water keeps us cool, so the name Cremation Camp carries no fear. For me, it brings back one of the most entrancing memories of my life.

Camped here on the last night of my second trip, which was prior to these charter trips and went only halfway, I couldn't seem to fall asleep. A bright full moon was filling the canyon with magical light, so I got up and went down without flashlight past sleeping bodies out onto a gravel bar protruding into the river. Everything was silver from the gleaming walls of schist to glistening silver gravels lining the banks to the silver splashes winding around the gravel bar. The schist wasn't black at all! Innumerable polished surfaces were shining brilliant silver moonlight back at me. Clefts were jet-black shadows between silver pillars and columns soaring upward into a bright sky. The camp in silent sleep…the sound of gently splashing ripples...silver everywhere. I sat there, but it didn't feel like I was at the bottom of a deep canyon. I felt like I was being transfigured into a silver seraph in a silver heaven. It was a spiritual ecstasy with no sense of time or place. Bliss, oh bliss. Soaring. Transcendent. Wonderful, oh wonderful. I don't know how long I sat out there in a trance before reality intruded. I realized that I simply must leave this paradise and try to get some sleep. The upcoming day would involve a grueling hike to the top of the South Rim and a long drive home.

I have been in the inner gorge in bright moonlight numerous subsequent times, but that midnight vigil was uniquely overwhelming. The profound beauty of that silver universe washed away all anxieties, thoughts, confusions, and desire to sleep. If that experience were on this trip, I would specially appreciate how it was created by light emitted from thermonuclear reactions in the nearest star, bounced off the 4.5-billion-year-old moon and then off 1.7-billion-year-old ocean mud that had risen from deep burial after being transformed into a crystalline mass and now being polished by a great river. That light ricocheting off so much profound history is what goes into the eyes of a lowly pilgrim. How unexpected that at the greatest depth in the Grand Canyon, a moonlit night and a little scientific knowledge might take a soul to one of life's Mount Everest summits. The memory of that silver universe has nourished my soul in many boring meetings, on long plane flights, and in countless other unpleasant situations. But not now; the pilgrim today is hunkered down under an enormous straw hat in hot, blinding sunshine and no magic.

Suddenly JP takes us out of the slow current and into a calm embayment where depth soundings have revealed the deepest known place in the river—95 feet. On all trips, everybody keeps asking how deep the river is, so once I brought a fish finder with depth sounder that sportsmen use. Yes, there have been official surveys but every line down the river crosses different bottom configurations that constantly change. JP lashed the sounder to the boat, and we watched the sonar pattern on and off for 180 miles. It was astonishing to see how irregular the bottom is. It ramps up and down the sides of fallen blocks and sand piles often going from over 60 feet deep to less than 10, and then back down again. Over and over, never just a smooth bottom or even a ragged one treading at the same depth. I concluded that if the water drained away instantly, a hiker would face serious obstacles trying to walk along the riverbed.

Just as we stare at this nondescript place over the deepest hole, we notice an overhead cable in front of us and then a big suspension bridge (Fig. 16.17).

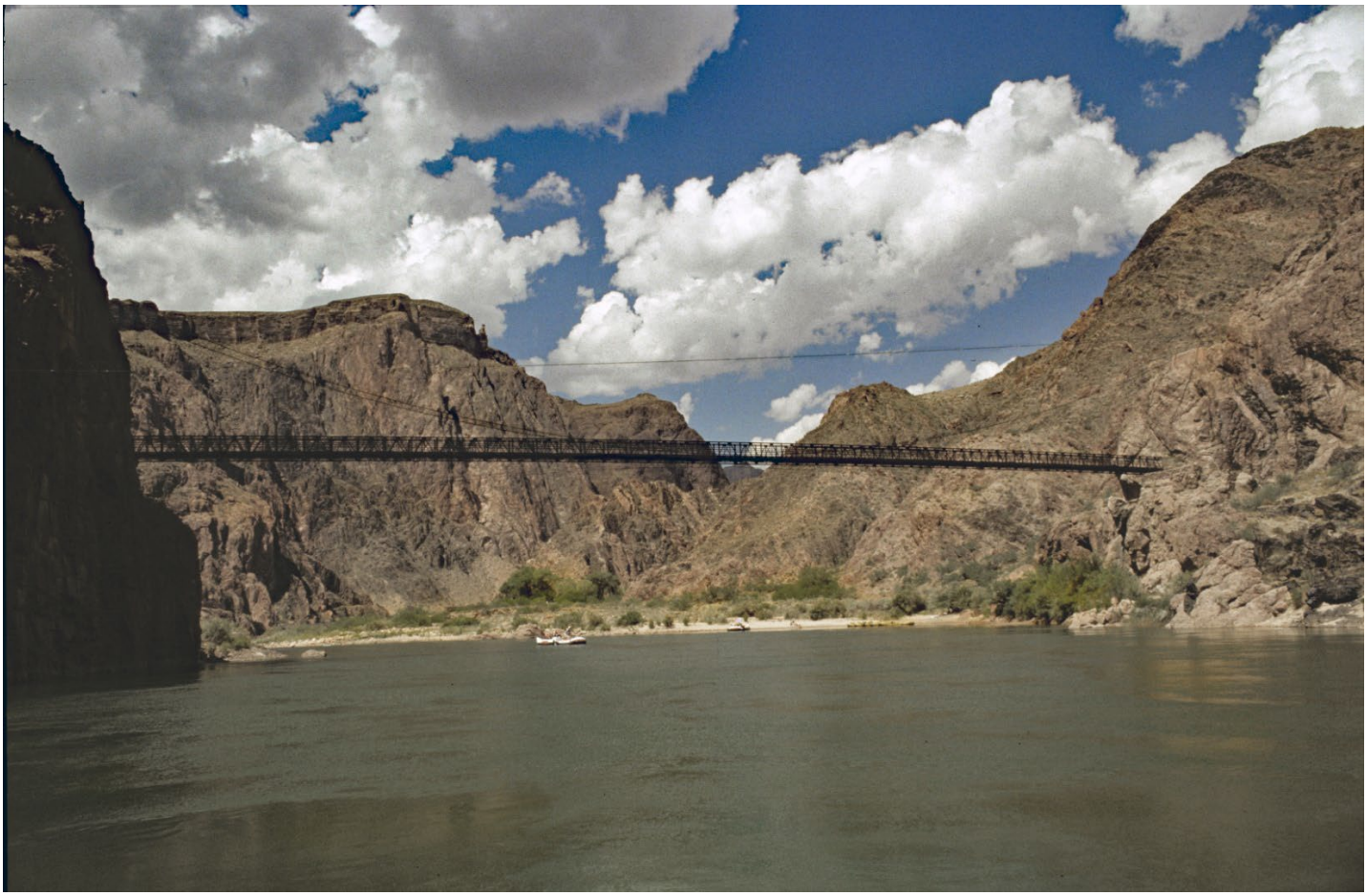

Fig. 16.17. Suspension bridge connecting the South Kaibab Trail to a short trail to Phantom Ranch. Another suspension bridge about one mile downstream connects Phantom Ranch to the Bright Angel Trail going up to the South Rim. Note the thin cable running above the bridge from which a small trolley used to carry operators out to the center of the channel to measure flow rates.

The cable attaches on the south side to a little cabin off the South Kaibab Trail before it reaches the suspension bridge. From this enclosure, observers used to step into a big bucket and hoist themselves out over the center of the river. They would lower a little propeller assembly that recorded the river velocity at various depths. From that, they could calculate the discharge in cubic feet per second passing under the cable. Modern instrumentation has now obviated the unusual job of dangling over an often-raging river to get discharge measurements. I bet those chaps had stories to tell. Today, we get real-time figures on the internet for this spot. The cable, the bridge, the hikers on the bridge, and people sitting along the banks come as a shock. The ambience of travelling through a wilderness suddenly vanishes. We are near the mouth of beautiful Bright Angel Creek and a half mile from the famous Phantom Ranch upstream from the river (Fig 16.17).

Fig 16.18. Bright Angel Creek joins the Colorado River in the deepest part of the Grand Canyon. This photo was taken from the South Kaibab Trail which crosses the river on a suspension bridge off the image to the lower right. A suspension bridge just visible where the river bends back to the right connects the distant Bright Angel Trail to Phantom Ranch from the South Rim. The schist is intensely intruded by small amounts of granite here.

Phantom Ranch is a popular hiking destination at the bottom of the deepest Grand Canyon near the junction of three maintained trails, two of which descend from the popular

South Rim and one from the North Rim. The ranch is a hiker motel and restaurant supplied only by mule trains going up and down the South Rim trails (Fig. 16.19).

Fig. 16.19. Mule train coming up the South Kaibab Trail from Phantom Ranch.

We motor right under the suspension bridge that brings hikers and mule trains across from the South Kaibab Trail. Here I make some enemies because I refuse to stop. People have heard about Phantom Ranch, and some want to hike up the creek to see it. They have even brought postcards they want to send to friends with a Phantom Ranch mule train postmark. Bright Angel Creek is one of the most beautiful creeks, but a stop amidst what seems like a crowd here breaks the spell for most of us. Someone on the trip is vocally disappointed about the postcards, so JP who is more accommodating than me pushes ashore near two backpackers soaking their aching feet in the cold river and asks if they would take the post cards on their hike upstream to the ranch in exchange for a six pack of cold beer. On a hot day like this, the outcome of the proffered trade is not in doubt. He hops back aboard while the other boat circles, and on we go.

We enter the little rapid at the mouth of Bright Angel Creek and see at once another suspension bridge ahead. This one is for the Bright Angel trail that runs for about a mile near river level on the left and then starts its long switchbacks up to the South Rim. Lots of waving back and forth as we pass a clump of hikers newly descended along that trail and now soaking their feet. We are quickly alone again with the black schist and pink crisscrossing veins and pods of granite. The walls close in and here comes Horn Creek Rapid--a sudden drop, smash, splash and you're out rapid. The jolting and hosing become routine as we splash along another three miles and pull in for lunch at one of the few big, sandy, green thickets in the Inner Gorge. Invasive tamarisk plants choke the area, but river runners have carved out paths and cubby holes, and a huge shady tree limb overhangs a great spot for a lunch table.

Several of us explore the adjacent outcrops of schist that hold centimeter-sized bundles of translucent white-mica flakes (muscovite) and a myriad of quartz and feldspar accumulations while the crew prepares the daily lunch spread. Most of the Inner Gorge is made of these pretty minerals that come and go in various concentrations and crystal sizes. And everywhere, nearly vertical shear zones produce polished vertical ridges, pinnacles, and walls that stream your soul upward. The geologic story here is complicated and fascinating, but now is still not the time for me to expound. We have a long way to go today, so we shorten lunch and shove off. We immediately slam through the upper part of Granite Rapid, and then the lower part slams us. Then we arrive at Hermit Rapid, the most fun ride on any raft trip. At least five smooth, giant waves are taken head on. Ride sitting in the front with your legs stretched ahead and you watch your feet go up into the blue sky. Suddenly everything rotates downward, and you see your feet descending steeply into a deep trough at the base of a titanic mountain of water rising before you. I once saw Jesus there. Bam! White water crashes you back against the duffel pile. As soon as you can see again, it is feet flinging water into the blue sky again. And so forth. Hardly free of water running off your body and shivering in bright hot sunshine, here comes Boucher Rapid. Bam and then a short quiet-water reprieve until you hear the roar ahead of much feared Crystal Rapid. This one went from a worn-down joy ride of a rapid to a ferocious killer after a single storm in 1966 when giant debris flows surged out to dump enormous piles of rocks and mud that the river has yet to push downstream. Although now significantly less violent, it still has a huge, raging hole that can be a trip ender, so every boatman goes through this one with trepidation and extreme concentration (Fig. 16.20).

Fig 16.20. Hatch guide JP Running inspects Crystal Rapid. This is one of the most ferocious rapids in the Grand Canyon. The idea is to plan a route around that nightmarish churning in the middle of the river.

Our crew nails it and has for so many trips that there is no longer the "ABC" celebration, "Alive Below Crystal!" Then we quickly encounter lower Crystal, Tuna, Agate, Sapphire, Turquoise, Emerald, Ruby, and Serpentine rapids, all within 8 miles and all serious contenders that pound, shake, and sop us with cold water that somehow gets around or through our waterproof gear. Isolated clouds have turned again into overcast and the sun is no longer giving us relief between sloshing. No one is thinking about geology or the meaning of life right now. Recovering, shivering, partially drying out, and exulting make life simple. You just want to adjust yourself into whatever comfort zone you can achieve. Some enjoy this ecstatically and think they are having the greatest day of their life. God bless them; I am happy to see coming straight ahead in the distance the end of this rough day. It is one of the most stupendous views that geology informed eyes can behold. It is the entire tilted and horizontal sedimentary sequence just as shown in more detail and simplified form on my red bandanna (Fig. 16.21).

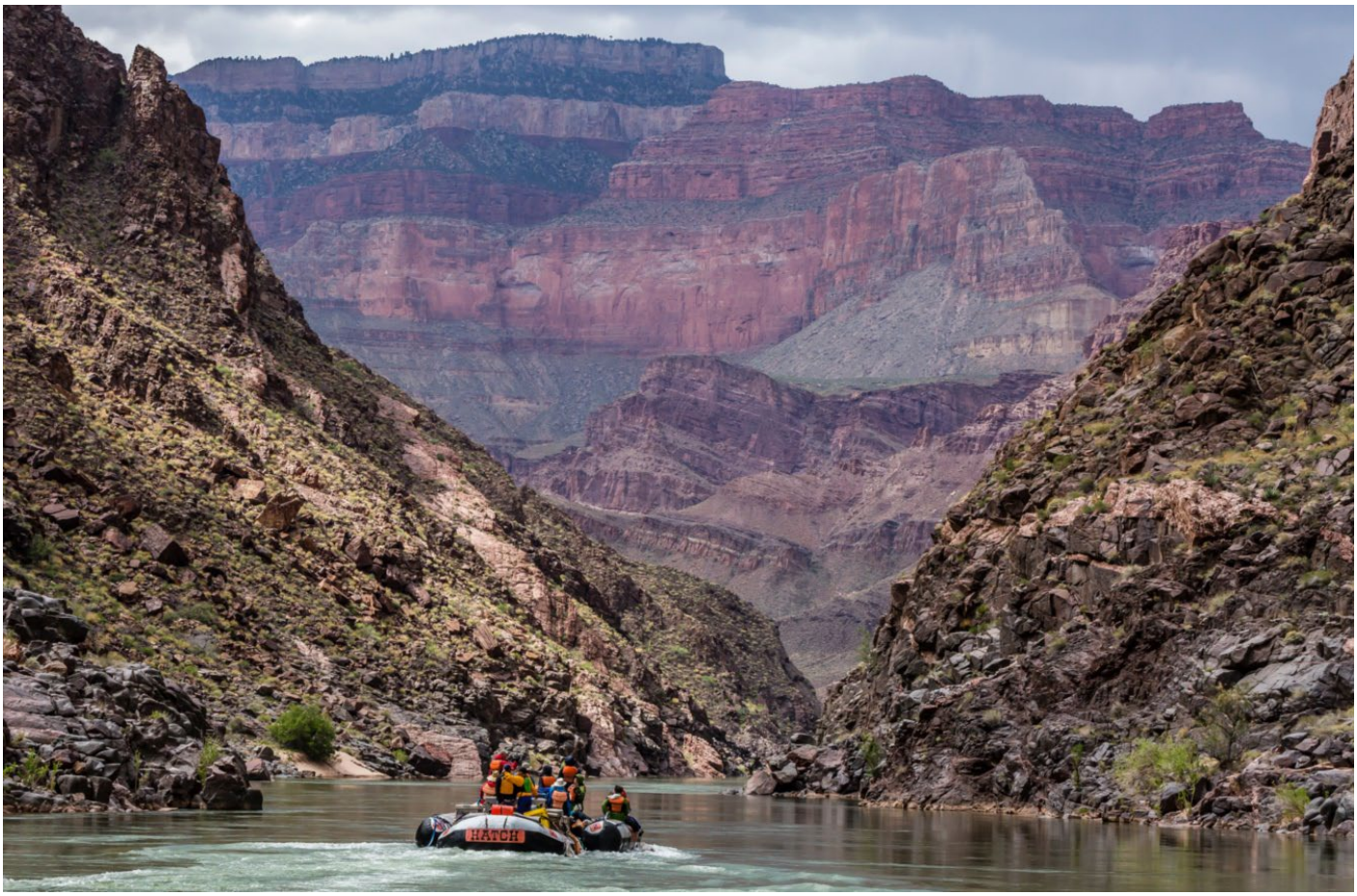

Fig 16.21. View from mile 107 where the tilted Precambrian strata are seen above the Vishnu Schist and below the Paleozoic strata. A prominent knob of Shinumo Quartzite is here weathering out at the base of the distant stack of strata capped by the Kaibab Limestone. The Hakatai has thinned here with the Bass Limestone forming a protruding layer beneath it. Although not visible from this angle, the Tapeats and much of the Bright Angel Shale are wrapped around this knob. It was an island in the early Paleozoic Sea and is now standing in the air again after 500 million years of burial. Modern erosion is here excavating an ancient mountain. Photo courtesy of Michael Nolan.

Yay, but I am probably the only one appreciating it right now. A distant rumble of thunder invites us to find a camp soon and call it a day.

JP and I now have our usual discussion at this location about the likelihood that Bass Camp, one of my favorites, is vacant. It is one of the most popular camps for private trips because adventurers can take a long, beautiful hike from there and lay over for two nights. No commercial trip passing toward the end of day will pass it if it is open because it is a large, comfortable, scenic camp just below some nice Indian ruins. We start calculating how many private trips we have passed and where the various commercial trips are likely to be now. It is too complicated to figure out, but we really haven't passed anyone in quite a while. River traffic comes in bunches the farther you get down the river for reasons I have never quite understood. So, it is a question of gut feeling based on what traffic we have seen. I say we go

for it, but JP has his heart set on a closer, beautiful site coming up on the right. Bass camp is around a bend and behind a protrusion such that you don't know if it is vacant until you get there. If it is occupied, we must go another mile to an exposed camp without a lot of good tent spots. If that camp is taken, we have a long drive to the next big one that will take us past a great geology stop I would like to take. JP will risk it if I really want, but who would go against the wisdom of this experienced, accommodating river pro? Besides, the "grassy knoll" JP thinks we should take has this stupendous geology view I am so admiring. We pull in there and some really battered but euphoric river runners scramble for camp spots with a view.

During dinner we witness a stupefying shaft of light from the setting sun coming through stormy clouds and mist that seem to be closing. A pitter patter of rain starts up as we finish washing dishes. Jabbering with my fellow rapid runners, I haven't even set up a tent. Still in rain gear for warmth, I throw up my nylon mesh cot near a low wall and decide to just lay down in my rain gear. God am I tired. My whole world shrinks to what I can see from lying on my side in an almost fetal position. The rain increases, and I watch drops stream off the bill of the hood on my rain jacket with everything cinched up to only an eye slit. It is remarkably cozy, and I enjoy being comfortable while utterly exposed to the pleasure of the gathering weather battle above. This is surely but a passing storm, and I will wake up before too long to stars. It works. The camp is silent. The triangle of stars making up the back half of Leo are just above the western cliffs; it must be approaching midnight. I pull out a sleeping bag, shed my raingear, and slip in thankful to be on solid ground free of water below, water above, water around, water everywhere. The ordeal of rapid after rapid is over.