Ch 19 **WHEN THE DUST SETTLED** Mile 120.7 to Mile 137

During the first several days of our raft trip we descended steadily through the various rock layers, together representing the accumulation of sediment during subsidence of northern Arizona on and off for over a billion years. The history from bottom to top of the layers involved intervals of uplift, erosion, and even tectonic disruptions that faulted, tilted, and uplifted the older strata before deposition of the younger. Then we descended into the underlying ancient continental crust all were deposited on-- the1700 million-year-old schist and granite. While passing through an uplifted block of all this, the Kaibab Uplift, we found ourselves deep in this jumble of pressure-cooked ocean sediment shot through with granitic intrusions and quartz veins, collectively known as the "crystalline basement." Now west of the uplift, we find we are in a tectonic block that was either never uplifted as much as the Kaibab Uplift or was uplifted and then dropped back down. We didn't see any clear breaks, but we are now travelling along just below the contact between the crystalline rocks and the overlying Tapeats Sandstone. We are apparently going upward in the stratigraphy and forward in time. At Garnet Canyon, we were able to climb up and sit on benches of gneiss just below the contact with the Tapeats Sandstone. Then we went into Blacktail Canyon at river level and found we could sit there on benches of the Tapeats with our feet right on the Precambrian. The Tapeats sandstone, the same unit we walked on just two days ago to frolic in the blue waters of the Little Colorado River is almost at river level again. Our descent into deep time is over.

As we pull away from Blacktail Canyon, we can see the contact between sandstone and the Precambrian on both the side walls just above river level. The sandstone is draped over humps of black schist (Fig 19.1).

Fig. 19.1. Cambrian Tapeats Sandstone lying over small hump of black Precambrian schist. The contact is largely obscured by slabs of the Tapeats Sandstone that fell off the river cliff. This was an island of schist that the Tapeats sea failed to level before its sands completely buried it.

Although mostly buried by talus from the vertical cliff of brown Tapeats above, small slabs of schist that broke off in raging surf along this ancient coastline are visible on the shoulders of the humps. We passed even better examples slightly upriver, and I bemoan those thousands of river runners who pass along here seeing the contact but not the vision of waves sloshing around and against these surf-breaking "haystacks," as such offshore outliers are called. The moon was closer to Earth back then, and many of the waves tearing into the schist may have been driven by stronger tides and storms. Tune in and you can hear the waves crashing. Others might interpret the scene differently. It is possible that this was an erosional surface on land that got buried by vast floodplain deposits of braided rivers which the sea then rose over. There is published evidence for that scenario in the Lower Cambrian to the west in California. All the smashing may have occurred in floods alternating with long dry intervals. Let multiple hypotheses and multiple reveries thrive! For the rest of our journey today, this contact will be

near river level--a fortuitous match of the slope of the river surface with the tilt angle of the tectonic block we are now traversing. This will be the last point on our raft trip where we can see with such clarity the record of the ocean advancing from the west over North America back in the Cambrian.

The river makes a sharp bend, and we now head almost due north. An elongated mound of gravel catches our attention because of the way the large clasts are stacked one over the other like shingles on a roof. The flattest face of each slants toward the current (Fig. 19.2).

Fig 19.2 Imbricated gravels. High, swift, right to left river flows pushed these tumbling, elongated boulders into this shingle-like arrangement with the flattest surface facing the flow. Piles like these can readily form just downstream from large clif-collapses followed by development of large rapids.

It is easy to imagine each cobble getting flipped in the opposite direction if the current were to reverse. It would have to be a current stronger than we have today because these are large and heavy boulders. This is a better-than-textbook example of “imbricated gravels” which geologists celebrate because when found interbedded in an ancient deposit, they shout out the direction of a very strong current at the time of deposition. We have been passing gravel piles by the millions this whole trip, but this is the first to attract attention by the large

number, size of the clasts, and perfect imbrication. It is the first of many oddities we are about to encounter in what is to be a most unusual stretch of the river.

We travel slightly deeper into the schist, and the walls turn jet black--darker than we have seen before. These are almost certainly ancient lava flows on the ocean floor that got buried and metamorphosed along with the deep-water sediment they flowed over. In the afternoon sun, these black walls seem as hot as lava, but wind over the cold river water keeps us rafters protected. On the left, the Tapeats layers come down closer to the river again. We stop briefly at about mile 127.5 to trudge up a clinker slope to look at a forest of salt stalactites, many having a little drop of evaporating brine at their tips (Fig. 19.3).

Fig. 19.3. Brine seeping and dripping out of the base of the Tapeats Sandstone on the west side of the river at mile 127.5. The dissolved salt precipitates into hanging stalactites and stalagmites that grow upward. Some have joined to form columns.

It is a miniature fairyland of white pinnacles hanging upside down over mounds and humps growing upward as the water drips down and evaporates. Brine buried in darkness and time under the huge stack of sedimentary layers to the west is here weeping out along the base of the sandstone. It emerges into the sunshine leaving salt that dissolved in it somewhere deep and far away to precipitate out drop by drop at the tips of these delicate saltcicles. After

heavy rains, this little aggregate of mini castles is almost certainly degraded if not dissolved away altogether. Beauty in this world can be so ephemeral, although we don't think of rocks being so evanescent. The massive wall of rock layers here by contrast seems indomitable, but it is only a matter of time before they too are eroded away. If ever there was any place on Earth to feel the transient nature of beauty and majesty, the Grand Canyon is it. Relentless, grinding erosion…time...all on this Earth is eventually gnawed away by toothless time.

The river level is low this trip. Just before entering scary Bedrock Rapid where the main river diverts around a huge outcrop of bedrock squat in its middle, we pull in on the right to the "dollhouse." This is a peculiar rock knob that becomes part of the river bottom at higher water levels. It is an open-air labyrinth of highly smoothed, polished passageways and low climb-over walls in the black schist. An explanation is that at high water the river pushes sand and silt through this roofless catacomb to polish the rock. But something puzzles here because the river bottom is usually choked with sand and rock piles along most of its length. Flow over bare bedrock has been unusual so far. The river hasn't been cutting down so much as simply pushing away debris fallen off the walls or washed in by the many side canyons. So why do we see an almost unique exposure of the high-water river bottom here? And why, after climbing back into the boats, do we see a huge mass of bedrock ahead of us right in the middle of the channel? Much of the river flow goes through a cleft to the left that tempts adventurous rowers. Alas, it is an intertwining congregation of shooting white water currents where a big, motorized pontoon boat could get shredded. Small boats can avoid it entirely by hugging the right bank where shallow waters go over gravels. Once around the bend caused by that obstacle, go back out into the current. A scary but necessary option for larger boats during low water levels to avoid hitting the gravels is to ease in sideways directly toward the giant obstacle and then goose the engine full blast at the last second to get around to the right and immediately into the center of the current that quickly rejoins what went through the cleft on the left. This is the first maneuver of this type on the trip and is a tense moment for the passengers. Floating sideways toward the facing wall of that giant obstacle, there is fear that we will crash into it if the motor dies when full power is necessary. Visions of catastrophe quickly vanish as a huge cushion of water pushed upward by the oncoming current rises against the wall to alleviate such an outcome. Once at full power, a new concern for the boatman is that the boat can shoot across the main flow that has suddenly turned left and wind up crashing into the right bank. There have been many exciting adventures at Bedrock rapid. JP is all concentration, but he zips completely around the thing, and turns to wait with concern for our second boat to appear. And will that boat successfully turn into the current to cruise toward us? Arms fly up with a cheer as exactly that happens. We are in good hands with the Hatch crew.

Things along this stretch continue to get puzzling--if not downright ominous. Why hasn't that blockage right in the middle of the river been eroded away by now? On our right, the Tapeats has vanished, and the Bass Limestone is sitting on the schist. We must have crossed another of those faults in the Precambrian basement rocks. A large black band of "diabase"

runs along in the Bass right above its contact with the schist below. The diabase sill is haloed above and below with lighter-colored rock--no doubt asbestos as we saw way back at Hance Rapid. Now we encounter seething, bank to bank white water formed by thousands of little waves dancing and splashing violently over gravels and around boulders. It is Dubendorf Rapid where even the most experienced river runners wind up banging along the bottom, cartwheeling sideways round and round, and even getting hopelessly stuck straddling a big rock. On an earlier trip we once spent two hours helping a motorized pontoon boat get off a big rock by using ropes and pulleys to nose its back end out into the current far enough to spin it off. The crew stuck in the boat out in the current were on the verge of calling in a helicopter to get the passengers lifted ashore when JP and Hatch boatman Tanner Patty made a final heroic effort using an astonishing pulley apparatus that finally worked. Never make plans about what you are going to do below Dubendorf until you have run Dubendorf. But why is this long stretch of relatively narrow channel here choked with so much gravel?

We take a break to walk up a few hundred yards to the nice waterfall in Stone Creek. A longer, wonderful hike higher up leads to an even bigger waterfall, but we save time on this hot afternoon and take turns standing under the lower one that is pretty much the heaviest water-pounding a person would want to butt heads with. Streams that turn into waterfalls in the dry season this close to the river are rare. This is the first of this size we have encountered. The side canyons usually dig out their channels rapidly in geologic terms and are usually close to river level before they debouch into it. A stormy sky has been building, and this contributes to the mysteries we seem to be encountering in this stretch of the river. High up to our left and set way back from the river we pass two giant scallops in the side of the Redwall Limestone called the “Owl’s Eyes,” another unique feature. The owl looks over us at another unique sight on the opposite wall. A gouge carved into a thick ledge of the Tapeats Sandstone is filled with limestone rubble. The rubble extends upward as pile upon contorted pile (Figs. 19.4,19.5).

Fig 19.4. A cliff segment of the Tapeats Sandstone is here missing and instead consists of crudely layered Redwall Limestone rubble (center of photo--see next figure). This gap in the Tapeats layers is unique because it is not related to a side stream entering the canyon.

Fig. 19.5. An interpretation of the gap in the Tapeats layers. A large mass of convoluted Redwall Limestone from higher in the stratigraphic succession lies at the top of the rubble pile.

This is bizarre. It is as if the river once flowed in the direction of that wall, carved a channel, and then got plugged with landslide rubble. Did the river here get diverted from an earlier previous course almost straight in the direction of that wall? If so, this is the first such case of it doing so that we have seen.

Still puzzled by the increasingly strange goings-on in this stretch of the river, we suddenly find ourselves in the narrowest channel width in the entire Grand Canyon (Fig. 19.6).

Fig. 19.6. The "Granite Narrows" at mile 135.5 This is the smallest river width in the Grand Canyon.

It is walled with beautiful, fresh-looking granite directly overlain by the 1.2-billion-year-old Bass Limestone. It is the contact known as "The Greatest Unconformity" that separates the Precambrian strata from the granite, gneiss, and schist of the "crystalline basement" (Fig 19.7).

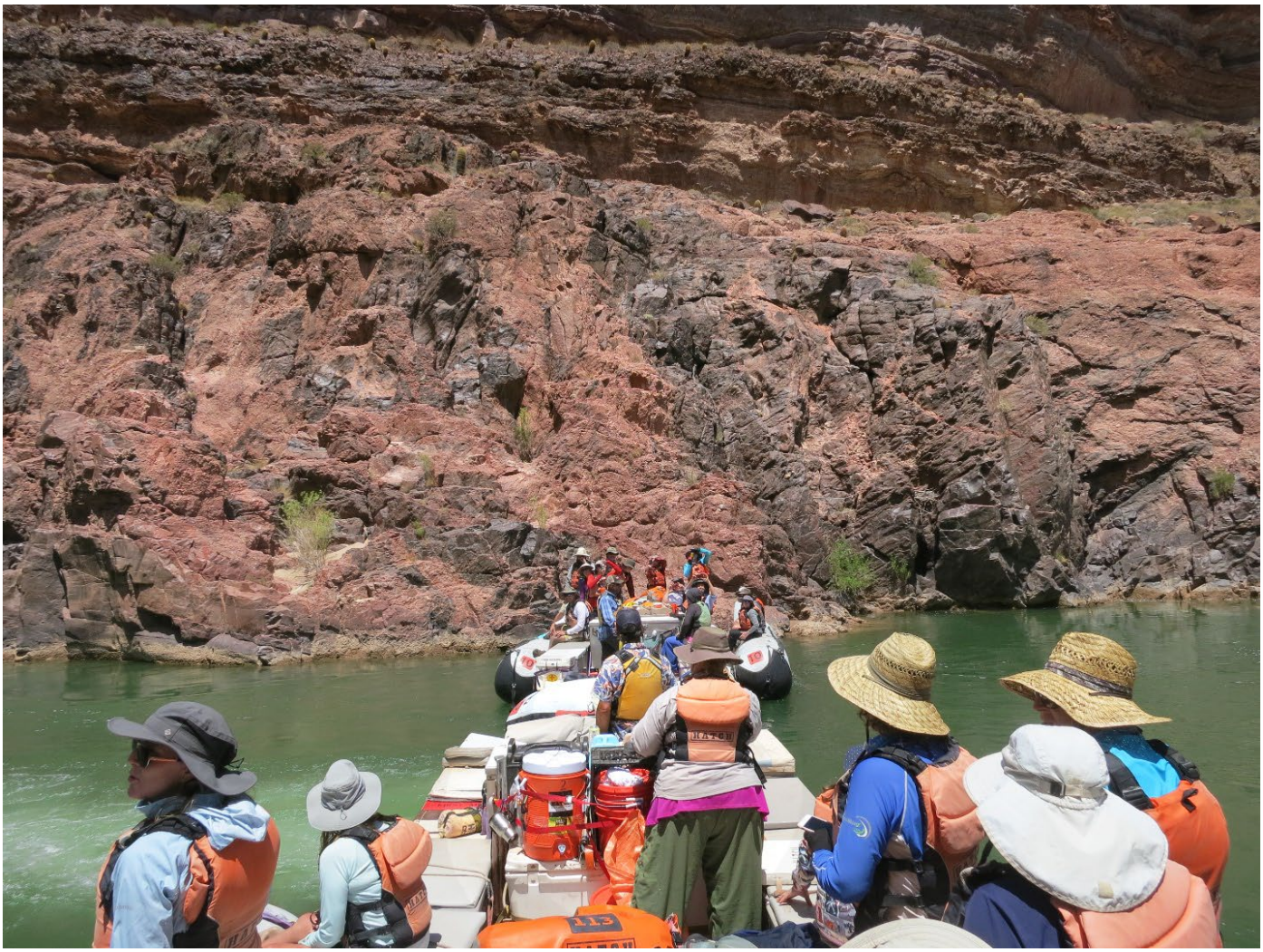

Fig. 19.7. Our boats end-to-end almost touch both walls at the entrance to the Granite Narrows. The horizontal 1.1-billion-year-old Bass Limestone lies here on an incredibly fresh exposure of the 1.7-billion-year-old granite on the far wall. There is no rapid in this--the greatest constriction of the river in the Grand Canyon where there should be a humdinger of a rapid. No, the water usually flows placidly through this one-mile stretch.

The lack of deep weathering and constant scrubbing by the river during flood stage makes this an exposure of an unconformity second to none. But we do not talk about this. Instead, we fixate on the confining narrowness of the channel. In previous stretches of the river, the water would increase in velocity whenever the walls closed in like this and would erupt into tempestuous madness. This should be one of the biggest rapids on the river! Instead, the water flows so slowly through it that we align the boats sideways to the flow and try to touch wall to boat to boat to far wall. With the engines running gently at right angles to counteract the lazy current, we are almost motionless as the crew breaks out a measuring tape to see how wide it really is here. Each boat is about 25 ft long, but the attempt fails as the relentless current pushes us along. Use a laser measuring device and you get about 75ft. Depth sounders reveal that this is not only the narrowest, but also one of the deepest segments of the river—

almost 100 ft. This is the narrowest, deepest slot canyon in the Grand Canyon! There is no rapid flushing through here because the depth is so great. The fluid really isn't being squeezed to make a rapid. But why is the river channel a slot here?

The mysteries seem to be mounting, but what we see coming into view on the wall sloping up on our left is truly dumbfounding. A ledge of rusty-brown dolostone in the Bright Angel shale has been ripped apart with boulder-sized fragments of it strewn UP the hillside. Yes—boulders have been torn off and tumbled uphill (Fig. 19.8)!

Fig. 19.8. A train of rusty brown dolomite boulders slants up the south wall to the left across the center from the lower right. The boulders are derived from the rusty brown bed entering the picture in the lower right corner. There are no rocks like this on the walls above; they were clearly transported UP the hill!

As if this isn't crazy mystery enough, we pull in amidst a gaggle of boats tied up on the right and hear water pouring out a slot cut into the top of a 200-foot cliff capped with the Tapeats Sandstone (Fig 19.9).

Fig. 19.9. Deer Creek Falls, the only place in the Grand Canyon where a large stream has failed to cut a side canyon and instead falls directly into the river. Intense erosion by the stream flow has slashed a narrow slot down through the Tapeats Sandstone until it encountered the much tougher granite underneath.

At times of high-water flow, this enormous waterfall, the largest in the Grand Canyon, falls directly into the river. The major stream feeding this cataract is vigorously cutting down into the sandstone, but it is has not carved a side canyon down to river level as all other streams have done—and this is one of the biggest side streams we have encountered. It is Deer Creek Falls, a must-stop place for any raft trip. Rare is the day that at least two other trips are not tied up here with their passengers out exploring. Indeed, the hike up to the top and the area beyond is one of the most entrancing areas of the Grand Canyon.

We pull in, and I try to gather the group for a quick word. I explain that they can choose to go an hour's hike up to the top to see "the patio," usually a paradisical spot of clear, flowing water, ledges, and lots of leafy plants and trees (Fig. 19.10).

Fig 19.10. The "patio area" around Deer Creek before it plunges into a slot and then over the side as Deer Creek Falls. It is a pastoral setting reminiscent of a Constable painting.

The trail goes up the wall beyond yonder waterfall and involves a bit of climbing and a short passage once on top where the trail is narrow ledge sticking out of a wall above the raging stream just before it goes over the side. To me, that stretch is surpassingly scary because at one point it is exceptionally narrow with nothing to hold onto (Fig 19.11).

Fig 19.11. Walking along a narrow bench on the way to the patio area above Deer Creek Falls. The area of the walkway outside the lower left corner of the image is too scary to photograph.

You must concentrate on the trail and stay on it. Above all, you must not get too distracted by the red handprint made on the far wall by one of the ancients that used this path to access the river. Although I always fear the worst, only one person is known publicly to have fallen. People have an amazing sense of self-preservation on narrow trails along cliffs. A wonderful alternative, which I almost always choose, is to hang out in the lush oasis around the plunge pool at the base of the waterfall (Fig 19.12).

Fig 19.12. Plunge pool at the base of Deer Creek Falls. The falling water hits the pool with lethal force and sends out a stinging, horizontal blast of water across the pool.

Most people always choose the hike option in this spectacular setting. This crowd is understandably anxious to get going, so there is no point in further engaging in geological mysteries. Why do we have that channel we saw going into the wall, the narrowest gorge in the Grand Canyon, the lack of a rapid, this unique waterfall, and rocks that rolled uphill? And what about all those other unusual features we passed in the past several miles. Can a single geologic process or event account for all this? It is probably good that the group is hot to trot and not hungry for answers right now. It is good because I have asked to camp just ahead across from one more mystery exposed on an even grander scale along with a special view

that explains everything. That special view is the climax of the story as viewed from a most unlikely setting. It will have to wait.

The crew leads the crowd up the trail past a returning group from another boat trip. After that group departs, I am left alone to wander over to the short stream racing from the plunge pool to the river. I slosh up it a short distance and do some tricky balance-walking on a slick ridge to the right just barely above the water. It takes me to an opening in the jungle growing against a high wall. I can squeeze along the wall through high, lush, and leafy plants. The din from the waterfall is almost deafening with spray and mist turning this into a small rain forest. Emerging on gravels at the edge of the plunge pool, I strip down to a bathing suit and wade out waste deep to within about thirty feet of where the free-falling water smashes down. A horizontal blast of cold spray at hurricane velocity moving away from the crash of the waterfall into the pool can be painful. I am not sure a person could walk against this stinging spray into the waterfall even if they wanted to get their skull crushed there. As is my usual tradition at this unique place, I go into an irrational fit of screaming hysterically, howling frantically, and splashing violently as hard as I can back at the waterfall until my voice hurts and becomes impossibly raspy. I know not wherefore I do this, and my poor vocal cords hurt for the next 24 hours. Once on a previous trip, I was surprised by a taciturn Navajo participant who quietly held back from the hike and suddenly popped out unseen from the shrubbery. He took off his shirt and waded in beside me to join in this primordial shrieking, howling, and rage. And that we did! We were probably even subconsciously egging each other on. Screams and shrieks for the ages. With voices finally gone from this elemental enactment, we waded back to the banks quivering in cold goose bumps where he looked severely into my eyes and said emphatically while gasping and rasping, “Um…uum…you are one with the rocks.” Wow, all I could do was stand there dripping, shivering, and blinking. I took it as an unexpected honor to be told that by one from a people known for their deep spiritual connections to nature. Alas, I later told this cautiously to his fellow Navajo on the trip, who was decidedly NOT taciturn. He laughed heartedly and said, “What he meant was, your head is full of rocks.” Er…I hope not…but…OK…fair enough. Our people return shortly and treat this habitation with more respect than me. Then we pile into the boats to beat other groups to the campsite I want about a half mile down the river.

We pull into “Poncho’s Kitchen,” a large pile of sand tucked up against a wall of ledgy Tapeats sandstone that got eroded back into an arc facing the river. Directly across from this camp is the most unusual wall of the Grand Canyon. The distinct layering has been replaced by an enormous, ragged pile of pulverized rocks. It is crudely layered with several alternating zones of gray vs reddish material. The setting sun blazes through the river canyon now trending almost due west. The fragmental wall with its innumerable brightly lit rock surfaces immediately adjacent to their jet-black shadows is an astonishing sight (Fig 19.13).

Fig 19.13. The unique north wall of the Grand Canyon across from Poncho's Kitchen campsite just downriver from Deer Creek Falls. The entire mass consists of crudely layered rubble.

Somewhat stormy-looking clouds add to the shocking splendor of this wall. Are we looking at it, or is it something looking at us? This is a culminating mystery for all those crazy features we have been passing through for the past several miles. It is also the answer as I can explain with views from this site. Well, not entirely from where we sit. We can't sit together where a single view resolves the mysteries because that site is always reserved for one person at a time. Yes, it is the view from where the crew has set up a porta-potty concealed behind some riverbank boulders and vegetation about 20 yards upriver.

We always have two "portos" set up far away from each other along the boundaries of the campsite. At least one usually has a clear view of the river. It is also IN clear view FROM the river. This is usually no problem, because all river traffic is usually camped somewhere by the time the porto is set up, and passing boats usually shoot by travelling along the center of the wide river. However, a sitter occasionally gets caught with pants down at a river-view porto site. As JP warns and explains, "If you get caught by a passing boat and that bothers you--just close your eyes." He often adds that since people may be waiting in line, it is not a good place to be reading "War and Peace." However, the eastside porto site at "Poncho's" is a good

place to see something in the distance which ought to be a figure in a geology textbook. For there in the mid-distance is the penultimate example of a “Toreva Block,” a landslide where part of a steep cliff detaches and slides downward as a single mass feet first. As it slides down the slope, it “heels out.” This leaves it internally crushed to pieces, rotated, and leaned back against the lower part of the wall it slid down. Here, a large piece of the north wall of the Grand Canyon is seen slumped down feet first against the part of the wall it cleaved off from (Figs 19.14 and 19.15).

Fig 19.14. Enormous, tilted landslide block just above the center of the image as seen from Poncho’s Kitchen campsite. The block is upstream of Deer Creek falls near the location of Fig. 19.4. This is a large piece of the north wall that simply broke off and slumped feet first down into the canyon when the river was in an older course now filled by the landslide itself. See next figure for an interpretation.

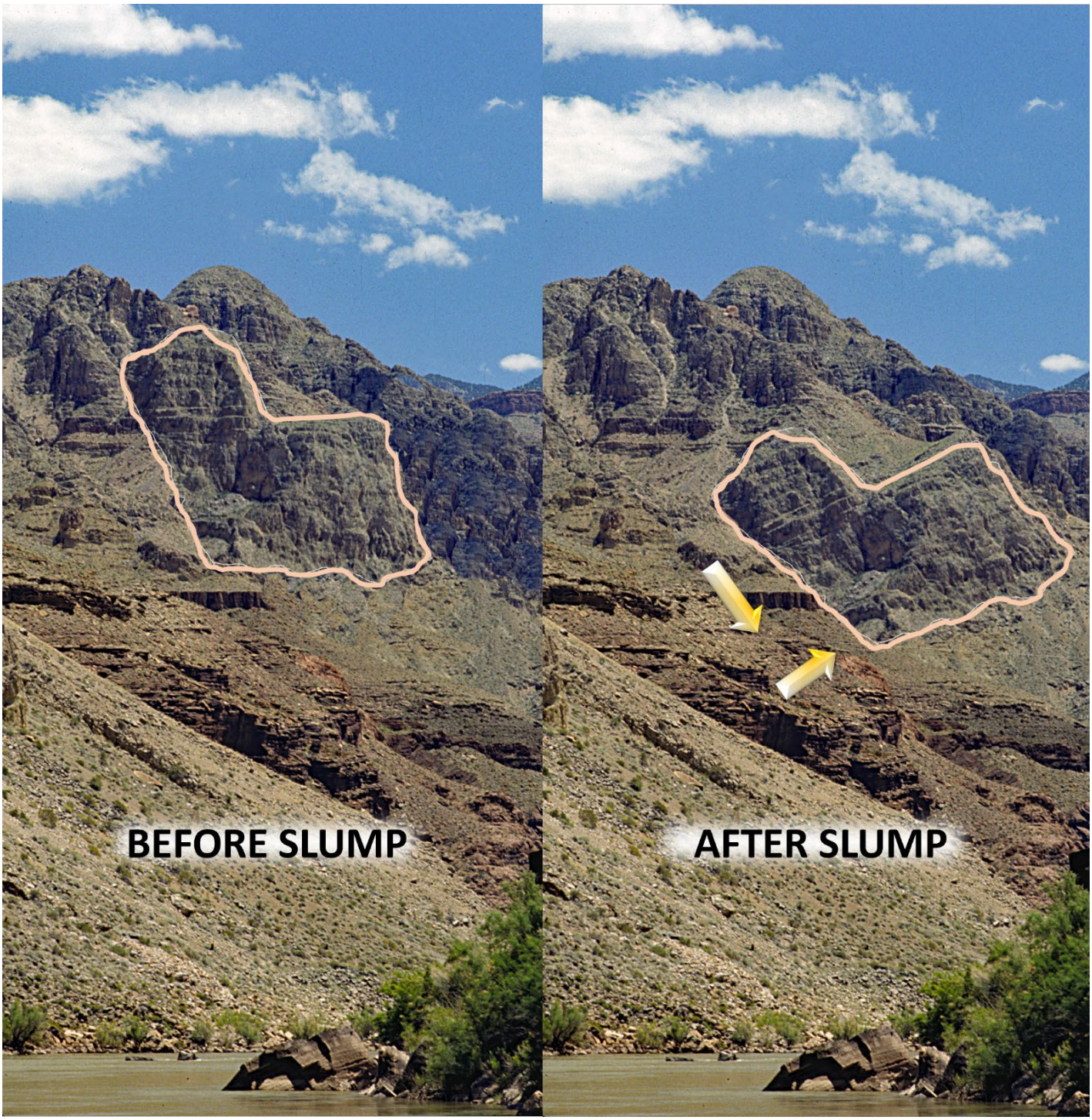

Fig. 19.15. Photoshop reconstruction of landslide block before slump. This section of the wall slumped off, slid down toward the river channel where it existed at the time, and "heeled out."

The block must have slumped right into where the river channel once was and filled it up to form a dam. The entire landslide area extends almost 3 miles along the north wall. This is only one small block of what was likely many slumps that did not necessarily happen all together at exactly the same time. The east porto site at Poncho's is a great place to take a pair of binoculars or a telephoto lens to see this feature that is the key to explaining the string of

mysteries we just encountered. However, shouting “eureka” is not a good idea because those waiting in the porto line might misinterpret.

There it is! The answer. The whole north wall of the Grand Canyon for a river length of about three miles broke off as a cosmic landslide or series of landslides probably as big as any that has ever happened anywhere. Cumulatively, this may be the Mt Everest summit of landslides. Our group waiting for dinner on the beach at Poncho’s is looking across the river at a segment of this great pile that came down the north wall that used to be there. It is now filling the old river channel which used to be over there. During that brief cataclysm, the detached wall quivered, shook, vibrated, and ground itself internally into pieces as it collapsed into the old river channel. The stratigraphy remained somewhat intact, and that is what we see in such dramatic lighting across the river here. Just before landing at Deer Creek Falls, we were able to look at the wall directly behind where we sit now. We saw rusty brown boulders that had rolled uphill. “Rolled” is hardly the appropriate term. The cliff face fell down the side in front of us with such force and violence that the bottom parts shot right up the wall behind us. They tore off protruding ledges of the rusty brown dolomite layer and exploded ragged pieces and boulders uphill. Those are what we saw as we disembarked to go to the top of the waterfall (Fig. 19.8).

Now, all makes sense. The rubble dammed the river with debris in a geologic instant. A lake formed behind it over weeks and months. Then it began to overtop the rubble piled against the wall where we are. Here it was thinnest, so the river cut downward through the rubble and into the granite and schist to drain the lake. Resistance to the flow of the Colorado is futile. This explains the narrowest width of the river in the Grand Canyon that we passed through two miles ago. It is the slot the river dug out, but it was not cut down into the rubble-filled channel. Instead, it carved down through part of the wall on the other side of the river. Quickly reaming out the layered rocks, it hit the crystalline basement and dug a hundred-foot slot into it. That was where we entered the narrows. Just upstream of those narrows, we were able to look up at the old channel going into the wall in its once more northerly direction and now filled with landslide rubble.

The “granite narrows” we then entered is the stretch where the river cut down through the rubble and into what was underneath it. It is the youngest channel segment in the Grand Canyon--narrow and deep. No wonder that granite and the unconformably overlying Bass Limestone are displayed with such unequaled freshness! So, the three-mile, rubble-filled channel now lies as a loop deeply buried under this amazing pile before us. Deer Creek is a major stream coming from the north that now flows over the rubble filling this old river course. It then plunges down into the new slot channel as the only waterfall falling directly into the river. Eventually, the waterfall will cut back and create a new side canyon like all those we have been passing for days. The view from Poncho’s Porto is a side view of one of the landslide blocks now sitting in the old channel near where we saw it head into the wall.

One event thus explains many mysteries simultaneously. A multi-mile stretch of the north wall of the Grand Canyon broke off and slid down into the river. Imagine what all

transpired in those fateful moments as enormous block after block fell! Imagine the deafening sound of the shaking, grinding, crashing, exploding and echoing as rocks tumbled and shattered. Was it all in a minute, and when the dust cleared here it sits? It is more likely that it fell in sections—first just a small one, then another and another separated by minutes, days, months, years, maybe even thousands of years? When, how, and why did all this happen? Many geologists have worked on these questions for decades. We may never know for sure, but different geologists have their opinions. A sophisticated method involving the effects of cosmic rays on weathering surfaces--and a lot of necessary assumptions-- suggests there were several landslides here over intervals of a million years or more. Some speculate that erosion of the river down to the level of the Bright Angel Shale which left the walls sitting on an unstable foundation prone to turning into gumbo during weathering. If so, why don't we get big landslides along other stretches where the river has cut down into the Bright Angel Shale? Some attribute the cause to possible earthquakes on a major fault about 50 miles to the west that shook the walls down. If so, why didn't other huge landslides occur during major earthquakes? My crowd fidgets and wants a definite answer for a change. So, I offer for those who need certainty that it was when Joshua blew his horn. This ends the discussion, but some people give me the "nobody likes a smartass" look.

Dinner is called, and I am left alone staring at this extraordinary sight. All this directly across from the camp probably fell as a single slide. However, this is not just the geologic record of a violent event. It is a great lesson regarding how we investigate nature. Until we saw the landslide rubble, it was impossible to understand why we had the waterfall, the narrowest canyon, rocks that moved uphill, and several other perplexing features. A lot of what we passed can probably be explained by the former lake or lakes that fouled up the whole drainage system and then rapidly drained when the dams breached. I remember yet again the example of early anatomists who wondered what the function of veins in a wrist served. Examine those veins all you want, and you can never figure it out until you stand back and understand the heart and the whole circulation system. Then it is easy. Here most everything popped into place when we recognized the landslide rubble, but now we must wonder why it happened here? What caused it? Why isn't this a common thing in the Grand Canyon? So, is it necessary to step back again and look at the larger picture just like for the wrist veins? JP has relentlessly studied the canyon walls up and down the river probably more than anyone and thinks there are numerous places we passed where large landslides left rubble piles and deposits of giant rapid deposits. Loose rubble gets cleared out rapidly because of the erosive power of water descending the steep walls and the relentless conveyer belt of the river carrying everything downstream. This must just be one of the biggest and most recent manifestations of episodic processes shaping the canyon over millions of years. A geologic feature we are trying to explain is thus more difficult to understand than a vein that is always at work in a living circulation system. How much we miss or misinterpret gives me pause. The grand themes of geology and geologic history are everywhere on display on my pilgrimage, but I know I am seeing only the tip of the iceberg. Earlier geologists struggling to

explain this place weren't yet aware of plate tectonics or other big picture systems; they didn't stand a chance. Do we now, or will future understanding push all we now think we know aside like a plow going through an anthill? Science progresses: it is a mistake to get too confident about what we currently "believe" in science. It is likely our best bet, but it is not gospel.

And then, look at those clouds above this spectacle! We understand the process that forms clouds. Humid air rises, cools, and then precipitates into tiny droplets. But look at any cloudy sky and you will see patterns that never existed exactly like that before and never will again. In fact, in a few moments, the gossamer filaments along the edges of an existing cloud will change before your eyes and join the whole sky panorama in another scene unique in time. Rising parcels of air rub and mix with their neighbors and cross the precipitation threshold at slightly different altitudes. Others fall in the same manner and the droplets evaporate. There are so many swirls and puffs in turbulent air that no one could calculate or predict the pattern. It happens so fast that the equilibrium configuration satisfying our physical "laws" is delayed. The upward flow into the cloud is equally complex and variable, so rerunning the processes produces a different pattern. A few simple processes act to create infinite diversity with a non-reproducible history. Furthermore, the cloud itself is not really an entity as our senses perceive it. It is a zone in which rising moist air cools and condenses into droplets. The through-going air parcels become depleted of their moisture and rise out the top of the zone or sink down at the edges. The cloud maintains an ever-changing shape or pattern as the air passes through it. That which makes it is constantly moving on through it and being continually and inexactly replaced. This should not be a surprise. Why, even the molecules in our body are replaced at various rates such that we are not the same physical material we were years ago. Yet this corporeal form persists for up to a hundred years. Yes, the mortal coil that holds our consciousness is constantly being replaced as life moves through it like the air in those clouds.

Philosophers and theologians have struggled for centuries with this problem of "existence" or "being" as they often call it. Their field of "ontology" is based on (usually unsuccessful) word and phrase definitions that can be utilized logically. The rock record may be a better foundation for the discussion. No definitions are required to see before us the reality of a landslide for the ages. It happened. It is here. We can deduce how our mortal coils fit into the history of the rock record of reality. How consciousness fits into the scheme is a tougher question. The pilgrim remains confounded, but the journey has a long way to go.

"Last call for dinner!" is yelled out. The landslide wall of layered rubble is turning into a featureless mass darker than the higher, distant walls still visible above in the twilight. The Earth is now wheeling from light to dark. Recognizing and feeling the infinite complexity behind natural events, I yield to the biologic call for molecules to replace those of this mortal coil. When it comes to "last call for dinner" on a raft trip—well---deep thoughts, philosophy, and wonderment come to a decisive end. Especially ontology.