Chapter 8 **THE LOUDEST PLACE ON EARTH** Mile 20-21

Flat on my back on a nice cot, I blink awake several times during the night to follow the Big Dipper rotating around the north star. Every 45 degrees is six hours, so it is an easy celestial clock marking the progress of the night. The name North Canyon is appropriate because the river flows largely north to south along this stretch, and the north star and dipper are prominently framed by colossal walls all night long. Dawn is making its first little peep, and I see a crew member dimly moving around the blue flames of a propane grill. Morning twilight coffee by the river! Nothing better. In the old days when I started leading these trips, this however was panic time. No more indecision. I had to tell the crew before launching where I wanted to stop to tell stories about what we were seeing. What should I focus on? Where can we stop in the shade amidst a geological spectacle? This morning it is no issue. I finally know the Canyon so thoroughly that we can stop almost anywhere, and I can enthusiastically prattle on far longer than anyone would want to listen. Indeed, I long ago concluded that mastery of the geologic profession is the ability to hold forth at any time in any place about the geology in front of you, even if someone were to remove a blindfold at an unknown location you have never seen before and say, "explain." You can expound on the local scene and incorporate it into the largescale picture of geological science altogether. Besides, none of my previous plans ever worked anyway; there are too many variables and contingencies that affect the daily schedule of a raft trip. What is critical is to strive for a specific campsite in the late afternoon with several alternatives clearly in mind. Competition for the best campsites has become keen ever since the National Park Service allowed drastically increased usage of the Canyon by private groups. I have a big group, so I want a big camp preferably at the mouth of a good side canyon hike so the hikers amidst us can get their workout. Fortunately, JP and the Hatch crew know all the strategies. That ultimately determines our schedule so why fret over the geology stops.

As a raft trip progresses, the participants become progressively overwhelmed with the scenery. At any stretch, you look up at a wall that in any State or Country would be itself a national park. It is also to the left and the right and behind you as well. As we float along it goes on and on until it seems surreal. We use motors and big boats for maximum safety, and the logistics are superbly handled by the Hatch crew. So, fears disappear, and minds become free and susceptible to what I want to instill—and, on this trip, to instill something even deeper into myself. The fearsome rapids that challenge and terrorize row trips in small boats are for us just plain fun. This fun will come to dominate in a few days when we get into the inner gorge and encounter one giant rapid after another. So now is the time to go all out with geology and its meaning. Fortunately, in the first few days, we traverse through most of the major concepts of geology. If you were crazy enough to write a book about it, there would be a lot of geology in the early chapters.

Here in morning twilight at North Canyon, this dreamlike world slowly brightens and makes itself corporal (Fig 8.1).

Fig. 8.1 Sunrise splendors at North Canyon Rapid. The shimmering, golden reflection of east facing cliffs is part of the morning pageant all along the river.

High up on the walls, blazing golden sunlight reflects the rising sun and gently expands downward amid shafts and frets next to blackest shadows. Ideally, we do not want this space heater to move down the wall and blast us until we are boarding the boats on the cold river. Until then, our shady enclave is a tranquil paradise seemingly cupped in the hands of a benevolent presence. The gently rippled river surface near the banks and far down river reflects the golden cliffs with incomparable beauty. It is prime time photography, as is the similar but profoundly different sunset pageant. This is just camp morning number one on the river. It will be like this at morning camps the whole trip.

All this is glorious beyond words, but it occurs to me this morning that the key element in this magnificence, the impression of a cathedral, results from a basic geologic process few know about. You do not even find this process that so profoundly creates scenery even mentioned in a standard geology text. Simply staring at the walls quickly reveals smooth vertical surfaces everywhere interrupted by straight up and down cracks that often terminate or originate at the tops of the nearly horizontal strata. Innumerable box-like blocks appear stacked one upon the other (Fig 8.2).

Fig 8.2 Block-like wall of Supai sandstones and shales near North Canyon.

The hard sandstones layers display two sets of vertical fractures. One parallels the river direction to form the smooth walls. The other is at right angles, going into the walls. A third direction perpendicular to both is parallel to the bedding planes. Rectangular blocks are defined by smooth vertical surfaces each at a right angle with the others. One surface is the wall parallel with the river direction here. Some of the blocks protrude various distances out from the wall allowing us to see part of the underside and smooth vertical surfaces on both sides. High up on a cliff face of the gray Kaibab Limestone, a block juts far out with nothing under to support it (Fig 8.3).

Fig 8.3 Here a large block has fallen and left a piece of its topmost part still attached weakly to the wall. With nothing supporting it, this rock could fall at any moment, most likely during heavy rain when water can penetrate and loosen whatever bonds still hold it on the wall. Campers noticing overhangs like this after they have set up may not sleep well.

It could fall at any time because behind it there is surely a weathered, vertical fracture plane across which the bonding cannot be very strong.

Rock strata are clearly not continuous pancake-like layers stacked up one upon the other as we might assume. Each layer is broken into highly geometric blocks along planar fractures: one parallel to the bedding and two at right angles to the bed and to each other. As we geologists say, three mutually perpendicular planar fracture sets. Every bed is broken by these fractures in the same direction from bottom to top of the canyon walls in all directions. When hard hitting rainwater flowing down the surface penetrates deeply into the bounding fractures, the final bonds holding a block against the wall eventually give and down it plummets. Blocks directly above the fallen one then no longer have a base support and immediately or eventually collapse scraping and screeching against the vertical wall surface below. Looking up at all the protruding block bottoms in the walls can give you a most uneasy feeling. And look you along the riverbanks on both sides in both directions: piles of shattered blocks, many still displaying parts of the rectilinear block surfaces. The apron of broken and shattered rocks along the riverbanks represents rock falls recent enough that high water flows of the river have not had enough time to decompose and wash them away. We call piles of rock physically dropped into place along the base of cliffs “talus” or “talus piles.”

So, the entire Grand Canyon area, and in fact--uplifted rocks everywhere are laced with fractured surfaces ranging from microscopic hairline width to open gashes that funnel rainwater into and through them. Indeed, as water first weeps down the tiny crevices it weathers the rock into its constituent components and then washes the debris downward or out into streams. The cracks widen which allows more water which allows more weathering which allows more widening, which allows more water…. the cracks grow wider and wider. Rainwater descends into this seemingly infinite, interconnected underground labyrinth and fills any opening down to the depth where the overlying rocks weigh so much that all vacant spaces crush together. The imaginary horizontal top of the water-filled network is called the "water table." Ground water in all northern Arizona is lodged in these fractures. Drill down into that water table and you can have a successful well. Beneath Lake Powell upstream, vast amounts of water drain away into the deep countryside through this endless array of openings. A huge new ground water supply is likely forming around lake Powell in the strata tilted to the northeast. It has not been mapped out or talked about, but it is surely there.

Here in the Grand Canyon, every side canyon started out as a hairline crack developing top down as the region rose vertically. The whole river course along any straight stretch of the Grand Canyon started out as a hairline crack! As the river flows down through this fractured terrain, it enlarges zigging and zagging along its course often changing direction almost at right angles. The river along here is following down the gravity gradient along a course largely governed by the regional fracture network. A straight stretch that started as a hairline fracture is now an enormous gorge into which whole blocks now fall. The geometric or cathedral-like aspect so prominent on the walls is thus governed by the planar fractures that formed during tectonic uplift. These highly ordered walls will begin to progressively vanish farther downstream for remarkable reasons best not to think about until we notice a change in the scenic ambience.

But what has caused these scenic tension cracks to form in the first place? They are all over the world so we need not think about some special event that can shatter rocks like earthquakes or a great asteroidal impacts. Well, here is a hint: The Earth is spherical. Think about what must happen if a tectonic mass the size of Arizona moves upward---outward away from the center of a sphere. It must expand or there will be huge gashes along the uplift margins. We do not see that on the Earth. Instead, the region opens internally along a myriad of tiny fractures left behind as the brittle rock snaps apart. The fractures together make up the openings that must occur if a region of solid rock is moved upward within a solid sphere. This happens in all uplifted regions; it is a grand, unique theme of geology shaping the Earth's surface that has not been observed on other solid objects in the Solar System.

But why are the fractures so regular, so geometric, so at right angles to one another? This used to keep me up at night. Seems like the rock would just shatter willy-nilly. Fortunately, I could and did long ago ask a geology colleague in the office next door. ASU Professor Donal Ragan was a specialist in "structural geology" which deals with stuff like this, and this is what he said to me (in paraphrase). "Rocks break in response to stresses applied externally or

developed internally. During uplift, expansion stresses develop within the rock. There is some specific direction where the stress is at a maximum, so this direction is the first to relieve itself with a multitude of parallel fractures that open laterally. Now that stress direction is relaxed, so the maximum stress left in the rock is as far from that direction as possible--namely, 90 degrees away. A multitude of fractures next open in that direction to relieve that stress. Now the maximum stress left in the rock mass is as far away from those two directions, so new fracture planes open at right angles to both the previous two. And there you have it, fractures opening along three mutually perpendicular planar directions." He offered to explain it on a sheet of paper using tensors, a mathematical construct that allows you track force directions quantitatively. No thanks, I slept through the week of tensor math when I took physics. I cannot improve on Ragan's verbal explanation; it makes sense to me. If you do not feel the same, just accept that during uplift, brittle rocks will try to crack themselves into rectangular blocks. This is demonstrated throughout the Grand Canyon with great clarity (Fig. 8.4).

Fig. 8.4. The block-like fracturing accounts for this special scenery. What would the place look like without it?

I assume the fractures open top down as the tectonic region slowly moves upward. If so, we can understand a remarkable sight we are going to encounter downriver in a couple of days.

While the boat crew is finishing loading, I assemble everyone and explain the story of the fractures to them. Some get it completely. Some get enough to hope that as they look at all the blocks about to fall off the walls above them, that I will not do the turn-up-the-volume-on-the-squawk-box-and-sneeze trick. An acoustic impact like that might be the last straw for some of those, especially the ones where you cannot imagine how such a heavy block could stick out so far without breaking away. I consider recognition and an understanding of the block-like fractures to be essential to understand and fully appreciate the cathedral like scenery of Grand Canyon and numerous other landscapes everywhere. No matter how much I try to stress it and explain what I know about it, I always have the feeling that others just do not connect with it. Ah, well, a person does what he/she can and moves on.

So, I need to convey a more exciting story that calls on the deeper significance of these canyon walls that can look so much like a cubist painting (Fig, 8.5).

Fig 8.5. Blocks falling off the innumerable fracture planes in the Grand Canyon sometimes make scenery resembling paintings from the cubist period of art history. Tuckup Canyon. Bush on floor of channel is about 2 ft high.

It so happens my mind's ears have been ringing all morning with something that once happened at this very spot during deepest night, sent me back to times long before the Earth was here, and is now readily called up by sights at every mile along the river. It is 2:05 am exactly, and I am snug asleep here at North Canyon about eight years ago in a tent under a drizzling rain. Suddenly, I bolt awake. Not like your usual morning wake-up when you wonder what day of the week this is and do you really need to get up, this one is a moment--in the twinkling of eye. Instantly awake and terrified. A noise such as few have ever heard is screeching all around like a cosmic freight train coming at you that has suddenly slammed on the brakes. Only it also has a very gravelly screeching sound like huge rocks sliding down a metal ramp. Then, an enormous boom, something less than a thunderbolt only greater. The boom echoes up and down North Canyon and at right angles up and down the Grand Canyon. And then…. dead silence. Shocking, instantaneous silence. I poke my head out of the tent and see a few lights coming on in tents nearby, but everything else looks normal in this strange silence. Only the sound of the rapid and a little pitter patter of rain as if nothing happened. I immediately worry that a debris flow has come surging down North Canyon. I have people camped over there near where it joins the main river at the rapid. No cries of distress. A few murmurs from the nearby tents, but amazing silence. I visualize some of my people instantly buried under tons of rubble. Gone in a flash. But wait. Debris flows do not culminate in a boom and, based on movies I've seen of them, probably don't screech like a freight train or last just for a few seconds. My head is getting wet and if there are people buried over there it will be morning before anything can be assessed. All now is normal. I lay back down now more perplexed than frightened. Strangely without guilt regarding what I should do and despite the possibly catastrophic character of the event…. I fall asleep.

At first light, I am awakened by chit-chat down by the blue flames of the propane stoves. I come face to face with Mark Franke, the lead Hatch boatman for that trip. He tells me that after the cosmic screeching and kaboom, he looked out across the river from his tent on his boat and saw a discrete strip up the vertical wall on the other side glowing and crackling with green lightning. In the twilight, we can see several small piles of white rocks directly across the river on top of a small talus apron. It was a rockfall that came screeching down the wall to explode on impact, directly across the river. The freshly shattered rocks are the true white color of the limestones, dolostones, and sandstones normally darkened by weathering of their surfaces. All suddenly makes sense, but I am surprised at the rather small amount of white rubble that could make such a monstrous sound. There are much larger shattered rocks and boulders all along the talus aprons for the entire length of the canyon. Suddenly, I hear in my mind's ears the vastly louder screeches and booms that happened over and over all along the river to make this regional avenue lined with talus. Nay, I hear truly colossal booms echoing up and down and ricocheting repeatedly in the alcoves and side canyons. What sounds have filled every mile of this place throughout its history! How few of us have ever heard a sampling of what it sounded like--this episodic but unrelenting violence associated with the widening of the gorge. I have never again been able to look at the ever-present talus lining the

river without hearing the sounds. Who knew that integrated over its length and time, the Grand Canyon could be the loudest place on Earth!

But there is more to it, as I explain to the now engaged audience no longer impatient to hit the rapids instead of listening to a geologist's blather. Wait! This sound energy is ultimately that of ancient supernovae, stars that exploded in our vicinity of the galaxy long before the Earth was born. It was those explosions in the silence of space that provided the acceleration of atoms sufficient to collide hard enough to slam and fuse together to form gigantic atoms. The biggest was uranium, and some of it got incorporated into the materials that aggregated to form the Earth over 4.5 billion years ago, if the theory is correct. This uranium provides most of the heat energy within the Earth that ultimately lifts regions like northern Arizona upward against the fierce pull of gravity. So that energy created in the supernova is now stored in the uplift-- like energy in a battery. Just let a rock fall, and the stored uplift energy is released as kinetic energy that is converted into screeches, exploding fragments, and a bit of heat. The green lightning along the walls is static electricity from rubbing the rocks together, much as you see green flashes when folding your laundry out of the dryer. So, Mark got to see light and we all got to experience other manifestations of stored energy that ultimately originated from a supernova long before the Earth was born. The delayed sound of a supernova! It stuns me to think of it in this way, but I am not sure the audience is so affected by this insight. No questions. Silence. People just stare vacantly at me. Awkward. Not sure what this means. Maybe now it is time to go rafting! A distinguished geochemist who is expert on tracking energy changes in geologic systems volunteers to me quietly as we walk toward the boat that he cannot find anything technically wrong with the story I just relayed. That's good enough. If someone later in the trip thinks of all this while floating past the miles of talus, I will be gratified that their world has been enlarged. Rock talus is not just talus. And that pairs with the objective of my current odyssey.

Alerted that we are about to be sloshed with the icy water of North Canyon Rapid everyone suits up into rain gear. It will not stay on long because the sun is shining brightly on the water just around the corner and we will be solar heated the rest of the day. Still going down through the stratigraphy, we are about to bottom out of the Supai ledges and start cutting down into the top of the underlying Redwall Limestone. The rapid is long, violent, mega-choppy, and the longest one we have encountered so far. JP aligns our boat to glide with the current almost silently right into the smooth water tongue jutting downstream into the frothing frenzy below. Positioned perfectly at the top, there is now little that can go wrong in this rapid. The master guns the engine, and we go plowing and splashing through the tumult. Exhilarated people still inexperienced in this kind of fun are hanging on tightly and screaming every time a pickup truck load of ice-cold water rises to wallop them. Blasting and crashing without fear through the frenzied waves and stratospheric misty air above them is wonderful. Before clearing this whole length of ecstatic madness, JP swirls the boat around and motors enough to keep us motionless and pointed back at the rapid. People scramble for their cameras to get a picture of the next boat coming through while JP monitors for trouble. Even if you do everything right,

the vagaries of the rapids and the River Gods sometimes cause even the best to careen off the walls, slam into big rocks, get stuck on big rocks, or even flip over. The river stories I could tell.

Now flooded in sunshine with the walls slightly wider than before, I ask to pull into a shallow grayish white ledge on river-left still in morning shadow. Having just loaded onto the boat and gotten jostled by a rapid, everyone is surprised we are stopping so soon. They use the opportunity to shed rain gear they probably are not going to need any more today. We climb with a little difficulty up a few of the entirely new kinds of rock ledges barely emergent above river level and sit on tiers of highly polished "marble." It is fretted, mottled, and streaked with rose colored beauty. We are about to enter another Grand Canon world totally different in scenery, geology, and significance. These are incredible rock ledges we are climbing up and will make perfect classroom seats adjacent to swirling translucent green water. No projections or wall charts are needed in this classroom; all around is a geologic display of unrivaled beauty. No need to pass around rock samples; just look at what you are sitting on. The amazing story here is not in any guidebook or professional publication. I can hardly wait and start explaining as soon as the last person arrives and sits down on….300-million-year-old soil!