CHAPTER 3 LEDGE ON THE EDGE

Having seen the Grand Canyon from all the easily accessible viewpoints on both north and south rims, I say the best of all is morning light at Desert View Vista Point at the east end of the South Rim. The river makes its geologically infamous bend to the west here and has carried away the greatest amount of material that sloughed off the walls. It is the widest and most extensive view of this giant crustal excavation. Perch here and you can see more geology in one gulp than probably anywhere else in the world. An entire geology course involving the different rock types, faults, folds, and geologic history could be taught with visual examples right here.

The first thing encountered while walking toward the viewpoint is the big “Watchtower” that was constructed here in 1932 (Fig 3.1).

Fig 3.1 Watch Tower at Desert View Vista Point on the South Rim of the Grand Canyon The roughhewn building stones at the bottom are derived from the local surface immediately west of the structure and tell an important geologic story.

Next to the tower is a short promontory rimmed with handrails that provides an easily accessible view not only across the chasm but also to the east off the edge of the Kaibab Upwarp. The stairs inside the tower allow a view from another 70 feet higher. The roughhewn building stones at its bottom are an unintentional, open-air exhibit of a geologic story as astonishing as any view from the top. Before contemplating that story, I step off the big walkway and go west about 100 yards to a colorful rock ledge and take in the spectacle.

Here is one of nature's most stunning panoramas ablaze in glorious morning sunlight (Fig. 3.2).

Fig. 3.2 View north from just west of Watchtower at Desert View Visa Point. Here the Colorado River makes a sharp bend to the west and cuts through the Kaibab Uplift. Note excellent view along the left margin of how maroon layers extend tilted down from underneath the lowest of the horizontal layers of the uplift. These constitute the "Grand Canyon Supergroup>"

No shadows here; uncountable horizontal layers exposed on vertical cliffs stretch from horizon to horizon in full view. Straight across, tilted layers extend down to the right under the lowest horizontal layer known as the Tapeats Sandstone. Going to the left, the foreboding bedrock of North American peeps out from under the tilted layers. Just before disappearing from the leftmost view deep in the gorge (off to the left of Fig. 3.2), the tilted layers seem to suddenly disappear. The Tapeats lies there directly on the dark bedrock. What? Here the geologic complexities begin. The relationships of all these ancient rocks to each other and the river are summarized in a diagram that appears in every Grand Canyon geology book, explanatory brochure, and even on bandanas sold at the gift shops (Fig. 3.3).

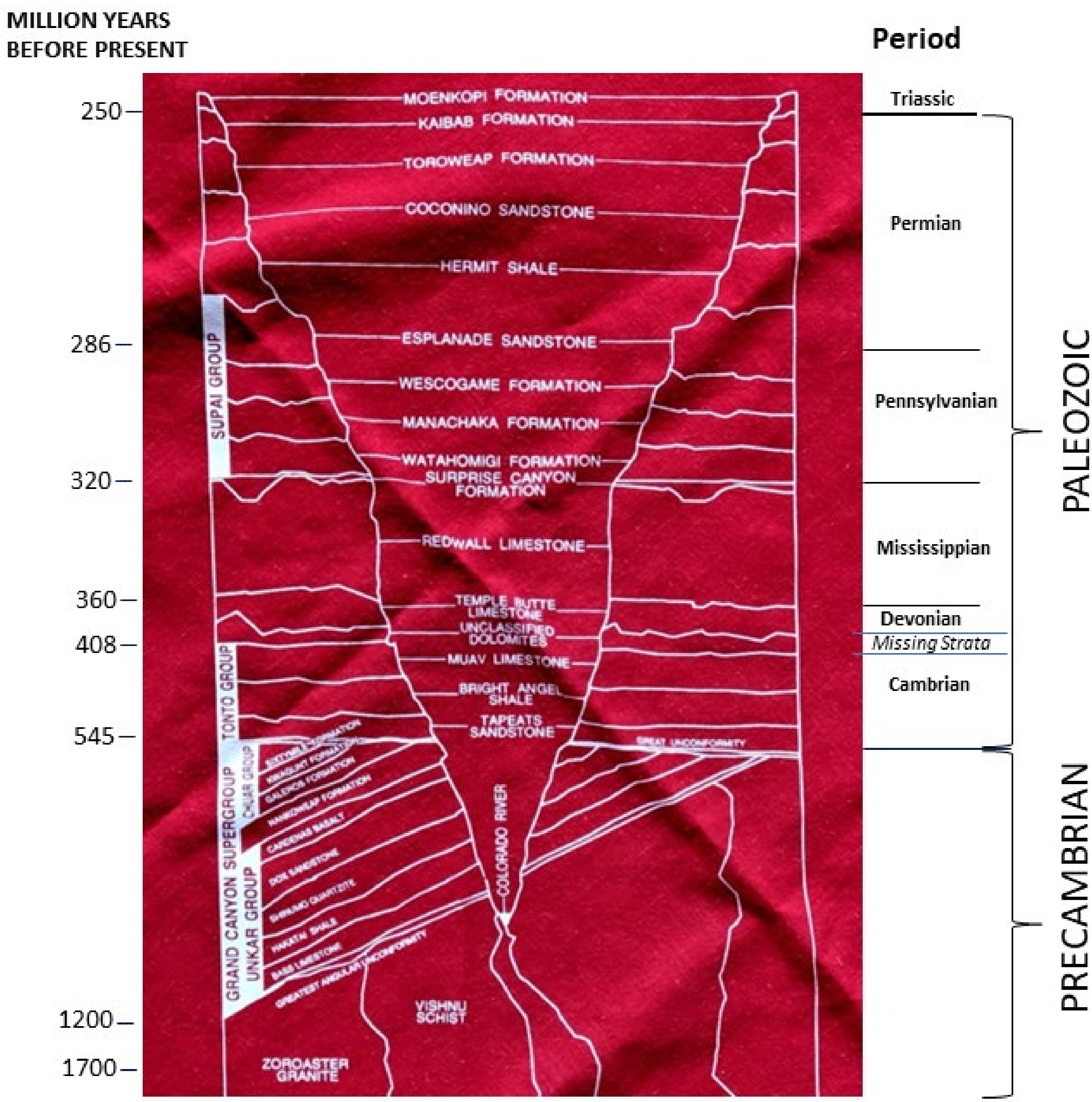

Fig 3.3. Stratigraphic Column bandanna showing the 3 major divisions of the vertical rock layout in the Grand Canyon. A thick section of flat lying strata from the Paleozoic Era lie over a tilted section of strata from the Upper Precambrian. The tilted strata were originally deposited horizontally over older Precambrian schist and granite. Note how the flat lying strata can lie over the older, tilted sedimentary strata or directly on the crystalline schist and granite. Both situations are encountered as the Colorado River weaves its way through the Kaibab Uplift.

The bandana corresponds well with what is seen at Desert View. However, it is like looking through the bandana from its backside because the tilted strata slope down to the right from this viewpoint instead of down to the left, but the layout is the same.

A bandana speaks

A quick summary of the geologic history on display at Desert View begins as shown on the bandana with the "basement" rock called the "Vishnu Schist." This was once ocean mud filling a vast basin that was slowing subsiding for reasons unknown. The sediment became deeply buried and experienced increasingly high temperatures and pressures. There it was folded, faulted, intruded by fingers and sheets of molten granite, and forged into "metamorphic" rock. Use of a technique called "Radiometric Age Dating" suggests that intrusion of molten granite and concurrent transformation of this gentle ocean mud took place about 1.7 billion years ago. After the torture at great depth, all that had once subsided began being uplifted in a great mountain building episode. It sounds incredible that parts of the Earth's crust could subside to great depth and then rise to form mountains. However, subsidence followed by uplift is a grand theme of geology that has repeated itself countless times everywhere on Earth.

Erosion went to work on all that was above sea level and started wearing it back down. Once uplift ended, the area began subsiding yet again. Meanwhile, relentless rains over millions of years continued eroding the uplifted schist and granite back down to sea level. What kinds of rocks were above the schist in those days can never be known. Every area of the Earth's surface is always either slowly rising or subsiding, albeit at rates that vary from place to place and time to time. It never happens much faster than the rate at which fingernails grow, although sudden jerks of up to 15 feet over areas of a few miles or so are known to happen. Some regions within large continents are relatively stable, but even those will eventually get eroded down to sea level. The bottom line is that subsidence of the schist here eventually allowed the sea to flood over the area again. Mountain remnants still around continued to shed sediment into the sea that produced layers over the "basement rocks" that include the schist and granite. The level surface that received the pulses of this sediment is labelled on the banana diagram as "The greatest angular unconformity." It is now tilted as shown but was horizontal at the time. Geologic evidence indicates that this was before 1.2 billion years ago.

As slow subsidence of the schist and granite proceeded again, a thick vertical sequence of red muds, a stack of black lava flows, and layers of sand accumulated to form the "Grand Canyon Supergroup" as labelled on the diagram. Tectonic rumblings resumed and broke the basement and these overlying sedimentary rocks into discrete blocks that jostled and tilted over much like a row of dominos pushed over. The innards of one of these tilted domino blocks holding "The Grand Canyon Supergroup" has been gouged out by modern erosion directly across from Desert View and dominates the lowest parts of the view across the gorge here. The black lavas are prominent just above the far side of the river in Fig. 3.2. Following the tectonic disturbances that cracked and tilted those blocks, erosion shaved their tops down to a planar surface at sea level. Renewed subsidence was underway, the sea returned, and sands of the Tapeats Formation formed a layer over the whole area starting before 500 million years ago. Subsidence continued in fits and starts for the next 300 million years to produce the great stack of nearly horizontal sedimentary layers visible in all their glory from here at Desert View. The stack includes sandstones, shales, limestones, and dolostones of the "Paleozoic" time period (Fig. 3.3). A renewed uplift of this area started about 70 million years ago to produce the Colorado Plateau and the Kaibab Uplift that the Colorado River is now excavating to form the Grand Canyon. All this history is clearly visible from Desert View and fairly easy to follow if you can relate the bandana diagram to what you see with your own eyes. The contact between the bottom horizontal layer called the Tapeats Sandstone and the underlying tilted strata is called the "Great Unconformity" on the diagram. Great, indeed; I can see it from here at Desert View where it slices off the tops of tilted strata underneath. I will sit on it in a few days because the raft trip will descend for over a week down through everything from the top to the bottom shown on the bandana.

View from the ledge on the edge

With geologic history in mind, you can look out from Desert View and almost feel how the Earth underfoot has been slowly bobbing up and down for almost two billion years. It is like a giant cork on the white-hot churning of the mantle a hundred miles below. What we see in the view and story here is a response to that inconceivably slow bobbing. This vivid display at Desert View warrants time to observe and thoughtfully digest, but for now it rockets through my mind on autopilot. When I first sat here in 1970, little did I know that I would return again and again typically with gaggles of students or public in tow, or that I would do 32 raft trips over 30 years right through the bottom of the view here. Nor did I ever think I would one day make a pilgrimage like this seeking knowledge denied to a mind thinking only in scientific terms.

While not obvious, the North Rim on the other side of the Grand Canyon is about a thousand feet higher here. If we could shovel all the material removed by erosion back into place or construct a bridge across the chasm, we would see a ramp rising along our line of sight. It would slope around to the right and connect with a ramp that drops off eastward at an ever-steepening rate. We can see straight across how the North Rim near the horizon bends downward to the east--and how it levels off again to form the immense plain extending toward the eastern horizon. Whoa, we are perched here on the smooth southeast edge of the "half a watermelon" Kaibab Uplift or Upwarp as a possibly better description (Fig 2.1). It is here at Desert View that the Colorado River abandons its seemingly most reasonable course and cuts right across the uplift instead of wrapping around to the south. Why did it do this?

As stunning as it is, this view is no more incredible than the geologic story of this ledge itself that I am sitting on. The walking surface at Desert View is composed of interlocking, translucent, red pale, dusky yellow, and gray rock fragments solidly stuck together. Blocks of this melded jumble were quarried out to make up the lower part of the Watchtower and part of the building itself. This is the top of the Kaibab Formation shown on the bandana at the end of the "Permian Period" as labelled on the bandana. It is the time of the largest mass extinction of animal life in Earth history. Most of the fossil types found in the Kaibab and the sedimentary layers below it vanished at this time never to appear again in younger strata. The reason remains a great mystery. Are there any clues here? For starters, did this rubble form at that time, or did it develop more recently? The once overlying Moenkopi Formation is a friable red shale that has been stripped off by erosion here and nearly everywhere else on the great Kaibab Uplift. However, exposures of the Moenkopi/Kaibab Formation contact abound in areas to the south and east. A remarkable boulder with that contact running right across it was found nearby and brought over to help the concrete walkway from the parking lot to the Watchtower (Fig.3.4).

Fig. 3.4. Block lying along Desert View walkway between the Watchtower and the parking area. It is an unintentional display of the contact between the overlying Moenkopi Shale and the chert weathering residuum atop the Kaibab Limestone. This block is lying on its side showing a fresh cross section.

This unintentional geology display shows the hardened, reddish shale of the Moenkopi Formation draped right over the rubble that now makes the jumbled natural walking surface all around here. This boulder shows that the rubble was already formed at the end of the Permian when the Moenkopi was deposited on it! It is at the transition from Permian time to that of the Triassic about 250 million years ago. It tells a clear and important story with a possible clue regarding what may have caused the mass extinction. That story is quite complex but easily understandable for anyone willing to absorb a little geologic background as summarized below. This understanding can transform a visit to Desert View into something almost hallucinatory. It involves what is known about the likely origin not just of the layers visible seen in the canyon walls but also of the extraordinary walking surface here.

1. ***Origin of limestone and dolostone***

The walking surface at Desert View is the top of the 100 foot thick Kaibab Formation ultimately derived from organisms that precipitated $CaCO_3$ (calcium carbonate) out of shallow ocean water to make shells--most abundantly in great reef tracts referred to by geologists as "carbonate factories." Currents and storms tear at the reefs to make white sands which are then transported by currents over vast areas. If the whole region is subsiding, layer after layer of this sand is piled up one over the other. Shortly after deposition, the loose sand grains begin to dissolve and reform in the pore fluids mostly in the same place as interlocking crystals of the mineral "calcite." The same atoms simply reconstitute themselves into more stable forms. The hard rock that results is called "limestone."

Sands that are regularly washed up to 50 miles onshore by storms and high tides in flat, arid regions like those of the Persian Gulf or on large islands undergo extensive evaporation which concentrates magnesium (Mg) and other sea salts in remnant pools. As the evaporated seawater sinks into the porous calcite, the shells are transformed into interlocking crystals of the mineral "dolomite" --a carbonate mineral similar in atomic structure to calcite but holding equal amounts of calcium and magnesium. Gypsum ($CaSO_4$) also forms as white blebs and nodules in this devil's brew from the SO_4 (sulfate) dissolved in the ocean. Extensive flats regularly flooded by seawater that undergo extensive evaporation in arid regions are called "sabkhas." The Kaibab Limestone is made of dolomite and is thus actually a "dolostone" instead of limestone. It was originally misnamed, but let it lie. The walking surface at Desert View was thus at about sea level as a vast tidal flat under a blistering tropical sun when it accumulated about 250 million years ago. Had you walked here between tidal influxes, you might even have had gypsum squish up between your toes. With time and burial, the sabkha sands made of fragmented seashells thus became dolostone. That is just the beginning of the story.

2. *Cherts and their origin*

Several maintained trails from the South Rim descend to the river. As you hike down one of them, you first descend through "the Kaibab" and can see up close a cross section of all the layers that represent repeated intervals of sabkha flooding and exposure. However, one of the most striking sights is that of fist-sized nodules called "cherts" (Fig. 3.5).

Fig. 3.5. Chert nodules in the Kaibab Limestone exposed on the vertical wall of a side canyon.

Some are almost as big as footballs. These are intergrown, microscopic crystals not of carbonate, but of quartz! Quartz is made of silicon bonded to oxygen (SiO_2). There is a tiny amount of SiO_2 dissolved in sea water—only about 120 parts per million. It is enough such that sponges living on the ocean floor in reef tracts developed the ability to extract it and assemble it into rigid spicules sticking out the sides of the organism to ward off predators. The clear, glass-like spicules are made of SiO_2 precipitated not as quartz but as opal (which has no ordered atomic array the way quartz does). Sponge fossils are abundant in the Kaibab, so it can be inferred that billions of opaline spicule fragments were washed in along with the white sands that accumulated in the sabkha flooding events. Just as the initially formed calcite shell fragments that make up the sand were transformed into dolomite during early burial, so the opaline spicules were transformed into quartz. Much of it is disseminated throughout the dolostone, but much of it developed into these large chert nodules. The volume now occupied by a chert nodule was once carbonate sand that dissolved in the pore fluids simultaneously with quartz precipitating in the vacated spaces. Apparently, this "replacement" of carbonate by quartz provokes adjacent carbonate to dissolve in a way that yields the nodular shape of the chert. The Kaibab Limestone is a "cherty dolostone." But wait! The walking surface at the Desert View Visa Point is made of chert nodules, but they are not isolated nodules within the dolostone. Instead, they are masses of broken and fragmented chert fragments thoroughly stuck together. Beautiful pieces of translucent red chert called "agate" are included in the mix (Fig. 3.6).

Fig. 3.6. Walking surface of chert and agate rubble west of the Desert View Watchtower. Individual pieces are cemented to each other due to tiny quartz crystals that have developed in every void space.

Almost none of this rubble is made of carbonate. This is not man-made but was created by some natural process that left it here before the overlying, red Moenkopi Formation was deposited--as demonstrated by that striking boulder on the main walkway (Fig. 3.4). Some kind of natural process removed the carbonate and left this disordered residue of fragmented cherts.

3. *Origin of the chert rubble*

Imagine what might happen to a chert-bearing limestone or dolostone if it became exposed for a long interval to intense rainfall either because it was lifted out of the sea without tilting or became exposed as global sea level dropped—or if the overlying layers were stripped off by erosion during uplift much later. Both limestone and dolostone can slowly dissolve in fresh rainwater. However, quartz is only sparingly soluble in water, so chert nodules are extremely resistant to such dissolution. Rainfall over long time intervals thus dissolves the carbonate preferentially and carries it in solution as "hard" water downward through cracks and openings that enlarge as dissolution progresses. The chert is left behind as disordered rubble that thickens as the surface lowers (Fig. 3.7).

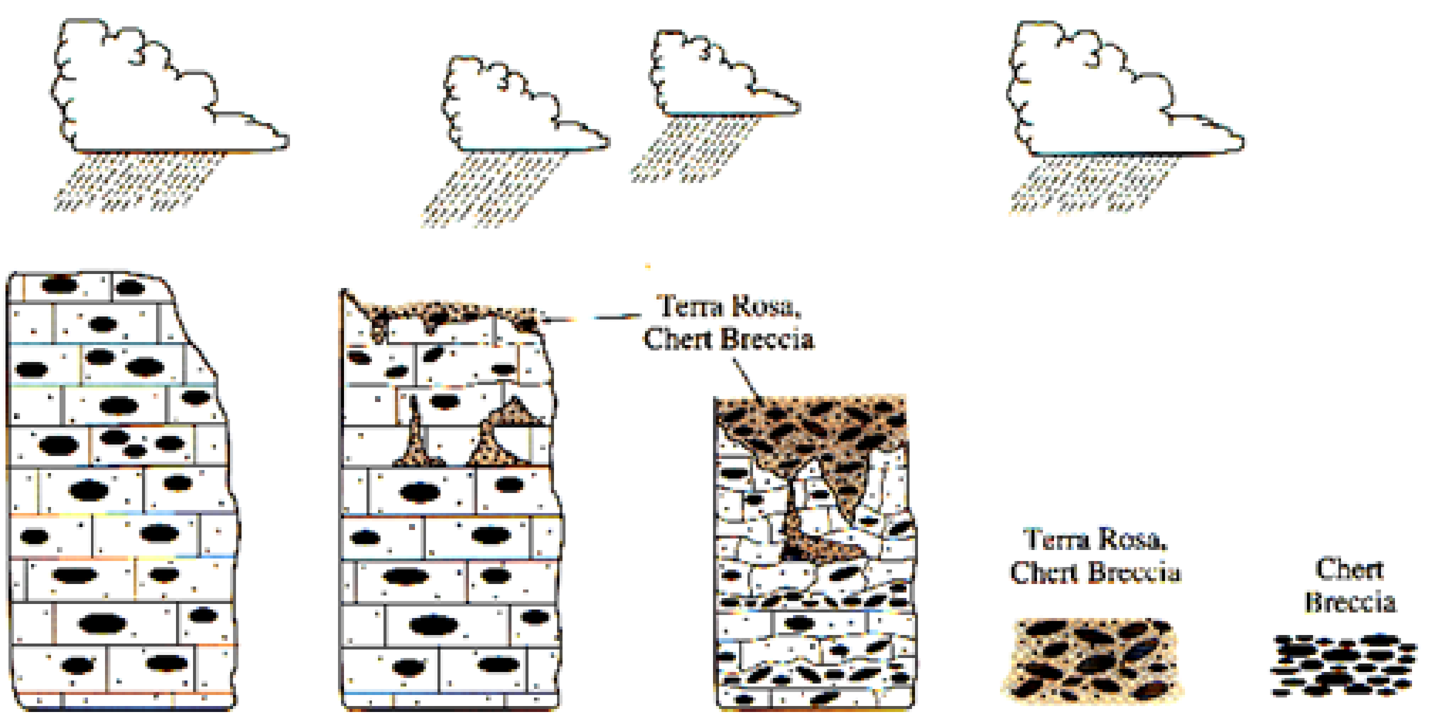

Fig. 3.7. Stages in the development of a karst surface on the top of a flat-lying cherty limestone or dolostone going left to right. Dissolution of the more soluble carbonate leaves behind progressively thicker accumulations of insoluble clay minerals (Terra Rosa) and chert.

The landscape so created by dissolution in rainwater is called "karst." It can become so studded with sinkholes that it resembles a bombed surface. The pits coalesce and grow to be miles wide. This is how sink holes are forming today in Florida and how karst forms everywhere on the continents where flat-lying carbonates of all ages are exposed to weathering. About 60% of the land area east of the Mississippi River is karst in various stages of development! Famous examples are also in China. A huge radio telescope was even built in a large karst pit in Costa Rica.

If karst gets covered by sediment due to renewed subsidence or global sea-level rise, the chert rubble will be preserved as a very distinctive layer sandwiched between its parent formation and the one deposited above it. This preserved layer of disoriented chert fragments and often partially dissolved carbonate fragments is called "paleokarst." Desert View is a Permian-aged paleokarst that got covered by the Moenkopi Formation after a long interval of weathering. It and the building stones at the base of the Watchtower quarried from it correspond to the top of the middle column illustrated in Fig. 3.7. Kaibab paleokarst comes and goes in thickness depending upon whether the specific spot was at the bottom of a wide karst pit, on its sides, or on broad pinnacles between the pits. Only the topmost parts of the formation were severely affected. Tiny, iron-rich clay particles in the chert rust during the process to make the beautiful, red Kaibab agate.

Modern karst is developing again today on Kaibab Dolostone surfaces exposed by erosional removal of the overlying strata. Some are on the South Rim, but precipitation is far more abundant on the higher North Rim where modern karst pits on that broad, nearly flat surface of the Kaibab Uplift are thus common (Figs 3.8 and 3.9).

Fig. 3.8. Modern karst pit (sink hole) developing on the Kaibab Limestone in the Kaibab National Forest about 20 miles southeast of Jacob Lake, Arizona.

Fig. 3.9. Miles-long coalesced karst pits developing on the Kaibab Limestone about 20 miles due south of Jacob Lake, Arizona. Highway 67 is visible coming through the horizon notch.

Small karst pits are commonly called “sink holes” and often hold scenic lakes and ponds. All are floored with chert rubble along with collapsed remnants of the more slowing dissolving Kaibab dolostone. The paleokarst surface is renewing there after a hiatus of 250 million years! Modern pits and sinkholes are rare on the sloping surfaces of the Kaibab Uplift because rainwater can flow freely down slopes. While primarily a Permian-aged paleokarst, minor dissolution of the carbonate components at Desert View is once again underway. It is noticeable where fractures which started as hairline cracks are now enlarging. On both north and south rims, the Moenkopi has been stripped off during modern erosion to expose the top of the Kaibab Formation.

4. *The great Permian mass extinction*

This strange walking surface of paleokarst rubble developed at the end of the Permian perhaps before, during, and/or after the greatest of all known mass extinctions in the fossil record. Is there a connection between the karst event and the mass extinction? The cause of mass extinctions is controversial. One of the major theories involves a global retreat of the sea like the one that exposed the top of the Kaibab Dolostone after its deposition to exceptionally intense weathering. Other continents also display evidence that there was a great lowering of sea level at the very end of the Permian. Indeed, it is a grand theme of geology that coastlines everywhere on Earth are either moving inland or retreating from a previous continental flooding event. Some of these changes result from local tectonic uplift or subsidence, but there were mysterious, synchronous rises and falls of the global sea level that occurred aside from small ones caused by ice coming and going in the polar regions. Without confronting the issue at this point of the pilgrimage, I just run with a “working hypothesis” based on the data and arguments of others that indicate a global drop in sea level at the end of the Permian--and that it was likely the biggest since animal life began. Continents which stand so high relative to their surrounding ocean basins are fringed with shallow water aprons that shrink or expand as sea level rises and falls. During a fall, the amount of shallow water with its unique habitats favorable to carbonate factories and thriving ecosystems decreases. Loss of habitat is one of the major causes of extinction of species. The loss of shallow water habitats during the great end-of-the-Permian sea level drop could have triggered extinctions that propagated up and down the food chain during and after this great, global sea-level lowering. Mass extinctions of lesser size have occurred repeatedly over geologic time coincident with major sea level drops. Indeed, they are used to help define the beginnings and ends of the named periods of time such as Cambrian, Devonian, Permian, etc. It thus may be no mystery that the biggest loss of shallow water habitat in the geologic record is correlated with the biggest loss of species. Remarkably, the second biggest lowering of sea level is claimed for the end of the Cretaceous Period 65 million years ago when the already fading dinosaurs finally became extinct. Claims by astrophysicists and many paleontologists that a giant asteroidal impact suddenly killed the dinosaurs captured the public's imagination and has become wildly popular--so a similar event has been suggested for the end-Permian extinction. However, exhaustive searches have yielded little evidence for the end-Permian or any of the other, smaller mass extinctions.

An increasingly popular alternative theory proposed long ago holds that volcanism was exceptionally voluminous in Siberia toward the end of the Permian, and that toxic volcanic emissions may have induced temporary, life-killing climate changes and/or poisoned the atmosphere. There are yet other speculations including changes in ocean chemistry and dissolved oxygen levels caused by various tectonic or other events yet to be determined. The paleokarst at Desert View might allow testing of some of these suggestions. As the paleokarst developed, tiny quartz crystals formed in openings within the rubble. Walk to the southwestern part of the Watchtower (Fig. 3.10) and look closely at the building stones there that were ripped up from the adjacent paleokarst.

Fig. 3.10. Close up of chert/agate rubble at the base of the Watchtower. These large building blocks were quarried out of the top surface of the Kaibab Limestone at this location. The fresh surfaces allow convenient examination of the internal nature of a paleokarst chert residuum.

Up close, a myriad of tiny quartz crystals sparkle in the sunlight (Fig. 3.11).

Fig. 3.11. Close-up of building blocks of the Watch Tower showing glistening quartz crystals in cavities. With a magnifier, the frosty coating resolves into tiny, perfectly formed quartz crystals that grew into open spaces of the chert/agate rubble during its long burial history. All spaces between the rubble were partially or totally filled with innumerable quartz crystals. The pocketknife is about 2" long.

A view with a magnifying glass shows their perfect forms all clustered together in a little universe of splendor. These grew together as rainwater in the Permian sank into open spaces throughout the rubble. It eventually dissolved some of the chert and then reprecipitated as quartz in the same voids to cement the loose rubble into a hard layer. These larger, intergrown quartz crystals together with far more numerous microscopic ones throughout the rubble are what cements the relict chert nodules and fragments together! As the crystals of all sizes grew, they trapped some of the down-flowing rainwater in little blebs called "fluid inclusions" now visible with a microscope. Yes, Permian aged rainwater is entombed in the quartz crystal cements from the time the sea retreated until the time when the Moenkopi Formation was deposited over it. These quartz crystals bearing fluid inclusions thus probably developed before, during, and after the extinction event. Some are probably still forming today. However, any poison gases in the atmosphere or dust from an asteroidal impact are likely dissolved or trapped in this fossil rainwater preserved in the earliest-formed quartz cements at Desert View! The technology now exists to determine if such are present, but it would be a huge project involving endless microscope work, many samples, skills, and expensive analyses. But there the samples sit.

5) *Reveries*

With this geology in mind, it is irresistible to stand here amidst the juniper trees under a deep blue sky with my back to the abyss and imagine what it was like on this very land surface near sea level that fateful day if the asteroidal impact hypothesis is correct. This very same colorful chert rubble was lying here in the broad low areas between hills and pinnacles of dolostone being slowly dissolved away. Ground-hugging vegetation had greened ephemeral ponds formed after recent rains. Off in the distant ocean, the great dying of life had possibly been going on for a few million years. The great global retreat of the sea is shrinking the apron of shallow water around continents and concentrating competitors into a desperate fight for life. Then the land begins to ripple like broad ocean waves followed by the sound of an explosion heard around the world. A blast of wind stronger than any hurricane hits followed by a darkening of the sky as asteroidal impact debris encircles the Earth above the atmosphere. It is glowing cherry red from the spangle of innumerable molten droplets created during impact. Everything exposed on the surface then wilts, writhes, and dies from temperatures as hot as those of a pizza oven. Long-term changes to atmospheric and ocean chemistry set in, and marine ecosystems already stressed from the loss of shallow water habitat collapse.

Or, if the volcanism theory is correct, an alternative reverie envisions the same landscape illuminated by sunsets that over the course of months and years dim and become a ghastly purple. The purple fades over the years only to resume even more intensely year after year or decade after decade. Distant volcanoes in Siberia are erupting at an unprecedented rate and filling the upper atmosphere with gaseous sulfur compounds that quickly react with moisture to form tiny droplets of sulfuric acid. It is these droplets that make the sunsets so horrifically strange. The climate becomes cold as less and less sunlight penetrates this covering of aerosols high above. Winds bearing toxic gases released by the volcanoes come and go. As increasingly (sulfuric) acid rainfall pelts the surface, dissolution of the carbonate accelerates and leaves behind this thickening residue of chert breccias. Life everywhere begins to die from the relentless volcanic belches over centuries of time. Right at this very spot on these very rocks!

The day at Desert View started out spectacularly beautiful, but now I am lost in reveries of global agony, death, and destruction. I need to get on the highway soon that slopes down the southeast part of the Kaibab Uplift so I can get to Lees Ferry to rendezvous with the raft trip launch. But I turn back to view the canyon again. This is a pilgrimage--so what do the rocks tell me here beside possible apocalypses in the past? I really need the rocks to speak now and give me some insight if possible. What caused these rocks to be here and look like this? What new angle have I missed here over all these years? I guess it works to force your soul to open, because I suddenly appreciate for the first time the extent to which ancient life left its imprint on these rocks. That is the story here! This view would not look anything like this if life had not been involved. The major carbonate layers that started out as white sands ultimately made by organisms in the sea-- the Kaibab, Toroweap, Redwall, Muav, Chuar, and Bass—would not be here. Weathering of granite and volcanic rocks to produce soil, sand and shale is greatly accelerated by lichens, mosses, and plants. The sandstones and shales themselves would be much thinner and fundamentally different in character in the absence of life. Most of the reddish sandstone and shale beds might not be red because the oxygen generated by photosynthesizing organisms would not have been present to rust the tiny iron components in them. Those black bands in the Dox Formation are lava flows about 900-1100 million years old. Could I have looked down from high above when those were erupting, I would have seen red glowing rivers flowing out from eruptive centers over the older Precambrian rocks barely visible from here. Volcanoes seem independent of life, but some geophysicists have proposed in the context of the global theory of Plate Tectonics that very deeply buried carbonates can act as a flux to trigger volcanism. So, maybe the character and eruption of those black bands was also affected by life. In any case, the sound of life being shouted from the younger rock layers in this morning sunshine is now too deafening to concentrate further on the issue. And the raft trip beckons, so it is time to depart from this ledge of wonder.

As I walk back toward the parking lot, a young oriental tourist asks me to take a picture of him and his girlfriend holding hands with the grand scene behind them. I frame them against the vista and see these two modern organisms against the effects, residue, and direct action of countless trillions of their predecessor organisms that left their signatures all over the view behind them. Here two lovers stand as evolutionary products emerging from this great lineage written on the walls of their Grand Canyon The hand-holding couple stand as a reminder to me that the genome strives relentlessly to reproduce itself at all costs and that this has shaped the geologic record. Should I tell these starry-eyed lovers about it now? No…they have other things in mind, and I have a boat to catch.