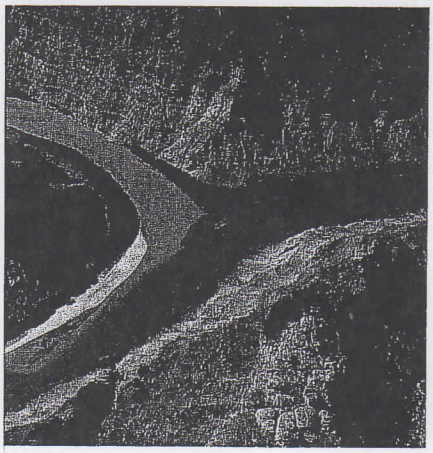
new perspectives GEOLOGY

BY WILLIAM J. BREED



Although the main ideas about Grand Canyon and the Colorado Plateau were known 30 years ago, much new knowledge has accumulated since that time. Four new rock layers have been recognized in the Grand Canyon—the Surprise Canyon Formation at the top of the Redwall Limestone and the Kwagunt, Carbon Butte, and Sixty Mile Formations in the Chuar Group.

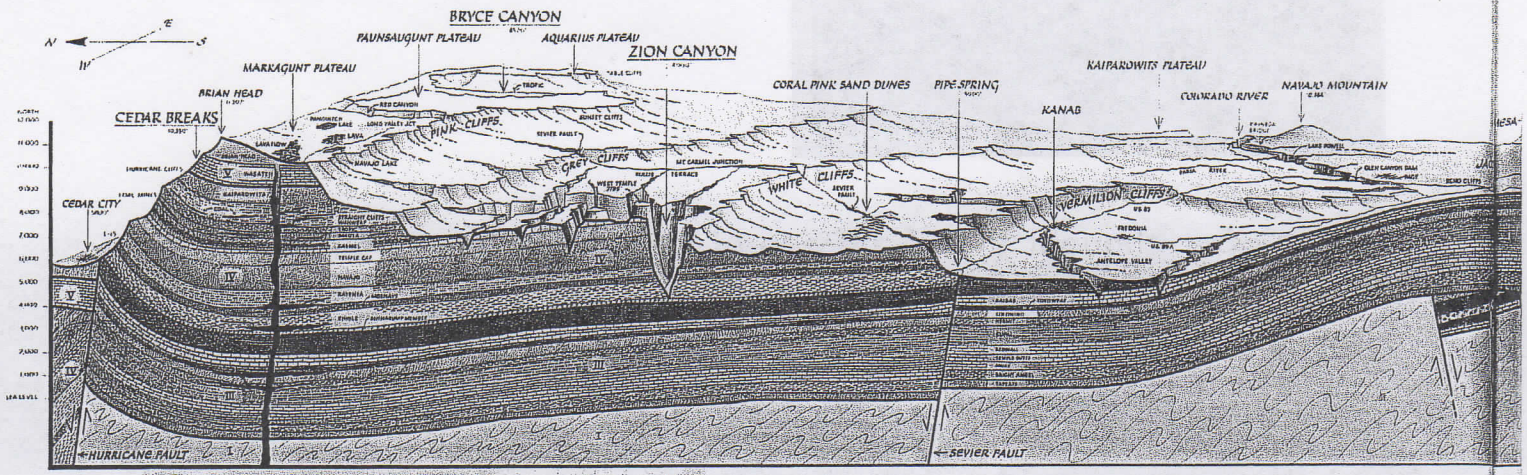
The sequence of events by which the Colorado River formed the Canyon is still in question. The problem is to find an outlet for the older, upper part of the Colorado to avoid the younger, lower portion. Previous suggestions have the river flowing to the southwest, the northwest, the southeast, or through caves. A recent suggestion has it flowing to the northeast out its present channel. So, every way but up has been considered and promoted by various geologists. The evolution of the Canyon may be a problem that will never be solved. Two things are certain however: its cutting was a complicated affair that took millions of years and it could not have been caused by the receding waters of a single giant flood.

Evidence from fossils shows that many animals and plants once present on the Plateau are no longer here. Some are still found in other parts of the world but others are now extinct. One well-known example is the dinosaur. They became extinct around 65 million years ago, and many explanations have been offered for their demise. Some suggestions include disease, competition from mammals, and climate change. A newer popular theory invokes a meteorite that crashed into Mexico, marked by a world-wide ash layer that includes an element called iridium. To me it is a coincidence that this layer coincides with the approximate end of the Mesozoic. All dinosaur remains are found below but not within the layer. Though the layer represents a catastrophic event that might not have preserved evidence of life, it indicates that the dinosaurs were extinct before the meteorite hit the earth.

The Colorado Plateau is, and has been, a treasure chest of information for geologists and other scientists. In the future, we will still find puzzles to challenge our ideas.

ABOVE: CONFLUENCE OF THE GREEN AND COLORADO RIVERS, CANYONLANDS NATIONAL PARK. TOM TILL
FACING PAGE: CANYONLANDS NATIONAL PARK. TIM FITZHARRIS

The Geologic Cross Section of Cedar Breaks, Grand Canyon



Geologic cross section from Cedar Breaks to Oak Creek Canyon

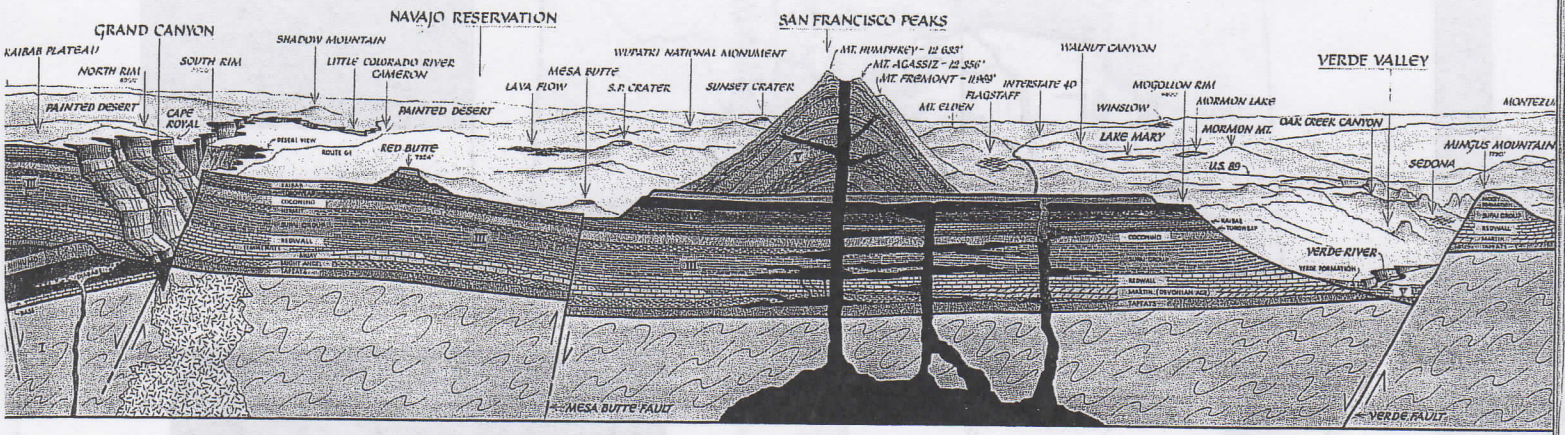
This slice through the strata of the southern Colorado Plateau illustrates the essentially horizontal layering of most of the rocks and their relationships to each other. The oldest rocks—almost two billion years old—are exposed in the Inner Gorge of the Grand Canyon, where the Colorado River has cut to its deepest point on the Plateau. The layers exposed in Oak Creek Canyon are similar to the upper layers in Grand Canyon. Rocks revealed in Bryce and Zion Canyons once extended over the Grand Canyon but have long since been worn away. The youngest rocks are the volcanics of the San Francisco Peaks and Sunset Crater.

Cross section: Zion Natural History Association

The ideal way to study geology would be to take a time machine and visit the Plateau throughout geologic time. We could observe mountains being built, dinosaurs stalking their prey, and primitive scorpions climbing about on sand dunes. However, this journey is not really necessary, for by studying the rocks and fossils of the Plateau, geologists have been able to piece together the past. It is a brief summary of this story that I would like to relate:

The story begins with the oldest rocks, found at the bottom of the Grand Canyon. The Inner Gorge of the Canyon is deep, black, and forbidding… carved into schists, granites, and gneisses that were formed almost two billion years ago during the Older Precambrian Age. Because these rocks, changed from their previous form by heat and pressure, can only be formed deep in the earth at the roots of mountains, one can deduce that a mountain range existed in this part of Arizona at that time.

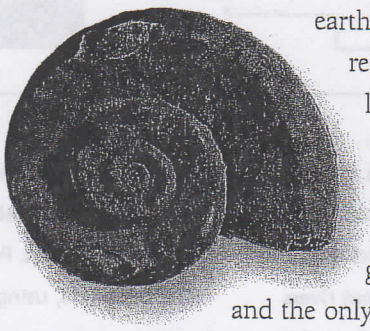
an Francisco Peaks, and Oak Creek Canyon



Evidence at the bottom of the Grand Canyon also reveals that these mountains were subsequently eroded to a featureless plain. Imagine the amount of time necessary to erode a mountain range perhaps 16,000 to 20,000 feet high to a plain at sea level... it probably took as long as 500 million years. That amount of time is hard for anyone to imagine; it could be roughly equivalent to how long it would take a troop of Boy Scouts to empty the Atlantic Ocean by carrying its water in one-quart canteens and dumping it into the Pacific!

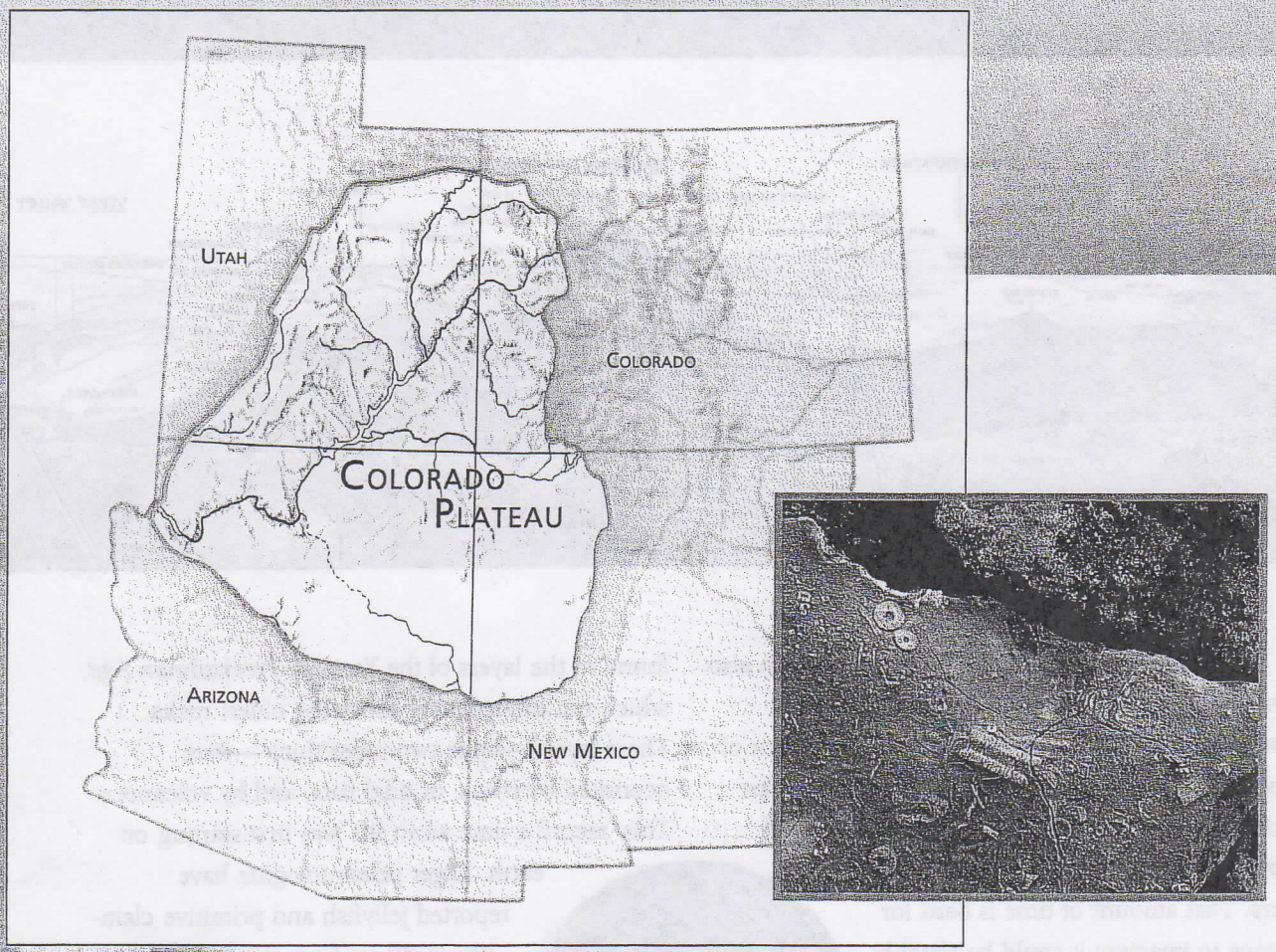
Studying these rocks that are forbidding and awesome is, however, less interesting to me than tracing life through geologic time—and all evidence of life in the Older Precambrian rocks has been destroyed.

The oldest rock record of life on the Plateau is found in the layers of the Younger Precambrian Age, which rest immediately above the oldest rocks. These layers—some two miles thick—were deposited by rivers, in tidal flats, and by volcanoes. They record a time when life was first starting on earth. Eager paleontologists have reported jellyfish and primitive clam-like molluscs from these sediments, but it is doubtful such creatures existed then. The jellyfish-like markings were probably caused by gas escaping from the sediments, and the only definite traces of life forms are the laminae built up by lime-secreting algae, along with some microscopic algal bodies. Comparatively, this is not a very impressive 500 million years of earth history, at least in terms of "life" productivity. For in the next half billion years, trilobites, dinosaurs, man, and other complex animals all developed.



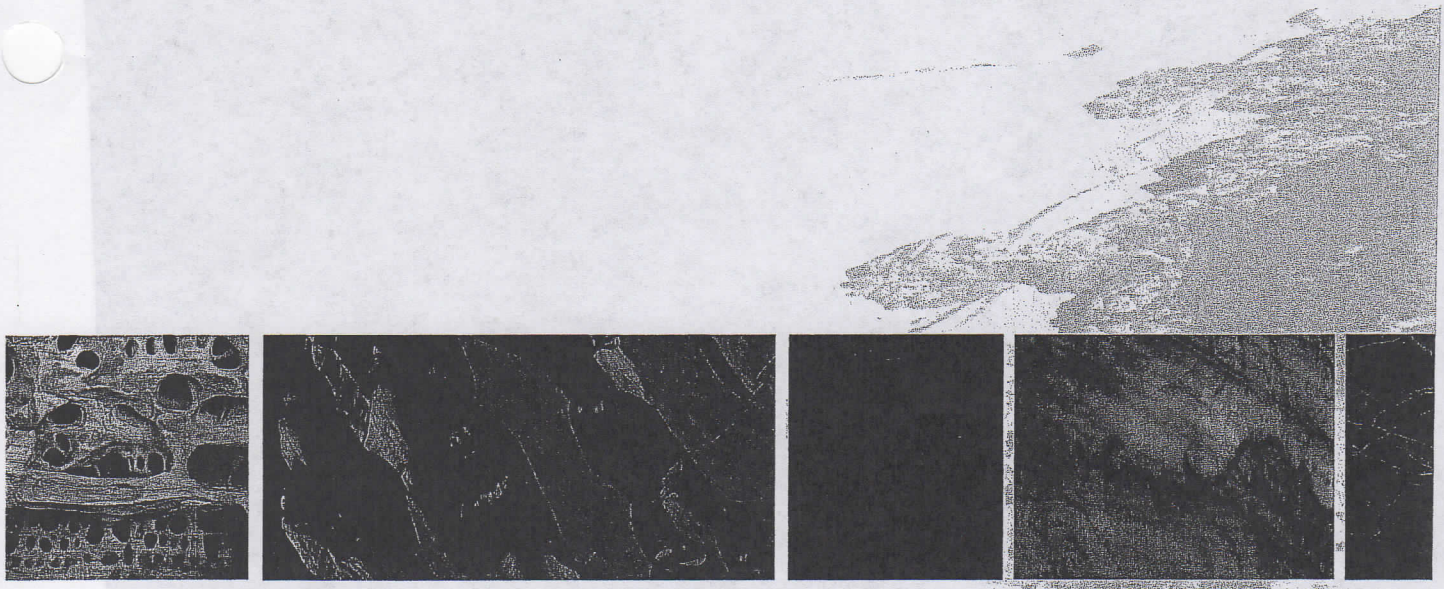
FOSSIL GASTROPOD. TOM BEAN

The Colorado Plateau



The Colorado Plateau is a heart-shaped province spanning the Four Corners states of Arizona, Utah, Colorado, and New Mexico. It is a world of canyons, swirling slickrock canyons scribed into stone by running water. Great rivers drain its 130,000 square miles—the Colorado River and its major tributary, the Green. The highest mountains approach 14,000 feet in elevation. The Plateau's scenic virtues arise from exposures of mostly sedimentary rock—sandstones, limestones, and shales—in incredible hues. The rock layers are mostly flat-lying, although faults and folds raise swells on the surface. Though it is arid, the Plateau is not all desert. With its array of rock and soil types, and extreme elevation ranges, it holds many kinds of biotic communities. People have lived on the Plateau for many millennia, using the land's resources and making their homes here.

ABOVE: FOSSIL CRINOIDS IN LIMESTONE, SHIVWITS PLATEAU, GRAND CANYON-PARASHANT NATIONAL MONUMENT. JACK DYKINGA
BACKGROUND: VISHNU SCHIST. MICHAEL COLLIER
FACING PAGE: NANKOWEAP DELTA IN GRAND CANYON. DUGALD BREMNER
MAP: COLORADO PLATEAU. MIKE DONALDSON



Left to right: Sandstone. Fred Hirschmann; Schist. Gary Ladd; Sandstone. Fred Hirschmann; Limestone. Larry Ulrich; Sandstone. Fred Hirsc

So, it took an immense amount of time to deposit these younger Precambrian rocks, uplift and fold them to form mountains, and then erode them to a flat, almost featureless plain. These rocks are now lying at angles in stark contrast to the horizontally bedded, brightly colored rocks immediately above. The line between them, known today as the "Great Unconformity," separates two rock groups of vastly different origins and represents a time of erosion.

When most people think of the Grand Canyon, they imagine its distinctive horizontal rock formations, looking not unlike layers of cake. Lying above the rocks of the Precambrian Age, these subsequent formations were deposited from 500 to 200 million years ago when this area was close to or below sea level. These horizontal rock layers, then, represent the next chapter in the book of the Plateau's geologic story.

At various times, when the land was below sea level, limestones such as the Muav, Temple Butte, Redwall, Toroweap, and Kaibab Formations were deposited. They contain fossils of trilobites and other ancient, primitive sea creatures that give us a glimpse of prehistoric sea life at that time.

At other times, the land was above sea level. For example, the red-bedded sandstones and shales of the Supai Group and Hermit Shale reveal a period of earth history when turbulent rivers ran through the Plateau to the sea, and when giant amphibians roamed its mud flats. Their only remaining traces are their footprints, visible in the redbeds mentioned above.

The rivers were followed by sand; winds created a desert rolling with dunes. As the wind blew up the gentler sides of these dunes, it picked up sand and deposited it in layers on their steep lee sides. The steep angle of these layers, or "crossbeds," can be seen easily in exposed sections of Coconino Sandstone, their current fossilized form. In the Grand Canyon, neatly cut cross-sections of Coconino Sandstone 600 feet thick can be found 500 to 700 feet below rim level, portraying the paths of winds that blew 240 million years ago.

Background: S.P. Crater. Michael Collier

Facing page: Navajo Sandstone, Grand Staircase-Escalante National Monument. Larry Ulrich

The sediment from another sea, invading the area about 200 million years ago, capped the Canyon with the Kaibab Limestone. In the Grand Canyon, then, we can trace several chapters in the story of earth history on the Plateau; a story that covers nearly two billion years, revealed by successive layers of rock that tell of mountains and plains, uplifting and erosion, rivers and deserts—a story that represents an almost unimaginable amount of energy, though comparatively little life.

Fire and ice have also helped shape the Colorado Plateau's landscape. Volcanoes such as the San Francisco Peaks and volcanic necks like Agathla and Ship Rock add diversity to the otherwise horizontal aspect of the landscape.

North and east of the Grand Canyon we find evidence for the next chapter in the geologic history of the Colorado Plateau, rocks of the Mesozoic Era—the Age of Dinosaurs.

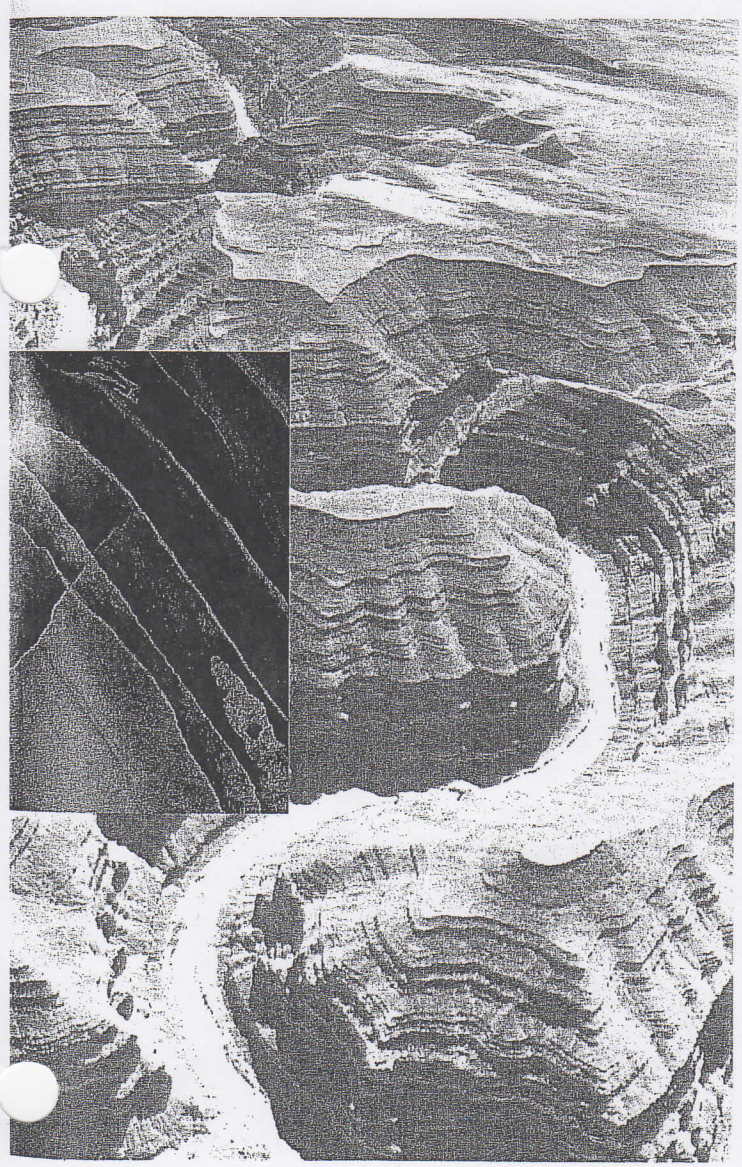
Like those in the Grand Canyon, these rocks are flat bedded, horizontal, and fossilfilled. One can decipher many stories from these rocks, and their composition continues to affect our lives today.

For the most part, the Mesozoic rocks of the Plateau were deposited on land. They're extremely

ABOVE: S.P. CRATER. MICHAEL COLLIER
FACING PAGE: EROSION PATTERN IN NAVAJO SANDSTONE. FRED HIRSCHMANN
BACKGROUND: GOOSENECKS, SAN JUAN RIVER. MICHAEL COLLIER

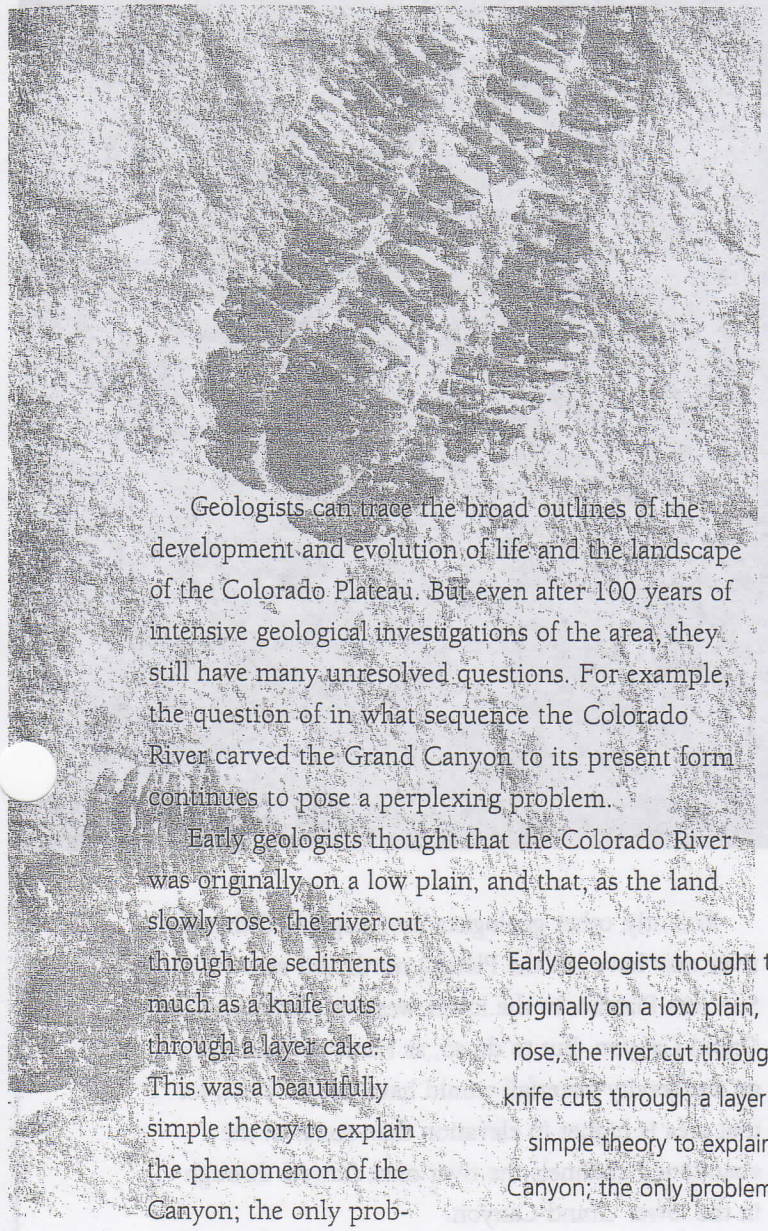
colorful, appearing in shades of red, white, and brown. Their erosion has created some of the most spectacular scenery found on the Plateau today—Zion, Canyonlands, Capitol Reef, Arches, and Petrified Forest National Parks, the Painted Desert, Glen Canyon, Vermillion Cliffs—the list is almost endless.

In many rock layers of the Mesozoic, geologists have found abundant remains of dinosaurs, in the form of both tracks and bones—sometimes even complete skeletons. The most complete specimens have been found in the Morrison Formation, a layer that has always been one of the prime sources of these mighty beasts, both on the Plateau and elsewhere. Although dinosaurs were abundant, they ceased to exist 60 million years ago. Numerous explanations have been advanced for their demise; most probably, they just became too specialized and couldn't adapt to changing conditions.



The Mesozoic Era also contributes to our lives in an immediate sense because it was during that time that coal was in the process of being formed on the Plateau. This occurred over 60 million years ago when there was a sea in the central to western part of the United States. At times the sea would invade northern Arizona, Utah, and New Mexico through Colorado since the Rocky Mountains had not been formed yet. Near the sea, swampy areas developed, areas lush with vegetation. The vegetation accumulated in these swamps, and, as the sea retreated and advanced, layers upon layers of plants became buried and hardened into coal deposits. Now these same deposits are being sought after, fought over, and mined in ever-increasing numbers all over the Plateau.

Fire and ice have also helped shape the Colorado Plateau's landscape. Volcanoes such as the San Francisco Peaks and volcanic necks like Agathla and Ship Rock add diversity to the otherwise horizontal aspect of the landscape. These forces, as well as the erosion of some high peaks by glaciers, have helped shape the Plateau into the form we see today.



Geologists can trace the broad outlines of the development and evolution of life and the landscape of the Colorado Plateau. But even after 100 years of intensive geological investigations of the area, they still have many unresolved questions. For example, the question of in what sequence the Colorado River carved the Grand Canyon to its present form continues to pose a perplexing problem.

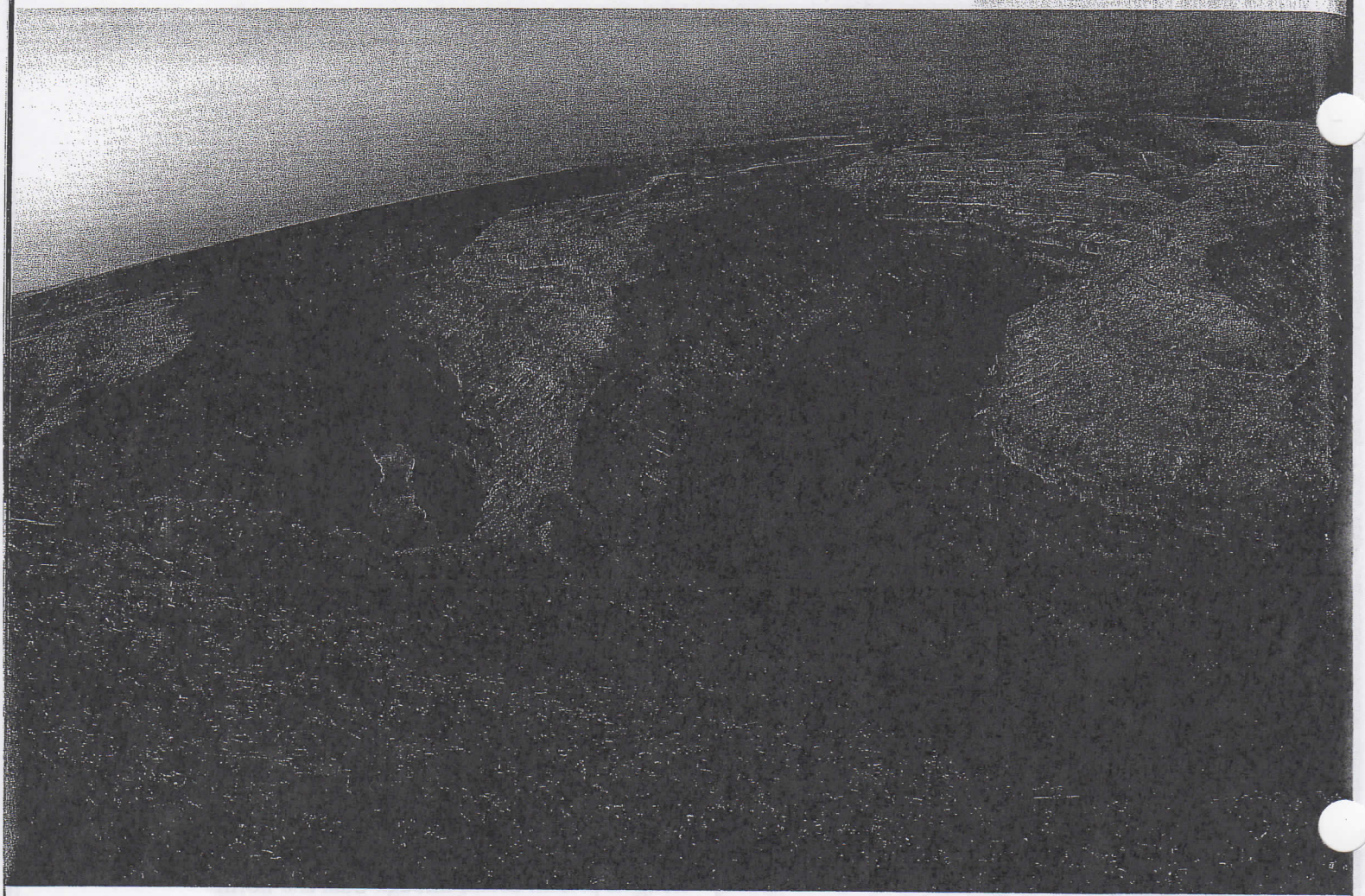
Early geologists thought that the Colorado River was originally on a low plain, and that, as the land slowly rose, the river cut through the sediments much as a knife cuts through a layer cake. This was a beautifully simple theory to explain the phenomenon of the Canyon; the only problem was, and is...it isn't true! After many years of geological studies on the Plateau, three facts emerged which negated the knife-and-cake theory: (1) the main uplift was older, not younger than the river; (2) the Colorado River downstream from western Grand Canyon was quite young, perhaps 8 to 10 million years old; and (3) the Colorado River upstream from eastern Grand Canyon was quite old, perhaps 30 to 40 million years old.

Early geologists thought that the Colorado River was originally on a low plain, and that, as the land slowly rose, the river cut through the sediments much as a knife cuts through a layer cake. This was a beautifully simple theory to explain the phenomenon of the Canyon; the only problem was, and is ... it isn't true!

To resolve these rather puzzling facts, the Museum of Northern Arizona held a symposium in 1964. At that symposium, known facts about the river were assessed, and new ideas about its history were tested. A hypothesis was suggested that the Colorado River, for much of its existence, flowed along its present course through Utah and northeastern Arizona to its present junction with the Little Colorado River, then in reverse direction up the present course of the Little Colorado, eventually emptying into the Rio Grande. Finally, another smaller river, eroding eastward into the Plateau from the west, captured the Colorado River and diverted it to its present course.

Dr. C. B. Hunt, however, pointed out a major weakness in the symposium theory. He found it difficult to conceive of a stream, with relatively little volume and a small drainage area, as capable of capturing the flow of a river with a great amount of

FACING PAGE: COLORADO RIVER IN MARBLE CANYON, GRAND CANYON NATIONAL PARK. JACK DYKINGA
BACKGROUND: FOSSIL TRILOBITES IN SHALE. MICHAEL COLLIER

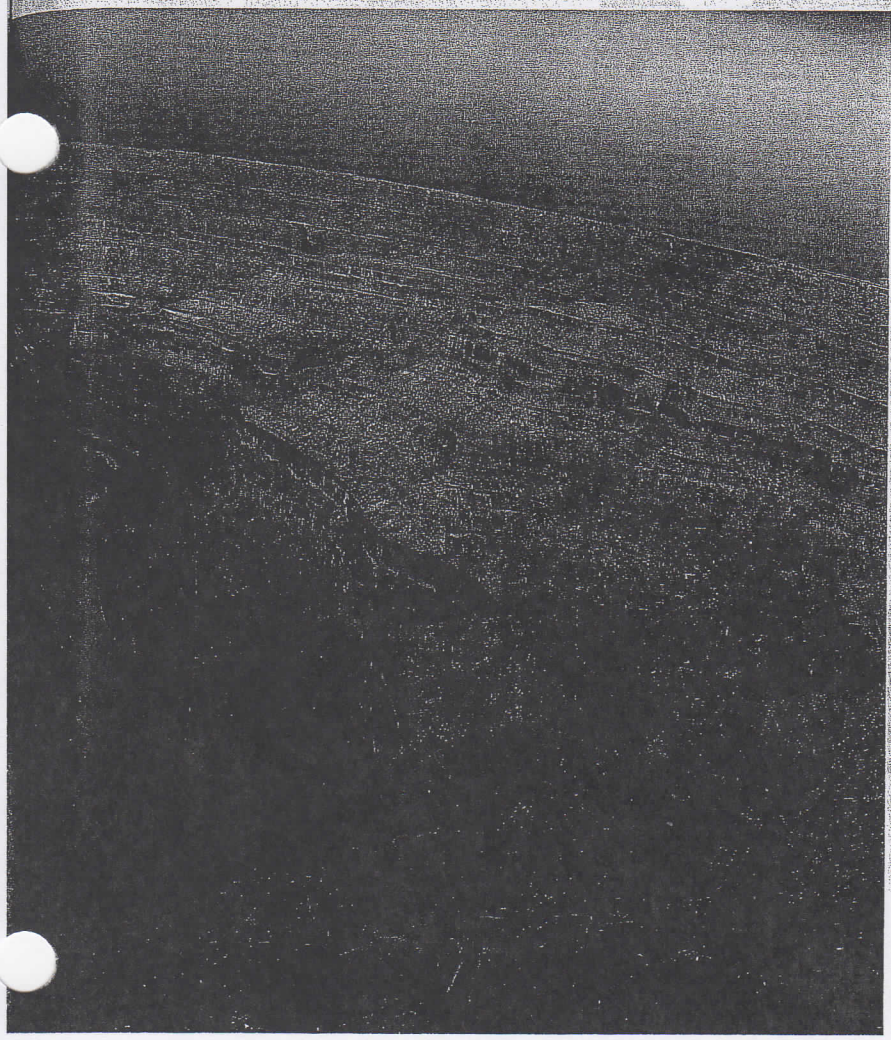


volume and a large drainage area, such as the former Colorado River must have had. In short, he thought it improbable that a small stream could be so "convincing," and hence referred to the idea as the "precocious gully" theory. Hunt suggested instead that drainage from the Grand Canyon flowed off to the south through today's Hualapai Reservation, was then blocked by an uplift and went underground, in caves, and into lakes. The caves eventually collapsed, and the Colorado River was forced to flow out its present exit from the Plateau at the Grand Wash Cliffs, the western terminus of the Grand Canyon. He realized that his hypothesis, too, was rather outrageous, but he could offer no better way of resolving the problem. One might refer to his ideas as the "precocious cave" theory.

Recently, other geologists have suggested that the river may have left the Plateau north and east of the Shivwits Plateau, in the lower western portion of the Grand Canyon. But to do so, as Hunt pointed out, an antigravity waterfall would have had to exist, for that area is higher in elevation than some of the abandoned channels the river once flowed through in the lower Grand Canyon.

So, the controversy remains unresolved, the question unanswered. For now, the three alternatives are: the precocious gully, the precocious cave, or the antigravity waterfall theory. Perhaps someday we will have more viable explanations to choose from.

GOOSENECKS, SAN JUAN RIVER. GEORGE H. H. HUEY



that has passed, and all the geological events that have occurred, I feel humble and insignificant. In the future, I know that just as I will live out my life, the Plateau will live out its geologic history. Erosion will perhaps once again level the whole land to a low-lying, featureless plain. The Grand Canyon, Rainbow Bridge, the San Francisco Peaks, and all the scenic and geologic wonders of the Plateau will disappear. Man may not be around to watch the whole process, for other animals in this land have flourished and then become extinct. Perhaps, like these fossils, man's existence on the Plateau may eventually be represented by nothing more than 30 feet of strata exposed in some future canyon.

I have tried in this article to convey the whole parade of events and life that has contributed to creating the Colorado Plateau. From our egocentric viewpoint, we could think that all this took place just so man would have a Grand Canyon to photograph, a San Francisco Peaks to climb, or coal to burn in our power plants. On looking through geologists' eyes, perhaps all of this happened to give us a natural laboratory in which to study.

Obviously, these possibilities are not so. The Plateau is an entity, separate unto itself. It is we who are privileged to be here at a time when all of the elements of this land have combined to reach a zenith, a culmination both in regard to scenery and geologic interest.

As I think about the enormous amount of time

William J. Breed was Curator of Geology at the Museum of Northern Arizona from 1960 until 1981. During that period his particular geologic research centered on the Colorado Plateau. He has written almost 100 popular and scientific articles on the Plateau and his fields of interest in geology. He is the past president of the Arizona Academy of Science and has conducted field projects in New Zealand, Australia, and Antarctica. He retired from the museum in 1981 to lead nature trips to many parts of the world. Breed is presently the Emeritus Curator of Geology at the Museum of Northern Arizona.