Cliffs, Canyons, and Plateaus – The Geology of the Arizona Strip
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The geology of the Arizona Strip, though spectacular to view, is relatively straightforward and easy to understand. Most of the area is flat, gently rolling terrain interrupted by, mesas, buttes, fault scarps (cliffs caused by the displacement of large blocks of land), and volcanic features.

The Strip Country is a block of the earth's crust that has been uplifted and tilted to the northeast. Over time this block has been divided into a series of elongated and nearly isolated north-south trending plateaus – including the Shivwits Plateau (between the Grand Wash and Hurricane faults), the Uinkaret Plateau (between the Hurricane and Toroweap faults), the Kanab Plateau (between the Toroweap Fault and the West Kaibab Fault-monocline), the Kaibab Plateau, and the Marble Platform. Along the major faults, the block to the east has been uplifted (in relation to the block to the west) so that the plateaus rise as a series of steps from west to east. This sequential uplifting has created magnificent cliffs ranging in height from two-hundred to well over four-hundred feet. Today, these cliffs form some of the most prominent landforms on the Arizona Strip.

Strata throughout the Arizona Strip are tipped, or tilted, one to two degrees to the northeast. But near the Grand Wash cliffs, the dip increases to as much as five degrees. This slight but persistent northeast dip is almost imperceptible from most vantage points on the ground. It is, however, one of the most important factors in the development of the landscape of the Strip and the tributaries to this part of the Grand Canyon since it is a major determinant of the region's erosional pattern.

The Rocks

During the Paleozoic and Mesozoic eras, the re-ion that we know today as the Arizona Strip was an environment in which sedimentary rocks were deposited. Gray marine limestone and shales formed in shallow Paleozoic seas. Red shale, siltstone, and sandstone, on the other hand, formed in tidal flats and river systems during Mesozoic time.

After the formation of the Strip's major rock units, volcanic eruptions occurred on the Shivwits and Uinkaret plateaus, covering the area with basaltic lava. These lava flows provide geologists with an excellent means of reconstructing the sequence of events in the evolution of landforms. We know for example, that the Colorado River assumed its present course across the Arizona Strip some time prior to a million years ago. At this time, the Shivwits Plateau was at least four-thousand feet above sea level. During the last several million years, the major geological processes have been uplift and erosion - with periodic deposition of basalt (volcanic action).

On the Shivwits and Uinkaret plateaus, erosion produced a gently sloping alluvial surface (or pediment) on the Moenkopi Formation and a strip surface on the Kaibab Formation. Lava flows in the Dellenbaugh and Poverty Mountain areas and in the Mt. Trumbull region were deposited upon these surfaces. Over time, the basalt was dissected into low-lying mesas and buttes, and new flows partially filled in the valleys.

There are five basic rock units in the Arizona Strip Country: the Kaibab Formation and the Toroweap Formation (often described together), the Moenkopi Formation and the Shinarump Conglomerate (also frequently described together), and later volcanic flows.

The Kaibab and underlying Toroweap formations, which form the uppermost five-hundred to seven-hundred feet of strata exposed in the walls of the Grand Canyon, constitute the surface upon which most of the Arizona Strip has been carved. Throughout most of the area north of the Grand Canyon, only the upper surface of the Kaibab Formation is exposed – forming a gently rolling terrain in which erosion has cut shallow valleys. The lower part of the Kaibab Formation and the underlying Toroweap Formation as well are exposed in major fault scarps throughout the region.

Both the Kaibab and Toroweap formations consist predominantly of limestone beds, which usually form steep cliffs, separated by weaker shale and gypsum beds that tend to form rounded slopes. This limestone and shale sequence represents cycles of transgression and regression of the sea during middle Permian time. The periods in which the sea inundated the area are represented by the fossiliferous (or fossil-bearing) carbonate rocks. Periods of regression are represented by beds of shale and gypsum that were deposited when

the sea withdrew and the area was occupied by coastal plains and restricted basins.

Moenkopi shales and the overlying Shinarump Conglomerate form the east-west trending Chocolate Cliffs – the lowest step in the "Grand Staircase" leading to the high plateaus of Utah. In the Arizona Strip, the Moenkopi Formation usually appears as a red shale, but one member, the Shnabkaib, is famous for its stratified red and white beds, which strongly resemble a bacon strip – albeit on a grand scale.

The contrast in the way the Kaibab and Toroweap formations and the Moenkopi shales erode has determined a great deal of the topography of the Strip Country. The Kaibab and Toroweap formations are very resistant rock units, whereas the overlying Moenkopi is soft, nonresistant, and easily eroded. In most areas of northern Arizona, the Moenkopi Formation has been stripped off from the top of the Kaibab Formation – with almost as much ease as one would wash dirt off the driveway with a hose. As a result, the upper surface of the Kaibab Formation frequently is exposed as a stripped surface. This means that in many places the land surface is parallel with the upper bedding plane of the Kaibab. The stripped surface of the Kaibab Formation is the single most widespread landform in North America.

The Shinarump Conglomerate rests unconformably upon the Moenkopi shales – forming a resistant cap rock for the Chocolate Cliffs. Unconformities occur when one laver of rock rests upon another, but there is a break in the sequence of time. In some cases, there was a long period of nondeposition. More commonly, the intervening layer(s) eroded away. The Shinarump unit is only 75 to 190 feet thick, but its resistant character means that a flat tableland forms wherever a large area of the rock unit is exposed.

Volcanic eruptions producing basaltic lava flows and cinder cones have occurred in the western part of the Arizona Strip at various times during the last six-million years. Many of the older eroded flows now form cap rocks for high, isolated buttes and mesas. The oldest flows, often referred to as Stage One flows, were deposited on a landscape that bears no relationship to the present drainage system. Frequently, flows of intermediate age are capped long, narrow, and sinuous ridges that geologists call inverted valleys. Like the older flows, the original features of Stage Two flows have been partially or totally destroyed by erosion – or were covered by sediment and soil. The youngest flows partly filled present-day stream valleys. A few also cascaded over cliffs – where they formed "frozen lava falls." These last flows have been only slightly modified by weather and erosion. In some cases, the flows are so recent that a soil has not yet been established upon them.

The Plateaus

The Shivwits Plateau is the westernmost plateau of the Arizona Strip. It is approximately seventy-five miles long and twenty-five miles wide. Its western boundary is the Grand Wash Cliffs. These cliffs mark the boundary between two major geological provinces – the Colorado Plateau and the Basin and Range Country.

Structurally, the Shivwits Plateau is a large block of gently dipping Paleozoic strata that has been uplifted along the Grand Wash Fault and tilted two to five degrees to the northeast. Most of the plateau's surface is stripped Kaibab Limestone, but isolated lava-capped mesas and buttes occasionally rise as much as one-thousand feet above the surrounding surface.

The Grand Wash Fault is expressed topographically by the majestic Grand Wash Cliffs, which reach a height of four-thousand feet near the Colorado River. Displacement along the Grand Wash Fault near the Colorado River is as much as sixteen-thousand feet. Northward, the displacement steadily decreases, and this change is reflected in a corresponding decrease in the height of the cliffs. At the north end of Grand Wash near the Utah State Line, the Moenkopi Formation is exposed on both the upthrown and downthrown blocks, indicating a displacement of less than fifteen-hundred feet. The profile of the Grand Wash Cliffs is similar to the profile of the western Grand Canyon. A series of steep, lower cliffs is formed on the Supai, Redwall, and Muav formations with a broad platform carved on top of the resistant Supai Sandstone. The upper cliffs are etched in the Kaibab and Toroweap limestones and are highly dissected with deep canyons eroded back more than five miles from the fault line.

The Shivwits Plateau is distinctive among the plateaus of the region in that it is broken by a number of minor, north-south trending faults. Most of these faults displace the Shivwits Plateau strata by one-hundred to two-hundred feet – producing small, well-defined fault line scarps trending north/south. The Washington Fault, one of the largest of these faults, extends

from the foothills of the Pine Valley Mountains north of St. George, Utah, into Arizona, a distance of thirty-six miles. In many ways, it is a small-scale version of the Hurricane Fault, which forms the eastern boundary of the Shivwits, since it is marked by a prominent west-facing cliff exposing the Kaibab and Toroweap limestones.

The Main Street Fault, located five to ten miles east of the Washington Fault, extends from Seegmuller Mountain southward across the entire Shivwits Plateau and into the Grand Canyon. Additional small faults to the east of these faults occur near the Hurricane Cliffs.

The regional drainage of the Shivwits Plateau is northeastward into the Virgin River system**.** But rapid headward erosion along the Grand Wash Cliffs and major tributaries to the Grand Canyon has created some striking examples of stream capture. Excellent examples are Hidden Canyon in the Grand Wash Cliffs and Parashant Canyon in the Grand Canyon. The headwaters of Parashant Canyon originally flowed due north but were captured by Parashant Wash and turned almost 180° to flow southward into the Grand Canyon.

Of all the great fault systems in the southwestern United States, none can compare with the Hurricane Fault in providing a clear record of structural events in the western part of the Colorado Plateau. It extends from Cedar City, Utah, to Peach Springs, Arizona, a distance of over two-hundred miles. This high, vertical cliff (ranging from fifteen-hundred to two-thousand feet in height) can be crossed in just three places: Hurrican Utah, the Navajo Trail, and at Bundyville just west of Mt. Trumbull. Unlike the Grand Wash Fault, displacement along, the Hurricane Fault increases from south to north – ranging from less than two-hundred feet at Peach Springs to nearly ten-thousand feet at the town of Hurricane, Utah.

The Uinkaret Plateau also trends north/south, varying in width from approximately fifty miles wide near the Utah state line to approximately ten miles at the Grand Canyon. Its structure is somewhat similar to the Shivwits Plateau in that it consists of a large block of Paleozoic strata gently dipping to the northeast. But large mesas composed of Mesozoic rocks in the north and a volcanic field in the south make the Uinkaret Plateau one of the most interesting segments of the Arizona Strip. The western boundary of the Uinkaret Plateau is the Hurricane Cliffs. From almost any point on the Hurricane Cliffs, visitors can see a broad, magnificent panorama of the lower Shivwits Plateau to the west. The plateau's eastern boundary is the less pronounced cliffs formed on the Toroweap Fault.

The lava flows and cinder cones of the Uinkaret Plateau constitute one of the more extensive volcanic fields in the western part of the Colorado Plateau. It ranks a close second to the volcanic field of the San Francisco Mountain regions near Flagstaff, Arizona. Mt. Trumbull, with an elevation of 8028 feet, is the most prominent landmark in the area and can be seen as far away as Fredonia, Arizona, and from various points in the Grand Canyon National Park nearly one-hundred miles to the east. South of Mt. Trumbull lies Mt. Login, which occurs at approximately the same elevation but is less prominent because of the clusters of, younger cones in the immediate vicinity. Another prominent landmark, Mt. Emma, is located near the southern tip of Uinkaret Plateau. It, too, is largely concealed by younger volcanic features.

The most impressive features in the Uinkaret Plateau are recent basaltic flows and cinder cones. They occur throughout much of the southern plateau, where they are superimposed on the older units. In many places, the flows disrupted the drainage system and cascaded over steep escarpments. Some cascaded over the outer rim of the Grand Canyon into Toroweap Valley and Whitmore Wash and followed these valleys southward toward the Colorado River. Other flows were extruded out onto the Esplanade of the Grand Canyon between the Hurricane and Toroweap faults, where they cascaded over the rim of the inner gorge into the Colorado River three-thousand feet below to form some of the most spectacular scenery in the Colorado Plateau.

The Toroweap Fault is the eastern margin of the Uinkaret Plateau. It is the longest line of displacement in the Colorado Plateau (over three-hundred miles) and can be traced from south of the Grand Canyon northward into central Utah, where it is known as the Sevier Fault. In the Arizona Strip, the fault is best exposed in the Toroweap and Prospect valleys. Here, the displacement on the fault is nearly eight-hundred feet, but northward, near the central part of the Uinkaret Plateau, displacement decreased to a few tens of feet – creating only a slight topographic break between the Uinkaret and Kanab plateaus. There is a rapid increase in displacement from this point

northward into Utah, where the scarp reaches a height of more than one thousand feet.

At Pipe Spring, the Toroweap Fault is marked by a ragged cliff formed on the downthrown block (instead of the upthrown block, which is more common). The resistant Moenave Formation forms the Vermilion Cliffs, where it abuts against the easily eroded Moenkopi Formation for a distance of nearly nine miles. The cliff formed by differential erosion is over eight-hundred feet high in some places.

The Kanab Plateau is the large structural block between the Toroweap Fault and the Kaibab Plateau. Because it lacks the volcanic features so characteristic of the Shivwits and Uinkaret plateaus, it appears as a flat, almost featureless plain. The most distinctive feature of the Kanab Plateau is that it is dissected by the deep canyon cut by Kanab Creek, the only, tributary to the Grand Canyon that comes down from the High Plateaus of Utah. This canyon dissects the Kanab Plateau – making many parts of the plateau inaccessible.

When viewed from the ground, Kanab Canyon is almost hidden in the landscape. Only when visitors approach by air – or arrive at the brink of the canyon – does the deep chasm suddenly reveal the fascinating variety of canyon landforms carved on the colorful Paleozoic strata. In its upper reaches, Kanab Canyon is one-thousand to two-thousand feet deep. Here, the floor of many of its tributaries is at the general level of the Esplanade (top of the Supai Sandstone). The canyon deepens as it approaches the Colorado River, however, reaching a depth of almost five-thousand feet.

Unlike many major tributaries to the Grand Canyon, Kanab Canyon shows no evidence of being produced or shaped by structural forces. Indeed, its position is somewhat surprising because the West Kaibab fault and monocline zone, located only a few miles to the east, would appear to be a much more favorable zone of weakness along which a major tributary could erode. This suggests that the course of Kanab Creek was established long before the Grand Canyon was eroded anywhere near its present depth.

The Kaibab Plateau is one of the highest and most visually diverse parts of the Arizona Strip. Its crest attains an elevation of 9200 feet. The east flank of the Kaibab Plateau is marked by the famous East Kaibab Monocline, a large flexure (or fold in the earth's crust) that descends three-thousand feet down to the surface of the Marble Platform. The monocline is a compound flexure extending from the San Francisco Mountains on the south to Bryce Canyon on the north, a distance of approximately one hundred-fifty miles. The geology of the East Kaibab monocline is fairly, complex since it varies from a single to a triple flexure and is broken in many places by faults. From its crest near the axis of the monocline, the surface of the Kaibab Plateau descends gently to the west for about ten miles and then drops abruptly to the level of the Kanab Plateau.

Unlike the monotonous, stripped surface of the Kanab, the Kaibab Plateau contains a variety of interesting surface features. For example, numerous wide valleys or basins called "parks" are found on the top of the plateau. These broad, shallow valleys have undulatory floors. When traced downstream, they become narrower and eventually grade into V-shaped canyons. The "parks" probably represent initial stream-cut valleys that were deepened and enlarged by solution activity in the underlying Kaibab and Toroweap limestones. Most of these streams have disappeared, and present drainage is mainly through sinks on the valley floors. Indeed, it is the subsurface drainage of the Kaibab Plateau that supports springs on the north side of Grand Canyon.

The Marble Platform, to the east of the Kaibab Plateau, is a broad, stripped surface on top of the Kaibab Limestone located between the flexures of the East Kaibab and Echo Cliffs monoclines. The strata here are nearly horizontal but do dip gently toward the northeast. Because of its low elevation (4700 to 5000 feet), vegetation is sparse, and when viewed from the ground much of the surface appears flat and featureless. From the air, and from viewpoints on the Echo Cliffs or the Kaibab Plateau, the Marble Platform represents a strikingly different picture. The Colorado River has cut a deep, vertically walled gorge into the platform to form Marble Canyon. Near Lees Ferry the Colorado River flows for a short distance on top of the Kaibab Limestone, but further downstream uplift has permitted the river to cut much deeper into the rock sequence.

One of the unique features of the Colorado River in this area is the spectacular development of "barbed" tributaries. Visitors to view points on Echo Cliffs can easily see that although the Colorado River flows to the south all of the tributaries flow northward down the dip slope of the Kaibab and then join the Colorado River at an acute angle (like a series of "V's" pointing upstream). This pattern is completely

different from normal drainage patterns in the area and has been interpreted as evidence of drainage reversals. It is apparent, however, that the tributaries flowing northward down the stripped surface on the Kaibab have simply been captured and diverted by headward erosion of the steep gullies formed as the Colorado River became entrenched into the Marble Platform.

The Strip Country is a distinctive part of Arizona, isolated from the rest of the state by the Grand Canyon. The geology, of this region represents a fascinating sequence of events involving rock formation during the Paleozoic and Mesozoic eras and erosion, faulting, and volcanism during the Cenozoic. The area is unique because the record of events is remarkably clear and easy to see.