# GEOLOGY OF THE COLORADO PLATEAU

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## Introduction

The Colorado Plateau is a land of scenic beauty characterized by sparsely vegetated plateaus, mesas, deep canyons, and barren badlands. It encompasses an area of approximately 140,000 square miles in the four corners region of Utah, Colorado, Arizona and New Mexico. It includes the area drained by the Colorado River and it's tributaries the Green, San Juan and Little Colorado Rivers (figure 1).

The combination of high relief and an arid climate over most of the plateau has resulted in limited plant cover. The products of weathering are easily eroded by fast moving streams leaving behind bare rocks which produce the dramatic scenery of this area. Not to mention, the excellent rock exposures waiting to be explored by a group of geology students.

Elevations on the plateau range from 3,000 to 14,000 feet with an average of 5,200 feet. Due to the high range in elevations, the climate ranges from Sonoran desert to Alpine, however, semiarid conditions prevail. The high Sierra Nevada mountains of the West Coast prevent Pacific, moisture laden air masses from reaching the southwestern states. As a result of this rain shadow effect, annual precipitation on the Colorado Plateau is low, averaging about 10 inches per year.

## General Physiography

The Colorado Plateau is a high standing crustal block of relatively undeformed rocks surrounded by the highly deformed Rocky Mountains, and Basin and Range Provinces. The Uinta Mountains of Utah and Rocky Mountains of Colorado define the northern and northeastern boundaries of the Plateau. The Rio Grande Rift Valley in New Mexico defines the eastern boundary. The southern boundary is marked by the Mogollon Rim, an erosional cuesta that separates the Colorado Plateau from the extensively faulted Basin and Range Province. To the west is a broad transition zone where the geologic features are transitional between typical Colorado Plateau, and Basin and Range. The margins of the Colorado Plateau are marked by major volcanic accumulations (figure 2).

Geophysical studies indicate the earth's crust is relatively thick below the province and heat flow (geothermal gradient) is relatively low. The plateau also has distinct gravity and magnetic signatures.

The Colorado Plateau has been divided into the following six sections (Rigby, 1977): 1) Grand Canyon section, structurally this is the highest part of the Colorado Plateau province. 2) High Plateaus section, this section is characterized by high, north-trending plateaus, separated from each other by faults. 3) Uinta Basin, this is structurally the lowest part of the Colorado Plateau. 4) Canyonlands section, deeply incised canyons are distinctive features of this section which contains large monoclines and laccolithic mountains. 5) Navajo section, this is an area of scarped plateaus that is less dissected than the Canyonlands section. 6) Datil section, this section is largely volcanic in origin.

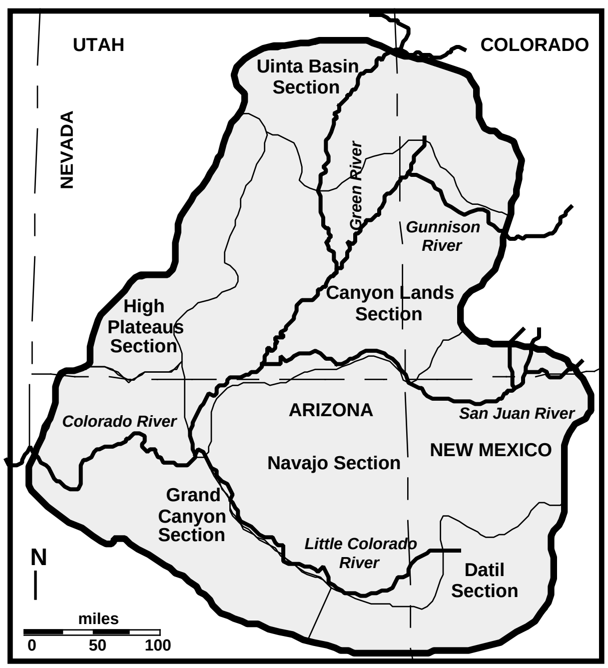


**Figure 1.** Map of the Colorado Plateau province showing major drainage and section boundaries. (After Hunt, 1956)

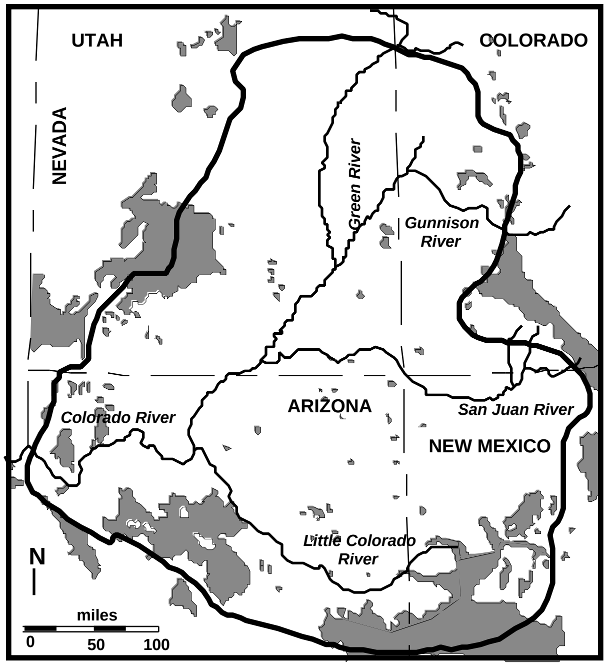


**Figure 2.** Distribution of volcanic and igneous centers (shaded areas) around the margins of the Colorado Plateau. (After Hunt, 1956)

## Geologic Structures

The major structures of the plateau include broad flexures, monoclines, vertical faults, igneous laccoliths and volcanics, and salt tectonic features.

Rather than the tight folds characteristic of orogenic belts, folds of the Colorado Plateau are broad open folds or flexures. As an example, the Kaibab Uplift forms a great arch 160 km long and 40 km wide.

Wide areas of nearly flat lying sedimentary rocks are separated by abrupt bends of strata along monoclinal folds. Monoclines, or one sided folds, form where sedimentary rocks are draped over deep-seated basement faults (figure 3). Some classic examples of monoclines on the Colorado Plateau include the north-south trending Comb Ridge monocline on the east flank of Monument Uplift, the San Rafael Reef, and the Waterpocket Fold which can be observed at Capitol Reef National Park.

The plateau is dissected by a number of long north-south trending normal faults. A normal fault forms by tensional forces and is defined as a fault where the foot wall has moved up relative to the hanging wall (figure 4). The Hurricane Cliffs, west of Zion are an impressive west facing scarp which is the surface expression of one of these faults. In the Grand Canyon the orientation of Bright Angel Canyon is defined by the Bright Angel Fault.

The Colorado Plateau is actually a series of plateaus separated by north-south trending faults or monoclines (figure 5). The faults are more prevalent to the west and monoclines tend to occur to the east. Formation of faults and monoclines is due to movement of crustal blocks in the Precambrian basement. Differential movement of these blocks are responsible for the differences in elevation across the plateau.

There are two types of igneous features on the Colorado Plateau, intrusive laccoliths and extrusive volcanics. Laccoliths are concordant igneous bodies, which form when magma is injected at shallow depths along the bedding planes of sedimentary rocks that results in doming of the overlying strata (figure 6). Examples of Colorado Plateau laccoliths include the Henry, La Sal, Abajo, Ute, La Plata and

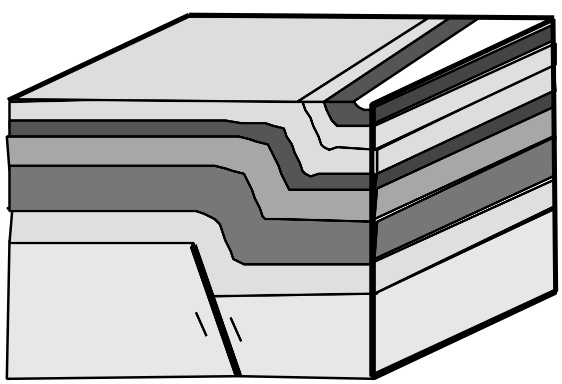

**Figure 3.** Monocline

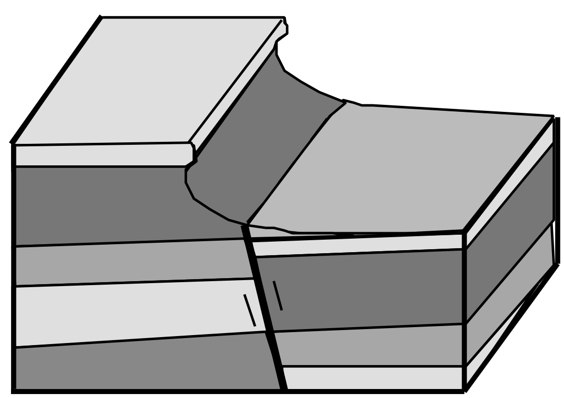

**Figure 4.** Normal Fault

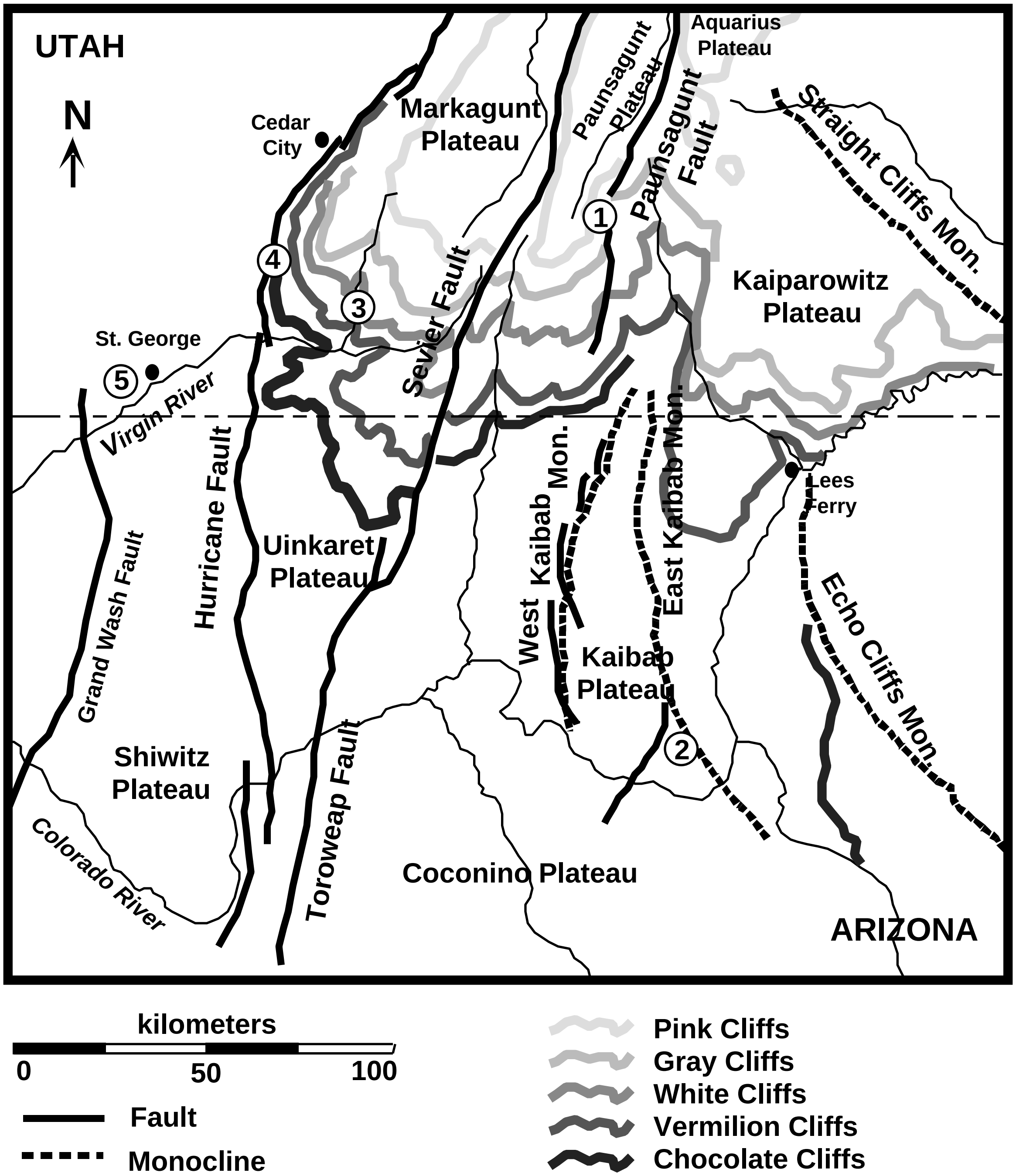


**Figure 5.** Major faults, monoclines and cuestas of the western Colorado Plateau. Numbers indicate field trip stops; 1. Bryce Canyon National Park, 2. North Rim Grand Canyon National Park, 3. Zion National Park, Canyon Section, 4. Zion National Park, Kolob Section, 5. Snow canyon State Park. (After King, 1977)

Carrizo Ranges. The Henry mountains are where G. K. Gilbert first described laccoliths and proposed their name. The Henry Mountains can be viewed at Capitol Reef National Park and the La Sal Mountains at Arches National Park. The laccoliths are Oligocene to Miocene in age and have an intermediate composition. The volcanics on the plateau were deposited less than 6 million years ago and are as young as 1,200 years. The older

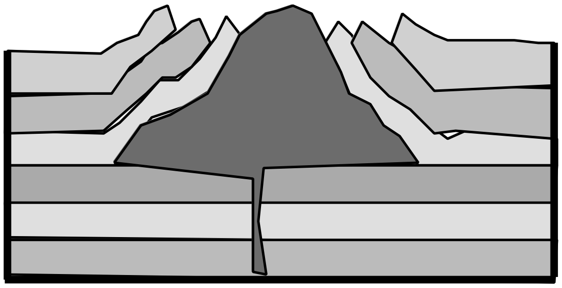

**Figure 6.** Laccolith

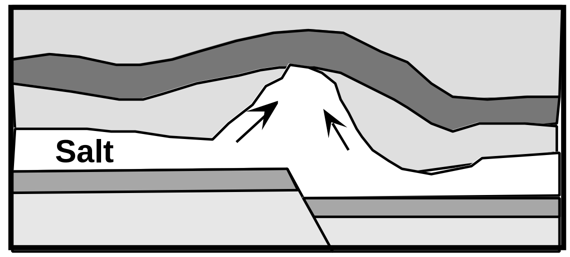


**Figure 7.** Salt Anticline

volcanics are andesitic and the younger volcanics are dominantly basaltic in composition and occur as lava flows and cinder cones. In some areas lava flowed down preexisting valleys, the softer sedimentary rocks which once formed the sides of the valley have been eroded away leaving the lava flow exposed as a ridge or inverted topography.

Thick accumulations of salt deposits occur in the subsurface of the Paradox Basin of the eastern Colorado Plateau. Because salt has a low density and is very ductile it will flow under pressure and rise toward the surface, deforming the overlying strata as it moves (figure 7). Excellent examples of salt anticlines and salt domes can be observed at Arches and Canyonlands National Parks.

## General Geologic History

Although the details may differ, the various regions of the Colorado Plateau all share a similar geologic history. The geologic time scale is presented in figure 8 and a generalized stratigraphic section for the Colorado Plateau is presented in figure 9

Precambrian rocks are exposed in the uplifts surrounding the Colorado Plateau and in the deeply entrenched Grand Canyon. They consist of older highly metamorphosed gneiss and schist and younger sedimentary rocks. Approximately 1.7 billion years ago north-south compression produced continent-scale lineaments of northwest and northeast trending wrench fault zones. One of these, the Colorado River Lineament extends from northern Arizona up to the Lake Superior Region of Michigan. Basement faults associated with the Precambrian lineaments were reactivated a number of times in later geologic history and are responsible for the orientation of most major structures on the Colorado Plateau.

| | Era | Period | Epoch |
|---|---|---|---|
| Phanerozoic Eon | Cenozoic | Quaternary | Holocene<br>Pleistocene<br>2 |
| | | Tertiary | Pliocene<br>Miocene<br>Oligocene<br>Eocene<br>Paleocene<br>66 |
| | Mesozoic | Cretaceous 144 | |
| | | Jurassic 208 | |
| | | Triassic 245 | |
| | Paleozoic | Permian 286 | |
| | | Pennsylvanian 320 | |
| | | Mississippian 360 | |
| | | Devonian 408 | |
| | | Silurian 438 | |
| | | Ordovician 505 | |
| | | Cambrian 570 | |
| Precambrian 3800 | | | |

**Figure 8.** Geologic time scale. Years before present given in millions of years.

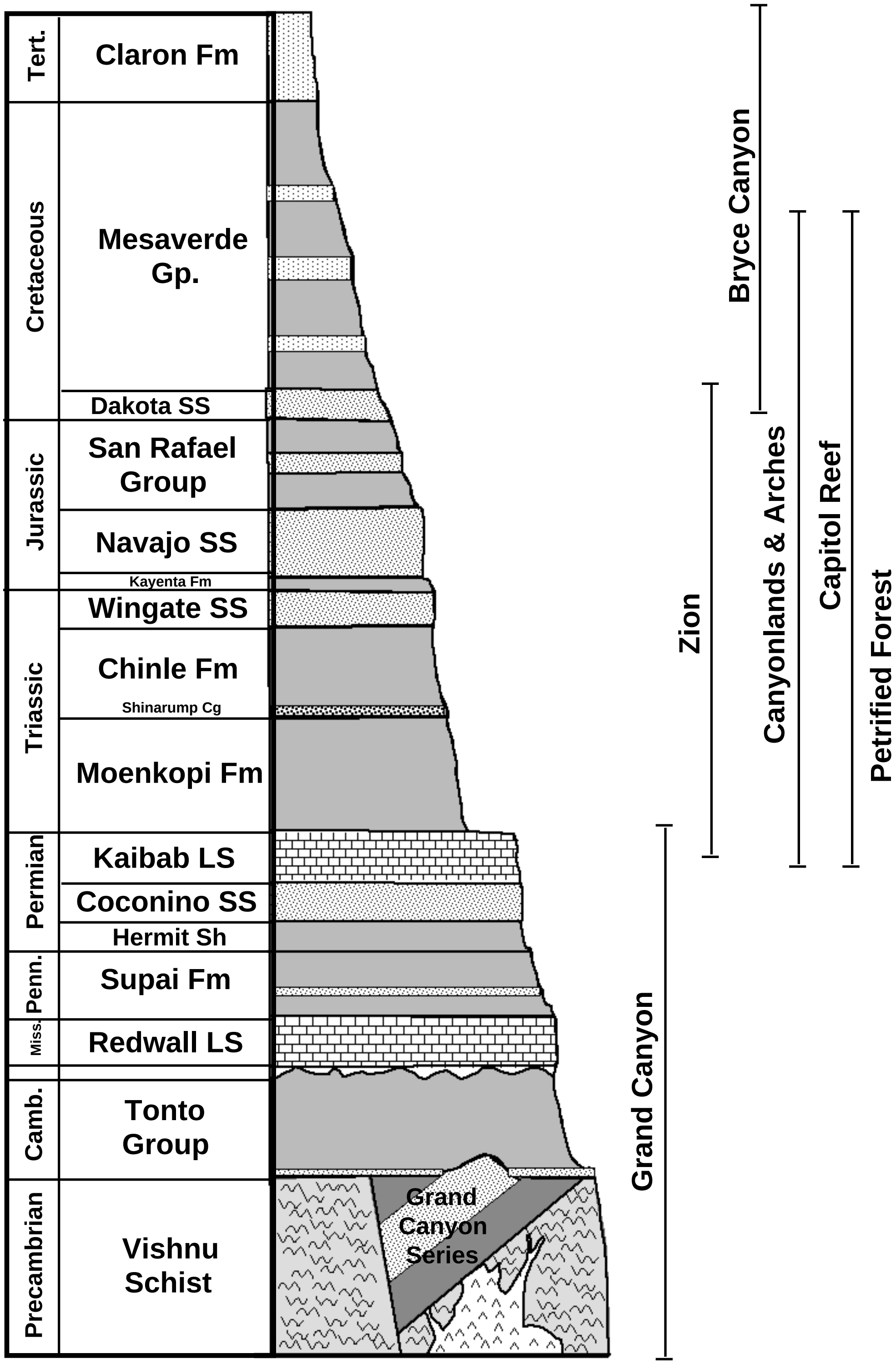


**Figure 9.** Generalized stratigraphic section of the western Colorado Plateau.

During the Lower Paleozoic (Cambrian through Mississippian) the Colorado Plateau was tectonically stable. Relatively thin, sheet like sedimentary rocks were deposited in shallow seas and are similar to other cratonic rocks of North America. Major unconformities which represent a global lowering of sea level have removed the Middle to Upper Ordovician and Silurian rocks. Lower Paleozoic rocks are exposed in the Grand Canyon the most prominent being the Tapeats Sandstone of the Tonto Platform and the Redwall Limestone of the Esplanade Platform.

Deep-seated basement faults were reactivated in the Late Paleozoic to Early Mesozoic (Pennsylvanian through Triassic) resulting in uplift of the Ancestral Rocky Mountains and formation of a series of northwest trending broad uplifts and sedimentary basins. The Kaibab and Uncompahgre Uplifts were elevated at this time. As they were being eroded they shed sediments into adjacent basins (deep, down-faulted troughs which accumulate sediments). One of these basins, the Paradox, had a geometry that allowed seawater to enter across the shallow margins and be trapped in the deeper parts where it evaporated and formed salt deposits. These salt deposits play an important role in shaping the landscape at Arches National Park.

During the Jurassic and Cretaceous, the Nevadan and Sevier orogenies on the west coast created highlands which shed considerable volumes of sediment onto the Colorado Plateau. Bentonites, weathered volcanic ash, which occur in Triassic, Jurassic and Cretaceous rocks are evidence of volcanic activity of these distant orogenic belts. The last marine deposits of the Colorado Plateau are Cretaceous in age. This tells us that at this time the plateau was at sea level.

The Laramide Orogeny occurred from the end of the Cretaceous to Early Tertiary periods and was responsible for formation of the Rocky Mountains. Deformation was more gentle on the Colorado Plateau, resulting in the formation of monoclines and normal faulting.

During the Eocene the Colorado Plateau was at a low elevation surrounded by mountains. These mountains were eroded and sediments were deposited in intervening basins, resulting in burial of Laramide structures.

Magmas migrated upwards through deep seated basement faults during the Oligocene resulting in volcanic activity and intrusion of laccoliths, of intermediate composition. Basaltic volcanism has continued since that time up to the present.

Approximately 5 million years ago the entire Rocky Mountains and Colorado Plateau were uplifted 4,000 to 6,000 feet. This type of uplift which does not involve deformation and effects a large area is termed epeirogenic uplift. On the Colorado Plateau, uplift was facilitated by reactivation of preexisting faults and accompanied by tilting of the plateau toward the north. Present day streams established their courses at this time and because they were lifted high above base level (sea level) they began to rigorously downcut. Deep entrenchment of streams and differential erosion of the plateau began at this time. The stream courses were established on flat lying, undeformed strata. When they eroded down to the buried Laramide structures they maintained their existing courses, eroding across the structures. This pattern is termed a superimposed stream.

During the Pleistocene, the climate was colder and precipitation was higher. Mountain glaciers formed at higher elevations. Many of the erosional processes we observe today occurred at a faster rate during the Pleistocene.

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