



Physiography of the Black Mesa Basin area, Arizona

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PHYSIOGRAPHY OF THE BLACK MESA BASIN AREA, ARIZONA

By MAURICE E. COOLEY

Museum of Northern Arizona

The Black Mesa basin area is part of a broad structural trough which includes the Kairparowits basin to the northwest and a shallow basin near St. Johns to the southeast. It is separated from the main trough by low structural saddles. The Black Mesa basin area is bounded on the east by the Defiance uplift, on the northeast by the Monument upwarp, on the northwest by the Kaibab uplift, and on the southwest by the broad Mogollon slope. This structural alinement controls the regional attitudes of the rock formations and has an effect on the types of land forms developed. Also, the ancestral and present drainage systems of the Little Colorado River were controlled by this structural pattern.

PHYSICAL GEOGRAPHY

In general the Black Mesa basin area contains two types of major physiographic landforms, such as (1) mesas, occurring in the center of Black Mesa basin, and plateaus, the elevated areas, on the Defiance and Kaibab uplifts; and (2) large subsequent valleys adjoining Black Mesa which are occupied by the Little Colorado River and Chinle Wash. Within the subsequent valleys, intermediate forms — such as hogbacks, cuestas, rock terraces or platforms — form subparallel lines of escarpments which, if projected, would roughly appear as concentric rings around Black Mesa.

Physiographically, the Black Mesa basin area lies in an intermediate position between the canyon-lands adjacent to the Colorado and San Juan Rivers, and the plains and broad mesas of the Datil section. It lies mostly within the Navajo section (Fenneman, 1931), or Navajo country, but also includes a part of the Grand Canyon section and a part of the Datil section. The basin comprises primarily the Black Mesa, Painted Desert, and Chinle Valley subdivisions; and includes part of the eastern Grand Canyon, Navajo uplands, Monument Valley, Defiance uplift, and Mogollon slope (fig. 1). Only the Black Mesa, Painted Desert, Chinle Valley, and Defiance uplift subdivisions are discussed in this paper.

Black Mesa Subdivision

Black Mesa is a large moderately dissected flat highland carved from Upper Cretaceous rocks. It is outlined by high sandstone cliffs of the Toreva formation and Yale Point sandstone, except in the Keams Canyon area where Bidahochi formation sediments have covered the Toreva formation. Many northwest-trending anticlines and synclines and northwest- to northeast-trending monoclines form minor undulations, superimposed on the regional basin structure. The summit is in general accordance as it forms a surface which slopes gently to the southwest, partly concealing the regional attitudes of the rocks and truncating indiscriminately the superimposed structures.

In the Hopi Mesas country in the southern portion of Black Mesa, Dinnebito, Oraibi, and Polacca Washes have dissected the Toreva formation into a series of "box" canyons and rock platforms — generally called First, Second, and Third Mesas. The sandstone cliffs overlie long slopes of Mancos shale which, in most places, are covered by colluvial material and tilted slump blocks composed of Toreva sediments, called "Toreva-blocks" (Reiche, 1937). Howell Mesa is an outlier of the Toreva formation which had become isolated from the main cliff line.

The central part of Black Mesa consists of parallel ridges and valleys having little or no relationship with the underlying geologic structure, and its sides comprise ledgy slopes cut from the Wepo formation. On the northeastern part, valleys have been formed on the Wepo sediments below cliffs of Yale Point sandstone. Dinnebito Wash flows on the Wepo formation throughout its course on Black Mesa, but Oraibi and Blue Canyon (Biko Hodo Kiizg) Washes have downcut through the Toreva formation and the Mancos shale is beautifully exposed in several anticlines. Polacca Wash has dissected the southeastern part of Black Mesa into canyons and valleys, many of these cut into the Mancos shale adjacent to small mesas, capped by the Toreva formation.

Painted Desert and Chinle Valley Subdivisions

The Painted Desert subdivision, developed along the main stem of the Little Colorado drainage area, is characterized by angular low cuestas and rock terraces, extensive gentle slopes, and bright multicolored badlands carved from the Moenkopi, Chinle, Moenave, and Kayenta formations. Pueblo Colorado Wash, Rio Puerco, and Zuni River occupy valleys cut chiefly on the Chinle formation between bluffs of the Bidahochi formation. In the upland regions between these streams, the Bidahochi has been eroded into broad rolling, slightly dissected highlands. This gentle rolling topography contrasts sharply with the angular cuestas and rock terraces adjacent to the Little Colorado River near Cameron.

The Hopi Buttes, a unique area of volcanic forms, is included as a subunit of the Painted Desert subdivision because it has similar stratigraphic and structural conditions as do other areas of the subdivision.

The Chinle Valley subdivision is similar to the Painted Desert subdivision. It comprises low subparallel cuesta ridges composed of the Wingate sandstone and the Owl Rock member of the Chinle formation and strike valleys cut on the soft Triassic and Upper Jurassic rocks. The Chinle valley lies between the scarred Shinarump dip slope on the Defiance Plateau and the imposing Mesaverde escarpment of Black Mesa.

Defiance Uplift Subdivision

The Defiance uplift subdivision, a large anticlinal upland having a plateau-like summit, is outlined by stripped planes cut on the dip slope of the DeChelly sandstone and the Shinarump member of the Chinle formation. Tributaries to the Rio Puerco and Chinle Wash have carved several deep vertical-walled canyons into the uplift; the most spectacular of these canyons is Canyon de Chelly. The highest point in the subdivision is Fluted Rock which is an old volcanic neck.

Black Creek lies in a strike or monoclinical valley, which has been cut into soft Chinle sediments between the Shinarump dip slope and the Jurassic and Cretaceous hogback ridges. Near Hunters Point the valley narrows at the fault and Black Creek was deflected a short distance eastward in a broad irregular loop across Cretaceous rocks. Black Creek has carved a very narrow V-shaped canyon across the uplift, approximately 600 feet deep, exposing the DeChelly sandstone and Supai formation. Bonito Canyon is a water gap cut through the Defiance monocline and is a narrow perpendicular-walled canyon eroded principally from the DeChelly sandstone. The valley above Bonito Canyon contains broad gentle slopes cut on the Supai formation.

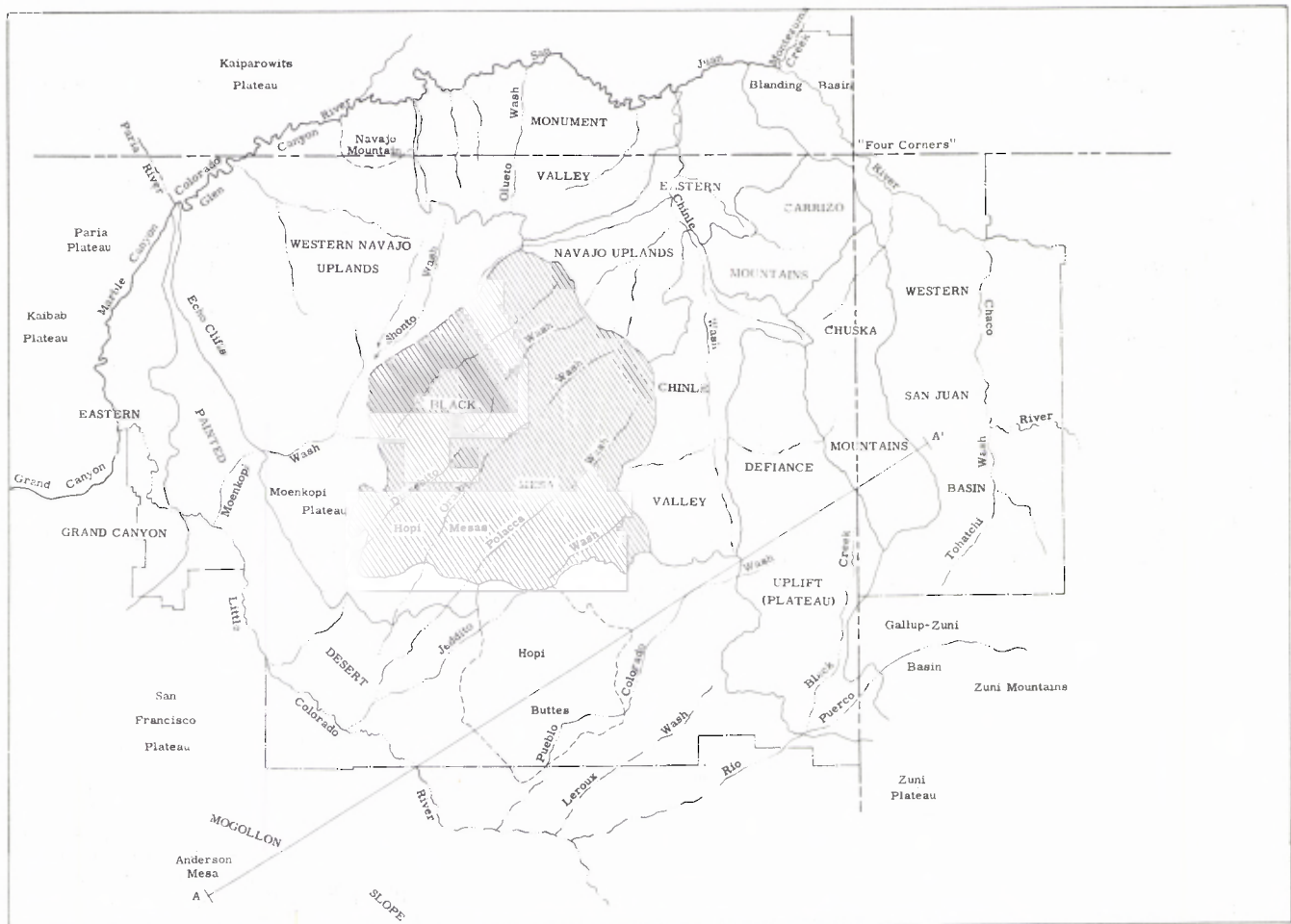


Figure 1.--Map of the Navajo country showing the outlines of the physiographic subdivisions.

EROSION SURFACES

The Tsaille erosion surface was formed prior to the present Colorado River drainage system (Table 1), and is underneath the Chuska sandstone at altitudes between 7,700 and 8,200 feet. This erosional process beveled the Mesozoic rocks along the Defiance monocline. The Tsaille surface occurs at higher altitudes at the extremities of the Chuska Mountains and forms a broad shallow swale in the central part, between the Defiance monocline and the Carrizo Mountains laccolith-Beautiful Mountain anticline. The surface is essentially flat in most areas but local channels about 15 feet deep and filled with fluvial crossbedded conglomeratic sandstone occur near Todilto Park.

Within the Black Mesa basin area the Hopi Buttes surface (Gregory, 1917; Hack, 1942) is the oldest erosion surface which is related to the early drainage system of the Colorado River. In this paper the Hopi Buttes surface is defined as the surface preserved beneath the lower member of the Bidahochi formation (fig. 2). The drainage on this surface formed a broad northwest-trending valley cut on soft Triassic rocks lying southwest of the Defiance uplift in the southeastern border area of Black Mesa basin. The more resistant rocks exposed in the same area occupied low uplands and irregularities protruding above the surface, which partly outlined the shape of the Defiance uplift and the southern part of Black Mesa basin.

The Zuni surface (McCann, 1938) underlies the upper member of the Bidahochi formation and is easily recognized throughout the Little Colorado River area. The surface

has been mapped on the summit of the Chuska Mountains and on the northeastern part of Black Mesa. In addition, the erosion surface at the base of the lava flows in the Hopi Buttes and on Anderson Mesa near Flagstaff are believed to be part of the Zuni surface. The ancestral Little Colorado River valley was similar to the present valley except that the relief was of less magnitude. Broad depositional plains had been formed owing to the partial filling of the lowlands by the Bidahochi sediments (fig. 2). The Zuni surface lies at an altitude of 6,000 feet in the Hopi Buttes and at Sanders, 6,500 feet near Ganado, 7,000 feet on the Zuni Plateau and Anderson Mesa, 8,000 feet on the northeastern part of Black Mesa, and 9,000 feet on the Chuska Mountains. The surface had a gradient of 29 feet per mile between the Zuni Plateau and Sanders and a gradient of 27 feet per mile between the Hopi Buttes and the Chuska Mountains.

The planation of the Zuni surface was terminated by the lowering of the base level of the ancestral Little Colorado River when the entrenchment of the present valley began. The succeeding erosion cycles, separated into periods of planation alternating with periods of downcutting, caused the formation of terrace levels within the present Little Colorado valley. The upper levels of these terraces were formed during the early stage of development of the present valley and have been named as the Black Point surfaces (Gregory, 1917; Childs, 1948); and the lower terraces, cut in an inner valley below the youngest Black Point terrace, are called the Wupatki surfaces (Childs, 1948).

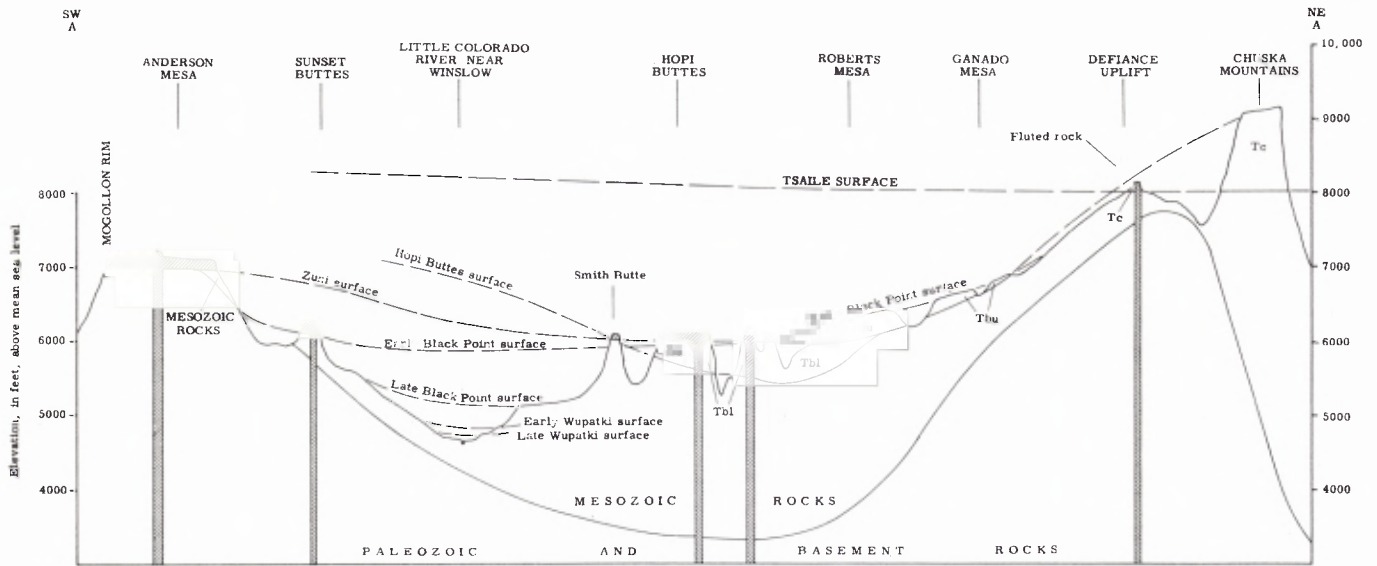


Figure 2.--Generalized cross section A-A' from Anderson Mesa to the Chuska Mountains showing physiographic relationships between the erosion surfaces, Bidahochi formation (upper member-TBU, lower member-TBL), Chuska sandstone (Tc), volcanic rocks, regional structure, and the present topography in the Little Colorado River drainage area.

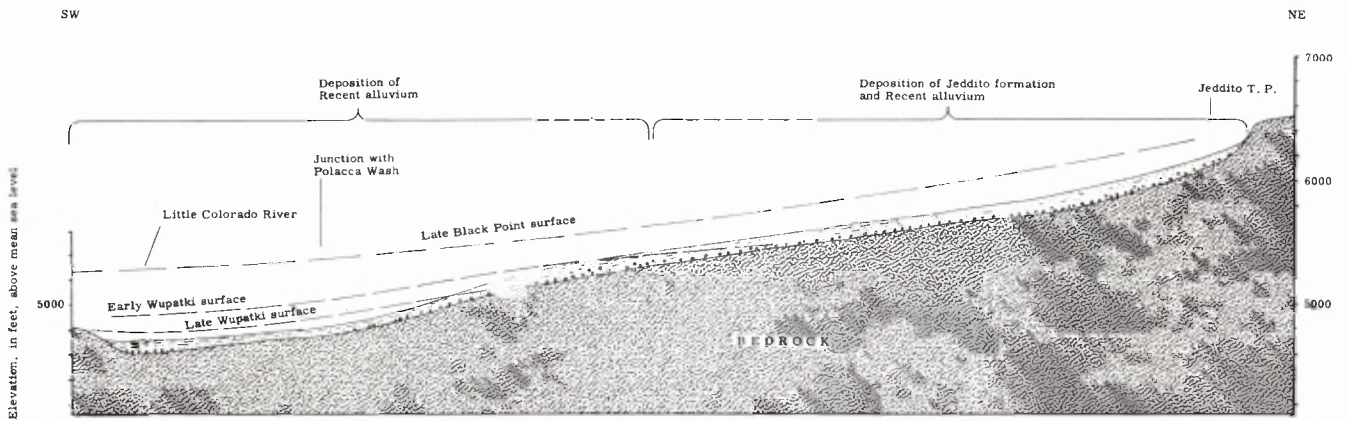


Figure 3.--Diagram showing relations of the alluvial Jeddito formation to the Wupatki erosion surfaces along Jeddito Wash, Arizona.

TABLE 1. Age of the erosion surfaces in the Black Mesa basin area.

Age	Erosion surface	Relationship with depositional unit
EROSION SURFACES RELATED TO THE COLORADO RIVER SYSTEM		
Late to middle Pleistocene	Wupatki surfaces	Contemporaneous with alluvial Jeddito formation.
Early Pleistocene to late Pliocene	Black Point surfaces	Terrace deposits preserved, maximum thickness 100 feet.
Middle Pliocene	Zuni surface	Underlies upper member of the Bidahochi formation.
Lower Pliocene and late Miocene(?)	Hopi Buttes surface	Underlies lower member of the Bidahochi formation.
EROSION SURFACE NOT RELATED TO COLORADO RIVER SYSTEM		
Mid-Tertiary	Tsaile surface	Underlies Chuska sandstone.

Terrace remnants of the Black Point surfaces are 400 feet or higher above the present Little Colorado River channel, and locally have gradients between 15 and 20 feet per mile. The Black Point surfaces can be traced upstream from Cameron along the Little Colorado River and along the Rio Puerco, Zuni River, and other tributaries to the Little Colorado. Remnants of the Black Point surfaces occur beneath the lava at Black Point (the type area); near Tuba City; and on the summits of Moenkopi Plateau, parts of the Hopi Mesas, Roberts Mesa, Defiance uplift, and the Zuni Plateau; and in the divide areas of the several tributaries to the Little Colorado between Dinnebito and Wide Ruins Washes.

The Wupatki surfaces occur along the Little Colorado River at altitudes ranging from a few feet to about 300 feet above the present stream bed. The gradients range upward to 30 feet per mile away from the river. The Wupatki terraces lie at several successive levels adjacent to the Little Colorado River between Cameron and Grand Falls, but upstream from Grand Falls near Holbrook these surfaces extend over a belt as much as 10 miles in width along both sides of the river.

The Wupatki surfaces appear to have been formed in the Little Colorado River at the same time that the alluvial Jeddito formation of Hack (1942) was deposited in the upstream parts of the tributaries. Correlation be-

tween the Wupatki surfaces and the Jeddito formation is best indicated in the valley of Jeddito Wash (fig. 3).

The erosion surfaces of the Little Colorado River system can be traced throughout the Black Mesa Basin area from the Mogollon Rim to the northern part of Black Mesa, and from the San Francisco Plateau to the Zuni Mountains. In much of the peripheral area of the basin, lava flows overlie and protect the erosion surfaces. Their conspicuous topographic features aid considerably in the tracing and correlation of the several surfaces. The surfaces represent several stages of valley development by the through-flowing ancestral Little Colorado River which drained toward the west and northwest and joined the Colorado River somewhere near the present junction.

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