BULLETIN 36

Mineral Resources of Fort Defiance and Tohatchi Quadrangles, Arizona and New Mexico

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side to the extent of several hundred feet, resulting in the stratigraphic displacement of the Todilto limestone of about 50 feet.

Small displacements of the Todilto limestone and the limestone conglomerate at the top of the Chinle formation are exposed in several gullies along the east edge of Todilto Park, and have probably been effective in the localization of the gullies. Displacements (south side down) seldom exceed 10 feet.

Fractures occupied by igneous dikes occur at several localities. A breccia vent in south Todilto Park has a vertical dike extending for 2 miles due east, and west towards Zilditloi. No displacement could be determined on this fracture.

LANDFORMS

General Statement

The map area lies entirely within the Navajo section of the Colorado Plateau province, and embraces within it the subdivisions of the Defiance Plateau on the west, Black Creek Valley, Chuska Mountain on the north, Manuelito Plateau on the south, and Chuska Valley on the east. These have been defined, after Gregory, by Fenneman (1931, fig 112, p 313) as follows:

1. Defiance Plateau: a domed plateau 6,000 to 7,000 feet high with wide flat valleys trenched by canyons of streams from the Chuska Mountains.
2. Black Creek Valley: chiefly the flat open valley of Black Creek.
3. Manuelito Plateau: steep-sided flat mesas above 7,000 feet elevation, separated by flat valleys or washes.
4. Chuska Mountains: steep-sided, flat-topped remnants of horizontal sandstone, reaching to 9,000 feet elevation, and in part forested.
5. Chuska Valley: broad scarped plains bearing mesas with wide swales trenched by shallow canyons; lower surface truncating the dipping beds of a shallow syncline, making some cuestas and hogbacks.

For the purpose of this report, several of the above have been further subdivided, as indicated on Figure 18 and in Table 18 below. Comparison of this outline map with the diagram of Figure 19 will bring out the various characteristics outlined in the table.

Defiance Plateau

Plateau

Between the wide expanse of Chinle Valley, with its lavish display of pastel tints of lavender, brown, and maroon, and the grayish-green Cretaceous hills northwest of Gallup, dotted with piñon, there rises a flat-topped broad ridge, the Defiance Plateau. Its slopes support a continuous forest of virgin ponderosa pines, and its dark outline sets it off from the surrounding terrane. The plateau is, geologically speaking, an uplifted arch, and erosion has reached in its core the oldest rocks of northeastern Arizona, a series of quartzites of unknown, perhaps Precambrian age. Overlapping it on all sides are sedimentary rocks of the Permian and Triassic systems. The beds dip gently off to the west,

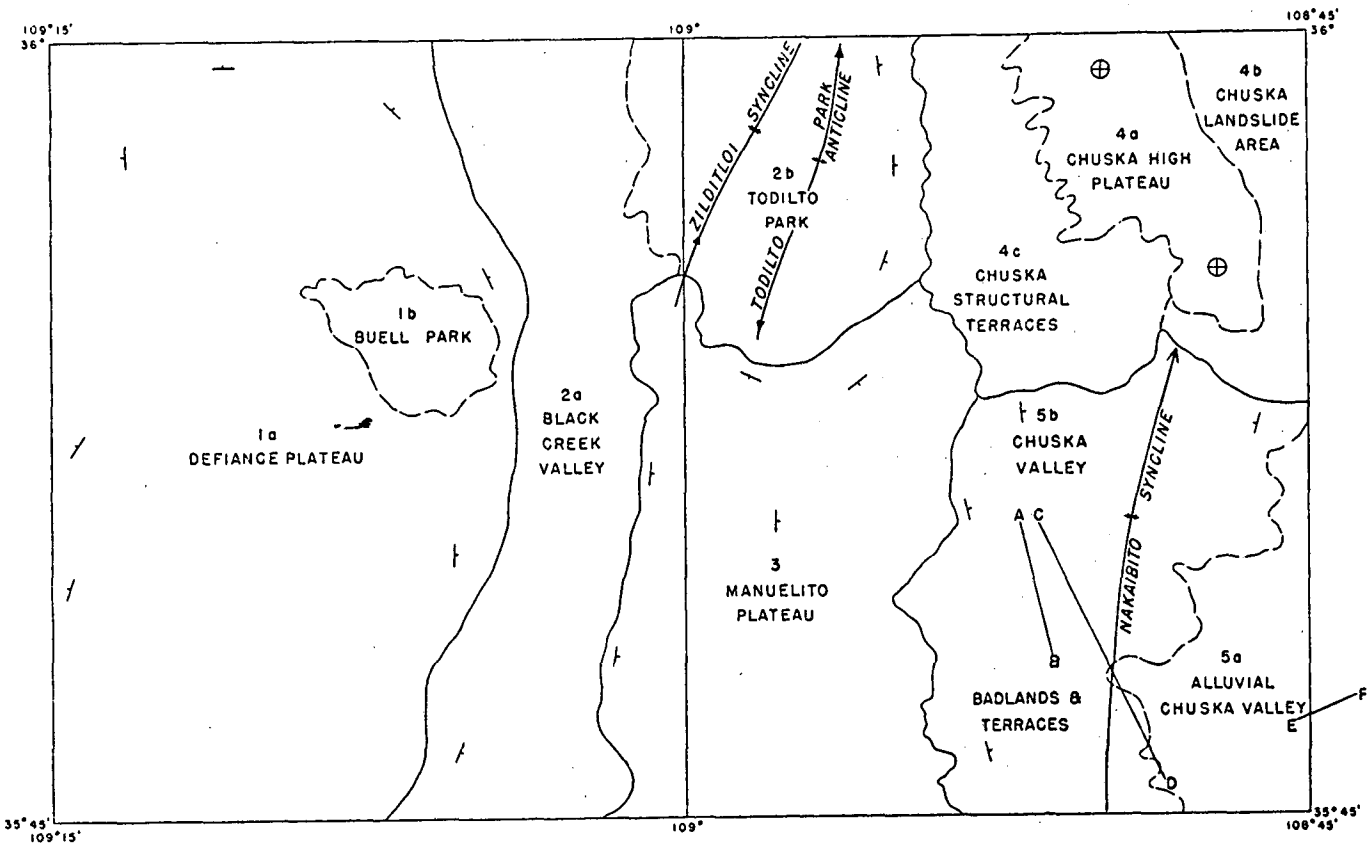


Figure 18

PHYSIOGRAPHIC DIVISIONS AND STRUCTURAL PATTERN OF FORT DEFIANCE AND TOHATCHI QUADRANGLES.

Arrows show direction of plunge of folds; T's show strike and dip of bedded rocks; cross within circle indicates nearly horizontal beds. Section lines A-B to E-F refer to Figure 20.

Figure 19

LANDFORMS SKETCH OF FORT DEFIANCE AND TOHATCHI QUADRANGLES.

Compare with Figure 18.

TABLE 18. PHYSIOGRAPHIC DIVISIONS AND THEIR CHARACTERISTIC FEATURES

Physiographic Divisions	Elevations (in feet)	Characteristic Features
1. Defiance Plateau		
a. Plateau	6,800-8,300	Broad, north-south anticline with stripped structural slopes.
b. Buell Park	7,100-7,800	Circular diatreme caldera, with ring and central intrusions.
2. Black Creek Valley		
a. Valley	6,700-7,100	Subsequent, monoclinal valley in Chinle formation.
b. Todilto Park	7,100-7,500	Eroded dome and syncline in massive Jurassic rocks.
3. Manuelito Plateau	7,500-8,200	Structural terrace in Mesaverde group, bordered on west by cuesta, on east by monocline.
4. Chuska Mountain		
a. High plateau	8,500-9,100	Horizontal mesa in Tertiary sandstone.
b. Landslide area	6,400-8,500	Wide strip of landslide splinters and debris around Chuska Mountain.
c. Structural terraces	8,200-8,400	Horizontal erosional bench in Tertiary sandstone.
5. Chuska Valley		
a. Alluvial valley	6,200-6,400	Broad pediment in Menefee formation, lower parts alluviated.
b. Badlands, terraces, and pediments	6,400-8,000	Eroded monocline and syncline in Menefee and Tohatchi formations, with pediment and terrace remnants at many levels.

north, and east, and so uniform is their composition that even the sensitive test of weathering, rain, and wind has discovered but few beds of superior resistance to mark them as cliffs, mesas, or bluffs. Brick-red, or gray, soil covers the innermost group of shaly sandstones, the Cutler formation. But where these rocks pass under the next younger De Chelly sandstone, a prominent cuesta develops, facing inward, and reaching elevations of nearly 8,000 feet on the west slope, almost 500 feet above the level of the innermost plateau. An ancient residual soil covers much of this, but none has been found on the De Chelly plateau. Instead, the flat surface follows essentially the bedding planes of this tan or pale-brick sandstone, and countless low outcrops dot the ground between the tall pines. The De Chelly plateau is wide on the west flank, but narrows northward. On the east, where the slope is steeper, the succeeding Shinarump conglomerate, of Triassic age, covers the De Chelly sandstone a short distance east of the eastern cuesta.

The resistant surface of the Shinarump conglomerate sustains a flat, spurlike extension of the plateau that reaches the southernmost

endings of the great De Chelly Canyon system seven miles northwest of Sawmill. From this point a gentle slope leads westward to Chinle Valley, and a flat prong extends north and northeast, gradually sinking to the level of the Chinle shale belt that fringes the Defiance uplift on the north and east.

Buell Park

The morphological simplicity of this uplifted block is interrupted in two places. At Buell Park, 2½ miles east of Sawmill, the Permian sandstone plate has been pierced by a volcanic explosion that drilled a vertical channel, 2 miles wide, through the plateau, and that must have showered the vicinity with ashes, lapilli, and lava. Possibly, an active volcano, with short lava flows extending from the central orifice, stood in Pliocene time above the park. However, the subsequent erosion has removed this entirely, and at present the pipe is a depressed circular area, rimmed with steep cliffs, in which the Cutler, De Chelly, and, in places, the Shinarump, are magnificently exposed. Some of the more resistant volcanic rocks form Buell Mountain, that rises above the level of the surrounding De Chelly sandstone plateau, but the bottom of the park is a gently undulating surface, revealing the green kimberlitic tuff under a discontinuous blanket of an old residual gravel, into which the tributaries of the present streams have etched narrow, but steep-walled, ravines.

Buell Park has counterpart in Fluted Rock, a massive block of lava rising 400 feet above the De Chelly plateau. It, too, is a volcanic plug, but of uniformly resistant material. Its flat summit, 8,308 feet in elevation, is the highest point on the Defiance Plateau.

Black Creek Valley

Valley

This valley drains the east flank of the Defiance Plateau and the southwestern slopes of Chuska Mountain. Like its western counterpart, Chinle Valley, it is carved in soft but colorful Chinle shales with intercalated sandstone lenses. The shales and clays make flat, grassy plains between low cuestas and hills supported by sporadic harder beds, giving the valley an average width of 2 miles.

The west slope of the valley is, essentially, the dip slope of the Shinarump conglomerate or, in the northern area, the dip slope of a group of thick sandstone and conglomerate lenses in the lower Chinle formation. South of Todilto Park, the east slope is the series of Jurassic sandstone cliffs that build up a succession of parallel, west-facing hogbacks, or cuestas, below the cliff of the Dakota (?) sandstone. At the south end of the park, the valley divides, and the northern continuation of the meridionally trending Black Creek Valley is a flat and featureless depression, the east flank of which gradually rises to the level of a group of limestone-pellet conglomerates that form a subdued plateau, about 200 feet above the valley.

In latest Pliocene or Pleistocene time, Black Creek must have flowed in a much flatter valley. Its slopes can be reconstructed fairly

accurately from remnants of gravels and sand, especially on the east side. They suggest that the crests of the highest cuestas were about flush with an apron of unconsolidated deposits that formed a smooth, more or less continuous slope from the Dakota (?) sandstone cuesta to the axis of the valley. This slope was about 30-150 feet higher than corresponding sections of the present slope, and debris from the Mancos shale has been transported thereon across the Morrison and Summerville-Entrada cuestas. Remnants of this high-level veneer of gravel are found also on the northwest flank of Todilto Park and on the west slopes of Black Creek Valley.

Todilto Park

Probably the most spectacular and scenic part of the entire area is Todilto Park. Here 20 miles of 200-foot, vertical, red cliffs, accentuated by great overhanging arches and narrow spires (see pl 2, Frontispiece), bound several thousand acres of wide, nearly flat, grassy plains and low-rolling hills. The name "Todilto," meaning "breaking out of the waters," is said to have originated in the legend that the park was once occupied by a great lake, which broke out and drained itself in a day. This legend may have some basis in geologic fact!

This magnificent amphitheatre is the result of erosion by streams which head in Chuska Mountain to the east and drain into Black Creek. Two geologic structures, an anticline and a syncline, arch the massive red Entrada and Summerville sandstones, so that the underlying soft and easily-worn-away Chinle shales could be cut out, sapping and undermining the cliff-making sandstones to produce the long escarpments. The gentle slopes at the foot of the cliffs are underlain generally by the Wingate sandstone, and long, low ridges in the park are held up by thin resistant layers of limestone and sandstone in the Chinle formation.

At least two erosional surfaces occur in Todilto Park, the upper being capped by terrace gravels, the lower representing the widespread surface of the Nakaibito alluvial or lake fill. Level areas between these two surfaces probably represent intermediate stages of lateral erosion during downcutting. Within the last 100 years erosion has cut steep-walled arroyos, from a few feet to 50 feet in depth, into the Nakaibito fill, in some cases exposing older underlying rocks in their walls. In one case it has exhumed a small forest of stumps buried thousands of years ago when the fill first began to accumulate, or lake was formed.

Manuelito Plateau

The Manuelito Plateau in this area is a northern extension of the subdivision as mapped by Gregory (1917, pl I). Like the plateau to the south, it consists of flat-lying and truncated east-dipping beds of Cretaceous age, and is bounded on the west by the escarpment of the Defiance monocline. Northward it terminates in the south- and east-dipping cuesta of the Todilto Park anticline, and to the east the Mesaverde rocks steepen to form a monoclinal escarpment, in part composed of dip-slopes of the more resistant beds, in part of dissected badlands and sandstone cuestas. The summit surface is partly a structural terrace of

resistant sandstone beds, partly a stripped peneplain, once capped unconformably by the Tertiary Chuska sandstone, which, northeast of the plateau, remains to form the main mass of Chuska Mountain. Near the center of the map area an isolated outlier or remnant known as Twin Buttes rises to an elevation of 8,546 feet, nearly 600 feet above the plateau surface. The surface of the plateau consists of low, rolling hills and long, low ridges with a relief of seldom over 50 feet. Narrow canyons from the east and west dissect the edges of the plateau.

Chuska Mountain

The southern end of Chuska Mountain occupies the northeastern part of the mapped area. This high, relatively flat-topped plateau is underlain by 700 to 1,100 feet of Tertiary Chuska sandstone which rests unconformably at about 8,000 feet elevation upon evenly bevelled, east-dipping beds of Jurassic and Cretaceous age. Within the area, the plateau surface is from 2 to 4 miles wide at about 9,000 feet elevation; lower terraces, eroded ridges, and landslide blocks extend several miles to the east and west.

High Plateau Subdivision

The Chuska Plateau is a gently undulating surface with low, generally rounded hills of sandstone not over 100 feet high, alternating with wide, alluvium-filled, and generally closed depressions, frequently occupied by small lakes and ponds, which in a few cases are as much as 1 mile in length. Nearly 130 such lakes and ponds can be counted on the large-scale aerial photographs (1933). The western edge of this surface is dissected by steep-walled canyons, the heads of which may occupy a narrow gorge, extending for as much as 1 mile into the plateau surface, and drain a considerable area. In contrast, the eastern edge of the plateau is a relatively straight, generally cliffed escarpment which abruptly transects all surface features.

Landslide Area Subdivision

Below the upper line of cliffs of Chuska sandstone and their talus slopes on the east side of the plateau, a series of from 2 to 5 more or less parallel ridges, from a few hundred feet to as much as 2 miles in length, occurs at successively lower elevations eastward. The depressions between the ridges, which are commonly closed, have been covered in part or wholly by silt and alluvium. These ridges and adjacent depressions have been explained as being formed, (1) by progressive splitting off and slumping of narrow splinters of Chuska sandstone from the cliffs above, which rode down the underlying slopes of highly bentonitic shales, and (2) by successive accumulation of talus material during the pluvial stages of the Pleistocene, when deep snowbanks formed on the eastern lee slopes of the plateau; this material falling from the cliffs, and sliding down the surface of the snowbanks and lodging at their base (Reiche, personal communication).

Below the ridged area, the surface breaks off into regions of typical hummocky landslide topography which in some places, as northwest of

Tohatchi, extends all the way down to the valley level, and in other places, as 3 miles north of Tohatchi, has been stripped off by erosion which has produced badlands in the underlying Cretaceous shales.

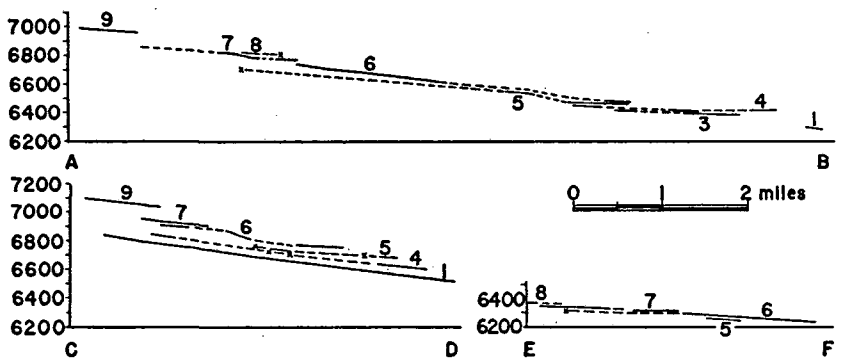
Structural Terraces Subdivision

West of Chuska Plateau, at an altitude around 8,300 feet, a wide, almost flat surface covering nearly 5 square miles has been developed upon a resistant sandstone layer about 200 feet above the base of the Chuska sandstone. This structural terrace extends from a point northwest of Chuska Peak 4 miles along the west side of Chuska Plateau, and is 1-2 miles wide. At the north end it is dissected by the youthful tributaries of Todilto Wash. Several outlying remnants occur farther north on ridges between these tributaries.

Chuska Valley

Chuska Valley occupies approximately the southeast quarter of Tohatchi quadrangle. The southeastern one-third of this area, comprising the alluviated valley subdivision, is nearly flat, with only occasional flat-topped mesas and low hills interrupting the alluviated plains. The rest of the area, here called the badlands and terraces subdivision, is dissected, and has relief varying from a few tens of feet to as much as 1,000 feet.

The landforms within the two regions referred to above have been largely sculptured during the late Pleistocene and Recent epochs. During these epochs several cycles of lateral planation and deposition more than once have reduced the area to near maturity, producing several east-sloping terrace and pediment surfaces, commonly capped with coarse gravels, which have been described by Reiche (1941) as being



Composite profiles of strips, a quarter of a mile wide, showing relations of surface remnants around Mexican Springs.

Dashed lines give correlations; x shows small remnant. For location of profiles, see Figure 18. (After Reiche, 1941, pp 62-63.)

Figure 20

divisible into 9 graded surfaces (see fig 20). Numbers 6 and 7 are best preserved and form the prominent flat top of the ridge north of Mexican Springs and the next north-south ridge to the west; similar surfaces cap the mesas along the east edge of the area. The lower surfaces represent successively lower strath developments along the drainage of Catron, Mexican Springs, and Norcross Washes, which originally coalesced to form pediments progressively farther to the east, but are now represented only by numerous isolated remnants.

Alluvial Valley Subdivision

The lowest widespread surface of alluvium is underlain by silty sediments 22 feet thick at the type locality, where it was named the Nakaibito formation by Leopold and Snyder (1951) for exposures in Mexican Springs Wash, 4,000 feet west of U.S. Highway 666. Recent gullying has cut channels up to 25 feet deep in this and older alluvial fills which occupy nearly all the larger washes.

Badlands Subdivision

Headward erosion northwestward into the east-dipping monoclinal sediments of the Mesaverde group in Manuelito Plateau and beneath Chuska Mountain, has produced a deeply incised badlands topography which borders the more subdued regions farther downstream. Some of the canyons cut in Menefee sandstones north of Tohatchi have almost vertical walls up to 100 feet high along the course of the incised meanders.

Age of the Surfaces

The highest graded surface below the Chuska Plateau surface and the Chuska structural terrace is represented by much of the rolling summit of Manuelito Plateau, and possibly by local wide-valley remnants at the headwaters of Mexican Springs Wash and the south branch of Todilto Wash.

The Manuelito Plateau surface represents nearly complete stripping of the Chuska sandstone, and erosion of 50 to 100 feet into the underlying rocks. If the Chuska unconformity represents the "plateau cycle" of Davis (1901, 1903), and the "Zuni erosion surface" of McCann (1938), this surface, upon which is found garnet and peridot derived from the Buell Park or Green Knobs volcanic vents, may be correlated with Robinson's (1910) "new erosion cycle" surface of early Pleistocene age at Grand Canyon. As Reiche points out (1941, p 64), this cycle was rejuvenated and in places covered by landslide debris from Chuska Plateau by a more humid period, undoubtedly connected with one of the pluvial epochs of the Pleistocene, and the succeeding lower terrace and pediment surfaces become stages of the later Pleistocene "Canyon" erosion cycle, as defined at Grand Canyon.