THE TOREVA-BLOCK—A DISTINCTIVE LANDSLIDE TYPE

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ABSTRACT

An end member of the "rock-slide" group is described and named from an assigned type locality in the Hopi Indian Reservation of northeastern Arizona. A Toreva-block consists essentially of an unbroken tilted mass of stratified material which in numerous instances measures over 1,000 feet along the strike. Attempt is made to relate the slides to pediment remnants at the type locality. Distribution and character of Toreva-blocks elsewhere in the Colorado Plateau Province are briefly discussed. Available data suggest the late Pleistocene formation of the larger slides.

INTRODUCTION

The following notes call attention to a kind of landslide which is widely distributed in the southern part of the Colorado Plateau Province, and which has been, in the past, an important factor in cliff recession. For this type of slide the name "Toreva-block" is proposed because of its splendid development near Toreva, in the Hopi Indian Reservation of Arizona. Most of the observations reported were made in the fall of 1934. They have been extended from time to time since, as opportunity offered. That they are here set forth is due in large part to the insistent encouragement of Professor Kirk Bryan, who visited the Toreva district with the writer in July, 1936.

CHARACTER AND CLASSIFICATION

A Toreva-block is a landslide consisting essentially of a single large mass of unjostled material which, during descent, has undergone a backward rotation toward the parent cliff about a horizontal axis which roughly parallels it. In the southern Colorado Plateau such blocks have developed from cliffed sections of low-dipping strata in which one or more relatively coherent beds rest upon others which are either incoherent or capable of so becoming when wetted.

According to Heim's classification[1] Toreva-blocks are *Felsstürtze* rather than *Felsschlipfe*, the latter being characterized by motion

[1] A. Heim, *Über Bergstürtze* (Zurich, 1882). Quoted by E. Howe.

along valleyward-dipping bedding planes. According to Howe's scheme[2] they constitute end members of the rock-slide group.

While none of Howe's photographs suggest the sort of slide discussed, it is clear from his text[3] that the Yellow Mountain and Sheep Mountain slides of the Telluride district approach the simplicity of form of what are here termed Toreva-blocks.

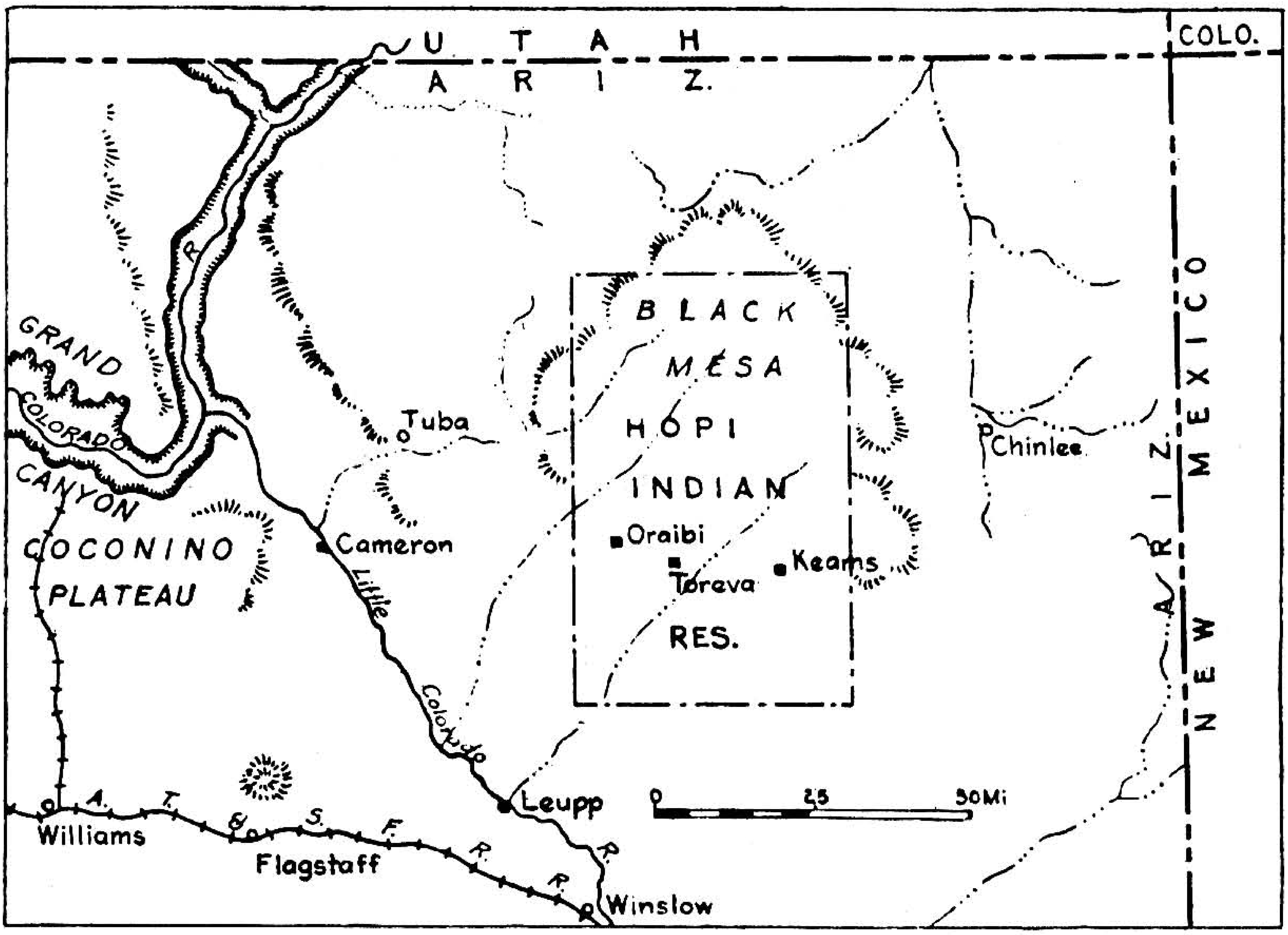

FIG. 1.—Index map

The slides described by Russell[4] in the Cascade Mountains closely resemble those under consideration, although the outcrops do not, apparently, permit detailed observation. The blocks, consisting of 400 to 500 feet of basalt resting on "clays and sands, or on volcanic lapillae . . . . are seldom over a half mile in length" and their component strata are stated to dip 10 to 15 degrees toward the parent cliff.[5]

[2] E. Howe, "Landslides in the San Juan Mountains of Colorado," *U.S. Geol. Surv. Prof. Paper 67* (1909), p. 55.

[3] *Ibid.*, pp. 19–20.

[4] I. C. Russell, "Cascade Mountains in Northern Washington," *U.S. Geol. Surv. 20th Ann. Rept.*, Part II (1898–99), pp. 193–200.

[5] *Ibid.*, p. 196.

GEOLOGIC SETTING OF THE TOREVA DISTRICT

The Toreva district lies midway of the deeply embayed southern margin of Black Mesa, which, according to Gregory[6] ". . . . is the center of a broad and shallow structural basin. . . . ." The Mesa is floored by sandstones and shales of the Mesaverde formation, upper Cretaceous. Of this only the lower 170 feet, including 77 feet of cliffed, basal soft sandstone, is present near Toreva. Underlying the Mesaverde is the Mancos shale, also upper Cretaceous, dominantly of grey, soft, fissile, silty shale with a local thickness[7] in excess of 295 feet. These formations dip 3°–4° northerly.

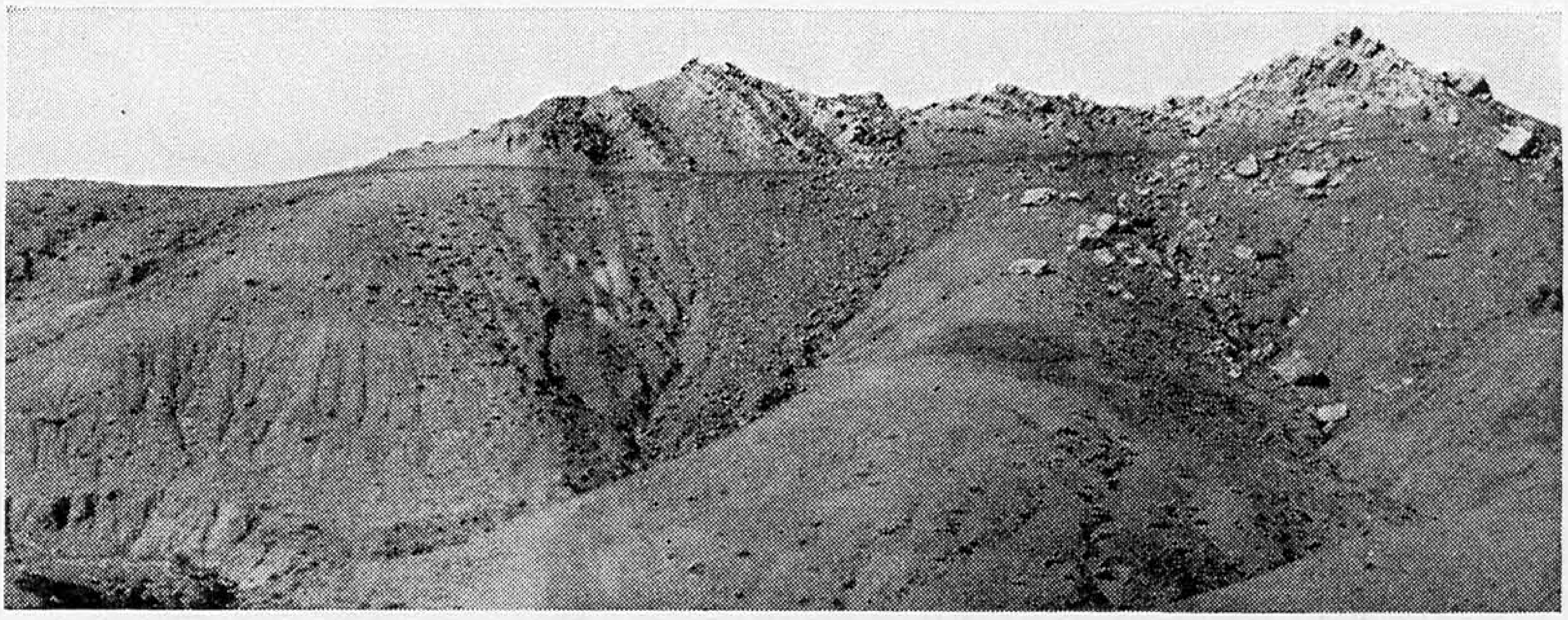

FIG. 2.—Section of a Toreva-block exposed by stream cut at the type locality. The block lies on the upper pediment, seen in profile at left. Its base is emphasized by a sheep trail.

The cliffed lower sandstone of the Mesaverde is obscurely cross-bedded and is interrupted by approximately vertical joints. Near the mesa point (Fig. 3) these are fairly closely spaced and strike between N. 13° E. and N. 64° E.; southwest of Mishongnovi they are widespaced and trend N. 30° W. Throughout the district joints and cliffs show a rough parallelism and not infrequent rapid change in direction. These relations suggest that the jointing is chiefly superficial, consequent on the removal of lateral support by canyon cutting and cliff recession.

[6] H. E. Gregory, "Geology of the Navajo Country," *U.S. Geol. Surv. Prof. Paper 93* (1917), p. 112.

[7] *Ibid.*, p. 74.


TO ORAIBI
MISHONGNOVI
A
TO KEAMS CANYON
school
spring
TOREVA
TO CHIMOPOVI
burial ground
CORN ROCK
spring
B
LEGEND
Upper sandstone marker
Top of lower Mesaverde sandstone
Mancos-Mesaverde contact
Strike & Dip of strata in the blocks
Cliff
Note: Undisturbed strata dip 3°-4° northerly
MISHONGNOVI
road
Mesaverde Fm.
Mancos Fm.
SCALE FOR PROFILE
① Mesaverde-Mancos contact; ② & ③ sandstone beds
Inferred trace of plane of slipping
PROFILE ALONG A-B
outer edge of middle pediment
SCALE
GEOLOGIC SKETCH MAP EAST OF TOREVA, ARIZONA
SHOWING OUTLINES OF MESA, AND OF "TOREVA-BLOCK" LANDSLIDES

FIG. 3

THE LANDSLIDES

In his excellent reconnaissance study Gregory wrote:

> Landslides . . . . occur at the sites of the Hopi villages. . . . . The Cretaceous strata forming the mesa dip south and the prominent saturated zone at the top of the Mancos shale favors the sliding of insecure blocks of the overlying Mesaverde sandstones. Sections of the cliffs at Shimopovi are found 1,000 feet from their original position. That the process has been long continued is indicated by gradations in the degree of decomposition of the fallen masses and by the traditions of the Hopis. In recent years slides have occurred at times when ground water was present in unusual amounts.[8]

While one might infer from Gregory's description that these are *Felsschlipfe* in Heim's sense, owing their mobility to the plane of weakness offered by the top of the Mancos shale, such is not the case. The local dip of the formations is northerly and so slight that this surface is not important as a plane of slipping; and the outwardly concave fractures on which movement takes place cut obliquely across the upper Mancos, part of which, therefore, moves and is rotated with the block. Only the lowermost 5–15 feet of the displaced material is found crushed and jostled. The vertical displacements (70–220 ft.) are not as impressive as the size of the blocks: nearly a quarter have strike lengths of 1,100 feet or more; occasional blocks exceed 1,700 feet. In places successive slides have occurred from the same stretch of cliff, building up step fashion below it to a profile in which further slides would have to cut or displace pre-existing ones. As suggested by Gregory, the slides farther removed from the present cliffs are in general clearly the older. In places disintegration has proceeded so far as to make the slide nature of ridges conjectural.

The general form of the rarely seen slip planes underlying Toreva-blocks, as inferred from a study of numerous examples, is shown in Figures 3 and 6. As illustrated in Figure 5, the cliffward portion of a block often shows a steeper dip than the outer portions. In the instance sketched erosion has left only a remnant of a large block, and has entirely destroyed the parent mesa-point. The tendency of the strata to preserve their initial angle with the plane of fracture throughout movement was interfered with both by frictional re-

[8] *Ibid.*, p. 136.

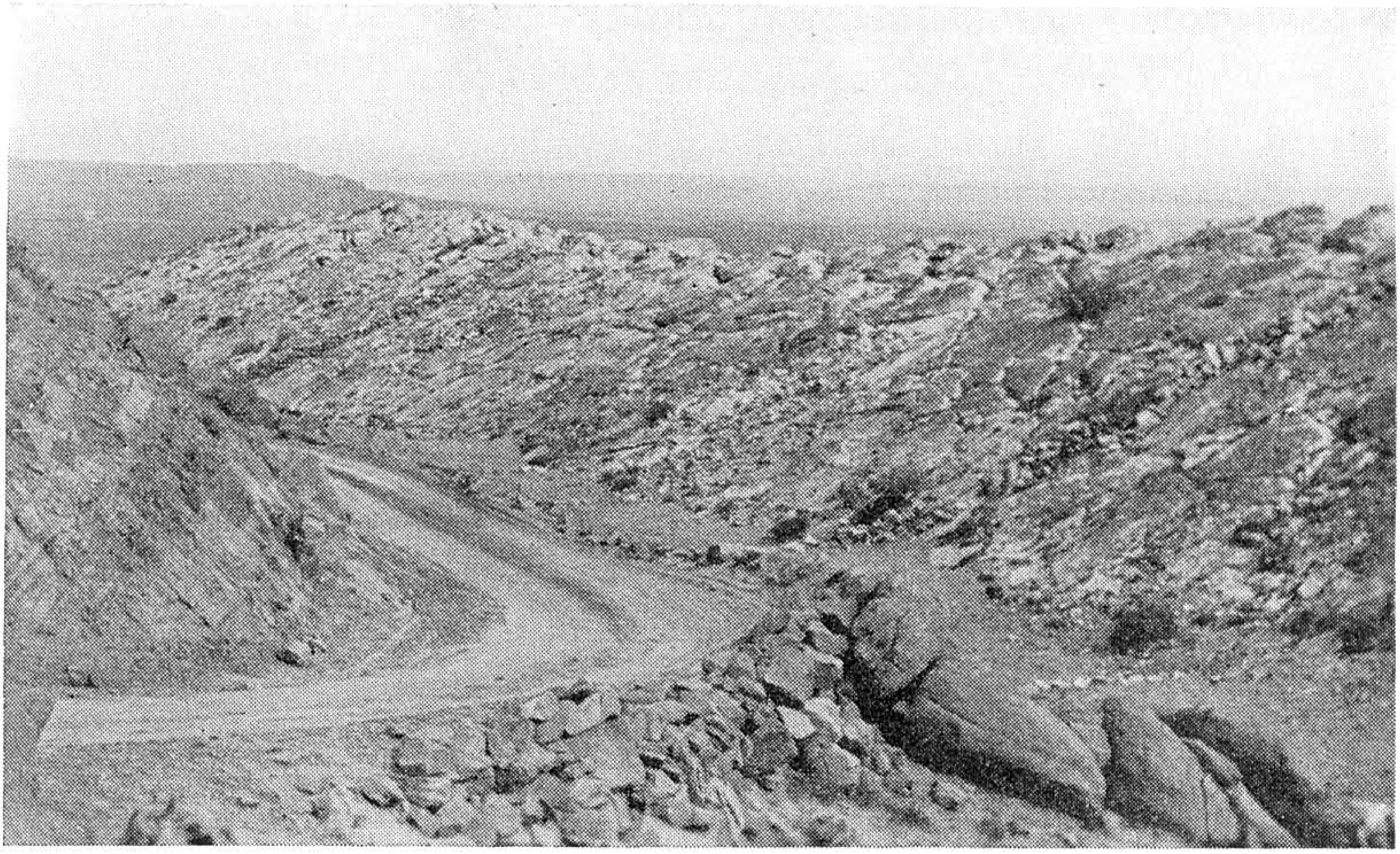

FIG. 4.—View down strike valley cut in the largest Toreva-block at type locality

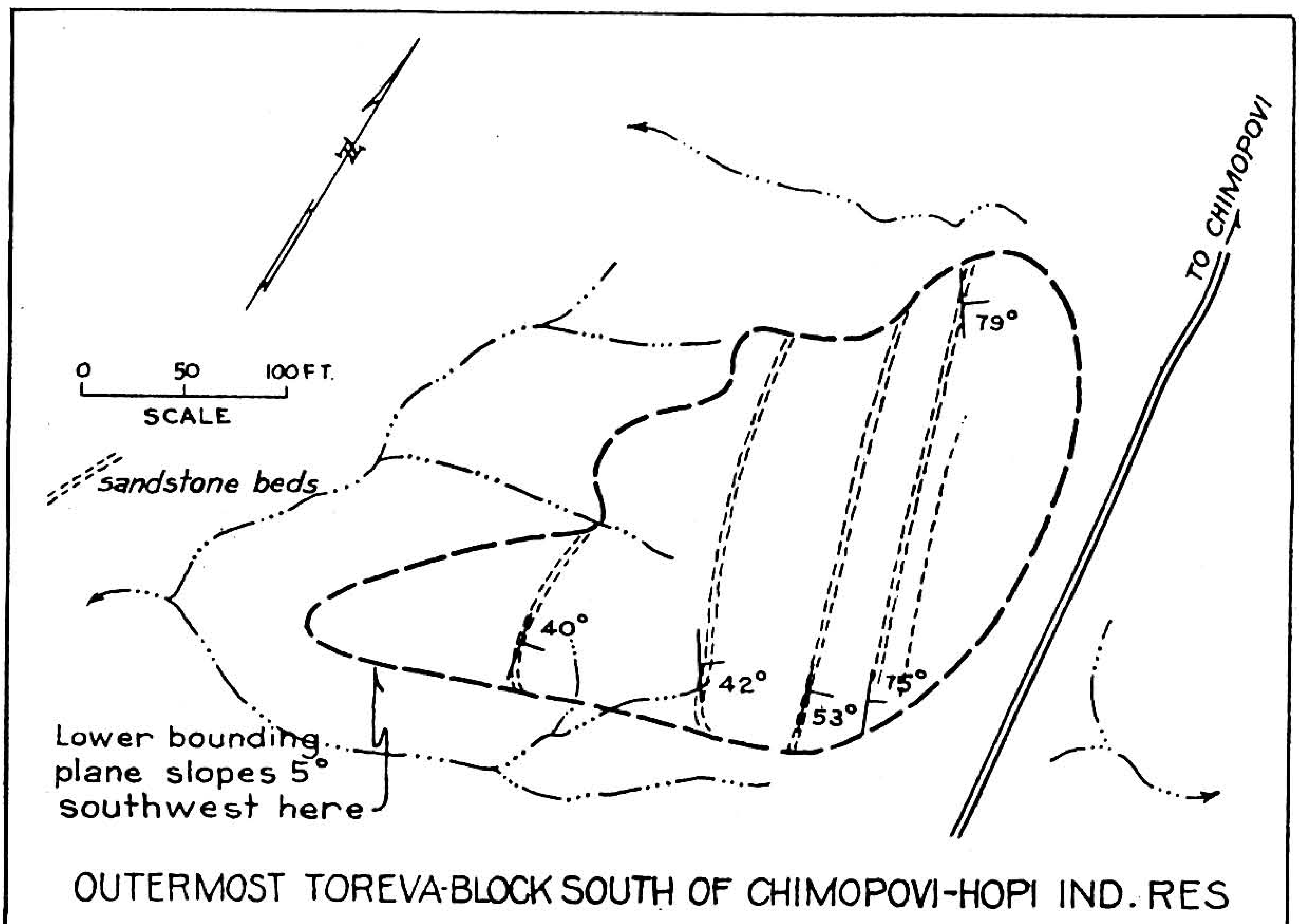

FIG. 5.—Erosion remnant of Toreva-block south of Chimopovi (2 miles southwest of Toreva), Hopi Indian Reservation, Arizona.

sistance on the plane of slipping and by the greatly diminished curvature of the lower part of that surface. The result was, as shown, a sort of fanning out of the beds.

The fact that no extensive catchment area of mesa-top was necessary to provide moisture for lubrication of the plane of slippage is

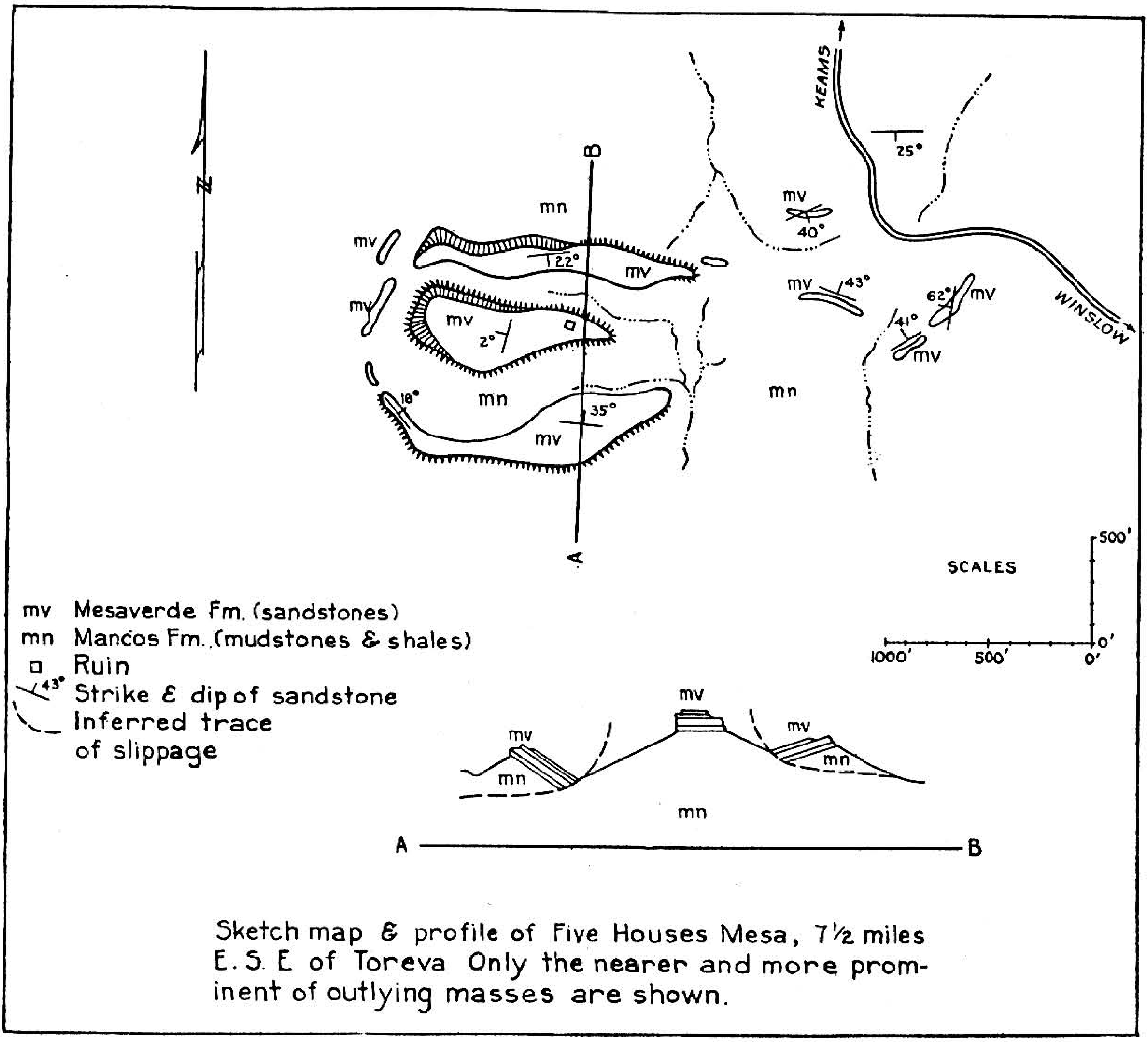

FIG. 6.—Geologic sketch map and profile of Five Houses Mesa, $7\frac{1}{2}$ miles east-southeast of Toreva, Hopi Indian Reservation, Arizona.

shown by the observations recorded in Figure 6, in which only the inner and more prominent of the Toreva-blocks have been drawn. The width of mesa, at the time the final slide took place, can scarcely have exceeded 700 feet (see section *AB*, Fig. 6). Similar or even smaller dimensions are indicated for the final stages of a former mesa remnant near the bend in the road in the northeast part of the area shown in the same figure. The former existence of this mesa remnant is attested by five partly destroyed inward-dipping Toreva-blocks.

What may be the initial stage in the splitting off of another block was noted about 1,000 feet east of Mishongnovi, where 5 feet of debris from a cliffed slope mantle the top of the "lower sandstone." A sink-hole in the debris has formed over a 10-inch fissure in the sandstone.

ASSOCIATED LAND FORMS AT THE TYPE LOCALITY

The surfaces on which the landslides came to rest are generally obscured. Because of their possible bearing on the time and conditions of maximum sliding, brief account is made of local morphology.

Near Toreva two early erosion surfaces, or pediments, slope toward the Polacca Wash and its tributaries. These surfaces have been almost completely destroyed by the headward extension of a third, whose thalweg has been trenched 30–50 feet by the Polacca Wash during the past half-century. The early pediments are represented by small remnants, trenched by gulches graded to the lowest surface; the recent incision of Polacca Wash has not as yet affected the mapped area.

The upper and middle pediments differ in elevation by 10–30 feet; the middle and lower by 50–65 feet. All have surface slopes of 3.5–5.5 in a hundred. East of the south-central part of the area sketched (Fig. 3) they are obscured by wind-blown sand.

Any attempt to tie the Toreva-block formation to the period of development of one or more of the pediments runs into an immediate difficulty: Chronologically the blocks that are lowest and outermost, with respect to the mesa outlines, were formed before those that are highest and innermost. Precisely the reverse order is true for the pediments. These circumstances make it progressively less possible for blocks to reach later pediments. A given slide is clearly younger than the surface on which it is found, but the time interval between the formation of that surface and the descent of the slide cannot in general be estimated.

Numerous Toreva-blocks rest upon both of the upper pediment surfaces. Several small outer slides appear to have come to rest in gulches cut into the middle pediment. As these are, perforce, among the oldest of the slides, it follows that most of those now identifiable postdate the completion and partial destruction of the second pediment. They thus fall within the period during which the lowest pediment was formed.

An interesting condition a half-mile east of Chimopovi[9] was called to the writer's attention in the field by Professor Kirk Bryan. For a distance along the strike of 90 feet Mancos shale has been shoved about 15 feet over the blow-sand filling of an old gulch. The latter had been cut into the uppermost pediment about 12 feet by a northward-flowing stream. The shove was from the west, in which direction the Mancos shale involved dips of 1°–3°. Whether this mass of disturbed shale is the toe of a Toreva-block or was merely pushed forward by such a toe is not determinable, due to outcrop discontinuity. The upper few inches of the blow-sand have been weakly cemented (lime) and preserve crude slickensides. The stage of erosion of the displaced shale mass suggests a relative antiquity both for the slide and for effective Quaternary wind action in this district.

TOREVA-BLOCKS OF OTHER DISTRICTS

As previously noted, the type of landslide under discussion is widely distributed in the southern part of the Colorado Plateau and at other contacts than that between the Mesaverde and the Mancos formations. To cite only a few examples:

Toreva-blocks are present in several tributary canyons of the Colorado in the Grand Canyon district, according to observations made by W. H. Swayne. The largest are stated[10] to occur in the Thunder River Canyon (near Tapeats Creek) and in the lower valley of Chuar Creek. In both places the blocks comprise part of the Redwall limestone, the Muav limestone, and the Bright Angel shale. In Surprise Valley in the Thunder River Canyon district, Mr. Swayne found slides 1,700 to more than 2,000 feet in length, measured along the strike. In the Chuar Creek examples, Carbon Butte, a slide mass about three-quarters of a mile in diameter, is pre-eminent. From the description afforded by Mr. Swayne it seems probable that the parent cliff has receded about 4 miles and the shape of the block greatly changed since the displacement.

Numerous examples occur along the San Jose and Rio Colorado drainages in and near the Laguna Indian Reservation of New Mexico. The strata involved are the sandstones of the lower Mancos

[9] Indian pueblo about 2 miles southwest of Toreva. Spelled also Shimopovi, Shungopovi, etc., etc.

[10] Letter to the writer, January 13, 1937.

and the Dakota formations and the shaley beds of the upper Morrison, which outcrop in the walls of the Rio San Jose canyon, and the Todilto limestone, Wingate sandstone, and upper Chinle shales appearing in the cliffs on the northwest side of the Rio Colorado valley. One example, 7 miles south and slightly east of Old Laguna, seems to have been mistaken for part of a fold and to have occasioned an oil prospect. The landslide mass measures about 550 feet along the strike, and the disturbed beds have dips as high as 50 degrees; the vertical displacement is approximately 175 feet. Erosion subsequent to sliding has caused retreat of the parent cliffs by more than 2,000 feet.

In many places, though the stratigraphy, jointing, and relief seem favorable for their production, Toreva-blocks are absent. Along the Book Cliffs of Utah and Colorado and the western rim of Mesaverde in southwestern Colorado, in both of which the Mancos-Mesaverde formation contact is conspicuous, this type of slide is either missing or extremely rare. The same is true of the northern and eastern faces of Black Mesa in the Navajo country.

Their destruction by later active pedimentation may be responsible for the absence of Toreva-blocks in many places. In others, as in Mesaverde, the coherent upper member appears deficient in strength due to shaley interbeds. Dips above a few degrees and a too-close spacing of joints are probably prohibitive of this type of sliding. Thus Toreva-blocks are present, although rare, along the Vermilion Cliffs, but absent along the Echo Cliffs monocline in Arizona.

AGE OF TOREVA-BLOCK FORMATION

Throughout the region it appears that most of the Toreva-blocks date back a thousand to many thousands of years. Near Chimopovi ruins of thirteenth- and fourteenth-century pueblos occur along the crests of the two largest and nearly the last-formed slides.[11] A similar condition was noted east of Mishongnovi. The mesa-foot springs below both these villages are doubtless largely responsible for the intermittent Indian occupation of the district for the past thousand years or more. These springs owe their existence to the dipslope surface and subsurface drainage of Toreva-blocks, which is sufficient

[11] L. L. Hargrave, "Shungopovi," *Mus. Notes, Mus. Northern Ariz.*, Vol. II, No. 10 (1930).

to insure their permanence. The extent to which streams have dissected the blocks and have been adjusted to their differentially resistant beds testifies even more emphatically to the antiquity of the process.

Two poor examples of Toreva-blocks are known to have formed in historic times. Both involve the Mancos-Mesaverde contact. One, about 250 feet long, lies back of Chimopovi Day School and dropped about 1870. It is stated to have caused a local quake and the drying up of the old walled spring. While dropping about 60 feet, with maximum rotation of 14°, it broke into several pieces, now standing at different levels. The other known recent slide is said to have occasioned a slight quake in 1927[12] at a place 43 miles northeast of Toreva, some 6 miles north of Black Mountain Store. The block, about 300 feet long, dropped 60 feet and tilted to 45°. It cracked into numerous angular fragments which, however, were not jostled.

That a more humid climate than the present would have been conducive to the production of Toreva-blocks, by moistening and lubrication of their relatively incoherent underpinnings, seems evident. The effects of the Pleistocene climatic regime were certainly marked in the region discussed. The writer has observed evidence of nivation along the top of the Chuska Mountains, about 160 miles east of Toreva and 2,000 feet or so higher; and the probably Wisconsin alpine glaciation of San Francisco Peaks 115 miles to the southwest has been made familiar by the work of Robinson.[13] That some late Pleistocene or post-Pleistocene climatic regime was responsible for the production of the majority of the Toreva-blocks seems not unlikely. A conspicuously wet climatic episode is believed[14] to have occurred during the first millenium B.C. That any appreciable number of Toreva-blocks were formed at that time may be doubted, both on the grounds of the relatively short duration of that episode and of the apparent antiquity of the slides as evidenced by their stage of dissection.

[12] T. Armijo (Indian trader), oral communication.

[13] H. H. Robinson, "The San Francisco Volcanic Field," *U.S. Geol. Surv. Prof. Paper 76* (1913).

[14] C. E. P. Brooks, *Climate through the Ages* (1928), p. 393.

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