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GEOMORPHIC HISTORY OF PART OF THE TUCUMCARI LAKE DRAINAGE BASIN, NEW MEXICO

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INTRODUCTION

Geomorphological reconnaissance and sedimentological study were done to aid archaeological investigations of sites along the route of Interstate 40 south of Tucumcari, New Mexico, initiated by archaeologists from the Museum of New Mexico during the spring and summer of 1979. The following review of the geomorphic evolution of the area is taken from an unpublished report on file at the Museum of New Mexico. This review is based on field observations, interpretations from aerial photographs (1951 and 1971), previous literature concerning the geomorphic history of the area (Dobrovolny and Townsend, 1946; Judson, 1953; Trauger and Bushman, 1964; Hawley, written comm. 1964; Berkstresser and Mourant, 1966; Trauger et al., 1972; Leonard and Frye, 1975; Frye et al., 1978, 1982; Barnes et al., 1983; Dolliver, 1984; Hawley, 1984) and discussions with J. W. Hawley.

The affected archaeological sites are peripheral to an unnamed watershed south and east of Tucumcari (herein called Tucumcari drainage) which drains into Tucumcari Lake, a natural lake (Fig. 1). Most of the investigation concentrated on sites salvaged prior to construction of the Mountain Road interchange on I-40. Although the archaeological sites were occupied only during the past few thousand years, the processes and surficial deposits result from development of the geomorphic system over the past few million years. Of particular importance is the evolution of the Tucumcari drainage itself and its relationship to surrounding drainages. Because detailed examination of all deposits over the area remains to be done (except for archaeological trenches), this review will be chronologic rather than presenting description and interpretation separately. The preliminary work in the area suggests the following general phases of landscape development: (1) Pliocene evolution of drainages after deposition of the Ogallala Formation, (2) formation of the highest remnant Pleistocene surfaces and deposits northeast of Tucumcari, (3) formation of lower geomorphic surfaces, (4) deposition of gravel deposits capping a ridge 2 km east of Tucumcari, (5) incision of an ancestral Tucumcari drainage, (6) formation of an extensive piedmont around the base of Tucumcari Mountains, (7) further incision of the Tucumcari drainage below its present level, (8) erosion of the margins of the Tucumcari drainage, particularly the former piedmont slopes, and consequent deposition along the floor of Tucumcari drainage and Tucumcari Lake and (9) subsequent erosion and deposition in, and adjacent to, the Mountain Road interchange south of Tucumcari. The amount of time involved in each of the above phases remains to be determined, but some of the phases lasted much longer than others. The entire region has been uplifted nearly 1000 m during the past 10 m.y. (Gable and Hatton, 1983) and has undergone episodic changes in climate. In contrast to regional uplift, solution subsidence may have affected the landscape position of some of the early deposits (Gustavson et al., 1980; Dolliver, 1985).

PLIOCENE AND QUATERNARY EVOLUTION OF DRAINAGE IN THE TUCUMCARI AREA

Pliocene and earliest Pleistocene events

Prior to about 4 m.y. ago, the landscape of eastern New Mexico and west Texas was a broad alluvial plain constructed by streams distributing sand and gravel from mountains to the west. Deposits ranged up to 60 m thick in paleostream valleys, but were much thinner on other parts of the plain. Deposition on the alluvial plain ceased between 7 and 4 m.y. ago (Hawley, 1984). Caprock caliche 1.5 to 5 m thick formed at the top of these alluvial deposits before 2.5 to 3 m.y. The predominantly fluvial deposits and the caprock caliche together comprise the Ogallala Formation (Frye et al., 1978; Seni, 1980). The Ogallala Formation in eastern New Mexico presently slopes southeast from 1620 to 1300 m above sea level. Deposits postdating the Ogallala Formation locally overlie the caliche on the Llano Estacado southeast of Tucumcari. These deposits include the Blanco Formation (about 2.5 to 1.4 m.y.), Tule Formation (0.6 m.y.), Blackwater Draw Formation (<0.5 m.y.), Double Lakes Formation (70,000? to 30,000 yr) Tahoka Formation (24,000 to 12,000 yr) and later eolian deposits (Hawley et al., 1976; Reeves, 1976). However, the synchroneity of the deposits overlying the Llano Estacado and deposits near Tucumcari has not been established.

The timing of the establishment of the course of the Canadian River, the master drainage in the area, is only partially determined (Dolliver, 1984). To the west, the Canadian River was entrenched 100 m below the Canadian Canyon rim (Las Vegas Plateau) near the junction with the Mora River prior to 1.4 m.y. ago (O'Neill and Mehnert, 1980). The Canadian River has entrenched 125 m further in that reach since then (O'Neill and Mehnert, 1980). A gravel terrace 50 m above Ute Creek, a major tributary to the Canadian River northeast of Tucumcari, contains a volcanic ash (Finch, 1972) identifed as Lava Creek Ash by Izett and Wilcox (1982), which is about 0.6 m.y. old. A second Lava Creek Ash locality near Tucumcari has been reported by Izett and Wilcox (1982), but this site has not been relocated. Sediments underlying terraces 4.5–7.6 m above tributaries to Ute Creek contain specimens radiocarbon-dated at 7800–8900 yr (Liu and Coleman, 1981).

In the Tucumcari area, tributaries to the Canadian River such as Pajarito Creek, Revuelto Creek and Plaza Larga Creek breached the Ogallala caprock and eroded large areas of bedrock, isolating remnants of the former alluvial plain as mesas such as Mesa Redonda, Tucumcari Mountain and Mesa Rica. At that time, the basal grade of the incised drainages had not eroded below about 1300 m above present sea level.

The earliest Pleistocene(?) deposits preserved in the Tucumcari area are fluvial(?) gravelly sand preserved on the mesas northeast of Tucumcari (Trauger et al., 1972) (shown as "highest geomorphic surfaces" in Fig. 1). The highest level is above 1280 m, and the next highest level is about 1265 m above present sea level and about 130 and 115 m above the present Canadian River. Both levels appear to slope from southwest to northeast. The geometry of these surfaces suggests that they may be remnants of distributary fans at the former mouth of Pajarito Creek. The course of Pajarito Creek later shifted to the north, and the course of Plaza Larga Creek eroded to the south of these early deposits. During this time, mesas such as Tucumcari Mountain continued to be reduced by mass wasting along their margins.

Intermediate geomorphic surfaces

Coarse-gravel deposits beneath a low ridge 2 km east of Tucumcari appear to have been laid down after the high surfaces to the northeast were abandoned as active areas of deposition, but before the modern drainages became incised (Fig. 1). The gravel deposit is presently 1250 m above sea level and slopes to the northeast. The flanks of the deposit have one or more valley-margin surfaces sloping east and west into the present drainages. Present exposures do not exhibit sedimentary structures to indicate whether the gravel was deposited in a fluvial system or as a debris flow. The possible origin, pathway and any confining channel have been eroded. Exposures and lithology do not indicate whether the gravel came from former flanks of Tucumcari Mountain or

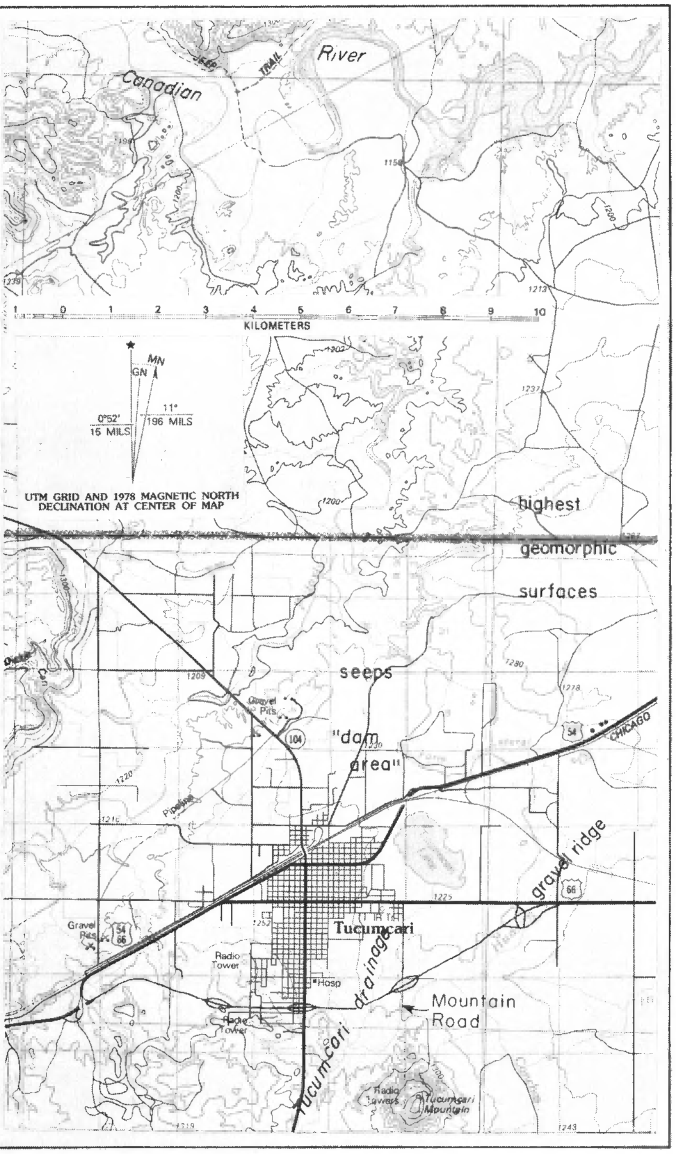

FIGURE 1. Topographic map of the Tucumcari area showing present drainages, highest geomorphic surfaces, Tucumcari Lake and route of I-40 south of Tucumcari. Base from U.S. Geological Survey 1:100,000-scale Tucumcari quadrangle.

whether the depositing agents flowed north to the ancestral Pajarito drainage or east to the Plaza Larga drainage.

After deposition of gravel presently forming the ridge, the drainage basins on both sides of the ridge became incised. The Plaza Larga drainage appears to have been eroded gradually (in the vicinity of Tucumcari Mountain; cf. Judson, 1953), whereas the development of the Tucumcari drainage appears to have had distinct episodes of erosion and deposition. An extensive piedmont fan (Qps of Fig. 2) from the north face of Tucumcari Mountain appears to have graded outward to a level below 1250 m (the level of the ridge gravel). Remnants of earlier landslides on the flanks of the Tucumcari Mountain remain above the level of the piedmont fan and/or are partially buried by it.

The origin of the Tucumcari Lake basin and its relationship to Pajarito Creek (Fig. 1) affect interpretations of the base level at the toe of the piedmont fan. The Tucumcari Lake basin has been explained by two hypotheses (Dobrovolny and Townsend, 1946; Trauger and Bushman, 1964). The first hypothesis suggests that the Tucumcari drainage previously flowed north to join Pajarito Creek, but was dammed in (late?) Quaternary time by sand dunes up to 21 m high (Dobrovolny and Townsend, 1946). The second hypothesis suggests that the Tucumcari Lake depression was formed by solution subsidence in underlying Permian evaporite beds (Trauger and Bushman, 1964).

Evidence in favor of an eolian dam includes (1) the petrographic character of the deposits along the crest of the dam northeast of Tucumcari, (2) subsurface drainage northward from the lake, (3) present wind direction and (4) modern dunes in the area near Tucumcari (Dobrovolny and Townsend, 1946). Dobrovolny and Townsend noted that sand grains from Quaternary exposures in the dam area are similar to sand grains in the friable "Wingate" Sandstone (also mapped as Entrada and Exeter Sandstone; cf. Mankin, 1972) which crops out west of the dam. Dobrovolny and Townsend noted that water in the lake remained fresh, unlike other closed depressions in the area which are saline. Seeps on the north side of the dam are active when there is water in Tucumcari Lake and are dry when the lake is dry.

Evidence in favor of solution subsidence includes (1) well logs indicating between 90 and 180 m of alluvial fill beneath the Tucumcari drainage, (2) other solution-subsidence depressions in the area (Trauger and Bushman, 1964) and (3) maps by the Soil Conservation Service indicating that the dam area consists of "upland alluvium" (Ross and Pease, 1974). However, the well logs could have been misinterpreted to indicate alluvium instead of upper Chinle Formation, which has a similar lithology. Furthermore, there are outcrops of upper Chinle Formation immediately adjacent to Tucumcari Lake, which would not be expected if the basin had subsided.

Further work is required to determine how the Tucumcari drainage formed. If the Tucumcari drainage was formerly connected with Pajarito Creek, the evolution of the two drainages should be somewhat parallel. However, if the Tucumcari drainage evolved in response to solution subsidence, the evolution of the drainage may not have been related to other drainages or to large-scale climatic changes in the region.

Development of the present valley of Tucumcari drainage

After the major part of the previously described piedmont deposits north of Tucumcari Mountain developed, the distal and proximal parts of the piedmont apron underwent further changes, while the medial part of the apron remained much more stable. The proximal portion of the piedmont apron continued to encroach on the mountain front and to receive debris flows and other sediments. The distal end of the piedmont apron in the Tucumcari drainage underwent several episodes of the dissection which influenced the geomorphology of the vicinity of the Mountain Road interchange. The distal part of the apron in the Plaza Larga drainage underwent more subtle erosion.

As base level was lowered (for whatever reason) near Tucumcari, drainage began to incise into the margin of the piedmont west of Tucumcari Mountain. The Tucumcari drainage underwent several stages of erosion and deposition below the level of the piedmont apron. At the distal end of the piedmont apron, several tributary drainages incised subtle channels into earlier deposits (Fig. 2). Because the topographic relief in the distal portion of the piedmont is not great and because deposits could have been formed under several episodes of transport and deposition, the exact conditions and timing of geomorphic events at the Mountain Road interchange have not yet been determined.

Along the valley-side slopes between the medial part of the piedmont apron and Tucumcari drainage, several distinct periods of erosion and stability are suggested by remnants of a stepped sequence of at least three valley-border surfaces (Fig. 3, surfaces 3 to 5). The highest remnants near Tucumcari Mountain (Figs. 2 and 3) may be part of the piedmont surface or they may be remnants of later surfaces graded to the ancestral Tucumcari drainage downslope to the west. The lower valley-border surfaces formed between the former piedmont surface and the modern entrenched drainages of tributaries south of the Mountain Road interchange.

The present valley of the Tucumcari drainage appears to have been incised more deeply during the late Pleistocene and appears to have aggraded episodically during the Holocene. Incised modern arroyos may have formed around 1900 (Judson, 1953).

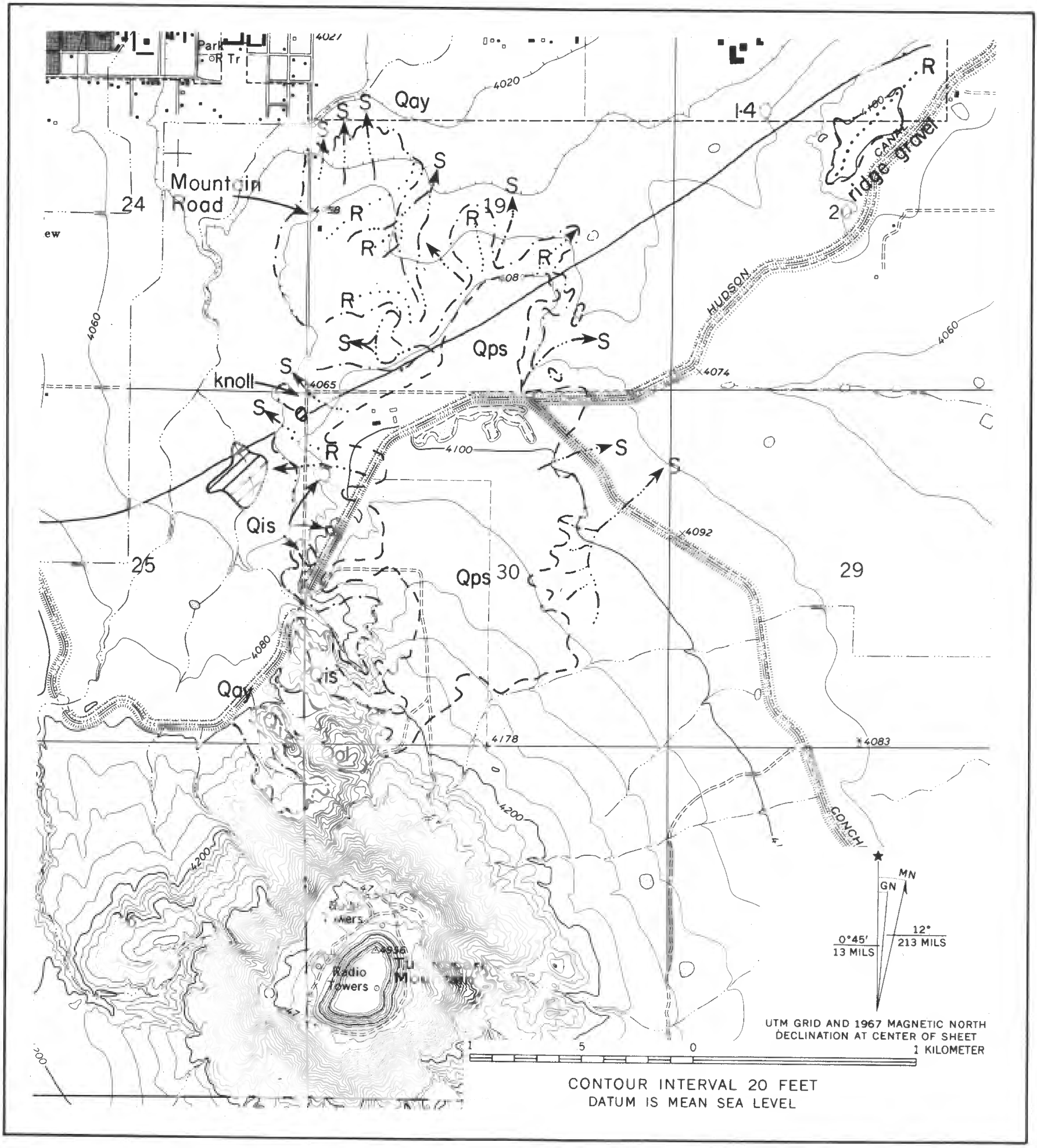

FIGURE 2. Map of deposits and geomorphic features north of Tucumcari Mountain. Qol = Quaternary old landslide; Qps = Quaternary piedmont surface; Qis = Quaternary intermediate surface; Qay = young alluvium (separated by dash-dot line); S = swale, (dash-dot-dot-dot trends), R = ridge (dotted trends); cross-hatched areas are depressions capable of holding water. Base from Tucumcari 7.5 Minute quadrangle.

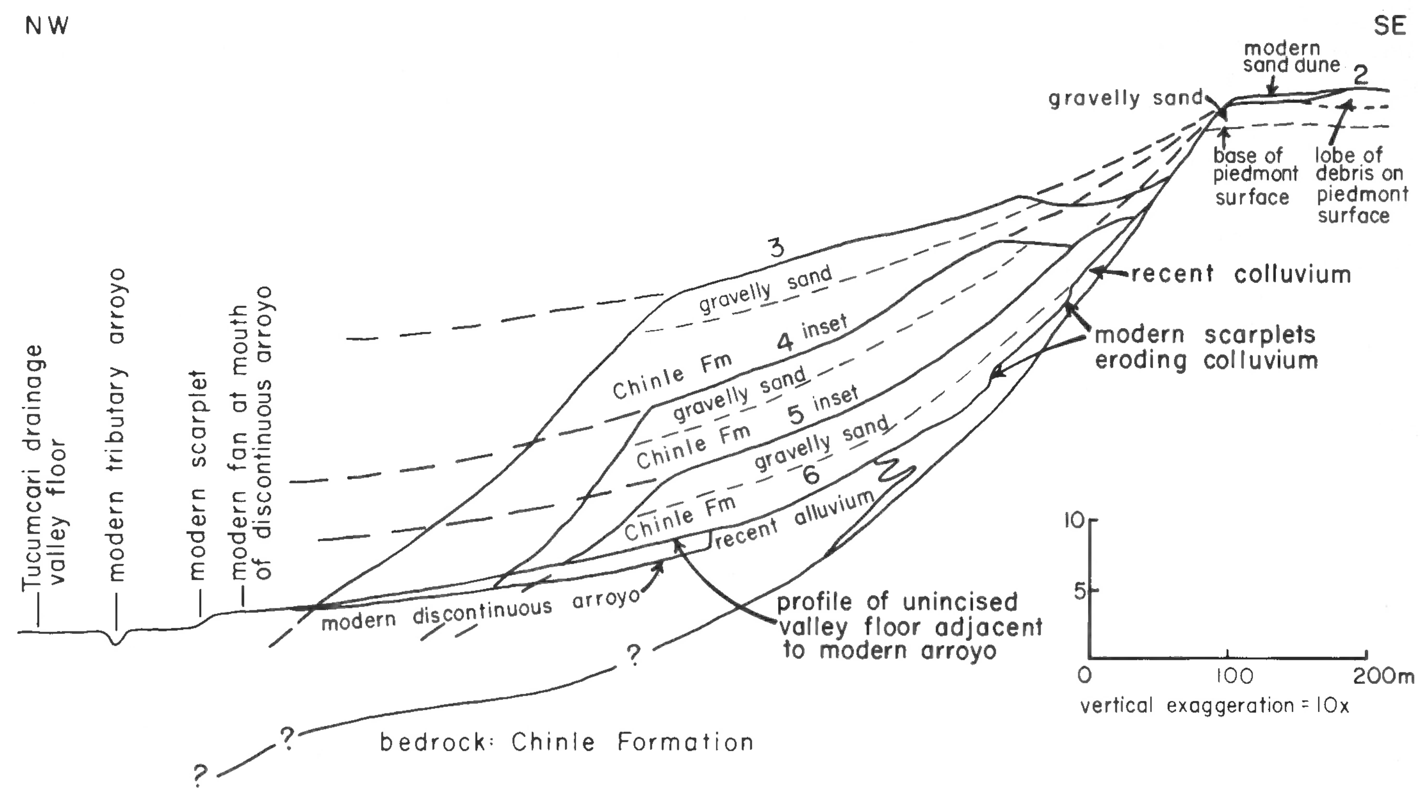

FIGURE 3. Schematic cross section of valley-border surfaces developed in tributary drainages south of the Mountain Road interchange.

LANDFORMS AT THE MOUNTAIN ROAD INTERCHANGE

In 1979 the topography near the Mountain Road interchange consisted of several west- to northwest-trending ridges and swales with less than 8 m of relief above the valley floor. The ridges sloped from the margins of the undissected piedmont apron. An archaeological site on the south side of I-40 occupied one of these ridges. The crest of the ridge had only minor amounts of erosion and deposition, while the flanks of the ridge had undergone several periods of more extensive erosion and deposition. The flanks of the ridge were cut by scarplets up to 0.5 m high, which eroded upslope, redistributing sediment downslope over short distances. As a result, soil development on the crest of the ridge is much more advanced than soil development on the flanks. Near the crest of the ridge artifacts occurred at shallow depths and tended to be large, heavy forms, whereas along the flanks of the ridge artifacts were distributed more deeply and were smaller forms (T. Seaman, personal comm. 1981).

The swale southeast of the south ridge also contained artifacts near the surface. Reconnaissance of the swale and modern arroyo-piping system suggested depositional relationships illustrated in Figure 4. The buried organic A horizon in the swale pinched out on both sides of the swale, indicating more dense vegetation during a brief period in the past. Artifacts occur only in the upper part of the deposits, so much of the erosional and depositional history of the swale predates late Archaic (?500 BC–AD 500) time. The present arroyo in the swale appears to have formed within the past hundred years, but there is no documentation of when arroyo-cutting began in this small drainage. Both the modern arroyo and the extent of piping may be related to modern irrigation ditches upslope.

A swale to the northeast of the south ridge (presently under I-40) also underwent a period of dark, clayey-soil development and later deposition of sandy slope-wash. These deposits appear to be earlier than artifacts in the vicinity, but they indicate that even subtle swales in the area have preserved earlier episodes of erosion and deposition.

The land now beneath the northern part of Mountain Road interchange had a complex history of erosion and deposition which was not completely revealed in shallow trenches dug across the area. Activities associated with a modern homestead and mesquite removal destroyed some of the depositional record and obscured the rest. Strata exposed at the site were divided into three units: (1) a basal archaeologically sterile unit, more than 1 m thick, of reddish-brown sandy clay with abundant calcium-carbonate accumulation (caliche), (2) a compacted pebbly loamy sand 20 to 55 cm thick, with a slightly reddish, poorly developed Bt zone in the upper part and (3) a local upper disturbed unit up to 20 cm thick, with highly variable internal stratigraphy and composition. All of the units are disturbed by rodent burrows and roots. The lowest unit appears to have been alluvium of an intermediate valley-side slope which underwent early episodes of ground-water accumulation of calcium carbonate in gravelly and sandy clay. After the lowest unit formed, the area appears to have been eroded to leave a remnant knoll of the alluvium as swales developed to the east and southwest (Fig. 2). The lowest unit was exposed and eroded on all sides of the knoll at different times. The swales to the east and southwest received sediment from the knoll and appear to have subtle facies changes between the swale margins and the center of the swales (as shown by

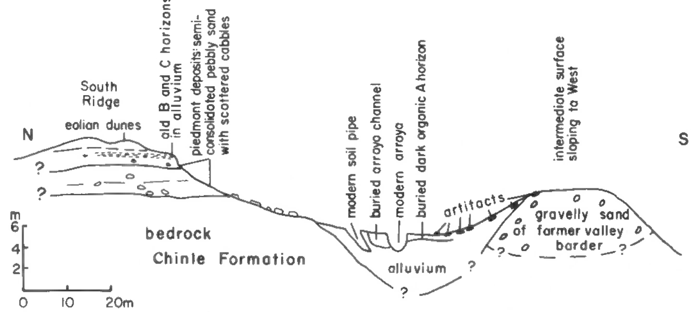

FIGURE 4. Cross section of tributary arroyo and geomorphic surfaces southeast of the Mountain Road interchange.

amounts of clay and amounts of post-depositional carbonate accumulation in unit 2). The slight development of a redder zone (Bt) at the top of unit 2 indicates a period of stability after the deposits formed. The accumulation of calcium carbonate on the bottoms of pebbles and artifacts also indicates a period of stability in the deposits. The amount of calcium-carbonate accumulation appears to be consistent with the age of the Archaic-style artifacts found in the deposit. Detailed facies relationships in unit 2 could not be adequately determined without more extensive study of the trench exposures. The uppermost unit consists of sediments remobilized during disturbances of the area during the twentieth century.

The general sequence of landforms developed in the vicinity of the Mountain Road interchange and Tucumcari Mountain is illustrated in Figure 5. After the separation of Tucumcari Mountain from the eroding caprock escarpment, extensive piedmont aprons developed in middle Pleistocene time (Fig. 5a). Later, as Tucumcari drainage incised, the margins of the piedmont apron were dissected and valley-margin tributaries developed at intermediate levels (Fig. 5b). After maximum incision of Tucumcari drainage occurred in late Pleistocene time, the valley floor aggraded while the upper valley margins continued to erode, forming the present landscape (Fig. 5c).

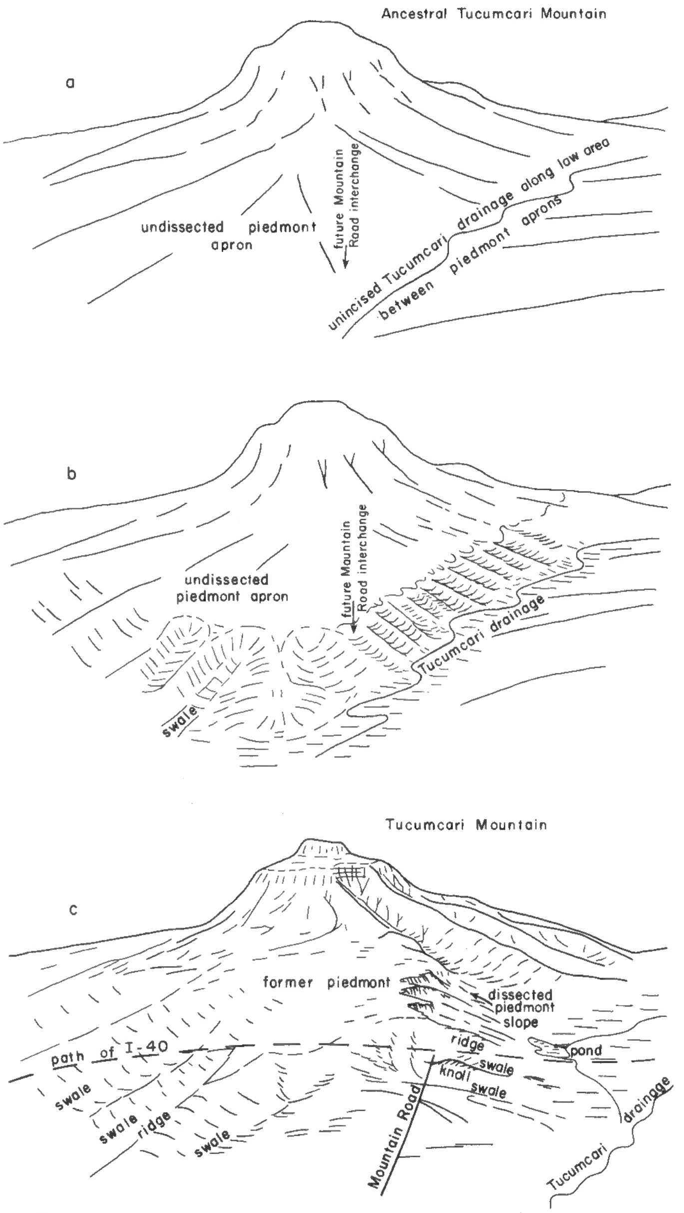

FIGURE 5. Landscape development near the Mountain Road interchange: **a**, middle Pleistocene undissected piedmont apron and unincised Tucumcari drainage. **b**, Episodic incision of Tucumcari drainage and dissection of margins and toe of piedmont apron. Ground-water accumulation of calcium carbonate occurred in deposits in swales. **c**, Modern conditions. Some former swales have undergone local topographic reversal to be preserved as ridges and knolls.

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