



## ***Geomorphic surfaces along the Rio Grande Valley from El Paso, Texas, to Caballo Reservoir, New Mexico***

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# GEOMORPHIC SURFACES ALONG THE RIO GRANDE VALLEY FROM EL PASO, TEXAS TO CABALLO RESERVOIR, NEW MEXICO\*

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## INTRODUCTION

The flood plain of the Rio Grande in southern New Mexico and Texas near El Paso is flanked by an ascending sequence of geomorphic surfaces graded to successively higher and older flood-plain positions of the ancestral river. These valley-border surfaces represent major cycles of erosion, accompanied by lesser amounts of backfilling, and they are in turn inset below remnants of an early(?) to mid-Pleistocene complex of basin-fill surfaces.

The geomorphology and late Cenozoic geology of the Rio Grande Valley and adjacent areas from El Paso to Caballo Reservoir have been studied in some detail by Lee (1907), Dunham (1935), Kelley and Silver (1952), Kottlowski (1953, 1958, 1960), and Ruhe (1962, 1964). In the preparation of this paper the writer has drawn upon these cited references in addition to information from his own investigations and to unpublished work of his predecessors R. V. Ruhe and F. F. Peterson on soil-geomorphology relationships in southern New Mexico. The writer is indebted to his associate L. H. Gile, to Dr. A. Metcalf of the Texas Western College Biology Department, and to Dr. F. E. Kottlowski of the New Mexico Bureau of Mines for their critical review of the manuscript.

The major physiographic units in the region are shown on figure 1. The valley of the Rio Grande between Truth or Consequences and Hatch is termed the Palomas Valley, and the valley between Hatch and Selden Canyon is designated the Rincon Valley. Mesilla Valley, Selden Canyon and El Paso Canyon designate the lower valley segment and the bedrock constrictions at its upper and lower ends, respectively.

## BASIN SURFACE AND BASIN FILL

Prior to initial entrenchment of the present Rio Grande system in mid-Pleistocene time (Ruhe, 1962; Strain, 1959, 1965), the landscape of the El Paso-Caballo region was characterized by a complex of broad internally drained structural basins and intervening north-trending mountain ranges.

The ancient basins from north to south comprised:

(1) the Palomas basin, whose surface is now partly preserved as isolated remnants above the Palomas, and Rincon Valley; (2) the Jornada del Muerto, on the whole still undissected, except at its southwest edge in the Rincon Valley and Upper Mesilla Valley areas; and (3) the Mesilla bolson (Strain, 1965), of which the broad La Mesa plain south of Las Cruces is the major preserved remnant. Remnants of the nearly level floors of these basin surfaces are preserved at elevations from 250 to 600 feet above adjacent parts of the present Rio Grande valley floor (fig. 1). Isolated remnants of the piedmont-slope elements of the basin surfaces occur at higher elevations in the divide areas between major incised streams tributary to the Rio Grande. Piedmont-slope surfaces include pediment (cut on both bedrock and older basin fill), alluvial-fan, and coalescent alluvial-fan piedmont surfaces.

The mid-Pleistocene landscape also contained elements of still older basin landforms, some of which probably date back to early Pleistocene time. The oldest basin remnant observed is a basin-floor and piedmont-slope surface preserved between Red House Mountain and the Rincon Hills at the southeast end of the Caballo Mountains (fig. 1). This surface, here referred to as the *Rincon surface*, ranges from about 500 to 700 feet above the flood plain and is underlain by as much as 50 feet of caliche-cemented pebbly sands to sands over tilted and faulted beds of the Palm Park and Thurma Formations (Kelley and Silver, 1952; Kottlowski, 1953) and Paleozoic bedrock. The upper few feet of the caliche caprock is characterized by "pisolitic" or "Rock House" structures identical to those described by Swineford, Leonard, and Frye (1958) and Bretz and Horberg (1949) in the upper parts of similar caprock sections below the High Plains surface of New Mexico and adjoining areas.

The Rincon surface stands from 100 to 300 feet above the extensive plain of the Jornada del Muerto basin east and south of Rincon. This plain is the La Mesa surface (Ruhe, 1964), deriving its name from the broad central plain of the Mesilla bolson. It is underlain by a caliche-capped and areally widespread unit of sand and rounded gravel of mixed composition (mainly quartz, quartzite, chert, volcanics and granite), here referred to as the "mixed-rounded grav-

\* Contribution of Soil Survey Investigations, Soil Conservation Service, U.S. Department of Agriculture.

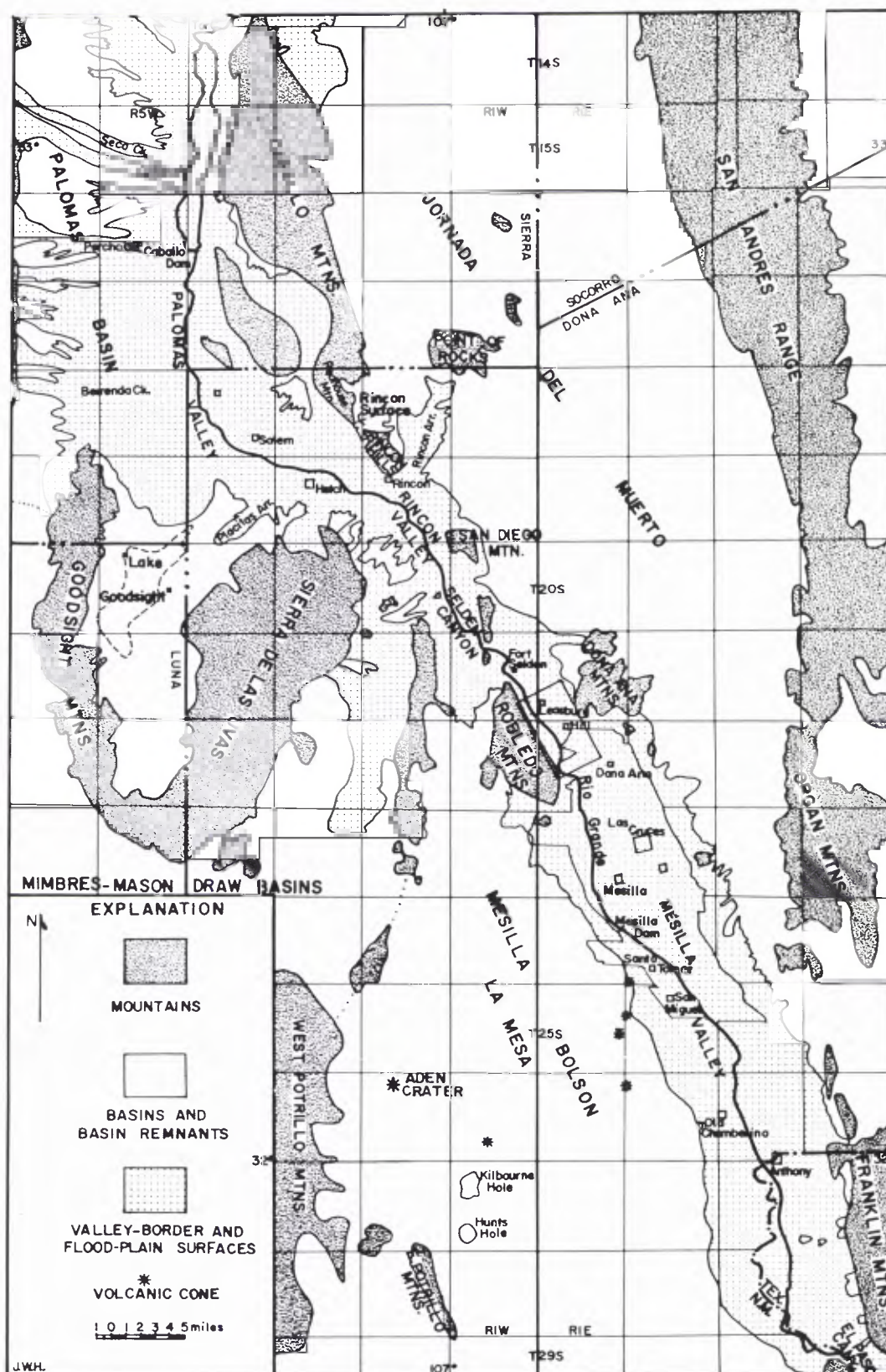


FIGURE 1

Index map. Rio Grande Valley and adjacent basins in southern New Mexico and western Texas.



els" (Ruhe, 1962). A mid-Pleistocene vertebrate fauna has been recovered from this unit near Las Cruces (Ruhe, 1962). The "mixed-rounded gravels" range from more than 60 to less than 5 feet in thickness and overlie sands, silts, clays and conglomeratic sediments of the Santa Fe Group (Kottowski, 1953, 1958, 1960). These lower beds locally exceed 1,000 feet in thickness (Kottowski, 1953; Leggat, and others, 1963). The piedmont slopes which ascend from this broad basin plain to the bordering mountain uplands are formed by surfaces of varying ages ranging from at least mid-Pleistocene to Recent. The extensive piedmont-slope surface, designated the Jornada surface by Ruhe (1964), postdates the deposition of the mixed-rounded gravels and development of the La Mesa surface. A still older and much less well-preserved piedmont-slope surface, named the Dona Ana surface by Ruhe (1964), may be a general time correlative of the La Mesa basin-plain surface. The La Mesa surface has been definitely offset by major faults, but it also may include member surfaces of at least two ages.

Northwest of Rincon, the Rio Grande flows in a valley cut 350-450 feet below remnants of the ancient basin surface designated the Palomas surface by Kelley and Silver (1952) in the areas west and north of the Caballo Mountains. Kottowski (1953) mapped this geomorphic surface southward to the piedmont slopes of the Sierra de las Uvas, west of the Rincon Valley and Selden Canyon. Relatively level basin-floor elements of the Palomas surface (analogous to the La Mesa surface of Ruhe, 1964) are not well preserved. The surface is characterized by remnants of various piedmont-slope land forms above deeply entrenched valleys of streams tributary to the Rio Grande. The only broad basin-plain remnant of the Palomas surface is located about 6 miles west of Hatch (Kottowski, 1953, map 1-5) and is about 450 feet above the present valley floor. The eastern part of this plain is underlain by caliche-cemented sands with lenses of "mixed-rounded gravels" which in turn overlie well-bedded, reddish silts, sands, and clays mapped as part of the Santa Fe Group by Kottowski (1953). The western part of the plain is an internally-drained basin occupying the synclinal depression between the Goodsight Mountains and the Sierra de las Uvas. Wave-built spits and bars indicate that a lake about 15 square miles in areal extent and as much as 50 feet deep occupied this basin in late Quaternary time and perhaps earlier (fig. 1, T. 20 S., R. 5 W.). This former lake is here named *Lake Goodsight*.

On the east side of the Rio Grande, high level deposits of the "mixed-rounded gravel" unit (also 400-450 feet above flood plain) are preserved at the lower

ends of several remnants of the Palomas piedmont-slope surface below Red House Mountain (secs. 20, 21, 28, T. 18 S., R. 3 W.). The well-rounded chert-quartz-granite content of the "mixed-rounded gravels" in this area is in marked contrast with the locally derived volcanic rock-limestone-siltstone-sandstone association of the piedmont-slope gravels.

The complex Palomas surface includes landscapes equivalent in age to the Jornada, La Mesa and Dona Ana surfaces of Ruhe (1964). However, all components apparently postdate development of the Rincon Surface in that the mid-Pleistocene mixed-rounded gravel unit associated with the La Mesa and Palomas basin-floor surfaces is inset below this highest surface remnant.

Ruhe (1962) has reviewed the literature on the origin of the "mixed-rounded gravels" and has demonstrated their wide areal distribution. Their general middle-Pleistocene age has also been established (Kottowski, 1958; Strain, 1959, 1965; and Ruhe, 1962, 1964). Since this lithologic unit occurs on both sides of the southern Caballo Mountains, the San Diego Mountain-Selden Hills uplift, the Robledo Mountains, the Dona Ana Mountains and the Franklin Mountains, it is evident that it is not a single channel deposit of an ancestral stream. The concept of a braided distributary stream system, with a shifting locus of deposition, could explain the widespread occurrence of the "mixed-rounded gravels." Such a system might have developed where an ancestral river emptied into the broad plains region of southwestern New Mexico and northwestern Chihuahua. A lacustrine origin or the unit has been proposed by Ruhe (1962) as another hypothesis which could explain the petrography and distribution of the "mixed-rounded gravels." Ruhe's (1962) nongenetic description of the unit as a widespread basinal fill whose precise origin has not yet been determined is perhaps still the best characterization available.

#### VALLEY-BORDER SURFACES INSET BELOW THE ANCIENT BASIN FLOORS

Incision of the Rio Grande below the ancient basin floors began in late mid-Pleistocene time (Strain, 1959, 1965; Kottowski, 1958; Ruhe, 1962, 1964). At least three geomorphic-surface units graded to successively lower stands of the ancestral stream have been independently recognized by various workers in the Rio Grande Valley of southern New Mexico (Lee, 1907; Dunham, 1935; Bryan, 1938; Kottowski, 1953, 1958; Ruhe, 1962, 1964). The most detailed delineation of these surfaces has been made by Kottowski (1958), for the El Paso area, and Ruhe (1962, 1964) for the Las Cruces area (table 1).

TABLE 1  
REGIONAL CORRELATION OF VALLEY-BORDER SURFACES, RIO GRANDE VALLEY  
EL PASO, TEXAS TO ALBUQUERQUE, NEW MEXICO<sup>1</sup>

El Paso, Texas (Kottlowski, 1958)	Upper Mesilla Valley, N. M. Robledo-Dona Ana Area	San Acacia, N. M. (Denny, 1941)	Albuquerque-Belen (Wright, 1946)
5-20 ft., nonpaired terraces	Fort Selden Surface Complex Fillmore-Recent (<5,000 years) <sup>2</sup> (near present flood-plain level) Maximum River entrenchment (< minus 100 ft.) Leasburg-Late Pleistocene (>5,000 years) (±30 ft.) <sup>3</sup>		
Gold Hill (±70 ft.)	Picacho-Late Pleistocene <sup>2</sup> (±90 ft.)	Canada Mariana (50-75 ft.) Fill Terrace (100 ft.)	Llano de Sandia (50-75 ft.)
Kern Place (±130 ft.)	Tortugas-Mid to Late Pleistocene <sup>2</sup> (120-140 ft.)	Valle de Parida (150-175 ft.)	Segundo Alto (125 ft.) Cochiti (200 ft.)
Intermediate Surface between Kern Place & La Mesa Pediment			

#### MIDDLE PLEISTOCENE COMPLEX OF BASIN SURFACES

La Mesa Pediment—Jornada—La Mesa—Palomas—Tio Bartolo—La Bajada—Ortiz

1. Correlations between Las Cruces area and the El Paso, San Acacia, and Albuquerque-Belen areas from R. V. Ruhe, 1964, table 3.
2. Ruhe, 1964, table 2.
3. Numbers of feet in parentheses are reconstructed elevations above the present valley floor of ancestral flood-plain levels to which the valley-border surfaces were graded (based on descriptions by the cited authors).

Both recognize three major geomorphic-surface units that are apparently related to temporary halts in the entrenchment of the Rio Grande, and in some cases associated with episodes of aggradation. These three surfaces in decreasing age and elevation are the Tortugas-Kern Place, the Picacho-Gold Hill, and the Fort Selden surfaces (table 1).

Each major geomorphic-surface unit is actually a complex of member surfaces graded to a range of local and regional base levels. The individual member surfaces contain three basic landscape elements that are preserved at one place or another along the valley. They are (1) footslope and backslope erosional surfaces, (2) toeslope alluvial-fan surfaces, and (3) stream terrace surfaces. It is uncommon to find all three elements preserved in pre-Fort Selden landscape remnants. At a very few places, notably near or within constrictions of the valley such as in the El Paso or Selden Canyons, strath-terraces representing ancestral flood-plain surfaces of the Rio Grande are present. Elsewhere the valley-slope elements associated with tributary drainage basins are all that remain, and the minimum elevations of these slope remnants give only a maximum elevation for any projected ancestral flood-plain level, barring consideration of faulting or warping.

Faulting and downwarping have taken place within the Rio Grande depression through late-Pleistocene time. The older pre-Picacho geomorphic surface com-

plexes are definitely displaced from at least 20 to more than 200 feet, in the case of older parts of the La Mesa surface, by major faults such as the Robledo fault (Kottlowski, 1953, 1958, 1960; Ruhe, 1962). There are also indications of slight warping and faulting of the Picacho and younger late Pleistocene surfaces on both sides of the upper Mesilla Valley (Ruhe, 1962, 1964, p. 157-158; and F. F. Peterson, personal communication).

Despite the above-mentioned complications, in the Mesilla-Palomas Valley region the three major valley-border surface complexes can be identified with considerable certainty away from their type areas near El Paso and Las Cruces. The fact that regional correlation of the major valley-border surfaces is possible indicates that other than local factors played a role in development of the existing sequence of geomorphic surfaces. Cyclic climatic change taking place since mid-Pleistocene time and operative over the entire Rio Grande watershed of Colorado and New Mexico probably was the major influencing factor. This possibility has been discussed by Kottlowski (1958) and Ruhe (1964). Unfortunately, geologic dating of deposits and surfaces is limited to (1) the fossil-mammal chronology for the mixed-rounded gravels and older basin-fill deposits (Strain, 1959, 1965; Ruhe, 1962), and (2) the radiocarbon chronology for Recent (less than 5,000 years B.P.) alluvial deposits (Ruhe, 1964). Thus, only the relative age of the various valley-border



surfaces between the mid-Pleistocene basin surfaces and the Recent members of the Fort Selden surface complex can be determined. In this part of the Rio Grande Valley, there is as yet no absolute method of correlating the alluvial events with glacial-pluvial or inter-glacial-pluvial cycles.

### LOWER MESILLA VALLEY- EL PASO CANYON

In the lower Mesilla Valley-El Paso Canyon area, Kottowski (1958, p. 52-55) shows that the Kern Place "terrace" descends to a level about 130 feet above the present flood plain (table 1). The next lower geomorphic surface, the Gold Hill "terrace," which he correlates with the Picacho surface of Dunham (1935), descends to a true river terrace surface preserved about 70 feet above the flood plain. Still lower are unnamed "low (5-20 feet) nonpaired terraces." Kottowski further recognized two high-level surfaces above the Kern Place "terrace." These are his La Mesa pediment and an intermediate surface which possibly can be included in the ancient, Jornada-La Mesa-Palomas complex.

### UPPER MESILLA VALLEY

Work by Ruhe (1962, 1964), Peterson (unpublished maps and field notes), and the writer in the Upper Mesilla Valley area shows a sequence of surfaces similar to that preserved near El Paso (table 1). The Tortugas surface named by Ruhe (1962) correlates with the Kern Place, and the Picacho surface with the Gold Hill (Ruhe, 1964). The low (5-20 feet) nonpaired terraces of Kottowski (1958) correlate with the Fort Selden surface complex of Ruhe (1962, 1964). The distribution of these geomorphic surfaces in the Upper Mesilla Valley near Hill is shown in figure 2. Ruhe (1962, 1964) has shown their distribution near Las Cruces.

### TORTUGAS SURFACE

The Tortugas surface in its type area east and southeast of Las Cruces is an erosional surface cut below the Jornada fan-piedmont and the La Mesa basin-plain surfaces. Graded erosional-depositional elements of the surface extend up major arroyos heading in the Organ Mountains in an intermediate position between the Jornada and Picacho surfaces (Ruhe, 1964, fig. 7). The lower preserved portion of the Tortugas surface consists of an erosion surface cut in the mixed-rounded gravel unit, but fan-toeslope or river-terrace elements are not preserved. North of Las Cruces, on the piedmont slopes of the Robledo and Dona Ana Mountains, a well-preserved graded surface intermedi-

ate between the Jornada and Picacho surfaces extends to elevations as low as 125-135 feet above the flood plain (fig. 2). Cemented fan-gravels immediately underlying this surface are downfaulted along the east boundary fault of the Robledo Mountains (hereafter referred to as the Robledo fault). The exact amount of displacement is impossible to determine because of the difficulty of identifying stratigraphic equivalents on both sides of a fault or zone of closely spaced faults. Along the Robledo fault, west of Hill (NE $\frac{1}{4}$ NW $\frac{1}{4}$  sec. 18, T. 22 S., R. 1 E.), displacements of Tortugas fan-gravels in the order of 20 feet can be identified with certainty, while sediments associated with the older basin-fill sequence (upper Santa Fe Group, Kottowski, 1953, 1960) appear to be displaced as much as 200 feet.

Even though no river-terrace elements of the Tortugas surface are preserved in the Robledo-Dona Ana area, there is a possibility that river gravels are interbedded with and overlain by piedmont slope deposits at the eastern extremities of the Tortugas erosional-depositional surfaces flanking the northern Robledo Mountains. The age of river gravels is difficult to ascertain because of lithologic similarities between such units and those associated with the Picacho surface, as well as with the gravels of the "mixed-rounded type" associated with the older basin deposits that have been downfaulted and channelled in the structural valley between the Robledo and Dona Ana Mountains.

### PICACHO SURFACE

The type area of the Picacho surface is located east of Picacho Mountain (sec. 5, T. 23 S., R. 1 E.) and along the southern Robledo piedmont (fig. 2). The Picacho surface here comprises erosional back and footslope surfaces along the mountain front and a coalescent alluvial-fan piedmont surface graded to an ancestral flood plain of the Rio Grande. East of Picacho Mountain, the surface descends to a point about 90 feet above modern flood plain where it is abruptly terminated by a scarp. No ancestral flood-plain surface remnants are preserved in the type area. However, across the river to the northeast, gravelly fan alluvium of Picacho age derived from the Dona Ana Mountains overlies and possibly intertongues with beds of clean, unconsolidated sands and gravels with abundant foreign pebble constituents. These beds may represent a flood-plain channel-gravel facies deposited by the ancestral Rio Grande during the Picacho cycle of erosion and deposition. Exposed thickness of these "river" gravels can be as much as 20-30 feet, with the top of the unit occurring 70-80 feet above the flood plain.

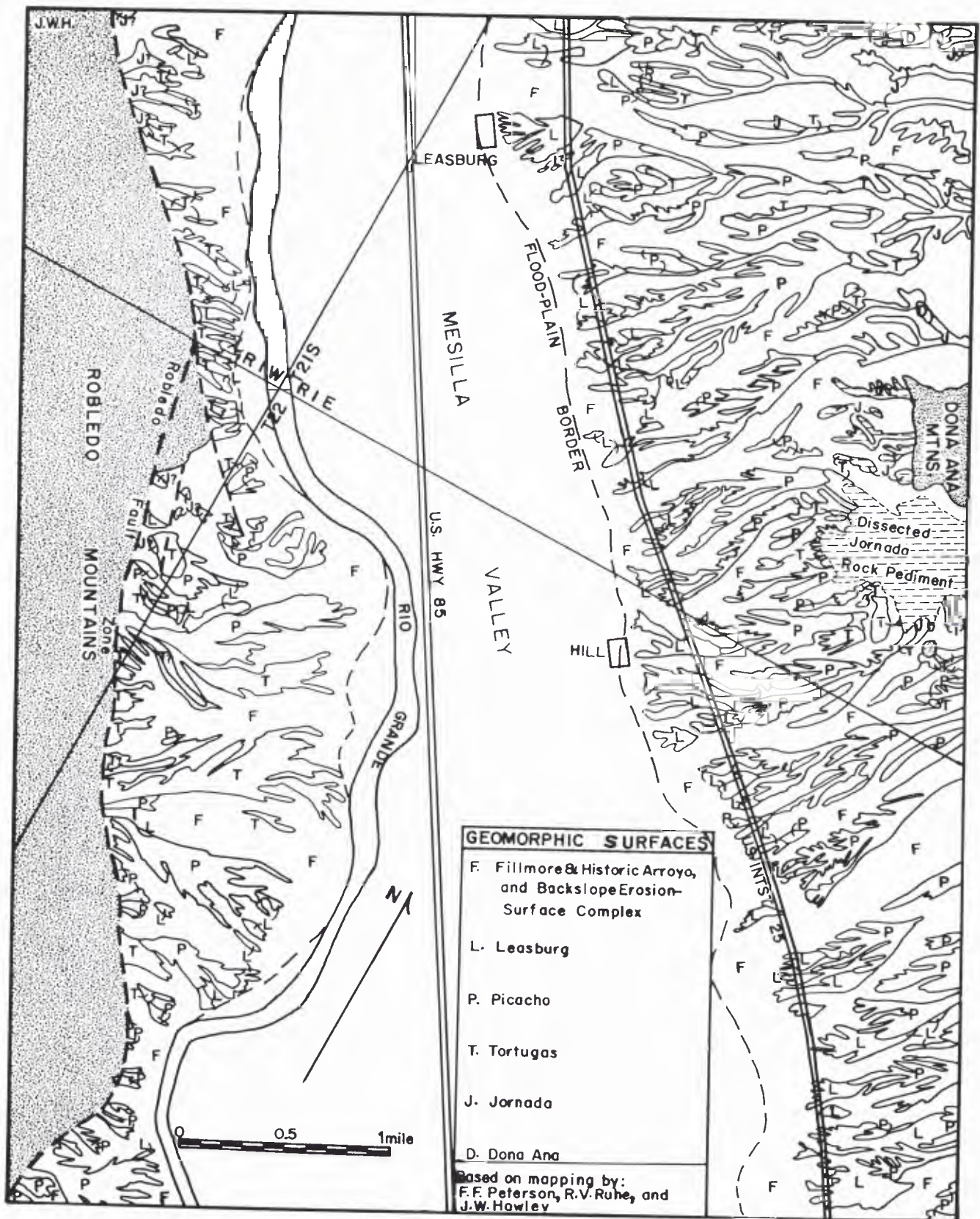


FIGURE 2

Map of geomorphic surfaces in the Robledo-Dona Ana Area, Upper Mesilla Valley, New Mexico.



The Picacho surface is also well preserved along the east side of the Rio Grande valley near Las Cruces-University Park (Ruhe, 1962, 1964) below residuals of "mixed-rounded gravels" whose exhumation began with the Tortugas cycle of valley cutting. Here the Picacho surface is represented by individual alluvial fans at the mouths of major arroyos heading in the Organ Mountains as well as by terraces extending back up the arroyos. Deposits as thick as 70 feet of gravelly to very gravelly loamy sands constitute the Picacho alluvium and rest on partly cemented sands with interbedded silt and clay of Kottlowski's (1953, 1960) Quaternary Santa Fe mapping unit. In most cases, Picacho fan and terrace deposits partially fill channels in Santa Fe sands cut to about the level of present arroyo bottoms, thus indicating a major cycle of aggradation after an initial episode of valley-cutting. Preserved Picacho fan surfaces descend to levels about 160 feet above the present flood plain.

On the west side of the Rio Grande Valley near Santo Tomas-San Miguel (secs. 31, 32, T. 24 S., R. 2 E., secs. 7, 8, T. 25 S., R. 2 E.) there are two sloping basalt-capped valley-border surface remnants, which descend to elevations as low as 120 feet above the flood plain. Dunham (1935) and Kottlowski (1953, 1958, 1960) have suggested that the basalt-capped surface was part of the Picacho surface. Others (Ruhe, R. V., and Peterson, F. F., personal communications) have suggested the possibility that this surface was remnants of a downwarped part of the La Mesa surface, rather than a graded valley-border surface. Reconnaissance mapping in the area west of Chamberino (secs. 13, 14, T. 26 S., R. 2 E.) indicates that, subsequent to the deposition of the mixed-gravels and prior to the development of the Picacho surface, downfaulting and warping of the basin-fill deposits occurred on the riverward side of a northwest-trending line extending from Old Chamberino (sec. 24, T. 26 S., R. 2 E.), along the La Mesa rim to the vicinity of Mesilla Dam (sec. 12, T. 24 S., R. 1 E.). North and south of these points the evidence is lost because the trace of the possible fault zone intersects the river valley. West of Chamberino it appears that the basin-fill section exposed immediately below the La Mesa rim (comprising caliche-capped "mixed-rounded gravels" over clays, silts, sands, and calcite cemented sands and gravels) is repeated along the flood-plain border with an offset of beds in the order of 100 feet. A northwest-trending zone of abrupt termination of strata separates these two sequences. It further appears that the surface capped with the basalt flows near San Miguel-Santo Tomas is part of a graded surface that formed after this faulting and warping. Remnants of this surface are present from Old Chamberino to Mesilla

Dam and could be elements of either the Kern Place-Tortugas or Picacho-Gold Hill surfaces.

#### FORT SELDEN SURFACE COMPLEX

Ruhe (1964) has designated the complex of geomorphic surfaces terminating at low scarps which rise from 5 to 40 feet above the flood plain as the Fort Selden surface. On the basis of detailed mapping, Peterson (Ruhe, 1964) proposed a fourfold subdivision of this complex in order to designate 1 major and 3 minor surfaces ranging in age from late Plesitocene to late Recent. Subsequently, Ruhe, Peterson and the writer reached the conclusion that a twofold subdivision of the Fort Selden surfaces would be more appropriate. The name Leasburg surface is here proposed for the older subdivision, and its type area is along the valley border from Dona Ana to Fort Selden (figs. 1 and 2). The Leasburg surface is typically expressed by one or two minor erosion surfaces, cut below the riverward extremities of Picacho fans and into a clean sand and coarse gravel facies of the Picacho alluvium. In several places, such as east of Leasburg (sec. 30, T. 21 S., R. 1 E.) and north of Dona Ana (fig. 2), the Leasburg surface comprises graded surfaces consisting of fans along the river and inset terraces up the arroyos. At the site of Fort Selden the Leasburg surface is represented by a broad rock-defended river terrace 25-30 feet above the flood plain.

A major cycle of valley entrenchment took place after formation of the Leasburg surface, resulting in cutting of wide valleys to depths at least several feet below the floors of modern arroyos. In some places, as much as 40 feet of subsequent aggradation has occurred along the inner valley borders during deposition of fans at the mouths of tributary arroyos. Radiocarbon dates obtained from charcoal recovered from this alluvium on both sides of the valley (Ruhe, 1964) indicate that this cycle of aggradation began prior to 4,900 years B.P. and culminated sometime after 2,600 years B.P. Peterson (Ruhe, 1964) originally proposed the name Fillmore for this younger member of the Fort Selden surface complex. It is typically represented by the lowest major valley-border fan surface and its associated arroyo terraces and valley-slope erosion surfaces. Minor erosional-depositional surfaces occurring between this surface and the arroyo bottom are now also included in the Fillmore geomorphic surface mapping unit. The present stream system is entrenched from about 3 feet to as much as 40 feet below the valley-border fan surfaces. Activity of the Rio Grande in the past several hundred years (U.S. Reclamation Service, 1914) has resulted in the cutting of scarps ranging from 5 to 40 feet high along the edge

of the flood plain as the river impinged on the toes of the valley-border fans.

In the Mesilla Valley and perhaps elsewhere, the maximum stage of entrenchment of the Rio Grande in latest Pleistocene to early Recent (Leasburg-Fillmore) time is represented by a buried surface occurring at relatively shallow depths below the present flood-plain surface (Kottlowski, 1958). Information from local well drillers, examination of cuttings from several wells, and review of published information on local ground water conditions (Sayre and Livingston 1946; Conover, 1954; Leggat and others, 1963) indicate that the late Quaternary river deposits extend to no more than 80-100 feet below the flood-plain level. This depth represents the approximate thickness of unconsolidated sediments over bedrock at the International Dam Site in El Paso Canyon (Schlichter, 1905) and over Tertiary volcanics and sediments in Selden Canyon-Rincon Valley areas (Conover, 1954).

The deepest occurrence of gravels below the flood plain (over 200 feet near Las Cruces) may not represent the depth of late Quaternary entrenchment (Conover, 1954) or the depth of scour in great floods (Bryan, 1938). Rather these deeper gravels appear to be part of the ancient basin fill and stratigraphically below the basin deposits exposed in the valley walls, except where they can be shown to be downfaulted or downwarped blocks of the upper basin-fill sequence.

## SELDEN CANYON

Kottlowski (1953) has shown Selden Canyon to be an area of complex block faulting, with the Rio Grande following a sinuous course in a canyon cut in Cenozoic volcanic and sedimentary rocks. The river first flows in north-south valleys parallel to the regional structural trend and then cuts eastward through the Selden Hills, across horsts consisting of tilted blocks of mid-Tertiary volcanics and later Tertiary sediments. The Sierra de las Uvas and Cedar-Selden Hills form the upland on the west and east sides of the canyon, respectively. Basin-fill deposits of the Santa Fe Group (Kottlowski, 1953, 1960), overlying tuffaceous sedimentary and pyroclastic rocks and basalt-andesite flows, are exposed in the canyon walls. The Palomas-Jornada-La Mesa complex of basin surfaces, representing several ages and levels of basin-flat and piedmont-slope surface development, occurs from 360 to 600 feet above the flood-plain level. In places, these surfaces and underlying sediments have been faulted and tilted (Kottlowski, 1953).

Strath terraces along the river as well as erosional-depositional surfaces formed by tributary streams graded to the ancestral Rio Grande are preserved in

Selden Canyon. At least three and possibly four geomorphic-surface complexes are cut below the Palomas Surface. The lower three complexes can be related to the Tortugas, Picacho and Fort Selden surfaces as described in the Robledo-Dona Ana Mountain area. The river terrace remnants of these valley-border complexes stand respectively 120-140 feet, 60-80 feet, and less than 40 feet above the flood plain.

Two higher surfaces that Kottlowski (1953) mapped as terrace levels inset below the Palomas surface are graded to elevations about 200 feet and 360 feet above the flood plain. The 200-foot surface represents a very early stage in the entrenchment of the Rio Grande Valley below the basin surfaces and could be considered as a high-level member of the Tortugas surface complex. The "360-foot" surface is here considered to be a downfaulted remnant of the Palomas surface. Along the west edge of secs. 5, 24, 25, T. 20 S., R. 2 W., this surface is underlain by about 70 feet of cobble to boulder gravels with a caliche cap 3 to 5 feet thick. The gravels rest on as much as 10 feet of volcanic ash which lies on 10 to 20 feet of silty sands to clays, and these in turn lie on 5 to 10 feet of rounded siliceous pebble to cobble gravel (mixed-rounded type). Beneath these deposits occurs an unknown thickness of partly cemented brown to reddish brown gravelly loams to sands that have been referred to the lower Santa Fe Group by Kottlowski (1953).

The ash occurs as a lenticular body which apparently pinches out laterally within several hundred yards. Zones as much as 5 feet thick of white, uncemented, massive to laminated glass shards of coarse silt and fine-sand size are present. The index of refraction of the glass is slightly greater than 1.500 ( $<1.510$ ). Ashes with similar physical properties and stratigraphic position (below the basin surface complex and above basal mixed-rounded type gravels) have been identified as belonging to the mid-Pleistocene(?) Pearlette group of ashes in the El Paso region (Strain, 1959, 1965).

## RINCON VALLEY

North of Selden Canyon the valley of the Rio Grande again widens, with the valley walls for the most part being cut in relatively unconsolidated basin-fill materials, ranging from upper clean sand and rounded gravel through sand to lower clays, silts, and sands with varying amounts of angular to subrounded gravel. The west valley border is formed by the broad dissected piedmont-slope surfaces of the Sierra de las Uvas. The east valley border is marked in its southern part by abrupt slopes rising to the surface of the Jornada del Muerto plain and San Diego Mountain.



North of Rincon, where the valley assumes an almost easterly trend, the flood plain is flanked by a stepped sequence of valley-border surfaces ascending to the Rincon Hills and the Rincon surface. The constriction of the valley at Hatch, formed by the fan-complexes at the mouths of Placitas and Thurman Arroyos (secs. 5 and 8, T. 19 S., R. 3 W.), marks the arbitrarily-selected boundary between the Rincon Valley to the south and Palomas Valley to the north.

A sequence of valley-border surfaces similar to those described to the south is present in the Rincon Valley. Two distinct erosional-depositional surface complexes appear to be graded to levels 115 to 150 feet and 65 to 100 feet above the flood plain. These surfaces, particularly well developed along and at the mouths of Bignell, Hershey, Reed, Angostura, and Rincon Arroyos on the west side of the valley, are correlated with the Tortugas and Picacho surfaces of the Las Cruces-Selden Canyon area. A still lower complex of surfaces graded to levels less than 40 feet above the flood plain is present, and it includes members analogous to both the Leasburg and Fillmore members of the Fort Selden surface complex. On the east side of the valley from Rincon to San Diego Mountain, the flood plain is flanked by a dissected 90- to 100-foot terrace surface underlain by a discontinuous veneer of coarse-rounded gravels of mixed composition over sandstone, sand, silt and clay of the Santa Fe Group. These gravels appear to represent a river-gravel facies of the Picacho alluvium.

The Palomas Surface remnants on the piedmont slopes of the Sierra de las Uvas south of Hatch descend as low as 320 to 410 feet above the flood plain. Kottowski (1953) shows that this surface is faulted in many places. Between the Tortugas and Palomas surfaces there is an intermediate graded-surface complex which extends as spurs almost to the flood plain in the Hershey-Angostura Arroyo area opposite Rincon. The lowest points on these spurs range from 180 to 210 feet above the flood plain. Similar surface levels are preserved both in Selden Canyon and in the Palomas Valley. In this area, Kottowski (1953) included most of the pre-Picacho geomorphic sequence within his Palomas surface mapping unit.

## PALOMAS VALLEY

The northernmost segment of the Rio Grande valley herein discussed extends from Hatch to Seco Creek north of the village of Caballo (fig. 1). The segment comprises the southern part of the Palomas Valley. This valley is characterized by a relatively narrow flood plain flanked on the east by the short steep (5-10%) piedmont slopes of the Caballo Mountains and

on the west by the long gentle (1-2%) slopes ascending to the base of the Hillsboro-Animas Hills.

Large tributary arroyos cut by streams heading in the Black Range cross the broad, western valley-border zone. Their floors are entrenched as much as 250 feet below the Palomas surface remnants. Creeks such as Seco, Las Animas, Percha, Tierra Blanca, and Berrenda have drainage basins on the order of 50 to 100 square miles in area, many times larger than the watersheds of most tributaries in the Rincon-Mesilla region. In addition, only in the Black Range do the upper parts or drainage basins exceed 9,000 feet in elevation. These factors coupled with movement of the west Caballo border faults may have contributed in some way to the development of a sequence of valley-border geomorphic surfaces that includes more levels than are typically preserved to the south. Besides the surfaces within 40 feet of the present flood plain associated with the Fort Selden surface complex, there are well-preserved surfaces that appear to be graded to ancestral flood-plain levels within the following elevation ranges above the valley floor: 70 to 95 feet, 115 to 140 feet, 180 to 200 feet, and 250 feet. Surfaces graded to levels from 300 to 500 feet above the present flood plain have been identified as members of the Palomas basin complex of surfaces (Kelley and Silver, 1952; Kottowski, 1953). The younger surfaces typically occur as stream terraces along the arroyos, and as arroyo-mouth fan remnants extending into the valley of the Rio Grande. The 70- to 95-foot surface, well developed at the mouths of Percha, Trujillo, Tierra Blanca, Cuervo Creeks and Placitas Arroyo, appears to be a Picacho-Gold Hill correlative. A small 70- to 90-foot Picacho river-terrace remnant is preserved one mile west of Hatch. The 115- to 140-foot surface is a prominent feature at the mouths of Seco, Trujillo, Berrenda, and Placitas Arroyos. This surface probably correlates with the Tortugas-Kern Place surface complex mapped to the south. The 180- to 200-foot and 250-foot surfaces are best preserved at the mouth of Seco Creek (secs. 13, 24, T. 15 S., R. 5 W.) The lower of these two surfaces is definitely associated with an early cycle of entrenchment below the Palomas surface, and may relate to the "200-foot surface" in the Rincon Valley and Selden Canyon. The upper surface could be a downfaulted or warped remnant of the Palomas surface.

On the east side of the valley, a similar sequence of surfaces is preserved. Because of steep slopes, a general absence of river-terrace remnants, and faulting along the west border faults of the Caballo Mountains, reconstruction of the older ancestral flood-plain levels is difficult. Alluvial fans, stream terraces and erosional surfaces graded to the 70- to 90-foot and 110- to 140-



foot levels (probably Picacho and Tortugas, respectively) are present at the mouths of, and along, most of the larger arroyos. In this area, alluvial deposits associated with the Tortugas and Picacho cycles are difficult to separate, both from each other and from gravelly sediments of the older basin fill attributed to the Santa Fe Group by Kottlowski (1953). Both the Leasburg and Fillmore members of the Fort Selden surface complex are represented by low terraces and fans graded to levels 5 to 30 feet above the present flood-plain surface. In some areas, two graded surfaces occur between the 110- to 140-foot level and definite Palomas pediment and fan remnants which descend to as low as 450 feet above the valley floor. The lower surface is graded to a 180 to 200-foot level and may correlate with similar unnamed surfaces up and down the valley. It may be a high-level member of the Tortugas surface complex. The upper surface could be part of the ancient Palomas basin complex. In this area, as in areas to the south, the correlation of these high-level valley-border surfaces is in doubt because of the possibilities of significant structural displacement since their formation.

## CONCLUSION

In mid-Pleistocene time, the landscape of the El Paso-Caballo region of southern New Mexico was characterized by three interconnected basins and numerous intervening mountain ranges. These basins were the Palomas and Jornada del Muerto basins, and the Mesilla bolson. The landscape also contained remnants of a possible early Pleistocene basin surface, herein named the Rincon surface.

A widespread sand and rounded-gravel unit, containing some rock types foreign to any given local watershed, forms the uppermost unit of the fills underlying the central basin-plain areas. Near Las Cruces a mid-Pleistocene vertebrate fauna has been recovered from these "mixed-rounded gravels." The La Mesa geomorphic surface is underlain by a thin layer of caliche-cemented sands to pebbly sands that grade downward into the "mixed-rounded gravels."

Cyclic entrenchment of the Rio Grande was initiated after development of the La Mesa surface and after a major episode of pedimentation and alluvial-fan deposition on the piedmont slopes that resulted in formation of the Jornada surface. Subsequently, four major cycles of river and arroyo entrenchment accompanied by varying amounts of aggradation have taken place. Disregarding faulting and tectonic warping of surfaces, levels of ancestral flood-plain stability can be reconstructed at elevations of 180 to 200 feet, 115 to 140 feet, 70 to 90 feet, and 20 to 30 feet above

the present valley floor. The 180- to 200-foot level is unnamed, but could be considered to be an older member of the "115-140 foot" surface complex. The 115- to 140- and 70- to 90-foot levels correspond to the Tortugas-Kern Place and Picacho-Gold Hill surfaces, respectively, of Kottlowski (1958) and Ruhe (1964). The Fort Selden complex of geomorphic surfaces (Ruhe 1964) includes late Pleistocene and Recent surfaces graded to ancestral flood-plain levels less than 30 feet above the present valley floor. Entrenchment of the Rio Grande in late Pleistocene to Recent time probably was not more than 100 feet below the present flood-plain level.

As Ruhe (1964) has pointed out, comparison of the sequence of geomorphic surfaces in the Mesilla-Palomas Valley region with the sequence in the San Acacia (Denny, 1941) and Albuquerque-Belen (Wright, 1946) areas (table 1) shows that the major valley-border surface units can be correlated up and down the Rio Grande Valley in central and southern New Mexico.

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