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TERTIARY AND QUATERNARY STRATIGRAPHY OF THE NORTHEAST PLATEAU, ESPANOLA BASIN, NEW MEXICO

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INTRODUCTION

The Espanola basin is the northernmost Rio Grande rift basin in New Mexico (Manley, 1979). It is both a structural and a topographic basin, in which erosion has exposed a thick sequence of predominantly Miocene to Pleistocene sedimentary rocks.

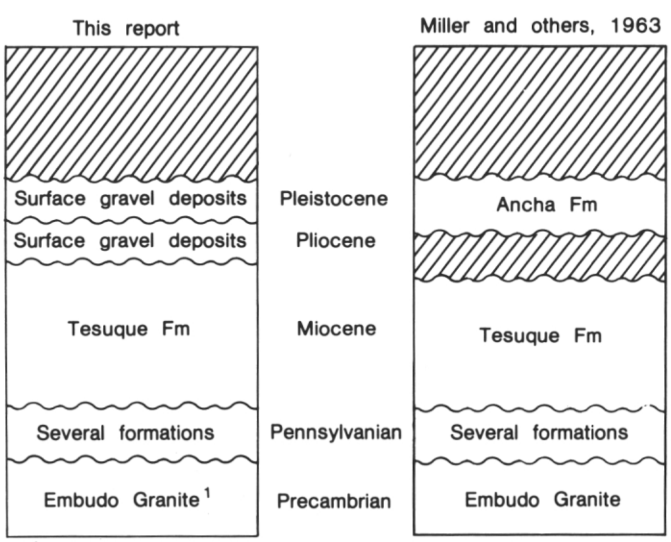
This paper discusses the Tertiary and Quaternary stratigraphy of the northedst part of the Espanola basin. Precambrian, Pennsylvanian, Tertiary and Quaternary rocks are exposed in the area. As a result of my recent mapping, the sedimentary rocks previously mapped (Miller and others, 1963) as the Pleistocene Ancha Formation and part of the underlying Miocene Tesuque Formation have been reassigned to (fig. 1):

1) The Cejita Member of the Tesuque Formation
2) A piedmont facies of the Tesuque Formation
3) High surface gravel deposits of Pliocene to early Pleistocene age
4) Quaternary gravel deposits (including the Santa Barbara, Santa Cruz and Chamisal gravel deposits)

Each of these units is discussed in the following text. The use of the term Ancha Formation for the varied gravel deposits is considered inappropriate and is not used in this report.

The northeast part of the Espanola basin (fig. 2) is a fan-shaped plateau with an apex near Jicarilla Peak; it extends from the Sangre de Cristo Mountains on the east to the Rio Grande on the west. The plateau is bounded on the south by the Rio Quemado and the Santa Cruz valley; on the northeast by the Picuris Range; and on the north by an erosional basin, the Dixon sub-basin.

The northeast plateau has received little study. Galusha and Blick (1971) referred to the area as the Picuris re-entrant fan, but did not map it. They assigned sedimentary rocks in the western Dixon sub-basin to the Ojo Caliente Sandstone Member of the Tesuque Formation and to gravels overlying the Truchas pediment (Galusha and Blick, 1971, p. 67, 70 and 96). Miller and others (1963) mapped the sedimentary rocks in this area and assigned them to three formations: the Tertiary Picuris and Tesuque formations and the Pleistocene Ancha Formation. The Ancha Formation was described as "remnants of a once-continuous sheet of unconsolidated gravel" that is locally more than 90 m thick (Miller and others, 1963, p. 51).



[1] Montgomery, 1963

Figure 1. Comparison of stratigraphic units of this report and an earlier report.

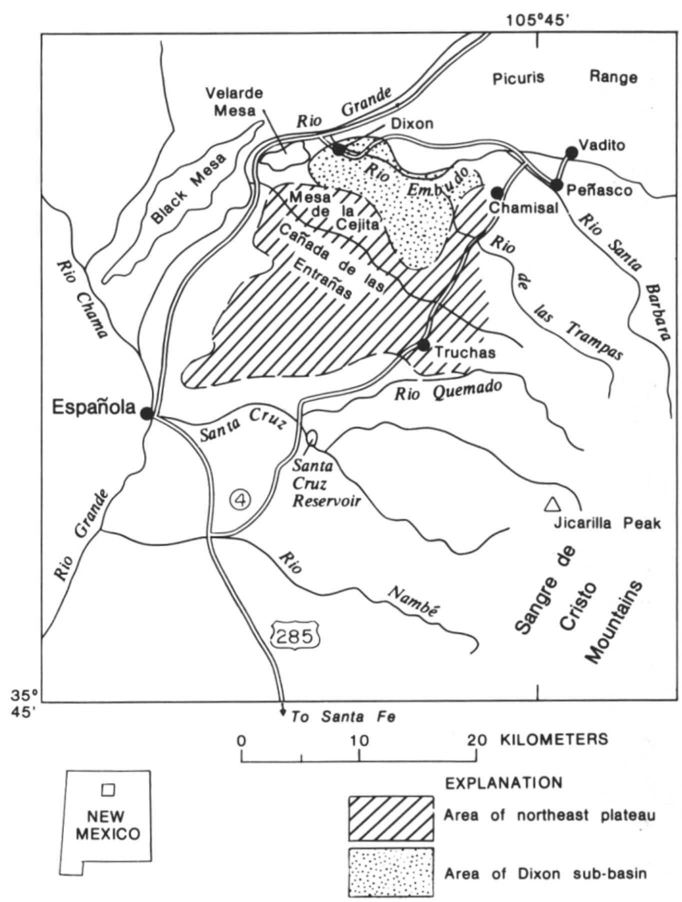


Figure 2. Geographic names in the eastern Española basin, New Mexico. Area of the northeast plateau, and Dixon sub-basin shown by patterns.

TESUQUE FORMATION

Cejita Member

The Cejita Member of the Tesuque Formation is exposed beneath Mesa de la Cejita at the northwest edge of the northeast plateau. The Cejita Member overlies the Ojo Caliente Sandstone Member of Galusha and Blick (1971) and a little known older unit of the Santa Fe Group in the Dixon sub-basin. The Cejita Member is overlain by gravels deposited on the Oso erosional surface. To the south, the Cejita Member interfingers with the piedmont lithofacies of the Tesuque Formation (fig. 3). The Cejita Member varies in thickness from 1.5 to 120 m. It is thickest in the northIPest and thins to the southeast. The original thickness is not known because the upper surface is erosional.

The Cejita Member consists of well-rounded pebble to cobble gravel with interbedded sand layers. Boulders are present in many outcrops; the largest measured is 1.2 m in length. Individual gravel beds may be as much as 37 m thick and laterally continuous for distances of 1.6 km. Large-scale crossbedding is present in some gravel beds. Sand beds are more common at the base and near the southern margin of the Cejita Member than elsewhere. Channels and flute casts are present locally in sand beds. Flute casts and pebble imbrication indicate that transport directions are generally from east to west. Directions and locations are shown on a detailed map of the area (Manley, 1977).

Clasts in the gravels vary from 5 to 65 percent quartzite and from 30 to 95 percent Paleozoic sedimentary rocks. Accessory rock types include granite, quartz and intermediate to silicic volcanic rocks; together, these accessories constitute less than 10 percent of the clasts. The volcanic clasts are found mainly in exposures at the north end of Mesa de la Cejita and are not common to the south. Cementation in the gravels varies from slightly to well cemented by microcrystalline and coarsely crystalline calcium carbonate.

The source area for the Cejita Member of the Tesuque Formation was the Sangre de Cristo Mountains and Picuris Range, based on the following evidence:

1) Clasts in the Cejita Member gravels include Pennsylvanian rocks that contain Pennsylvanian faunas similar to those in exposures at the north end of Mesa de la Cejita and are not east of the Cejita Member exposures.

2) Sillimanite-bearing quartzites in the Cejita Member are similar to the Precambrian rocks of the Sangre de Cristo Mountains and Picuris Range.

3) The intermediate and silicic volcanic clasts seen in the Cejita Member may have been derived from reworking of older sedimentary rocks that contain volcanic clasts. Sedimentary rocks rich in volcanic clasts are exposed presently flanking, and steeply dipping away from, the Picuris Range.

4) Paleotransport directions determined from pebble imbrication and flute casts indicate an eastern source area.

5) Lithologies in the Cejita Member gravels are comparable to those of the terrace gravels along the Rio Embudo. The Rio Embudo has a source in the Picuris Range and the Sangre de Cristo Mountains.

The Cejita Member probably was deposited by a major river that flowed westward from the Sangre de Cristo Mountains into or through what is presently the Española basin. The direction of flow and provenance indicate that this river was not an ancestral Rio Grande. The river was aggrading and shifting across a valley floor at least 5.6 km wide. Along the southern margin of the flood plain, the river gravels interfinger with piedmont sands and gravels of the Tesuque Formation.

Piedmont Lithofacies

These deposits were mapped previously by Miller and others (1963) as part of the Ancha and Tesuque formations. My work (Manley, 1976a) shows no basis for a contact between these units as shown by Miller and others (1963). Almost all of their Ancha Formation is considered here to be continuous with the Tesuque Formation. Only the uppermost thin (3 m) surface gravels are Pliocene/Pleistocene in age. The piedmont facies of the northeast plateau is continuous with the Tesuque Formation as mapped by Galusha and Blick (1971) to the south.

The piedmont lithofacies of the Tesuque Formation underlies most of the northeast plateau. The piedmont lithofacies overlies older sedimentary rocks, such as the Picuris Tuff of Cabot (1938) and the unmapped older Santa Fe Group of the eastern Dixon sub-basin; it is overlain unconformably by the high surface gravels.

The piedmont lithofacies varies considerably in thickness. It is 310 m thick at the southern margin of the plateau and may be considerably thicker toward the center of the basin, where accurate measurements are not feasible because of numerous high-angle faults. East of State Highway 4, the piedmont lithofacies thickens and thins where it fills valleys cut into the Precambrian Embudo Granite prior to deposition of the Santa Fe Group. In several places, the piedmont lithofacies has been stripped from the Embudo Granite. The original thickness of the piedmont lithofacies cannot be determined because its upper surface has been truncated during the formation of the three high erosional surfaces of the northeast plateau. Gravel-capped hills of Embudo Granite protrude 60 m above the

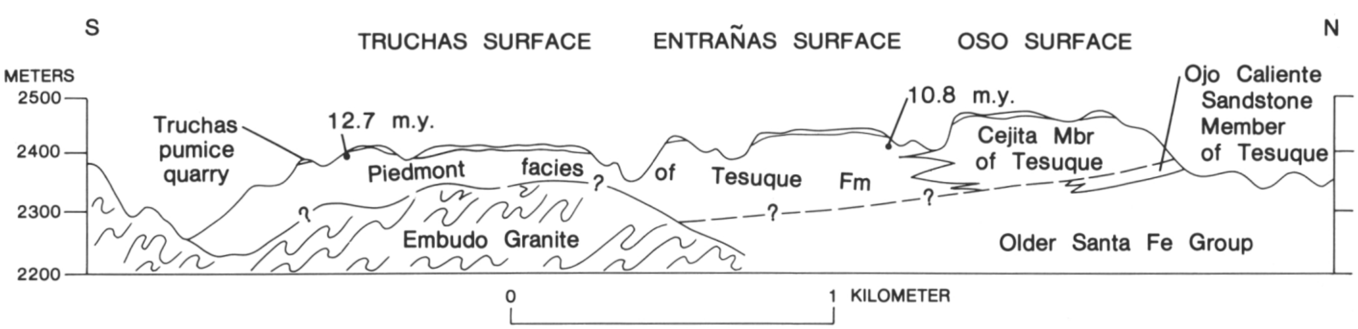


Figure 3. Cross section of the northeast plateau. Location of section shown on Figure 4 as D-D′-D″.

highest surface near the mountains, which implies that the piedmont lithofacies was once at least 60 m thicker.

The piedmont lithofacies consists of poorly defined, discontinuous beds of sandy pebble gravels with some gravelly sand, gravel and sand beds. Clay content is generally low, although locally dark-red, clay-rich zones are present. Several tephra layers and tuffaceous sediments are present, especially toward the northern part of the plateau. Crossbedding is locally present in the sand and gravelly sand beds. Channel cuts at the base of gravel beds are common. Individual beds are as much as 12 m thick. Clasts are angular to subround. Sorting varies from poorly sorted in the sandy gravels to moderately well sorted in the sand beds. Sand samples average 3.50 (determined by visual comparison to sized standards (Folk, 1968)). Gravels are predominantly quartzite (some of which contains sillimanite) and granite. Muscovite or biotite schist, gneiss, amphibolite and quartz also may be present in lesser amounts. The sand and granule fractions commonly contain abundant quartz and feldspar grains because of the disintegration of the granite into mineral grains.

Some parts of the piedmont lithofacies are cemented with microcrystalline calcium carbonate cement. Gravel beds are better cemented than sands, but both may weather to ledges. Some poorly cemented sands contain high percentages of altered shards, pumice fragments and phenocrysts. Cementation is more prevalent near the center of the basin than near the mountain front.

The piedmont lithofacies was deposited as coalescing alluvial fans which prograded westward from the Sangre de Cristo Mountains. The source rocks were the Precambrian granites of the Embudo Granite and Precambrian quartzites of the Ortega and Vadito formations (Montgomery, 1953). Deposits of the piedmont facies resemble the sheetflood and sieve deposits described by Bull (1972) as being characteristic of alluvial fans.

Ash and pumice beds occur in the piedmont facies of the Tesuque Formation in numerous localities (Manley, 1976a, 1977). Miller and others (1963, p. 51) mention one locality north of the town of Truchas and suggest its source to be the Valle Grande (Valles) caldera in the Jemez Mountains. Most tephra deposits can be traced for only short distances (1.5 m or less) because of limited exposures or lensing of the deposits. In order to establish the stratigraphic relations of four geographically separate tephras, detailed chemical and petrographic studies were completed. Only two of the pumices correlate with each other.

Stratigraphic Relations and Ages

The Cejita Member interfingers with the piedmont facies; the interfingering relationship is observed best along the north side of Canada de las Entranas. Several Cejita gravel beds are separated by piedmont sand and gravel beds within a zone of small faults. The differences in clast composition, size and angularity allow for easy separation of these two lithofacies. Farther west, just west of the windmill, at 2,152 m altitude, a single bed of Cejita gravel is intercalated with nontuffaceous piedmont deposits below and piedmont deposits containing some tuffaceous layers above. The Cejita Member gravel pinches out westward, but the tuffaceous piedmont deposits are present. A pumice layer in these deposits, the Orilla pumice, a local informal unit, has provided an age for the formation.

Previous work has not determined unequivocally the age of the Tertiary rocks of the northeast plateau. Galusha and Blick (1971) assigned most of the sedimentary rocks along the southern margin of the plateau to their Pojoaque Member of the Tesuque, to which they have given a late Barstovian (Valentine) to Clarendonian land-mammal age (Wood and others, 1941). The western margin of the plateau was mapped partially as the Chamita Formation (Galusha and Blick, 1971) of Hemphillian land-mammal age. The upper several hundred meters of deposits in some places were considered Pleistocene in age by Galusha and Blick (1971) and Miller and others (1963).

Zircon fission-track dating of two tephra deposits in the piedmont lithofacies establishes a Miocene age. The Orilla pumice, originally mapped as part of the Pleistocene Ancha Formation, has a radiometric age of 10.8 m.y. A pumice west of Truchas, mapped as part of the Pojoaque Member by Galusha and Blick (1971) and as part of the Ancha Formation by Miller and others (1963), is 12.7 my. old (Manley and Naeser, 1977).

Radiometric dating and stratigraphic evidence indicate that the piedmont facies and the Cejita Member are contemporaneous and that both units are part of the Tesuque Formation, as described by Galusha and Blick (1971).

POST-TESUQUE FORMATION DEPOSITS

High Surface Gravel Deposits on the Northeast Plateau

The Embudo Granite and Tesuque Formation are truncated by three distinct geomorphic surfaces that extend northwest from the Sangre de Cristo Mountains to the northern margin of the Espanola basin. Gravel deposits on these erosional surfaces were included in the Ancha Formation by Miller and others (1963) and given a Pleistocene age. The presence of these erosional surfaces and the overlying gravel deposits helped create the illusion that all the sedimentary rocks of the northeast plateau were young fan or pediment-gravel deposits (Cabot, 1938; Galusha and Blick, 1971; Miller and others, 1963).

The erosional surfaces from north to south are the Oso, the Entrafias and the Truchas (fig. 4). Each surface has been named for the drainage to the north of it. The Oso is the highest in altitude; the Truchas is the lowest. The differences in altitude between each two surfaces are about 30 m. Unfortunately, only one good exposure has been found of the contact between the gravels on these surfaces and the underlying Tesuque Formation. This exposure shows that gravels overlying the Oso surface truncate the underlying Tesuque Formation with angular unconformity. Here the gravel is 3 m thick.

Gravel deposits on these erosional surfaces are distinct in size and composition from the underlying Tesuque Formation. Clasts are quartzite, with only traces of other metamorphic rocks and granite. Surface gravels are coarse: boulders are commonly 100-130 cm in length and more well rounded than pebbles and cobbles. Boulders as large as 139-176 cm long have been found in gravels on the Oso and Entranas surfaces, respectively, 20 km from the mountain front.

Each of the gravel deposits has a well developed soil. Relic soils consist of cambic and argillic B horizons underlain by indurated calcium carbonate and silica-enriched horizons

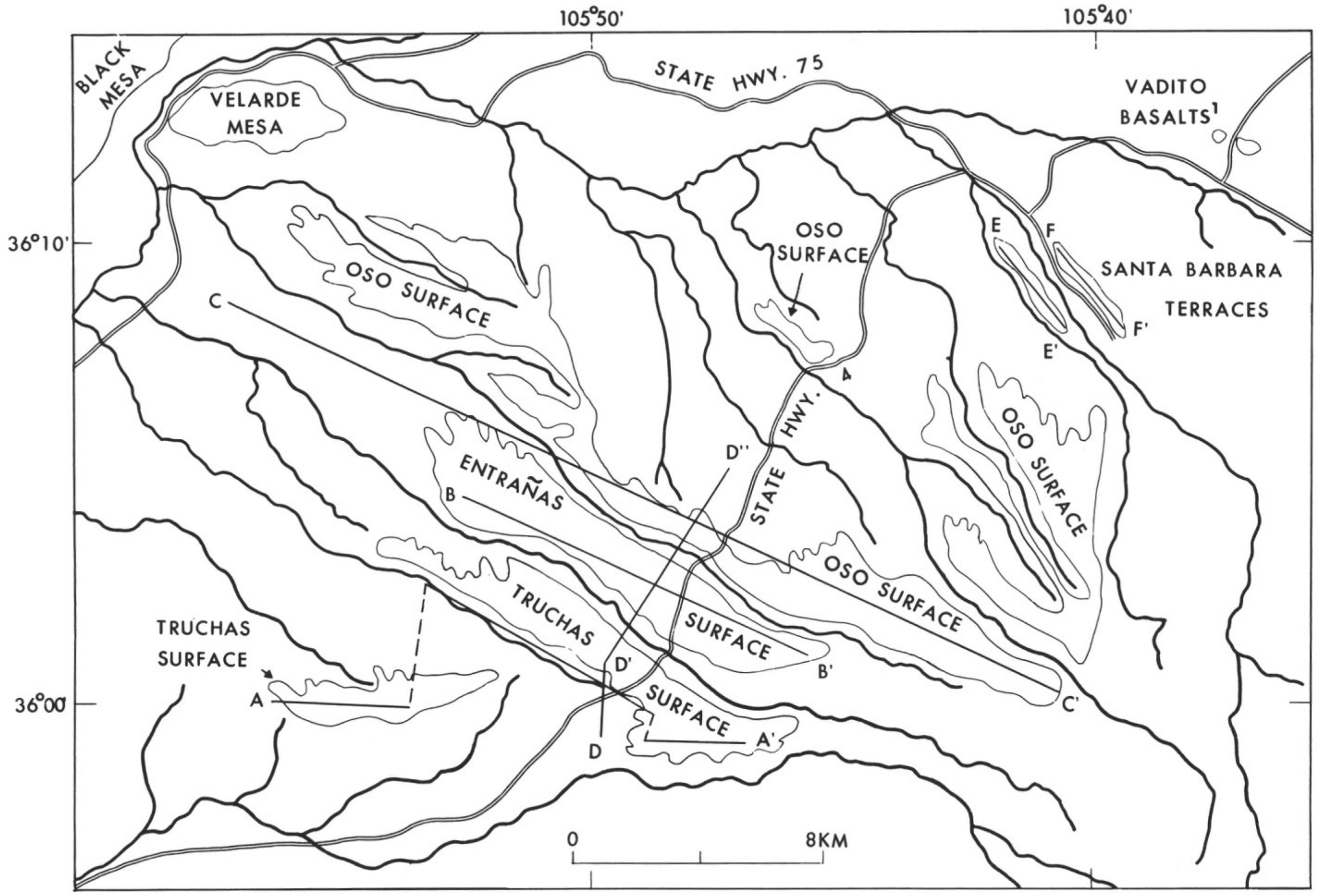


Figure 4. High surfaces on the northeast plateau. The profiles indicated by A-A', B-B' and C-C' are shown in Figure 5. Profiles for the Santa Barbara terraces, E-E' and F-F', are compared to the profile for the Oso surface in Figure 6.

(hardpans). The B horizons are as much as 0.3-1 m thick. The hardpans are 0.6-1.2 m thick, and the upper part of each horizon shows laminar structure. The few foliated metamorphic clasts present have been wedged apart by calcium carbonate crystallization.

Longitudinal profiles for the Oso, Entrarias and Truchas surfaces show gentle gradients (fig. 5). Distal extension of these profiles suggests former base levels of the Rio Grande.

The ages of the surface gravels have been determined approximately by K-Ar dating and correlation of pumice. The Oso surface, which is the highest and oldest surface, extends to within 2 km of Velarde Mesa. By extending the profile of this surface, it appears to be graded to a surface on Velarde Mesa which is overlain by gravel deposits that, in turn, are overlain by a basalt flow of the Servilleta Formation (Cabot, 1938). The composition of the gravel below the basalt flow is similar to that of the gravel overlying the Oso surface, with the exception of the intermediate volcanic clasts found in the gravel deposits of Velarde Mesa. The basalt on Velarde Mesa was once continuous with the basalt that caps Black Mesa on the west side of the Rio Grande; this Black Mesa basalt has a K-Ar age of 2.8 m.y. (Manley, 1976b). This basalt overlies the Chamita Formation, which has two zircon fission-track ages near 5 my. Therefore, the gravel deposits on the Oso erosional surface are as old or older than 2.8 my., but younger than 5 m.y.

The three high erosional surfaces appear to represent a stair-stepped sequence of downcutting and valley-broadening cycles; the drainage had shifted southward prior to each rejuvenation. The gravel deposit on each surface was deposited simultaneously with the cutting of the underlying surface.

A minimum age for the formation of the youngest erosional surface is 1.4 m.y. The Truchas pumice quarry, south of the town of Truchas, is located at the head of a valley cut 37 m below the Truchas surface. Underlying the pumice are gravels related to the cutting of this valley (fig. 3). These gravels overlie older, more weathered gravels belonging to the Tesuque Formation. These relationships indicate that the air-fall pumice is younger than the formation of the Truchas surface. The pumice at the Truchas quarry has been correlated with the Guaje Pumice Bed of the Bandelier Tuff (Manley, 1976a). The Guaje Pumice Bed has been K-Ar dated at 1.4 m.y. (Doell and others, 1968).

In summary, the age of the high surface gravels can be bracketed between 5 and 1.4 m.y., and they probably were deposited between 3 and 2 m.y. B.P.

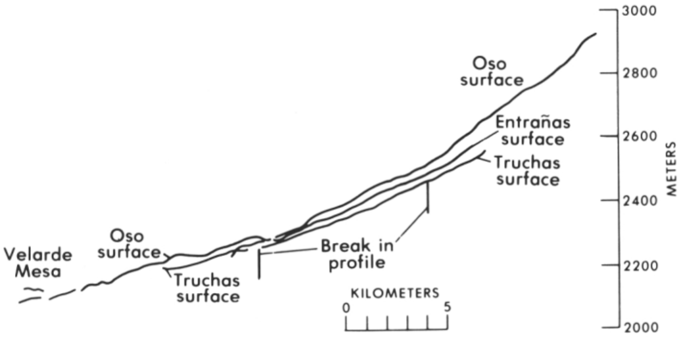


Figure 5. Profiles of the high surfaces. The Oso surface extends beneath the basalt-capped Velarde Mesa. See A-A′, B-B′ and C-C′ on Figure 4 for locations.

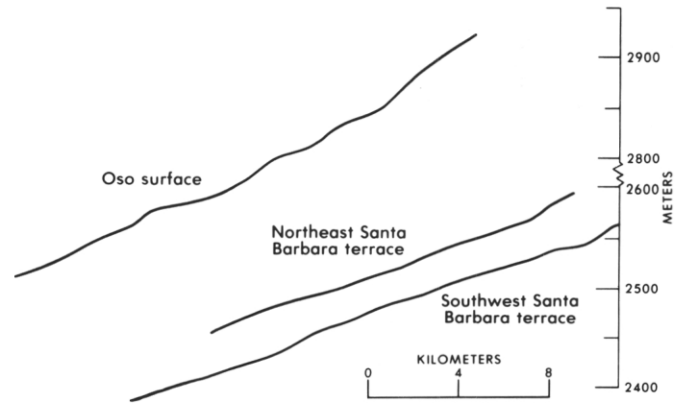


Figure 6. Surface profiles for the terraces along the Rio Santa Barbara compared to the profile for the Oso surface. See E-E′ and F-F′ on Figure 4 for locations.

Quaternary Gravel Deposits

Along the eastern margin of the Espariola basin are several Quaternary erosion surfaces and terraces. Many of the gravel deposits were included in Miller and others' (1963) Ancha Formation. Near the northeast plateau, three areas of gravel deposits have been examined to determine stratigraphic relations with respect to the gravel deposits on the three high surfaces and in the Tesuque Formation.

Santa Barbara gravel deposits

Two prominent terraces parallel the Rio Santa Barbara from the mountain front to the town of Periasco. The terrace on the northeast side of the river is the higher of the two, approximately 50 m above the valley floor, and is underlain by 24 m of gravel. Gravel deposits of the lower terrace are 4.6 m thick and are 24 m above the present flood plain. Gravel deposits of both terraces are composed mainly of well rounded cobbles of Paleozoic rocks that overlie the more quartzite-rich, pebble gravel and sand of the Santa Fe Group.

Both of the terraces are cut into the Santa Fe Group below the elevation of the Oso surface gravels to the south and are, therefore, younger. The terraces have more gentle gradients at equivalent distances from the mountains than do the high erosion surfaces (fig. 6), implying a source area farther east. It is probable that the terraces are outwash terraces. Although neither of them can be traced physically to glacial deposits, there are moraines farther up the Rio Santa Barbara in the Sangre de Cristo Mountains. On the basis of their altitude and proximity to present drainage, they are most likely of Wisconsin age.

Santa Cruz gravel deposits

The gravel deposits on prominent erosion surfaces northeast and southwest of Santa Cruz reservoir overlie the Tesuque Formation with angular unconformity. The gravel deposits are 17 m thick and mainly consist of cobbles and small boulders (maximum size observed, 76 cm) of quartzite. The erosion surfaces are cut into the Tesuque Formation below the base of the lowest high-surface gravel (the Truchas surface gravel) and are, therefore, younger. Imbrication of clasts indicates a westward direction of transport for the gravels.

Chamisal gravel deposits

The flat-topped hills north of the town of Chamisal are underlain by well rounded cobble gravel and silty sand beds. The gravel is 3 m thick, overlies the Santa Fe Group, and is overlain by 4.6-9 m of silty sand beds that contain small angular pebbles. The gravel-sized clasts are predominantly Paleozoic sandstones accompanied by minor basalt, quartzite and Paleozoic limestone clasts. Angular pebbles in the silty sand beds are quartzite with granite and limestone clasts scattered across the surface. The origin of these gravel deposits is unknown. They do not resemble the Cejita Member or the piedmont lithofacies of the Tesuque Formation. The presence of basalt and abundant Paleozoic clasts suggests that the Sangre de Cristo Mountains and the basalt flow near Vadito were source areas. If this assumption is correct, then the gravel deposits postdate the 5.1-m.y. age of the flow (Manley, 1976b) and are late Pliocene or Pleistocene in age.

CONCLUSIONS

The sedimentary rocks of the northeast plateau have been assigned to the Tesuque Formation and to a series of Pliocene and Pleistocene surface and terrace gravel deposits on the basis of detailed mapping and radiometric dating. The Tesuque Formation contains pumice beds radiometrically dated at 11 and 13 m.y. old. These ages should correlate with rocks containing Barstovian or early Clarendonian fauna (Evernden and others, 1964). This northeastern part of the Tesuque Formation would be equivalent in age to the lower part of the Pojoaque Member of Galusha and Blick (1971).

The surface and terrace gravels are divided into three high deposits of Pliocene age and several distinct, less extensive Quaternary units. The high surfaces were cut across older basin fill (Tesuque Formation) between approximately 3 m.y. and 1.4 m.y. ago.

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