Circular 175 1982

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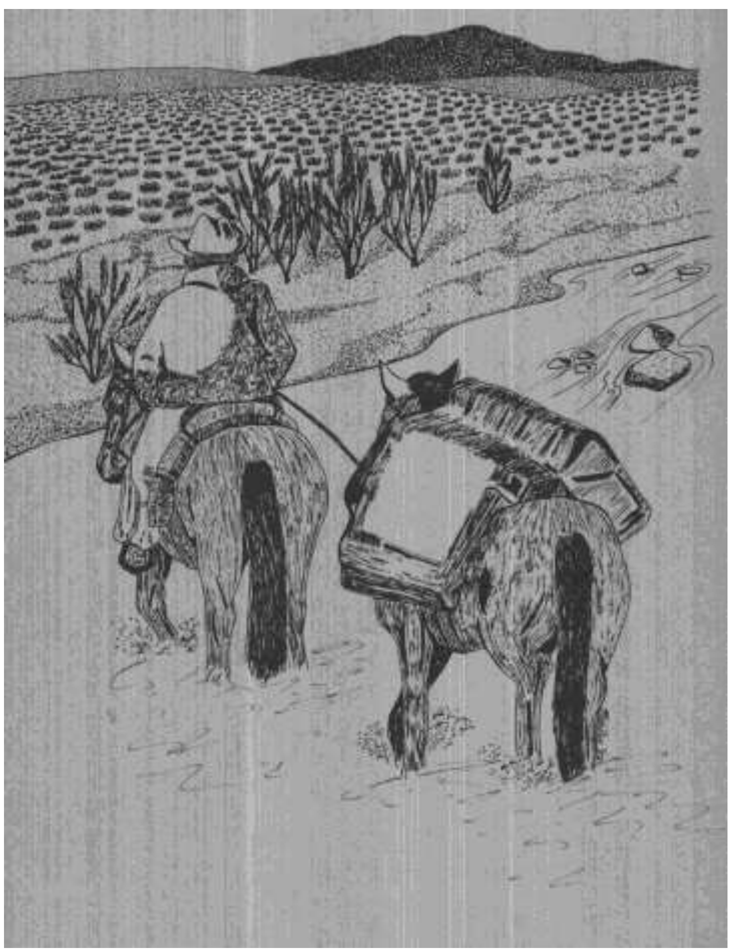

New Mexico Bureau of Mines & Mineral Resources
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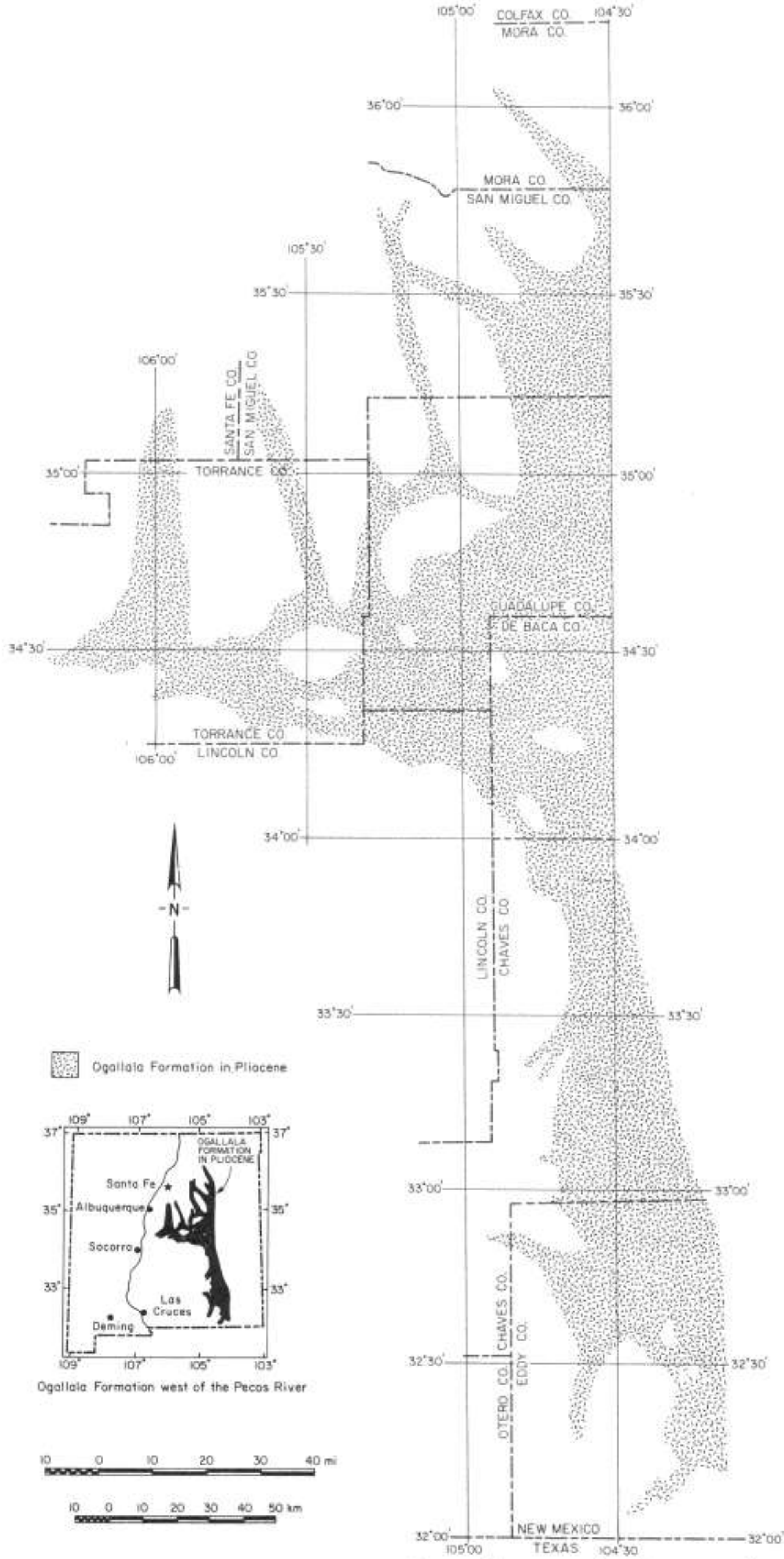


FIGURE 1—MAP SHOWING MAXIMUM WESTERN EXTENT OF OGALLALA FORMATION IN NEW MEXICO DURING PLIOCENE.

Abstract

The present study defines the western limits of the Ogallala Formation (upper Tertiary) and documents the late Cenozoic geology of the region including fragmentary deposits of early Pleistocene age and molluscan faunas of Wisconsinan and Holocene age. The Ogallala was deposited during the latest Tertiary episode of alluvial deposition throughout the Great Plains, where this formation has been documented extensively. However, the Ogallala has not been previously traced to its primary sediment source in the Rocky Mountain belt. Streams feeding the extensive Great Plains alluvial blanket of Ogallala sediments headed in the mountain belt and flowed east and southeast, but identification of these streams and their sediments is obscured in northern New Mexico by extensive volcanic activity. Farther north in Colorado, the extensive erosional belt of the Colorado piedmont has removed evidence of late Tertiary history. Therefore, central and southern New Mexico are the only regions where tracing of headwater sources is possible. This unique situation is largely the result of the late- and post-Ogallala structural history of the region. Extensive warping of the uppermost Tertiary surface occurred here, with less differentiated uplift of the mountain belt to the west than the uplift that occurred farther north.

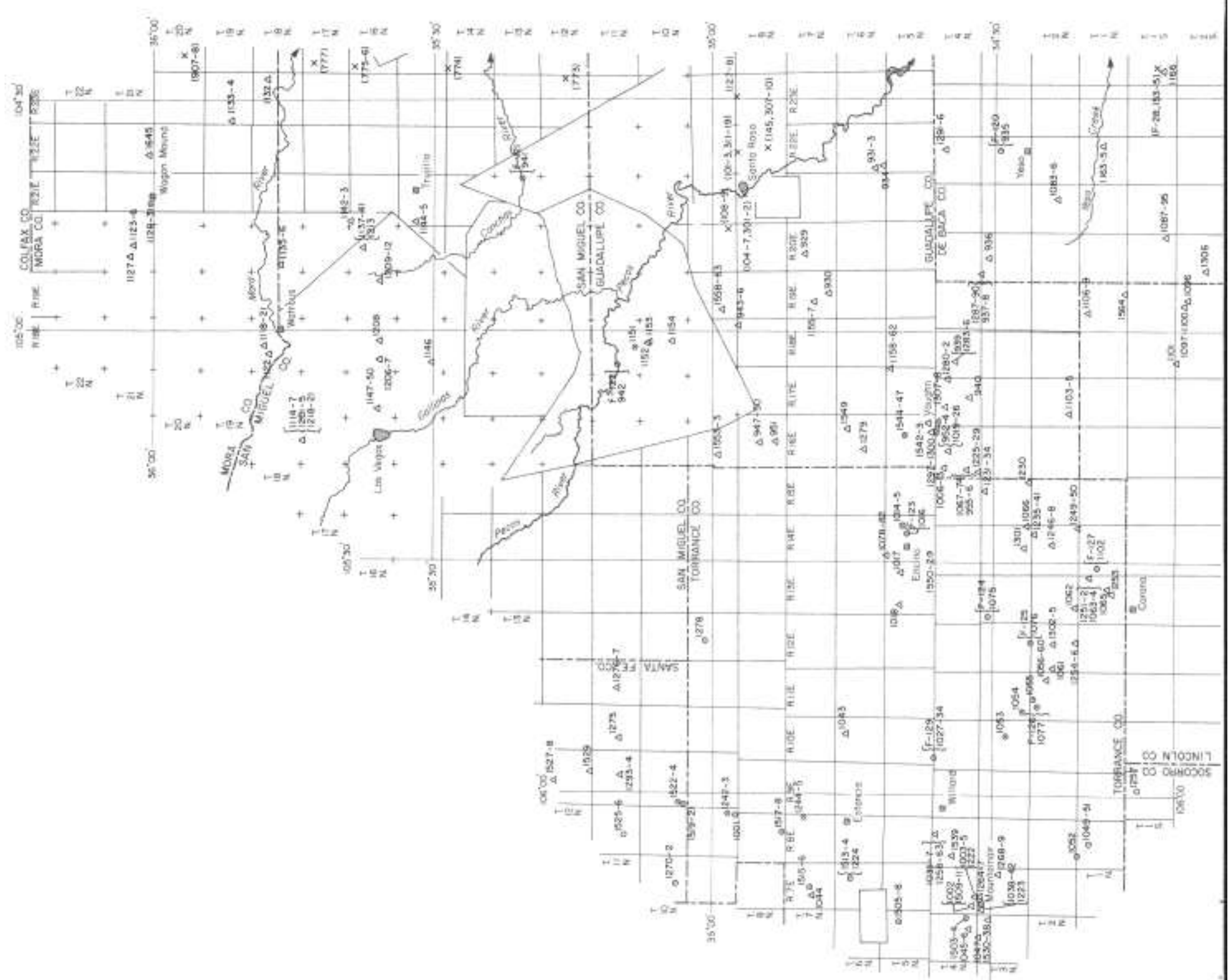
Introduction

A reconnaissance study of the late Cenozoic geology of eastern New Mexico (east of the Rio Grande drainage) was undertaken during the summer of 1971. Since then, this program was continued through 1979 with 2 to 3 weeks of field work each summer. Results of this work have been presented in a series of regional and topical short reports (Frye and Leonard, 1972; Frye and others, 1974; Frye and others, 1978; Glass and others, 1973; Leonard and Frye, 1975, 1978; Leonard and others, 1975).

The program was started on the High Plains of extreme eastern New Mexico and dealt with the stratigraphy of the Ogallala Formation (upper Tertiary) and associated Pleistocene and Holocene basin fills, terrace deposits, molluscan faunas, and clay-mineral compositions. The study initially was concerned with the westward correlation of units described earlier in west Texas (Frye and Leonard, 1957a, 1959, 1968; Leonard and Frye, 1962). As the field work proceeded westward to include the valley of the Pecos River, it became clear that large areas are underlain by the Ogallala Formation west of the Pecos Valley but that the westward extent of the formation had not been defined. The irregular belt of mountains between the Rio Grande and Pecos River drainages was a major sediment source for the generally easterly flowing streams that carried and deposited sediments of the Ogallala Formation. Delineation of the western extent of the Ogallala and location of through-flowing drainages are of considerable significance to the understanding of the late Tertiary history of the region. Another aspect of this understanding involves the Plio-cene-Pleistocene structural warping of the region east of the mountain belt. Because the Ogallala sediments were deposited on a generally easterly sloping surface, identification of stratigraphic units in conjunction with present elevations aids in determining structural warping that occurred in post-Ogallala time. In order to understand the stratigraphy, the sparse Pleistocene and Holocene deposits of the region also were studied to determine approximate dates from their molluscan faunas.

The present study is intended to address these questions. Stratigraphic studies of the Ogallala Formation relied heavily on clay-mineral compositions and descriptive lithologies. Earlier work in eastern New Mexico developed a stratigraphic zonation of the Ogallala Formation based on distinctive sequential stratigraphic changes in the clay-mineral assemblages of the sediments. These zones have been traced from the southern to the northern borders of the state, and in northeast New Mexico the zones have been correlated with the fossil-flora zones identified in west Texas and traced northward to Nebraska. Maps of the area covered (fig. 2) show the location of samples collected and analyzed and the sites of fauna collections described.

Field work on the project, conducted for a brief period during each summer from 1975 through 1979, was supported by the New Mexico Bureau of Mines and Mineral Resources. The x-ray and clay-mineral analyses and radiocarbon dates were determined in the laboratories of the Illinois State Geological Survey.



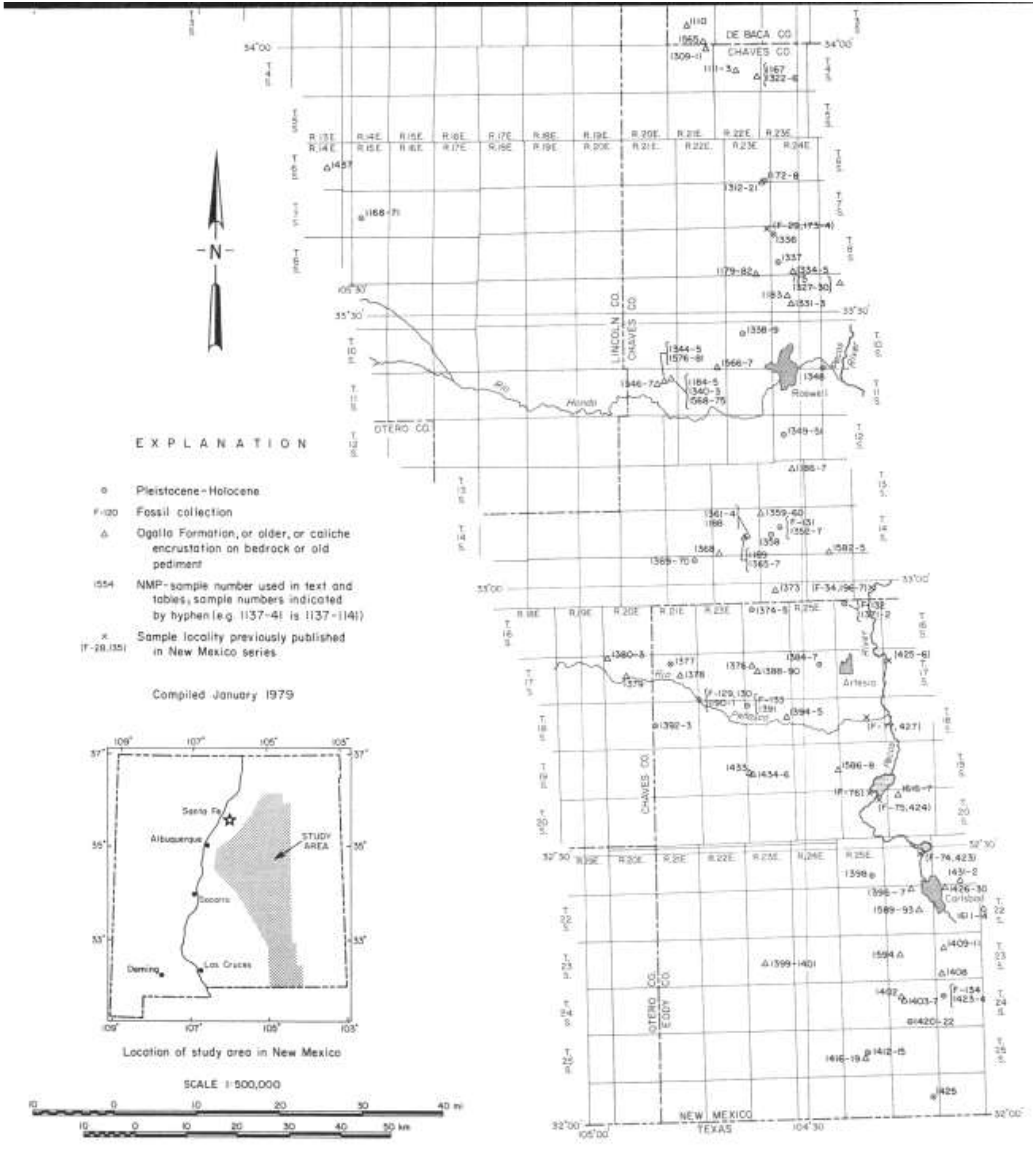


FIGURE 2—MAP SHOWING LOCATION OF SAMPLES AND FAUNA COLLECTIONS.

Ogallala Formation

The Ogallala Formation (originally spelled Ogalalla) was named and first described by N. H. Darton in 1899 from its occurrence in the territory occupied by the Ogalalla Indians in southwest Nebraska and adjacent parts of Kansas. In his original description, Darton did not designate a type section but later (Darton, 1920) he stated that the formation was typically exposed near Ogallala Station in western Nebraska. Later, Elias (1931) and Hesse (1935) reexamined the area and proposed a type section on the Feldt Ranch, 2 mi east of the present town of Ogallala, Nebraska. In 1942 Elias described the fossil-seed floras of the Ogallala Formation in Kansas and Nebraska and established floral zones for the region.

After Darton's original description, Johnson (1901) and other workers correlated and described these deposits southward across Kansas and the Oklahoma panhandle into north Texas. In 1915 Baker described these deposits in northwest Texas and adjacent east-central New Mexico but did not use the term Ogallala in New Mexico. The name Ogallala Formation was introduced into New Mexico by Darton (1928, p. 58). Subsequently, Theis (1932) described the formation in some detail in Curry and Roosevelt Counties, New Mexico. During the past decade, there has been a regional program to study the Ogallala and younger deposits in eastern New Mexico.

Stratigraphy

The Ogallala Formation consists of alluvial sediments, ranging from coarse gravels to silt and clay, with locally intercalated eolian deposits in the southern part of the region. The primary sediment source was in the Rocky Mountain belt that extends northward across New Mexico and Colorado into Wyoming. The Ogallala was deposited during the late Tertiary (Miocene and early Pliocene) on the widespread erosional surface extending eastward from the mountain front. Early deposition, localized along erosional valleys with gentle side slopes, occurred in the same pattern as the drainage on the middle Tertiary erosion surface. Sediments did not accumulate as a typical mountain-front alluvial fan, as suggested by Sellards and others (1933), because the earliest deposits accumulated along former valleys some 100 mi east of the mountain front (Frye and others, 1956). The progressively younger deposits spread in all directions from the earliest areas of deposition until the entire region east of the mountains became an alluviated apron.

Deposition appears to have been caused by a combination of factors, the most important of which were slow but progressive climatic changes toward dessication and perhaps even slower tectonic tilting of the region. Cessation of the long episode of alluviation probably was brought about by progressive development of the same factors that reduced the competency of the mountain streams that carried sediments eastward and deposited them in the alluvial apron.

The lithologic character of the Ogallala sediments is controlled by: 1) the mountain-headwater source, 2) the increment added from rocks in the region east of the mountains, and 3) the diagenetic changes in clay-mineral species caused by the progressively changing climate and the resulting chemistry of ground water and near-surface water. These factors also caused a progressive change in the fossil floras and faunas.

The mountain sediment source is significantly different from north to south. In northern New Mexico, the Sangre de Cristo Mountains are the dominant source of coarse clastics contributed to the Ogallala sediments. The sediments of these mountains are from metamorphic and igneous rocks (mostly Precambrian); these sediments also contain some Tertiary crystalline rocks and Pennsylvanian sedimentary rocks. Southwest of the Sangre de Cristos, the Sandia and Manzano Mountains become major source areas of similar sediments. Southeast of the Sandias and Manzanos, in the Jicarilla Mountains, Triassic, Cretaceous, and Tertiary sedimentary and volcanic rocks predominate. Source areas southeast of the Jicarillas include the Capitan Mountains, the Sacramento Mountains, and the Guadalupe Mountains on the southern border of the state. In this southern segment metamorphic and igneous rocks thin out, and sedimentary rocks that are dominantly limestone become the predominant clastic component of Ogallala sediments.

The secondary sediment source for the Ogallala throughout the region is in Triassic, Cretaceous, Pennsylvanian, and Permian rocks. However, the mix changes southward where Permian rocks become dominant.

The primary and secondary sources of Ogallala sediments furnish convincing evidence concerning the northwest-southeast flow of the depositing streams; however, these sources do not aid in the stratigraphic subdivision of the formation because the alignment of the Ogallala-depositing streams remained reasonably constant throughout deposition of the formation. Therefore, for aid in stratigraphic subdivision it is necessary to study the minerals of Tertiary sediments and the diagenetic changes of the clay-mineral component.

The stratigraphic zonation of the Ogallala Formation in eastern New Mexico was described by Frye and others (1974); the correlation of clay-mineral stratigraphic zones with floral zones recognized from Texas to Nebraska was described by Leonard and Frye (1978).

The description of the clay-mineral zones as originally presented for east-central New Mexico follows (Frye and others, 1974, p. 7-8):

At depths greater than about 50 ft below the top of the formation, the clay-mineral assemblage consists predominantly of montmorillonite, ranging from 76 to 98%, with very minor amounts of kaolinite and illite, and locally accompanied by identifiable amounts of heulandite. This lowest zone is low in carbonate minerals, and will be referred to as the montmorillonite zone, or *zone I.* At about 50 ft below the top, small amounts of attapulgite (palygorskite) appear and increase upward to about 10 ft below the top, locally reaching a maximum of about 85% of the clay-mineral assemblage. As illite and kaolinite remain essentially constant at very small percentages, and as attapulgite increases upward at the expense of montmorillonite, this zone (from about 50 to about 10 ft) will be called the attapulgite zone, or *zone II.* Calcium carbonate increases sharply in the upper part of this zone. Opal commonly occurs in the middle and upper part of the attapulgite zone, as well as in the overlying sepiolite zone.

Next above the attapulgite zone is an interval characterized by the presence of sepiolite in association with attapulgite *(zone III).* In this unit sepiolite generally exceeds attapulgite in amount, and the sum of the two may reach a maximum of about 85^{0}7o of the clay-mineral assemblage. Only in *zone III* has the mineral sepiolite been detected. This zone is only 2-4 ft thick, contains small amounts of illite and kaolinite, and commonly the lowest percentage of montmorillonite found in the Ogallala Formation. This zone generally contains a high percentage of calcium carbonate, ranging up to more than 90%. In contrast to the sepiolite-rich Woodfordian pond deposits which may contain authigenic dolomite (Glass and others, 1973), the mineral has not been detected in *zone II* and *III* of the Ogallala. Opal, which locally occurs in the middle and upper part of the attapulgite zone, terminates upward in the sepiolite zone. *Zones I, II,* and *III* present an upward sequence of progressive clay-mineral change through Pliocene time.

Sepiolite and attapulgite terminate sharply at the top of the sepiolite zone *(zone III),* commonly 4-6 ft below the top of the formation. Above is a zone 2-4 ft thick, characterized by a sharp increase in well-crystallized montmorillonite to an average of about 75% of the clay-mineral assemblage, accompanied by an increase in illite (15%), and in kaolinite (10%). This thin zone is referred to as the montmorillonite-illite zone, or *zone IV.*

The uppermost clay-mineral zone, *zone V,* generally coinciding with the pisolitic limestone, is rarely more than 2 1/2 ft thick. The clay-mineral composition is characterized by a decrease in montmorillonite, and a corresponding increase in illite and kaolinite, and generally the presence of chlorite. In contrast with the well-crystallized montmorillonite of *zone IV,* the montmorillonite of *zone V* is always weathered, and is characterized by poorly defined x-ray diffraction peaks (Glass and others, 1973). This rock is predominantly calcium carbonate, having a unique and distinctive appearance because of its contained pisolites, many of which have been brecciated and recemented.

The identification of clay-mineral zones was particularly valuable in this study of the Ogallala because the thin Ogallala west of the Pecos yielded no fauna or flora, and stratigraphic zonation was entirely dependent on lithology and clay-mineral zones. The Ogallala in the region of western limit is predominantly in the upper stratigraphic part (clay-mineral zone **II** and higher) of the formation.

Distribution west of Pecos River

The location of samples and fauna collections used in this study are shown in fig. 2; localities are listed in table 1 (in Appendix 2, p. 25). Maximum western extent of Ogallala sediments is shown in fig. 1. In table 2 (in Appendix 2, p. 26) results are given for 562 x-ray analyses of clay minerals in samples collected for this project. Table 3 (in Appendix 2, p. 33) presents 50 measured stratigraphic sections (with descriptions) from the region (fig. 10, p. 32). These stratigraphic sections show the stratigraphic placement of many of the analyzed samples (table 2) and thus serve as a primary basis for the westward correlation of the Ogallala Formation.

The lithology of the Ogallala west of the Pecos Valley (figs. 3, 4, 5) is not much different from its lithology east of the valley except for a much coarser texture locally; therefore, the lithology will not be described in detail (except for the 50 described sections in table 3).

The topographic expression of the Ogallala west of the Pecos Valley is strikingly different from the topography of the formation east of the valley. East of the Pecos Valley, the Ogallala caps the upland surface almost everywhere. The unit, together with its massive, uppermost caliche, caps the High Plains (Llano Estacado) surface that extends from eastern New Mexico into west Texas and has been described thoroughly in previous literature. West of the Pecos Valley (except on upland surfaces north and south of Yeso Arroyo), the Ogallala commonly has the topographic expression of terraces or strata below much higher, adjacent uplands that are developed on older rocks.

This topographic relationship illustrates the purpose of this study, namely, to define the headwater sources of late Tertiary sediments that accumulated in the extensive alluvial blanket spreading eastward from the Rocky Mountains. If this relationship is to be defined anywhere, it must be studied in central and southern New Mexico; in extreme northern New Mexico the Ogallala has been obscured by subsequent volcanic rocks, and northward across Colorado and southern Wyoming, tectonic activity and Quaternary erosion have removed the necessary evidence. In central and southern New Mexico there is no Colorado piedmont; instead, remnants of the Ogallala deposits are preserved up to and

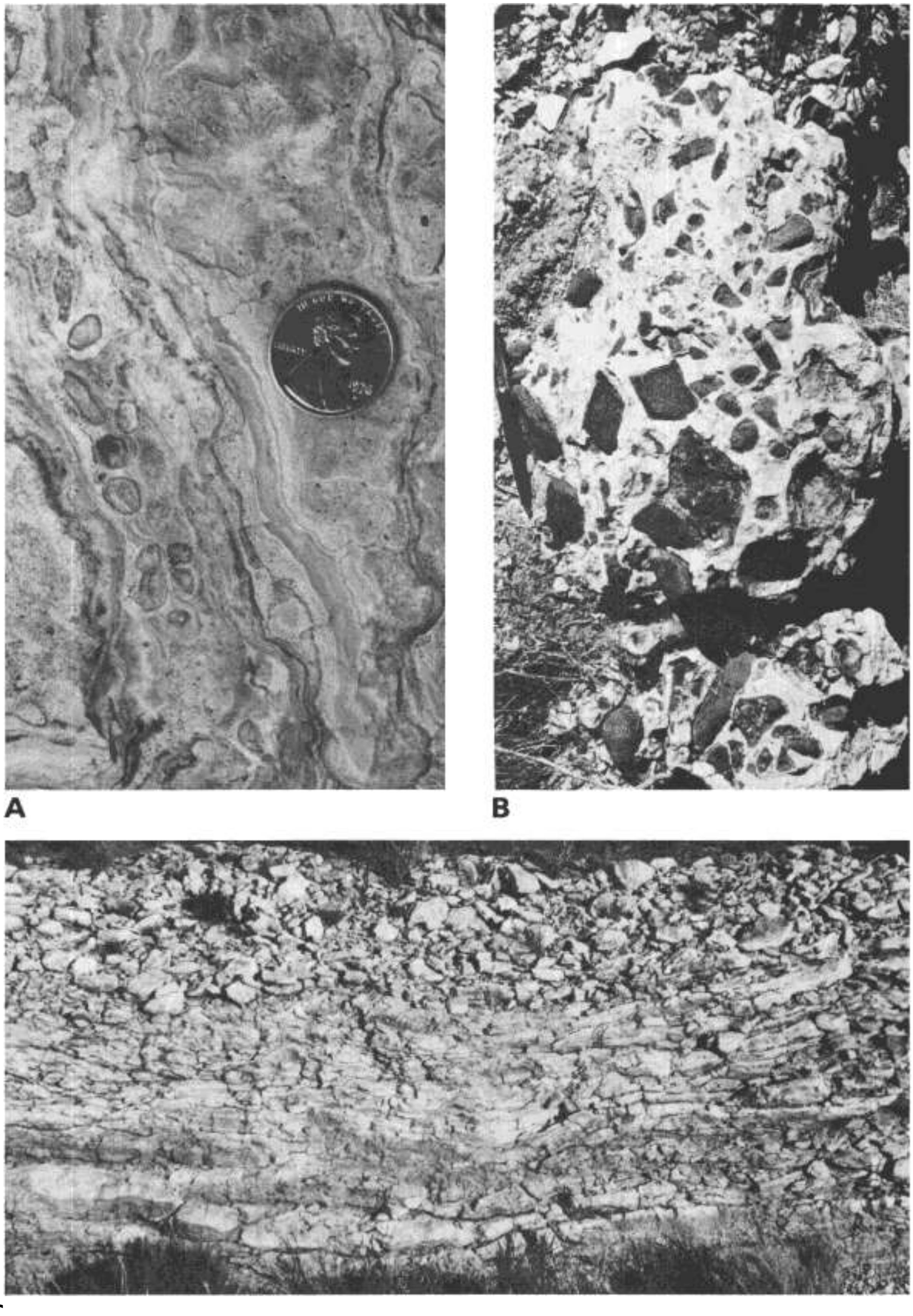


FIGURE 3—DENSE CALICHE; photographed in 1976.

A) Pisolitic limestone at top of thin Ogallala section; 2 1/4 mi northeast of NM-104 on Maes Road and 9 mi northwest of Trujillo, San Miguel County.
B) Dense caliche crust on pediment veneer; center sec. 23, T. 1 N., R. 13 E., Torrance County.
C) Platy caliche at top of Ogallala Formation, NE' sec. 30, T. 4 N., R. 16 E., Guadalupe County.

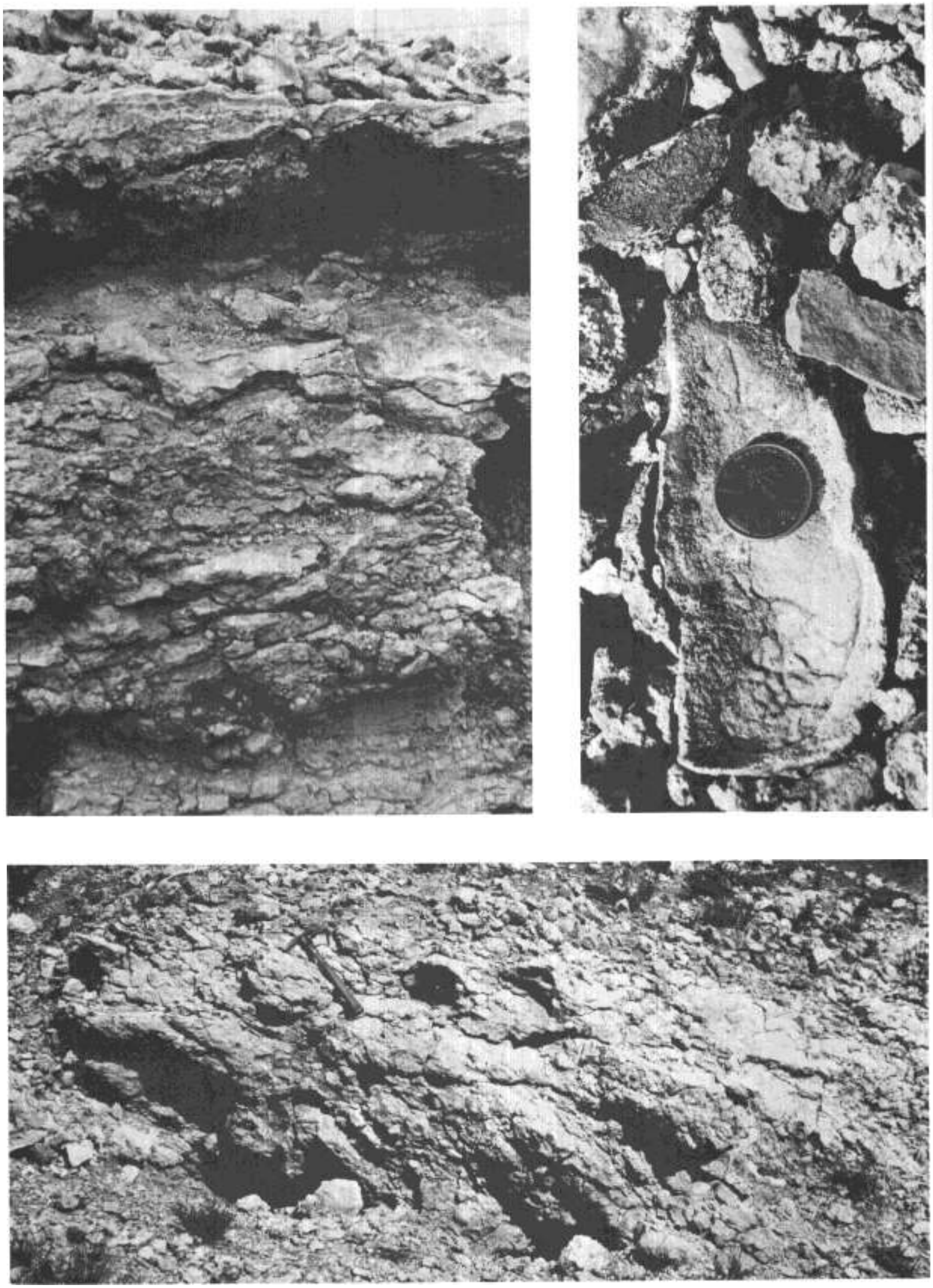


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FIGURE 4—CALICHE AND SOLUTION CUP; photographed in 1976 (A) and 1977 (B, C).

A) Platy caliche in top of Ogallala Formation, 6 mi northwest of Wagon Mound, Mora County.
B) Solution-cupped limestone pebble, NW 1/4 sec. 28, T. 9 S., R. 24 E., Chaves County.
C) Platy caliche in upper part of Ogallala Formation at Stanley railway cut section, NE 1/4 NE 1/4 sec. 22, T. 11 N., R. 9 E., Santa Fe County.

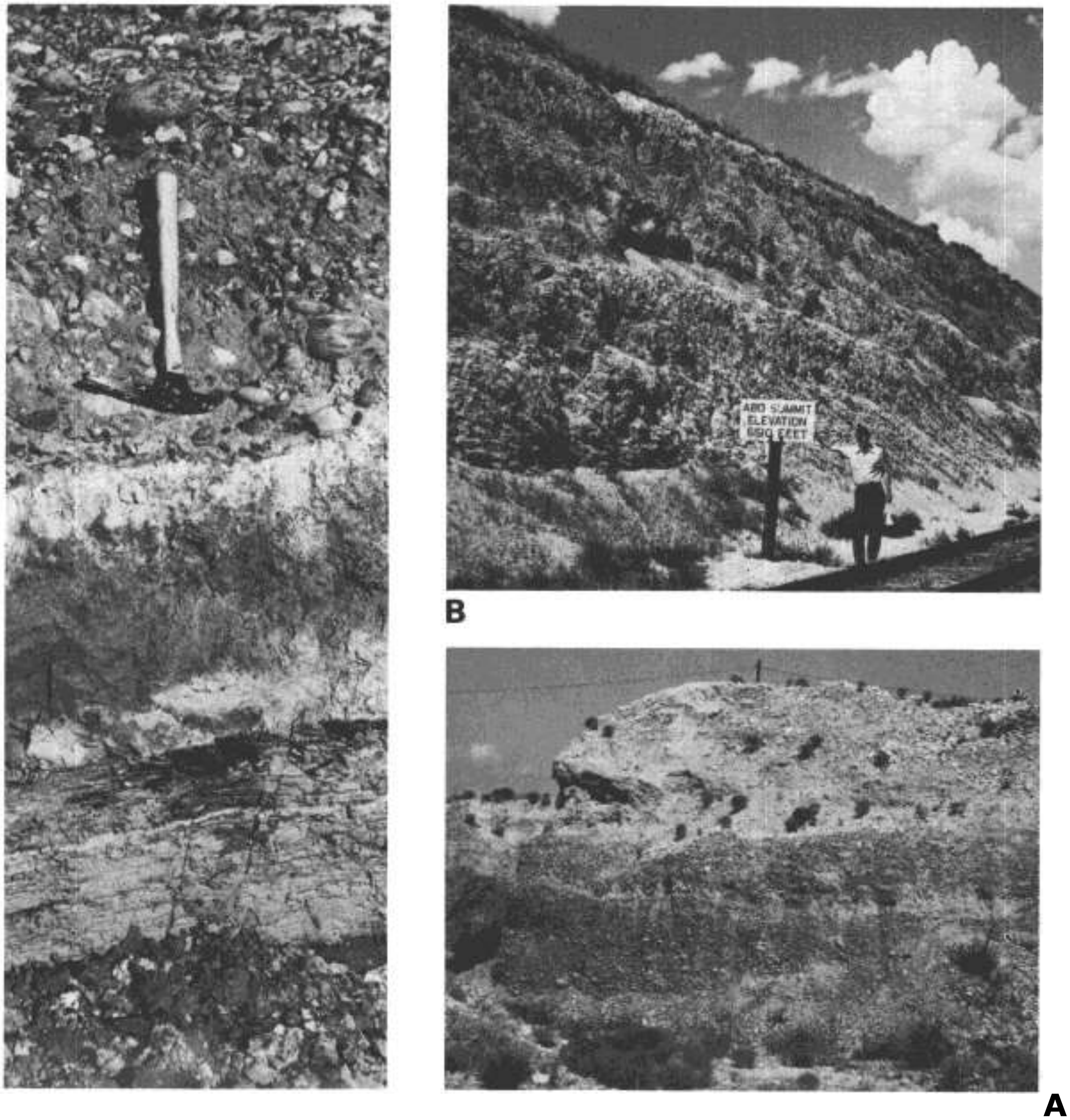

FIGURE 5—OGALLALA FORMATION AND EARLY PLEISTOCENE PEDIMENT VENEER; photographed in 1977.

A) Basal Ogallala Formation on weathered Cretaceous shale in upland gravel pit, Las Vegas east section, San Miguel County.
B) Ogallala Formation in the Abo Summit railway cut, southwest of Mountainair, SE'/ sec. 6, T. 3 N., R. 7 E., Torrance County.
C) Limestone gravels, sand, and caliche; early Pleistocene pediment veneer in Artesia sanitary landfill, SW 1/4 NW 1/4 sec. 10, T. 17 S., R. 25 E., Eddy County.

into the mountain fronts from which the sediments were derived.

The reconstructed maximum extent of the western front of the Ogallala sedimentary apron, including tributary streams from mountain sources, is shown in fig. 1. The topographic relations of these headwater valleys are shown in fig. 6A and B; the relationship of the Ogallala surface under study to the mountain source is shown in fig. 6C.

The pattern of distribution displayed in fig. 1 is that of streams that developed in an erosional topography modified by structural warping and subsequently modified by localized subsidences. The basic control of the pattern is from the preexisting structure of the bedrock, which ranges in age from Precambrian to Cretaceous.

This study makes no attempt to determine the causes of the structural warping in late- and post-Ogallala time; the study describes only what transpired. The character of this warping is shown graphically by five west-to-east profiles (fig. 7) drawn from north to south on the reconstructed top of the Ogallala Formation. In discussing the maximum early Pliocene extent of Ogallala deposits (fig. 1) and the stratigraphy supporting the interpretation (tables 2, 3), post-Ogallala (late Pliocene to Pleistocene) warping of the region must be considered. Profiles are constructed on the basis of

A

B

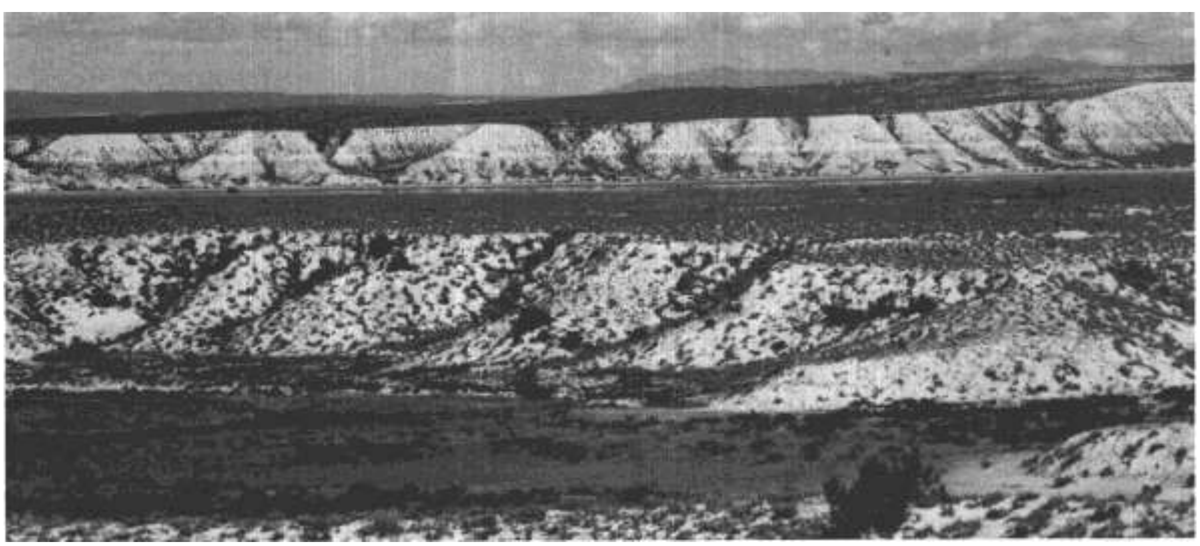

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FIGURE 6—PHYSIOGRAPHIC EXPRESSION OF OGALLALA FORMATION.

A) Duran Mesa, view toward south-southeast from NE 1/4 sec. 8, T. 4 N., R. 14 E., Torrance County. Mesa stands prominently above the Ogallala level on two sides; photographed in 1978.

B) Upland surface erosionally graded to the Ogallala surface; view east-southeast from northwest of Las Vegas, San Miguel County; photographed in 1977.

C) Jicarilla Mountains, view toward northwest from NE'/ sec. 22, T. 6 S., R. 14 E., Lincoln County, across an erosion surface graded to the Ogallala level and veneered with dense caliche; photographed in 1977.

D) View of lake deposits (late Pleistocene) from the Willard east section in south part of Estancia Basin; view to north from N 1/2 sec. 5, T. 4 N., R. 10 E., Torrance County; photographed in 1976.

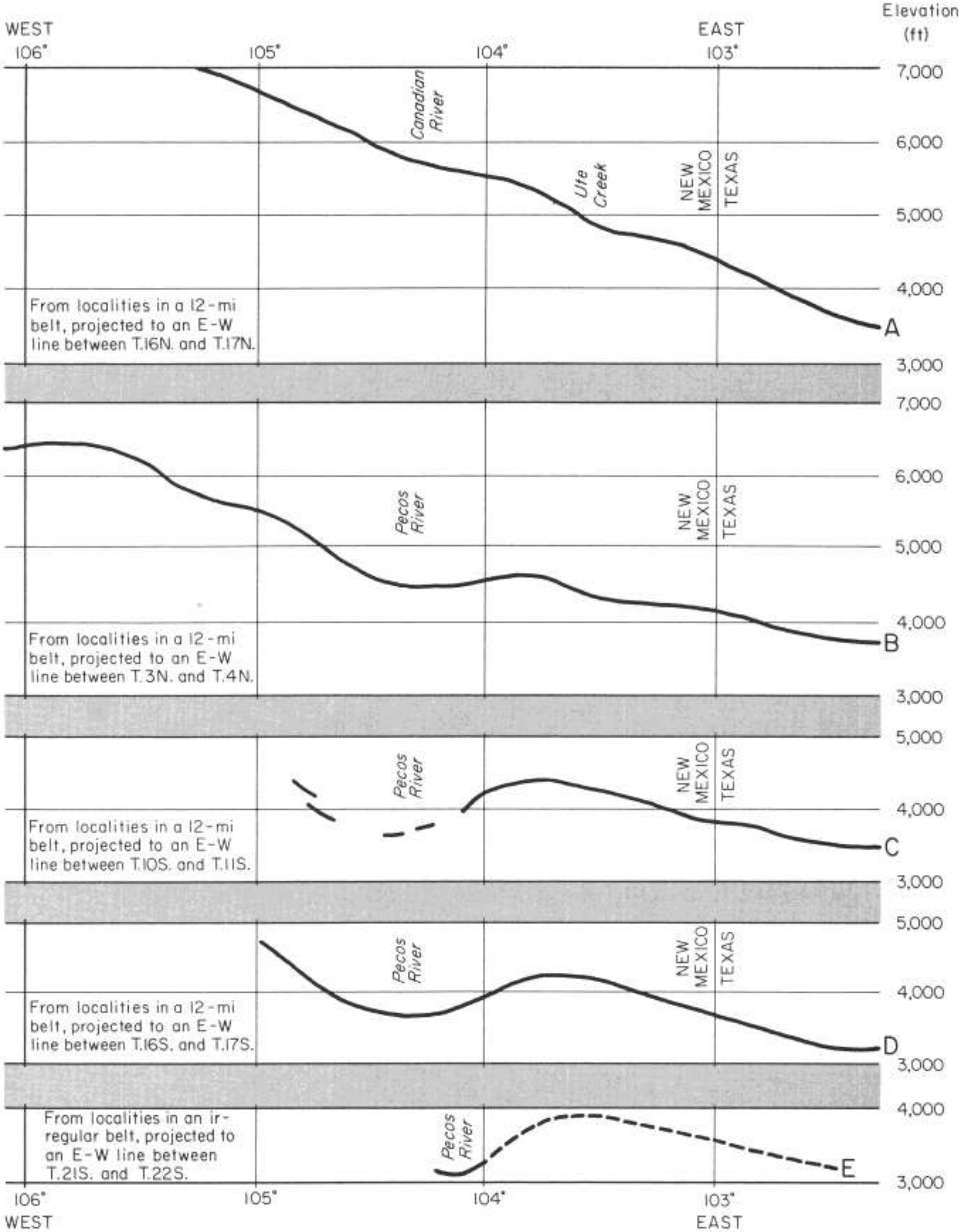

FIGURE 7—West-to-east structural profiles projected to top of Ogallala Formation, showing postdepositional warping.

points identified as zones IV or V of the Ogallala (tables 1, 2, and 3) along west-to-east belts two townships wide; datum points have been projected to an east-west line between the two townships. Profiles have been extended into west Texas on the basis of our earlier work in west Texas (Frye and Leonard, 1957a, b, 1959, 1963, 1964; Swineford and others, 1958; Leonard and Frye, 1962).

A north-to-south progression in the degree of post-Ogallala warping is clearly evident in the profiles. Structure indicated by the profiles is consistent with structural contours previously drawn on top of the Ogallala in east-central New Mexico (Frye and Leonard, 1972). In the northern part of the region **(profile A),** contours show a relatively smooth slope from west-northwest to east-southeast; these contours suggest that a shallow arch east of the 104° meridian persists in the other four profiles southward and becomes more pronounced to the south. Starting with **profile B** and continuing south to **profile E,** a pronounced structural sag occurs west of the 104° meridian. The valley of the Pecos River lies within this structural sag. In **profile B** only, an arch occurs in the area of the 105 ° meridian, with a shallow sag west of the meridian; a flattening of the slope occurs east of the 106° meridian, with a suggestion of a westward slope in the vicinity of the 106° meridian. **Profiles C, D,** and **E** do not extend as far west as the 105 ° meridian; therefore, data on this feature are not available south of **profile B.** The structural warping that progressively increases from north to south is a regional phenomenon.

The construction of west-to-east structural profiles (fig. 7) and development of maps (fig. 1) showing the maximum (early Pliocene) extent of alluvial sediments now classed as Ogallala Formation are based on field observations of Ogallala deposits, their physical stratigraphy and correlation, and the clay-mineral stratigraphic zonation of the formation. The reader is referred to the 50 described sections in table 3; geographic locations of these sections are in fig. 10. Details of the clay-mineral zones are in table 2 (locations in table 1).

Using this background, we will discuss the distribution pattern and its implications as presented in fig. 1. Maximum distribution of the Ogallala shows a pattern of drainage from mountain sediment sources in the west toward the extensive alluvial apron to the east, extending into west Texas.

In developing the distribution pattern of Ogallala deposits (fig. 1), definition of details of stratigraphy is of prime importance; topography and Pliocene-Pleistocene erosional history of the Ogallala also are important. In those areas where the pre-Ogallala bedrock topography is preserved (fig. 6), developing the distribution pattern is not a difficult task, but in those areas where subsidence or collapse (like the Estancia-Willard Basin) or Pliocene-Pleistocene erosion (as in south-central San Miguel County) has removed all Ogallala topography, the problem of extrapolation is difficult at best. In some areas (for example, along and west of the 105 ° meridian in southern San Miguel County), we postulate two drainage routes because the topography that would have contained the Ogallala deposits has been removed by erosion. In other areas, where the Ogallala was the upland blanket, the formation can be projected across erosional topography. On the other hand, the Ogallala channel (that headed in the Sangre de Cristo Mountains and flowed south-southeast) can be projected from the north rim of Glorieta Mesa (southeast of Rowe) with more confidence because much of the containing topography is preserved, even though the northern end of the channel is 1,000 ft above the present erosional valley of the Pecos River.

Reconstruction of Ogallala drainage through the Estancia-Willard Basin presents a special problem. This linear (north-south) basin has been significantly modified during Pliocene-Pleistocene time by subsidence, collapse, or structural warping. Clearly definable Ogallala deposits were examined and sampled only in the northern and southern parts of the basin. The intervening deposits on the floor of the basin are Pleistocene and Holocene, flanked by pediment veneers of indeterminate age. However, Ogallala drainage probably flowed south through the basin and joined the west-to-east Ogallala drainage between Mountainair and Willard.

In the area around Mountainair during Ogallala time, drainage from west of the present Abo Summit flowed east as a tributary to the Ogallala; however, during late Pliocene-Pleistocene time the westward drainage captured the headwaters of this formerly eastward-flowing drainage by headward encroachment. Bedrock islands (fig. 1) that persisted above the early Pliocene alluvial plain now stand as mesas above the Ogallala deposits.

Southward into Chaves and Eddy Counties (fig. 1), the long Ogallala tributaries from the mountains to the west are not detectable. The regional structural setting suggests that these tributaries never existed and that the western limit of Ogallala sedimentation was sharply limited by the structural front of the mountains. Nevertheless, the lithologic character of the Ogallala changes southward to a predominantly limestone source for the coarse clastic components, indicating that the adjacent western mountains continued to be a major sediment source.

This relationship is well illustrated by exposures 15-20 mi west of Roswell (Blackwater Draw west and Diamond-A northwest sections). In this area two distinct levels of upper Tertiary (Ogallala) deposits exist, indicating that structural warping was in progress during Ogallala deposition. The higher and older of the two deposits consists largely of cobbles of limestone traceable to a mountain source immediately to the west. The lower and younger deposit contains rock types from a source farther north, although this deposit also contains abundant limestone.

Progressing southward, expansive, early Pleistocene pediments appear west of the Pecos River, grading eastward from an Ogallala upland that occupies deep, western reentrants (like those in the vicinity of Hope) into the mountains to the west (fig. 1). This series of flanking pediments that are graded to lowest Pleistocene (Nebraskan?, Kansan, and Wisconsinan) levels, some of which are preserved as terrace remnants east of the Pecos River, will be described in the Pleistocene section of this report.

Farther south are two structurally controlled reentrants of the Ogallala, both oriented toward the north or northeast in opposition to the general trend of mountain-source tributaries for the Ogallala sediments. The northernmost of these reentrants (fig. 1) trends northward along the east flank of the Guadalupe Mountains and west of Azotoa Mesa and Seven Rivers Hills, joining the general eastward slope of the Ogallala surface northwest of Carlsbad. The southernmost reentrant consists of dissected Ogallala terrace remnants along the valley of the Black River, trending northeast to merge with the general east-sloping Ogallala surface south of Carlsbad.

This reversal of Ogallala source streams in southernmost New Mexico is consistent with the pattern in west Texas, where the extensive blanket of Ogallala sediments is limited south of Midland by gently rising bedrock topography.

The maximum extent of Ogallala sediments during early Pliocene time in eastern New Mexico (fig. 1) shows a pattern of alluvial valleys (originating in the mountains to the west) that surround bedrock islands now standing as topographic mesas; these features merge eastward into the extensive alluvial plain that extended as a blanket of sediments as far as the present east scarp of the Llano Estacado in west Texas. The structural history of this alluvial plain remains a fascinating story to be deciphered by future research.

Early Pleistocene deposits

The region covered contains both sparse and scattered deposits of Pleistocene and Holocene age. To place the Ogallala Formation in proper context, we will briefly describe these Quaternary deposits and faunas.

The earliest Pleistocene deposits are those that have been determined to be younger than the Ogallala by physiographic position, presence of Ogallala clasts, and clay-mineral composition; these deposits are older than the extensive early Pleistocene deposits in eastern New Mexico that have been referred to in earlier reports as Kansan. The fact that these earliest post-Ogallala deposits also have been referred to as Nebraskan does not imply that the deposits have been firmly correlated with Nebraskan sections in the middle reaches of the Missouri River valley; rather, they are Pliocene-Pleistocene deposits, clearly younger than Ogallala and older than units classed as Kansan.

In this region only the El Paso Natural Gas north-northwest-A section (tables 2, 3; fig. 10) is clearly assignable to this Nebraskan age. Others that may be tentatively assigned to this age include the Encino east section, Aston Ranch north section, Donnahoo Hills southwest section, and Encino south section (NMP1500-1552). These localities are not only distinguished by their physiographic positions, but also by their different clay-mineral assemblages. In this region and throughout eastern New Mexico, rocks deposited immediately after the Ogallala (late Pliocene and earliest Pleistocene) are exceedingly sparse. Some of the earliest and highest of the pediment-veneer deposits on the west side of the Pecos Valley also may be Nebraskan in age.

Along the Pecos Valley, the next younger deposits have been called Kansan and have been described from several localities in earlier papers (fig. 2). These deposits are east, south, and west of Fort Sumner, east of Hagerman, and east of Artesia. These middle Pleistocene deposits are remnants of alluvial terraces of the Pecos River and will be discussed in detail in a forthcoming study of Pecos Valley terraces.

From the region of Roswell southward, extensive areas of pediment surface are veneered with deposits ranging in age from Nebraskan to early Wisconsinan. These pediments are directly related to the present study because they must be clearly distinguished from the Ogallala. Because the deposits of the pediment veneers in some places are derived largely from the Ogallala at higher levels, these deposits may be confused with the Ogallala Formation. Slope angles of the older pediment surfaces are only slightly greater than the surface slope of the Ogallala. These features are particularly evident in the area east of Hope in Eddy County.

The lower Pleistocene pediment surfaces typically display a dense, cemented, caliche crust (fig. 3B) at the surface that may superficially resemble the uppermost caliche of the Ogallala (clay-mineral zones IV and V), although the caliche crust lacks the strong development of pisolites and brecciated, travertine banding commonly present in Ogallala zone V (as in the Roswell Air-base south section). Locally, major stream channels flowed across the pediment surface (Artesia landfill section, fig. 5C); deposits of such channels are now preserved below a superficial caliche crust and are beveled by a graded-pediment surface that does not indicate the existence of the former stream channel. The caliche crusts on the lower Pleistocene pediment veneers strongly resemble caliche crusts that have developed on bedrock surfaces above the level of Ogallala deposits and pediment surfaces (table 2).

Clay-mineral assemblages (table 2) of the lower Pleistocene pediment veneers commonly resemble the clay-mineral assemblages previously described for Kansan deposits of eastern New Mexico; in addition to detrital clay minerals, attapulgite is commonly present and, rarely, sepiolite also is observed.

Pediment deposits that appear to be younger than Kansan but older than Wisconsinan have been observed at several places (like the Englewood section and Orchard Park west section). These younger pediments do not have the dense caliche crusts of the older pediment surfaces, and the surface gradients of the younger pediment surfaces are distinctly greater. From physiographic expression, the Orchard Park west section appears to be older than the Englewood section. Clay-mineral assemblages appear to confirm this judgment because the Orchard Park west section contains a clay-mineral suite, including attapulgite, similar to the older pediment deposits; the Englewood section contains clay-mineral assemblages similar to the Wisconsinan terrace deposits.

West of the Pecos River, younger pediments generally slope more steeply toward the pediment toe or dissected pediment toe. This steepening is consistent with the interpretation that the earlier pediment surfaces were graded to an earlier, higher, and more westerly position of the Pecos River channel.

In the Midwest, a major episode of glacial, alluvial, and eolian deposition occurred during Illinoian time (older than Wisconsinan and younger than Kansan) (Willman and Frye, 1970). However, in eastern New Mexico and west Texas this episode has not been recognized; if these deposits exist in this region, they have merged in a major episode of post-Kansan, pre-Wisconsinan pediment development not described in this report.

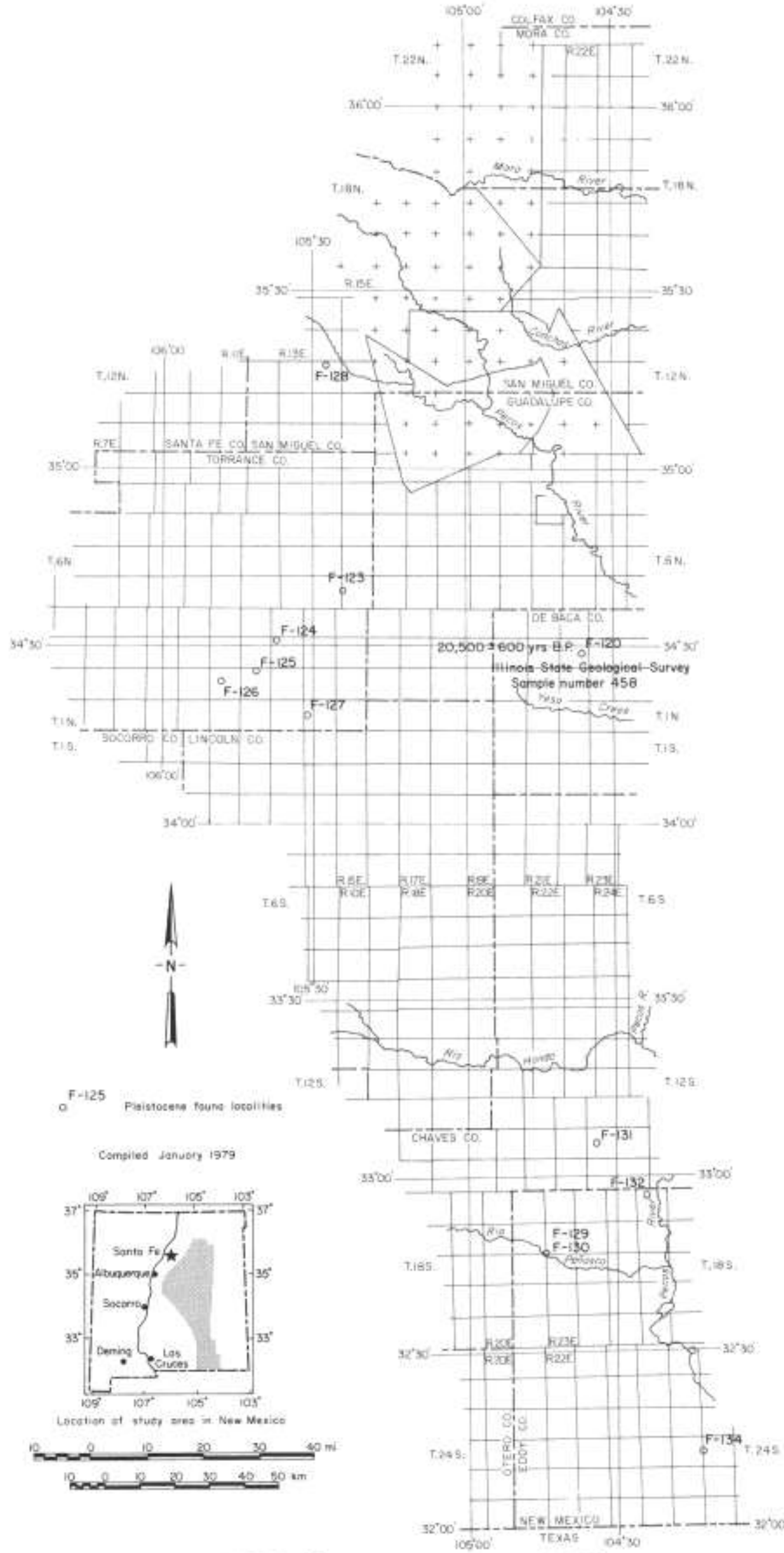

FIGURE 8—MAP OF DESCRIBED FAUNAL LOCALITIES.

Wisconsinan and Holocene deposits

In the region under consideration, some areas contain basin-fill deposits of Wisconsinan age, and remnants of Wisconsinan terraces are along streams that contribute to the Pecos River drainage. These deposits and their molluscan faunas will be described briefly.

In spite of the sparse distribution of earlier Pleistocene deposits in this region, terraces and some shallow basin-fill deposits (late Wisconsinan and Holocene age) are present at many scattered localities. Remnants of terraces of this age occur along all western tributaries to the Pecos River in this region and, in a few places, along tributaries to major undrained depressions. Frequently, these young terraces contain fossil mollusks (figs. 8, 9).

Upper Wisconsinan and Holocene terraces from which molluscan faunas have been reported include the Hope south section (F-129; F-130) along Rio Peñasco, the Rio Felix section (F-131), the Walnut Draw section (F-133), and the Black River section (F-134). In each case, deposits containing fauna include a suite of detrital clay minerals that are intensely weathered in some cases (as in the Rio Felix section). These localities are all Holocene or very late Wisconsinan. In the case of the Hope south locality along Rio Penasco, three ages of terrace deposits occur—the youngest (F-129) appears to be late Holocene, the next older (F-130) may be late Wisconsinan, and the oldest (a nonfossiliferous, terrace deposit) is still older late Wisconsinan. Although all deposits contain a detrital clay-mineral suite, the oldest deposit contains more montmorillonite and less illite.

An exception to the general uniformity of mineral composition occurs in the Rio Felix section, where fossil mollusks occur in remnants of a very young Holocene terrace. Clay minerals in this young terrace are intensely weathered. However, the higher and older deposits contain a significant percentage of attapulgite, along with dolomite and chlorite (table 2), and may be pre-Wisconsinan.

At one locality (F-125) south of Pinos Wells, terrace deposits along a tributary to a large undrained depression yielded a molluscan fauna. The clay-mineral suite in this deposit, although high in montmorillonite, contains a significant percentage of attapulgite. Whether this indicates an older age for this terrace than for others sampled or is a reflection of unusual environmental circumstances is not readily determinable. Deposits from the floor of this basin that also yield a fauna (F-124) are high in illite and contain chlorite but no attapulgite.

Wisconsinan-age basin deposits of considerable diversity occur at several places in this region. Many of these deposits have yielded molluscan faunas, but others appear to be devoid of fossils. The most impressive of these are the lake and dune deposits east of Willard in the southern part of the Estancia Basin (fig. 7D). Typical of the lacustrine deposits overlain by lee-dune deposits is the Willard east section. In the lower lacustrine beds are clay, silt, sand, gypsum, ostracod faunas, and local assemblages of small vertebrate fossils; the overlying lee-dune deposits are predominantly fine to medium sand and silt. The clay-mineral suite throughout consists of detrital minerals with 50 percent or less of montmorillonite and approximately equal percentages of illite, kaolinite, chlorite, and gypsum. Although lake beds at the bottom of the basin are clearly Wisconsinan, the upper part of the lacustrine and dune deposits may be Holocene. A similar but much subdued lee-dune deposit (NMP-1014 and 1015) was sampled in the cuts of the Santa Fe Railroad east of Encino, on the east side of the Encino Basin. Here, illite is more abundant than montmorillonite, but fibrous clay minerals are absent and chlorite is present, giving the clay-mineral suite some similarity to the Willard east section deposits. Westward, on the floor of the Encino Basin, pond deposits containing fossil mollusks (F-123) largely consist of gypsum and sand. Another locality that has the aspect of a Wisconsinan basin deposit is the Vaughn north section. Although no fossil mollusks were found here, the clay-mineral assemblage is high in montmorillonite, contains chlorite, and lacks fibrous clay minerals. Much farther south is a deposit with similar clay-mineral composition.

Fossiliferous pond deposits, although not abundant in the region, occur in a variety of physiographic settings. A shallow but extensive pond deposit occurs north of Yeso in De Baca County, above the Ogallala Formation (F-120; sample number 935). The fauna at this locality has been radiocarbon dated at 20,500 ± 600 yrs (Illinois State Geological Survey sample number 458). This deposit of gray sand, silt, and clay is exceptionally high in montmorillonite and contains gypsum. In contrast, the fauna in an interdune depression (F-126) is sparse. The pond deposits also are high in montmorillonite and contain gypsum. Wisconsinan molluscan faunas occur in lake or pond deposits on the margin of the larger basins. Examples are found north of Pinos Wells (F-124; NMP-1075) and east of Encino (F-123; NMP-1016). The deposit east of Encino contains gypsum, but no detectable clay minerals, whereas the deposit north of Pinos Wells has a typical assemblage of montmorillonite, illite, kaolinite, and chlorite. Two other fossiliferous pond deposits deserve mention. Fauna 127 occurs in gray, fine sand and silt containing fragments of caliche; the clay-mineral assemblage is high in montmorillonite and contains attapulgite and chlorite, which is an unusual Pleistocene assemblage for this region. Although the present topography does not clearly indicate a paleobasin, the sediments and fauna appear to have accumulated in a pond. Fauna 132 occurs in cream to greenish-gray- cream silt and fine sand of a pond deposit on a terrace. The area is now drained, and badger and gopher holes have been filled with a mixture of tan to tan-cream sand, silt, and clay (NMP-1373) that appears to have been derived from a former deposit above the pond deposit. The deposit containing fossils (NMP- 1371) has no detectable clay minerals but does have abundant gypsum.

Molluscan species	Localities												
	F-120	F-123	F-124a	F-125	F-126	F-127	F-128	F-129	F-130	F-131	F-132	F-133	F-134
Catinella sp.	o		o	o		o						o	
Deroceras cf. *laeve* (Müller)	o					o							
Gastrocopta riograndensis Pilsbry + Vannata	o					o		o					
Gyraulus circumstriatus Tryon									o	o			
Gyraulus parvus (Say)									o	o			o
Hawaiia minuscula (Binney)	o			o		o		o		o			o
Helicodiscus eigenmanni Pilsbry							o						
Helisoma antrosa (Conrad)	o								o				o
Helisoma campanulatum (Say)													o
Helisoma trivolvis (Say)													o
Ligumia subrostrata (Say)													o
Lymnaea dalli (Baker)	o												
Lymnaea humilis Say	o		o			o					o		
Lymnaea palustris (Müller)	o				o	o							
Lymnaea parva Lea				o		o			o	o			
Oxyloma retusa (Lea)										o			
Physa anatina Lea									o		o		o
Pisidium casertanum Poli	o									o			
Pisidium compressum Prime													o
Pupilla blandi Morse				o						o			
Pupilla muscorum (Linné)		o	o	o	o							o	
Pupoides albilabris (Adams)			o	o					o	o			
Sphaerium transversum (Say)									o				
Succinea grosvenori Lea		o	o	o	o	o		o	o	o		o	
Vallonia cyclophorella Sterki	o			o		o							
Vallonia gracilicosta Reinhardt	o			o								o	
Total number of species	11	2	5	9	3	9	1	3	8	8	2	5	7

FIGURE 9—CHART SHOWING COMPOSITION OF 13 PLEISTOCENE FAUNAS DESCRIBED.

Molluscan faunal assemblages

The assemblages of fossil mollusks included in this report comprise 10 species of aquatic pulmonate gastropods, 12 species of terrestrial gastropods, and four species of branchiate mollusca (all pelecypods); the assemblages come from 13 faunal localities in Wisconsinan and Holocene deposits, not including localities near the Pecos River. The fossiliferous deposits yielded few species (the most prolific site contained 11 species) and small populations of fossil mollusks. A few localities may be regarded as exceptional. Locality F-120, from the margin of a large basin on the surface of Ogallala sediments, contained 11 species, of which the largest group is lymnaeids. The absence of *Physa* represents an unexplained anomaly, because this genus usually is well represented in assemblages where dense populations of aquatic pulmonates occur. At locality F-134, molluscan assemblages were recovered from terrace deposits on the Black River crossing, approximately 15 mi south of Carlsbad; the number of species (7) was relatively small, but populations were unusually dense.

Radiocarbon dating of the Wisconsinan and Holocene faunal assemblages has been limited to faunal assemblage F-120. The assemblage at the Black River crossing (F-134) is the only other possibility known to us from which sufficient shell material can be collected to allow dating. Deposits at this site contain the only unionid pelecypod recovered thus far from this region, but this specimen is too small to provide a sufficient quantity of shell for dating.

In our judgment, the fossil mollusks appearing in the faunal assemblages described in this report generally represent hardy species that survived under adverse circumstances. No branchiate gastropods are present in the assemblages, which indicates the general absence of permanent waters in the region. Even sphaeriid pelecypods can survive periods of drought if crayfish or insect burrows in ponds or streams offer protection from dessication; branchiate gastropods usually require permanent water. Further evidence that the faunal assemblages in this region are composed of durable and hardy species is contained in previous reports on eastern New Mexico faunal assemblages. Leonard and Frye (1975) reported 47 species of mollusks from an equal number of localities in east-central New Mexico; 17 species from the assemblages in this report occur in common with those mentioned in previous publications. Leonard and others (1975) reported 30 species of fossil mollusks from southeast New Mexico; 17 species occur in common with the general assemblage listed in this report. An even more striking similarity is found in the faunal assemblages listed by Frye and others (1978), who reported 50 species from deposits in northeast New Mexico. Twenty-four species are common to both composite faunal assemblages. Finally, 10 species of the fossil mollusks of this report are common to the 26 species listed from an Ogallala deposit in northeast New Mexico (Leonard and Frye, 1978). Thus, hardy species persist and recur in significant numbers throughout a considerable period of time and in different depositional environments.

In table 4 and in Appendix 1, each species listed is followed by citations of previously published reports that also list species discussed in this report.

Summary and conclusions

The top of alluvial deposits that are the culmination of deposition of the Ogallala Formation defines the topographic surface in latest Tertiary time. These alluvial deposits define the drainageways from the mountains on the west, eastward into the broad alluvial plain that composes the western part of the Great Plains. This alluvial plain, starting in valley fills at its western limit, grades eastward through an area of circumalluviated mesas and coalescent plains that covered all preexisting topography in extreme eastern New Mexico.

At the culmination of alluvial deposition in latest Tertiary time, an episode of tectonic stability and climatic dessication produced extensive soils (with strong calcic or petrocalcic horizons) that blanketed the preexisting surface and the adjacent erosional topography.

This expansive, well-graded alluvial surface served as a structural plane of reference (sloping east-southeast from the mountain front) that now can be used to measure structural warping during Pliocene and Pleistocene time. In northeast New Mexico there was little distortion of this surface, other than accentuation of the eastward tilt. However, southward into eastern New Mexico, this surface was progressively and more intensively warped. Major downwarping occurred along the present Pecos Valley and upwarping occurred both east and west of that trend. This warping was accentuated southward from northeast New Mexico to the southern border of the state.

The major part of this warping probably occurred during latest Tertiary and early Pleistocene time, but warping east of the Pecos Valley suggests that some deformation continued in middle Pleistocene time, after the abandonment of the Portales Valley segment of the upper Pecos.

The distribution pattern of Ogallala deposits demonstrates that streams depositing from the east (like those near Mountainair) had headwaters now captured by the Rio Grande drainage system. Extensive downwarping or subsidence isolated major headwaters (like those of streams flowing into the Estancia-Willard Basin) from the earlier eastward drainage pattern and produced systems of internal drainage. Also, lateral erosion along the mountain fronts diverted former eastward drainage patterns to local north-south drainage systems. The integration of two former stream systems to form the present Pecos River during the Pleistocene Epoch will be described in a subsequent paper.

Pleistocene deposits are sparse in this region, except in subsidence areas like the Estancia-Willard Basin. However, eastward-sloping pediments of Pleistocene age are extensive on the west side of the Pecos Valley in the region from Roswell to Artesia. Also, Wisconsinan and Holocene terraces occur along most of the east-flowing streams of the region. Some of these terraces have yielded significant faunas of fossil mollusks. The area west of the Pecos is the one region on the continent where it has been possible to trace the streams feeding the late Tertiary apron of the Great Plains to their mountain source to the west.

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Appendix 1 —Systematic index

SYSTEMATIC INDEX TO MOLLUSCA DESCRIBED IN THIS REPORT (cross reference with table **4).**

CLASS GASTROCOPTA

ORDER PULMONATA

Suborder Basommatophora

Family Lymnaeidae

Lymnaea palustris (Muller). Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978)

Lymnaea dalli (Baker). Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Lymnaea humilis Say. Leonard and Frye (1975); Leonard and Frye (1978)

Lymnaea parva Lea. Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Family Planorbidae

Gyraulus parvus (Say). Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Gyraulus circumstriatus Tryon. Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978

Helisoma trivolvis (Say).

Helisoma antrosa (Conrad). Leonard and others (1975); Frye and others (1978)

Helisoma campanulatum (Say). Leonard and others (1975)

Family Physidae

Physa anatina Lea. Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Suborder Stylommatophora

Family Limacidae

Derocaras cf *laeva* (Muller). Leonard and others (1975)

Family Zonitidae

Helicodiscus eigenmanni Pilsbry.

Hawaiia minuscula (Binney). Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Family Succineidae

Catinella sp. Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978) (including *S. gelida)*

Oxyloma retusa (Lea). Frye and others (1978)

Succinea grosvenori Lea. Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Family Pupillidae

Gastrocopta riograndensis Pilsbry & Vanatta. Frye and others (1978)

Pupoides albilabris (Adams). Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Pupilla blandi Morse. Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Pupilla muscorum (Linne). Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978); Leonard and Frye (1978)

Family Vallonidae

Vallonia gracilicosta Reinhardt. Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978)

Vallonia cyclophorella Sterki. Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978)

CLASS PELECYPODA

ORDER EULAMELLIBRANCHIA

Family Unionidae

Ligumia subrostrata (Say). Leonard and others (1975)

Family Sphaeriidae

Sphaerium transversum (Say). Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978)

Pisidium compressum Prime. Leonard and others (1975); Leonard and Frye (1975); Frye and others (1978)

Pisidium casertanum Poli. Frye and others (1978); Leonard and Frye (1978)

Appendix 2-Tables 1-4

TABLE 1—LOCATION OF SAMPLES USED IN THIS REPORT (New Mexico county in parentheses).

Sample No. (NMP-)	Location (section, Township–Range and/or mileage, county)
929	NW¼ 16, 7N–20E (Guadalupe)
930	NW¼ 34, 7N–19E (Guadalupe)
931–933	NW¼SE¼ 30, 6N–22E (Guadalupe)
934	SE¼ 31, 6N–22E (Guadalupe)
935	NW¼SE¼ 14, 3N–22E (DeBaca)
936	SE¼SE¼ 4, 3N–20E (DeBaca)
937–938	NE¼NE¼ 6, 3N–20E (DeBaca)
939	SE¼ 16, 4N–18E (Guadalupe)
940	SE¼NW¼ 27, 4N–17E (Guadalupe)
941	(Projected) SW¼NE¼ 14, 13N–21E (San Miguel)
942	(Projected) NW¼NE¼ 20, 4N–18E (Guadalupe)
943–946	NW¼NW¼ 1, 8N–18E (Guadalupe)
947–950	SE¼ 16, 8N–16E (Guadalupe)
951	SE¼ 28, 8N–16E (Guadalupe)
952–954	NW¼SW¼ 10, 4N–16E (Guadalupe)
955–956	NE¼ 30, 4N–16E (Guadalupe)
1001	NW¼SW¼ 36, 9N–8E (Torrance)
1002	SW¼NW¼ 32, 4N–7E (Torrance)
1003–1005	SW¼ 33, 4N–7E (Torrance)
1006–1013	SW¼NW¼ 8, 4N–16E (Guadalupe)
1014–1015	SW¼SE¼ 23, 5N–14E (Torrance)
1016	NE¼SE¼ 13, 5N–14E (Torrance)
1017	SW¼SW¼ 12, 4N–13E (Torrance)
1018	SW¼ 8, 5N–13E (Torrance)
1019–1026	SW¼ 10, 4N–16E (Guadalupe)
1027–1034	N½ 5, 4N–10E (Torrance)
1035–1037	SW¼ 2, 4N–8E (Torrance)
1038–1042	SW¼ 6, 3N–7E (Torrance)
1043	NE¼NE¼ 10, 6N–10E (Torrance)
1044	NW¼SE¼ 20, 7N–7E (Torrance)
1045–1046	NE¼NW¼ 35, 4N–6E (Torrance)
1047	SW¼NW¼ 3, 3N–6E (Torrance)
1048–1051	NW¼SW¼ 10, 1N–8E (Torrance)
1052	NW¼NE¼ 5, 1N–8E (Torrance)
1053	NW¼ 23, 3N–10E (Torrance)
1054	NW¼ 32, 3N–11E (Torrance)
1055	SE¼NE¼ 4, 2N–11E (Torrance)
1056–1060	NW¼NW¼ 13, 2N–11E (Torrance)
1061	SW¼ 20, 2N–12E (Torrance)
1062	SW¼ 33, 2N–13 E (Torrance)
1063–1064	NE¼ 12, 1N–13E (Torrance)
1065	Center 23, 1N–13E (Torrance)
1066	SW¼ 36, 3N–14E (Torrance)
1067–1074	NE¼ 30, 4N–16E (Guadalupe)
1075	SE¼ 6, 3N–13E (Torrance)
1076	NE¼ 3, 2N–12E (Torrance)
1077	NE¼ 8, 2N–11E (Torrance)
1078–1082	NW¼ 5, 5N–14E (Torrance)
1083–1086	SW¼NW¼ 23, 2N–21E (DeBaca)
1087–1095	SW¼SE¼ 25, 1S–20E (DeBaca)
1096	SE¼NE¼ 15, 2S–19E (Lincoln)
1097–1100	NW¼NW¼ 15, 2S–19E (Lincoln)
1101	NE¼NW¼ 9, 2S–18E (Lincoln)
1102	NE¼NE¼ 18, 1N–14E (Torrance)
1103–1105	SW¼SE¼ 29, 2N–17E (Guadalupe)
1106–1109	NW¼ 9, 1N–19E (Lincoln)
1110	NE¼SE¼ 17, 3S–21E (DeBaca)
1111–1113	NE¼NE¼ 21, 4S–22E (Chaves)
1114–1117	2.4 mi south-southeast of Sapello on NM-3 (San Miguel)
1118–1121	3 mi west of I-25 at Watrous (Mora)
1122	4 mi west of Watrous on NM-161 (Mora)
1123–1126	6 mi northwest of Wagon Mound on NM-120 (Mora)
1127	7.5 mi northwest of Wagon Mound (Mora)
1128–1131	0.25 mi west of I-25 at Wagon Mound (Mora)
1132	NW¼SE¼ 13, 18N–23E (Mora)
1133–1134	NE¼NW¼ 19, 19N–23E (Mora)
1135–1136	2 mi south-southeast of Cherry Vale Lake (San Miguel)
1137–1141	9 mi northwest of Trujillo on Maes Rd. (San Miguel)
1142–1143	8.5 mi north-northwest Trujillo on Maes Rd. (San Miguel)
1144–1145	NE¼NW¼ 18, 15N–21E (San Miguel)
1146	6 mi south, 0.75 mi east, of jct. NM-67 and NM-104 (San Miguel)
1147–1150	3.4 mi east of Las Vegas (south of NM-104) (San Miguel)
1151	6.4 mi south-southeast of Guadalupe County line, NM-84 (Guadalupe)
1152	8 mi south-southeast of north county line on NM-84 (Guadalupe)
1153	7.75 mi south-southeast of north county line on NM-84 (Guadalupe)
1154	11 mi south-southeast of north county line on NM-84 (Guadalupe)
1155–1157	NW¼ 21, 7N–19E (Guadalupe)
1158–1162	SE¼NE¼ 1, 5N–17E (Guadalupe)
1163–1165	SE¼ 14, 1N–22E (DeBaca)
1166	SW¼NE¼ 29, 1S–24E (Chaves)
1167	NW¼NW¼ 25, 4S–22E (Chaves)
1168–1171	Near center 21, 7S–15E (Lincoln)
1172–1178	S½NW¼NW¼ 36, 6S–23E (Chaves)
1179–1182	NW¼NW¼ 11, 8S–23E (Chaves)
1183	NW¼SE¼ 17, 9S–24E (Chaves)
1184–1185	NE¼NE¼ 8, 11S–22E (Chaves)
1186–1187	Center 4, 13S–24E (Chaves)
1188	Near northwest corner 26, 14S–23E (Chaves)
1189	NE¼ 27, 14S–23E (Chaves)
1190–1191	SW¼ 31, 17S–23E (Eddy)
1201–1205	2.4 mi south-southeast of Sapello on NM-3 (San Miguel)
1206–1207	11.4 mi east of Las Vegas on NM-104 (San Miguel)
1208	14.4 mi east of Las Vegas on NM-104 (San Miguel)
1209–1212	1 mi west-southwest of Conchas Rd. on NM-104 (San Miguel)
1213	9 mi northwest of Trujillo on Maes Rd. (San Miguel)
1218–1221	2.4 mi south-southeast of Sapello on NM-3 (San Miguel)
1222	SW¼ 33, 4N–7E (Torrance)
1223	SE¼ 6, 3N–7E (Torrance)
1224	NE¼NE¼ 15, 4N–7E (Torrance)
1225–1229	SE¼NE¼ 30, 4N–16E (Guadalupe)
1230	Northeast corner 36, 3N–15E (Torrance)
1231–1234	SW¼NE¼ 2, 3N–15E (Torrance)
1235–1241	SW¼ 36, 3N–14E (Torrance)
1242–1243	NW¼NW¼ 25, 9N–8E (Torrance)
1244–1245	SW¼SE¼ 13, 7N–8E (Torrance)
1246–1248	SE¼SE¼ 21, 2N–14E (Torrance)
1249–1250	Center section line 31, 2N–14E (Torrance)
1251–1252	NE¼ 12, 1N–13E (Torrance)
1253	SE¼NE¼ 27, 1N–13E (Torrance)
1254–1256	Center 34, 2N–12E (Torrance)
1257	SW¼ 10, 1S–9E (Socorro)
1258–1263	SW¼ 2, 4N–8E (Torrance)
1264–1267	SE¼SW¼ 4, 3N–7E (Torrance)
1268–1269	Northwest corner 23, 3N–7E (Torrance)
1270–1272	Center 28, 10N–7E (Santa Fe)
1273–1274	NE¼NE¼ 22, 11N–9E (Santa Fe)
1275	NE¼NE¼ 21, 11N–10E (Santa Fe)
1276–1277	NW¼NW¼ 21, 11N–11E (Santa Fe)
1278	NE¼ 16, 9N–12E (Torrance)
1279	NW¼NE¼ 21, 6N–16E (Guadalupe)
1280–1282	SE¼SE¼ 12, 4N–17E (Guadalupe)
1283–1286	SW¼ 16, 4N–18E (Guadalupe)
1287–1290	NE¼NE¼ 6, 3N–20E (DeBaca)
1291–1296	SW¼NE¼ 10, 4N–22E (DeBaca)
1297–1300	SW¼SW¼ 35, 5N–16E (Guadalupe)
1301	NW¼NW¼ 34, 3N–14E (Torrance)

TABLE 1 (continued)

Sample No. (NMP-)	Location (section, Township–Range and/or mileage, county)
1302–1305	SW¼NE¼ 15, 2N–12E (Torrance)
1306	SE¼NE¼ 20, 2S–20E (DeBaca)
1307	NE¼ 9, 4N–17E (Guadalupe)
1308	NW¼ 10, 4N–17E (Guadalupe)
1309–1311	NE¼ 2, 4S–21E (Chaves)
1312–1321	SW¼SW¼ 36, 6S–23E (Chaves)
1322–1326	NW¼NW¼ 25, 4S–22E (Chaves)
1327–1330	NE¼ 15, 9S–25E (Chaves)
1331–1333	NW¼ 28, 9S–24E (Chaves)
1334–1335	NW¼ 33, 8S–24E (Chaves)
1336	NW¼NW¼ 7, 8S–24E (Chaves)
1337	NW¼ 29, 8S–24E (Chaves)
1338–1339	NW¼NW¼ 9, 10S–23E (Chaves)
1340–1343	SW¼SE¼ 6, 11S–22E (Chaves)
1344–1345	NE¼NE¼ 11, 11S–21E (Chaves)
1346–1347	SW¼NW¼ 10, 11S–21E (Chaves)
1348	SE¼ 31, 10S–24E (Chaves)
1349–1351	SW¼ 17, 12S–24E (Chaves)
1352–1357	SE¼ 16, 14S–24E (Chaves)
1358	SW¼ 21, 14S–24E (Chaves)
1359–1360	NW¼SW¼ 6, 14S–24E (Chaves)
1361–1364	NW¼ 26, 14S–23E (Chaves)
1365–1367	NE¼ 27, 14S–23E (Chaves)
1368	SW¼SW¼ 32, 14S–23E (Chaves)
1369–1370	SE¼ 3, 15S–22E (Chaves)
1371–1372	NW¼ 4, 16S–26E (Eddy)
1373	NE¼NW¼ 28, 15S–24E (Chaves)
1374–1375	SW¼SW¼ 5, 16S–24E (Eddy)
1376	SW¼ 8, 17S–24E (Eddy)
1377	NE¼ 9, 17S–21E (Eddy)
1378	SE¼ 10, 17S–21E (Eddy)
1379	NE¼SW¼ 10, 17S–20E (Chaves)
1380–1383	NE¼SW¼ 6, 17S–20E (Chaves)
1384–1387	SW¼NW¼ 10, 17S–25E (Eddy)
1388–1390	NW¼SW¼ 17, 17S–24E (Eddy)
1391	SE¼NE¼ 24, 18S–23E (Eddy)
1392–1393	SE¼NE¼ 24, 18S–21E (Eddy)
1394–1395	SW¼NW¼ 13, 18S–24E (Eddy)
1396–1397	NE¼SE¼ 3, 22S–26E (Eddy)
1399–1401	SW¼ 21, 23S–23E (Eddy)
1402	SW¼NW¼ 16, 24S–26E (Eddy)
1403–1407	SW¼NE¼ 15, 24S–26E (Eddy)
1408	SE¼NE¼ 31, 23S–27E (Eddy)
1409–1411	NW¼ 17, 23S–27E (Eddy)
1412–1415	NW¼NW¼ 21, 25S–25E (Eddy)
1416–1419	SW¼ 20, 25S–25E (Eddy)
1420–1422	NW¼ 33, 24S–26E (Eddy)
1423–1424	NW¼ 18, 24S–27E (Eddy)
1425	SW¼ 13, 26S–26E (Eddy)
1426–1430	NE¼SE¼ 5, 22S–27E (Eddy)
1431–1432	NW¼ 34, 21S–27E (Eddy)
1433	NW¼ 18, 19S–24E (Eddy)
1434–1436	NE¼ 18, 19S–24E (Eddy)
1437	SE¼ 2, 6S–14E (Lincoln)
1503–1504	NW¼SW¼ 25, 4N–6E (Torrance)
1505–1508	NE¼SE¼ 14, 5N–6E (Torrance)
1509–1511	NW¼ 31, 4N–7E (Torrance)
1513–1514	NE¼ 16, 6N–7E (Torrance)
1515–1516	SW¼ 18, 7N–7E (Torrance)
1518	SW¼ 35, 8N–8E (Torrance)
1519–1521	SW¼ 31, 10N–9E (Santa Fe)
1522–1524	SE¼ 30, 10N–9E (Santa Fe)
1525–1526	SE¼ 28, 11N–8E (Santa Fe)
1527–1528	NW¼NE¼ 4, 11N–9E (Santa Fe)
1529	SE¼ 34, 12N–9E (Santa Fe)
1530–1538	NW¼NW¼ 12, 3N–6E (Torrance)
1539	SE¼SE¼ 17, 4N–8E (Torrance)
1540–1541	SW¼SE¼ 31, 2N–13E (Torrance)
1544–1547	NE¼ 15, 5N–16E (Guadalupe)
1548	SE¼ 16, 6N–16E (Guadalupe)
1549	SW¼NW¼ 10, 6N–16E (Guadalupe)
1550–1552	NW¼ 33, 5N–14E (Torrance)
1553–1555	SE¼ 20, 9N–16E (Guadalupe)
1556	NW¼ 31, 8N–18E (Guadalupe)
1558–1563	SW¼ 29, 9N–19E (Guadalupe)
1564	SE¼ 35, 1N–19E (Lincoln)
1565	SE¼ 35, 3S–21E (DeBaca)
1566–1567	SW¼SW¼ 36, 10S–22E (Chaves)
1568–1575	NE¼NE¼ 11, 11S–21E (Chaves)
1576–1581	SE¼NW¼ 10, 11S–21E (Chaves)
1582–1585	SE¼ 33, 14S–25E (Chaves)
1586–1588	NE¼ 25, 19S–25E (Eddy)
1589–1593	SE¼SE¼ 22, 22S–26E (Eddy)
1594	SW¼NE¼ 20, 23S–26E (Eddy)
1611–1614	NE¼ 19, 22S–28E (Eddy)
1616–1617	NE¼NE¼ 5, 20S–27E (Eddy)
1718	NW¼ 9, 14N–12E (San Miguel)
1720–1721	SW¼ 22, 14N–12E (San Miguel)
1722	NE¼ 15, 13N–12E (San Miguel)

TABLE 2—Clay-mineral analyses (*stratigraphic sections described in table 3; location of samples shown in fig. 1 and table 1).

Sample No. (NMP-)	Clay minerals (%) Montmorillonite	Illite	Kaolinite and chlorite	Attapulgite (palygorskite)	Sepiolite	Remarks, supplementary mineral data, and stratigraphic notes
929	49	20	4	27	—	barite; Ogallala?
930	72	21	7	—	—	Ogallala?
931	62	25	13	—	—	Ogallala?
932	42	30	4	11	13	Ogallala?
933	10	12	4	—	74	barite; Ogallala?
934	2	8	8	—	82	caliche crust
935	78	16	6	—	—	gypsum; F-120; C-14 date: 20,500 ± 600 yrs (Illinois State Geological Survey sample number 458)
936	60	(5)	2	33	—	
			*Microwave relay tower west section			
937	57	32	11	—	—	chlorite, Ogallala, zone V
938	14	(5)	3	78	—	Ogallala, zone II
939	57	(5)	3	35	—	Ogallala, zone II
940	7	10	2	18	63	Ogallala, zone III
941	15	71	14	—	—	chlorite; F-121; Pleistocene
942	31	50	19	—	—	chlorite; F-122; Pleistocene
			*Pintanda Canyon north section			
943	46	41	13	—	—	Ogallala
944	54	22	6	18	—	Ogallala
945	24	(5)	2	33	36	Ogallala
946	34	28	17	21	—	Ogallala
			*Dahlia south section			
947	57	25	18	—	—	Ogallala, zone V
948	6	(5)	1	39	49	Ogallala, zone III
949	74	(5)	2	18	—	Ogallala, zone II
950	59	19	5	17	—	Ogallala, zone II
951	54	23	3	19	—	Ogallala, zone II

Sample No. (NMP-)	Clay minerals (%) Montmorillonite	Illite	Kaolinite and chlorite	Attapulgite (palygorskite)	Sepiolite	Remarks, supplementary mineral data, and stratigraphic notes
***Vaughn railway cut section**						
952	25	(5)	3	67	—	Ogallala, zone II
953	25	(5)	3	67	—	Ogallala, zone II
954	64	(5)	6	25	—	Ogallala, zone II
***Vaughn southwest section**						
955	42	42	16	—	—	chlorite, Ogallala, zone V
956	28	(5)	6	61	—	Ogallala, zone II
1001	20	(5)	2	38	35	platy caliche
1002	45	34	21	—	—	chlorite; pisolitic limestones
***Mountainair east-northeast section**						
1003	61	29	10	—	—	Pleistocene
1004	4	(5)	1	63	27	Ogallala, zone III
1005	54	(5)	4	37	—	Ogallala, zone II
***Vaughn west section**						
1006	70	14	4	12	—	Ogallala, zone II
1007	73	10	4	13	—	Ogallala, zone II
1008	38	(5)	4	53	—	Ogallala, zone II
1009	61	(5)	2	32	—	Ogallala, zone II
1010	13	(5)	3	79	—	Ogallala, zone II
1011	3	(5)	1	24	67	Ogallala, zone III
1012	10	(5)	2	83	—	barite; Ogallala, zone III
1013	43	45	12	—	—	chlorite; Pleistocene
1014	17	66	17	—	—	chlorite; Pleistocene
1015	16	64	19	—	—	chlorite; Pleistocene
1016	—	—	—	—	—	gypsum; F-123, Pleistocene
1017	8	(5)	3	37	47	dolomite; Ogallala?
1018	2	6	1	—	91	caliche crust
***Vaughn railway cut section**						
1019	65	(5)	4	26	—	Ogallala, zone II
1020	47	(5)	6	42	—	Ogallala, zone II
1021	41	(5)	7	47	—	Ogallala, zone II
1022	46	(5)	6	43	—	Ogallala, zone II
1023	19	(5)	3	73	—	Ogallala, zone II
1024	23	(5)	5	67	—	Ogallala, zone II
1025	30	(5)	4	61	—	Ogallala, zone II
1026	18	(5)	2	75	—	Ogallala, zone II
***Willard east section**						
1027	37	50	13	—	—	chlorite, gypsum; Pleistocene
1028	50	39	11	—	—	chlorite; Pleistocene
1029	—	—	—	—	—	volcanic ash; Pleistocene
1030	50	42	8	—	—	chlorite; Pleistocene
1031	49	39	12	—	—	gypsum; Pleistocene
1032	38	46	16	—	—	Pleistocene
1033	31	54	15	—	—	chlorite; Pleistocene
1034	40	48	12	—	—	
***Willard west section**						
1035	69	(5)	2	24	—	Ogallala, zone II
1036	51	(5)	6	38	—	dolomite; Ogallala, zone II
1037	40	(5)	5	50	—	dolomite; Ogallala, zone II
***Mountainair southwest section**						
1038	69	10	6	15	—	Ogallala
1039	64	13	7	16	—	Ogallala
1040	69	13	5	13	—	Ogallala
1041	38	(5)	3	31	23	dolomite; Ogallala
1042	34	(5)	3	58	—	Ogallala
1043	1	(5)	1	19	74	caliche crust
1044	63	24	13	—	—	chlorite; caliche crust
1045	61	(5)	3	31	—	pediment material
1046	64	27	9	—	—	chlorite; pediment material
1047	61	(5)	3	31	—	Ogallala
***Gran Quivira section**						
1048	74	(5)	3	18	—	Pleistocene (Kansan or older)
1049	14	(5)	1	80	—	Pleistocene (Kansan or older)
1050	64	26	10	—	—	Pleistocene (Kansan or older)
1051	55	31	14	—	—	Pleistocene (Kansan or older)
1052	71	(5)	3	21	—	caliche crust
1053	28	34	7	31	—	Pleistocene
1054	49	(5)	5	41	—	
1055	41	26	8	25	—	Pleistocene
Cedarvale northwest section						
1056(1)	—	—	—	—	—	barite; Ogallala
1056(2)	20	(5)	3	72	—	Ogallala
1056(3)	15	(5)	3	29	48	Ogallala
1057	21	(5)	1	24	49	Ogallala
1058	51	35	14	—	—	chlorite; Ogallala
1059	6	(5)	1	11	77	barite; Ogallala
1060(a)	—	—	—	—	—	Ogallala
1060(b)	11	(5)	3	13	68	barite; Ogallala
1060(c)	48	36	16	—	—	Ogallala
1061	44	38	18	—	—	chlorite; pisolitic limestones; Ogallala
1062	1	(5)	1	23	70	caliche crust
1063	32	(5)	3	60	—	Ogallala
1064	48	25	9	18	—	Ogallala
1065	50	37	13	—	—	pediment veneer
1066	63	(5)	4	28	—	Ogallala, zone II
***Vaughn southwest section**						
1067	56	17	15	12	—	Ogallala, zone II
1068	68	(5)	4	23	—	Ogallala, zone II
1069	68	(5)	6	21	—	Ogallala, zone II
1070	21	(5)	1	73	—	Ogallala, zone II
1071	37	(5)	4	54	—	Ogallala, zone II
1072	2	(5)	2	60	31	barite; Ogallala, zone III
1073	35	13	5	—	47	barite; Ogallala, zone III
1074	34	41	25	—	—	barite; Ogallala, zone V
1075	50	34	16	—	—	chlorite; F-124; Pleistocene
1076(a)	67	16	7	10	—	chlorite; F-125; Pleistocene
1076(b)	75	17	8	?	—	chlorite; F-125; Pleistocene
1077	69	25	6	—	—	chlorite; F-126; Pleistocene
***Encino north section**						
1078	84	12	4	—	—	basin fill; Ogallala?, zone I?
1079	59	(5)	10	26	—	basin fill; Ogallala?, zone II?
1080	48	(5)	5	42	—	basin fill; Ogallala?, zone II?
1081	55	(5)	6	34	—	basin fill; Ogallala?, zone II?
1082	64	(5)	10	21	—	basin fill; Ogallala?, zone II?
***Yeso southwest section**						
1083	64	(5)	5	26	—	Ogallala, zone II
1084	—	12	6	—	—	82% corrensite; Ogallala, zone II
1085	13	(5)	2	80	—	Ogallala, zone II
1086	41	40	19	—	—	chlorite; Ogallala, zone V
***Ramon southeast section**						
1087	61	(5)	6	28	—	Ogallala, zone II
1088	86	(5)	2	7	—	Ogallala, zone II
1089	90	4	2	4	—	Ogallala, zone II
1090	33	(5)	4	58	—	Ogallala, zone II
1091	63	(5)	6	26	—	Ogallala, zone II
1092	36	(5)	4	55	—	Ogallala, zone II
1093	1	(5)	1	93	—	Ogallala, zone II
1094	1	(5)	1	93	—	Ogallala, zone II
1095	1	(5)	1	93	—	Ogallala, zone II
1096	49	33	18	0	0	chlorite; pisolitic limestones; Ogallala
***Ramon southwest section**						
1097	34	(5)	3	58	—	Ogallala, zone II
1098	47	(5)	3	45	—	Ogallala, zone II
1099	85	10	5	—	—	Ogallala, zone IV
1100	27	48	25	—	—	chlorite; Ogallala, zone V
1101	80	(5)	4	11	—	
1102	80	(5)	4	11	—	chlorite; F-127; Pleistocene
***Guadalupe sinkhole section**						
1103	24	(5)	4	67	—	Ogallala, zone II
1104	12	(5)	2	81	—	Ogallala, zone II
1105	58	25	17	—	—	chlorite; Ogallala, zone V
Aston Ranch north section						
1106	60	31	9	—	—	chlorite; early Pleistocene?
1107	79	(5)	2	14	—	early Pleistocene?
1108	36	(5)	3	56	—	early Pleistocene?
1109	65	25	10	—	—	chlorite; early Pleistocene?
1110	53	(5)	4	38	—	Ogallala?

TABLE 2 (continued)

Sample No. (NMP-)	Clay minerals (%) Montmorillonite	Illite	Kaolinite and chlorite	Attapulgite (palygorskite)	Sepiolite	Remarks, supplementary mineral data, and stratigraphic notes
***Poquita Mesa west section**						
1111	67	(5)	4	24	—	Ogallala, zone II
1112	63	(5)	2	30	—	Ogallala, zone II
1113	53	33	14	—	—	chlorite; Ogallala, zone V
Sapello south section						
1114	—	—	—	—	—	Cretaceous
1115	54	32	14	—	—	Ogallala?
1116	64	25	11	—	—	Ogallala?
1117	65	24	11	—	—	chlorite; Ogallala?
Watrous west section						
1118	40	41	19	—	—	chlorite; Cretaceous
1119	—	—	—	—	—	no crystalline material
1120	—	—	—	—	—	no clay minerals
1121	14	22	9	—	55	Ogallala
1122	50	37	13	—	—	Ogallala
Wagon Mound northwest section						
1123	—	—	—	—	—	Cretaceous
1124	—	—	—	—	—	Ogallala
1125	77	(5)	3	15	—	Ogallala, zone II
1126	50	34	15	—	—	Ogallala, zone IV
1127	60	28	12	—	—	chlorite; caliche crust on basalt
Wagon Mound section						
1128	—	—	—	—	—	Cretaceous shale
1129	92	5	3	—	—	Pleistocene above Cretaceous
1130	88	10	2	—	—	Pleistocene above Cretaceous
1131	96	3	1	—	—	Pleistocene below basalt
1132	28	45	27	—	—	chlorite; caliche crust
1133	13	(5)	3	28	51	Ogallala, zone III
1134	59	26	16	—	—	Ogallala, zone IV
1135	65	22	13	—	—	Ogallala
1136	35	44	21	—	—	chlorite; Ogallala
***Trujillo northwest section**						
1137	58	(5)	6	31	—	Ogallala, zone II
1138	64	(5)	5	26	—	Ogallala, zone II
1139	60	(5)	10	25	—	Ogallala, zone II
1140	59	(5)	9	27	—	Ogallala, zone II
1141	59	27	14	—	—	chlorite; pisolitic limestones; Ogallala, zone V
1142	53	(5)	3	16	23	Ogallala, zone III
1143	50	(5)	7	13	25	Ogallala, zone III
Trujillo west section						
1144	80	7	6	7	—	caliche crust
1145	18	12	5	—	65	caliche crust
1146	9	10	11	—	70	caliche crust
Las Vegas east section						
1147	65	25	10	—	—	Cretaceous shale
1148	91	5	4	—	—	Ogallala, zone I
1149	84	9	7	—	—	Ogallala, zone I
1150	86	8	6	—	—	Ogallala, zone I
1151	57	30	13	—	—	chlorite; Pleistocene
1152	61	(5)	11	23	—	Ogallala
1153	74	19	7	—	—	Ogallala
1154	48	44	8	—	—	Ogallala
Pastura north-northwest section						
1155	70	(5)	7	18	—	Ogallala, zone II
1156	70	(5)	10	15	—	Ogallala, zone II
1157	33	48	19	—	—	chlorite; Ogallala, zone IV
***Vaughn northeast section**						
1158	54	(5)	8	33	—	Ogallala, zone II
1159	56	(5)	7	32	—	Ogallala, zone II
1160	57	(5)	5	33	—	Ogallala, zone II
1161	57	(5)	5	33	—	Ogallala, zone II
1162	29	16	6	—	49	Ogallala, zone III
***Conejo Mesa section**						
1163	32	(5)	5	58	—	Ogallala, zone II
1164	25	(5)	3	67	—	Ogallala, zone II
1165	33	52	15	—	—	chlorite; pisolitic limestones, zone V
1166	66	(5)	3	26	—	Ogallala, zone II
***Poquita Mesa east section**						
1167	66	18	3	13	—	Ogallala, zone II
***Encinoso east section**						
1168	70	13	4	13	—	early Pleistocene or Ogallala
1169	82	8	2	8	—	early Pleistocene or Ogallala
1170	55	18	7	20	—	early Pleistocene or Ogallala
1171	46	27	11	16	—	early Pleistocene or Ogallala
***El Paso Natural Gas north-northwest A section**						
1172	9	(5)	1	57	28	early Pleistocene (Nebraskan?)
1173	9	(5)	2	84	—	early Pleistocene (Nebraskan?)
1174	4	(5)	1	90	—	early Pleistocene (Nebraskan?)
1175	17	(5)	3	53	22	early Pleistocene (Nebraskan?)
1176	22	(5)	3	70	—	early Pleistocene (Nebraskan?)
1177	5	(5)	1	48	41	early Pleistocene (Nebraskan?)
1178	12	(5)	1	52	30	early Pleistocene (Nebraskan?)
Bitter Lake Refuge west section						
1179	63	31	6	—	—	shale; Permian
1180	40	31	5	24	—	Ogallala?
1181	52	41	7	—	—	Ogallala?
1182	47	42	11	—	—	Ogallala?
1183	55	21	5	19	—	Ogallala?
1184	39	(5)	4	52	—	Ogallala, zone V
1185	78	(5)	3	14	—	Ogallala, zone V
Roswell Airbase south section						
1186	78	12	3	7	—	early Pleistocene; pediment
1187-tan	34	(5)	7	54	—	caliche; Pleistocene; pediment
1187-white	4	(5)	3	88	—	caliche; Pleistocene; pediment
1188	87	(5)	1	7	—	Ogallala, zone II
1189	6	(5)	1	39	49	Ogallala, zone III
1190	76	18	6	—	—	Pleistocene; Holocene
1191	57	32	11	—	—	Pleistocene; F-130; F-129
Sapello south section						
1201	10	78	12	—	—	Cretaceous shale
1202	29	63	8	—	—	(NMP-1114–1117, 1218–1221); Cretaceous
1203	46	47	7	—	—	Cretaceous
1204	46	42	12	—	—	B horizon; Ogallala?
1205	29	51	20	—	—	B horizon; Ogallala?
1206	15	10	7	16	52	banded caliche; caliche crust
1207	8	(5)	3	23	61	dense caliche; caliche crust
1208	54	34	12	—	—	gypsum; caliche crust
1209	35	33	32	—	—	chlorite; Cretaceous
1210	3	(5)	3	51	38	Ogallala, or caliche crust
1211	2	7	2	?	89	Ogallala, or caliche crust
1212	3	8	2	—	87	Ogallala, or caliche crust
***Trujillo northwest section**						
1213	4	(5)	2	19	17	Ogallala, zone III; (NMP-1137–1141)
Sapello south section						
1218	54	37	9	—	—	Ogallala?
1219	55	32	13	—	—	Ogallala?
1220	65	27	8	—	—	Ogallala?
1221	46	42	12	—	—	Ogallala?
***Mountainair east-northeast section**						
1222	65	(5)	5	25	—	(NMP-1003–1105); Pleistocene lens above Ogallala
1223	54	(5)	5	36	—	Pleistocene on Ogallala; (NMP-1038–1042)
1224	62	32	6	—	—	Ogallala?

Sample No. (NMP-)	Clay minerals (%) Montmorillonite	Illite	Kaolinite and chlorite	Attapulgite (palygorskite)	Sepiolite	Remarks, supplementary mineral data, and stratigraphic notes
			***Duran northeast section**			
1225	56	32	12	—	—	Ogallala, zone I
1226	66	(5)	7	22	—	Ogallala, zone II
1227	28	(5)	3	64	—	Ogallala, zone II
1228	1	(5)	1	18	75	Ogallala, zone III
1229	71	22	7	—	—	Ogallala, zone IV
1230	17	(5)	14	64	—	caliche crust
			Torrance northeast section			
1231	—	—	—	—	—	gypsum; weathered Permian
1232	12	(5)	1	82	—	disturbed Ogallala
1233	15	(5)	1	42	37	disturbed Ogallala
1234	34	(5)	5	56	—	caliche crust
			***Duran southwest section**			
1235	66	23	11	—	—	Ogallala
1236	64	23	13	—	—	chlorite; Ogallala
1237	66	27	7	—	—	Ogallala
1238	70	22	8	—	—	chlorite; Ogallala
1239	72	20	8	—	—	chlorite; Ogallala
1240	5	(5)	2	33	55	(above NMP-1066); Ogallala
1241	62	27	11	—	—	Ogallala
1242	78	16	6	—	—	early Pleistocene
1243	46	40	14	—	—	early Pleistocene
1244	75	18	7	—	—	chlorite; early Pleistocene
1245	74	19	7	—	—	chlorite; early Pleistocene
			Torrance section			
1246	53	(5)	3	39	—	Ogallala, zone II
1247	31	(5)	4	60	—	Ogallala, zone II
1248	41	(5)	6	48	—	reworked Ogallala
1249	31	(5)	4	60	—	Ogallala, zone II
1250	19	8	4	—	69	barite; Ogallala, zone III
1251	—	—	—	65	—	Ogallala, zone II
1252	16	(5)	4	29	46	barite; Ogallala, zone III
1253	41	23	9	27	—	Ogallala, zone II
			Cedarvale southeast section			
1254	47	(5)	6	41	—	Ogallala, zone II
1255	50	(5)	4	41	—	Ogallala, zone II
1256	6	3	2	—	89	Ogallala, zone III
1257	73	10	6	11	—	Pleistocene
			***Willard west section**			
1258	15	(5)	2	78	—	Ogallala, zone II
1259	54	(5)	4	37	—	Ogallala, zone II
1260	25	(5)	4	66	—	Ogallala, zone II
1261	57	(5)	5	33	—	Ogallala, zone II
1262	12	(5)	4	22	57	dolomite; Ogallala, zone III
1263	3	(5)	1	23	68	Ogallala, zone III
			***Mountainair southeast section**			
1264	49	(5)	8	38	—	Ogallala, zone II
1265	6	(5)	1	60	28	Ogallala, zone III
1266	13	(5)	1	51	30	Ogallala, zone III
1267	37	(5)	5	29	24	Ogallala, zone III
1268	38	(5)	3	54	—	(NMP-1257); Ogallala?
1269	1	5	1	—	93	Ogallala?
			***Edgewood section**			
1270	56	35	9	—	—	pediment veneer
1271	60	31	9	—	—	pediment veneer
1272	69	20	11	—	—	pediment veneer
			Stanley railway cut section			
1273	10	(5)	3	52	30	Ogallala, zone III
1274	11	14	7	—	68	Ogallala, zone III
1275	1	10	3	—	86	(NMP-1269); Ogallala?
1276	60	29	11	—	—	caliche crust
1277	27	58	15	—	—	chlorite; Triassic shale
1278(a)	2	15	16	—	67	authigenic kaolinite; Ogallala?
1278(b)	—	—	—	—	—	opal, calcite, and quartz vein filling
1279	28	(5)	2	65	—	Ogallala
			Vaughn east section			
1280	68	(5)	4	23	—	Ogallala, zone II
1281	43	(5)	2	50	—	Ogallala, zone II
1282	45	(5)	2	48	—	Ogallala, zone II
			Perez Straughn southeast section			
1283	15	(5)	3	77	—	Ogallala, zone II
1284	11	(5)	2	38	44	Ogallala, zone III
1285	57	29	14	—	—	Ogallala, zone IV
1286	25	20	5	—	50	caliche crust; Pleistocene
			***Microwave relay tower west section**			
1287	24	33	2	41	—	Ogallala, zone II
1288	26	39	7	28	—	Ogallala, zone II
1289	21	(5)	3	70	—	Ogallala, zone II
1290	4	(5)	1	90	—	Ogallala, zone II
			***Arroyo Salado south section**			
1291	60	27	13	—	—	Triassic shale
1292	38	35	4	23	—	Ogallala, zone II
1293	64	(5)	3	28	—	Ogallala, zone II
1294	69	21	10	—	—	gypsum; Ogallala, zone IV
1295	53	30	17	—	—	Ogallala, zone IV
1296	50	35	15	—	—	chlorite; Ogallala, zone V
			***Vaughn gravel pit section**			
1297	94	4	2	—	—	Ogallala
1298	84	7	9	—	—	Ogallala
1299	83	(5)	3	9	—	Ogallala
1300	50	37	13	—	—	Ogallala
1301	1	(5)	1	12	81	caliche crust
			***Cedarvale northeast section**			
1302	67	(5)	2	26	—	Ogallala, zone II
1303	42	(5)	5	25	12	Ogallala, zone III
1304	54	(5)	5	20	16	Ogallala, zone III
1305	57	26	17	—	—	Ogallala, zone V
1306	55	18	7	20	—	Ogallala
1307	—	—	—	—	—	corrensite; Permian
1308	13	83	4	—	—	Permian limestone
			Mesa north section			
1309	46	(5)	3	36	—	Ogallala, zone II
1310	44	(5)	2	49	—	Ogallala, zone II
1311	52	34	14	—	—	Ogallala, zone IV
			***El Paso Natural Gas north-northwest B section**			
1312	—	—	—	—	—	corrensite; Permian
1313	—	—	—	—	—	corrensite; Permian
1314	—	—	—	—	—	corrensite; Permian
1315	—	—	—	—	—	corrensite; Permian
1316	—	29	2	37	—	32% corrensite; Ogallala, zone II
1317	19	26	2	30	—	23% corrensite; Ogallala, zone II
1318	3	(5)	2	70	20	Ogallala, zone III
1319	2	(5)	2	50	41	Ogallala, zone III
1320	1	(5)	1	39	54	Ogallala, zone III
1321	27	(5)	3	65	—	Ogallala, zone IV
			***Poquita Mesa east section**			
1322	—	23	7	—	—	70% corrensite; Ogallala, zone I
1323	39	10	2	11	—	38% corrensite; Ogallala, zone II
1167	66	18	3	13	—	Ogallala, zone II
1324	51	18	3	28	—	Ogallala, zone II
1325	50	20	4	26	—	Ogallala, zone II
1326	60	28	12	—	—	Ogallala, zone IV
			***Donnahoo Hills section**			
1327	51	20	5	24	—	Ogallala, zone II
1328	52	24	7	17	—	Ogallala, zone II
1329	11	10	4	—	75	Ogallala, zone III
1330	25	(5)	4	68	—	Ogallala, zone III
175	53	33	14	—	—	pisolitic limestone used for C-14 dating, zone V

TABLE 2 (continued)

Sample No. (NMP-)	Clay minerals (%)					Remarks, supplementary mineral data, and stratigraphic notes
	Montmorillonite	Illite	Kaolinite and chlorite	Attapulgite (palygorskite)	Sepiolite	
Dunahoo Hills southwest section						
1331	41	27	4	28	—	chlorite; early Pleistocene
1332	39	(5)	3	53	—	dolomite; chlorite; early Pleistocene
1333	41	27	4	28	—	dolomite; chlorite; early Pleistocene
1334	60	18	6	16	—	Pleistocene
1335	48	(5)	7	40	—	Pleistocene
1336	53	33	14	—	—	chlorite; Pleistocene
1337	34	54	12	—	—	Pleistocene
1338	32	21	4	34	—	dolomite, chlorite; pediment veneer; early Pleistocene
1339	33	28	8	31	—	dolomite, chlorite; pediment veneer; early Pleistocene
Blackwater Draw west section						
1340	30	(5)	3	62	—	equivalent to NMP-1184; Ogallala?
1341	76	(5)	3	16	—	chlorite; equivalent to sample 1185; Ogallala?
1342	79	(5)	4	12	—	chlorite; Ogallala?
1343	51	32	17	—	—	chlorite; equivalent to NMP-1336; Ogallala?
***Diamond-A northwest section**						
1344	79	(5)	3	13	—	Ogallala (or older)
1345	56	(5)	6	33	—	Ogallala (or older)
1346	(no data)					caliche crust
1347	25	(5)	6	40	24	chlorite; caliche crust
1348	50	42	8	—	—	chlorite, dolomite; late Pleistocene
***Orchard Park west section**						
1349	61	17	4	18	?	Pleistocene pediment
1350	18	(5)	6	71	—	Pleistocene pediment
1351	11	46	6	37	?	chlorite; Pleistocene pediment
***Rio Felix section**						
1352	79	(5)	4	12	—	Pleistocene
1353	66	27	7	?	—	dolomite, chlorite; Pleistocene
1354	68	24	8	?	—	dolomite, chlorite; Pleistocene
1355	57	(5)	3	35	—	Pleistocene
1356	50	40	10	—	—	Pleistocene
1357	(clay minerals weathered beyond recognition)					Rio Felix terrace (F-131); Holocene
1358	85	(5)	2	8	—	Pleistocene
1359	38	(5)	3	54	—	Ogallala, zone II
1360	54	34	12	—	—	chlorite; Ogallala, zone V
***Made Well Draw east section**						
1361	67	(5)	6	22	—	Ogallala, zone II
1362	80	(5)	4	11	—	Ogallala, zone II
1363	52	(5)	4	39	—	Ogallala, zone II
1364	71	(5)	2	22	—	Ogallala, zone II
1188	87	(5)	1	7	—	Ogallala, zone II
Made Well Draw east offset section						
1365	6	(5)	2	87	—	Ogallala, zone II
1366	1	(5)	1	52	31	Ogallala, zone III
1189	6	(5)	1	39	49	Ogallala, zone III
1367	33	(5)	5	57	—	Ogallala, zone III
1368	68	22	10	—	—	dolomite chlorite; Ogallala, zone V
1369	—	66	7	—	—	27% corrensite; Pleistocene
1370	7	(5)	4	38	46	Pleistocene; caliche crust
1371	—	—	—	—	—	gypsum; F-132; Pleistocene
1372	(clay minerals weathered beyond recognition)					Pleistocene
1373	45	26	8	21	—	Ogallala
1374	45	28	7	20	—	dolomite; colluvium
1375	58	20	5	17	—	colluvium
1376	65	24	11	—	—	Ogallala?
1377	69	21	10	—	—	Pleistocene
1378	65	24	11	—	—	Ogallala?
1379	53	(5)	5	37	—	caliche crust
Blackwater Creek east section						
1380	48	27	3	—	—	22% corrensite, dolomite; Ogallala?
1381	74	(5)	1	20	—	Ogallala?
1382	6	(5)	2	57	30	Ogallala?
1383	42	26	—	—	—	32% corrensite, dolomite; Ogallala?
***Artesia landfill section**						
1384	67	16	4	13	—	early Pleistocene; pediment
1385	57	17	5	21	—	early Pleistocene; pediment
1386	62	(5)	4	29	—	early Pleistocene; pediment
1387	64	26	10	—	—	chlorite; middle to late Pleistocene; caliche
***Eagle Creek north section**						
1388	55	14	11	20	—	Ogallala, zone II
1389	43	(5)	2	50	—	Ogallala, zone II
1390	60	35	5	—	—	dolomite; Ogallala, zone IV
1391	56	30	14	—	—	F-133; Holocene
1392	21	28	5	25	—	21% corrensite; chlorite; colluvium
1393	3	(5)	2	90	—	caliche crust
1394	62	(5)	3	30	—	Ogallala
1395	82	12	6	?	—	chlorite; Ogallala
1396	57	(5)	8	30	—	Ogallala
1397	34	31	9	26	—	dolomite, chlorite; Ogallala
1398	59	31	10	—	—	Pleistocene?
***Last Chance section**						
1399	30	8	3	—	—	59% corrensite; Ogallala
1400	62	9	2	—	—	27% corrensite; Ogallala
1401	54	33	13	—	—	dolomite, chlorite; Ogallala
1402	40	27	10	23	—	dolomite, chlorite; caliche crust
Mays Ranch section						
1403	80	13	7	?	—	Ogallala
1404	68	13	5	14	—	Ogallala, zone II
1405	56	20	6	18	—	Ogallala, zone II
1406	43	(5)	6	46	—	Ogallala, zone II
1407	17	(5)	2	54	22	dolomite; Ogallala, zone III
1408	2	(5)	1	17	75	Ogallala
1409	55	(5)	7	33	—	Ogallala
1410	31	(5)	4	60	—	Ogallala
1411	43	23	11	23	—	dolomite, chlorite; Ogallala
***Jones Ranch north section**						
1412	76	14	10	—	—	Pleistocene
1413	80	13	7	—	—	Pleistocene
1414	82	8	4	6	—	Pleistocene
1415	52	30	18	—	—	dolomite, chlorite; Pleistocene
***Jones Ranch section**						
1416	70	12	5	13	—	Ogallala, zone II
1417	69	12	7	12	—	Ogallala, zone II
1418	38	(5)	5	52	—	Ogallala, zone II
1419	2	13	85	—	—	dolomite; Ogallala, zone IV
1420	72	18	10	—	—	Pleistocene pond deposit
1421	74	19	17	—	—	Pleistocene pond deposit
1422	72	14	14	—	—	Pleistocene pond deposit
1423	45	33	22	—	—	F-134; Pleistocene
1424	45	37	18	—	—	chlorite; Pleistocene
1425	43	47	10	—	—	chlorite; Holocene
***Carlsbad east section**						
1426	62	(5)	3	30	—	Ogallala, zone II
1427	67	(5)	4	24	—	Ogallala, zone II
1428	22	(5)	1	72	—	Ogallala, zone II
1429	10	(5)	2	83	—	Ogallala, zone III
1430	43	36	21	—	—	Ogallala, zone V
1431	3	(5)	1	37	54	Ogallala?
1432	3	(5)	2	54	36	dolomite; Ogallala?
1433	16	(5)	6	73	—	dolomite; caliche crust
1434	68	(5)	6	21	—	Ogallala?

Sample No. (NMP-)	Clay minerals (%) Montmorillonite	Illite	Kaolinite and chlorite	Attapulgite (palygorskite)	Sepiolite	Remarks, supplementary mineral data, and stratigraphic notes
1435	64	(5)	3	28	—	Ogallala?
1436	20	(5)	3	72	—	Ogallala?
1437	22	55	23	—	—	chlorite; caliche crust
1503	51	(5)	3	41	—	pediment veneer
1504	56	(5)	4	35	—	pediment veneer
Manzano east section						
1505	71	21	8	—	—	middle to late Pleistocene
1506	71	23	6	—	—	caliche; soil profile
1507	79	17	4	—	—	platy caliche, early Pleistocene
1508	75	19	6	—	—	early Pleistocene
1509	51	29	20	—	—	chlorite; Ogallala, zone V; pisolitic
1510	60	28	12	—	—	chlorite; Ogallala, zone V
1511	2	(5)	2	15	76	Ogallala, zone III
1513	68	23	9	—	—	Pleistocene
1514	42	41	17	—	—	Pleistocene
1515	81	12	7	—	—	caliche; Pleistocene
1516	68	17	15	—	—	chlorite; Pleistocene
1518	71	22	6	—	—	Pleistocene
***Bassett section**						
1519	62	28	10	—	—	Pleistocene
1520	67	22	11	—	—	Pleistocene
1521	19	55	26	—	—	Pleistocene
***Bassett north section**						
1522	4	5	—	—	91	platy sand; Ogallala
1523	10	3	1	—	86	dense caliche; Ogallala
1524	5	(5)	5	37	48	dense caliche; Ogallala
1525	49	31	20	—	—	Pleistocene; chlorite
1526	49	27	24	—	—	Pleistocene; chlorite
1527	62	(5)	1	19	13	caliche crust; Ogallala?
1528	2	(5)	2	26	66	caliche crust; Ogallala?
1529	5	(5)	8	26	56	caliche crust
***Mountainair southwest section**						
1530	13	(5)	18	64	—	Ogallala
1531	57	(5)	4	34	—	Ogallala
1532	62	14	11	13	—	Ogallala
1533	29	(5)	5	61	—	Ogallala
1534	78	10	5	7	—	Ogallala
1535	59	18	6	17	—	Ogallala
1536	62	(5)	6	27	—	Ogallala
1537	34	(5)	6	55	—	Ogallala
1538	38	(5)	4	53	—	Ogallala
1539	10	(5)	2	83	—	Ogallala
1540	—	—	—	—	—	Permian; corrensite
1541	—	—	—	—	—	Permian; weathered corrensite
***Vaughn north section**						
1544	54	33	13	—	—	Pleistocene; chlorite
1545	67	21	11	—	—	Pleistocene; chlorite
1546	75	17	8	—	—	Pleistocene
1547	64	24	12	—	—	Pleistocene
1548	42	46	12	—	—	Ogallala, zone IV
1549	66	23	11	—	—	Pleistocene
1550	64	14	4	18	—	Pleistocene
1551	41	29	9	21	—	Pleistocene
1552	20	38	9	33	—	chlorite; Pleistocene
***Cherokee Kid Trading Post section**						
1553	77	13	10	—	—	Ogallala
1554	72	12	5	11	—	Ogallala
1555	45	(5)	4	46	—	Ogallala
1556	—	—	—	—	—	corrensite; Triassic red shale
***Vegas Junction section**						
1558	22	29	49	—	—	Triassic sandstone
1559	3	(5)	3	89	—	Ogallala, zone II
1560	7	(5)	28	60	—	Ogallala, zone II
1561	8	(5)	6	81	—	Ogallala, zone II
1562	2	(5)	4	32	57	Ogallala, zone III
1563	6	38	20	?	36	Pleistocene
1564	3	(5)	1	21	70	caliche crust; Ogallala
1565	40	42	18	—	—	Caliche crust; Ogallala?
1566	58	(5)	6	31	—	Ogallala
1567	44	(5)	6	45	—	Ogallala
***Blackwater Draw west section**						
1568	70	(5)	7	18	—	Ogallala (or younger)
1569	55	(5)	3	37	—	Ogallala (or younger)
1570	9	(5)	4	82	—	Ogallala (or younger)
1571	9	(5)	3	83	—	Ogallala (or younger)
1572	49	(5)	6	40	—	Ogallala (or younger)
1573	65	(5)	3	27	—	Ogallala (or younger)
1574	56	(5)	8	31	—	chlorite, dolomite
1575	40	38	20	—	—	—
***Diamond-A northwest section**						
1576	68	(5)	6	31	—	Ogallala (or older)
1577	74	(5)	5	16	—	Ogallala (or older)
1578	73	(5)	3	19	—	Ogallala (or older)
1579	62	(5)	6	27	—	Ogallala (or older)
1580	50	(5)	6	39	—	Ogallala (or older)
1581	49	(5)	7	39	—	chlorite; Ogallala (or older)
***Mossman siding west section**						
1582	51	(5)	5	39	—	Ogallala?
1583	57	(5)	5	33	—	Ogallala?
1584(a)	16	68	16	—	—	chlorite; Ogallala?
1584(b)	25	49	26	—	—	chlorite; Ogallala?
1585	28	(5)	4	63	—	Ogallala?
1586	63	19	4	14	—	Permian
1587	82	8	3	7	—	Ogallala? (or older)
1588	73	12	5	12	—	Ogallala? (or older)
***Carlsbad south-southwest section**						
1589	47	38	15	—	—	dolomite; Ogallala
1590	49	45	16	—	—	dolomite; Ogallala
1591	45	42	13	—	—	dolomite; Ogallala
1592	19	(5)	9	67	—	dolomite; Ogallala
1593	45	40	15	—	—	chlorite, dolomite; Ogallala
1594	3	(5)	1	66	25	pediment veneer
***Carlsbad southeast section**						
1611	43	16	4	17	20	Ogallala?
1612	43	19	5	16	17	Ogallala?
1613	8	(5)	3	84	—	Ogallala?
1614	24	(5)	11	60	—	Ogallala?
1616	50	(5)	6	44	—	caliche crust, or thin Ogallala
1617	2	(5)	1	18	74	caliche crust, or thin Ogallala
1718	52	19	8	21	—	caliche crust at edge of Ogallala channel
1720	73	19	8	—	—	chlorite; Ogallala, zone I
1721	30	68	2	—	—	Permian shale below Ogallala
1722	67	25	8	—	—	chlorite; Ogallala, zone I

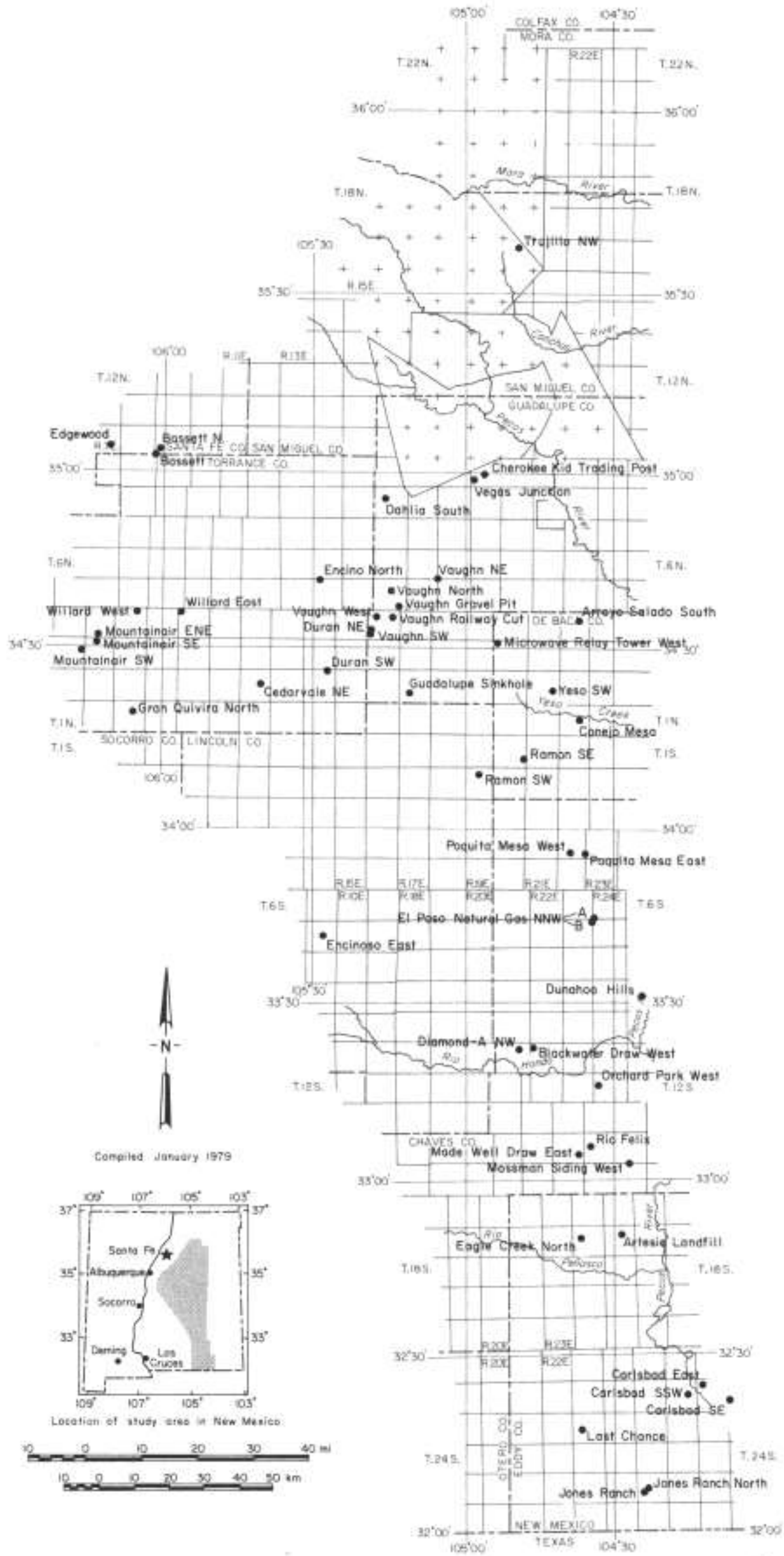

FIGURE 10—Map showing location of described stratigraphic sections listed in Table 3.

TABLE 3—Measured stratigraphic sections (New Mexico county, year(s) of field work, and sample numbers in parentheses).

Arroyo Salado south section—NW¼SE¼ sec. 10, T. 4 N., R. 22 E., north of Yeso (DeBaca County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	39.0
	Ogallala Formation	
5	Caliche, dense, hard, tough, locally contains pink-tan pisolites in gray-tan matrix; some sand (NMP-1296, top); poorly exposed lower part	5.0
4	Caliche, dense, gray to gray-tan; banding but no pisolites, sand grains (NMP-1295, upper)	4.0
3	Caliche with sand, massive, gray to cream-tan; indistinct platy structure with no pisolites or banding; moderately compact (NMP-1293, lower; NMP-1294, upper)	12.0
2	Sand and silt, with small pebbles, red-brown, mottled throughout with caliche nodules; covered in upper part of interval (NMP-1292, lower)	18.0
	Triassic	
1	Shale, gray-green, with boxwork veinlets of gray caliche (NMP-1291) (not measured)	—

Artesia landfill section—SW¼NW¼ sec. 10, T. 17 S., R. 25 E. (Eddy County, 1977)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	20.0
	Earliest pediment deposits	
	(Note: From here east to Artesia the pediment surface slopes approximately 40 ft per mi)	
3	Caliche, dense, banded, gray-tan and gray; sand and limestone pebbles dispersed; top of pediment surface (NMP-1387)	3.0
2	Sand, silt, pebbles, and caliche; soft caliche cement throughout, massive but contorted; caliche coating on pebbles; sharp contact at base (NMP-1386)	3.0
1	Gravel (predominantly limestone), sand and silt in interstices; boulders up to 1 ft diameter; not distinctly bedded except for zones of sand and silt; samples from tan-brown sand in middle and upper part (NMP-1384, middle; NMP-1385, upper)	14.0

Bassett section—in abandoned railway cut, SW¼ sec. 31, T. 10 N., R. 9 E., north-northeast of Moriarty (Santa Fe County, 1978)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	10.0
3	Silt and sand, blocky, tan to light-tan-brown; sharp but irregular contact at base (NMP-1521, 4 ft below top)	6.0
2	Caliche, silt and sand, massive, soft, gray to gray-tan (NMP-1520)	2.0
1	Silt and sand with spots of caliche, tan; blocky to locally indistinct bedding, moderately compact (NMP-1519); gradational upward	2.0

Bassett north section—in abandoned railway cut, SE¼ sec. 30, T. 10 N., R. 9 E., north-northeast of Moriarty (Santa Fe County, 1978)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	8.0
	Ogallala Formation	
3	Caliche, gray, very dense, tough; sparse, incipient pisolites; grades to local upper surface (NMP-1524)	2.0
2	Caliche and sand, moderately dense, gray, crenulate; locally contains a few small pebbles; gradational at top and bottom (NMP-1523, lower part)	4.0
1	Sand with caliche cement, moderately dense, gray-white, platy to crenulate (NMP-1522)	2.0

Blackwater Draw west section—in roadcut along US-70, NE¼NE¼ sec. 11, T. 11 S., R. 21 E. (Chaves County, 1976, 1977, 1978)

Unit	Description	Thickness (ft)
	Pliocene Series (*or Pleistocene*) (total thickness)	14.0
	Ogallala Formation (or younger)	
5	Caliche, in thin plates on top of gravels, and crusts on boulders (NMP-1575)	0.5
4	Gravel and sand with small boulders; samples are from pinkish-tan silt and sand in interstices in the gravel and from streaks and lentils of silt and sand in the gravels (NMP-1571, lower; NMP-1572, 2 ft up; NMP-1573, 2 ft up; NMP-1574, 2 ft up)	9.5
3	Silty sand, pinkish-tan, with a few small pebbles (NMP-1570)	2.0
2	Gravel, coarse, contains crystalline rocks; samples are from gray-tan to pinkish-tan silt and sand in the gravels (NMP-1569)	1.5
1	Sand and silt with a few pebbles, gray-tan to pale pinkish-tan, irregular contact at top, base of section not exposed (NMP-1568)	0.5

Carlsbad east section—NE¼SE¼ sec. 5, T. 22 S., R. 27 E. (Eddy County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	18.0
	Ogallala Formation	
4	Pisolitic limestone and dense caliche, gray; with abundant, well-developed, red-brown pisolites and brownish-gray banding (NMP-1420)	1.0
3	Sand, cemented, light-gray to light-gray-tan; indistinct, crenulate, platy structure (NMP-1429)	4.0
2	Silt, sand, and clay, pink-tan; caliche nodules throughout; massive to microblocky (NMP-1428); widely dispersed pebbles up to 2 inches diameter	8.0
1	Sand, silt, and caliche, cream-tan, with a pinkish cast in lower part; moderately cemented, massive to microblocky structure; widely dispersed pebbles (NMP-1426, base; NMP-1427, upper)	5.0

Carlsbad southeast section—in shallow pit of upland surface, NE¼ sec. 19, T. 22 S., R. 28 E. (Eddy County, 1978)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	10.0
	Ogallala Formation	
4	Caliche, dense, hard; prominent banding but no pisolites; crenulate, platy structure (NMP-1614)	1.0
3	Sand, gravel, and nodules, gray, irregularly cemented, massive (NMP-1613)	4.0
2	Caliche-cemented sand, gray to light-tan; thin, platy structure (NMP-1612); grades downward into well-cemented sand and gravel	3.0
1	Sand, loose, with some pebbles; gray-tan (NMP-1611)	2.0

TABLE 3 (continued)

Carlsbad south-southwest section—in gravel pit and adjacent roadcut, SE¼SE¼ sec. 22, T. 22 S., R. 26 E. (Eddy County, 1978)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	25.0
	Ogallala Formation	
4	Caliche-cemented cobbles, banded, hard, dense; sand in caliche; underlies local upland surface (NMP-1593)	2.0
3	Gravel, coarse; consists largely of cobbles and small boulders of limestone with interstices filled with sand, silt, and relatively soft caliche (NMP-1592, sand, silt, and caliche from interstices)	6.0
2	Sand and silt, tan, little caliche cement; found in distinct bed between coarse gravels (NMP-1591)	1.0
1	Gravel, coarse; consists largely of cobbles and small boulders of limestone with interstices filled with loose sand and silt; some boulders up to a maximum diameter of 2 ft (NMP-1589, sand and silt of interstices 4 ft above floor of pit; NMP-1590, a 3-inch lenticular bed of tan sand and silt within the gravels, 12 ft above floor of pit)	16.0

Cedarvale northeast section—SW¼NE¼ sec. 15, T. 2 N., R. 12 E. (Torrance County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	25.0
	Ogallala Formation	
4	Pisolitic limestone, dense caliche, gray-tan, with pink-tan pisolites, and travertine banding (NMP-1305); found up to the upland level	2.0
3	Caliche, dense, banded; indistinct platy structure; poorly exposed in lower part (NMP-1304)	5.0
2	Sand, pink-tan, with some soft caliche cement and dispersed caliche nodules; poorly exposed (NMP-1303)	6.0
1	Sand and gravel, boulders of crystalline rocks up to 1 ft diameter; zones and streaks of caliche-cemented sand poorly exposed in upper part (NMP-1302, lower part)	12.0

Cherokee Kid Trading Post section—in roadcut along I-40, SE¼ sec. 20, T. 9 N., R. 16 E. (Guadalupe County, 1978)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	22.0
	Ogallala Formation	
4	Sand, gravel, and silt, irregularly cemented with caliche; gray to dirty-gray (NMP-1555, 2 ft below top)	7.0
3	Coarse gravel, contains predominantly crystalline rocks; caliche coating on many pebbles; sharp contact at base, gradational at top	4.0
2	Sand and silt, yellowish-tan, with caliche nodules and stringers; few, small pebbles, moderately compact (NMP-1554, middle)	5.0
1	Sand, tan-brown, loose to moderately compact, massive to irregular blocky structure (NMP-1553, base)	6.0

Conejo Mesa section—in gravel pit east of gravel road at crest of south side of Yeso Creek valley, SE¼SE¼ sec. 14, T. 1 N., R. 22 E. (DeBaca County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	20.0
	Ogallala Formation	
4	Caliche and pisolitic limestone; pink-tan-brown, dense, brittle; found at upland surface (NMP-1165, zone V)	2.0
3	Sand, partly covered; locally contains some gravels and caliche cement	5.0
2	Sand and gravel, gray; in upper part generally caliche-cemented, less cemented in lower part; contains crystalline-rock cobbles up to ½ ft diameter (NMP-1164, zone II)	10.0
1	Sand, with dispersed, small pebbles and caliche nodules, some caliche cement throughout, massive; (NMP-1163, zone II)	3.0
	Contact with Permian below is covered, but Permian rocks are exposed 5 ft below base of this unit	

Dahlia south section—road cuts, SE¼SE¼ sec. 16, T. 8 N., R. 16 E. (Guadalupe County, 1975)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	20.0
	Ogallala Formation	
4	Caliche, dense, gray; sand grains throughout, travertine banding, platy (NMP-947, zone V)	3.5
3	Caliche, massive, white, with few dispersed sand grains (NMP-948, zone III)	1.0
2	Sand, pink-tan to gray-tan, irregularly cemented with some nodules and streaks of harder caliche, blocky (NMP-949, zone II)	4.5
1	Sand, reddish-tan; some caliche nodules, generally uncemented, massive; this interval is partly covered (NMP-950, base, zone II)	11.0

Diamond-A northwest section—SE¼NW¼ sec. 10, T. 11 S., R. 21 E., in roadcuts on north side of highway and in gully in pasture north of highway; deposits on relatively small outlier of high surface (Chaves County, 1978)

Unit	Description	Thickness (ft)
	Pliocene Series (or older) (total thickness)	32.0
	Ogallala Formation	
3	Gravel, coarse, predominantly limestone; interstices filled with silt, sand, small crystalline pebbles, and abundant caliche in platelets and as crusts on boulders (NMP-1581)	4.0
2	Gravel, coarse, predominantly limestone; interstices of silt, sand, and small crystalline pebbles with little caliche; samples all from interstices (NMP-1578, lower; NMP-1579, middle; NMP-1580, upper)	21.0
1	Sand, silty, tan; mottled with gray-tan; soft caliche nodules dispersed; massive, compact (NMP-1576, lower; NMP-1344 and 1577, upper)	7.0

Dunahoo Hills section—NE¼ sec. 15, T. 9 S., R. 25 E. (Chaves County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	18.0
	Ogallala Formation	
5	Pisolitic limestone and dense caliche; gray with reddish-brown pisolites; top of mesa (NMP-175)	1.0
4	Caliche, platy, gray, contains sand grains and small, dispersed pebbles; moderately dense (NMP-1330)	4.0
3	Gravel, coarse, and sand; contains abundant pebbles and cobbles of crystalline rocks; some soft caliche in sand (NMP-1329)	5.0
2	Gravel, fine, and sand; irregular cementation (NMP-1328)	4.0
1	Sand, pink-tan to cream-tan; contains caliche nodules and some caliche cement; contact (not exposed) occurs a few feet above Permian (NMP-1327)	4.0

Duran northeast section—in roadcuts on southeast side of US-54, SE¼NE¼ sec. 30, T. 4 N., R. 16 E. (Guadalupe County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	20.0
	Ogallala Formation	
4	Caliche, dense, gray; platy to massive; top of cut (NMP-1229)	1.0
3	Sand and fine sand, gray to light-cream-tan; irregularly cemented; locally dense and soft (NMP-1228)	3.0
2	Sand, pinkish-tan, massive; dispersed caliche nodules throughout; loosely cemented in upper part (NMP-1226, lower; NMP-1227, upper)	8.0
1	Sand, tan, loose, massive (NMP-1225)	8.0

Duran southwest section—in creek valley and roadcut of US-54; top 2 samples in railway cut of Chicago, Rock Island, and Pacific Railroad southwest of main section, NE¼ sec. 2, T. 2 N., R. 14 E. (Torrance County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	21.0
	Ogallala Formation	
5	Caliche, gray-brown with cream-tan travertine banding; dense, massive to platy; contains a few dispersed pisolites; section overlain by aeolian sand and spoil from railway cut (NMP-1241)	3.0
4	Sand, well-cemented, crenulate to massive, pebbles up to 3 inches diameter; some crystalline rocks dispersed in streaks (NMP-1240)	4.0
3	Sand, tan; massive, soft caliche dispersed throughout (NMP-1239)	6.0
2	Sand, pink-tan; massive, soft caliche throughout lower and middle part; locally compact and mottled with gray (NMP-1236, lower; NMP-1237, middle; NMP-1238, upper)	5.0
1	Silt, clay, and sand, reddish to light-brown; contains filaments of caliche; B horizon of buried soils; columnar structure (NMP-1235)	3.0

Eagle Creek north section—in abandoned pit, NW¼SW¼ sec. 17, T. 17 S., R. 24 E. (Eddy County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	8.0
	Ogallala Formation	
3	Caliche, dense, tough, platy, gray-tan with gray banding; contains a few pebbles cemented in caliche (NMP-1390)	2.0
2	Caliche, massive, white to cream-tan; forms lenticular body with some sand and coarse gravel; gravel predominantly limestone with some quartzite (NMP-1389)	5.0
1	Sand and silt, pinkish-tan, massive, with a few small pebbles and soft caliche throughout (NMP-1388)	1.0

Edgewood section—borrow pit in center of sec. 28, T. 10 N., R. 7 E. (Santa Fe County, 1977)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	25.0
	Pediment veneer	
3	Sand and silt, massive; alternating with caliche-impregnated sand and silt, tan to gray-tan, massive in indistinct units (NMP-1272, upper part)	14.0
2	Clay, silt, and sand, brown; resembles B horizon of buried soil (NMP-1271)	2.0
1	Sand and silt, tan, massive, overlain by rubble of cobbles and angular fragments of local bedrock; matrix of sand, silt, and some clay; resting on bedrock (NMP-1270)	9.0

El Paso Natural Gas north-northwest A section—in roadcuts of US-285 and adjacent butte to east, SW¼ sec. 36, T. 6 S., R. 23 E. (Chaves County, 1976)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	33.0
	Nebraska Stage	
6	Caliche, dense, platy, hard and tough; travertine banding (NMP-1178)	2.0
5	Sand, gray, dense, caliche cement; irregular platy structure; contains pebbles throughout (NMP-1177)	5.0
4	Sand, gray to gray-tan, generally not densely cemented; small pebbles sparsely dispersed throughout; irregular platy to blocky structure (NMP-1176)	6.0
3	Sand, mottled pink-tan and gray; irregular caliche cementing; hard, dense caliche nodules and pebbles dispersed throughout; massive (NMP-1175)	4.0
2	Sand with small, dispersed chert pebbles generally cemented with caliche; massive to indistinct platy structure (NMP-1174)	8.0
1	Sand with some silt, pink-tan; some small pebbles dispersed in upper part, irregular caliche cement and some dispersed caliche nodules; basal contact on Permian covered, but base of this unit is less than 5 ft above Permian contact (NMP-1172, base; NMP-1173, upper part)	8.0

TABLE 3 (continued)

El Paso Natural Gas north-northwest B section—in gullies and eroded slope west of US-285 to highest element of upland west of highway (see A section at lower elevation east of highway) SW¼ sec. 36, T. 6 S., R. 23 E. (Chaves County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness) *Ogallala Formation*	15.0
6	Caliche, dense, platy, gray with a few zones of pinkish-tan with gray-tan banding; lacks well-developed pisolites and travertine banding; caps upland (NMP-1321)	2.0
5	Sand and caliche, densely cemented, gray with some pinkish-tan zones; tough, massive to indistinct platy structure (NMP-1320)	3.0
4	Sand, densely cemented, gray to light gray; sparse pebbles in lower part; areas of pale-pinkish-tan opal cement in upper part (NMP-1318, lower part; NMP-1319, upper part)	3.0
3	Sand and gravel, contains cobbles of quartzite and crystalline rocks up to 4 inches diameter; well-cemented (NMP-1317)	3.0
2	Sand and gravel, irregularly cemented, gray, tan, and pinkish-tan; sharp contact on weathered Permian at base (NMP-1316, basal part)	4.0
	Permian (total thickness)	20.0
1	Siltstone, shale, and fine sandstone, brick-red with gray streaks; weathered (NMP-1315, 5 ft below top; NMP-1314, 10 ft below; NMP-1313, 15 ft below; NMP-1312, 20 ft below top)	20.0
	Total thickness of section	35.0

Encino north section—in fresh road ditch, NW¼ sec. 5, T. 5 N., R. 14 E. (Torrance County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (or younger) (total thickness) *Basin fill* (*Ogallala Formation*?)	20.0
3	Sand, gray, cream, and tan; soft caliche cement becoming denser in upper part; dispersed crystalline-rock pebbles increasing in diameter upward; massive, some nodular cement in upper part (NMP-1082, top; NMP-1081, lower, zone II)	6.0
2	Sand, massive, tan to pink-tan, nodular caliche cement; some dispersed small pebbles of crystalline rocks (NMP-1080, upper; NMP-1079, lower, zone II)	10.0
1	Sand, gray-green, with irregular areas of caliche cement, massive; contains a few scattered pebbles of crystalline rocks (NMP-1078, zone I)	4.0

Encinoso east section—in gravel pit on north flank of Capitan Mountains, near center of sec. 21, T. 7 S., R. 15 E. (Lincoln County, 1976)

Unit	Description	Thickness (ft)
	Pleistocene or Pliocene Series (total thickness) *Kansan Stage* (or older) *or Ogallala Formation*	13.0
4	Caliche, dense, tough, banded to platy; contains some pisolites in bands; found at local upland level but grades upward to Capitan Mountains to the south and downward to drainage of Arroyo del Macho to north (NMP-1171)	2.0
3	Sand with some silt and dispersed, small pebbles of crystalline rocks; some caliche throughout; moderately dense locally; massive (NMP-1170)	4.0
2	Sand with some silt, tan; a few dispersed pebbles and cobbles of crystalline and volcanic rocks; massive, blocky (NMP-1169)	4.0
1	Sand and silt, with a few small, dispersed pebbles; massive, some soft caliche cement throughout; floor of the pit below this zone is strewn with large limestone boulders, but none were observed in the section (NMP-1168)	3.0

Gran Quivira north section—roadcuts 4½ mi north of entrance to Gran Quivira National Monument, NW¼SW¼ sec. 10, T. 1 N., R. 8 E. (Torrance County, 1976)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness) *Kansan Stage or older*	19.0
4	Sand, massive, loose, tan-brown; sharp contact at base	3.0
3	Silt, clay, and sand, massive, reddish-tan; contains a few small pebbles (NMP-1050); grades upward into loosely cemented pinkish-gray-tan sand, with a few small pebbles; contains a thin zone of platy caliche at top (NMP-1051)	7.0
2	Caliche and caliche-cemented sand, gray-tan; contains pebbles and cobbles of crystalline rocks up to ½ ft diameter, and rounded masses of cream-tan caliche that lack the abundant sand that characterizes the matrix; massive (NMP-1049)	5.0
1	Sand, tan, massive; compact but not cemented; extends to base of exposure (NMP-1048)	4.0

Guadalupe sinkhole section—SW¼SE¼ sec. 29, T. 2 N., R. 17 E. (Guadalupe County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness) *Ogallala Formation*	8.0
3	Caliche and pisolitic limestone; tough, brittle, dispersed pisolites; the entire section appears to have been let down below the general Ogallala level by subsidence associated with sinkhole development (NMP-1105, zone V)	3.0
2	Sand, caliche-cemented throughout, massive to indistinct platy structure; gradational top and bottom (NMP-1104, zone II)	2.0
1	Sand and silt, pink-tan, massive, some caliche (NMP-1103, zone II)	3.0

Jones Ranch section—roadcuts in SE¼ sec. 20, T. 25 S., R. 25 E. (Eddy County, 1977)

Unit	Description	Thickness (ft)
	Pliocene (?) Series (total thickness) *Ogallala (?) Formation*	13.0
4	Gravel, coarse, cemented; pebbles and cobbles predominantly of limestone; zone of platy caliche at top (NMP-1419)	5.0
3	Caliche with some sand, gray to cream-white, massive (NMP-1418)	2.0
2	Sand, silt, clay, and caliche, pinkish-gray-tan, massive to blocky; gradational contact at top (NMP-1417)	2.0
1	Conglomerate, cemented; cobbles predominantly of limestone; zone of sand, silt, and caliche at base, cream-tan to pale-pinkish-tan, massive to blocky (NMP-1416)	4.0

Jones Ranch north section—roadcuts in NW¼NW¼ sec. 21, T. 25 S., R. 25 E. (Eddy County, 1977)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	22.0
4	Sand, cemented, gray, platy structure in upper part; conglomerate interzoned with sand; moderately dense (NMP-1415, top)	10.0
3	Caliche and sand, soft, gray to cream-tan; contains a few dispersed, small pebbles (NMP-1414)	2.0
2	Conglomerate, coarse, cemented; zone of silt, sand, and caliche at base (NMP-1413), gray-tan, massive to blocky, compact	8.0
1	Sand, cemented, gray, hard, tough; contains cobbles (NMP-1412)	2.0

Last Chance section—basin fill opening to the north-northeast toward Pecos Valley, SW¼ sec. 21, T. 23 S., R. 23 E. (Eddy County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	20.0
	Ogallala Formation	
3	Coarse gravel cemented with caliche; caliche crust on top and in interstices of gravel (NMP-1401)	9.0
2	Sand and silt, with some pebbles and caliche; pinkish-tan to light-brown, massive (NMP-1400)	8.0
1	Sand, silt, and pebbles; pink-tan; pebbles are mostly of Permian bedrock; massive to contorted (NMP-1399)	3.0

Made Well Draw east section—NW¼NW¼ sec. 26, T. 14 S., R. 23 E.; composite section, upper part in NE¼ sec. 27, T. 14 S., R. 23 E. (Chaves County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness, composite section)	24.0
	Ogallala Formation	
5	Caliche, platy, dense, some banding but no pisolites; found at upland level (NMP-1367)	3.0
4	Sand, silt, and caliche, cream-tan; contains a few dispersed pebbles and caliche nodules (NMP-1189; NMP-1366, upper; NMP-1365, lower); zone of soft cemented sand in middle of interval	5.0
Section offset by ¼ mi		
3	Caliche, soft; sand and silt, cream-tan (NMP-1188, NMP-1364); zone occurs in coarse gravels	5.0
2	Sand, bedded, loose, tan to gray; below zone of cemented sand in sand and gravel; gravels above and below (NMP-1363)	2.0
1	Gravel and sand, coarse, multicolored, locally cemented; samples from gray-tan to pink-tan sand and silt in the interstices (NMP-1361, lower; NMP-1362, upper)	9.0

Microwave relay tower west section—along US-60, in NE¼NE¼ sec. 6, T. 3 N., R. 20 E. (De Baca County, 1976–77)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	18.0
	Ogallala Formation	
4	Pisolitic limestone and dense caliche; red-brown pisolites in gray matrix; brittle, hard, massive to platy (NMP-937)	2.0
3	Caliche, massive, light-gray to tan-gray, moderately dense; indistinct platy structure (NMP-1290)	2.0
2	Sand, well-cemented, massive to indistinct platy structure, gray to gray-tan (NMP-1289)	2.0
1	Sand and silt with a few dispersed, small pebbles; massive, loosely cemented with less cement in upper part; contains gray-tan patches of caliche in lower part; gray-tan in lower part grades upward to red-brown; some blocky structure in upper part (NMP-1287, base; NMP-1288, middle; NMP-938, upper)	12.0

Mossman Siding west section—near SE¼ sec. 33, T. 14 S., R. 25 E. (Chaves County, 1978)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	11.0
	Ogallala Formation	
4	Caliche-cemented sand and gravel, hard, dense, gray, irregular platy structure (NMP-1585)	1.5
3	Sand and silt, cream-tan to pinkish-tan, with a few dispersed, small pebbles and soft caliche throughout (NMP-1584a, lower; NMP-1584b, upper)	5.0
2	Sand, gray-tan to pale-pinkish-tan; cemented with caliche; indistinct bedding to crossbedding; pebbles in streaks, some pebbles and cobbles of Triassic and Permian shale (NMP-1583)	4.0
1	Sand, fine gravel, and silt; loose, pink-tan (NMP-1582)	0.5

Mountainair east-northeast section—in Santa Fe railway cut, SW¼ sec. 33, T. 4 N., R. 7 E. (Torrance County, 1976)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	8.0
	Cover sand and colluvium	
5	Sand and silt, red-brown, massive; B horizon of surface soil with well-developed A horizon at top (overlain by spoil from the cut) (NMP-1003, B horizon)	4.0
4	Sand, caliche-cemented, pinkish-gray, containing caliche cobbles and gravel; massive, thickness 0–4 ft; east along cut, lenticular body of sediment erosionally above unit 3, conformably overlain by unit 5 (NMP-1222)	
3	Colluvium of sand, silt, and abundant fragments of caliche resembling the adjacent Ogallala caliche, pink-tan and gray-tan	4.0
	Pliocene Series (total thickness)	6.0
	Ogallala Formation	
2	Caliche, banded to platy, contains gray-tan sand; prominent travertine banding; erosionally truncated top (NMP-1004, zone III)	2.0
1	Sand, massive, contains nodular caliche, reddish-tan (NMP-1005, zone II, to base of railway cut)	4.0
	Total thickness of section	14.0

Mountainair southeast section—in roadcuts in SE¼SW¼ sec. 4, T. 3 N., R. 7 E. (Torrance County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	15.0
	Ogallala Formation	
3	Caliche, chalky, gray to white, with a few sand grains; massive with indistinct platy structure; no pisolites or travertine banding (NMP-1267)	3.0
2	Sand, gray; irregularly but moderately well cemented; contains some fine gravel (NMP-1265, lower; NMP-1266, upper)	9.0

TABLE 3 (continued)

1	Sand, massive, gray-tan; with areas of light-pinkish-tan; soft caliche cement throughout (NMP-1264)	3.0

Mountainair southwest section—in roadcuts, NW¼NW¼ sec. 12, T. 3 N., R. 6 E. (Torrance County, 1978). This section is approximately the same elevation but west of the Abo Summit railway cut section sampled in 1976–1977; samples from Abo Summit are NMP-1038 through 1042 and NMP-1223

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	40.0
	Ogallala Formation	
2	Caliche, massive, relatively soft, irregular platy structure; contains sand, silt and a few dispersed crystalline pebbles (NMP-1538). A covered slope extends upward to the north approximately 20 ft to a bench that probably is the top of the Ogallala	5.0
1	Sand with some silt, pinkish-tan, dispersed crystalline pebbles, loose; locally contains large areas of gray-tan opal, zones of caliche nodules, and lenticular cemented areas (NMP-1537, top; NMP-1536, 5 ft below top; NMP-1535, 10 ft below top; NMP-1534, 15 ft below top; NMP-1533, 20 ft below top; NMP-1532, 25 ft below top; NMP-1531, 30 ft below top; NMP-1530, 35 ft below top at base of section) The Ogallala surface extends eastward from here to the Willard west section in the western rim of the Estancia Basin. This locality is now in a southwest drainage but the sediment source is to the northwest.	35.0

Orchard Park west section—roadcuts along US-285, SE¼ sec. 17, T. 12 S., R. 24 E. (Chaves County, 1977)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	10.0
	Pediment veneer	
3	Silt and sand, light-tan-brown, massive; constitutes surface material of the pediment; slope toward Pecos River of 22¼ ft per mi, except in cuts essentially on unscarred surface (NMP-1351)	5.0
2	Caliche and silt with some sand, pinkish-cream-tan; contains a few caliche nodues; sharp but irregular contacts at top and bottom (NMP-1350)	2.0
1	Caliche and silt, soft, cream-tan; contains very little sand, a few small caliche nodules; massive (NMP-1349)	3.0

Poquita Mesa east section—in roadcuts and in gully adjacent to NM-20, NW¼NW¼ sec. 25, T. 4 S., R. 22 E. (Chaves County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	17.0
	Ogallala Formation	
5	Caliche, dense, gray with reddish-tan banding and a few incipient pisolites; brittle, irregular platy structure (NMP-1326)	1.0
4	Sand and caliche, cream-tan, massive, moderately loose (NMP-1325)	2.0
3	Sand, pink-tan, contains cream-tan caliche nodules and a few small dispersed pebbles of quartzite and crystalline rocks; massive (NMP-1324)	4.0
2	Sand, tan-brown, massive, contains stringers and nodules of caliche (NMP-1323, middle; NMP-1167, upper)	4.0
1	Sand and silt, reddish-tan, massive (NMP-1322, lower); basal contact not exposed but overlies Permian	6.0

Poquita Mesa west section—in roadcuts, east side of US-285, NE¼NE¼ sec. 21, T. 4 S., R. 22 E. (Chaves County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	11.0
	Ogallala Formation	
3	Caliche, dense, hard, gray, platy; contains strongly developed travertine banding but lacks pisolites; found at level of upland surface (NMP-1113, zone V)	2.0
2	Sand, weakly and irregularly cemented with caliche; some dispersed caliche nodules; gray, massive (NMP-1112, zone II)	6.0
1	Sand, pink-tan mottled with red-brown; caliche nodules throughout; contains a few streaks of grayish-pink caliche cement and a few dispersed pebbles of crystalline rocks (NMP-1111, zone II)	3.0

Ramon southeast section—face of small butte capped by Ogallala Formation, with a strong westerly dip on Ogallala beds, SE¼SW¼ sec. 25, T. 1 S., R. 20 E. (De Baca County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	42.0
	Ogallala Formation	
8	Caliche, dense, brittle, irregular platy structure, travertine banding; contains a few pisolites (NMP-1095, zone II)	2.0
7	Caliche, dense, tough, gray, platy; contains abundant opal, crenulate plates (NMP-1094, zone II)	4.0
6	Sand with dispersed pebbles; densely cemented with caliche, nodular surface (NMP-1093, zone II)	5.0
5	Sand with some silt and small pebbles, massive; caliche cement (NMP-1092, zone II)	3.0
4	Silt and clay with some sand, reddish-brown to tan; massive to microblocky structure; sharp contacts at top and bottom (NMP-1091, zone II)	5.0
3	Sand and fine gravel, tan; some caliche nodules and caliche cement; massive (NMP-1090, zone II)	5.0
2	Sand and silt grading upward into sand with some pebbles, gray-tan, massive (NMP-1088, lower; NMP-1089, upper, zone II)	8.0
1	Sand, tan-brown, massive; grading upward into sand and coarse gravel with abundant crystalline rocks; base on weathered Permian shale (NMP-1087, lower, zone II)	10.0

Ramon southwest section—exposed in rim of sinkhole developed in Permian gypsum, NE¼NE¼ sec. 9, T. 2 S., R. 19 E. (Lincoln County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	14.0
	Ogallala Formation	
4	Caliche; pisolitic limestone; hard, dense, well-developed pisolites and travertine banding (NMP-1100, zone V)	2.0
3	Caliche and caliche-cemented sand, massive, gray; locally quite hard (NMP-1099, zone IV)	4.0

2	Sand, caliche-cemented, gray; massive to irregular blocky structure (NMP-1098, zone II)	4.0
1	Sand with some caliche, pink-tan, massive (NMP-1097, zone II); lower part partly covered; rests on Permian; solution openings in Permian gypsum 5-10 ft below base of Ogallala	4.0

Rio Felix section—west of US-285 along Rio Felix, SW¼ sec. 16, T. 14 S., R. 24 E. (Chaves County, 1977)

Unit	Description	Thickness (ft)
	Holocene Series (total thickness)	5.0
	Terrace deposits	
4	Silt and sand, bedded, gray and gray-brown; contains a few streaks of gravel; shows an A-C soil profile in upper part; loose; narrow terrace along valley side, cut into older beds described below and inset into bed 1 of section (NMP-1357; fauna F-131)	5.0
	Pleistocene Series (total thickness)	30.0
	Pediment and alluvial deposits	
3	Sand, tan-brown, with some silt and clay; contains a few dispersed pebbles; underlies extensive surface (NMP-1356)	6.0
2	Sand and silt, pink-tan, contains some pebbles; gradational at top and bottom; massive (NMP-1355)	7.0
1	Sand and silt; sand and caliche, pink-tan, at base (NMP-1352); grading upward into coarse gravel and sand; boulders of limestone more than 1 ft in diameter; sand matrix with some silt and clay; bedding evident only in some zones of sand and silt (NMP-1353, 10 ft above base; NMP-1354, 15 ft above base)	
	Total thickness of section	35.0

Trujillo northwest section—in caliche pit near Maes Road, 9 mi northwest of Trujillo; by projection, sec. 15, T. 16 N., R. 20 E. (San Miguel County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	9.0
	Ogallala Formation	
4	Caliche, dense, gray, strongly developed travertine banding, well-developed pisolites; found at level of regional upland (NMP-1141, top, zone V; NMP-1213, lower, zone III)	1.5
3	Sand, well-cemented, gray; platy to blocky structure, moderately hard (NMP-1140, zone II)	2.0
2	Caliche, pink-tan and gray-tan, abundant sand grains; dense, well-developed pisolites and thick travertine banding (NMP-1139, zone II)	1.0
1	Sand, pink-tan, abundant caliche nodules with local cementing; massive (NMP-1137, bottom of pit; NMP-1138, middle of unit, zone II)	4.5

Vaughn gravel pit composite section—in gravel pit and adjacent railway cut, SW¼SW¼ sec. 35, T. 5 N., R. 16 E. (Guadalupe County, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	13.0
	Ogallala Formation	
3	Clay, silt, and sand, with filaments of gray caliche; indistinct, blocky structure; B horizon of soil related to caliche below (NMP-1300); activities in the pit have removed an overlying layer of sediment	1.0
2	Caliche, soft; and sand; contains dispersed pebbles and some caliche nodules; indistinct platy structure; soil developed on underlying Ogallala deposits or in a colluvial zone overlying the Ogallala (NMP-1299)	2.0
1	Gravel and sand, contains cobbles up to 1 ft diameter, mostly of crystalline rocks; zones of sand occur in the gravel (NMP-1297, lower; NMP-1298, upper)	10.0

Vaughn northeast section—roadcuts of US-54, SE¼NE¼ sec. 1, T. 5 N., R. 17 E. (Guadalupe County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	17.0
	Ogallala Formation	
5	Caliche, banded with crenulate structure and chalky texture; moderately tough (NMP-1162, zone III)	1.5
4	Sand, well-cemented, gray, contains very few dispersed small pebbles; blocky to massive structure (NMP-1161, zone II)	4.0
3	Sand, gray-tan, cemented with caliche; nodular cement; massive (NMP-1160, zone II)	4.0
2	Sand, caliche nodules, massive, pink-tan, locally soft cement (NMP-1159, zone II)	3.0
1	Sand, interbedded with sand and gravel, crystalline-rock pebbles up to 4 inches diameter; to base of roadcut (NMP-1158, zone II)	4.5

Vaughn north section—in small pit in NE¼ sec. 15, T. 5 N., R. 16 E. (Guadalupe County, 1978)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	11.0
3	Caliche, with sand and silt, gray, soft, massive; vertical jointing; 1 ft of tan-brown, silty sand above caliche and below surface (NMP-1546, caliche, 2 ft below top)	4.0
2	Sand and silt, gray to gray-tan, massive (NMP-1545)	3.0
1	Sand and silt, brown, massive, moderately compact (NMP-1544); overlain by thin beds of fine gravel (NMP-1547, Ogallala pebbles from these gravels are interbedded with sand and silt)	4.0

Vaughn railway cut section—in roadcuts near SW¼SW¼ sec. 10, T. 4 N., R. 16 E. and in railroad cut to the southwest (Guadalupe County, 1975-1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	50.0
	Ogallala Formation	
5	Caliche, dense, hard, platy, gray; some crenulate structure in platy units, upper surface solution-modified (NMP-1026, top; NMP-952, 2 ft below top, zone II)	2.0
4	Sand, well-cemented with caliche, massive, gray, blocky; locally scattered red pebbles (NMP-1025, zone II)	6.0
3	Sand, pink-tan, massive; contains a few scattered red pebbles; soft caliche cement more prevalent in upper part; some gray-tan areas in upper part (NMP-953 and 1024, upper part; NMP-1023, lower part, zone II)	7.0
2	Mostly covered, massive, loose sand	15.0
1	Sand, reddish-tan; grading upward into pinkish-tan, massive; contains a few pebbles throughout, ranging up to 10-inch cobbles in middle part; irregular caliche cement and caliche nodules more common in upper part (NMP-1019, base; NMP-954 and 1020, middle part; NMP-1021, 5 ft below top; NMP-1022, top, zone II)	20.0

TABLE 3 (continued)

Vaughn southwest section—in roadcuts on US-54, NE¼ sec. 30, T. 4 N., R. 16 E. (Guadalupe County, 1975, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	30.0
	Ogallala Formation	
6	Caliche, dense, gray, platy, hard; well-developed travertine banding (NMP-955, 1074, zone V)	2.0
5	Caliche-cemented sand, dense, hard, gray; well-developed, thin, platy structure (NMP-1073, zone III)	2.5
4	Sand, caliche-cemented, blocky, platy; pendants of caliche cement extend downward from this unit into the less-well-cemented sand below (NMP-1072, zone III)	1.5
3	Sand, pink-tan in lower part, gray in upper part, loose to weak cementing in lower part becoming stronger upward; massive; caliche nodules in middle and upper part; (NMP-1069, lower; NMP-1070, middle; NMP-956, 1071, upper, zone II)	17.0
2	Sand with dispersed small pebbles, nodular caliche cement, massive, gray-tan to pink-tan (NMP-1068, zone II)	4.0
1	Sand, tan-brown, loose at base, grading up into sand and gravel; massive; to bottom of roadcut; contact with bedrock not exposed (NMP-1067, base, zone II)	3.0

Vaughn west section—measured in roadcuts, Santa Fe railway cut, and slope, SW¼NW¼ sec. 8, T. 4 N., R. 16 E. (Guadalupe County, 1976)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	6.0
	Cover sand and colluvium	
8	Sand and silt, tan-brown, massive, filling an erosional sag cut into Ogallala; A horizon on top (NMP-1013, middle)	4.0
7	Colluvium of Ogallala-derived material resting on truncated surface of Ogallala	2.0
	Pliocene Series (total thickness)	36.0
	Ogallala Formation	
6	Caliche with some sand; dense, brittle, gray with some areas of pinkish-tan; no pisolites (NMP-1012, zone III)	2.0
5	Sand, well-cemented with caliche, tough, gray, jointed, locally banded (NMP-1011, zone III)	7.0
4	Sand and gravel well-cemented with caliche, gray, locally blocky; forms ledge at top of railway cut (NMP-1010, zone II)	2.0
3	Sand and gravel; contains boulders with maximum diameter of ¾ ft; indistinct bedding; well-cemented in middle and upper part but loose in lower part; quartzite, igneous rocks, and sandstone common in boulders and cobbles (NMP-1009, lower part, zone II)	5.0
2	Sand, gray-tan to pinkish-tan, massive; contains dispersed caliche nodules; generally loose but locally contains some caliche cement (NMP-1008, zone II)	5.0
1	Sand and silt, pinkish-tan, massive with local jointing and platy structure; compact but not cemented (NMP-1006, base; NMP-1007, 5 ft above base, zone II)	15.0
	Total thickness of section	42.0

Vegas Junction section—in roadcuts along I-40, SW¼ sec. 29, T. 9 N., R. 19 E. (Guadalupe County, 1978)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	22.0
	Ogallala Formation	
5	Caliche, dense, hard, brittle, gray; strongly banded but no pisolites observed; found at level of local upland (NMP-1563)	2.0
4	Caliche, chalky, platy, moderately dense, light-gray (NMP-1562)	2.0
3	Sand with some silt, tan-brown to pink-tan to gray-tan; generally loose cementing with caliche; massive and nodular with some local platy zones (NMP-1561)	8.0
2	Sand with a few pebbles, gray-tan, massive, nodular, caliche-cemented (NMP-1559, base; NMP-1560, middle)	10.0
	Triassic	
1	Sandstone, brown (NMP-1558) (not measured)	—

Willard east section—N½ sec. 5, T. 4 N., R. 10 E. (Torrance County, 1976)

Unit	Description	Thickness (ft)
	Pleistocene Series (total thickness)	75.0
	Lake deposits and lee-dune sediments	
5	Sand, massive, loose, gray-tan to greenish-tan in upper part; this interval appears to be composed entirely of sediments of lee dunes derived from the lake basins immediately adjacent (NMP-1032, lower; NMP-1033, middle; NMP-1034, top)	40.0
4	Sand, massive to indistinct, thick bedding; in some zones in the lower part, gypsum is the predominant mineral (NMP-1031, 10 ft below top); the lower part is probably the top of lake deposits and the upper part of the first episode of eolian deposits	15.0
3	Alternating beds of sand and silt, with silty clay, green clay (NMP-1030), and one thin bed of volcanic ash (NMP-1029); a fine-sand zone below the bed of volcanic ash contains abundant ostracods (F-129) and bones of salamanders in the upper part; some beds are composed predominantly of gypsum; well-bedded throughout; lake deposits	10.0
2	Silt and clay, well-bedded, fine-textured, loose, tan-brown (NMP-1028, lower part)	6.0
1	Clay and silt, massive, plastic, olive-gray (NMP-1027); to level of present saline-lake flat	4.0

Willard west section—along and near US-60 approximately 3 mi west of Willard, SW¼ sec. 2, T. 4 N., R. 8 E. (Torrance County, 1976, 1977)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	35.0
	Ogallala Formation	
4	Caliche, chalky, moderately dense, weakly developed platy structure at top; lacks pisolites or travertine banding (NMP-1263); lower and middle part poorly exposed to covered	12.0
3	Sand and gravel, locally well cemented, gray (NMP-1262, middle; NMP-1037, lower)	6.0

TABLE 3 (concluded)

2	Sand and gravel, gray to gray-tan, cobbles up to 1 ft diameter, many subangular; caliche present throughout but not densely cemented; massive (NMP-1261)	5.0
1	Sand, massive, pinkish-tan; a few small pebbles and some caliche nodules; very loosely cemented (NMP-1258, base; NMP-1035; NMP-1259; NMP-1036; NMP-1260, upper)	12.0

Yeso southwest section—7½ mi southwest of Yeso, SW¼NW¼ sec. 23, T. 2 N., R. 21 E. (De Baca County, 1976)

Unit	Description	Thickness (ft)
	Pliocene Series (total thickness)	13.0
	Ogallala Formation	
4	Caliche; pisolitic limestone, dense, brittle, pink-tan pisolites in gray-tan matrix; travertine banding; contains sand with some small pebbles (NMP-1086, zone V)	3.0
3	Sand and gravel, cemented with caliche (NMP-1085, zone II)	3.0
2	Sand with a few small pebbles, gray; irregularly cemented with caliche and generally well cemented; massive (NMP-1084, zone II, with corrensite)	3.0
1	Sand, with caliche nodules, a few pebbles dispersed throughout, massive; this unit rests on weathered greenish-gray sandstone (NMP-1083, zone II)	4.0

TABLE 4—Molluscan faunal localities described in this report (date of collection in parentheses).

Fauna locality no.	Location (sec., Twp.-Rge., Co.)	Description
F-120	NW¼SW¼ 14, 3N-2E, De Baca	Sediments exposed in border of former large alkaline lake
F-124a	SE¼ 6, 3N-13E, Torrance	Western border of lake sediments exposed in roadside ditch (8/5/76)
F-125	NE¼ 3, 2N-12E, Torrance	Terrace related to basin in sand dunes (8/5/76)
F-126	NE¼ 8, 2N-11E, Torrance	Pond sediments exposed in roadside ditch (8/5/76)
F-127	NE¼NE¼ 18, 1N-14E, Torrance	Pond sediments exposed in roadside ditch (8/7/76)
F-128	SE¼ 4, 12N-15E, San Miguel	*Heliscodiscus eigenmanni* exposed in anthill debris (8/8/76)
F-129	SW¼ 31, 18S-22E, Eddy	Sediments in Rio Peñasco, exposed above gravel zone, south of Hope (8/14/76)
F-130	SW¼ 31, 18S-22E, Eddy	Sediments exposed in Rio Peñasco, below gravel zone (8/14/76)
F-131	SE¼ 16, 14S-24E, Chaves	Young terrace on Made Well Draw (8/13/77)
F-132	NW¼ 4, 16S-26E, Eddy	Pond sediments exposed in roadside ditch (8/14/77)
F-133	SW¼ 6, 18S-23E, Eddy	Young terrace on Walnut Draw, 2.8 mi south of Hope (8/15/77)
F-134	SE¼NE¼ 18, 24S-27E, Eddy	Terraces exposed at crossing of Black River

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