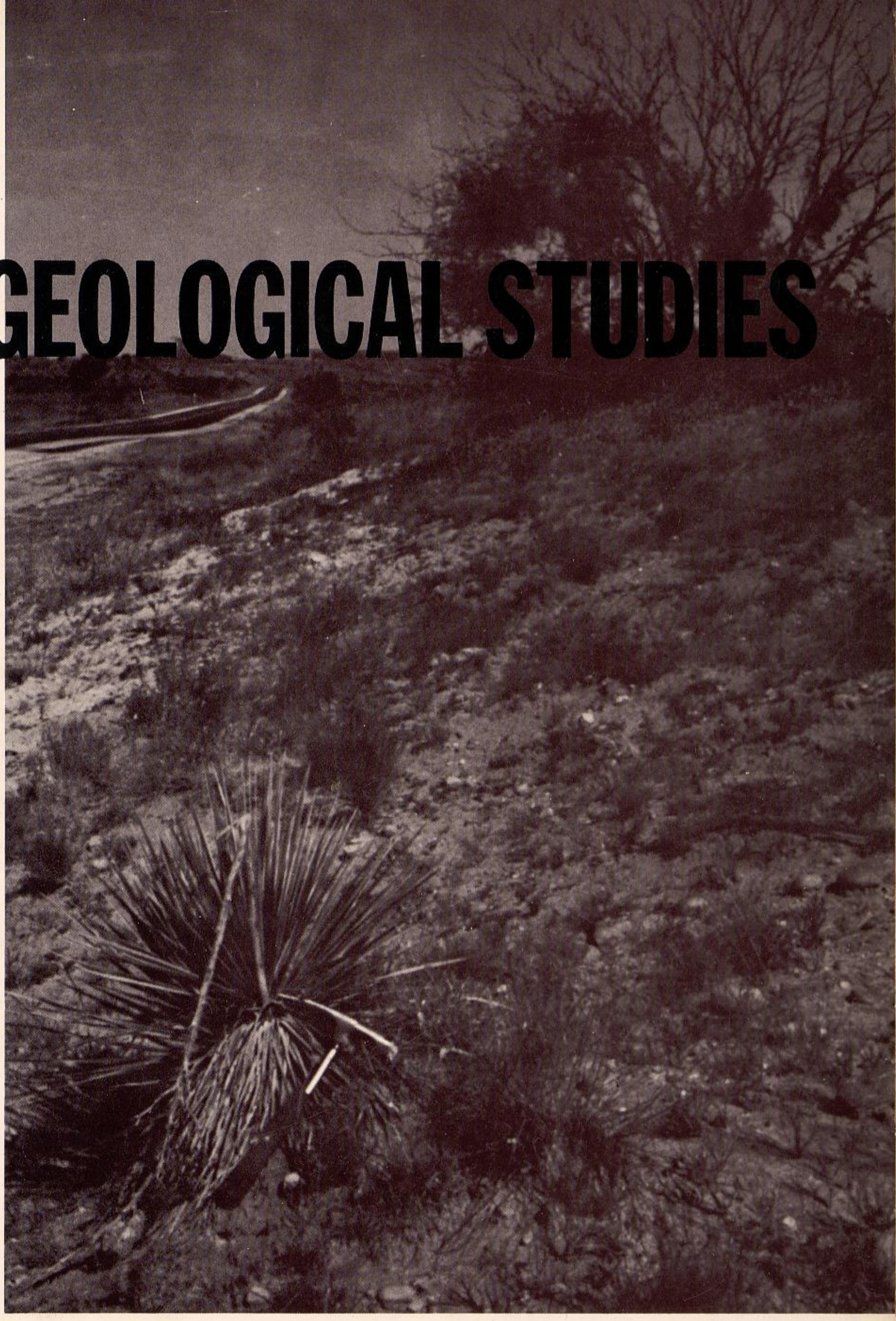
BAYLOR GEOLOGICAL STUDIES



SPRING 1971

Bulletin No. 20

Origin and History of the Uvalde Gravel of Central Texas

CLIFFORD LEON BYRD

"Creative thinking is more important than elaborate equipment--"

Frank Carney, Ph.D.
Professor of Geology
Baylor University
1929-1934

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The training of a geologist in a university covers but a few years; his education continues throughout his active life. The purposes of training geologists at Baylor University are to provide a sound basis of understanding and to foster a truly geological point of view, both of which are essential for continued professional growth. The staff considers geology to be unique among sciences since it is primarily a field science. All geologic research including that done in laboratories must be firmly supported by field observations. The student is encouraged to develop an inquiring objective attitude and to examine critically all geological concepts and principles. The development of a mature and professional attitude toward geology and geological research is a principal concern of the department.

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Origin and History of the Uvalde Gravel of Central Texas

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BAYLOR UNIVERSITY
Department of Geology
Waco, Texas
Spring, 1971

Baylor Geological Studies

The Baylor Geological Studies Bulletin is published semi-annually, Spring and Fall, by the Department of Geology at Baylor University. The Bulletin is specifically dedicated to the dissemination of geologic knowledge for the benefit of the people of Texas. The publication is designed to present the results of both pure and applied research which will ultimately be important in the economic and cultural growth of the State.

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Origin and History of the Uvalde Gravel of Central Texas

CLIFFORD LEON BYRD

ABSTRACT

The Uvalde Gravel is a lag deposit of waterworn siliceous gravels anomalous to the geology of central and south Texas and unrelated to the present river channels and terrace deposits of Pleistocene age. It occurs typically in soil matrix that mantles the gently rolling or flat stream divides in central and south Texas. These lag accumulations tend to drape over irregularities in the topography and are therefore considered more as a part of the soil than as a mappable geologic unit. Composition of the Uvalde Gravel ranges from pebbles to boulders of chert, quartz, jasper, quartzite, limestone, and silicified wood.

The great elevation of the gravels above present rivers precludes their deposition by modern drainage. The Uvalde gravels are coarser than the bed load of any of the present rivers in the region. Most of the material found in the Uvalde Gravel is foreign to the immediate area and thus must have been "imported" from some distance by streams far different from present drainage. The most probable source for the quartzitic material in the Uvalde Gravel is the Ogallala Formation of the Llano Estacado, the deposits of an alluvial plain derived by stream erosion from the easternmost ranges of the Southern Rocky Mountains in central New Mexico.

Originally, the main body of the Llano Estacado apparently terminated somewhat west of the major area of outcrop of the Uvalde Gravel. Tongues of Ogallala Formation probably extended eastward along the valleys, which were cut in bedrock. As weathering and erosion continued, finer particles were carried away, ultimately leaving only the coarse gravel as a lag accumulation. This layer of coarse material in the valleys formed a resistant veneer against further erosion while the adjacent unprotected uplands were more rapidly worn away, eventually leaving the original valleys as uplands capped by Uvalde Gravel.

INTRODUCTION*

During the late 1800's and early 1900's, geologic investigation was conducted at a more leisurely pace either on foot, by horseback, or by some type of horse-drawn vehicle. This offered distinct advantages in that it gave the investigator ample time to evaluate his findings while traveling from one outcrop to the next. Subtle anomalies became more obvious, and thus the curiosity of several geologists was aroused by the appearance of obviously foreign waterworn gravels at abnormally high elevations in central and south Texas. There were numerous papers written about these deposits (later termed the Uvalde gravels) during this time of primary exploration. Since those early reports, the Uvalde gravels have been largely ignored or mentioned only in passing. Because of the reconnaissance nature of the early geologic reports, very little attention was given to the origin and history of the Uvalde gravels. Only recently, with renewed interest in Quaternary geology and fluvial processes, has the problem of origin of Uvalde gravels become of more than passing interest. This study was undertaken as a product of this renewed interest.

*A thesis submitted in partial fulfillment of the requirements for the M.S. degree in Geology, Baylor University, 1970.

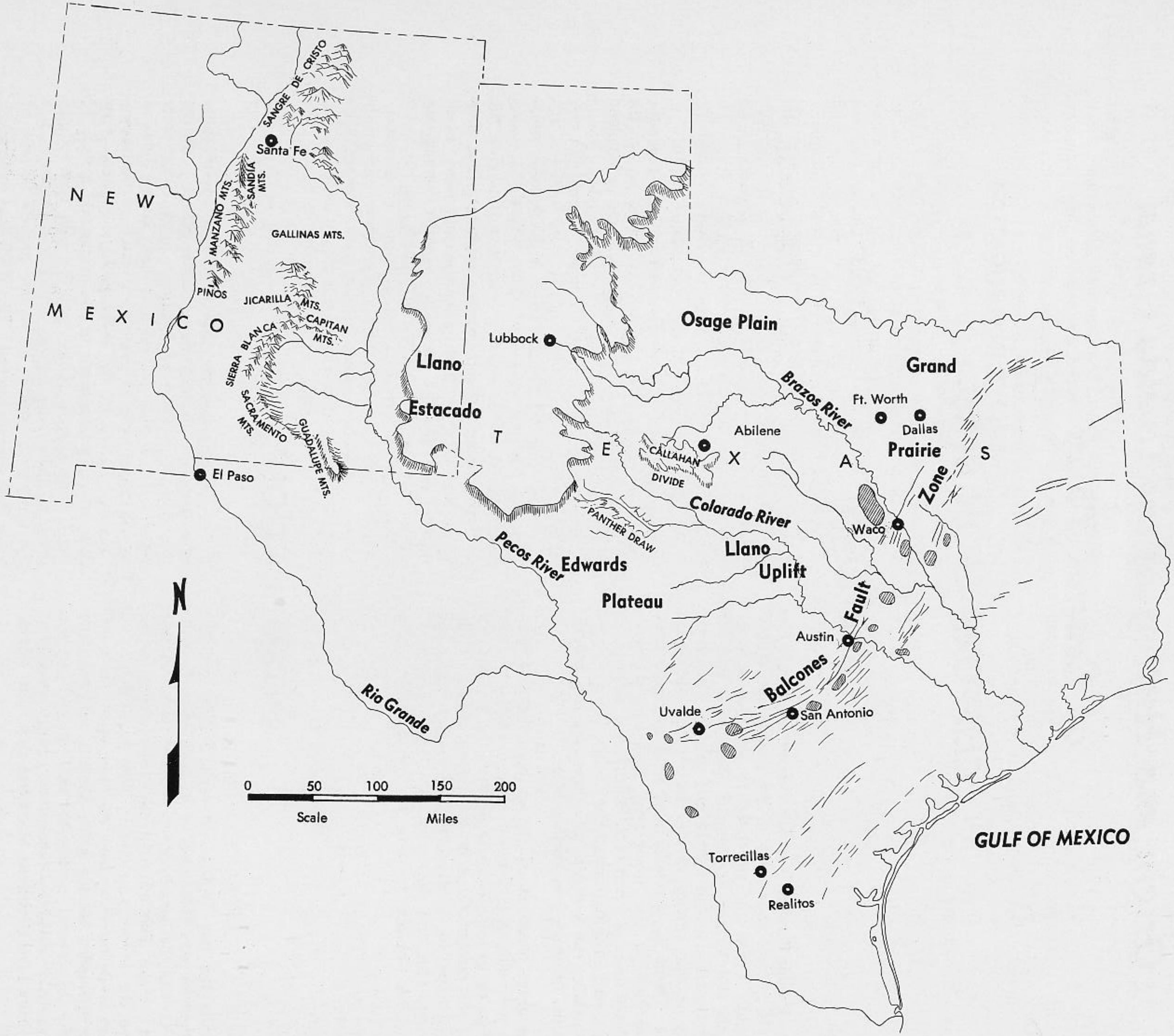


Fig. 1. Index map showing the location of some of the regions referred to in this report and the general distribution of Uvalde Gravel (pattern).

PURPOSE

This study is designed to interpret the origin, history of emplacement, and post depositional modification of the widely distributed Uvalde gravels of the central Texas region.

Occurrence of the high gravels varies over Texas. Generally the interstream divides of central Texas are capped by Uvalde gravels. West of the Balcones fault zone (fig. 1) the gravels occur as disseminated lag deposits with only the coarser fraction remaining. Areas of outcrop diminish in number and area toward the west. Outcrop abundance increases east of the fault zone as does the thickness of individual deposits. The Uvalde gravels do not appear to have any direct relation with the underlying geologic formations. They are chiefly composed of waterworn quartzitic gravel while underlying strata consist of sedimentary rock of marine origin.

A major problem of origin and history of the Uvalde gravels exists because there is no apparent direct connection between the Uvalde gravels and existing drainage in central Texas. Transportation of gravels of such large size is beyond the competence of existing rivers. No source for such coarse siliceous gravel exists in the major basins of present central Texas streams.

LOCATION

The area of this study is that shown in figure 1. It includes all or parts of the Southern Rocky Mountains of New Mexico, the Pecos River valley, the Llano Estacado, the Osage Plains, the Edwards Plateau, the Grand Prairie, the Balcones fault zone and the western edge of the Gulf Coastal Plain. Detailed investigation was conducted in central Texas, including all or parts of Austin, Bastrop, Bell, Bosque, Brazos, Burleson, Caldwell, Coryell, Falls, Freestone, Hamilton, Hays, Hill, Lee, Leon, Limestone, McLennan, Milam, Navarro, Robertson, Travis, Washington and Williamson counties. The major study area is bounded on the north by the 32nd parallel, on the south by the 30th parallel, on the east by the 96th meridian, and on the west by the 98th meridian.

PROCEDURE

The method of approach utilized in this study included five steps: (1) A comprehensive review was made of the literature pertaining to the Uvalde gravels and other late Tertiary and Quaternary gravel deposits of Texas. This included a review of the evolution of the nomenclature of the various formations and their possible correlations; (2) topographic and geologic maps, areal photographs and well logs were studied to determine possible localities of occurrence of "upland" gravel to relate these localities to existing drainage, topography and geology, and to determine the probable areal extent of original alluviation; (3) representative samples of gravels were collected in the basin of the Pecos River of New Mexico, the Canadian, Red, Brazos and Colorado River basins of Texas and compared with Uvalde gravels for similarities in petrology and physical appearance; (4) petrologic study of samples permitted correlations of Uvalde gravels, through intermediate sources, to a probable original sediment-source area; (5) extensive field reconnaissance confirmed, modified, and strengthened the conclusions based on the initial studies.

PREVIOUS INVESTIGATION

The name "Uvalde Gravel" was proposed by Hill (1891, p. 368) to describe the upland gravel deposits of central and south Texas. Near Uvalde, these gravels are of detrital origin composed of chert and limestone pebbles and boulders occurring 400 to 1000 feet above the Rio Grande. The name Uvalde Gravel was not generally accepted by geologists for many years, and the nomenclature became confusing and ambiguous. Penrose (1890, p. 63) had earlier named upland gravel and caliche deposits along the Rio Grande, "Reynosa gravel," for the town of Reynosa, Tamaulipas, Mexico. Dumble (1894, p. 560; 1903, pp. 91-93), describing upland gravels, used the name Reynosa following Penrose's example. Udden, Baker and Böse (1916, pp. 91-93) used the name "Lafayette." Sellards (1919, p. 65) and Liddle (1918, p. 63), also working along the Rio Grande, accepted the name Uvalde. All of the names were used to describe undifferentiated upland gravels on the highlands adjacent to the river.

Trowbridge (1923, p. 98) followed Dumble's usage of the name "Reynosa" to describe the series of deposits forming the plateau between the Nueces River and the Rio Grande, which he called the Reynosa Plateau. He stated that the "Reynosa limestone" of Penrose formed the top member of the Reynosa division, which rested on the Lagarto Formation. These downstream deposits, to which Dumble applied the name Reynosa, are now known to be equivalent to the upstream remnants to which Hill applied the name Uvalde, and the necessity for discarding one of the names has become apparent. Because the name "Reynosa," as applied to a part of this formation, had priority over Uvalde (and perhaps because the downstream deposits afforded a better type locality), the name Reynosa was adopted by the United States Geological Survey and "Uvalde" was abandoned (Plummer, 1933, p. 777).

The position of the limestone gravels at Reynosa, Tamaulipas, Mexico, 50 feet above the Rio Grande and 732 feet below the limestone gravels at Torrecillas (100 miles to the northwest), suggests that Reynosa is a lower terrace than the terraces at Torrecillas and Realitos and that the Reynosa is thus younger than either of the higher terraces. However, lacking definite evidence of age of either the limestone at Torrecillas and Realitos, or the gravels at Reynosa, it was considered advisable to continue the use of the name Reynosa (as defined by Dumble and Kennedy) (Deussen, 1924, p. 102).

F. B. Plummer (1933, p. 777) accepted the term "Uvalde," the name given by Hill to the upland gravel

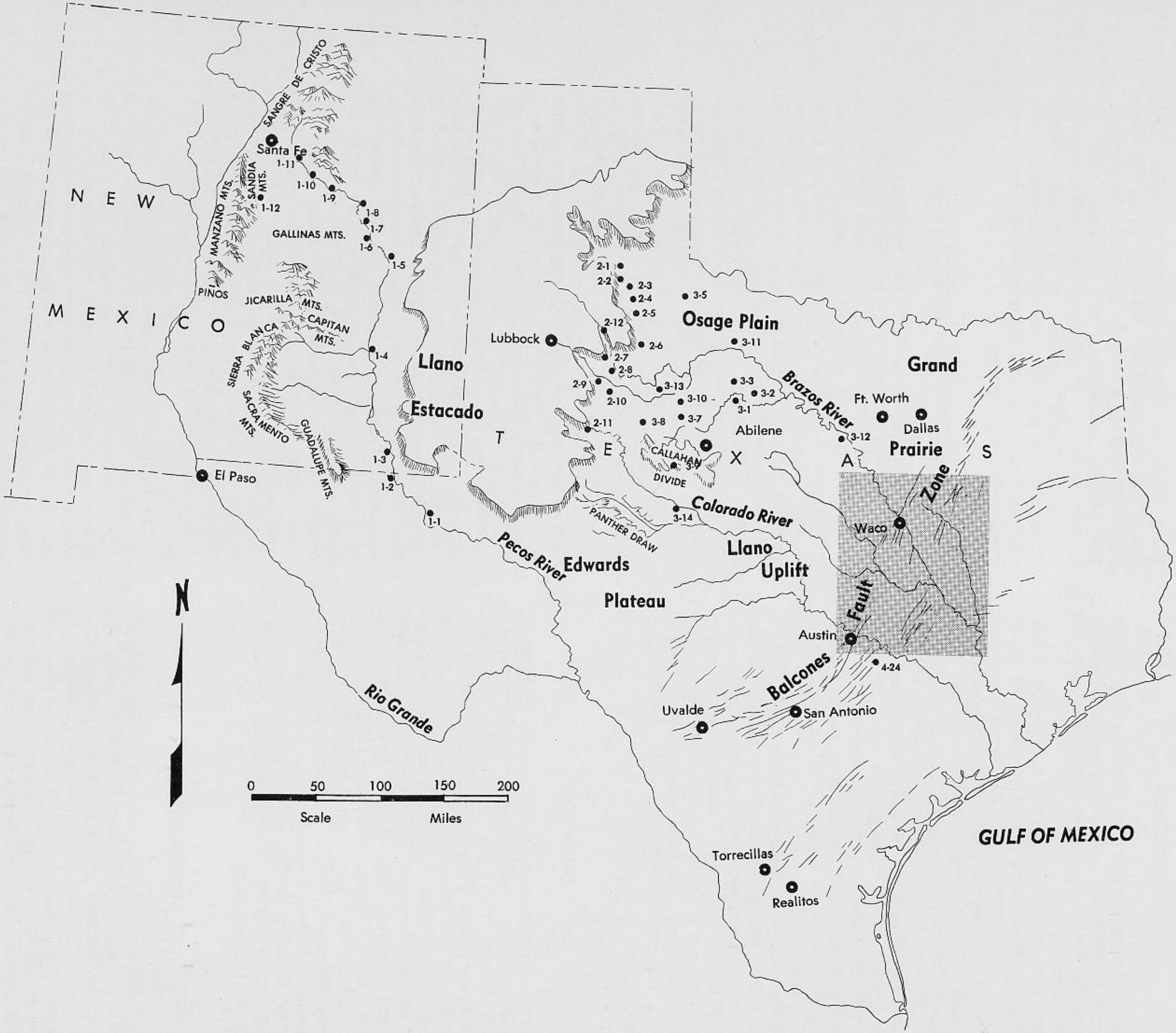


Fig. 2. Map of Texas and New Mexico showing the distribution of sampling localities. Sampling stations in shaded area shown in figure 3.

Table 1. Stratigraphic nomenclature of the Uvalde Gravel

System	Series	Penrose 1890	Hill 1891	Dumble 1894		Udden Baker & Böse 1916	Liddle 1918	Sellards 1919	Trowbridge 1923	Duessen 1924	Plummer 1933	Lonsdale & Day 1937	Mathis 1944	Weeks 1945	Blank 1952
QUATERNARY	Pleistocene	Reynosa Fm.		Reynosa Division	Reynosa Member						Lissie				
TERTIARY	Pliocene		Uvalde (upstream)	Reynosa Division		Lafayette	Uvalde	Uvalde	Reynosa	Reynosa	Uvalde	Uvalde	Uvalde	Uvalde	Uvalde
TERTIARY	Miocene-Pliocene			Lagarto Fm.							Goliad Sand	Goliad Sand			
TERTIARY	Miocene-Pliocene										Lagarto Clay	Lagarto Clay			

deposits of south Texas (fig. 1). No fossils have been found in the upland interstream deposits. However, the topographic position and general physiographic relationships of these deposits indicate clearly that they antedate existing river terraces. The Uvalde gravels occur on the stream divides and in many places cap the highest hills in the area south of the Edwards Plateau. They rest on formations ranging in age from Early Cretaceous to Miocene. They are especially prominent in the area between the Brazos and Devils rivers and occur in even greater thickness in northern Mexico.

In a report on Webb County, Texas, Lonsdale and Day (1937, p. 72) regarded the Uvalde Gravel as equivalent in age to the high-level gravel near Uvalde, Texas. The composition of the Uvalde is similar to that of the sand and gravel of the Goliad Formation of Pliocene age, but it is found at considerably lower altitudes and hence is probably younger than the Goliad.

As a result of the work of Lonsdale and Day, the Texas Bureau of Economic Geology and the United States Geological Survey in 1937 discontinued the use of the name Reynosa as applied to the gravel and limestone deposits along the Rio Grande in Texas. Uvalde Gravel was the name approved for the high-level gravels near Uvalde; the Goliad Sand was the approved name for the older deposits that overlie the Lagarto Clay in Washington County (fig. 3).

R. W. Mathis (1944, p. 87) described Uvalde Gravel near Austin, where it consists of rounded flint cobbles, boulders, and occasional limestone pebbles, occurring coastward from the Balcones fault zone (fig. 2). He noted that in the vicinity of Austin, Uvalde Gravel crops out on hilltops at elevations up to 320 feet above the Colorado River though the deposits are not continuous, nor is the level constant. A lower gravel, the Delaney gravel *(idem)*, occurs about 245 feet above river level on the Delaney Ranch, 3 miles southwest of Austin, and is apparently younger than the Uvalde Gravel. A. W. Weeks (1945, p. 1695) believed the Delaney gravel was derived from Uvalde gravels at higher levels, and thus may not represent original fluvial deposition.

R. L. Bronaugh (1950, p. 16) described the Brazos River terraces in McLennan County and recognized residual gravel deposits which did "not appear to belong to the Brazos River terrace system." The highest of these which, in McLennan County, were found to occur as much as 290 feet above the level of low water in the Brazos River at Waco, he assigned to the Uvalde Gravel.

H. R. Blank, *et al.* (1952, p. 16) described "upland" gravel (Uvalde Gravel) older than the Brazos River terraces which occurred in deposits as much as one foot thick, unconformably overlying the Pecan Gap Member of the Taylor Formation, near Riesel, McLennan County.

Bennett and Sayre (1962, p. 57) described the Uvalde Gravel in Kinney County, Texas, where it veneers a plain whose surface slopes gently south-southwestward. "In Kinney County the Uvalde gravel is composed primarily of well-cemented pebbles and cobbles of limestone, chert, and acidic igneous rocks, caliche, clay, and calcareous sandstone. In a few places cobbles of purplish quartzite and brown jasper were noticed" (*idem,* p. 58). The Uvalde Gravel in Kinney County is as much as 75 feet thick.

From this rather erratic history of piecemeal investigation has come the presently accepted definition of Uvalde Gravel . . . a disseminated deposit of cobbles ranging in size from 2 to 6 inches in diameter; generally composed of limestone, quartzite, quartz, chert, jasper, and igneous rock; and occurring in isolated patches on stream divides far above any well developed terraces.

Various other investigations of Tertiary and Quaternary rocks of Texas are of interest to the study of the Uvalde Gravel for they show possible correlations

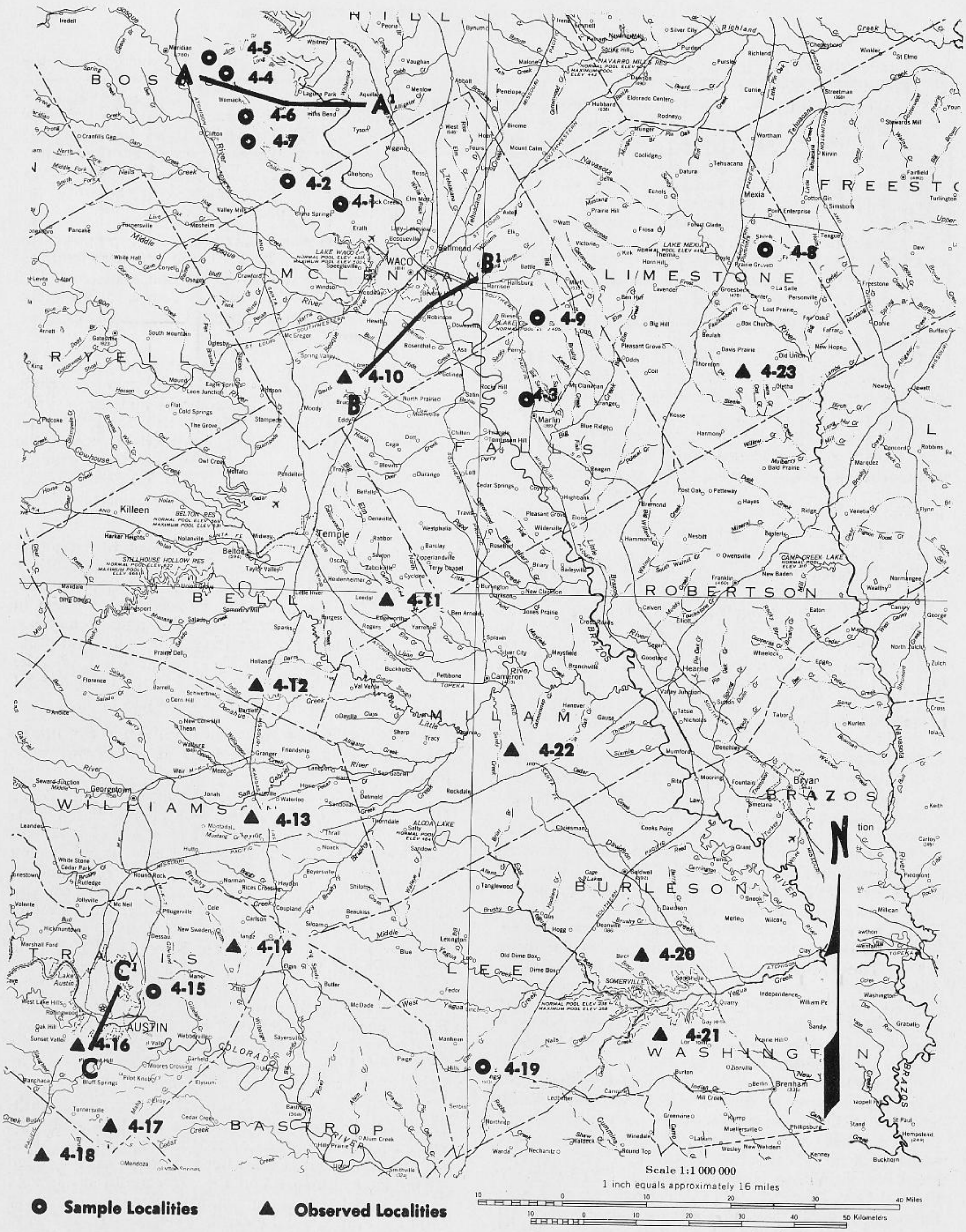


Fig. 3. Map of central Texas showing the distribution of sampling localities (Base map from U. S. Geological Survey).

and parallel histories. Principal among these are studies of gravel deposits of the high plains.

Stratigraphic studies of the Neogene of the Great Plains started a century ago with the early scientific expeditions (Meek and Hayden, 1862; Englemann, 1876; King, 1878) and were followed by more localized work which included studies of fossil vertebrate faunas in Texas (Hawn, 1866; Hay, 1855; Cummins, 1891, 1892, 1893; Cope, 1892, 1893). General studies of relatively large regions were undertaken near the close of the last century by Gilbert, 1896; Haworth, 1897; Darton, 1899; Matthew, 1899; W. D. Johnson, 1901 (Frye and Leonard, 1959, p. 7). Among these works, those relating to the Ogallala Group are most significant.

The name "Ogallala" (originally spelled Ogalalla) was proposed by Darton (1899, p. 734) for a town in Nebraska to apply to "a calcareous formation of late Tertiary age," that in its typical development "is a calcareous grit or soft limestone containing a greater or less amount of interbedded and intermixed clay and sand, with pebbles of various kinds sprinkled through it locally, and a basal bed of conglomerate at many localities. . . . The pebbles it contains comprise many crystalline rocks, which appear to have come from the Rocky Mountains" (*idem*, p. 735).

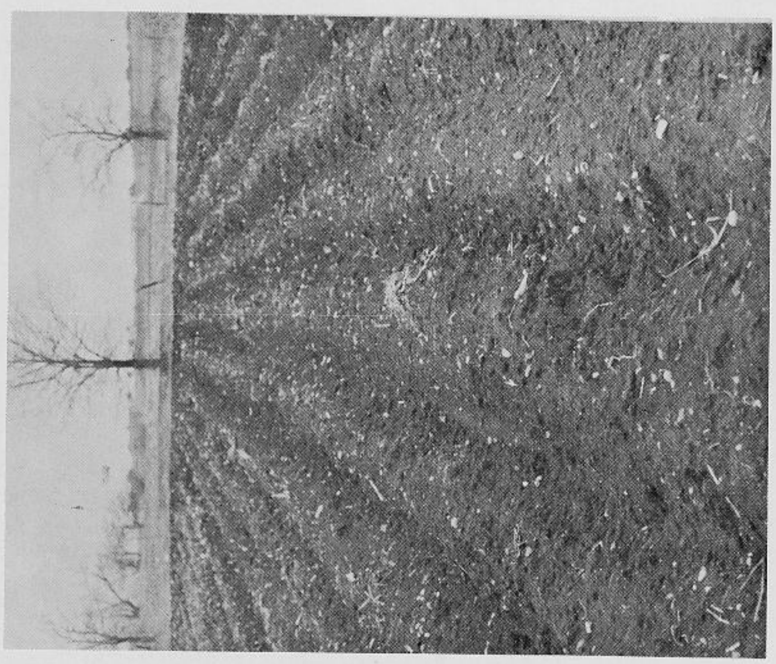
The Nebraska term "Ogallala" has gradually replaced a large number of local names and is now commonly used for the rock-stratigraphic unit including deposits of Neogene age from Howard County, Texas, northward to South Dakota. Stratigraphic terms formerly in use in northwestern Texas to describe late Tertiary-Quaternary fluviatile deposits possibly equivalent to the Uvalde gravels were summarized by Plummer (1933, pp. 765-766) as follows:

> "*Loup Fork beds.* This name was used by Cummins (. . ., pp. 203-208, 1893) to designate the oldest Tertiary strata in the Panhandle thought then to be of Miocene age.
>
> *Blanco beds.* The term Blanco division was used by Cummins (. . ., p. 431, 1891; . . ., pp. 200-201, 1893) and made to include the strata that outcrop along the rim of the Llano Estacado from Double Mountain Fork of Brazos River on the south to Paloduro Canyon on the north. These beds have a thickness of about 160 feet.
>
> *Panhandle formation.* This name was proposed by Gidley (. . ., pp. 634-635, 1903) to include the finer clay deposits of the High Plains above the Mesozoic and Paleozoic beds and below the Recent sands. This unit as originally defined appears to be more or less equivalent to the Blanco beds of Cummins.
>
> *Clarendon beds.* These beds were named by Gidley (. . ., pp. 632-634, 1903) to denote strata that occur north and northeast of Clarendon in Donley County. These beds had previously been called Loup Fork by Cummins, as he regarded them as equivalent to the type section in Nebraska, but they are now known to be lower Pliocene in age and therefore younger than the Loup Fork.
>
> *Goodnight beds.* This name was given by Cummins (. . ., pp. 201-203, 1893) to sands outcropping at the head of Mulberry Canyon and thought by Cummins to be older than the Blanco beds. Matthew and Stirton have since confirmed this opinion (. . ., pp. 365-366, 1930).
>
> *Potter formation.* This name was proposed by Patton (. . ., p. 78, 1923) for the coarsely stratified and more or less consolidated sand and gravel above the Dockum beds and below the Coetas formation exposed along Canadian River in Potter County.
>
> *Coetas formation.* This formation was named by Patton (. . ., p. 80, 1923) and made to include the slightly consolidated sand and sandy limestone strata above the Potter formation and below the surface silts and marls occupying the surface of the Llano Estacado. The formation has a thickness of about 200 feet. The type locality is along Coetas Creek in eastern Potter County.
>
> *Hemphill beds.* This name was given to the upper-lower Pliocene strata in the Canadian River valley by Reed and Longnecker (. . ., p. 20, 1932). The formation includes all the strata in Hemphill County above the Triassic formations. It is thought by Matthew to be older and probably younger than the Clarendon. It is quite possible that the Hemphill beds are equivalent to the Goodnight beds of Cummins."

Most of these names apply only locally and can not be used outside the respective areas in which they were proposed.

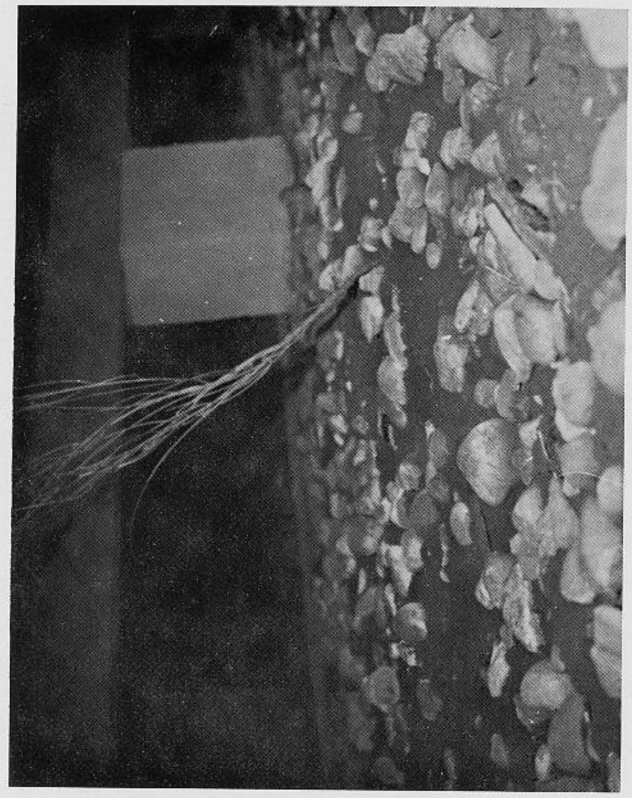
In Armstrong and Howard counties in the Texas High Plains, the Pliocene Ogallala Formation consists of fluviatile deposits, predominantly of sand but with some silt and local lenses of coarse gravel resting on an erosional bedrock topography of several hundred feet of relief. Distinctive fossil seeds permit correlation of floral zones as far south as Howard County with subdivisions (Valentine, Ash Hollow, and Kimball) recognized to the north in Kansas and Nebraska. The formation becomes thin and discontinuous to the south where the upland surface of the High Plains merges with the Edwards Plateau. Remnants of a still higher surface are preserved in outliers of Cretaceous limestone. The Ogallala Formation is capped by the "Caprock" limestone, unconformably overlain by the Blanco Formation (Frye and Leonard, 1957, p. 5).

The Southern High Plains of Texas slope southeastward, as the Ogallala Formation thins onto the erosional surface of the Edwards Plateau. Studies along the southern and southeastern borders of the High Plains have demonstrated the presence of outliers of fossiliferous Ogallala Formation in Borden and Scurry counties (Frye and Leonard, 1964, p. 20) and have documented the occurrence of Pliocene deposition as far southeast as Sterling County. In this part of Texas,



A. Gravel exposed in plowed field.

B. Accumulation of gravel beside abandoned farmhouse.



C. Gravel under farmhouse.

Fig. 4. Occurrence of Uvalde Gravel, 6.5 miles southeast of Meridian, Bosque County, Texas (locality 4-4). Gravels consist of pebbles and cobbles of quartzite, quartz, chert, and jasper.

the High Plains, Osage Plains, and Edwards Plateau merge, and clear physiographic distinction is virtually impossible.

Cronin (1969, p. 4), in a study of the aquifers of the High Plains, described the Ogallala Formation where it ranges in thickness from nothing (where the formation wedges out against older rocks) to as much as 500 feet. It consists of clay, silt, fine to coarse-grained sand, gravel and caliche. Silt is commonly associated with the fine- to medium-grained sand in the upper part of the formation; coarse-grained sand generally occurs in the lower part of the formation; gravel is present in many places at the base of the formation; and at other horizons, gravel is also present in lenses interbedded with sand.

In summary, the literature which is most important to this study includes that which relates directly to Uvalde Gravel, and that which considers other gravel possibly correlative with or ancestral to the Uvalde Gravel.

ACKNOWLEDGEMENTS

The writer wishes to express his gratitude for the support of O. T. Hayward, Department of Geology Baylor University, who suggested this project and significantly contributed to field interpretation and manuscript revision. Charles M. Tolbert, Department of Sociology, and R. L. Bronaugh, Department of Geology, Baylor University, critically reviewed the manuscript. Dan Muller, Texas Water Development Board, provided cross sections and topographic profiles of the southern High Plains. Others who contributed significantly to the project through discussion include I. A. Flodin, Texas Water Development Board, and L. W. Epps, Department of Geosciences, Texas A&M University. A special note of appreciation is extended to Vikki Freeman, Texas Water Development Board, for preparation of the thesis manuscript, with assistance from Marie Fuller, Texas Water Development Board.

GEOLOGY OF THE UVALDE GRAVELS

Uvalde Gravel, consisting of chert, quartz, quartzite, and limestone cobbles, is river-transported debris from upstream regions of west Texas and eastern New Mexico. West of the Balcones fault zone, these deposits may be found as occasional high terraces along the streams of the Edwards Plateau and rivers of the Grand Prairie and the Osage Plains (fig. 1). Where stream valleys emerge east of the Balcones Escarpment, the gravel deposits become more distinct and widespread, finally coalescing across the present divides within the Black Prairie Province. This expansion takes place a few miles east of the Balcones scarp, usually over the area occupied by the Taylor Marl (Hill, 1901, p. 346).

NATURE OF OCCURRENCE OF UVALDE GRAVEL

In central Texas (fig. 3), the Uvalde Gravel caps the divides of major rivers. West of the Balcones fault line, the Uvalde gravels are present as lag deposits resting upon soils formed from the underlying strata. To the east of the Balcones fault line, the Uvalde Gravel is a generally thin blanket deposit or scattered lag accumulation of gravel, sand, and clay (Plummer, 1933, p. 777).

Individual pebbles and cobbles range from one inch to six inches in diameter; the smaller pebbles are usually well rounded, the larger ones are mostly subrounded, while flat surfaces are exhibited on some of the large fraction. Composition of the gravel varies somewhat, though it consists largely of quartz, quartzite, chert, jasper, granite, and silicified wood.

Along inter-stream divides capped by this deposit are isolated patches ranging in width from a few yards to ten miles or more. Outcrops of the Uvalde Gravel range in elevation from 200 to 600 feet above the beds of present rivers (figs. 9, 10, 11, 12). There are no later deposits covering this deposit. Younger terraces are all topographically lower.

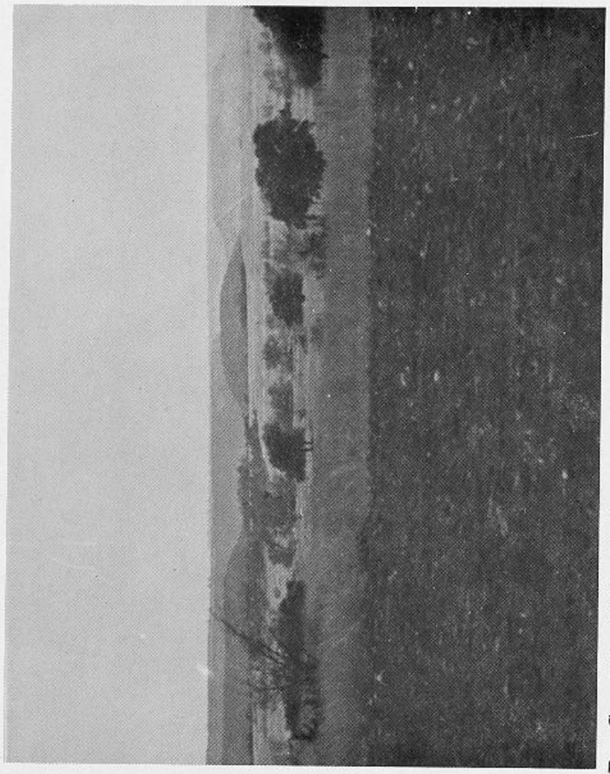
Uvalde gravels occur typically in a soil matrix that mantles the gently rolling or flat stream divides. These lag concentrates tend to drape over irregularities in the topography and are therefore considered more as a part of the soil than as a mappable unit.

In Bosque County, the Uvalde Gravel forms a veneer in cultivated and pasture land hills (locality 4-4). The formation does not exceed one foot in thickness and is usually represented by boulders, cobbles, and pebbles scattered about the soil of the Cretaceous Georgetown Formation (figs. 4, 5).

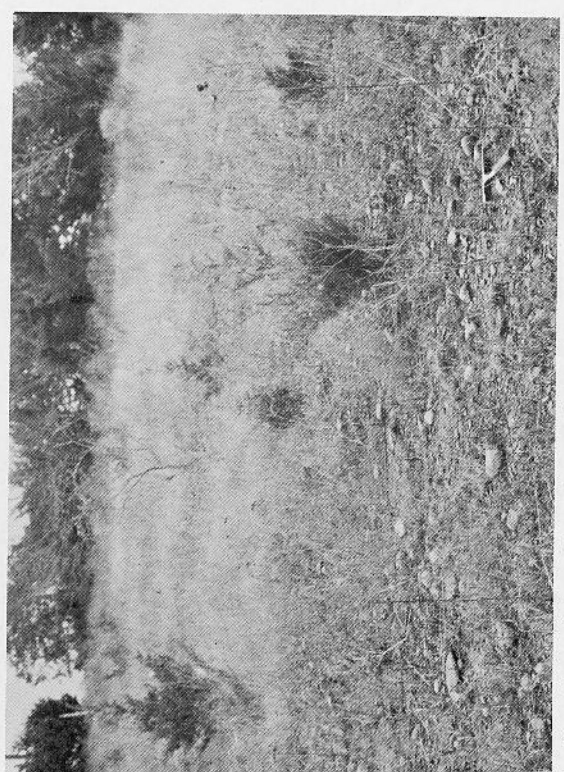
In McLennan County, Uvalde Gravel is found primarily on the eastern side of the Balcones fault zone. Outcrops frequently consist of scattered cobbles on slopes and along channels of minor streams (locality 4-9), but outcrop concentration is greatest on the tops of divides (fig. 6).

Uvalde Gravel deposits become more prominent southward. In Travis County (locality 4-16), the Uvalde Gravel reaches a thickness of 20 feet or more. Just west of Lockhart, Caldwell County (25 miles south of Austin) (locality 4-24), Weeks (1930, p. 917) described approximately 30 feet of Uvalde terrace deposits, and gravel is conspicuous in tilled fields (fig. 7).

A. Gravel in plowed field consists of tan, yellow, and purple quartzite cobbles with some vein quartz and silicified wood (locality 4-7).



B. Gravel in field with Lampasas Cut Plain in background (locality 4-8). Principal lithologic types include yellow, white, and purple quartzite with some vein quartz.



C. Gravel overlying Georgetown Formation (locality 4-2), mostly tan, yellow, and purple quartzite with some chert, limestone and jasper.

D. Close view of gravels at locality 4-2.

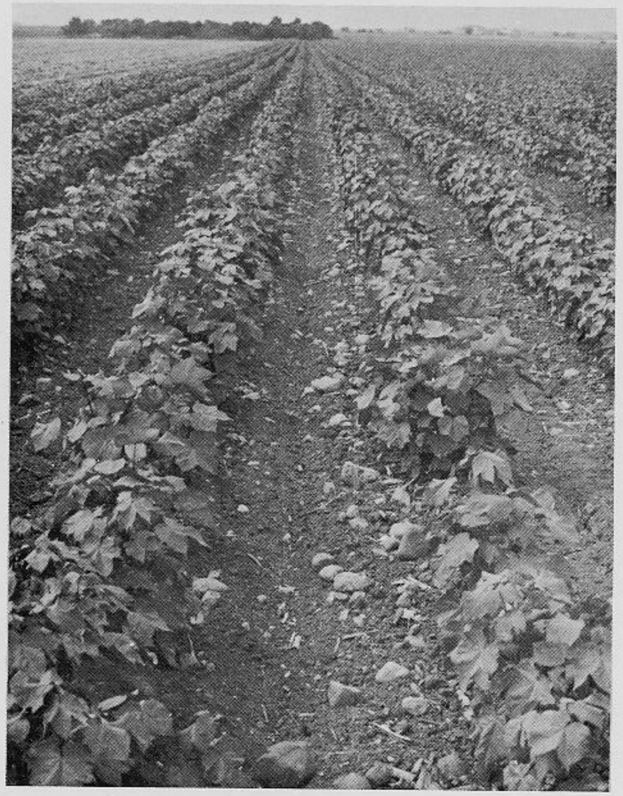
Fig. 5. Occurrence of Uvalde Gravel in Bosque County, Texas.

A. Gravel resting on the Austin Chalk, Travis County, Texas (locality 4-16). Cobbles consist dominantly of tan quartzite and limestone with lesser amounts of jasper, vein quartz.

B. Gravel in road cut, Travis County, Texas (locality 4-15). Cobbles of chert and limestone most abundant with lesser amounts of clear and milky quartz.

C. Gravel in plowed field includes tan, yellow, and purple quartzite cobbles and pebble-size vein and banded quartz, McLennan County, Texas (locality 4-9).

Fig. 6. Various occurrences of Uvalde Gravel.



A. Uvalde Gravel in a field east of Lockhart, Caldwell County, Texas (locality 4-24).

B. Close view of gravels at locality 4-24 (See fig. 7-A).

C. Uvalde Gravel south of Austin, Travis County, Texas (locality 4-17).

Fig. 7. Occurrence of Uvalde Gravel, consisting of cobbles of quartzite, quartz, chert and limestone.

REGIONAL DISTRIBUTION, UVALDE GRAVEL

Uvalde Gravel occurs on the high stream divides in an area from Tarrant and Dallas counties southwestward into northern Mexico. These deposits are hardly recognizable within the Grand Prairie region (fig. 1). An occasional piece of rounded quartz or other gravel foreign to the region can be found on some of the isolated buttes of the Lampasas Cut Plain, (e.g. Comanche Peak, fig. 8, locality 3-12) according to Hill (1901, p. 347). Scattered pebbles of rounded quartz may also be found atop the Callahan Divide in Taylor County (locality 3-9). In referring to the Tertiary and Quaternary sand and gravel deposits of Stonewall County, Texas, located within the Osage Plains, Patton (1930, p. 53) said: "The deposit which is perhaps of the most interest is found on the top of Double Mountain. Here a thin veneer of waterworn gravel is spread over the flat top of the mountain. The deposit is composed of waterworn gravels, mostly quartzite, the individual pieces of which measure from a fraction of an inch to two inches in diameter." The anomalous occurrences of these gravels attest to the former occupation of the areas by alluvial deposits.

The Uvalde Formation overlies rocks varying in age from Early Cretaceous up through middle Pliocene. West of the Balcones fault zone, in Bosque County, it rests in small isolated patches, unconformably upon the Georgetown Formation capping the divide between the North Bosque River and the Brazos River. At locality 4-2, approximately 5 miles northeast of Valley Mills, Bosque County, gravels, which are foreign to the surrounding area, form a veneer on the cultivated fields. This location is at an altitude of 750 feet, 240 feet above the Brazos River.

About 4.0 miles east of Clifton, Bosque County (locality 4-6), the Uvalde Gravel occurs at an elevation of 850 feet, which is approximately 430 feet above the Brazos River. Figure 9 illustrates the topographic relationship of the high level gravels to the various younger terraces deposited by the present Brazos River (elevation 560 feet).

Gravels were discovered in abundance at locality 4-4, approximately 6.5 miles southeast of Meridian, Bosque County. The elevation at this point is 940 feet or 490 feet above the Brazos River, far above the oldest well defined Pleistocene terrace.

Scattered cobbles were observed on the Powell Ranch (locality 4-5), about 5.5 miles southeast of Meridian, Bosque County, but the size distribution was comparable with other Uvalde gravels of the area. This is the highest elevation at which the gravels occur in the area, 960 feet above sea level and 510 feet above the Brazos River.

East of the Balcones fault zone, the old alluvial deposits are conspicuous features of the Black Prairie. The Uvalde Gravel is especially well exposed in the eastern part of Travis County, where it covers all of the higher divides between the streams and extends west, in places, to the Balcones fault line (Hill, 1901, p. 347).

On the Blacklands Experimental Watershed, located in Falls and McLennan counties, about 15 miles southeast of Waco, between the towns of Riesel and Mart (locality 4-9), "coarse gravel and cobbles are abundant in the soil on the tops of certain of the higher hills and ridges on the western and southwestern borders of the project area," (Blank, Stoltenberg and Emmerich, 1952, p. 16). The "coarse gravel and cobbles" here refers to the Uvalde Formation (elevation 565 feet, 225 feet above the Brazos River) which rests unconformably upon Pecan Gap Member of the Taylor Marl. Soils developed on the gravel-capped hills were mapped as Houston black clay, gravelly phase by Baird, Lauritzen, *et al.* (1942, p. 35).

Between the towns of Lorena and Bruceville, McLennan County, Uvalde Gravel rests unconformably on Taylor Marl forming the divide between the North and South forks of Cow Bayou (locality 4-10). This divide is 260 feet above the present Brazos River level (340 feet). Figure 9 shows how the gravel deposits are related to the topography and the Brazos River terraces.

The eastern portion of Bell County, east of Heidenheimer, Little River and Rogers, the Uvalde Gravel lies unconformably on the Taylor Marl (locality 4-11). Both Wolfe City and Pecan Gap members of the Taylor Formation are included in this area. Between Holland and Bartlett (locality 4-12) the gravels overlie the lower Taylor Marl. Several other areas of Uvalde Gravel rest unconformably upon the Taylor Marl. These include the ridge north of Taylor, Williamson County (locality 4-13); east of Pflugerville (locality 4-14), between Manor and Austin (locality 4-15), between Creedmoor and Manchaca (locality 4-17), Travis County; and south of Buda, Hays County (locality 4-18).

South of Austin, Travis County, a massive deposit of Uvalde Gravel rests unconformably on the Austin Chalk (fig. 7) at an elevation of 620 feet, 210 feet above the Colorado River (locality 4-16). Figure 10 shows the relationship of the Uvalde Gravel to the topography and to the younger Colorado River terraces.

Gravels overlying the Eocene Wilcox Group occur in Limestone County between Mexia and Personville (locality 4-8), 560 feet above sea level. Five miles southeast of Thornton (locality 4-23), gravel appears at an elevation of 500 feet. In Bastrop County, southeast of McDade (locality 4-19) the gravels overlie the Wilcox Group and the Carrizo Member of the Claiborne Group.

From Giddings, Lee County, westward to the county line (locality 4-19), Uvalde Gravel unconformably overlies the Cook Mountain Member of the Claiborne Group. To the north in Burleson County, the gravels overlie the Yegua Member of the Claiborne Group between Caldwell and Somerville (locality 4-20).

In Washington County, both the Eocene Jackson Group and the Miocene Catahoula Sandstone are unconformably overlain by the Uvalde Formation. These occurrences are about 5 miles north of Burton (locality 4-21) and between Ledbetter and Carmine (locality 4-19).

LITHOLOGY OF UVALDE GRAVEL

Lithologic content of the Uvalde Gravel varies locally. Typically it is composed of waterworn pea-gravel to boulder-size quartz, quartzite, chert, limestone, silicified wood, and a few Cretaceous fossils.

In some areas chert and limestone are the dominant constituents. Such areas always display badly worn fossils from the Lower Cretaceous limestones as shown in figure 11A taken north of Bartlett (locality 4-12) and figure 11B taken south of Austin on I. H. 35 (locality 4-18). Associated with this suite are cobbles of quartz and quartzite indicating a mixing of materials from two source areas.

Some outcrops of Uvalde Gravel consist entirely of siliceous material: quartz, quartzite, chert and silicified wood. Quartz is represented by several types which include jasper, white vein quartz, and red to black banded quartz. The quartzite suite contains fine- to coarse-grained specimens which are tan, purple, yellow and pink in color. Some clear quartz, granite, and orthoclase are present in the vicinity of Austin, apparently derived from the granites and pegmatites of the Llano Uplift region to the northwest (fig. 1).

RELATIONSHIP OF UVALDE GRAVEL TO OTHER LATE TERTIARY-EARLY QUATERNARY GRAVELS

DISTRIBUTION

Most early Texas geologists described the Uvalde Gravel as exposed generally south and east of the Balcones fault zone and extending from McLennan County southward into Mexico. This general concensus seems valid save for a few isolated exceptions where the gravel is found on the west side of the fault zone. The outcrop of the Uvalde Gravel is a discontinuous band generally paralleling the outcrop pattern of the older strata upon which it rests. It is distinguished from other late Tertiary-Quaternary gravels by its geographic and topographic position, and by its size, grade, and composition.

River Terraces

Gravel deposits of younger age are found adjacent to the various rivers which transect the Uvalde outcrop (fig. 2). These younger gravels are present in terraces formed by the rivers during an earlier stage. Vertebrate fossils give evidence of Pleistocene age for some of the terraces and Recent age for others. Dr. O. P. Hay recorded diagnostic Pleistocene fossils along the Leon River in Bell County (Adkins and Arick, 1930, pp. 67-69) and along Hog Creek and the Brazos River in McLennan County (Adkins, 1923, p. 84). "A Pleistocene fauna persists in the successively lower and younger terraces" of the Brazos River (Bronaugh, 1950, p. 16). The first terrace and the floodplain now in the process of alluviation were considered to be of post-Pleistocene or Recent age by Bronaugh (*idem*) on the basis of artifacts and fragments of mammal bones of existing species of bison and deer. Pleistocene and Recent terraces may be found the full length of the Brazos and Colorado rivers, from the Llano Estacado to the Gulf of Mexico (fig. 12).

Uvalde gravels are found at various elevations above younger Pleistocene river terraces in central and south Texas. Nowhere does the deposit occur at a consistent elevation. This is probably due to the wearing away of softer formations leaving a coarse gravel lag which migrates downward as erosion lowers the underlying formations.

The more easily weathered underlying materials (marls, clays, shales) allow the lag gravels to vary more in elevation than do the more resistant limestones. Figures 9 and 10 show the relationship of the Uvalde gravels to the younger Pleistocene terraces and the present river levels of the Brazos and Colorado rivers.

Seymour Formation

The Seymour Formation is exposed between the Red River and the Clear Fork of the Brazos River. It occurs east of the Llano Estacado resting unconformably on strata of Permian age. The Seymour Formation occupies the inter-stream divides in north-central Texas much as the Uvalde Gravel occurs on the divides in central and south Texas. Vertebrate remains from the Seymour Formation were collected by W. W. Dalquest, below the Pearlette ash horizon and dated as late Kansan (2nd glacial) age (Hibbard and Dalquest, 1960, p. 21). The location of the vertebrate find was 3.5 miles southeast of Gilliland along the South Wichita River, Knox County, Texas (*idem*).

Ogallala Formation

The Llano Estacado (fig. 1) is bounded on the north by the Canadian River, on the west by the Pecos River in New Mexico; on the east it forms an escarpment several hundred feet high where the headwaters of the Red, Brazos, and Colorado rivers have cut into it; and the southern edge overlaps and forms a feather edge on the Edwards Plateau. The basal sediments of this plateau are composed primarily of sand and gravel of the Ogallala Formation of Neogene or Pliocene age (Elias, 1942, p. 133 and Frye, Leonard and Swineford, 1956, p. 24), as indicated by fossilized plant remains found within the formation.

The Ogallala Formation occurs at an elevation which suggests a former continuous surface sloping eastward (fig. 14). Topographically the Ogallala Formation occurs at higher elevations than the Uvalde Gravel, but dips to the southeast and apparently forms part of the same planar depositional surface. This dip direction corresponds to the pre-Neogene peneplain described by Cronin (1961, p. 38).

LITHOLOGIC CORRELATIONS AMONG GRAVEL DEPOSITS

The Uvalde Gravel is composed of waterworn stones having a wide variety of sizes and compositions. Some of the larger boulders reach a maximum diameter of six inches, while the bulk of the deposit is made up of cobbles and pebbles ranging from 2 or 3 inches to one inch in diameter (figs. 16, 17). This compares both in size, grade and composition with suites of gravels from the east and west sides of the Llano Estacado and the Osage Plains (fig. 17). However, in these latter areas, the coarsest fraction is composed of slightly larger boulders, possibly due to the proximity of the source area (fig. 2).

Tan quartzite, yellow quartzite and chert are the dominant siliceous rocks in the Uvalde suite of central Texas. In the course of this study, these same lithologies have been traced from central Texas westward along the Brazos and Colorado rivers across the Osage Plains to the eastern edge of the Llano Estacado (figs. 18, 19). In New Mexico on the western edge of the Llano Estacado, bounded by the Mescalero Escarpment, similar gravels were observed in higher terraces along the Pecos River.

Less abundant, but still persistent throughout the above described areas, are fragments of silicified wood, cobbles and pebbles of purple quartzite, vein quartz, banded quartz, and jasper (figs. 20, 21, 22). Several of the samples collected in all areas exhibited chatter marks and calcium carbonate encrustation (fig. 23).

Sampling along the Callahan Divide (locality 3-9) yielded what appears to be a completely different suite of gravels. Grain size of the suite ranges from one-half inch to two inches in diameter (fig. 24A). The principal lithology is milky quartz varying from white to yellow to pink in color. Some hematite pebbles and several varieties of chert were observed. These include solid gray, white with grey spots (possibly an artifact), (fig. 24B) and a yellow-to-red angular fragment which appears to be opalized. This deposit is apparently of fluviatile origin but does not appear to be related to the Uvalde, Ogallala, Seymour, or Pleistocene terrace deposits. The surface of the Callahan Divide is substantially higher than the projected surface formed by the Ogallala Formation. This suggests an alluvial surface older than Ogallala, graded to uplands which are no longer obvious (fig. 14). This is one of the most interesting of geological side-issues encountered in this study.

PROBABLE CORRELATIONS OF UVALDE GRAVEL

Considering the lack of any diagnostic vertebrate, invertebrate, or microscopic fossil remains and the absence of an obvious direct correlation with any other lithologic unit, correlation of the Uvalde Gravel is at best both difficult and tenuous. There have been several attempts by early geologists to interpret the genesis of the Uvalde gravels (Deussen, 1924, p. 102; Hill, 1891, p. 368; and Weeks, 1945, p. 1695). For the most part these attempts were unsuccessful because of inadequate information, and in recent years, the problem has been largely ignored.

However, by using similarities in gross lithology, the Uvalde gravels can be traced (via possible Uvalde Gravel and younger terrace deposits) across the Grand Prairie and Osage Plain to the eastern edge of the Llano Estacado. Similarities extend from the Pleistocene terraces of the various rivers that head in the Llano Estacado to the basal Ogallala conglomerate of the eastern High Plains and across the High Plains to the Pecos River terraces (figs. 25, 26).

AGE AND DISTRIBUTION OF UVALDE AND CORRELATIVE GRAVELS

In order to trace the probable correlation of Uvalde gravels with other stratigraphic units of the High Plains, central Texas, and upper Gulf Coast, some reiteration is useful.

Uvalde gravels occur as isolated bodies, ranging from a few yards to ten miles or more in width, occupying the high stream divides in an area from Tar-

A. Comanche Peak, Hood County, Texas (locality 3-12).

B. Double Mountain, Stonewall County, Texas (locality 3-13).

Fig. 8. Isolated buttes upon which waterworn gravels similar to Uvalde Gravel have been found.

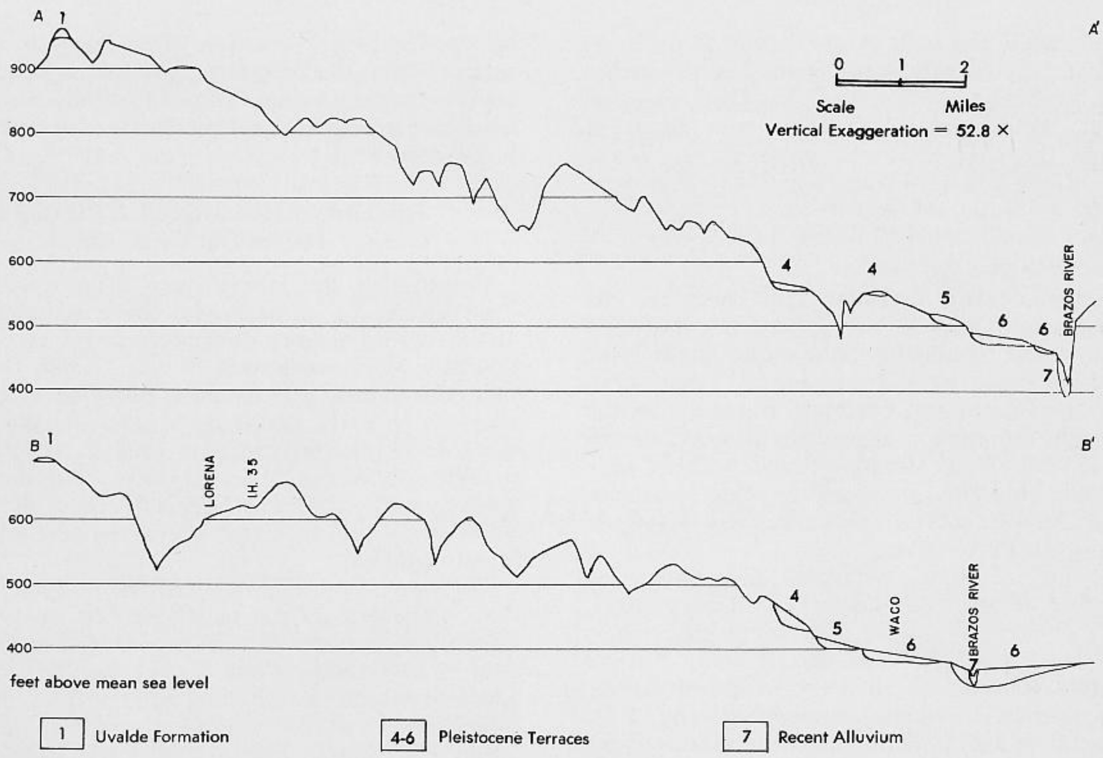


Fig. 9. Diagrammatic sections near Meridian and Waco, Texas showing terrace levels.

rant and Dallas counties southwestward into northern Mexico. With minor exceptions, the Balcones Escarpment marks the eastern margin of the most extensive outcrops of Uvalde Gravel.

The western margin of the Uvalde outcrop is located approximately 250 miles east of the Llano Estacado, the easternmost outcrop of the Ogallala Formation (fig. 1). Conglomerate at the base of the Ogallala Formation consists of gravels similar to those of the Uvalde Gravel. At present, the Llano Estacado extends over an area of northwest Texas and eastern New Mexico covering approximately 32,000 square miles (Cronin, 1969, p. 1). Some 150 miles farther to the west are the Southern Rocky Mountains, the original western boundary of the Southern High Plains. At the time of deposition, the Ogallala Formation extended in an unbroken alluvial surface from the Southern Rocky Mountains to a terminus far east of the present caprock escarpment.

The Uvalde was probably deposited during or shortly after the deposition of the Ogallala Formation of the Llano Estacado which began in Miocene time (Elias, 1942, p. 133) and continued into Pliocene time (Frye, Leonard, and Swineford, 1956, p. 24).

Gravels from the Uvalde have been found to unconformably overlie strata of various ages from the Lower Cretaceous (Paluxy Formation) to the upper Tertiary (Catahoula Sandstone). This would place the time of deposition of the Uvalde Gravel somewhat after late Tertiary time. Dating of the Brazos and Colorado river terraces as Pleistocene (Bronaugh, 1950, p. 16) has fixed the recent time limit of Uvalde deposition because the Uvalde gravels are higher in elevation, and hence older, than adjacent Pleistocene terraces (table 2). "Uvalde time" is therefore somewhat after Miocene time (middle Neogene) and before Pleistocene (upper terrace) time. If the Pleistocene should be subdivided in central Texas as it has been in the Osage Plains (Frye and Leonard, 1957, p. 18) a more precise time limitation might be assigned to deposition of Uvalde Gravel.

PROVENANCE OF UVALDE GRAVEL

The only readily available source for the large quartzitic material in the Uvalde Gravel is the Ogallala Formation of the Llano Estacado, or the common source of both Ogallala and Uvalde gravels, the Southern Rocky Mountains. The Ogallala Formation of the Southern High Plains is the remnant of an alluvial plain, the gravels of which were derived from the easternmost ranges of the Southern Rocky Mountains in central New Mexico. Streams that had their headwaters in the Sangre de Cristo, Sandia, Manzano, Los Pinos, Gallinas and Jicarilla mountains discharged eastward and deposited sediment to form the Llano Estacado.

Drainage on the pre-Ogallala surface was in a southeasterly direction. The Ogallala surface slopes to the east-southeast at rates from 8 to 20 feet per mile (Cronin, 1969, p. 2) reflecting the ancient general drainage direction. Rivers of the adjacent Osage Plain also drain to the east or southeast suggesting that they may, at one time, have had courses on an ex-

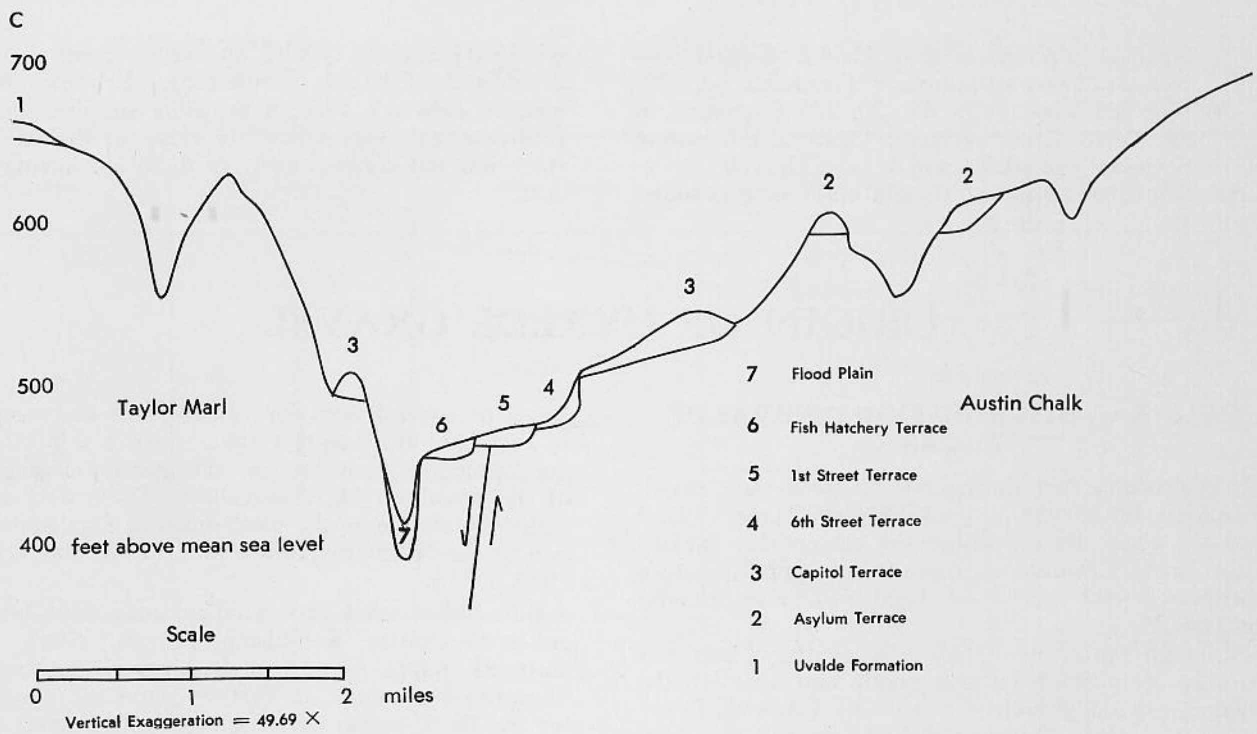


Fig. 10. Diagrammatic section through east Austin showing terrace levels.

tended Ogallala surface (Neogene) and have not changed since the erosional stripping of that surface. Basal gravels of the Llano Estacado may thus have been an intermediate source for the large quartzitic gravels of the Uvalde Gravel.

The Manzano Mountains (fig. 27) were probably major contributors of siliceous material to Ogallala and Uvalde deposits, as suggested by the following description: "The South Manzano Mountains in central New Mexico form a unit of the easternmost of the Basin Ranges and are structurally continuous with the Los Pinos to the south and the North Manzano and Manzanita Mountains to the north. Precambrian metaclastics . . . [are] overlain by the Blue Springs schist and White Ridge quartzite in conformable sequence, followed by 5,000 ft. of rhyolite flows and intercalated basic sills. A small outcrop of granite in the northwest part of the area is similar to and correlated with the Ojito stock of the North Manzano Mountains, which intruded metaclastics older than the Sais quartzite. In the south, the Priest granite and associated pegmatite and aplite dikes intrude all older formations. Vein quartz ranging from thin stringers to massive quartz reefs over 1,000 ft. thick are prominent throughout the range and represent several periods of intrusion" (Stark, 1956, abstract).

The Sais quartzite varies from light to dark gray, with greenish and nearly white facies in a few outcrops. Tightly fused and often banded reddish to purplish beds occur near the base. Muscovite, biotite, feldspar and epidote are recognized in hand specimens (Stark and Dapples, 1946, p. 1128).

The White Ridge Formation is dominantly quartzite ranging in color from white, gray, pink, red to purple. Some laths of biotite, sericite and hematite appear in the less pure beds. Bedding planes commonly show reflecting surfaces of muscovite (fig. 26). Grains range in size from 0.1 to 1.0 millimeter. Veins of nearly pure (95%) white milky quartz from a fraction of an inch to 40 feet in thickness occur in abundance within the Los Pinos and Manzano ranges (Stark and Dapples, 1946, p. 1140).

Petrologic correlation of the siliceous rocks of the Los Pinos and Manzano Mountains, the Uvalde gravels and the intermediate Ogallala Formation is based on the following petrologic similarities:

1. Similarities in granite cobbles from either side of the Llano Estacado (fig. 25) and from streams draining the North Manzano Mountains.
2. Muscovite flakes along bedding planes of quartzite (fig. 26) exposed in the eastern Manzano Mountains, and found in cobbles from Uvalde Gravel and Ogallala and Seymour formations.
3. Milky (vein) quartz cobbles (figs. 21, 22) in Ogallala, Seymour and Uvalde gravels and in veins in Manzano Mountains.
4. White, purple, red and yellow quartzite cobbles in Uvalde Gravel and Ogallala Formation (figs. 18, 19, 21, 22), identical in appearance to quartzite beds outcropping in Manzano Mountains, New Mexico.
5. Banded quartz (figs. 21, 22) in cobbles of

Ogallala Formation and Uvalde Gravel and streams of eastern Manzano Mountains.

6. Silicified wood (figs. 18, 20, 22) fragments in the Pecos River terraces, Ogallala Formation, Seymour Formation and Uvalde Gravel.

An abundance of limestone and chert is also found within the Uvalde Gravel, apparently from the Lower Cretaceous Edwards Limestone. Eroding of the western Edwards Plateau probably supplied these ingredients and was sufficiently close so that the limestone was not abraded away or dissolved during transport.

ORIGIN OF UVALDE GRAVEL

ORIGINAL DISTRIBUTION OF UVALDE ROCKS

It is probable that throughout Neogene time, major alluviation terminated a considerable distance inland from the coast. By extending the present-day surface of the Llano Estacado, it is possible to approximate a possible original extent of Ogallala-Uvalde alluviation (fig. 28).

Although the Llano Estacado in central Texas was probably terminated on the south and east of the Callahan Divide (which is capped by Edwards Limestone) in Nolan, Taylor and Callahan counties (fig. 28), tongues of the Ogallala Formation apparently extended along the valleys of the eastward flowing rivers. The Callahan Divide was described as a major drainage barrier ridge by Lewand (1969, p. 21). Where the rivers were entrenched in Paleozoic and Comanchean rocks, they transported quantities of bedload gravel derived from the Southern Rockies, perhaps by an intermediate depositional rest in the Ogallala Formation. Where the valleys widened in the less resistant Gulfian and Tertiary rocks, the streams were free to meander widely, and here the bedload gravels were left as floodplain accumulations of braiding sediment-choked rivers. Gravels of Uvalde age were thus originally distributed from the edge of the Ogallala alluvial plain at the Callahan Divide, along the valleys transecting the divide and the canyon-forming Paleozoic and Lower Cretaceous rocks to the east, and then over a wide area where the valleys widened in the softer Upper Cretaceous and lower Tertiary rocks.

HISTORY OF DEPOSITION OF UVALDE GRAVEL

At the beginning of the Neogene Epoch, an erosional surface existed in northwestern Texas and eastern New Mexico. Generalized reconstruction of the erosional topography indicated broad eastward-trending valleys with gently sloping sides. Local relief on this surface exceeded 500 feet (Frye and Leonard, 1959, p. 7; Cronin, 1969, p. 4) prior to deposition of the Ogallala Formation.

Work in Kansas (Frye, Leonard and Swineford, 1956) suggested the mechanism of deposition of the Ogallala Formation of the Northern High Plains. Evidence there is interpreted to refute the theory of coalescence of a series of adjacent gigantic fans (for this theory see Plummer, 1933, p. 769) that spread out over an essentially flat surface. It is possible to trace zones of several ages for considerable distances west to east, and the younger units display a north-south overlapping relationship on the gently sloping sides of the broad pre-Ogallala valleys. These data suggest valley alluviation as the mechanism of Ogallala deposition in the Northern High Plains (Frye and Leonard, 1959, p. 71).

Initial alluviation of the valleys may have been due either to climate, tectonism, or both. Stark (1956, abstract) refers to normal faulting of the Southern Manzano Mountains in Tertiary time as "responsible for the block tilting of the range with respect to the Rio Grande Valley on the downthrown side." As alluviation progressed, the existing erosional topography was laterally overlapped, the lower divides were buried and ultimately much of the region northward from Howard County, Texas to southern South Dakota became a coalescent plain of alluviation. From Howard County eastward, large mesas such as the Callahan Divide, protected by resistant Cretaceous limestone, stood prominently above this alluvial plain forming a barrier to further alluviation (fig. 28). Southward, these Neogene deposits feather out over the surface of the Edwards Plateau (Frye and Leonard, 1957, p. 7).

Fluvial alluviation of the region east of the Southern Rocky Mountains must have begun almost with the beginning of the uplift of the ranges. From the first of the rising mountains, the detritus was carried eastward by gulfward flowing streams during periods of most rapid erosion coinciding with major uplift or arid climates. First the valleys nearest the mountains were filled with coarse detritus, and initial topography was buried beneath an alluvial cover deposited by anastomosing streams. This developed a plain of alluviation, which was probably extended eastward both by valley filling and by gentle progradation. From the margin of the alluvial plain, tongues of river-borne detritus extended along the routes of the major watercourses. These relationships are shown in table 2. While detritus was carried eastward along rivers originating in the southern ranges of the Rocky Mountains throughout a long erosional history, only during the times of gravel alluviation of the mountain front would similar gravels be transported eastward along the streams. Thus, Uvalde gravels are at least partially equivalent in age to the gravels of the Ogallala Formation (table 2).

In central Texas, the Ogallala plain terminated at a topographic ridge formed by Lower Cretaceous rock. There were several valleys through this ridge, along which tongues of alluvial gravel extended. Panther

Table 2. Stratigraphic correlation of related Tertiary and Quaternary gravel-bearing formations

System	Series		Llano Estacado	Osage Plains	Central Texas
Quaternary	Recent and Pleistocene		depression fills Tahoka Formation "Cover Sands" Tule Formation Blanco Formation	River Terraces Seymour Formation	River Terraces
Tertiary	Neogene	Miocene-Pliocene	Ogallala Formation	Ogallala remnants	Uvalde Gravel

A. Cultivated field exhibits cobbles of chert and limestone with occasional quartzite pebbles, Bell County, Texas (locality 4-12).

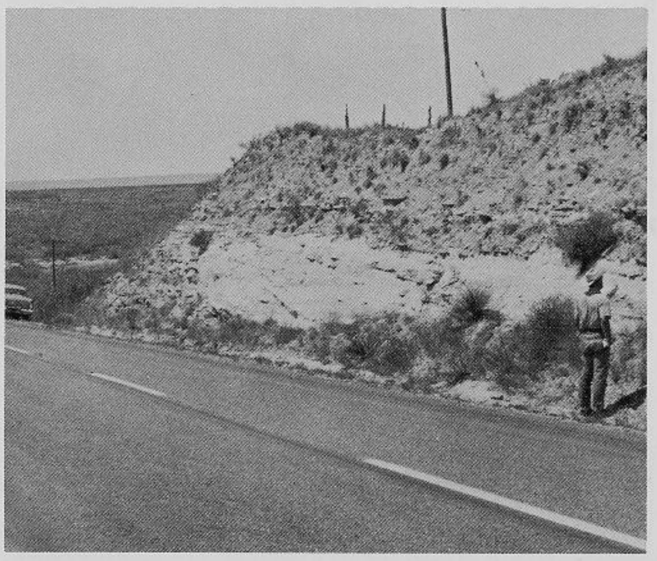
B. Limestone and chert cobbles resting on Austin Chalk, lesser amounts of vein quartz and quartzite, Hays County, Texas (locality 4-18).

Fig. 11. Occurrence of Uvalde Gravel with abundance of limestone and chert.

A. Pleistocene terrace of the Colorado River on Taylor Marl, Travis County, Texas (locality 4-16). Gravels consist of vein quartz, purple and yellow quartzite, granite, and limestone.

B. Colorado River terrace, Coke County, Texas (locality 3-14) consisting primarily of limestone pebbles with some quartz and quartzite.

C. Headwaters, Salt Fork of the Brazos River, Garza County, Texas (locality 2-8) containing tan, purple and yellow quartzite, milky and banded quartz, and limestone cobbles.



D. Terrace of the North Double Mountain Fork of the Brazos River, Garza County, Texas (locality 2-9) consisting of red, yellow, purple, and micaceous quartzite, quartz, and granite.

Fig. 12. Examples of terrace and stream gravels from the Llano Estacado to central Texas.

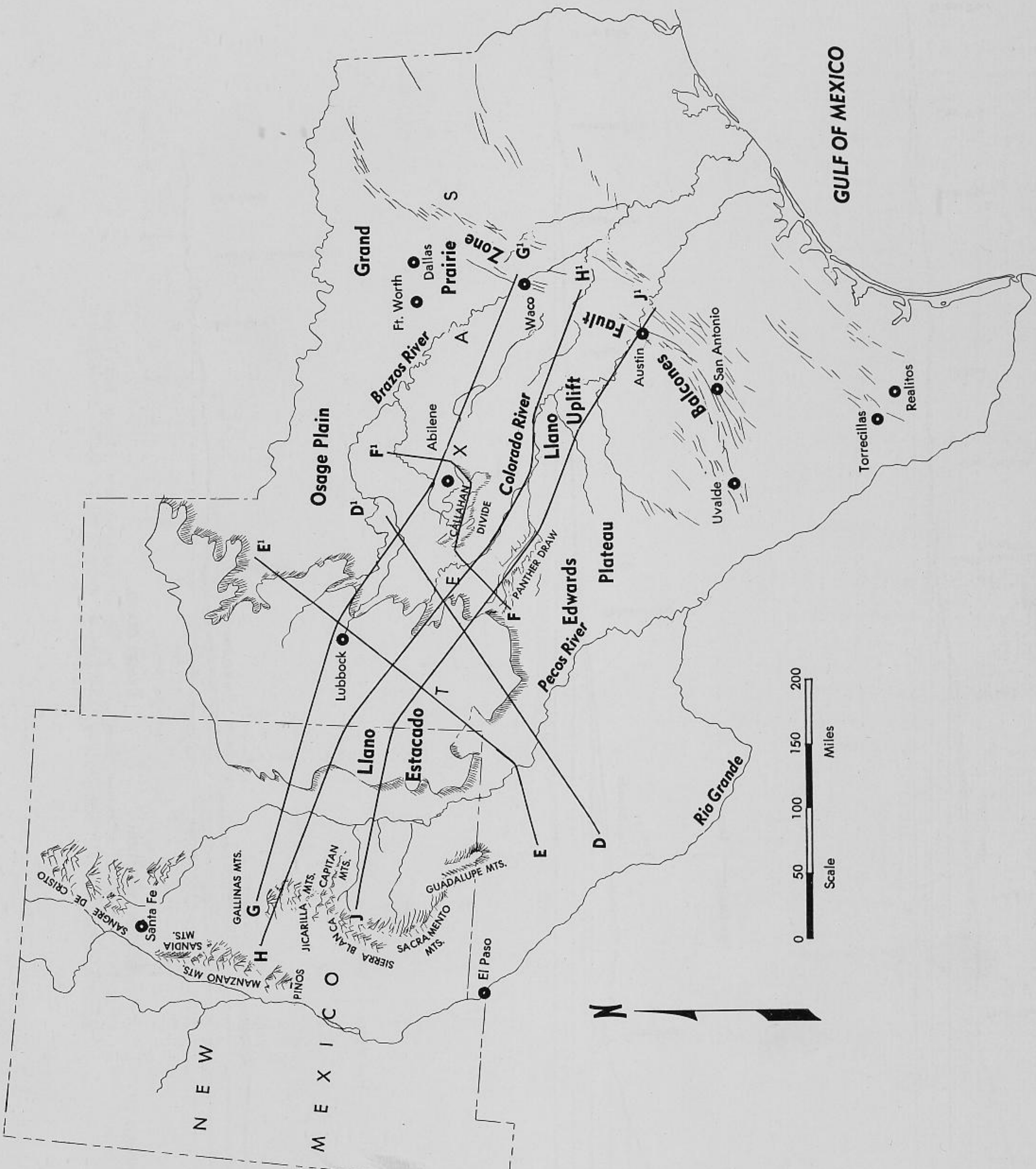


Fig. 13. Map of Texas and New Mexico showing locations of cross sections on figures 14 and 15. Sections in shaded area shown in figure 3.

Fig. 14. Generalized schematic topographic profiles of parts of New Mexico and Texas. Based on a 200-foot contour interval, 1:500,000-scale maps issued by the U. S. Geological Survey.

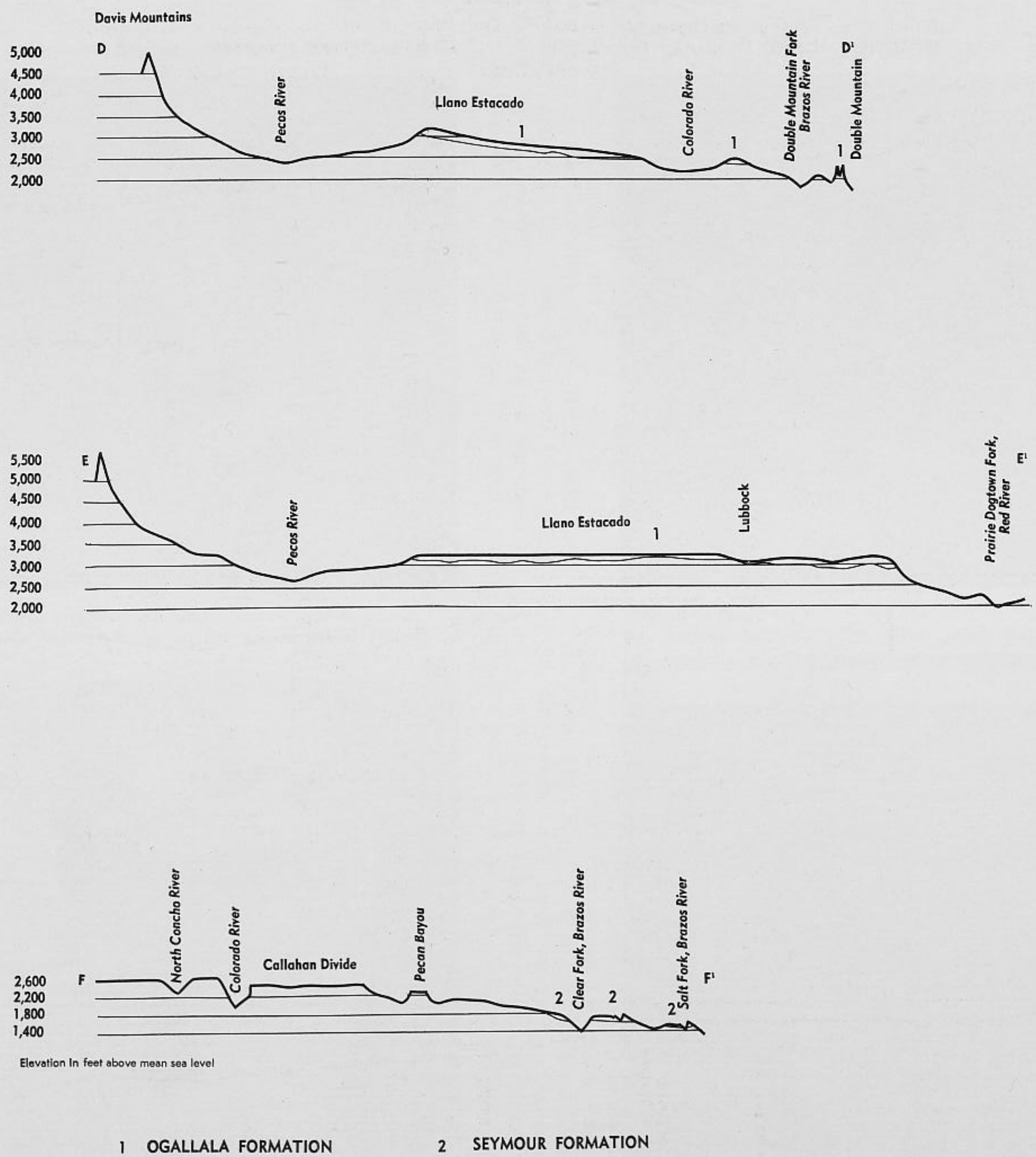
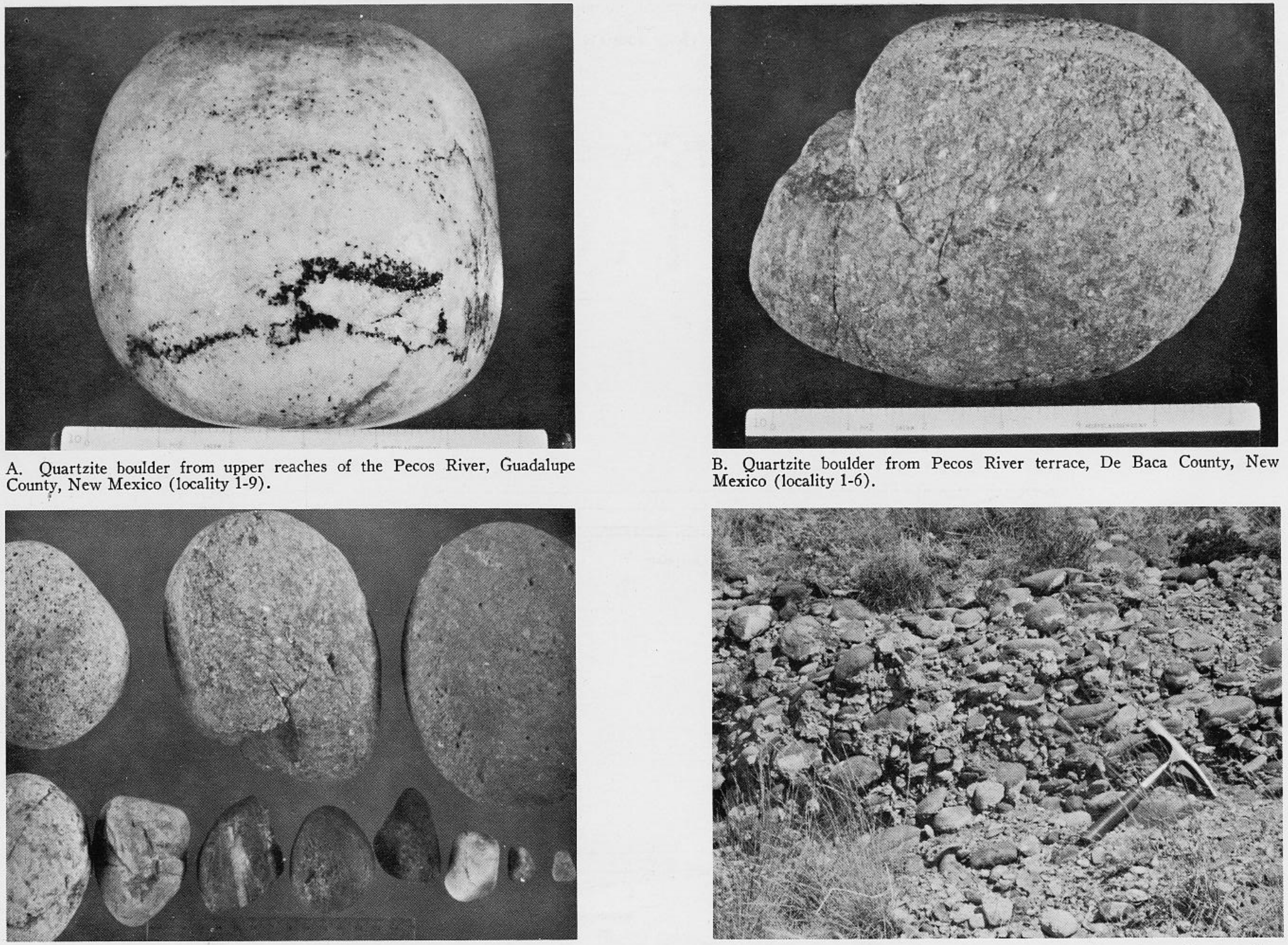


Fig. 15. Generalized schematic topographic profiles of a part of west Texas. Based on a 200-foot contour interval, 1:500,000-scale maps issued by the U. S. Geological Survey.



A. Quartzite boulder from upper reaches of the Pecos River, Guadalupe County, New Mexico (locality 1-9).

B. Quartzite boulder from Pecos River terrace, De Baca County, New Mexico (locality 1-6).

C. Representative sizes of siliceous material from the Pecos River, New Mexico.

D. Gravel in place, Alamogordo Reservoir, De Baca County, New Mexico (locality 1-6).

Fig. 16. Size relations of Pecos River gravels.

Draw was one of the valleys through which Ogallala drainage breached the barrier ridge (fig. 29). The floor of Panther Draw slopes at the same rate as the Llano Estacado (fig. 14). Another probable breach through the ridge was the Colorado River valley (fig. 28), and a third, where the present Clear Fork of the Brazos River cuts through the "ridge" (Lewand, 1969, p. 21) at Fort Griffin (locality 3-1). Quartzitic boulders were observed at this locality 215 feet above the river (fig. 19). Rivers flowing through these valleys during Ogallala deposition apparently carried bed-load gravels to be deposited as Uvalde Gravel in lower lands to the east. The Uvalde Gravel on the highlands is not closely related to present drainage, since it constituted a product of deposition where drainage was just beginning. Terraces of the river valleys are closely related to present drainage since they represent successive steps in an erosional-depositional process which yet continues.

Thickening of the Uvalde deposits southward into Mexico is a result of larger through-flowing Ogallala drainageways. Leonard and Frye (1962, p. 10-12) note a change in slope of the Llano Estacado from east-southeast to south in Crane, Ector, Ward, and Winkler counties. An ancestral Pecos River had to exist in the late Tertiary to allow alluviation of this area.

The major destruction of the Llano Estacado in eastern New Mexico and southwest Texas probably extended throughout Pleistocene time to the end of the Kansan stage (Leonard and Frye, 1962, p. 10-12). By capturing the headwaters of the rivers which originally constructed the Llano Estacado, the Kansan "Pecos River" eventually carried all of the drainage from the Southern Rocky Mountains. In so doing, this through-flowing drainage removed sediments of the Ogallala Formation from an area approximately 510 miles wide by 300 miles long (fig. 28). All of this sediment was either delivered to the Gulf of Mexico, or deposited on the way. It is to this source that the southern Uvalde gravels are attributed. There is little evidence of Uvalde material having been derived from the thin Ogallala of the Edwards Plateau region, through which the present Pecos River flows. Just south of the Edwards Plateau where Upper Cretaceous rocks crop out in Val Verde County there are scattered remnants of alluvial deposits (Leonard and Frye, 1962, p. 11). This marks the terminus of incised early Pleistocene streams in the Lower Cretaceous limestones and the northern margin of deposition of Uvalde bedload material on Upper Cretaceous and lower Tertiary sediments.

POST DEPOSITIONAL MODIFICATION, UVALDE GRAVEL

Broad valleys formed by Neogene through-flowing drainage in Upper Cretaceous and lower Tertiary sediments were partially filled with coarse sediment from the Ogallala Formation. At the time of deposition, the Uvalde sediments occupied the bottoms of river valleys. These valley floors, armored against rapid erosion by thick accumulations of coarse gravel, were thus protected; while adjacent highlands, without the gravel cover, were more rapidly eroded away.

Thus, through time, the topography was "reversed." The original valley floors became the uplands and now the Uvalde gravels cap the divides east of the Balcones Escarpment (fig. 30). West of the Balcones Escarpment the gravels were never widely distributed, and the valleys have apparently remained in essentially the same position for as long as there has been eastward-flowing drainage from the Ogallala surface. Thus, Uvalde gravels west of the Balcones Escarpment are a rarity, for they were never widely distributed.

SUMMARY AND CONCLUSIONS

1. Gravel deposits described as Uvalde have been traced from Dallas County southwestward into northern Mexico. Throughout this region they occur as thin veneers mantling interstream divides on Upper Cretaceous and lower Tertiary rocks.

2. The Uvalde Gravel is composed of pebbles, cobbles and boulders of vein quartz, quartzite, chert, jasper, silicified wood and limestone.

3. There is no clearly defined horizon at which the Uvalde Gravel occurs. It may occur anywhere within an interval from 225 to 510 feet above the floodplains of present rivers.

4. Age determination of the Uvalde Gravel is strictly conjectural. Uvalde Gravel unconformably overlies strata from Early Cretaceous to late Tertiary age and is older than the Quaternary (Pleistocene) terraces formed by the present Brazos and Colorado rivers. Deposition occurred within an interval from earliest Ogallala (late Miocene) to early Pleistocene. Assuming deposition to be contemporaneous with the Ogallala Formation, the Uvalde Gravel is Neogene (Miocene-Pliocene).

5. Quartzitic pebbles and cobbles of the Uvalde Gravel were not derived from older formations in the area of Uvalde outcrop, for these are exclusively fine-grained dominantly marine rocks. Uvalde lithology also suggests a source other than the Llano Uplift.

6. The only readily available source for the large quartzitic material in the Uvalde Gravel is the Ogallala Formation of the Llano Estacado, or the common source of both Ogallala and Uvalde gravels, the Southern Rocky Mountains in New Mexico.

7. Suites of gravel comparable both in size, grade, and composition were traced from central Texas westward along the Brazos and Colorado rivers across the Osage Plains to the eastern edge of the Llano Estacado.

In New Mexico on the western edge of the Llano Estacado similar gravels were observed in higher terraces along the Pecos River.

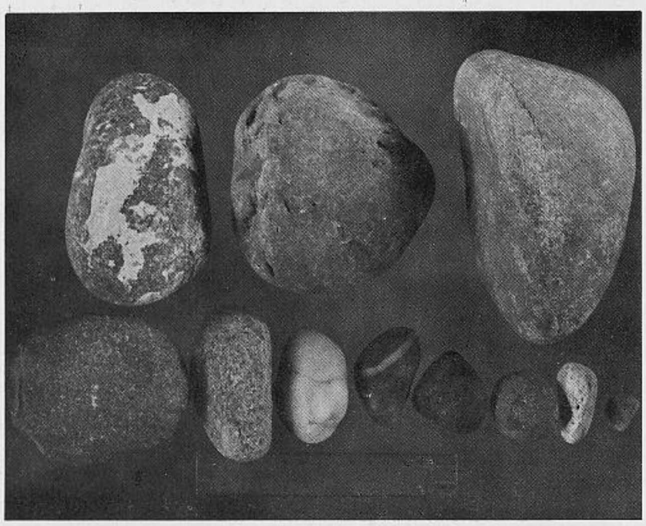
8. Gravels of Uvalde age were originally distributed from the edge of the Ogallala alluvial plain at the Callahan Divide, along the valleys transecting the divide and the canyon-forming Paleozoic and Lower Cretaceous rocks to the east, and then over a wide area where the valleys widened in the softer Upper Cretaceous and lower Tertiary rocks.

9. At the time of deposition, the Uvalde sediments occupied the bottoms of river valleys. The valley floors were thus armored against rapid erosion; while adjacent highlands, without the gravel cover, were more rapidly eroded resulting in a reversal of original topography.

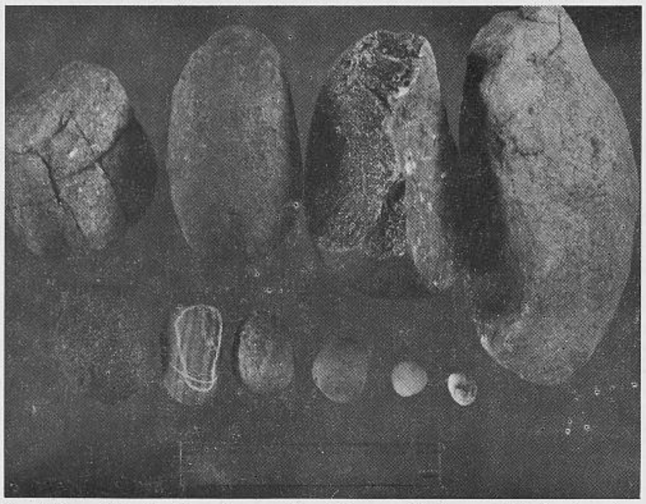
10. At the beginning of the Neogene Epoch, an erosional surface existed in western Texas and eastern New Mexico. Valley alluviation was initiated in the Southern Rocky Mountain area. The existing erosional topography was overlapped, the lower divides were buried and the region became a coalescent plain of alluviation.

11. From the margin of the alluvial plain, tongues of river-borne detritus extended along the routes of major watercourses. Where the rivers were entrenched in Paleozoic and Comanchean rocks, they transported quantities of bedload gravel. The less resistant Gulfian and Tertiary rocks allowed the valleys to widen and the streams were free to meander widely. Here the bedload gravels were left as floodplain accumulations of braiding sediment-choked streams.

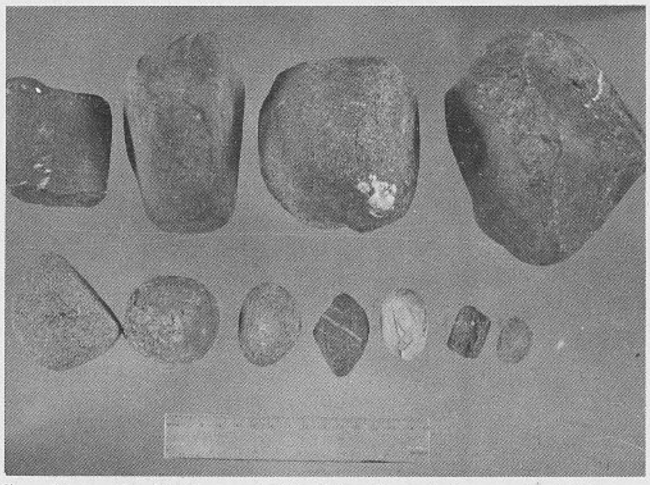
12. Therefore, all of the existing topography, from the eastern edge of the Llano Estacado to the Balcones Escarpment was developed in Pleistocene time.



A. Size distribution from the eastern edge of the Llano Estacado. Lithologies include tan, yellow, and purple quartzite; white and banded quartz; and jasper.

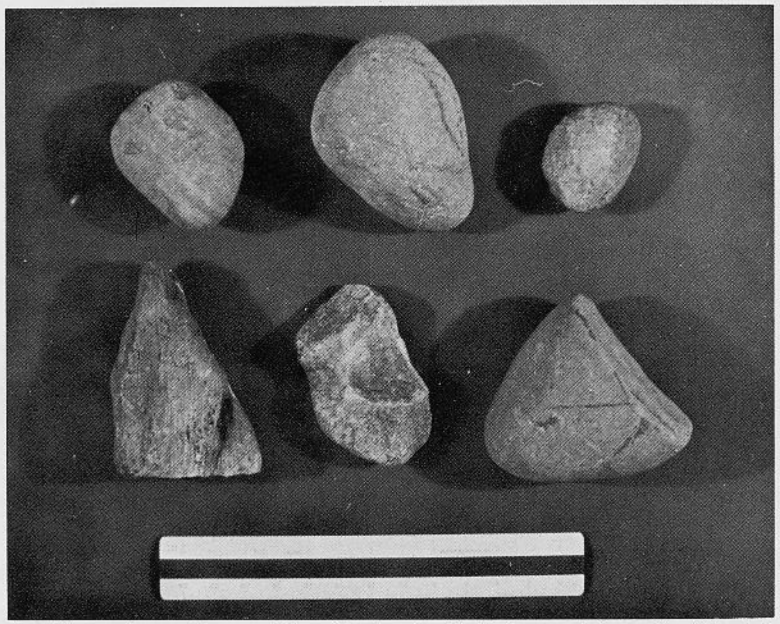


B. Size distribution from the Osage Plains. Lithologies include tan, grey, and purple quartzite; white and banded quartz.

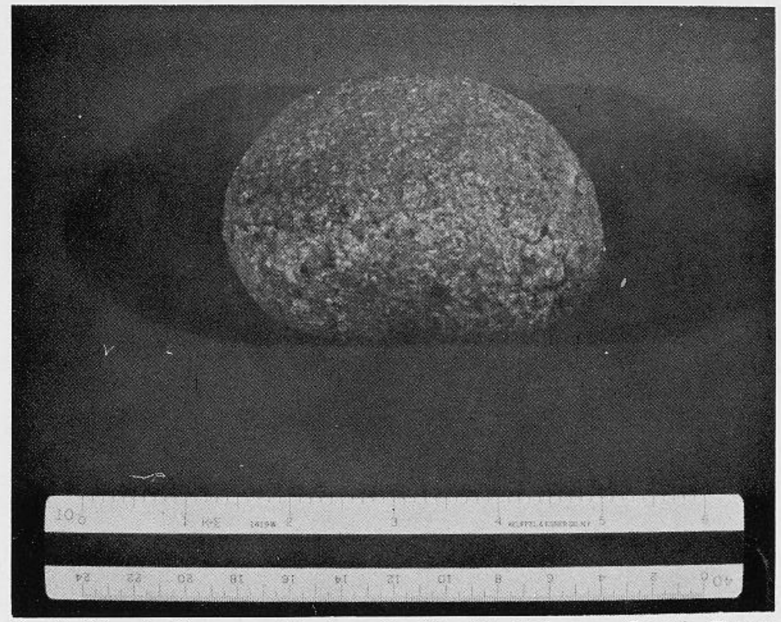


C. Size distribution of Uvalde Gravel in central Texas. Lithologies include tan, yellow, and purple quartzite; red banded quartz; white quartz; and silicified wood.

Fig. 17. Size comparisons of siliceous material from three separate areas.

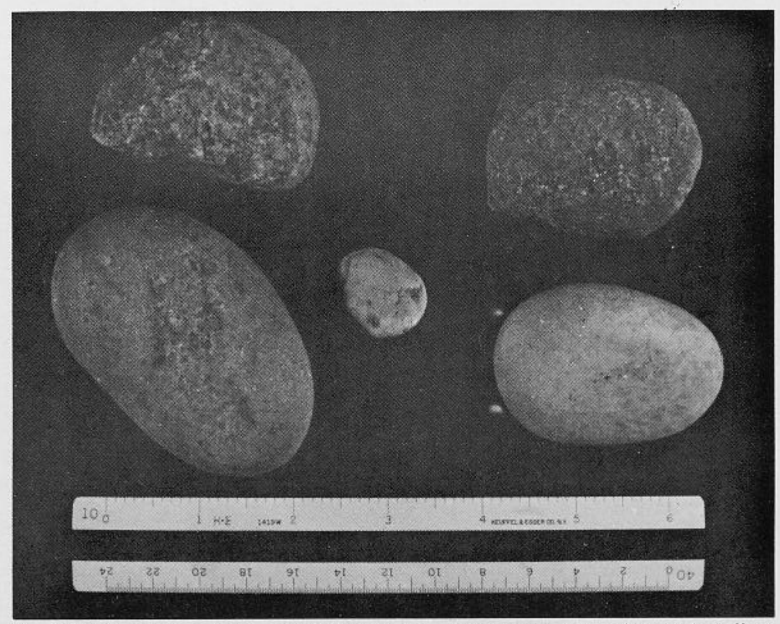


A. Tan and purple quartzite, chert and silicified wood from locality 4-7, Bosque County, Texas.



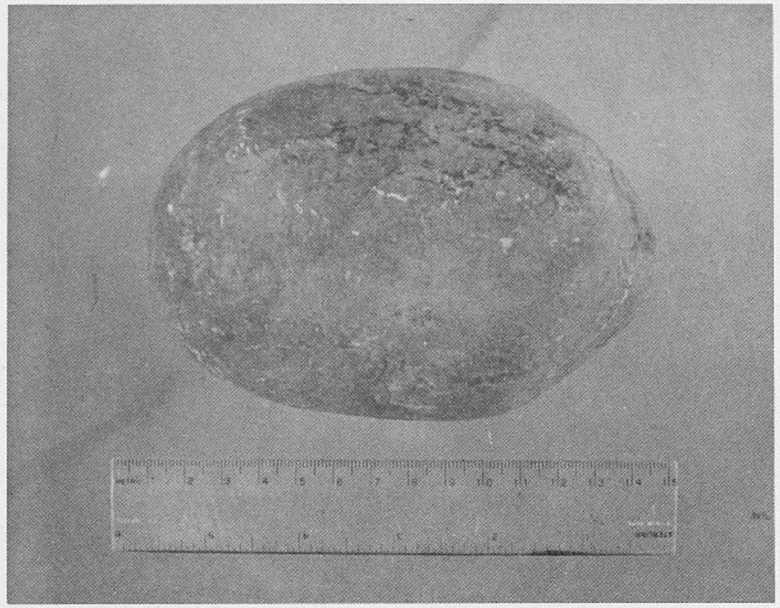
B. Cobble of yellow quartzite from locality 4-1, McLennan County, Texas.

C. Left, cobble of chert from localities 4-3, Falls County, Texas. Right, cobble of chert from locality 4-23, Limestone County, Texas.

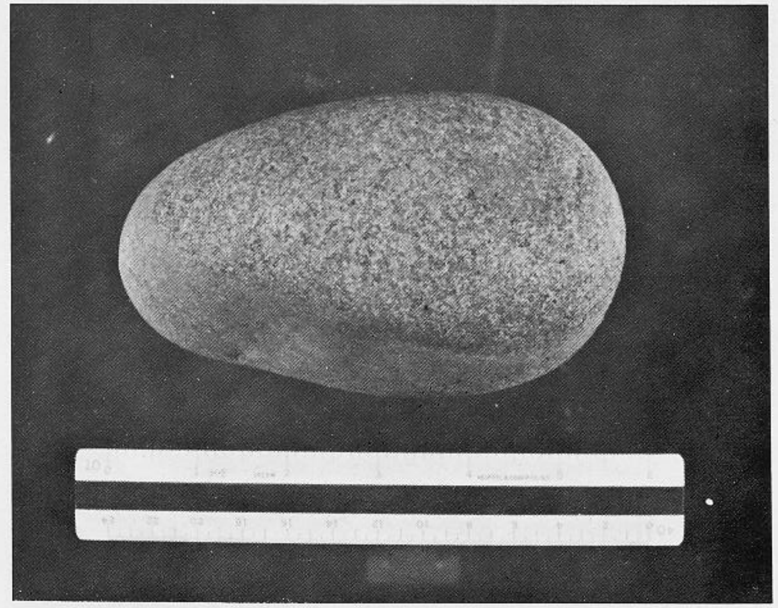


D. White, yellow, and purple quartzite, micaceous quartzite and yellow vein quartz from locality 4-8, Limestone County, Texas.

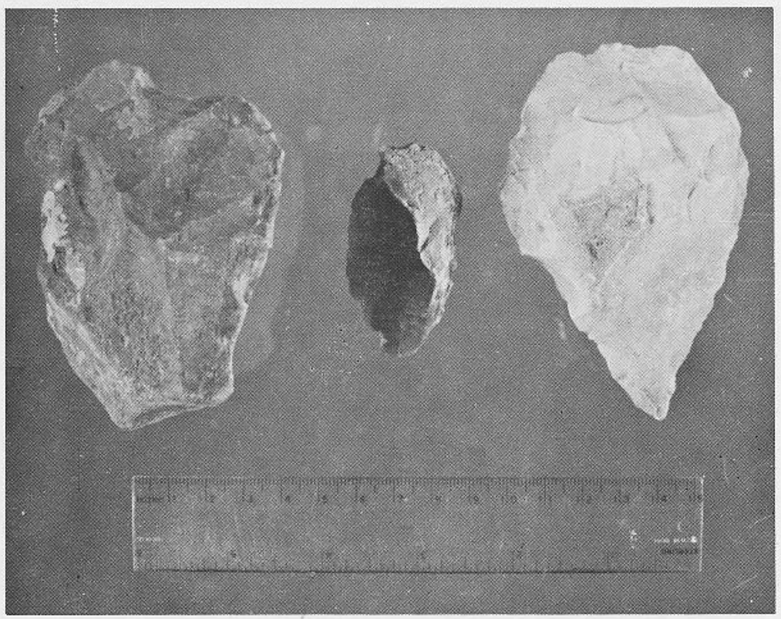
Fig. 18. Various lithologies of Uvalde Gravel.



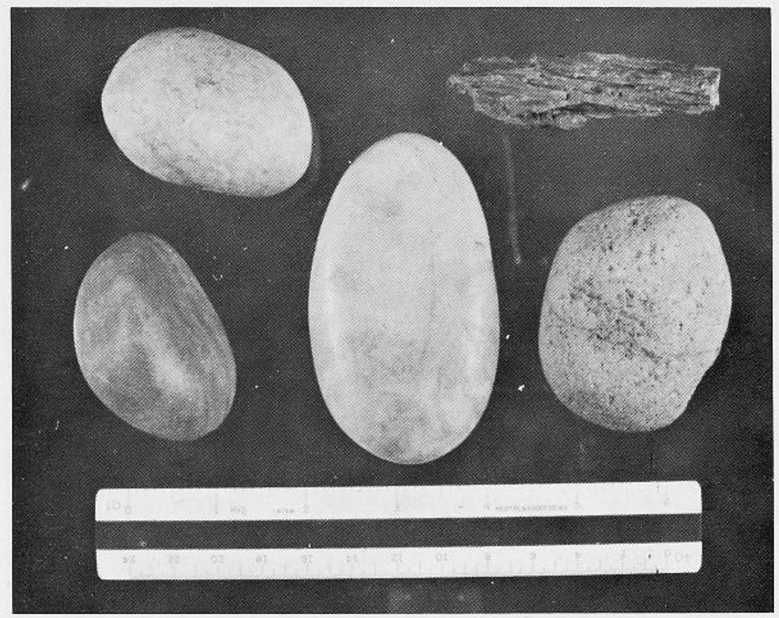
A. Tan quartzite boulder from Ft. Griffin, Shackelford County, Texas (locality 3-1).



B. Yellow quartzite boulder from Garza County, Texas (locality 2-8).

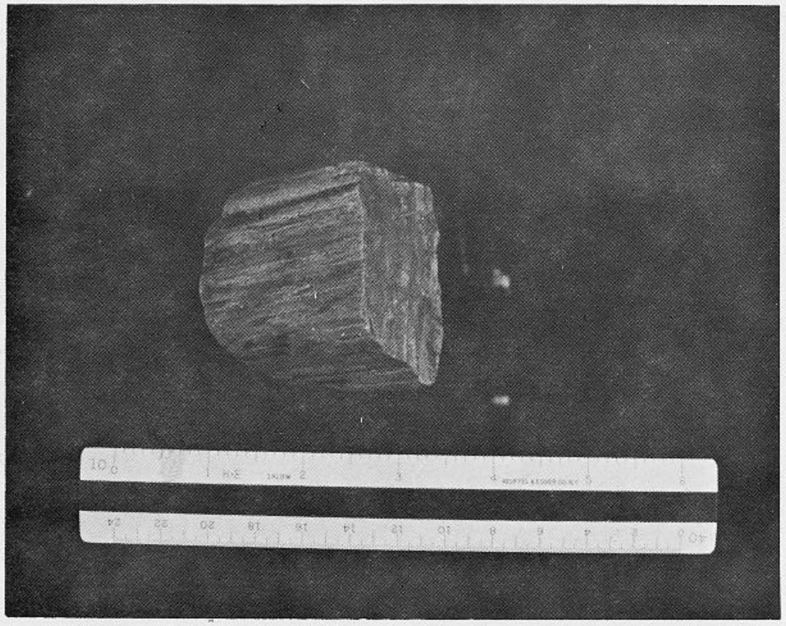


C. Examples of chert (localities 3-7, Jones County, Texas; 1-6, De Baca County, New Mexico; 3-8, Scurry County, Texas).

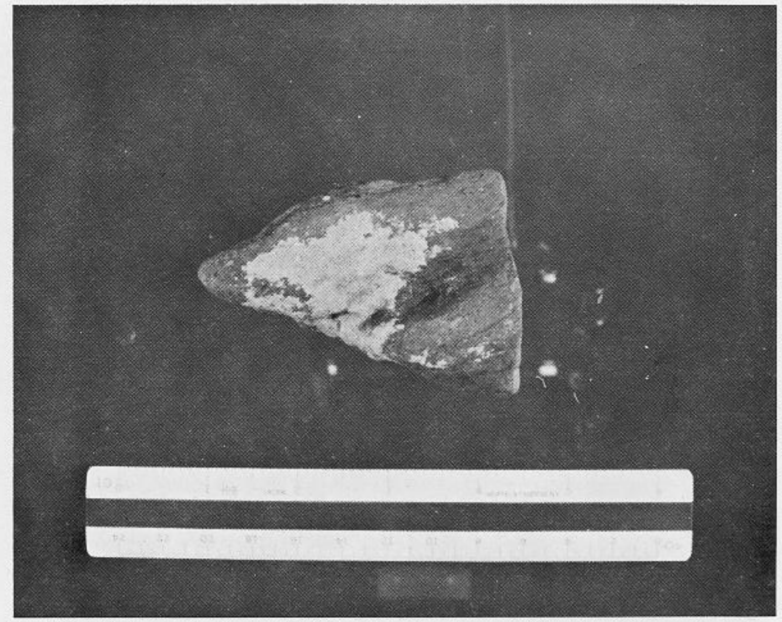


D. Cobbles of quartz and quartzite Cottle County, Texas (locality 3-5).

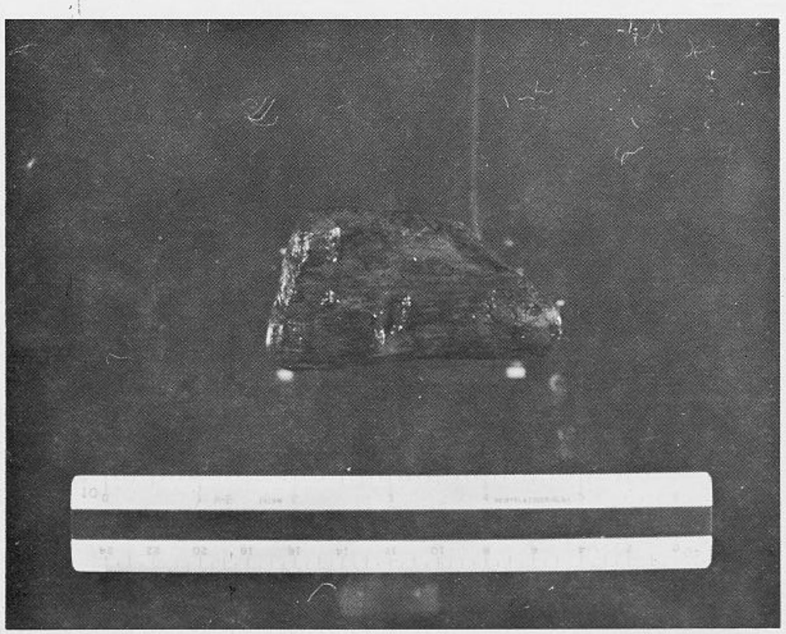
Fig. 19. Quartzite and chert from areas other than central Texas, showing similarities to lithologies of Uvalde Gravel.



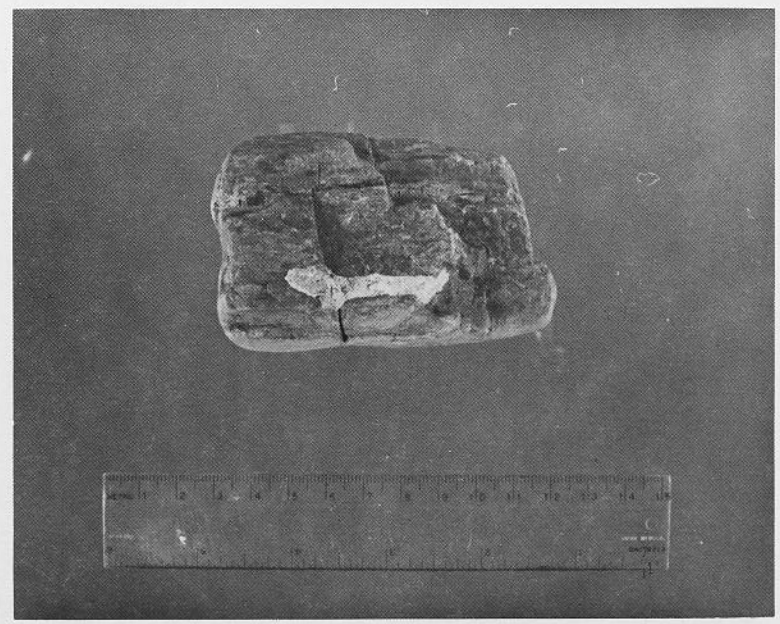
A. Silicified wood from Uvalde Gravel, Falls County, Texas (Locality 4-3).



B. Silicified wood from Uvalde Gravel, Bosque County, Texas (locality 4-7).

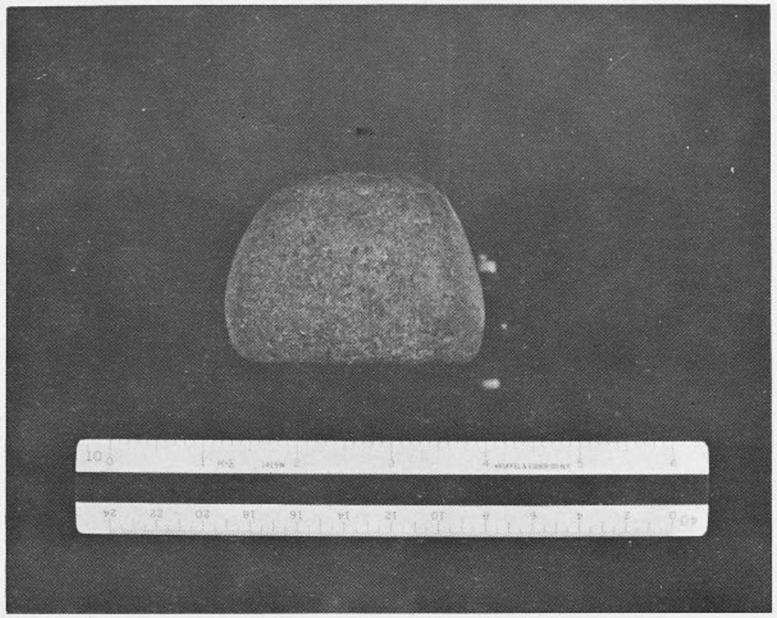


C. Silicified wood from eastern edge of Llano Estacado, Garza County, Texas (locality 2-7).

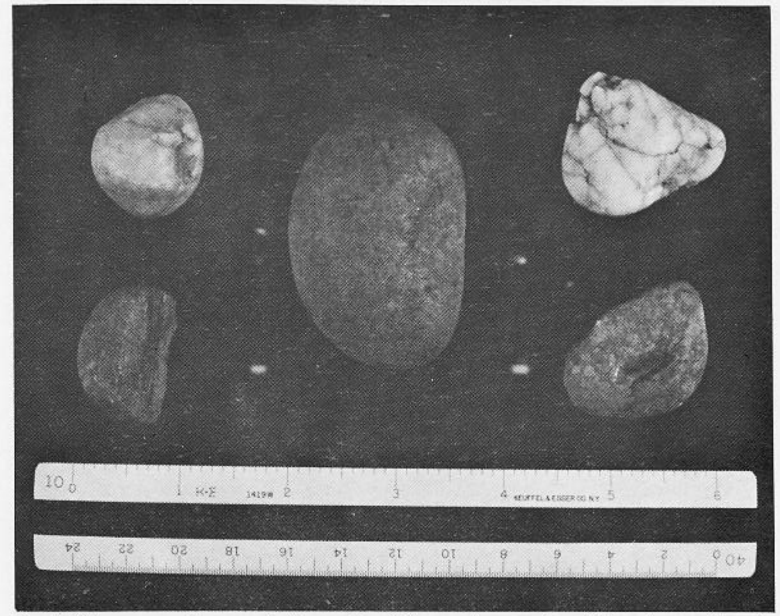


D. Silicified wood from Pecos River, De Baca County, New Mexico (locality 1-6).

Fig. 20. Comparison of silicified wood from Uvalde Gravel, central Texas; Ogallala Formation, Llano Estacado; and terraces, Pecos River.



A. Purple quartzite, Falls County, Texas (locality 4-3).

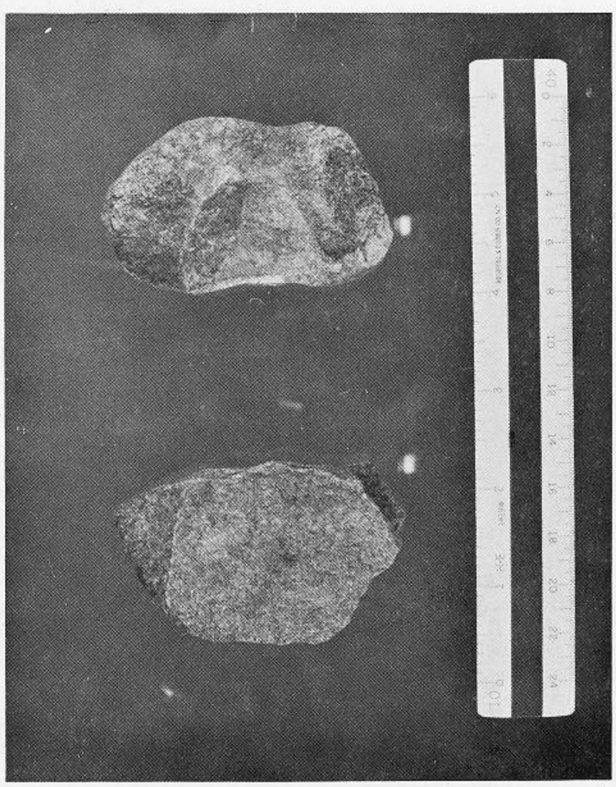


B. Yellow, purple quartzite and white vein quartz, Limestone County, Texas (locality 4-8).

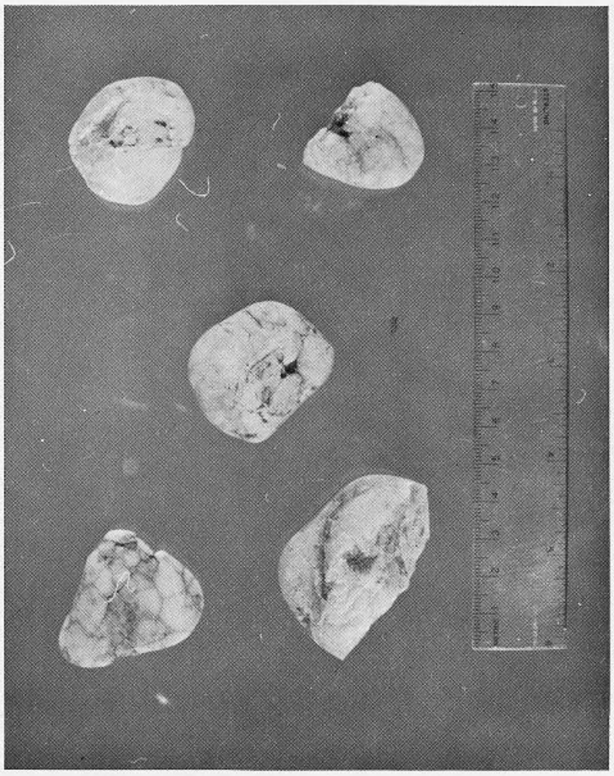
C. Jasper, banded quartz, silicified wood and plutonic cobble, Bosque County, Texas (locality 4-7).

D. Yellow quartzite and vein quartz, Falls County, Texas (locality 4-3).

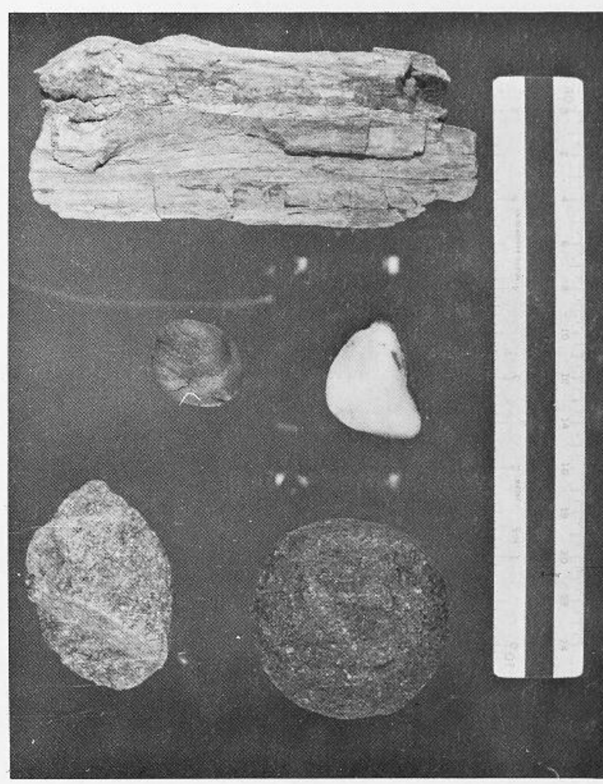
Fig. 21. Varieties of quartz and quartzite found within the Uvalde Gravel.



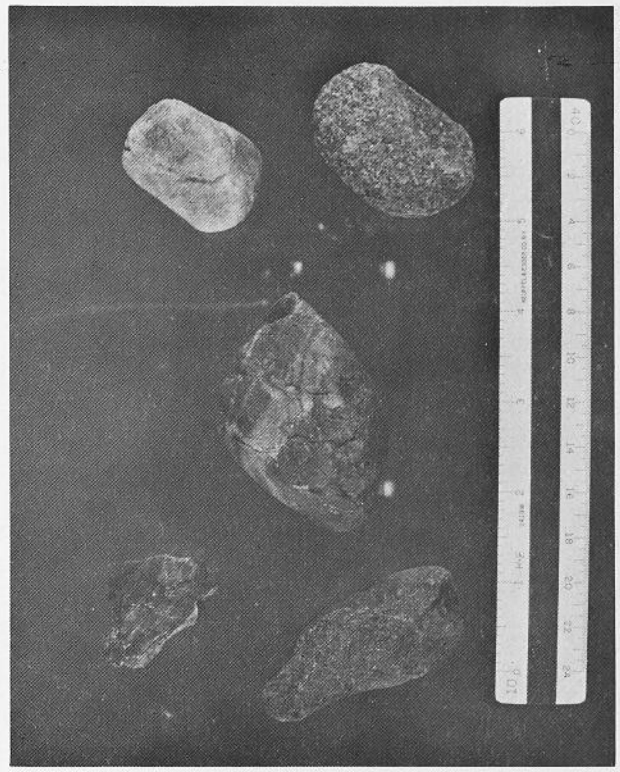
A. Purple quartzite from Garza and Bosque counties, Texas localities 2-9 and 4-7.



B. Vein quartz from localities 3-1, Shackelford County, Texas; 2-10, Garza County, Texas; 4-3, Falls County, Texas; 1-8, Guadalupe County, Texas; 4-8, Limestone County, Texas.

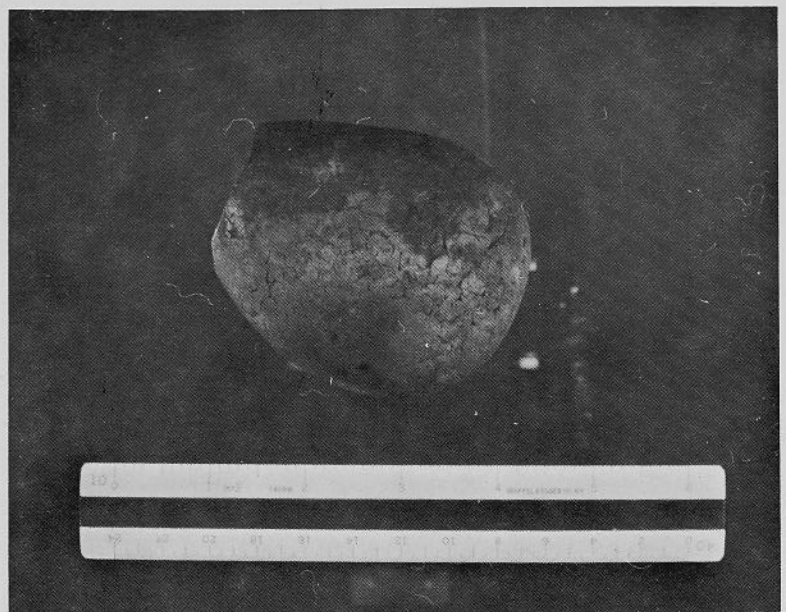


C. Siliceous material from Jones County, Texas locality 3-10 includes silicified wood, vein and banded quartz, and purple and tan quartzite.



D. Siliceous material from Chavez County, New Mexico locality 1-4 includes yellow and purple quartzite, white and banded quartz, and jasper.

Fig. 22. Comparison of siliceous gravel.



A. Uvalde purple quartzite cobble exhibiting chatter marks, Bosque County, Texas (locality 4-5).

B. Quartzite boulders exhibiting chatter marks, Jones County, Texas (locality 3-10).

C. Quartzite cobbles encrusted with calcium carbonate, Motley County, Texas (locality 2-2).

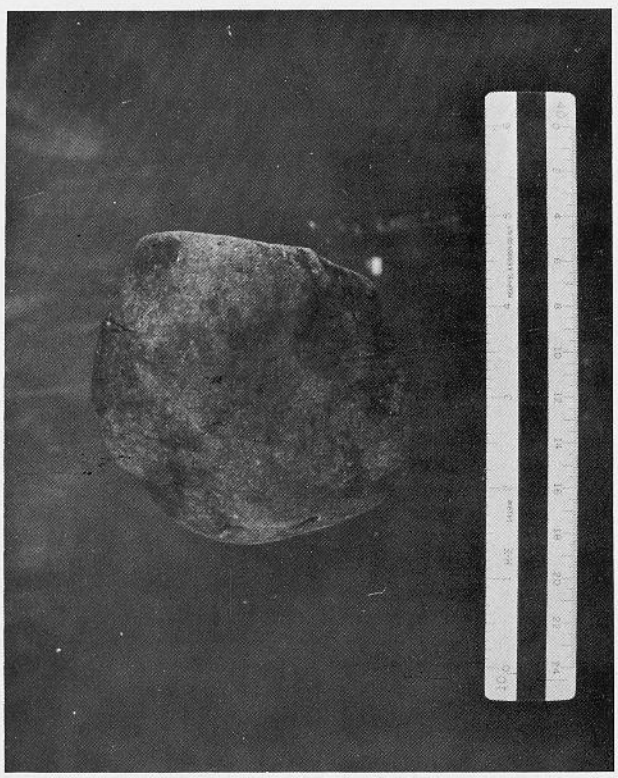
Fig. 23. Chatter marks and calcium carbonate encrustations of gravels from suites of Uvalde Gravel and Brazos River terraces.

A. Size range of gravel suite found on the Callahan Divide, Nolan and Taylor Counties, Texas (locality 3-9).

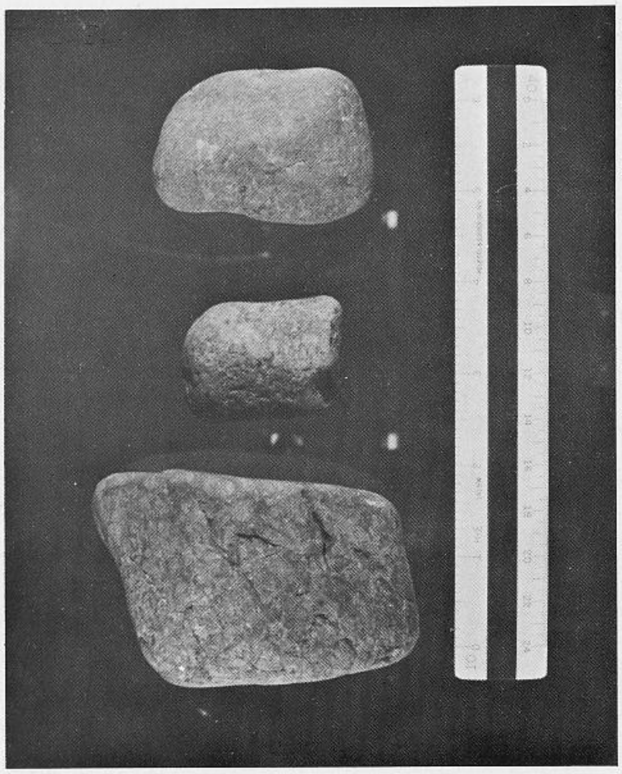
B. Representative samples of white, yellow, pink and grey vein quartz; yellow quartzite; chert; and opalline fragment, Nolan and Taylor Counties, Texas (locality 3-9).

C. Size range of gravel suite found on top of Double Mountain, Stonewall County, Texas (locality 3-13).

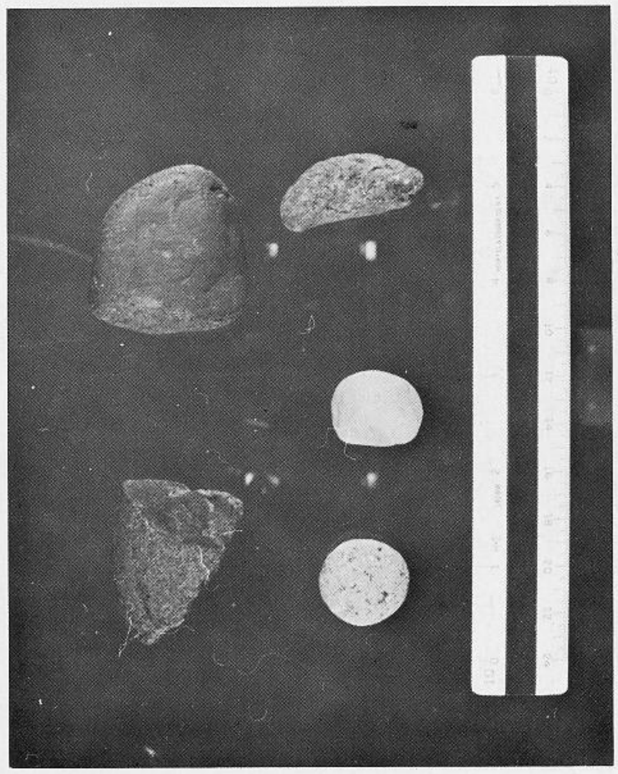
Fig. 24. Gravel suite found on the Callahan Divide (locality 3-9) and Double Mountain (locality 3-13).



A. Boulder of granite from Sangre de Cristo Mountains, De Baca County, New Mexico (locality 1-5).

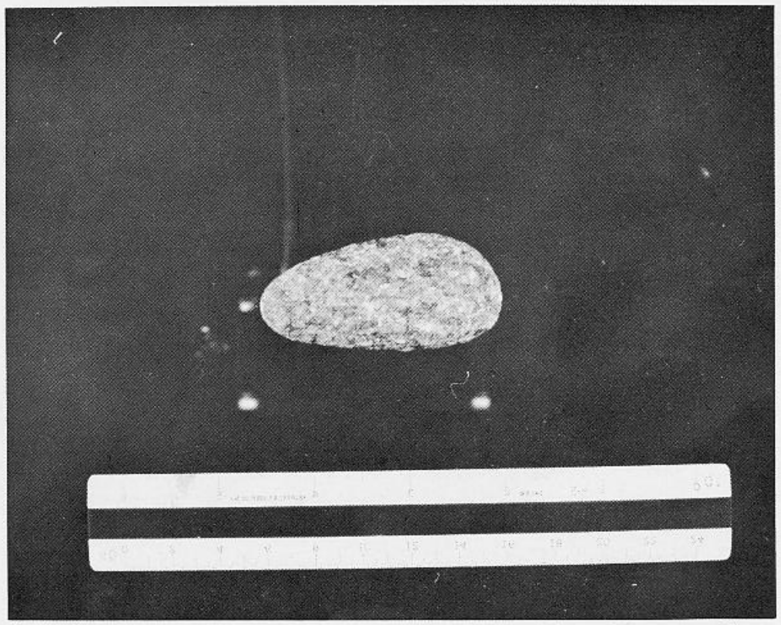


B. Boulder and cobbles of granite from Sangre de Cristo Mountains (localities 2-10, Garza County, Texas; 1-9, Guadalupe County, New Mexico; 1-10, San Migel County, New Mexico.



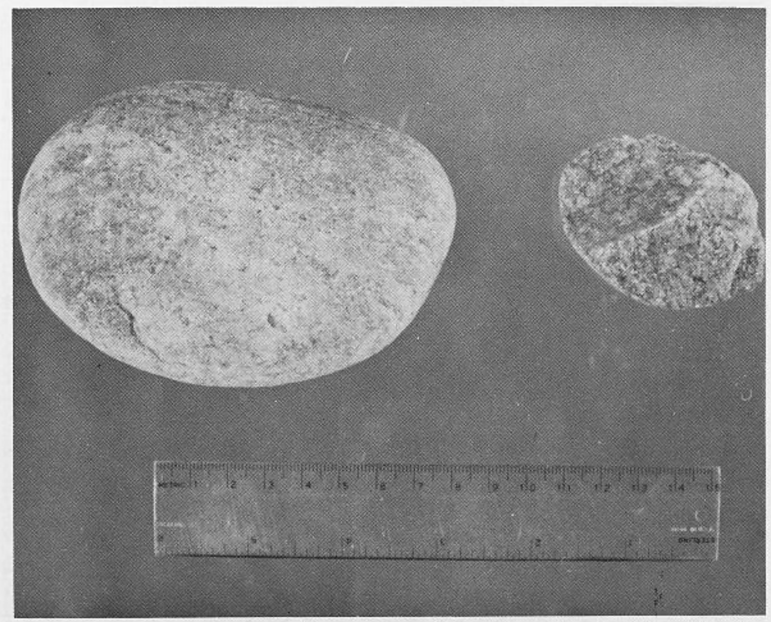
C. Granite, vein quartz, micaceous quartzite, jasper, and purple quartzite, Garza County, Texas (locality 2-10).

Fig. 25. Examples of granite from the Sangre de Cristo Mountains found on the east and west sides of the Llano Estacado.



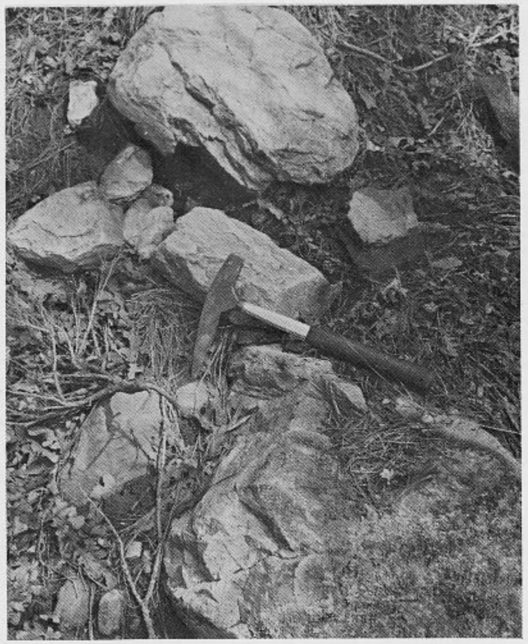
A. Micaceous quartzite from eastern edge of the Llano Estacado, Garza County, Texas (locality 2-9).

B. Close up of A showing reflective surfaces of mica flakes.

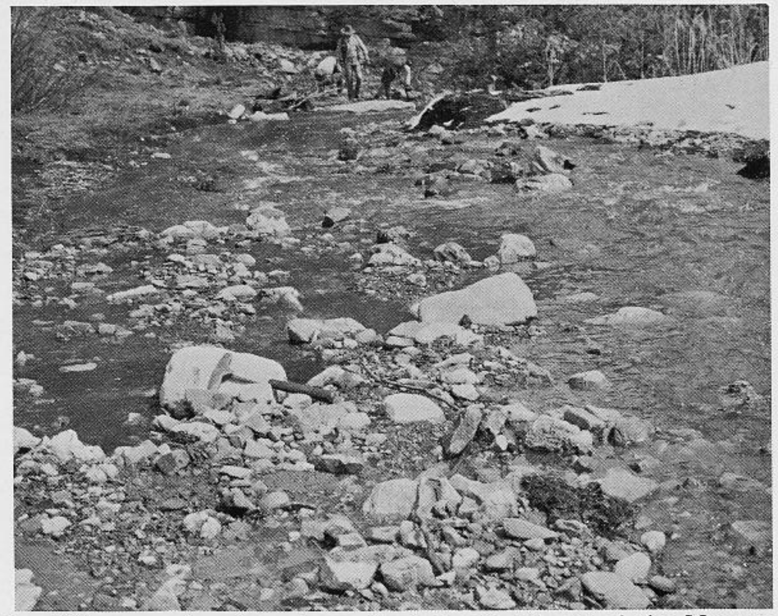


C. Micaceous quartzite from Pecos River, Guadalupe County, New Mexico (locality 1-9) and Osage Plain, Jones County, Texas (locality 3-10).

Fig. 26. Examples of micaceous quartzite found on the east and west sides of the Llano Estacado.



A. Vein quartz at locality 1-12.



B. Siliceous rocks along stream flowing eastward out of the Manzano Mountains in Trigo Canyon, one mile west of Manzano, Torrance County, New Mexico.

C. View of the Manzano Mountains from the east.

Fig. 27. Manzano Mountains of Torrance County eastern New Mexico (locality 1-12).

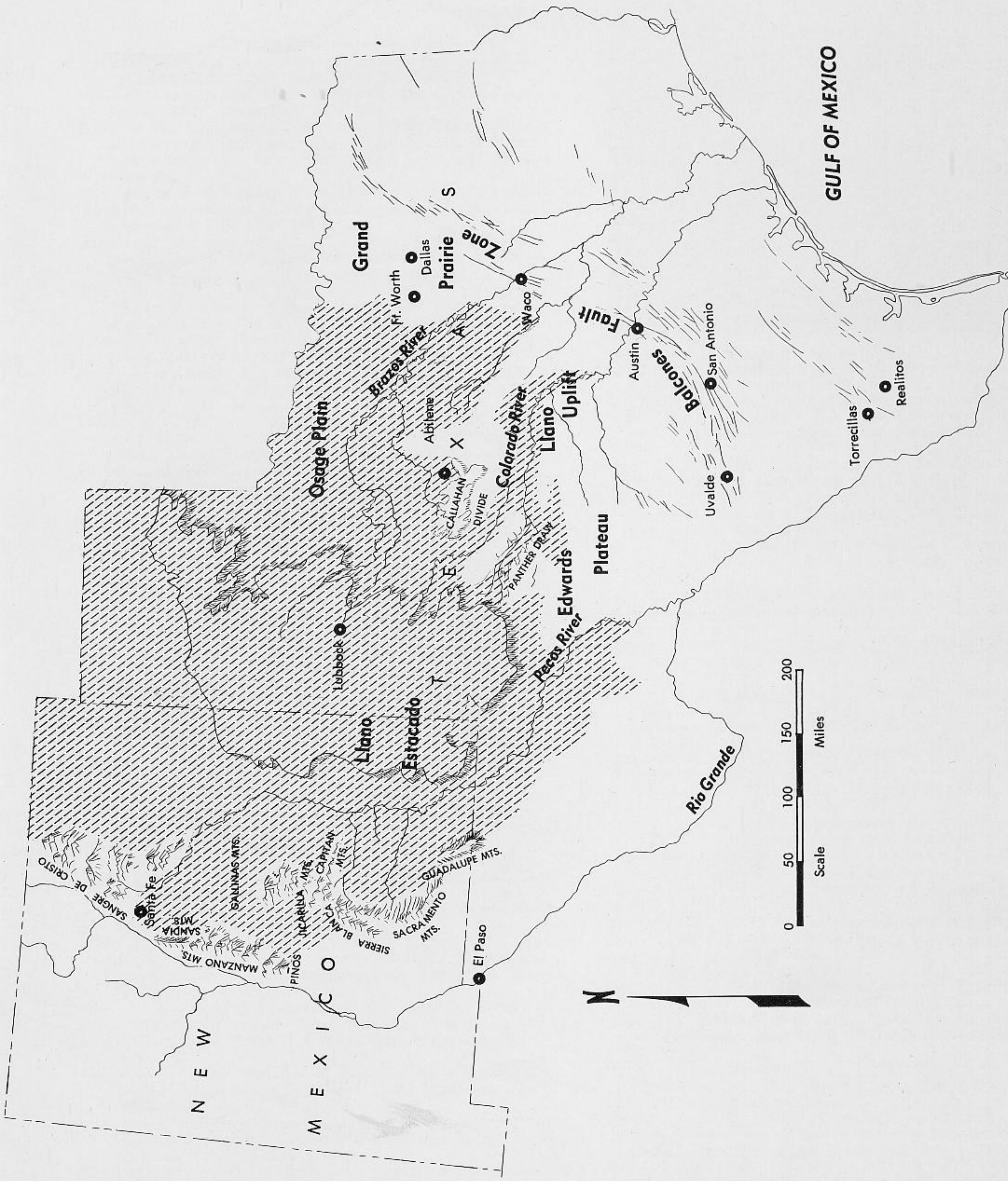
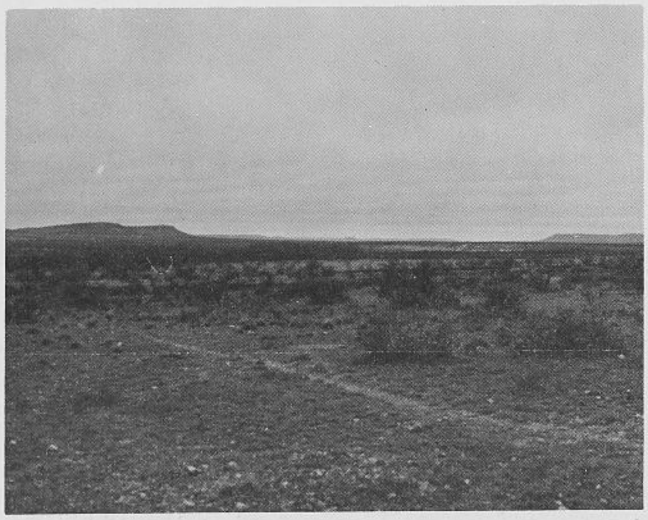
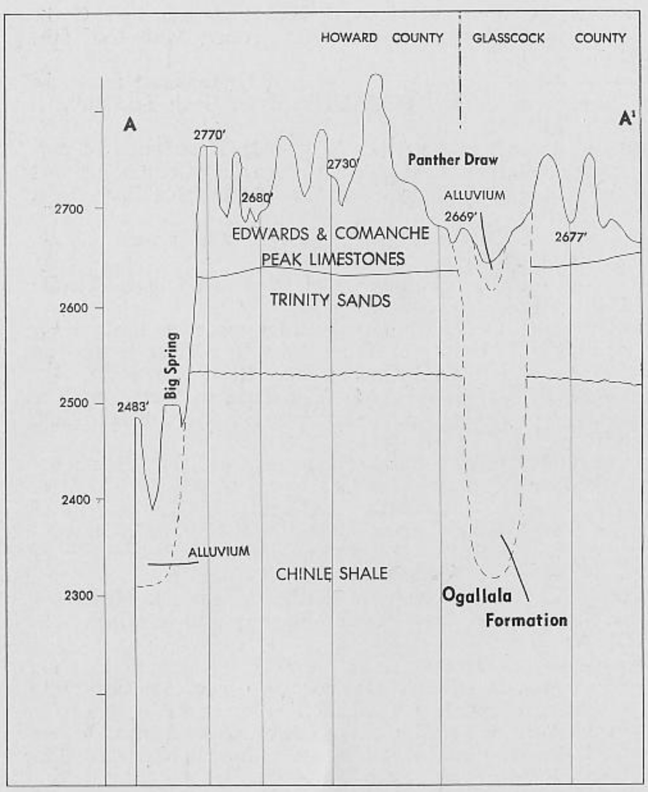


Fig. 28. Map of Texas and New Mexico showing postulated original extent of the Ogallala Formation.



A. Surface of Ogallala Formation in Panther Draw between Cretaceous outliers (looking south). Glasscock County, Texas.



B. Diagrammatic cross section of Panther Draw (Texas Water Development Board).

Fig. 29. Views of Panther Draw.

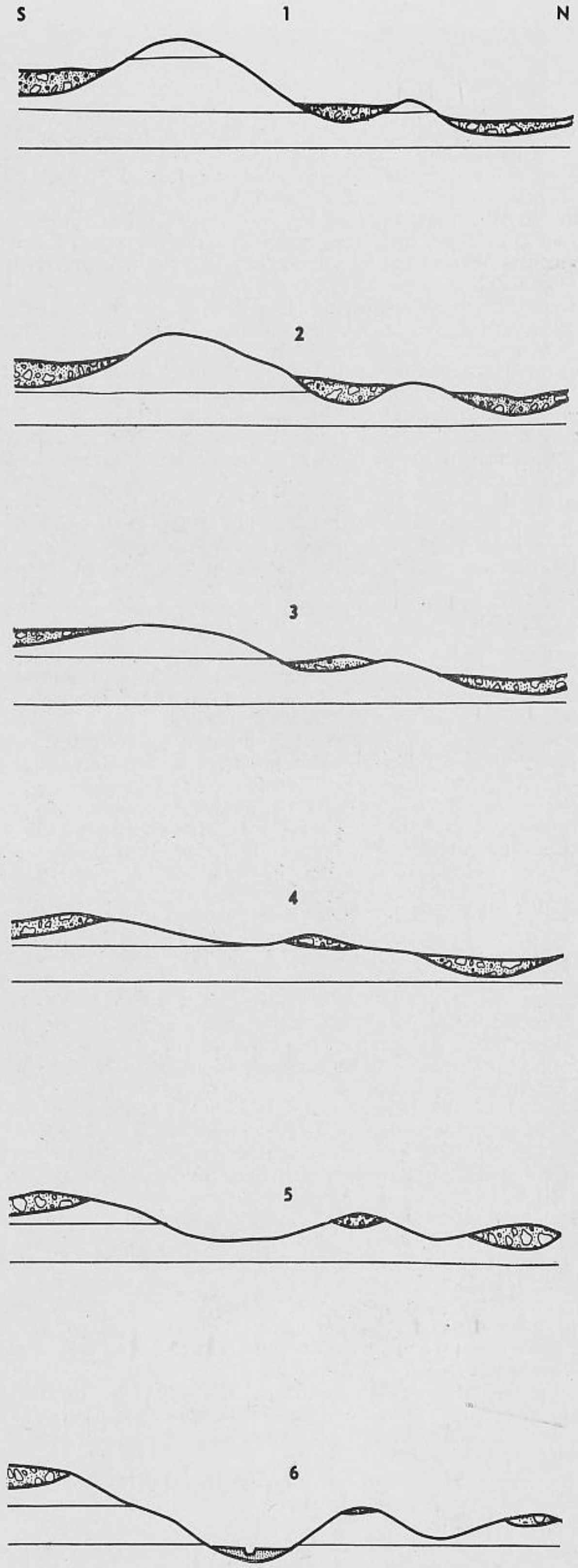


Fig. 30. Generalized diagrammatic cross sections showing evolution of the Uvalde surface in Pliocene and Pleistocene time.

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APPENDIX

SAMPLED LOCALITIES

LOCALITY

1-1 Reeves County, Texas.

1.0 mile southeast of Arno, Texas on Panhandle and Santa Fe Railroad tracks (31° 38' N; 103° 37' W).

Cobble-size limestone and chert, purple quartzite pebbles 1-2 inches in diameter, milky quartz and some vein quartz, angular to sub-rounded. Limestone is angular to sub-rounded.

1-2 Eddy County, New Mexico.

2.0 miles north of Texas-New Mexico border where U. S. Highway 285 crosses Delaware River (32° 01' 30" N; 104° 03' W).

Abundant pea-size limestone gravel, limestone cobbles up to 4 inches in diameter, flat and angular to well rounded. Some anhydrite, gypsum and sandstone present.

1-3 Eddy County, New Mexico.

1.0 mile southeast of the Carlsbad, New Mexico city limits on the west side of the Pecos River (32° 24' N; 104° 12' 30" W).

Limestone pebbles, cobbles and boulders to 7 inches in diameter, sub-rounded to well rounded. Limestone conglomerate from 1 to 4 inches in diameter. Occasional quartzite pebbles.

1-4 Chavez County, New Mexico.

A gravel pit 15.0 miles northeast of Roswell, New Mexico where the Pecos River intersects U. S. Highway 70 and the Atchison Topeka and Santa Fe Railroad (33° 34' N; 104° 22' W).

Abundant siliceous pea gravel. Vein quartz, purple quartzites, yellow quartzites most common, occurring in angular to sub-rounded condition. Chert and calcedony also present. Numerous limestone cobbles from angular to well rounded.

1-5 De Baca County, New Mexico.

A recent terrace deposit of the Pecos River 2.0 miles south of the eastern city limits of Ft. Sumner, New Mexico (34° 26' N; 104° 14' W).

Yellow quartzite boulders predominate, with some milky quartz, dark gray quartzite and chert. Numerous igneous cobbles (Sangre de Cristo granite) and some limestone.

1-6 De Baca County, New Mexico.

0.5 miles south of dam on Alamogordo Reservoir on the Pecos River, 6 miles west of the junction of U. S. Highway 84 and State Highway 203. Approximately 3.0 miles northwest of Fort Sumner, New Mexico (34° 36' N; 104° 24' W).

Yellow quartzite boulders are abundant and chert cobbles are numerous. Numerous pieces of black flint and some silicified wood and purple quartzite.

1-7 Guadalupe County, New Mexico.

10.0 miles southeast of Santa Rosa, New Mexico on the west side of State Highway 91 (34° 50' N; 104° 37' W).

Yellow quartzites are the most abundant. Igneous material becoming more abundant. One large boulder of banded quartzite was collected. All specimens encrusted with a calcium carbonate deposit.

1-8 Guadalupe County, New Mexico.

0.5 miles northwest of Santa Rosa, New Mexico western city limits on north side of U. S. Highway 66 (34° 57' N; 104° 42' W).

All sizes are here represented by a dominance of yellow quartzite. The remainder of the sample is composed of Sangre de Cristo granite cobbles. One piece of ore slag is present.

1-9 Guadalupe County, New Mexico.

Terrace deposit 1.7 miles southeast of Dilia, New Mexico where U. S. Highway 84 crosses the Pecos River (35° 11' N; 105° 02' 30" W).

Most outstanding in this sample is a boulder 6" in diameter of white quartzite with bands of tourmaline crystals. Various sizes of Sangre de Cristo granite are in the majority. The white and yellow quartzite cobbles and pebbles are round to sub-angular.

1-10 San Miguel County, New Mexico.

Under old U. S. Highway 85 bridge 0.2 miles north of San Jose, New Mexico (35° 23' N; 105° 28' W).

This sample is almost entirely granite rocks. There are a few yellow quartzite cobbles.

1-11 San Miguel County, New Mexico.

1.0 mile north of Pecos, New Mexico on the east side of State Highway 63 (35° 34' N; 105° 40' W).

Only three quartzite specimens were collected here, the remainder of the sample consists of various igneous rocks mostly Sangre de Cristo granite.

1-12 Torrance County, New Mexico.

Manzano Mountains, 4.0 miles west of Manzano, New Mexico (34° 40' N; 106° 25' W).

2-1 Briscoe County, Texas.

4.0 miles northwest of Quitaque, Texas on the south side of State Highway 86 (43° 22' N; 101° 07' W).

An abundance of yellow quartzite pebbles from 1 inch to 3 inches in diameter. Some 2 to 3 inch variegated quartzite cobbles were collected. A small amount of granite present.

2-2 Motley County, Texas.

North bank of Quitaque Creek 4.3 miles north of Flomot, Texas on the west side of Farm Road 599 (34° 17' N; 100° 59' W).

Yellow, pink and variegated quartzites from 1 to 6 inches diameter and several samples of milky quartz from 0.5 to 1.5 inches in diameter were present. Also present were well worn fossils and some silicified wood. All of the specimens were encrusted with a calcareous deposit.

2-3 Motley County, Texas.

13.0 miles south of Turkey, Texas where State Highway 70 intersects the North Pease River (34° 11' N; 100° 53' W).

This locality was dominated by yellow quartzite boulders from 2 to 7 inches in diameter. Some banded quartz, gray quartzite and igneous rock were present.

2-4 Motley County, Texas.

4.5 miles northwest of Matador, Texas where State Highway 70 intersects the Middle Pease River (34° 05' N; 100° 52' W).

All of the gravels have a calcareous encrustation. There was an abundance of yellow and coarse-grained quartzite. Present in lesser amounts were micaceous quartzite, banded quartz, vein quartz and silicified wood.

2-5 Motley County, Texas.

2.5 miles south of Roaring Springs, Texas on the west side of State Highway 70, just north of the South Pease River (33° 52' N; 100° 51' W).

Calcareous encrustations were present on a majority of the gravels. Coarse- and fine-grained yellow quartzite were abundant. Some vein quartz and micaceous quartzite was observed. Black quartz and jasper were present in small quantities.

2-6 Dickens County, Texas.

1.7 miles north of Dickens, Texas on the west side of State Highway 70 where it crosses J2 Creek (33° 39' N; 100° 51' W).

The gravel suite at this locality was composed of the same materials as found at locality 2-5 with the addition of silicified wood and badly weathered Cretaceous Gryphaea.

2-7 Garza County, Texas.

8.0 miles southwest of Kalgary, Texas where Farm Road 651 intersects McDonald Creek (33° 21' N; 101° 13' W).

The larger gravels are mainly coarse- and fine-grained yellow quartzite with milky quartz and purple quartzite less abundant. Present in smaller size range and fewer individuals are red quartzite, black quartz, red and yellow silicified wood, micaceous quartzite and jasper.

2-8 Garza County, Texas.

12.8 miles northeast of Post, Texas where Farm Road 651 intersects the Salt Fork of the Brazos River (33° 18' 30" N; 101° 15' W).

Coarse- and fine-grained purple and yellow quartzite are abundant in large specimens. Milky and banded quartz are present and one agate pebble was observed.

2-9 Garza County, Texas.

4.6 miles northeast of Post, Texas where Farm Road 651 intersects the North Fork of the Double Mountain Fork of the Brazos River (33° 16' N; 101° 20' W).

A Brazos River terrace consisting mainly of large coarse- to fine-grained red, yellow and purple quartzite. Also present are a few pieces of micaceous yellow quartzite, silicified wood, badly weathered Cretaceous fossils, and banded black quartz. One sample of granite from the Sangre de Cristo Mountains is present.

2-10 Garza County, Texas.

12.5 miles south of Post, Texas where Farm Road 669 crosses the Double Mountain Fork of the Brazos River (33° 01' N; 101° 25' W).

A Brazos River terrace consisting mainly of large coarse- to fine-grained red, purple and yellow quartzite. Smaller pieces of micaceous yellow quartzite, pink quartzite, chert, jasper and silicified wood are less abundant. Some banded black quartz, badly weathered Cretaceous fossils and granite from the Sangre de Cristo Mountains are present.

2-11 Borden County, Texas.

11.6 miles south of Gail, Texas on Farm Road 669, 0.5 miles north of the Colorado River (32° 38' N; 101° 28' W).

The majority of the gravel suite consists of coarse- to fine-grained boulders and cobbles of red, yellow and purple quartzite. Present in lesser amounts are pieces of silicified wood, micaceous yellow quartzite and banded black quartz.

2-12 Crosby County, Texas.

A terrace deposit in a road cut 5.5 miles east of Crosbyton, Texas where the White River intersects U. S. Highway 82, on the east wall of Blanco Canyon (32° 12' N; 101° 8' W).

A majority of boulders and cobbles of fine- to coarse-grained yellow, grey and white quartzite. Abundant in the smaller size ranges is milky quartz, pink quartz, chert and micaceous quartzite.

3-1 Shackelford County, Texas.

The ruins of old Fort Griffin on a hill 215 feet above the Clear Fork of the Brazos River, west of U. S. Highway 283 (32° 55' N; 99° 14' W).

Boulders of tan, yellow and purple quartzite comprise the large fraction. Banded quartz, vein quartz and chert are present as pebble-sized fragments. Some silicified wood occurs at this locality.

3-2 Throckmorton County, Texas.

A thick gravel cover caps the hill north of U. S. Highway 183, 6.5 miles northwest of Woodson, Texas and 2.5 miles southeast of the junction of U. S. Highways 183 and 283 (33° 5' N; 99° 9' W).

Large pieces of yellow, grey, purple and pink quartzite are abundant. Some pebbles of chert and basal Cretaceous conglomerate are present. Badly worn Cretaceous fossils and fragments of silicified wood are also present.

3-3 Throckmorton County, Texas.

Lag gravels on a hill 410 feet above the Clear Fork of the Brazos River, 3 miles south of State Highway 24, and 11 miles west southwest of Throckmorton, Texas (33° 9' N; 99° 22' W).

Yellow, white and purple quartzite from 2 to 3 inches in diameter are scattered over the hillside. Vein quartz is present in a smaller size range in colors of yellow, pink and white. All particles appear highly weathered.

3-5 Cottle County, Texas.

Gravels lying in a plowed field 11 miles northeast of Paducah, Texas on the north side of U. S. Highway 70 (34° 5' N; 100° 7' W).

The large fraction of this sample consists of tan, yellow, grey and purple quartzite and vein quartz from 3 to 4 inches in diameter. Some banded quartz is present. Loose sand is mixed with the gravel.

3-7 Jones County, Texas.

Gravels draped over the Merkel Escarpment 3.5 miles northeast of Trent, Texas (32° 33' N; 100° 7' W).

Chert is the most abundant of particles. Some large pieces of yellow, grey and purple quartzite are present. Vein quartz appears as the smaller fraction.

3-8 Scurry County, Texas.

Twelve miles east of Snyder, Texas on the north side of Highway 180, one mile west of Midway (32° 44' N; 100° 42' W).

White and pink quartz are the most prominent while banded white quartz and grey quartzite are present in small quantities. Some particles of chert and silicified wood are present.

3-9 Nolan and Taylor Counties, Texas.

Lag gravels strewn in the cultivated fields atop the Callahan Divide 15 miles southwest of Merkel, Texas and 6 miles northeast of Nolan, Texas (32° 18' N; 100° 7' W).

Pebble-size particles of white, pink and yellow vein quartz are scattered thinly over the area. Some chert is present, much of which resembles artifacts.

3-10 Jones County, Texas.

Gravel draped over the Merkel Escarpment some 9 miles west of Anson, Texas and 2 miles east of Boyds Chapel, Texas on the south side of U. S. Highway 180 (32° 47' N; 100° 5' W).

Purple, yellow, grey and tan quartzite is abundant in boulders from 4 to 6 inches in diameter. Much vein quartz and banded quartz is present in pebble to cobble size. Some silicified wood and micaceous quartzite is present. Chert is less obvious than at locality 3-7, but is still abundant.

3-11 Baylor County, Texas.

3 miles northwest of Seymour, Texas on the north side of U. S. Highway 82 (33° 37' N; 99° 18' W).

The large fraction of this sample consists of tan, yellow, grey and purple quartzite and vein quartz from 3 to 4 inches in diameter. Some banded quartz is present. Loose sand is mixed with the gravel.

3-12 Hood County, Texas.

Comanche Peak, 1.0 miles west of State Highway 144, south of Granbury, Texas, 5.0 miles (32° 22' N; 97° 47' W).

3-13 Stonewall County, Texas.

Double Mountain, 12.5 miles southwest of Aspermont, Texas and 3.5 miles northwest of Farm Road 610 (33° 05' N; 100° 27' W).

3-14 Coke County, Texas.

Colorado River terrace 0.5 mile south of Robert Lee, Texas on the west side of State Highway 208 (31° 53' N; 100° 29' W).

4-1 McLennan County, Texas.

Two miles northeast of China Springs, Texas on a county road. (31° 41' N; 97° 18' W).

4-2 Bosque County, Texas.

Approximately 5 miles northwest of Valley Mills, Texas on the north side of a county road 2 miles northwest of Rock Springs and one mile north of the Bosque-McLennan County line (31° 42' 30" N; 97° 25' 00" W).

Pebble- to boulder-size tan, yellow and purple quartzite is abundant. Some angular chert and dense limestone cobbles are present.

4-3 Falls County, Texas.

Plowed field adjacent to State Highway 6, 4.5 miles north of Marlin, Texas (31° 22' N; 96° 55' W).

4-4 Bosque County, Texas.

Under and around an abandoned farm house, approximately 6.5 miles southeast of Meridian, Texas (31° 52' 30" N; 97° 33' 30" W).

Both yellow and purple quartzite pebbles and cobbles are abundant. Some limestone cobbles are present. Jasper, vein quartz and banded quartz pebbles are present in small quantities. Silicified wood is present.

4-5 Bosque County, Texas.

Located on the Powell Ranch about 5.5 miles southeast of Meridian, Texas and one mile south of State Highway 22 (31° 54' 00" N; 97° 34' 00" W).

Limestone cobbles are the most abundant. Several cobbles of tan, yellow and purple quartzite are present. There are a few fragments of banded quartz and vein quartz.

4-6 Bosque County, Texas.

Approximately 4.0 miles east of Clifton, Texas and 3.0 miles west of Coyote, Texas (31° 46' 25" N; 97° 30' 45" W).

Limestone cobbles and pebbles are predominant. Several yellow and purple quartzite pebbles are present.

4-7 Bosque County, Texas.

Next to a cemetery 2.0 miles southwest of Coyote, Texas (31° 44' 20" N; 97° 29' 20" W).

Boulders of tan, yellow and purple quartzite are in abundance. Some vein quartz and silicified wood fragments are present as well as limestone pebbles.

4-8 Limestone County, Texas.

Eight miles southeast of Mexia, Texas on Farm Road 39 (31° 35' N; 96° 24' W).

There is an abundance of 2 to 3 inch yellow, white and purple quartzite. Much silicified wood is present. Vein quartz is common in pebble-size fragments. Some chert is present.

4-9 McLennan County, Texas.

Blacklands Experimental Watershed, 2 miles east of Riesel, Texas (31° 28' N; 96° 53' W).

Tan, yellow and purple quartzite cobbles are spread over the field. Some black banded quartz is present along with vein quartz from pebble- to pea-gravel size.

4-10 McLennan County, Texas.
Between north and south forks of Cow Bayou, about 3.0 miles west of Interstate Highway 35 (31° 22' N; 97° 16' W).

4-11 Bell County, Texas.
Area north of Rogers, Texas east of U.S. Highway 190 (30° 55' N; 97° 15' W).

4-12 Bell County, Texas.
On State Highway 95, 3.0 miles north of Bartlett, Texas (30° 50' N; 97° 25' W).

4-13 Williamson County, Texas.
Along State Highway 95, 2.0 miles north of Taylor, Texas (30° 36' N; 97° 25' W).

4-14 Travis County, Texas.
One mile east of New Sweden, Texas (30° 26' N; 97° 30' W).

4-15 Travis County, Texas.
Five miles east of Interstate Highway 35 at Austin, Texas south of U. S. Highway 290 (30° 20' N; 97° 38' W).
Cobbles of chert and limestone are the most abundant constituents. Some yellow quartzite cobbles are present. Clear and milky vein quartz is abundant in pebble size and some clear quartz is 3 to 4 inches in diameter. Jasper is present in small quantities.

4-16 Travis County, Texas.
Within the corporate limits of Austin, Texas adjacent to Ben White Blvd. south of the Colorado River (30° 13' N; 97° 46' W).

4-17 Travis County, Texas.
One mile west of Creedmoor, Texas (30° 05' N; 97° 45' W).

4-18 Hays County, Texas.
In road cut east of Interstate Highway 35, 16.0 miles south of Austin, Travis County, Texas (30° 01' N; 97° 51' W).

4-19 Lee County, Texas.
One mile west of Giddings on the south side of U. S. Highway 290 (30° 12' N; 96° 57' W).
Limestone and chert cobbles and boulders are the most common. Yellow quartzite is common with some purple quartzite present. Vein quartz, silicified wood and jasper are all represented in the suite.

4-20 Burleson County, Texas.
Nine miles south of Caldwell, Texas (30° 25' N; 96° 44' W).

4-21 Lee County, Texas.
Five miles northwest of Burton, Texas (30° 15' N; 96° 38' W).

4-22 Milam County, Texas.
Two miles west of Milano, Texas on U. S. Highway 79 (30° 42' N; 96° 55' W).

4-23 Limestone County, Texas.
Five Miles southeast of Thornton, Texas (31° 25' N; 96° 30' W).

4-24 Caldwell County, Texas.
Two miles east of Lockhart, Texas on Farm Road 20 (29° 52' N; 97° 41' W).

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