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TERTIARY-QUATERNARY STRATIGRAPHY AND GEOMORPHOLOGY OF WEST TEXAS AND SOUTHEASTERN NEW MEXICO

by

C. C. REEVES, JR.
Department of Geosciences
Texas Tech University

INTRODUCTION AND LOCATION

For the purpose of this [abbreviated] report *southeastern New Mexico* is arbitrarily considered as that area west and north from the Texas-New Mexico state line to the Pecos River and to the Canadian River Valley: mainly Quay, Curry, Roosevelt and Lea Counties. *West Texas* is defined as that area from the Texas-New Mexico state line east to 100° Longitude and north to 35° Latitude. This area, of approximately 32,000 square miles and covered principally by the Clovis, Tucumcari, Brownfield, Hobbs, Plainview, Lubbock, and Big Spring 1:250,000 AMS topographic sheets, has been mapped as part of the University of Texas' Geologic Atlas project. Specifically, the writer, supported by the New Mexico Bureau of Mines, Socorro, mapped the western parts of the Clovis, Brownfield and Hobbs sheets. The eastern parts of the Clovis, Brownfield and Hobbs sheets, as well as the Plainview, Lubbock and Big Spring sheets, were the responsibility of Dr. Gus Eifler, Bureau of Economic Geology, Austin, Texas.

Physiographically most of the area is occupied by the southern High Plains or Llano Estacado. To the east of the Llano Estacado are the "red rolling plains" formed by outcrops of Triassic and Permian strata. To the west, between the Pecos River Valley and the western escarpment of the Llano Estacado is the Mescalero pediment.

CLIMATE*, DRAINAGE AND TOPOGRAPHY

The entire southeastern New Mexico-Texas area, by the Koppen-Geiger system, is classified as a *steppe* region (BSH) even though the many square miles of sand dunes in certain areas resemble a "classic" desert. The climate is characterized by low annual humidity, low annual precipitation and a high average annual temperature. Averal annual precipitation in the southwestern part of the area is about 12 inches, increasing to about 20 inches in the far northeastern part of the area. The average annual temperature, about 60° F for nearly all the area, is somewhat cooler in the northwest corner than in the extreme southwest. Mean relative humidity in July and January is about 50 percent.

Although the fluvial scars of Pleistocene drainage channels occur throughout southeastern New Mexico and West Texas there are presently no through-flowing streams; the Pleistocene channels are, however, utilized during sporadic wet periods. The area is bordered on the west by the south-flowing Pecos River and on the north by the east-flowing Canadian River (fig. 1).

*All climatic data from Environmental Science Services Administration, 1966.

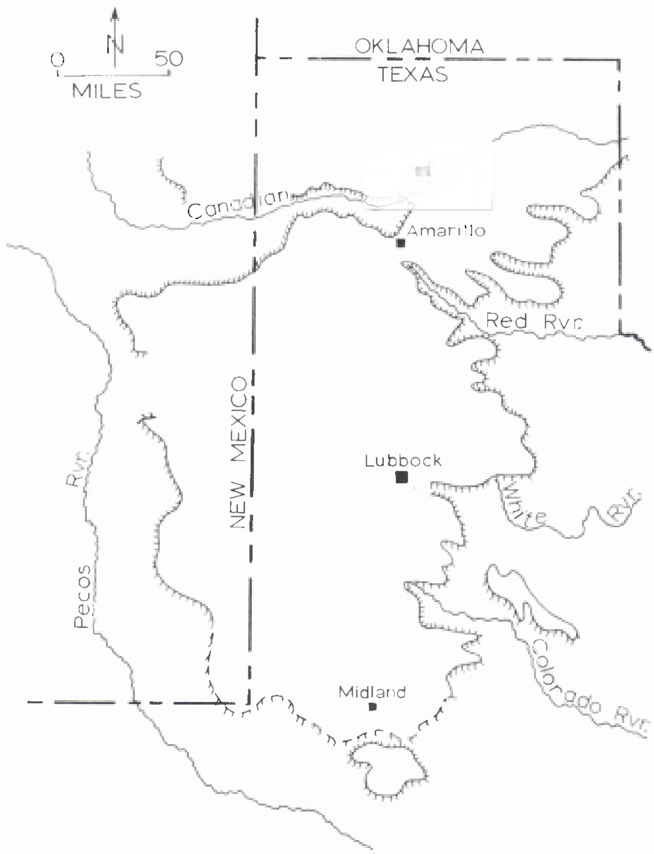

Figure 1. Index map of West Texas and southeastern New Mexico.

Topographically the area is ony of contrast between vast depositional plains (Llano Estacado and Mescalero Dunes) and large erosional surfaces (Pecos and Canadian River Valleys) locally altered by subterranean solution and near-surface collapse. Altitudes range from about 5,000 feet in the northwest corner to about 2,700 feet near Big Spring in the southeast; maximum relief of about 450 feet occurs near San Juan Mesa in Chaves County, New Mexico.

STRATIGRAPHY

Tertiary

Ogallala Formation

The Ogallala Formation (Darton, 1905), forms a massive piedmont alluvial plain on the east side of the southern Rocky Mountains and extends from southern South Dakota to southeastern New Mexico. Throughout the 800-mile north-south extent, as well as from west to east, the Ogallala Formation consists predominantly of fluvial gravel, sand, silt and clay. Minor quantities of betonitic clay, buried soil, chert lentils and volcanic ash also occur in the Ogallala (Frye, 1970) section, but generally only in the northern parts of the depositional area.

The original easternmost extent of the Ogallala Formation is unknown. Outliers occur in Dickens, Scurry, Fisher and Nolan Counties, Texas, but Menzer and Slaughter (1970) found evidence of Ogallala gravel as far east as Dallas County, Texas, suggesting that the Ogallala alluvial deposits once formed a "gangplank" type ramp (as presently found in Wyoming-Nebraska) across Texas. This was originally suggested by Plummer (1932).

Thickness of the Ogallala Formation ranges from a feather edge to more than 500 feet, the thickest wedge trending east-west through Parmer and Castro Counties, southeast through Hale County and the southwestern corner of Floyd County, and southeast through Crosby County, Texas (fig. 2). However, small narrow channels with thick Ogallala clastics controlled by relief on the post-Cretaceous unconformity exist in many areas. In eastern New Mexico the Ogallala is usually thinner than in West Texas, typical thicknesses being from 75 to 225 feet around Lovington (Ash, 1963), 100 to 200 feet in the Causey-Lingo area (Cooper, 1960), and up to 350 feet north of Maljamar (Ash, 1963). Along the escarpment from Taiban Mesa east to Ragland, the San Jon area, and into Deaf Smith County, Texas, the Ogallala is commonly less than 100 feet thick. On the plains the areas where the Ogallala section is thin or absent correspond to topographic highs on the post-Cretaceous unconformity.

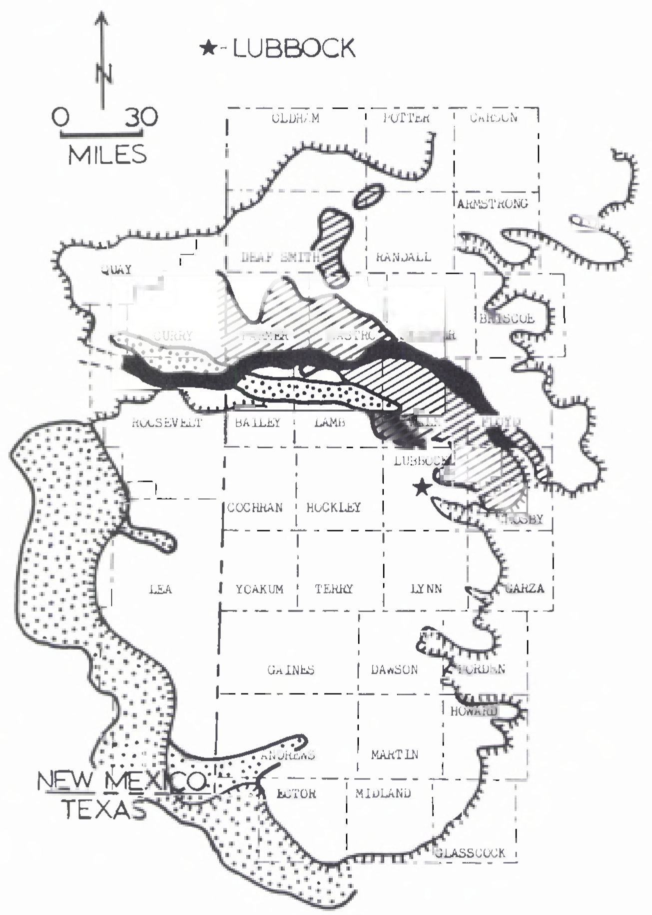

Figure 2. County map of southeastern New Mexico and West Texas, illustrating major sand dune areas (stippled) and the area where the Ogallala is thicker than 200 feet (cross-hatched); the black band traces the deepest part of the Portales Valley.

The Ogallala is defined and recognized by the U.S. Geological Survey (Keroher and others, 1966) as a formation, but recognizable units in the Ogallala have been termed formations, members, and floral zones (Frye, 1970). In 1949 Evans and Meade informally elevated the Ogallala Formation to group status by proposing division of the section into the Couth Formation and the overlying Bridwell Formation from studies along the eastern escarpment in Crosby County, Texas. Frye and Leonard (1957), however, concluded that recognizable rock-stratigraphic units in the Ogallala section in a 225-mile north-south traverse along the eastern escarpment, exist only on a local scale and thus considered the Ogallala a formation with no recognizable members. To date no regional attempt has been made to trace the suggested Couch and Bridwell "formations" from their type locality westward in the dip direction, principally due to the absence of outcrops.

In Nebraska the Ogallala Formation contains three identifiable floral zones, the basal Valentine overlain by the Ash Hollow, the Sidney gravels, and the Kimball (Johnson, 1935; Lugn, 1938 and 1939), but distribution is not uniform to the south. The lower Valentine is overlain by the Ash Hollow, the Sidney gravels and the Kimball (Johnson, 1935; Lugn, 1938 and 1939), but distribution is not uniform to the south. The lower Valentine zone apparently does not exist south of Floyd County, Texas, (Frye and Leonard, 1964) but the overlying Ash Hollow and Kimball zones have been identified by Frye and Leonard (1964) from various localities in West Texas. Unfortunately, correlation of these zones has not been extended to the western escarpment in eastern New Mexico. In Kansas and Nebraska the Ogallala Formation can also be correlated on the basis of volcanic ash zones, lithology, the topmost pisolitic limestone and by topography at the base of the section (Frye and Leonard, 1959), but such methods have met with little success in West Texas and southeastern New Mexico. Age of the Ogallala, which ranges from late Miocene to Pliocene, has been based mainly on several vertebrate faunas (Frye, 1970).

Evans' (1949) Couch Formation consists of ". . . .well-sorted calcareous sand and gravel. . . ." which is deep brown to dark red, subangular to angular, well-sorted and massive bedded. The gravel, which may or may not be present, consists of quartzite and jasper cobbles in a clean quartz sand matrix, often with water-worn Cretaceous shells. The overlying Bridwell Formation (Evans, 1949) consists of unconsolidated, fine-grained, reddish sand, silt and clay with sporadic gravel; thus a color contrast often marks the contact in the type area (fig. 3).

As classically envisioned (Fenneman, 1931; Plummer, 1932) the Ogallala section was spread over the plains as a vast fan of alluvial debris from the central and southern Rocky Mountains, but Frye, Leonard, and Swineford (1956) found evidence that the Ogallala represented mainly valley alluviation. In central-eastern New Mexico the Ogallala section consists, in many areas, of coarse-grained fluvial sand and gravel but in southeastern New Mexico, where Ogallala section is

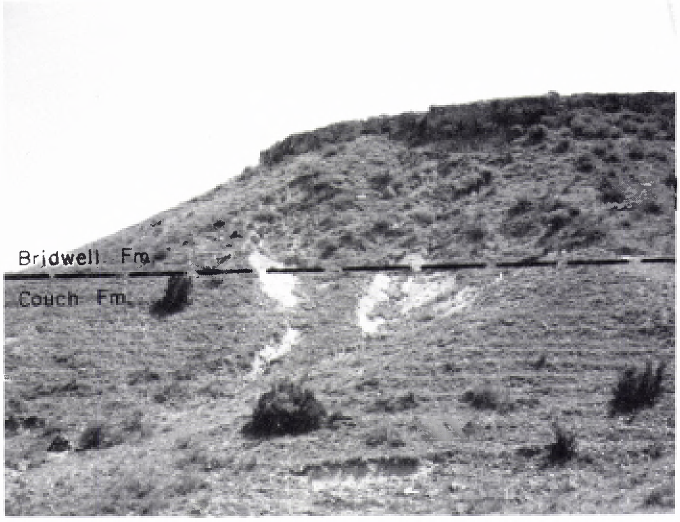

Figure 3. Ogallala showing the Couch and overlying Bridwell Formations. View to the south in Yellowhouse Canyon, southeastern Lubbock County, Texas.

"within sight" of the mountains, the section consists mainly of fine-grained calcareous sand and silt, the only fluvial-appearing sands and gravels being a basal section measuring 5 to 10 feet thick. The predominance of fine-grained sand and silt and the absence of fluvial sand and gravel indicates that there were no eastward-flowing Pliocene streams south of the San Juan Mesa (fig. 6) area after earlymost Ogallala time.

The widespread basal Ogallala gravel is typical of regional piedmont-type deposits, but a great part of the Ogallala Formation, even in the Lubbock, Texas area, consists of a great thickness of overlying fine-grained, brownish to reddish calcareous sand and silt (loess?) especially in the upper part. The coarse gravel at San Juan Mesa and north of Tolar indicates high discharge rates during all of the time represented by the section, thus if these sections correlate with the entire Ogallala depositional period in other areas, the regional change from basal gravel to eolian debris must have been caused by a change in source area.

As a working hypothesis, I propose that during uppermost Miocene time, when lower Ogallala gravel was being deposited, an ancient Pecos Valley (as originally suggested by Bretz and Horberg, 1949) developed by solution-subsidence. Its extension northward progressively pirated the streams which were flowing eastward off the low Sacramento Mountains onto the southern part of the Llano Estacado. Thus, most of the Ogallala south of the San Juan Mesa region consists mainly of indurated eolian sheet sand and finer debris deflated from this ancient Pecos Valley whereas in the northwestern part of the Llano Estacado the Portales River continued to deposit mainly fluvial deposits. The Triassic high from about Maljamar southeast to U.S. 180 (and actually running northwest of Maljamar for at least 20 miles), shown by Nicholson and Clebsch (1961), Ash (1963) and Cronin (1969), was covered by lowermost Ogallala gravel, and thus was not high enough to interfere with Ogallala deposition and act as a local drainage drive. The high is also indicated by Ogallala outliers south of Maljamar and west of Jal which also show an eolian sand-silt lithology.

As the ancient Pecos Valley developed by solution-subsidence it was contemporaneously filled with several hundred feet of fluvial, eolian and sheetwash debris, a unit which Lang (1938) termed the Gatuna Formation. The Gatuna Formation was named for a section of terrestial sand, silt and gravel at Gatuna Canyon in Eddy County It has been mistaken in the Pecos Valley where similar appearing Triassic and Permian red beds also occur. Illustrative of the confusion which can arise between these similar appearing red bed sequences is the mapping of Pierce Canyon southeast of Carlsbad, New Mexico and east of the Pecos River. Pierce Canyon was given by Lang (1935) as the type section for the Pierce Canyon red beds and the area was mapped as Permian by Dane and Bachman (1958). Vine's (1963) work in the Nash Draw area considered the Pierce Canyon red beds to be of either Triassic or Permian age, thus it was startling to find, when mapping Pierce Canyon*, that the outcrops were of Gatuna strata. Kelley (1971, p. 24) also noted this.

Age of the Gatuna Formation is unknown. Lang (1938) thought Gatuna sediments, which obviously represent fill in the Pecos Valley after maximum development, were deposited in post-High Plains time, but Kelley (1971) suggests that Gatuna, based on lithology and induration, may be of pre-Ogallala age. However, on the basis of minimal stratigraphic evidence, I suspect the Gatuna Formation represents an ancient Pecos Valley fill contemporary with the post-basal gravel part of the Ogallala Formation on the Llano Estacado.

Accurate dating of the Gatuna will have to wait on a paleontologic evidence; however, age of the Gatuna Formation in relation to the Portales Valley, to the southern High Plains and to the Ogallala Formation may be clarified by stratigraphic studies now underway north of Roswell and in the Fort Sumner and Taiban areas. As discussed in the section "The Pecos and Portales Valleys" (p. 27), interception of the Portales River supposedly occurred during Kansan time, thus if the Gatuna Formation is of pre-Pleistocene age it should be limited to that part of the Pecos depression south of the Fort Sumner-Taiban area. If, however, the Gatuna Formation is of Pleistocene age, outcrops should occur upstream from the Fort Sumner-Taiban area. Kelley (1971) mapped the northernmost outcrop of Gatuna in T. 6 S., R. 26 E. just south of Bosque Draw and approximately 60 miles south of Fort Sumner (fig. 6). To date I have been unable to find any Gatuna north of the preceding location.

Quaternary

Sediments of Quaternary age in the eastern New Mexico-West Texas area consist mainly of eolian sands, lacustrine deposits and fluvial clastics.

Lacustrine Strata

Lacustrine strata in southeastern New Mexico and West Texas are of Nebraskan (Blanco Formation), Kansan (Tule Formation), and Wisconsin (Tahoka Formation) age. No lacustrine deposits of Illinoian age, other than possibly some thin playa fills in Lea County, New Mexico (Nicholson and Clebsch, 1961), are known from the area. If Illinoian lakes did exist in the area, the resultant sediments must be beneath present playas; however, widespread Illinoian eolian deposits argues against the presence of permanent lakes at that time.

The Blanco Formation (Frye and Leonard, 1957), consists mainly of sand, clay and gravel and is exposed along the major reentrant canyons of the eastern "caprock" escarpment.

*For the State of Texas Geologic Atlas Project, field work supported by State Bureau of Mines, Socorro, New Mexico.

Isopachous maps of the Ogallala Formation (Wyatt, 1968) and contours drawn on the base of the Ogallala (Cronin, 1961: 1969) show that most of the present channels follow older drainage. Thus extensive Nebraskan and Kansan lacustrine sediment along present channels indicates regional blocking of the drainage channels, perhaps by fluvial debris as glacial discharges decreased with approaching interglacial periods. Age of the Blanco Formation is established by vertebrate evidence (Cope, 1893; Matthew, 1924; Meade, 1945), stratigraphic position, and a distinctive invertebrate fauna in Kansas and Nebraska.

The Tule Formation (Cummins, 1893), consisting of grayish sand, bentonitic clay, thin-bedded limestone and the distinctive Pearlette volcanic ash crops out, mainly along the major canyons extending westward from the eastern escarpment. Age of the Tule Formation is based on extensive vertebrate remains (Cope, 1893; Matthew, 1924), stratigraphic position, and correlation with the Mississippi valley glacial section (Frye and others, 1948).

The Tohoka Formation, consisting of sand, gravel, characteristic blue-gray clay, gypsum lenses and thin interbedded dolomite and limestone (Evans and Meade, 1945; Reeves, 1966), occurs around all playas of the present large (Class IV) pluvial lake basins of southeastern New Mexico and West Texas (fig. 4). Other outcrops also occur in the larger "playa"-type basins and sinks of southeastern New Mexico (such as Bell Lake). Age of the Tahoka Formation, ranging from about 20,000 to 14,000 years B.P., is based on vertebrate remains (Evans and Meade, 1945), pollen (Hafsten, 1961; Oldfield and Schoenwetter, 1964) and C^{14} dates (Bates and others, 1970; Reeves, 1970A).

The upper part of the Tahoka Formation, in most basins, is characterized by the thin Vigo Park Dolomite (Oldfield and Schoenwetter, 1964) which correlates to the Interstage de Lascaux of Europe (personal communication, A, Lerio-Gourham, 1965), the Sehoo Formation in the Lake Lahontan area and the diastem of the Bonneville Formation of Utah (Reeves, 1966; Parry and Reeves, 1968). Because of this regional continuity I suggested (1970A) that the Tahoka Formation be divided into the Rich Lake Member and the overlying Brownfield Lake Member* named for their respective lake basins in Terry County, Texas; the Vigo Park Dolomite would mark the top of the Rich Lake Member. Age of the lacustrine section beneath the Rich Lake Member, which ranges from about 40 feet thick at Rich Lake to about 100 feet at Brownfield Lake, is unknown. Cores of this section (from four different lake basins) are on file at Texas Tech University.

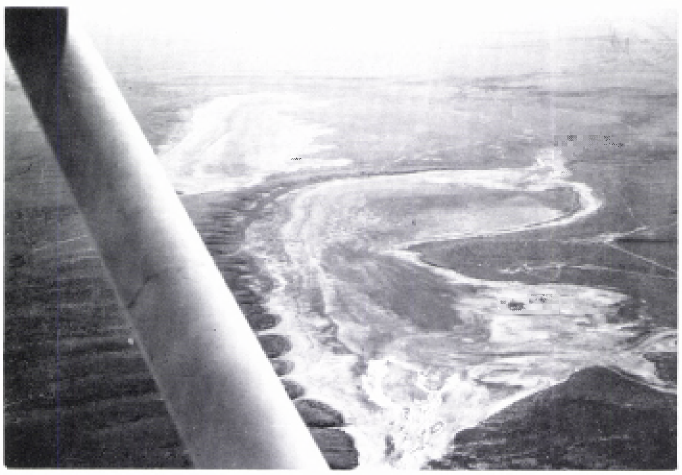

Figure 4. Illusion-Yellow Lake complex, Bailey County, Texas. A typical large pluvial lake basin of southeastern New Mexico and West Texas. Sediments of the Tahoka Formation are exposed around the present playas. View is toward the south.

Several surprising lithologic differences which reflect the change in sedimentary source area caused by isolation of the Llano Estacado, exist between early and late Pleistocene sediments in the West Texas-southeastern New Mexico area. Early Pliocene (Blanco and Tule) sediments are mainly light-colored, fluvial sand with gravel, greenish bentonitic clay, volcanic ash and thin carbonate beds, but late Pleistocene sediment consists mainly of dark bluish-to-black clay with salt lenses in the central basin areas and silt and carbonate lenses along the shore.

During early Pleistocene time the northern Llano Estacado was receiving runoff from the nearby mountains, and high discharges (which were "flushing" the Portales Valley) transported sand and gravel perhaps as far east as Dallas County (Menzer and Slaughter, 1970). To the south, where no Blanco or Tule sediment is known, the already isolated plains basins were being filled by local sheet-wash debris composed mainly of older lacustrine sediment which cropped out around the playas. However, once the Portales River was beheaded and the Llano Estacado effectively isolated, filling of the pluvial basins in the northern part of the plains was also controlled by local runoff and sheet wash over older lacustrine deposits.

Eolian Strata

Several extensive sand dune areas exist in southeastern New Mexico and West Texas (fig. 2), none of which I consider to be older than late Pleistocene.

Monahans Dunes–The Monahans dune area is about 20 miles wide and 70 miles long, extending from west of Eunice, New Mexico, southeast to near the Pecos River in Crane County, Texas, and northeast into Andrews and Ector Counties (fig. 2). The eolian sequence was divided into the basal Judkins and overlying Monahans formations by Huffington and Albritton (1941), but Green (1961) found the terminology useless because of complex stratigraphic relations. Green (1961) recognized nine units, two of which were lacustrine, throughout the area; however, no attempts to correlate Green's (1961) stratigraphy to other nearby dune areas are known.* The oldest stratigraphic unit in the Monahans dunes was considered of Aftonian (Green, 1961) or possibly Yarmouthian-Illinoian age (Frye and Leonard, 1957), but I suspect the basal Monahans sand is no older than Sangamonian (Reeves, 1970).

Mescalero Dunes–The Mescalero dunes, flanking Mescalero Ridge on the west side of the southern High Plains, extend from about Eunice, New Mexico, north to about Kenna, New Mexico (fig. 2). The dune belt, often 10 to 20 miles wide, is about 100 miles long, the dune sands resting mainly on Triassic redbeds. Stratigraphically, the Mescalero dunes resemble the section found by Green (1961) in the Monahans dunes and are, therefore, probably of about the same age.

*Names on file with Geologic Names Committee, Washington, D.C.
*A study is currently underway.

Lenses of lacustrine sediment are also particularly apparent in the lower part of the section.

Muleshoe Dunes—The Muleshoe dunes, extending east-west 110 miles from about Tolar, New Mexico, into Hale County, Texas, are up to 8 miles wide near Sudan, Texas. Green (1951) divided the dune sequence into four stratigraphic zones, the oldest probably being of post-Illinoian age (Reeves, 1970). Green (1951) believed source of the basal Muleshoe dunes was the Pecos Valley and the westernmost High Plains, but Jones (1959) and Hefley and Sidwell (1945) suggested local streams and related floodplain deposits. Because the Muleshoe dunes are confined to the Portales Valley, the site of the last major Pleistocene stream flowing across the Llano Estacado, and because of the regional absence of eolian crossbedding and decrease in grain size from the central part of the dune area (Jones, 1959), I also suspect the fluvial deposits of the Portales Valley as the original source area.

In the southwestern part of the plains Pliocene caliche forms the surface, but to the northeast the plains are covered by an increasing thickness of Pleistocene eolian sand (fig. 5). In eastern Lea County, New Mexico, a brown to grayish-brown pre-Illinoian eolian sand is preserved in ancient Pliocene dune swales trending N. 65° W. The eastern limit of this sand is unknown, for at about the Texas state line, and to the north and south, it is covered by reddish-brown Illinoian "cover sands" and younger sands. The Illinoian "cover sands," named

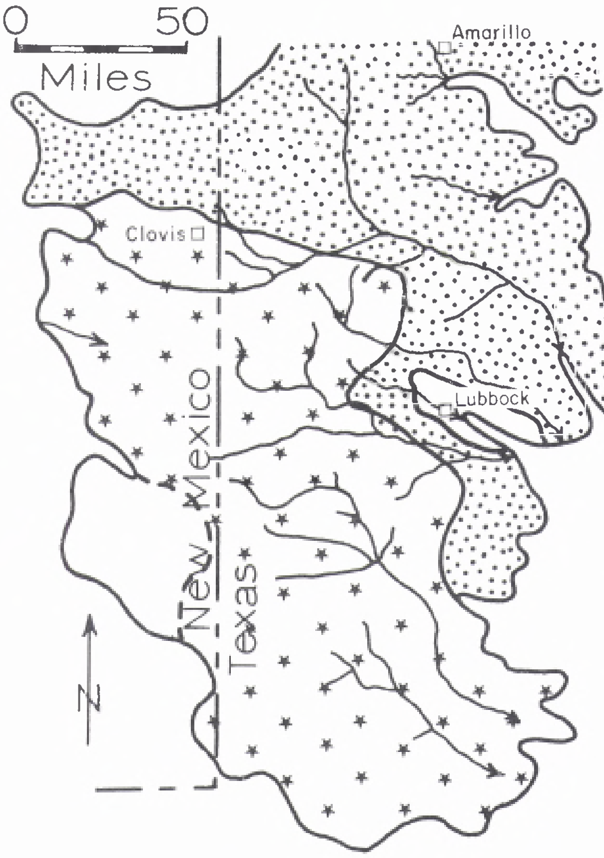

Figure 5. Ancient drainage channels of the Southern High Plains. Stippled area illustrates that part of the southern High Plains covered by Pleistocene (Peoria?) loess. Starred area illustrates the outcrop of the "cover sands" which are buried by the loess to the northeast.

by Frye and Leonard (1957), outcrop over about 50 percent of the Llano Estacado, but north from a line joining Clovis southeast to Brownfield and Big Spring, the "cover sands" are themselves buried by the dark grayish-brown (10YR4/2) Peoria Loess (fig. 5). It is interesting to note that as the surficial sediments of the Llano Estacado become increasingly finer to the northeast, the deflation basins become increasingly larger.

Lake Basin Dunes—The extensive transverse dunes associated with the large pluvial lake basins of the northern High Plains of West Texas and eastern New Mexico were studied by Melton: Reeves (1965) studied the large transverse dunes related to the large pluvial lake basins of the southern High Plains. Melton (1946) distinguished three different dune series, those formed over 15,000 years B.P. by winds blowing S. 70° E., those formed 5,000-10,000 years B.P. by winds blowing N. 40°-70° E., and those formed during the last 5,000 years B.P. by winds blowing N. 10°-25° E. Reeves (1965) also recognized three dune series, but with a mean wind direction of S. 60° E. for the dunes formed during the period 15,000-5,000 years B.P., slightly different from Melton's (1940) wind direction of N. 40°-70° E.

Loess—About the northeastern half of the southern High Plains is mantled by loess (fig. 5) which was correlated with the Peoria Loess of Kansas by Frye and Leonard (1965). The Peoria Loess ranges in color from dusky yellowish brown (10YR2/2) to dark yellowish to dark grayish brown (10YR4/2), even becoming dark brown (7.5YR5/4) in many localities, thus contrasting clearly with the reddish-brown (5YR5/3) of the underlying stripped Illinoian "cover sands."

Thickness of the Peoria Loess ranges from a feather-edge to perhaps 10 feet, the section thickening to the northeast. Where thin the Peoria Loess shows little soil development, but where several feet thick, the A-zone will be underlain by a 3- or 4-foot B-zone clay loam in turn underlain by a soft caliche C-zone profile. The Peoria Loess rests unconformably on Illinoian "cover sands" in that underlying "cover sands" show an absence of A-zone development but a well-developed B-zone profile.

Fluvial Deposits

The abandoned Pleistocene drainage channels on the Llano Estacado (fig. 5) and the large pluvial lake basins as well as the basal deposits of present playas (such as Muleshoe, Yellowhouse, Cedar) exhibit several feet of fluvial sand and gravel, many areas yielding commercial supplies. Thickest deposits tend to be east of the "caprock," for example Blanco and Yellowhouse canyons have nearly 100 feet of fill in places. The Simanola Valley-Ranger Lake drainage, which was produced by a post-Pliocene stream, also may contain fluvial strata, but I have no subsurface information.

GEOMORPHOLOGY

The Llano Estacado

The Llano Estacado, "Staked Plains" or southern High Plains, is the largest physiographic unit in the considered area, covering about 32,000 square miles. On the north, east, and west the southern High Plains are bounded by escarpments created by the hard Pliocene "caprock" caliche, but to the south the plains and Pliocene caliche grade imperceptably into the caliche profile on top of the Edwards Limestone which forms the Edwards Plateau.

The Llano Estacado has always been considered a depositional feature (piedmont plain) representing the now isolated alluvial apron of the southern Rocky Mountains, the surface being regionally flat with a southeastward slope of about 10 to 20 feet per mile. However, on close inspection much of the Ogallala Formation appears to be eolian and the plains surface, instead of being flat, is pitted with tens of thousands of shallow natural depressions (the so-called "playa lakes") and about 30 large depressions covering from 5 to 50 square miles. An abandoned subparallel drainage pattern is also evident.

The small lake basins are polygenetic, but deflation and unequal deposition of Pleistocene eolian sand probably account for most. However, sinks and undulatory depressions are also undoubtedly present (Reeves, 1966).

The escarpment surrounding the Llano Estacado on the west, north, and south is capped by the massive Pliocene "caprock" caliche, the varying thickness and undulating attitude of which result from the long exposure of the Ogallala surface at the end of Pliocene time.

Distribution of the majority of the small lake basins seems to be random over most of the southern High Plains, although some obvious alignment occurs along abandoned drainage channels. In the "scabland" area of southeastern Chaves and western Lea Counties, sinks are aligned along N. 60° W. fractures (joints?), thus it is possible that aligned basins in the areas covered by Pleistocene sand or loess also represent sinks formed along buried fractures.

Regional analysis of the Llano Estacado's drainage pattern from high-altitude photo indexes (1:360,000 to 1:315,000) shows mainly a northwest-southeast alignment with abrupt local changes to the northeast, southwest or south (Reeves, 1970A: 1970B). Although these lineaments do not seem to have affected the locations of the smaller lake basins, nearly all the larger pluvial lake basins occur at the intersections of the major lineaments, the trends of the basins and playas often corresponding to the trend of one of the lineaments (Reeves 1970A: 1970B). Whether these lineaments are joints or faults is presently unknown; however, Finch and Wright (1970) find evidence of displacement along the Running Water Draw-White River lineament trending from north of Clovis southeast to northwestern Crosby County, Texas.

The Pecos and Portales Valleys

Headward erosion of the present Pecos Valley in southeastern New Mexico must have started with the earliest Pleistocene glacial advance, but the time of capture of the Portales River, the last major eastward flowing stream across the Llano Estacado (fig. 6), is unknown.

The Pecos Valley is bounded by the eastward-sloping Sacramento Plain on the west, and extension of the plain across the present river valley correlates with the Llano Estacado (Fiedler and Nye, 1933). About 200 feet lower, and representing the first major adjustment the ancient Pecos River made, is the Diamond A-Mescalero piedmont, the Diamond A sloping west. Three lower terraces, the Blackdom, Orchard Park and the lowermost Lakewood, are then found around Roswell (Fiedler and Nye, 1933), as far north as Fort Sumner (Jelinek, 1967), and as far south as Carlsbad (Kelley, 1971).

The Portales Valley, also termed Blackwater Draw for the present small stream north of Portales, was suggested by Baker

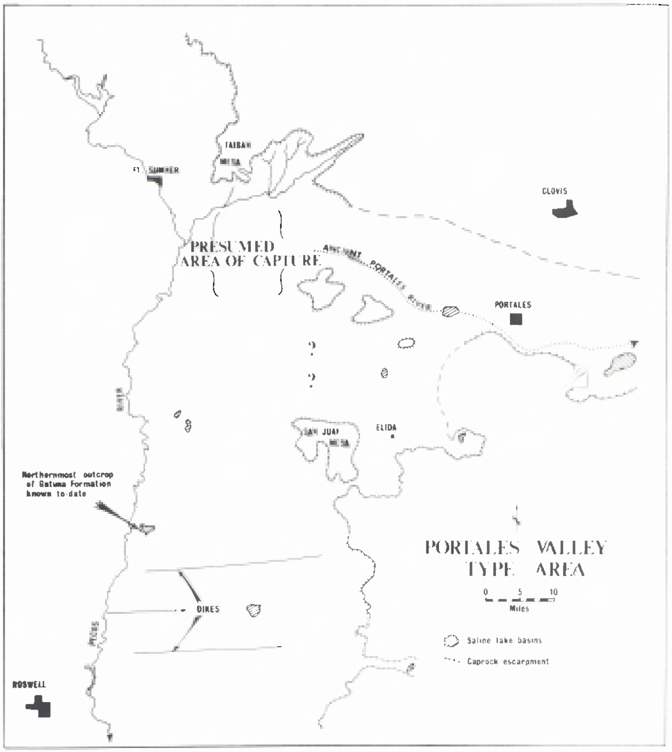

Figure 6. Inferred area of piracy of the ancient Portales River by the present Pecos River.

(1915) and Fiedler and Nye (1933) as the route of the ancient Pecos River (Portales River) across the Llano Estacado before its piracy by the present Pecos River drainage somewhere in the Fort Sumner area (fig. 6). Price (1944) considered the Portales Valley a "slump trough" produced by deep-seated solution and collapse, but dips on the south side of the valley are south, not north, and actually the valley is superimposed over an incised trough in the "red beds" (personal communication, S. A. Galloway, 1970). Perhaps this incisement was due to accelerated erosion in a trough formed between the Running Water Draw-White River lineament and the Double Mountain Fork lineament of the Lubbock area (Finch and Wright, 1970).

Baker (1915) thought the Brazos River once flowed through the Portales Valley before it was captured by the present Pecos River drainage. Price (1944) at first found no evidence of an old valley east of Hockley County, Texas, but in a footnote stated that a shallow trough "... 40 miles wide, ..." extended to the Lubbock, Texas, area; however, no evidence for this trough was presented.

Contours on the Quaternary fill in the Portales Valley and on the Ogallala Formation to the east (Cronin, 1969) indicate that the ancient Portales River flowed northwest of the Coyote Lake area where it joined a southeastward-trending stream west of Muleshoe. The ancient Portales River then flowed east along the Lamb-Castro County line, bending southeast just north of Plainview and flowing off the plains down the present White River through Blanco Canyon (fig. 2). Throughout most of its course the Portales River flowed in a valley 5-8 miles wide which corresponds with the Running Water Draw-White River lineament (Finch and Wright, 1970).

The exact position of capture of the Portales River by the Pecos River can be closely determined from subsurface evidence. The northwesternmost part of the Pliocene escarpment south of the Portales Valley is at San Juan Mesa thus the capture point must be between San Juan Mesa and the escarpment outcrop on the south of Alamosa Creek (fig. 6). Contours on Portales Valley fill (Cronin, 1969) suggest that the main valley trends northwest of Portales (fig. 6) at least to the latitude of Buffalo Creek, thus with the outliers of Ogallala in T. 1 S., R. 31 E. and in T. 1 S., R. 30 and 29 E., capture must have been somewhere in Tsps. 1-2 N., R. 27 E. unless the present Pecos River has since shifted eastward.

Examination of well logs and a water level map of the area northwest of Portales (Courtesy S. A. Galloway, State Engineer's Office, Roswell, New Mexico) indicates the buried channel and valley is about 8 miles wide south of Melrose but narrows to only 1-2 miles in Sec. 7, T. 1 N., R. 30 E. By Sec. 17, T. 1 N., R. 30 E., the channel disappears because of a drainage divide (old delta of Taiban Creek?), the channel reappearing to the west; however, surface as well as subsurface drainage is now west to the Pecos because of the superimposed Taiban Creek system.

The Portales Valley, floored by 5 to 15 feet of gravel which is covered by up to 170 feet of eolian sands and lacustrine sands and clays (personal communication, S. A. Galloway, 1970), exhibits about ±300 feet of regional relief, but whether the valley was ever completely filled with fluvial deposits is unknown. In various localities both on the north and south sides of the Portales Valley the Ogallala Formation consists wholly of fluvial sands and gravels, thus it is possible that by the end of Pliocene time the Portales River had aggraded the valley to the level of the surrounding plains of the Llano Estacado, but this is considered unlikely. If, however, major filling of the valley did occur in Pliocene time, the present thin lowermost gravel in the Portales Valley fill suggests much flushing. This must have started during the Nebraskan glacial, because present gravel is unlike typical Ogallala gravel (personal communication, S. A. Galloway, 1972). The present gravel represents fluvial debris deposited with the declining competency of the Portales River, probably at the onset of Aftonian time.

Fiedler and Nye (1933) considered the paired terraces of the Pecos Valley the result of Quaternary climatic changes, erosion of the Diamond A Plain representing Nebraskan time with entrenchment occurring during the Kansan glacial. Deposition of the Blackdom terrace then supposedly took place during the Sangamonian interval, the Orchard Park forming in late Wisconsin and the Lakewood forming during the Holocene (Fiedler and Nye, 1933). On the other hand, Jelinek (1967) suggested that the Blackdom gravel was of Illinoian age and the Blackdom terrace surface of Sangamonian age because of incisement of a Pearlette Ash bed along Taiban Creek (Sec. 31, T. 2 N., R. 27 E.).

If the Gatuna Formation, as I suspect, choked the ancient Pecos Valley by late Pliocene time, and the Portales Valley was even partly filled with fluvial debris, it is unlikely that either Pecos or Portales valleys could have been incised deeply enough to permit piracy of the Portales River during the first glacial period. Robbins (1941) reports that a high-level terrace,* termed the Fort Sumner, is present in the Portales Valley but not in the Pecos Valley, thus the Fort Sumner terrace would represent the initial entrenchment of the ancient Portales River during early Pleistocene time, its absence below the point of capture illustrating the separateness of the two drainage systems. The oldest terrace found both above and below the theoretical point-of-capture is supposedly the Diamond A-Mescalero (Robbins, 1941), thus the time of capture of the Portales River would be at the time of incisement of the Diamond A Plain, probably during the Kansan glacial period.

Kelley (1972) suggests the possibility that an ancient (pre-Pliocene to Pliocene) Pecos River, draining southward ". . . as a wide valley system . . ." was instead first captured by the Portales River, recapturing by the Pecos of its head taking place sometime later. This would mean an ancient Pecos River Valley, which contained pre-Ogallala to Ogallala sediments, once existed, therefore, present remnants of such fill may still exist. Although I have seen no evidence for Kelley's suggestion of capture and recapture, the remnants of his suggested pre-Ogallala and/or Ogallala fill could well be the presently defined Gatuna Formation.

In certain areas of the Pecos Valley, such as southeast of Malaga and in Nash Draw, domal structures (Vine, 1960) or piercement domes (Kelley, 1971) with brecciated cores occur (fig. 7). The domes, which average 1,000-1,500 feet in diameter (Vine, 1960), originated by sink fillings which were then pushed upward, probably by pressures resulting from alteration of underlying anhydrite to gypsum. A ring fault surrounds the older domes northeast of Carlsbad (Vine, 1960) and is probably a characteristic feature of the old domes, but exposures are usually too poor for determination.

Mescalero Plain

The Mescalero Plain, the pediment surface sloping from the base of the Mescalero Ridge westward toward the Pecos River, extends from about Fort Sumner south into Loving County, Texas (Morgan and Sayre, 1942). Regionally the Mescalero Plain appears extremely flat but locally many irregularities exist due to sinks, dunes, and resistant rock areas. About 80 percent of the Mescalero Plain is covered by the Mescalero dunes, the main area of which extends from about Kenna south to Jal, New Mexico.

Figure 7. Piercement dome in Pecos Valley, east southeast of Rio Grande de Sal.

*There is some question about Robbins' (1941) terraces.

Mescalero Ridge and "The Caprock"

The western escarpment of the southern High Plains, termed the *Mescalero Ridge,* ranges from a sand-drifted hillside to precipitous cliffs 450 feet high (fig. 8). The Mescalero Ridge is formed mainly of Ogallala sand topped by the "caprock" caliche, the underlying Triassic redbeds. The Triassic crops out only for a few miles south of U.S. 380 and at a few other local spots until reaching the San Juan Mesa area where most of the relief is due to the Triassic section. From about Jal northwestward to Mescalero Ridge is highly irregular and, as on the east side of the San Simon Sink, drifted over by dune sand. From about Maljamar northward to Caprock the ridge is surprisingly straight and averages about 200 feet high, but from Caprock to the Kenna area the ridge is often buried by dune sand. However, from Kenna northward relief increases until at San Juan Mesa the "caprock" caliche is some 450 feet above Hoot Owl Draw. San Juan Mesa is actually an outlier of the Ogallala Formation, the main escarpment trending north to just south of Elida, and then due east to about the Red Lake area. From the Red Lake area the escarpment is buried by dune sand. It essentially trends southeast, forming the southern side of the Portales Valley, and it does not again make bluffs until the Tolar-Taiban area. At Taiban the escarpment swings west on the north side of Red Lake (different than preceding locality) and meanders north along the De Baca-Quay County line, the northwesternmost area known as Luciana Mesa.

Along the northern part of the area the escarpment, known as "The Caprock," trends irregularly eastward from the Guadalupe-Quay county line to just north of Amarillo, Texas, Jurassic and Cretaceous sediments forming much of the escarpment for several miles southeast and southwest of San Jon, New Mexico.

"The Caprock" escarpment from the vicinity of Amarillo, Texas, southward, ranges from about 1,000 feet high at Palo Duro Canyon to only a gently sloping ridge ±100 feet in the southeastern part of the area north of Big Spring. From Palo Duro Canyon south the escarpment is formed mainly by Triassic and Pliocene strata but south of Post (Garza County), and from Big Spring to west of Midland, Cretaceous strata crop out beneath the Ogallala Formation.

Figure 8. View east of Mescalero Ridge, south of Caprock and east of Roswell. Notice the dissected spurs of Quaternary debris underlain by Triassic sand and shale.

The eastern escarpment of the southern High Plains, is not as precipitous or as high as the Mescalero Ridge because of the greater thickness of soft Ogallala sand and silt. Also, the local trend of "The Caprock" escarpment is irregular due to the myriad of small headward-eroding canyons formed by the intermittent streams of Holocene age. The regional trend is also irregular due to the rapid headward erosion that large Pleistocene streams experienced. In many localities, such as along Yellowhouse Canyon at Lubbock, Texas, "The Caprock" retreats westward more than 30 miles.

The Cuneva and the San Simon Swale

The San Simon Swale, which covers about 100 square miles of a low trough between Ogallala outliers southwest of Eunice, New Mexico, is approximately 18 miles long and up to 7 miles wide. At the southeastern end, in Sec. 18, T. 23° S., R. 35° E., is the San Simon sink which, in the early 1930's (personal communication, Joe Pierson, San Simon Ranch, 1970) underwent subsidence which produced the annular fractures which are still observable (fig. 9).

Nicholson and Clebsch (1961) thought the swale "subsided as a unit" due to deep-seated solution, although deflation and fluvial erosion into several large sinks was considered more probable. Presence of other sinks in the area, activity of the San Simon sink itself, and the extensive dune field to the southeast, confirm solution, resulting subsidence, and deflation. The flanking escarpments of the Ogallala Formation on both sides of the swale indicate formation in post-Pliocene time by fluvial erosion in Pleistocene time through the thin protective Ogallala section which once existed at the northwestward corner of the swale. As the contours on top of the Triassic redbeds show (Nicholson and Clebsch, 1961), most of the subsidence has taken place in the southeastern half of the swale.

Surficial sediments in the swale consist of the Wisconsin Tahoka Formation, but the age of the underlying fill, which exceeds 400 feet in places (Nicholson and Clebsch, 1961), is unknown.

The Cuneva ("bowl") sink, in the far northwestern part of the southern High Plains of Quay County, New Mexico (T. 7° N., R. 28° E.), covers about 7-8 square miles. The Cuneva is bounded by Ogallala sand and "caprock" caliche on all sides with Triassic redbeds appearing along creek bottoms in the northwestern corner. Appreciable local subsidence occurred on the north flank in 1910 and again in 1934, but the present bottom, which is covered by lacustrine clay of apparent Tahoka age, has been stable for some time. On the northern flank incompetent sand of the Ogallala Formation, about 100 feet thick, is being washed out along northwest-southeast-trending fractures which cut through the "caprock" and which do not seem to be radial to nearby sinks. Thus, continued subsidence and extension of the Cuneva to the north and west will undoubtedly occur.

Other large sinks in southeastern New Mexico (not mentioned under other regional headings), which appear to contain Wisconsin (Tahoka Formation) lacustrine sediments at surface (perhaps over earlier Pleistocene sediments at depth) are located southeast of Button Mesa in Chaves County, southwest of San Simon Swale (Bell Lake), 5-6 miles east of San Simon sink, 6 miles northeast of San Simon sink, west and northwest

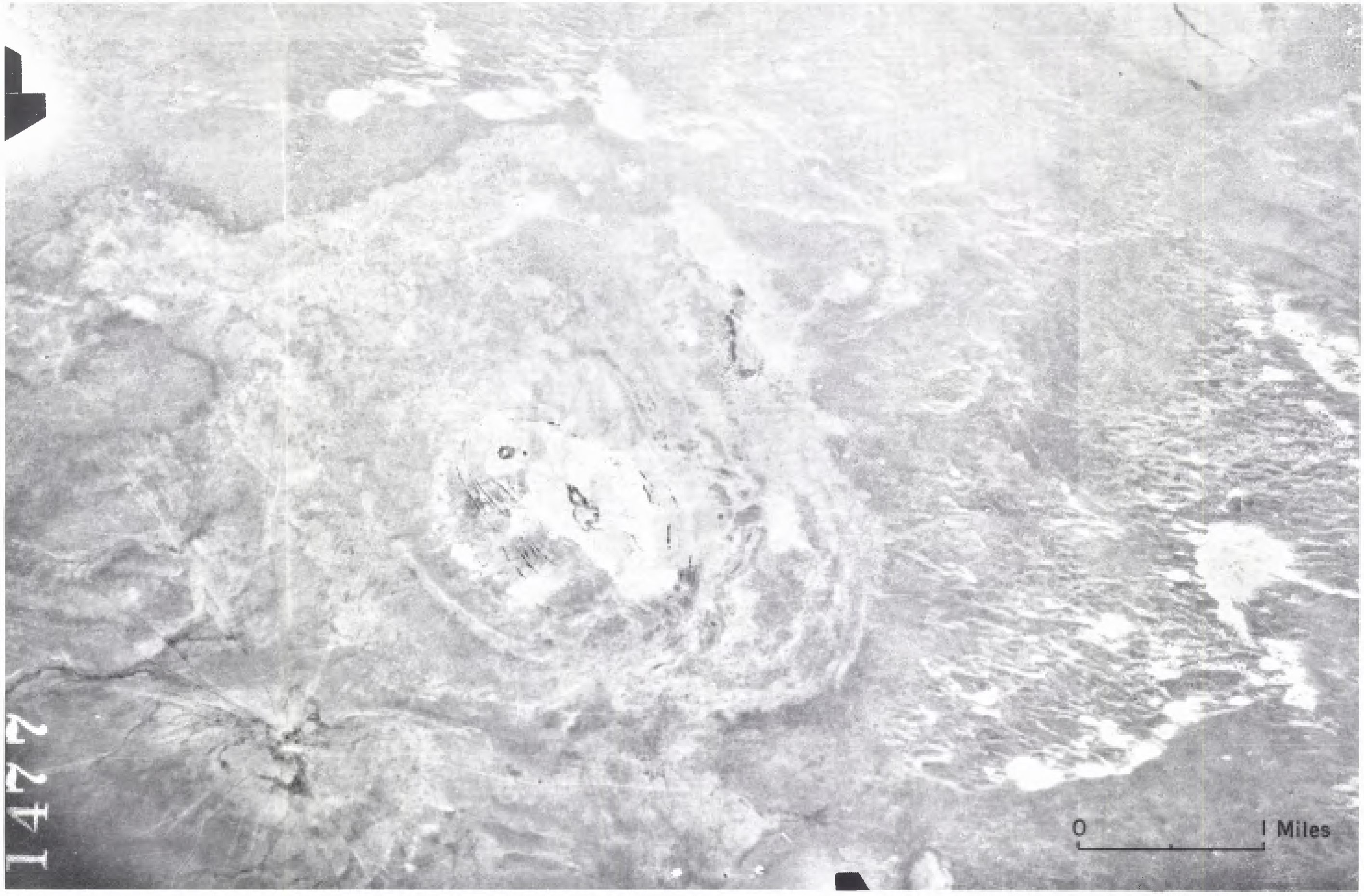

Figure 9. San Simon sink illustrating annular fractures produced by collapse in early 1930's. Army Map Service index photo, 1954.

of Elkins, the area east of Diamond Mound and north of Pavo Mesa, the area southwest of Pavo Mesa and the area east of Clayton Basin.

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