BUREAU OF ECONOMIC GEOLOGY
The University of Texas
Austin, Texas 78712

Peter T. Flawn, Director

Report of Investigations—No. 51

Relation of Ogallala Formation to the Southern High Plains in Texas

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ABSTRACT

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 and have documented the occurrence of Pliocene deposition as far southeast as Sterling County. The limit of characteristic Ash Hollow seed floras is extended to the southeast. An abandoned Pliocene and Pleistocene valley is described across a prong of Edwards Plateau south of Big Spring, and the drainage of the late Pleistocene Lake Lomax is determined to have occurred in pre-Bradyan Wisconsinan time. A meaningful physiographic boundary cannot be drawn between the southern limits of the High Plains and the Edwards Plateau.

INTRODUCTION

The High Plains surface is the dominant physiographic feature of central-western and northwestern Texas (Sellards, Adkins, and Plummer, 1933, fig. 3). It is a high plateau, sloping generally toward the southeast. This plateau is terminated toward the east by a striking escarpment, and its western extent is likewise abruptly terminated in eastern New Mexico. Northward, the High Plains surface is transected by the trench of the Canadian River valley, but the upland surface extends through the Texas panhandle, across the Oklahoma panhandle and western Kansas into western Nebraska.

Since the early work by Johnson (1901; 1902) and Darton (1905; 1920), the High Plains as a physiographic feature has been regarded as virtually coextensive with the deposits of the Ogallala Formation, and the Plains are terminated to the east, west and north at the truncated limits of this formation. To the south and southeast, however, the limits of the High Plains are less firmly fixed because here the upper surface of the Ogallala Formation does not stand as the capping layer of a plateau above the adjacent terrain, nor does the truncated edge of the Ogallala Formation cap a prominent escarpment. In fact, in the region north of Pecos Valley (Leonard and Frye, 1962) and west of Sterling City, it is indeed difficult to draw a meaningful line of separation between the High Plains and the Edwards Plateau as physiographic subdivisions based on topographic expression (Pl. I, B) and, as physiographic units, they cannot be differentiated, even by the arbitrary acceptance of the feather edge of the Ogallala Formation as the dividing line.

Furthermore, southeast from the High Plains scarp, particularly in Borden and Scurry counties, there are outliers of Ogallala that coincide with the projected gradient of the High Plains surface; these pose the question if such areas should be regarded as outliers of the High Plains,

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even though within the Osage Plains region. An additional complicating factor is the presence of extensive Pleistocene lake basins within the area of the Ogallala Formation (Evans and Meade, 1945) and within the region that has generally been classed as High Plains. Therefore, this physiographic feature, so clearly recognizable farther north in Texas and in western Kansas (Frye and Leonard, 1952), becomes difficult to define at its southern and southeastern limits.

It is the purpose of this report to describe the regional relations of the southern extremities of the Texas High Plains, to list fossil seeds from the Ogallala Formation in some of the outliers and from near its southern limit, and to describe the extensive late Pleistocene lake that existed in southwestern Howard and adjacent counties.

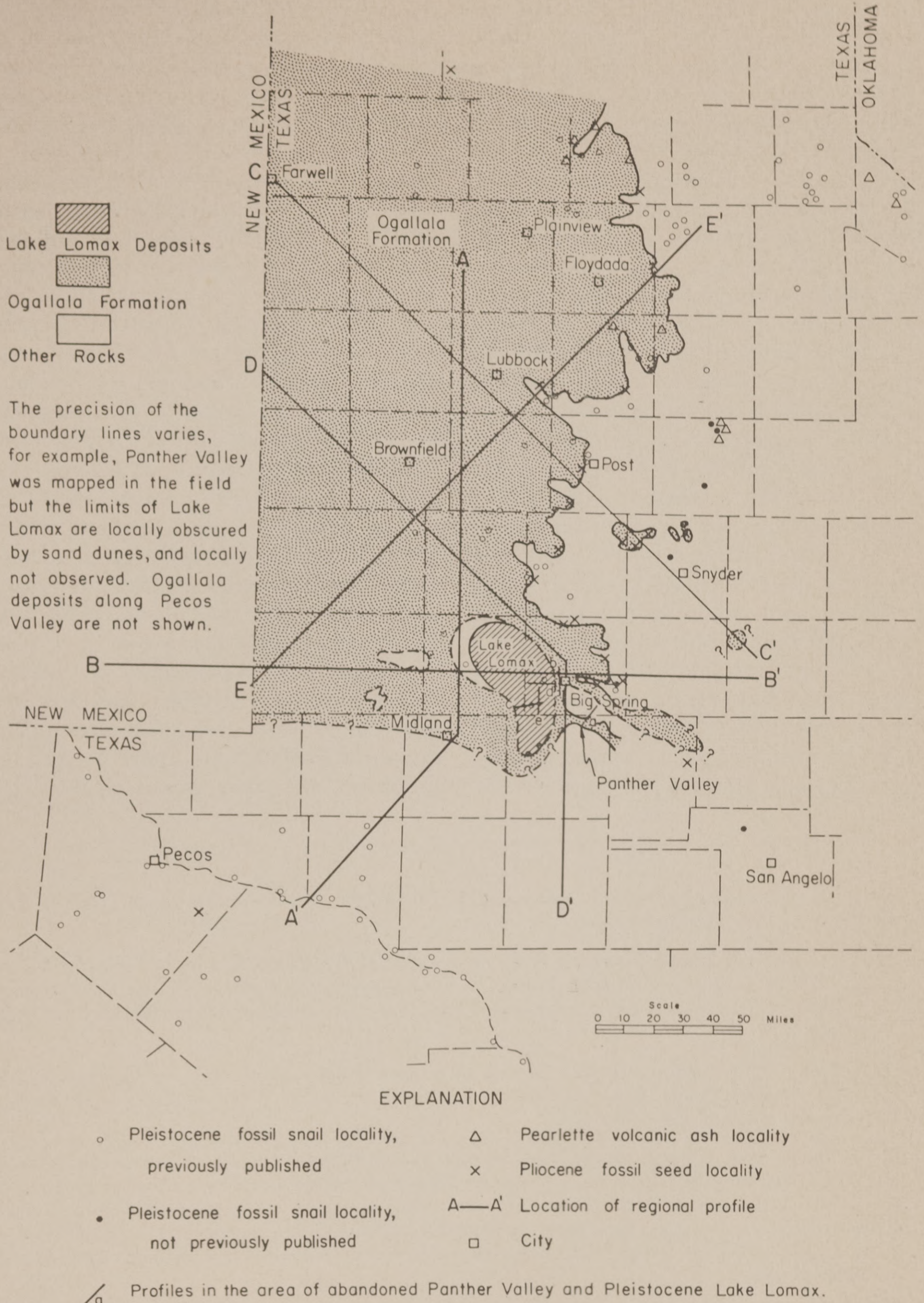

FIGURE 1. Map of central-western Texas showing locations of cross sections on figures 2 and 3 and locations of Pleistocene fossil snail faunas and Ogallala fossil seed floras used in this report.

REGIONAL PHYSIOGRAPHY

In central-western Texas the High Plains is an extensive table-land on top of the modified upper surface of the late Tertiary plain of coalescent alluviation, defined by the top of the Ogallala Formation. Pleistocene veneers of sheet flood or eolian deposits occur on large parts of the surface; in some areas the upland plain is indented by Pleistocene lake basins; and locally the High Plains are notched by Pleistocene and Recent canyons. However, the surface preserves in general the initial depositional slope of the Ogallala sediments as it has been modified by subsequent regional tilting, and, perhaps, very gentle warping.

The general character of this surface is shown by the generalized profiles, located in figure 1 and presented in figure 2. The present gradient of the surface is about 5 feet per mile from north to south, 6 to 8 feet per mile from west to east, and 8 to 9 feet per mile from NW to SE. At right angles to the direction of maximum gradient shown in figure 2, the profiles show a slope of a little more or less than 2 feet per mile from SW to NE, and therefore, if we ignore subsequent structural movement, the suggested initial slope is from slightly west of NW to slightly east of SE and is at a rate of approximately 10 feet per mile. The character of the sediments in the upper part of the Ogallala Formation suggests that the gradients on which they were deposited were less than this, and the flora and invertebrate fauna of the formation suggest that during most of the time of its deposition the region was at a lower altitude and received more precipitation than it now does (Frye and Leonard, 1957; 1959). However, below the upper surface of the Ogallala sediments there developed an extensive thick zone of soil caliche that has been modified by several cycles of brecciation and recementation (Swineford, Leonard, and Frye, 1958) and that now serves as a resistant capping layer. Interspersed throughout the upper part of the formation are other zones, wherein the

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Figure 2. Generalized schematic physiographic profiles in central-western Texas (plotted from 1:250,000 Army Map Service Sheets).

A. From west-central Hale County south to north-central Midland County, and then southwest along the western limit of the Edwards Plateau to the Pecos River in southwest Crane County, showing the southern feather edge of the High Plains, the Cretaceous bedrock divide, and the Pecos Valley.

B. West-east from southwestern New Mexico to western Nolan County, showing the eastern component of High Plains slope. Lake Lomax basin, and the Osage Plains standing above the projection of the High Plains surface.

C. Southwest from Farwell, at the New Mexico line in Parmer County, to northwestern Nolan County, showing the High Plains (Ogallala Formation) slope along its maximum gradient, its eastern escarpment in Garza County, the prominent outliers in northeastern Borden and northwestern Scurry counties, the Pleistocene veneered upland in the Snyder area, and the bedrock surface of the Osage Plains rising above the projected slope of the High Plains in northwestern Nolan County.

D. Southwestward from the New Mexico line in Cochran County to central Howard County, and thence southward to central Reagan County, showing the regional slope of the High Plains surface, and the position of the Edwards Plateau (Cretaceous) standing above the projected slope of the High Plains surface.

E. Northeastward from the New Mexico line in Andrews County to central Motley County showing the High Plains surface, at right angles to the direction of its major regional slope, and the High Plains escarpment at the Floyd-Motley County line.

sediments are irregularly cemented with calcium carbonate and locally silica, that help to give the Ogallala Formation the greatest resistance to erosion of any of the pertinent stratigraphic units, with the exception of the limestones of Cretaceous age (Fredericksburg). Therefore, it is in the region where the Ogallala pinches out against the resistant limestone, or feathers out onto gently sloping surfaces developed

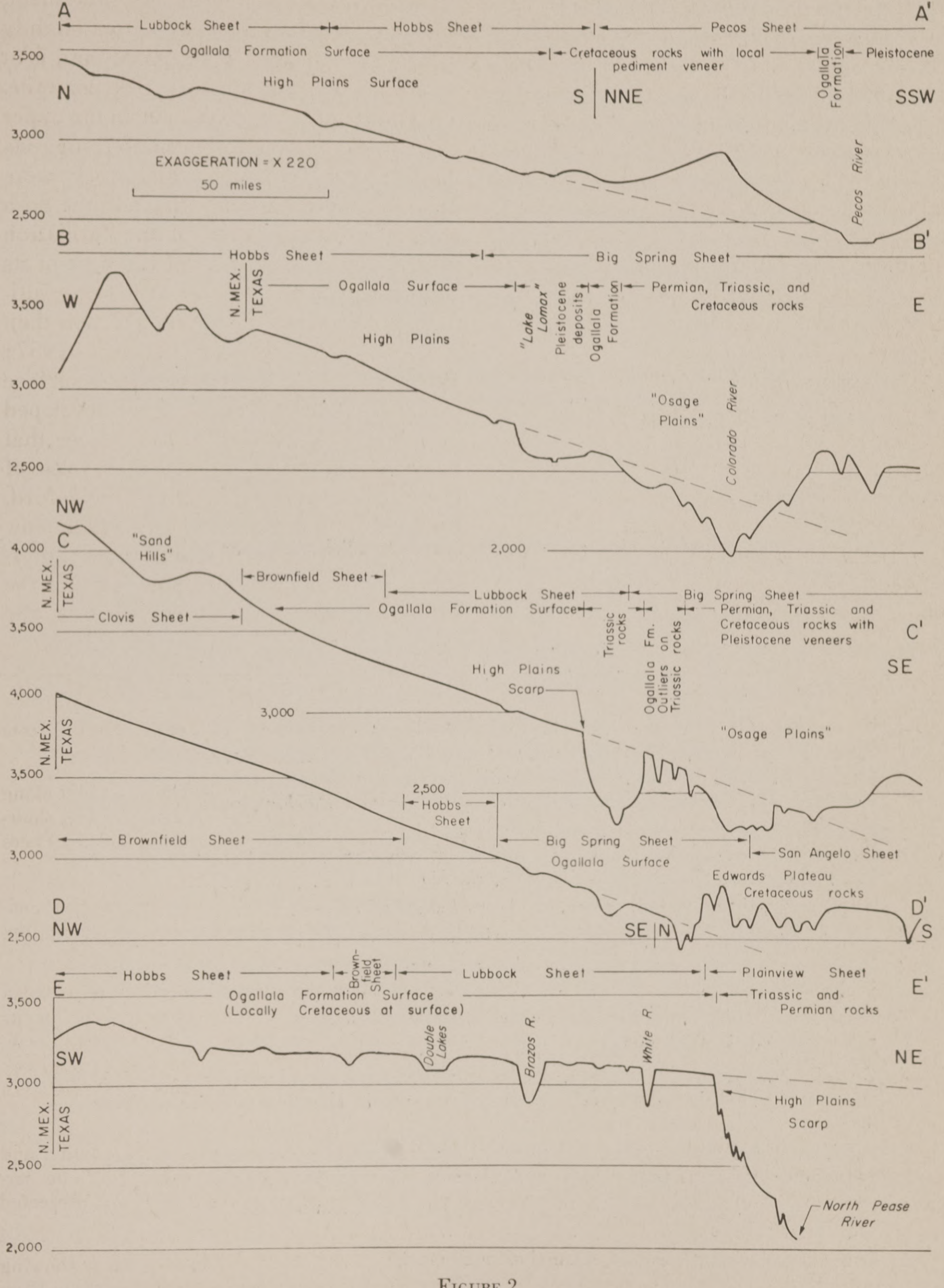

Figure 2
(explanation on opposite page)

on these limestones, that the limits of the High Plains are indistinct. Where upland surfaces underlain by limestones of the Fredericksburg Group stand distinctly above the surface of the Ogallala Formation, a differentiation between the Edwards Plateau and the High Plains is clear.

The Ogallala Formation and the High Plains surface.—It is not our intention here to redescribe the stratigraphy of the Ogallala Formation in western Texas (Frye and Leonard, 1957; 1959) but rather to discuss the stratigraphy and fossil seed floras only insofar as they are involved in identifying the deposits below the surfaces of outliers to the southeast of the boundary escarpment that marks the generally accepted limits of the High Plains.

The major body of rock that has long been considered an isolated outlier of the Ogallala Formation (Sellards, Adkins, and Plummer, 1933) is in the NW to SE elongate belt shown on the geologic map of Texas as extending from the northeastern corner of Borden County to south of Roscoe in Nolan County. At the northern end, this high mesa is bounded by a precipitous escarpment exposing Cretaceous limestones. The northwestern part of this upland surface is veneered with Ogallala deposits (Pl. I, C) that contain a diagnostic seed flora, and where the formation is thick it displays the characters described in the section below.

Stratigraphic section measured in road cuts and creek bank exposures along ½ mile of E-W road from 4 miles south and 2½ miles west of highway intersection north of Fluvanna, Scurry County, Texas (1962, A. Byron Leonard).

	Thickness (feet)
Pleistocene Series—	
"Cover Sands"—	
14. Sand, red, tan and white, mottled, fine with some silt, caliche in upper part	8.0
Pliocene Series—	
Ogallala Formation—	
Kimball(?) floral zone—	
13. Sand, fine, tan, irregularly cemented with large masses of caliche; upper 5 feet densely welded caliche with nodular surface	23.0
Ash Hollow floral zone—	
12. Sand, light gray, generally but irregularly cemented with caliche	3.0
11. Sand, fine to medium; contains lenses of coarse sand, scattered quartz pebbles in some zones; deep brick red in lower part grading upward to pinkish gray and gray; strongly cemented with $CaCO_3$ in upper and lower parts; contains *Biorbia papillosa* and *Panicum eliasi* in lower part	15.0
10. Silt and fine sand, brick red, weakly and irregularly cemented at top, massive; contains *Biorbia papillosa*, *Panicum eliasi*, and *Berriochloa* sp.	3.0
9. Sand, fine, pale brick red, cemented; forms ledges on slopes	0.4
8. Silt and fine sand, tan to pale brick red, friable, massive	1.0
7. Sand, fine to medium, and gravel, weakly cemented to well cemented at top; coarse sand in discontinuous lenses; pebbles are Cretaceous limestone and crystalline rock	8.0
6. Sand, fine, pinkish tan to pale buff; caliche nodules throughout	6.0
5. Sand, fine, tan to buff, massive	5.0
4. Gravel, coarse, gray, tan to white; grades laterally to fine gravel and coarse sand, bedded and cross-bedded, irregularly cemented; gravels contain abundant pebbles of Cretaceous limestone	9.0
3. Sand, fine, and silt, massive, red brown, bedded; irregular cementation gives mottled appearance; contains some pebbles of Cretaceous limestone in uppermost part	10.0
2. Sand, fine, well sorted, massive, tan, compact but not cemented; contains some dispersed nodules of caliche	10.0
1. Cover of colluvium to level of channel of small creek	5.0
Total	106.4

Figure 2, C shows upland surfaces that are concordant with the projection of the slope of the High Plains surface. However, eastward from the Borden-Scurry County line the Ogallala pinches out against the very gently rising surface of Cretaceous limestones; northeast of Fluvanna the upland surface is underlain by recemented colluvium and weathering residuum that rest directly on Cretaceous rocks.

South and southeast 6 to 8 miles from Fluvanna along this upland belt, there occurs an irregular low scarp that marks the limit of the Ogallala Formation in this direction. Farther southeast, in central Scurry County, the upland level drops well below the projected slope of the Ogallala (High Plains) surface, and here Triassic rocks are veneered with several ages of Pleistocene deposits, locally yielding a few faunas of fossil snail shells and elsewhere containing a few pebbles derived from the older Ogallala Formation.

Although the upland surface displays no distinct physiographic break toward the southeast, in the area northwest of Roscoe near the Mitchell-Nolan County line the projected gradient of the Ogallala surface is again concordant with the topographic surface, and in this area very thin Ogallala deposits cap the upland. Unfortunately, as yet fossil seeds have not been collected in the Roscoe area to confirm the lithologic and physiographic correlation.

Another outlier of Ogallala Formation (not shown on the geologic map of Texas) occurs in northern Sterling, southwestern Mitchell, and southeastern Howard counties. The deposits in this area (south of Beals Branch, Colorado River) are relatively thin; they reflect a local sediment source in contrast to those farther northwest (Pl. I, G); and they pinch out against the gently rising surface of the Cretaceous limestones (Pl. I, B). Although these rocks are an outlier of Ogallala Formation, they are nearly connected with the main body of the formation in southeastern Howard County. Furthermore, south of this area of Ogallala, on the slightly higher Edwards Plateau surface, there are local and discontinuous deposits (as much as 8 to 10 feet thick) of locally derived sediments. In some places these highly calcareous deposits are cemented at the top to form a dense capping caliche, and at one locality (7½ miles NE of junction of State Highway 158 and U. S. Highway 87, Sterling County) a fossil seed of *Berriochloa* was collected.

An extensive outlier of Ogallala has been mapped in northern Upton and southern Midland counties (Sellards, Adkins, and Plummer, 1933, map). Unlike the outliers to the southeast, these rocks do not stand as a mesa or upland area but rather underlie a surface that is topographically continuous with the mapped Cretaceous rocks on all sides. The topographic relationship of this supposed outlier to the High Plains surface is shown in figure 2, A. The field relations throughout the region confirm the topographic implication that the Ogallala Formation feathers out southward in northern Midland County on the gently rising surface of Cretaceous limestones. The surficial veneer in the area of this formerly supposed Ogallala outlier is quite thin (Pl. I, D, E), ranging from less than 2 feet to somewhat more than 12 feet, and consists predominantly of sediments derived from the adjacent Cretaceous rocks. The character of the sediments, of the caliche soil profiles, and of the physiographic relations, combine to indicate an early- to mid-Pleistocene age for these surficial veneers. The upland surface underlain by Cretaceous limestones in Midland and Ector counties (and parts of Andrews, Winkler, Crane, and Upton counties) is genetically related to the surface of the Edwards Plateau rather than to that of the High Plains (fig. 2, A). In this region the physiographic units called High Plains and Edwards Plateau merge imperceptibly into a continuous surface.

Fossil seeds of the Ogallala Formation.—Following the pioneering studies of Elias (1931; 1935; 1942) fossilized plant remains consisting of the hulls of grass fruits, the nutlets of various small herbs, and the stones of a single tree (*Celtis*, the hackberry) became, because of widespread occurrence and demonstrated stratigraphic significance, highly useful tools in the recognition of the Pliocene Ogallala Formation and of its several members (Frye and Leonard, 1957; 1959; Frye, Leonard, and Swineford, 1956). The most abundantly fossiliferous Ogallala sediments are found in the central Great Plains; exposures in northwestern Kansas and southwestern Nebraska almost invariably contain fossils representing at least one plant species. In this region local floras are also likely to be varied; in Decatur County, Kansas, for example, as many as nine different species of prairie plants are known from a single locality (Frye, Leonard, and Swineford, 1956, fig. 4). Ogallala floras tend to decrease both in variety and population numbers toward the southern limits of the formation, but as many as six species are known from a single floral assemblage as far south as Howard County, Texas (Frye and Leonard, 1957, p. 48; fig. 6).

There is also some geographic variation in the floras toward the south. For example, nutlets of *Biorbia fossilis* (Berry) Elias, that occur widely distributed in great numbers in Ogallala sediments in the central Great Plains, are replaced south of Prairie Dog Town Fork of Red River in Texas by the smaller nutlets of *B. papillosa* Leonard. At approximately the same latitude, the occurrence of *Panicum elegans* Elias gives way to that of *P. eliasi* Leonard; although there is a zone of sympatry in the case of each of the two pairs of species, intergradation between them has not been observed.

For reasons not yet fully understood, fossil seeds in the Ogallala are less likely to be found in fine-grained sediments than in relatively coarse clastics. The general and rather pronounced trend toward reduction in average grain size observed in Ogallala sediments as the southern limits of the formation are approached seems to be correlated with the fact that fossil floral assemblages here become increasingly local in distribution. However, useful floral assemblages can be found in many local exposures of reasonable extent if sufficient diligence is used in the search.

The generally excellent preservation of floral remains found in the Ogallala Formation seems attributable to infiltration by silica; the hulls and stems of grasses, nutlets, and stones are replaced with opal, and thin sections commonly reveal good to excellent cellular detail. The remarkable preservation of the known plant remains in Ogallala sediments seems related to deposition in the original tissues of silica that probably served as a nucleus for further deposition of silicon dioxide after the seeds came to rest in the deposit. Thus the occurrence of the numerous, well-preserved "seeds" (actually only the fertile glumes or hulls) of such grasses as those found in the tribes *Stipeae* and *Paniceae* is correlated with the fact that the epidermis of the fertile glumes of these plants is indurated during life by deposits of silica in the tissues. At the same time, the absence of *any* evidence of the existence of other plants that might be expected to have lived with those now known as fossils is probably accounted for, at least in part, by their lack of stored silica in the original tissues.

Several flora assemblages are characteristic of stratigraphic zones within the Ogallala Formation (Frye and Leonard, 1959, p. 21). The Valentine Member of the northern Plains (in Texas, Valentine, Ash Hollow, and Kimball are used as floral zones) is characterized by the occurrence of several species of *Stipidium*, but in Texas *S. commune* is the unique representative of the Valentine floral zone. The Ash Hollow floral zone comprises a variety of grasses, nutlets of several forbs, and, like the other zones, locally abundant aggregations of the stones of *Celtis willistoni*. In Texas, *Stipidium* is not well represented in Ash Hollow sediments; among the few species known, *S. intermedium* Elias is by far the most common. The genus *Berriochloa* is better represented; at least four species are known from the Ash Hollow floral zone. The grasses and forbs characteristic of the basal part of Ash Hollow sediments as recognized in the central

Great Plains are seemingly absent, and it may be that the lowest part of the Ash Hollow zone is not present along the escarpment of the High Plains in Texas, from whence the major part of the Ogallala exposures were studied. The Kimball floral zone is not well known in Texas, but adequate floral assemblages were described from Briscoe County (Frye and Leonard, 1957, p. 15).

Fossil floral assemblages have been useful not only in the zonation of the Ogallala Formation of Texas but have aided in the recognition of the limits of Ogallala deposition on outliers east of the principal High Plains escarpment, and in the recognition of deposits of Pliocene age that are not obviously referable to the Ogallala Formation. In this latter category are the isolated minor basin deposits on Cretaceous limestones far from the High Plains escarpment, such as those in a marl pit (7½ miles NE of junction of State Highway 158 and U. S. Highway 87, Sterling County), from which a characteristic Pliocene *Berriochloa* sp. was obtained.

Fossil floral assemblages have aided in defining the limits of Ogallala deposition on the High Plains topographic outlier in the vicinity of Fluvanna, Scurry County. Collections of fossil seeds were made at several locations: 2 miles north and 3 miles west of the farm road intersection just north of the village of Fluvanna; 4 miles south and 2½ miles west of this same intersection (see measured section, p. 10); 6 miles east of Fluvanna near the junction of Farm Road 612 and U. S. Highway 84; and a few individuals at other localities. Another series of outlying remnants of Ogallala Formation occurs still farther east; excellent exposures occur along State Highway 208. Fossil seeds were collected at a locality about ¼ mile east of State Highway 208 and 7 miles north of its intersection with the Santa Fe Railroad in Snyder, Scurry County. The fossils, locally numerous, were collected in pockets of loose sand near the top of the local caprock.

The floral assemblages from these several localities are diagnostic of the Ash Hollow floral zone; locally the assemblages contain adequate numbers of individuals, but few species. Most abundant and most widely distributed are the nutlets of *Biorbia papillosa*, that are comparable in size and other characters with topotypical individuals from Ogallala exposures west of Post, Garza County, except for the tendency of some examples to be smooth or nearly so. The significance of these non-rugose individuals remains to be determined, but the occurrence recalls the more perfectly smooth nutlets associated with the normally rugose seeds of *B. fossilis*. The seed of a grass, *Panicum eliasi*, represented, of course, only by the fertile glumes, is also fairly abundant in these collections; fragmentary examples of an indeterminate species of *Berriochloa* complete the floral assemblages, except for the rare occurrence of stones of *Celtis willistoni*. The last is not limited in occurrence to the Pliocene and so is not of immediate stratigraphic importance. *Biorbia fossilis* (although most abundant in middle Ash Hollow assemblages) is associated with *Panicum elegans* in a floral assemblage known to be diagnostic of the upper Ash Hollow in the central Great Plains; because *Biorbia fossilis*, *B. papillosa*, *Panicum elegans*, and *P. eliasi* occur together in Ogallala deposits in Briscoe County, it may be inferred that *Biorbia papillosa* and *Panicum eliasi* are indicators of the upper part of the Ash Hollow even in the absence of their northern counterparts. Partial confirmation of this conclusion is perhaps afforded by the occurrence of *B. papillosa* in the basal part of the Kimball floral zone in Briscoe County (Frye and Leonard, 1957, p. 15). The Ogallala deposits that mantle parts of the High Plains outliers in northeastern Borden and northwestern Scurry counties are therefore assigned to the middle and upper Ash Hollow zone.

Road-cut exposures near the eastern limits of the city of Big Spring, Howard County, reveal Ogallala floral assemblages that extend the southern known range of *Biorbia papillosa*, *Panicum eliasi*, and

Berriochloa sp. beyond that previously reported. The exposed sediments are generally fine to medium sand, and the flora is not abundantly represented.

The Ogallala floral assemblages from exposures in Howard County, occurring as they do at the southernmost fossiliferous localities known (except for a few fragmentary fossils known from Reeves County in the Pecos Valley), represent almost all the species known from the Ash Hollow floral zone in Texas and include *Berriochloa amphoralis* Elias, *B. conica* Elias, *Celtis willistoni* (Cockerell) Berry, *Panicum eliasi* Leonard, and *Stipidium intermedium* Elias. Only the northern counterparts of *Biorbia papillosa* (*B. fossilis*) and *Panicum eliasi* (*P. elegans*) are missing from these assemblages. Fossils reliably diagnostic of the lower Ash Hollow, such as *Krynitzkia coroniformis* and several species of *Stipidium* and *Berriochloa*, are likewise unknown from exposures in Howard County. From these considerations, it seems safe to conclude that these southernmost Ogallala floral assemblages indicate deposition during the middle to late, but not the early part of Ash Hollow sedimentation. We have discovered little concrete evidence of Valentine sediments south of Floyd County, but the cap-rock probably represents at least part of the Kimball zone, even in the southern extensions of the Ogallala Formation, where no corresponding floral assemblages are known.

To the extent that one may judge ecological requirements of fossil species from knowledge of their nearest living counterparts, it can be asserted that the time of Ash Hollow deposition in the southernmost areas of Ogallala was characterized by a prairie environment of moderate rainfall; soils were probably well drained over a relatively low water table (Hitchcock and Chase, 1959, p. 455). The state of the iron salts in these sediments, as inferred from their generally reddish-tan color, tends to confirm these inductions.

Southwest of Howard County, where the Ogallala Formation feathers out upon rocks of Cretaceous age in the Edwards Plateau, fossil seeds have not been recovered. These generally thin sediments, weathered, and commonly recemented with caliche as well as infiltrated with opal in the upper part, are not suitable materials from which to obtain fossil seeds.

Pleistocene dissection of the High Plains margin.—The erosional modification of the High Plains margin has been as spectacular in some areas as it has been non-existent in others. Northward from Borden County the resistant upper beds of the Ogallala, standing above the relatively non-resistant lower Ogallala, Triassic, and Permian rocks, serve as a cap-rock for a prominent east-facing escarpment (Frye and Leonard, 1963). At the southeastern and southern limits of the High Plains, however, it is the resistant Cretaceous limestones (largely of the Fredericksburg Group) that exert the primary control on the topography. These limestones had formed the positive elements of the pre-Ogallala erosional topography, and although the Pliocene sediments overlapped them in Garza, Borden, Dawson, and Martin counties, they failed to cover them in northern Scurry, Midland, Ector, Glasscock, and Howard counties. Farther to the southeast, the limestones stood above the late Pliocene surface as a distinct upland.

The quantity of rock removed by erosion during the Pleistocene to produce the High Plains scarp north of Howard County appears to be quite large. The maximum depth of erosion appears to occur immediately adjacent to the scarp, and the position of the escarpment seems to have migrated little since Kansan time even though it has increased somewhat in height because of erosion to the east. This is suggested by the position of Kansan deposits west of Post in Garza County and at several other places (Frye and Leonard, 1957). The lesser depth of rock removed east of the scarp is indicated by the topographic positions in north-central Kent County, of several deposits of Pearlette volcanic ash and associated fossil snail faunas, and of pisolitic limestone of the Ogallala Formation to which we were directed by R. C. Baker of the U. S. Geological Survey.

In contrast, farther south the erosional lowering by Kansan time appears to have been much less. This is suggested by the topographic position of Pearlette volcanic ash and associated fossil snail fauna in relation to the Ogallala deposits in eastern Howard County (north of Beals Branch) and by the position of the Pleistocene deposits in central Scurry County. With these observations in mind, we conclude that the area of eastern and central Borden County experienced the most extensive mid- to late-Pleistocene erosion. In striking contrast, the surface at the southern fringe of the Ogallala deposits has been scarcely modified since Tertiary time.

With the exception of the anomalous eroded area in eastern Borden County, the marked differences seem to be related to the absence or presence of resistant Cretaceous limestones, and this prompts one to speculate that these limestones may have been stripped from the eastern Borden County area during the episode of earlier (pre-Ogallala) erosion.

There is also a pronounced contrast in the erosional histories of the streams that transect the High Plains scarp in the part of Texas north from Borden County (Frye and Leonard, 1957; 1963) with those in Howard County and farther south. Spring Creek Canyon, Yellowhouse Canyon, Blanco Canyon, Tule Canyon, and Palo Duro Canyon all sharply incise the High Plains escarpment and contain Pleistocene deposits at least as old as the Kansan. However, Beals Branch (and Mustang Draw) have evidence of only a Wisconsinan history in their present location. Furthermore, the extensive late Pleistocene lake (Lake Lomax, described on p. 17) did not drain eastward along the present outlet valley until late Pleistocene (perhaps Wisconsinan) time.

Abandoned Panther Valley.—Perhaps the most unusual feature of the southeastern margin of the High Plains is the abandoned filled valley, here named Panther Valley from Panther Creek, Panther Draw, and Panther Draw School, that carried the Pliocene (Ogallala) drainage across northern Glasscock County (south of the Cretaceous upland in south-central Howard County) and into the drainage basin of the North Concho River in northeastern Glasscock and northwestern Sterling counties. The relation of this abandoned valley to the bedrock upland and the Ogallala plain is shown by the generalized cross sections in figure 3, A and B. Although the water-table contours presented by Livingston and Bennett (1944) clearly reflect the position of this filled valley, it was not shown on their geologic map or described in their text. Its presence is clearly demonstrated by the logs and cuttings of irrigation wells drilled during 1962 into the deposits filling the bedrock valley. The floor of this valley is approximately on the projection of the gradient of the Ogallala surface from west of the Lake Lomax basin, but the upper part of the fill is probably Pleistocene in age. In fact, it seems certain that early and mid-Pleistocene drainage flowed through this valley toward the southeast. Although we were unable to obtain field data pertinent to the point, Ogallala deposits may underlie the floor of parts of the upper reaches of the North Concho Valley. As exposures are sparse and our field time was limited, it was not possible to examine North Concho Valley in detail, but in northwestern Tom Green County a few fragmentary *Succinea*, together with the nature of the soil caliche, suggest that the exposed part of the valley fill is early Pleistocene rather than Pliocene in age. To the best of our knowledge, abandoned Panther Valley and the associated part of North Concho Valley is the only filled and abandoned Ogallala valley segment along the eastern margin of the High Plains in Texas.

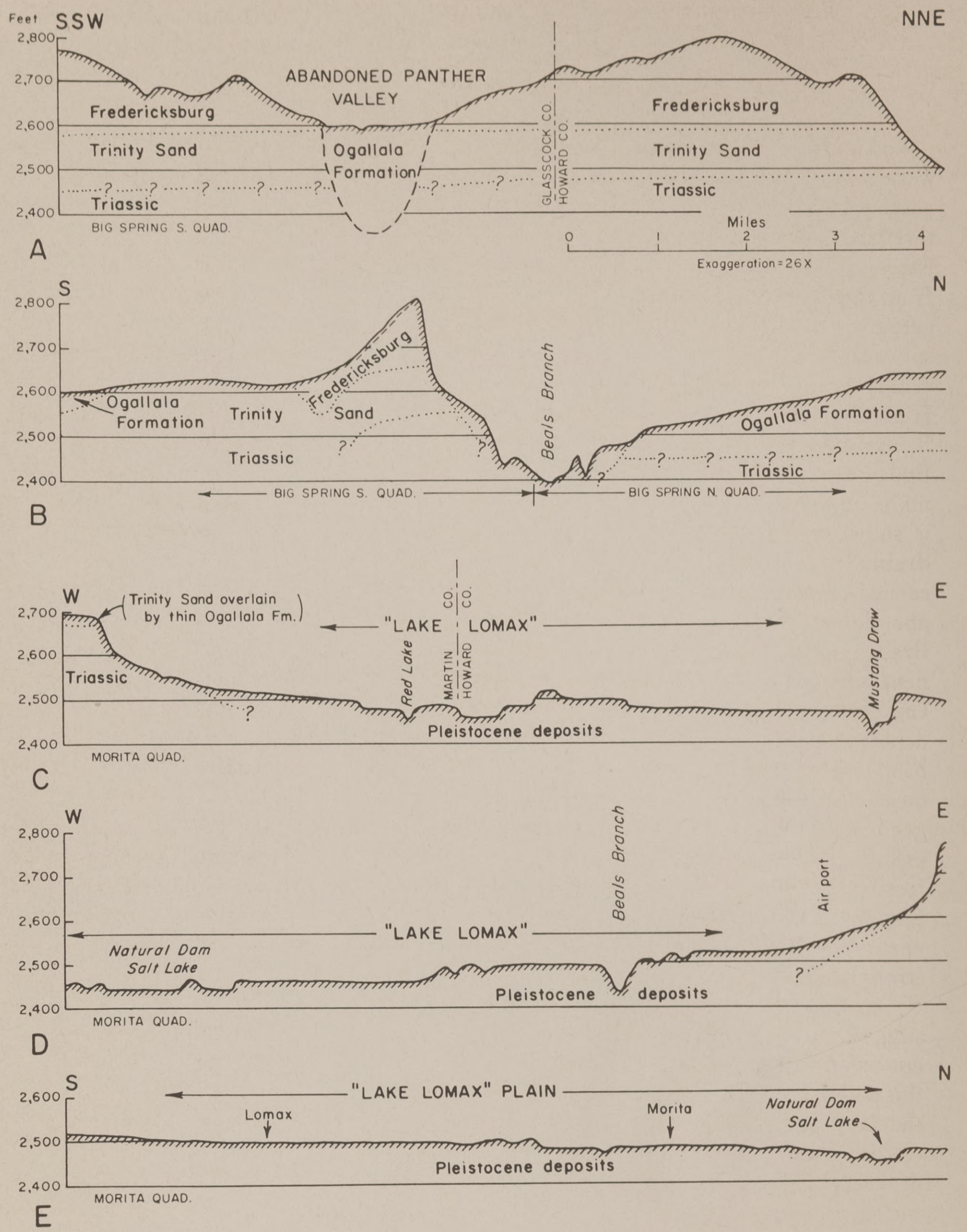

FIGURE 3. Cross profiles in the Big Spring region showing the abandoned Pliocene "Panther Valley" and the late Pleistocene "Lake Lomax." Cretaceous stratigraphy is adapted from Livingston and Bennett (1944), and profiles were plotted from the Big Spring North, Big Spring South, and Morita quadrangles.

A. South-southwestward to north-northeastward in southern Howard and northern Glasscock counties, showing the abandoned Panther Valley.
B. North-south across the western end of Big Spring showing the relation of Beals Branch valley to the Cretaceous upland and the Ogallala surface.
C. West to east across the western part of Lake Lomax basin.
D. West to east across the eastern part of Lake Lomax basin.
E. North to south through the central part of Lake Lomax basin.

West and southwest of Big Spring in southwestern Howard, southeastern Martin, and northwestern Glasscock counties, occurs the partly filled basin of an extensive Pleistocene lake, here named Lake Lomax from the small community of that name located on the surface of the lake plain in southwestern Howard County. The general setting of this lake with respect to the High Plains surface is shown in figure 2, B; its topographic character is shown in figure 3 (C, D, and E); and a view of the plain developed on the lacustrine deposits is shown in Plate I, A. The basin is now drained by Mustang Draw (which at an earlier stage presumably flowed through abandoned Panther Valley) and Beals Branch to the Colorado River. A prominent escarpment, exposing Triassic and Cretaceous rocks overlain by thin Ogallala deposits, marks the western limit of the basin in southeastern Martin County. The toe of this scarp is a pediment that is graded to the upper level of lacustrine deposits in the basin (figs. 2, B; 3, C). The fossil snail faunas in these sediments suggest an early Wisconsinan age (or perhaps earlier within the Pleistocene), and the strongly developed Sangamon Soil (Pl. I, F) in eolian deposits capping the scarp suggests that the development of the present basin took place after the formation of this soil profile. The Pleistocene deposits in the lake basin are horizontal, and at the eastern edge (where the lake basin is now drained by Beals Branch) they approach but do not reach the upper level of the Ogallala Formation (fig. 2, B).

The general level of the flat plain on Lake Lomax deposits is indented by relatively minor secondary depressions that contain terrace deposits at a level below the general lake plain, and by the still deeper depressions that form the basins of Red Lake and Natural Dam Salt Lake. Natural Dam Salt Lake is held behind a low natural sill but above that level is drained by way of Sulphur Springs Creek into Beals Branch. Red Lake lacks a defined surface outlet and may be classed as undrained. Just west of Big Spring, Beals Branch flows in a narrow steep-sided canyon cut in relatively unconsolidated Pleistocene deposits and at the west edge of the city cuts through slightly higher Ogallala deposits.

An extensive tract of sand dunes occurs in the northern and northwestern parts of the basin and extends out of the basin onto the surface of the Ogallala. A dune tract also occurs at the southern end of the basin, particularly in northwestern Glasscock County, and here has encroached not only over some Ogallala but also onto the edge of the Cretaceous bedrock area.

The late Pleistocene sediments of Lake Lomax, although texturally not unlike much of the Ogallala Formation, are quite distinctive in appearance. They consist predominantly of fine to medium sand and silt, are gray to ash gray in color, contain zones of abundant small gypsum crystals (locally the gypsum crystals are so abundant that they interlock), and are thick bedded to locally laminated. At a few places, 20 to 25 feet below the top of the lacustrine deposit, red sand with gypsum crystals was observed. The surface soil is thin and relatively poorly developed.

The origin of the extensive basin that contained Lake Lomax is not clearly understood. Although Livingston and Bennett (1944) discussed collapsed sinkhole features in the area of Cretaceous outcrop, they did not refer to this extensive basin, nor did they present subsurface data that shed light upon the subject. Nevertheless, the only plausible explanation for this large depressed area is that it was formed by the coalescence of a series of solution-subsidence, or collapse, areas resulting from water movement in the bedrock. In size and general relationships, the Lake Lomax basin suggests a genetic similarity to the Ashland-Englewood basin of southwestern Kansas and Oklahoma (Frye and Schoff, 1942). It seems reasonable that solution-subsidence may have occurred at several times and that the present minor basins of Red Lake and Natural Dam Salt Lake are relatively recent subsidence areas, rather than being merely the unfilled parts of an earlier, more extensive, basin. Also, the times of basin formation are not known with accuracy. That its present extensive development was post-Ogallala is indicated by the regularity of the slope of the Ogallala surface to the west, north, and east of the basin; by the elevations of the bedrock floor and alluvial fill of abandoned Panther Valley; and by the sharpness of the escarpment along the western side of the basin. That the present configuration of the basin occurred during late Pleistocene time is indicated by the fossil snail faunas in the lake deposits; by the youthful character of the canyon of Beals Branch developed in weakly resistant beds west of Big Spring; by the weakly developed soil profiles in the surface of the lake deposits; and by the youthful character of the sand dune tracts that have been derived from the sediments within the basin. At only one place (8½ miles north, 7 miles west of Garden City, Glasscock County) did we observe evidence of earlier Pleistocene lakes that may have occupied the basin. Here, on the north side of Mustang Creek, are exposed the typical Lake Lomax gray-green silt and fine sand (lacking gypsum) containing a fossil snail fauna and a moderately developed soil in the top. On the south side of the creek at a slightly higher elevation is exposed gray-green sand with a strongly developed caliche in the upper part that probably is the Yarmouth Soil; the caliche has been secondarily pitted by solution and is overlain by typical "cover sands" which in turn contain a well-developed Sangamon Soil in their upper part; the Sangamon Soil is overlain by dune sand that presumably was derived from Lake Lomax. In any event, the character of Beals Branch valley west of Big Spring indicates that the Lake Lomax basin was not drained by way of its present outlet prior to mid-Wisconsinan time.

Fossil molluscan assemblages.—Assemblages of fossil mollusks have long been utilized in stratigraphic paleontology in studies of Pleistocene deposits on the High Plains (e.g., Frye and Leonard, 1952; 1957). It is well known that there is a diagnostic molluscan faunal assemblage characteristic of each of the major Pleistocene depositional intervals, although it is obvious that such a diagnostic assemblage does not occur at every fossiliferous locality. Fossil molluscan assemblages have been previously reported from Texas (Frye and Leonard, 1957; 1963; Leonard and Frye, 1962) and will not be reviewed here, except to point out that everywhere on the High Plains, as well as elsewhere in the mid-continent region of the United States, Wisconsinan fossil molluscan assemblages are characterized by drastic reduction in variety of composition, and generally by concomitant reduction in local population numbers, following the formation of the Brady Soil. Although a subtle faunal zonation (Leonard, 1951) occurs in the pre-Bradyan of the northern High Plains, a single major faunal break persists throughout the Great Plains region. This has led to the general reference to pre-Bradyan time as "Early Wisconsinan" and to post-Bradyan time as "Late Wisconsinan" in this region. This has been done even though it is now known that this break is approximately equivalent to the Twocreekan interstadial and that "Early Wisconsinan" time in Illinois encompassed a series of complex events reflected by a sequence of distinctive faunal zones (Leonard and Frye, 1960) and glacial advances and retreats extending from perhaps 70,000 radiocarbon years B.P. to approximately 12,000 radiocarbon years B.P. During and/or following the Bradyan interval, ecological conditions trending toward greater aridity resulted in the extinction on the High Plains of the greater part of the "Early Wisconsinan" molluscan faunas. In summary, the faunal break between pre-Bradyan and post-Bradyan Wisconsinan is everywhere a distinct and easily recognized change. It is this faunal change that is of especial interest in connection with the history of Lake Lomax.

A conclusion bolstered by literally hundreds of collections is that *Pupilla muscorum* and *P. blandi*, both commonly and widely distributed in early Pleistocene sediments, were extirpated from molluscan faunas in the Great Plains region at or immediately following the Bradyan soil-forming interval. *Pupilla* is, therefore, diagnostic of pre-Bradyan Wisconsinan sediments, and no exceptions are known to its complete absence from the latest Pleistocene faunules. This observation is especially useful in the definition of basin-fill deposits that commonly do not reflect regional geological and meteorological conditions.

Molluscan faunal assemblages are not abundant in the sediments of Lake Lomax deposited when it was draining through Panther Valley, or was for a time undrained. The sandy sediments are highly gypsiferous, and it is probable that ecological conditions, both aquatic and terrestrial, were not highly favorable to mollusks, even during pre-Bradyan Wisconsinan time. In spite of generally unfavorable habitat situations, molluscan faunal assemblages locally occur in the shallow water deposits of Lake Lomax and are judged to be related to the lake level when the basin was being drained through Panther Valley. Some of our local collections are so sparse as to suggest post-Bradyan Wisconsinan faunal assemblages, but in general the features of pre-Bradyan Wisconsinan assemblages are present and are confirmed by the physiographic position of the deposits. The composite fauna from the highest stage of Lake Lomax consists of *Gastrocopta cristata*, *Gyraulus circumstriatus*, *Helicodiscus parallelus*, *Pupilla blandi*, *P. muscorum*, *Pupoides albilabris*, *Succinea* cf. *grosvenori*, *S.* cf. *avara*, *Vallonia gracilicosta*, and *V. parvula*. At two localities (4 miles S-SE of junction of Highways 137 and 176 in Martin County, and 9 miles W of junction of U. S. Highway 87 and State Highway 176 in Howard County) virtually this entire assemblage was collected. The greater part of this assemblage consists of long-ranging species that locally occur even in "Late Wisconsinan" assemblages, but *Pupilla blandi* and *P. muscorum*, as well as *Vallonia gracilicosta*, are nowhere known from post-Bradyan Wisconsinan molluscan faunal assemblages. It can be concluded, therefore, that the narrow channel that now drains the old Lake Lomax basin became active sometime during "Early Wisconsinan" time, at about which time, of course, the Panther Valley exit was abandoned.

CONCLUSIONS

The physiographic expression of the southern High Plains in Texas is gradational with the Edwards Plateau through a belt where the late Tertiary Ogallala Formation (characteristic of the High Plains) feathers out onto an erosional surface on the Cretaceous rocks that make up the Edwards Plateau. Although Pliocene (Ogallala) deposition occurred along the trench of the Pecos Valley in Texas (Leonard and Frye, 1962), this narrow belt of alluviation was separated from the vast extent of the late Tertiary alluvial plain (extending northward to South Dakota) by a belt of erosional topography on Cretaceous limestones that genetically represents the westward extension of the Edwards Plateau. This relationship has produced a topographic continuity between the Plains and the Plateau that renders the recognition of a line of physiographic demarcation difficult to impossible, even by the arbitrary use of the limits of the Ogallala Formation because these latest Tertiary deposits feather out and are discontinuous on the Tertiary erosion surface. The problem is further complicated by the presence in this area of extensive Pleistocene lake basins (e.g., Lake Lomax) that modify the topography of the late Tertiary surface, and by the abandoned Panther Valley that connected the extensive Ogallala area to the North Concho basin.

The southeastern margin of the High Plains is complicated in a very different way. Here there are remnant outliers of Ogallala Formation, which are outliers of the High Plains, east of the bounding escarpment. Furthermore, toward the southeast a prominent valley outlet of late Tertiary drainage (abandoned Panther Valley) extends across segments of what otherwise would be considered Edwards Plateau. It is suggested that in this part of Texas, the High Plains, Osage Plains, and Edwards Plateau merge in a transition zone and that a sharp line of physiographic separation is not only virtually impossible to draw, but if drawn, is meaningless in a topographic sense.

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PLATE I

Field Views

A. Flat depositional plain on the upper surface of the "Early Wisconsinan" (pre-Bradyan) deposits in Lake Lomax. The beds under this surface have yielded several collections of fossil snails. Ten miles west-southwest of Big Spring, Howard County, Texas, looking east-northeast. The Cretaceous upland at Big Spring appears on the skyline near the right side of the photograph (1962).

B. North-central Sterling County, looking south along State Highway 163. The Ogallala Formation pinches out southward, and the High Plains surface, defined by the top of the Ogallala, terminates against the gently rising Cretaceous bedrock which forms the distant skyline (1962).

C. Thin, fossiliferous Ogallala Formation overlying Cretaceous rocks forms the skyline and caps this part of the dissected mesa. Eastward from here the Ogallala Formation pinches out against a very gently rising bedrock surface. View in northeastern Borden County, 4 miles northwest of Fluvanna (in Scurry County) (1962).

D. Pit 2 miles south of the Midland-Upton County line and 200 yards west of State Highway 349. The thin Pleistocene veneer above Cretaceous bedrock in an area formerly mapped as Tertiary rocks and the generally featureless surface are shown. In this region the surficial veneer ranges in thickness from less than 2 feet to more than 12 feet and in many excavations ranges in thickness from 4 to 8 feet. Except in the soil caliche ("E") the material is loose and poorly sorted and consists largely of material from Cretaceous rocks; a few cobbles of Ogallala pisolitic limestone were observed in this pit (1962).

E. The caliche soil profile in the pit shown in "D." This profile displays the morphology and degree of development typical of the Sangamon Soil in this part of Texas and is covered by less than 2 feet of surface rubble (1962).

F. Exceptionally well-developed Sangamon Soil in cover sands. The bench across the middle of the photograph is developed on top of the caliche zone of the soil, and the top of the Sangamon A-horizon is two-thirds the distance from the bench to the top of the cut. Several feet of Wisconsinan eolian deposits overlie the Sangamon Soil profile, and the modern surface soil has been developed at the top. Exposed in railroad cut 1½ miles east-northeast of Stanton, Martin County, Texas (1962).

G. Ogallala Formation from which a diagnostic fossil seed flora was collected. Road cut 0.2 mile south of junction of Farm Road 700 and U. S. Highway 80, east of Big Spring, Howard County, Texas (1962).

A

B

C

D

E

F

G

Index