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QUATERNARY STRATIGRAPHY OF THE WESTERN ROLLING PLAINS OF TEXAS--PRELIMINARY FINDINGS

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ABSTRACT

Quaternary deposits as much as 76 m (250 ft) thick discontinuously cover more than 7,800 km^2 (3,000 mi^2) of the western Rolling Plains of northwestern Texas. The stratigraphy of this sedimentary sequence is complex, reflecting changes in paleoclimate during the late Pleistocene and Holocene Epochs. In addition, there are clear indications of syngenetic structural control of deposition and postdepositional deformation of the Quaternary strata. These effects were caused by regional and local karstic subsidence resulting from dissolution of Upper Permian evaporites, particularly halite, at depths of 120 to 240 m (400 to 800 ft). Dissolution created voids within the bedded evaporites. As the voids expanded the overlying strata collapsed, forming depressions wherein sediment accumulated preferentially. Subsidence also caused local faulting and downwarping of some of the Quaternary deposits. Affected deposits include beds of coarse-grained sediment eroded from the westward-retreating Caprock Escarpment (adjacent to the Rolling Plains). This sediment was trapped within the zone of subsidence, forming a broad bajada at the base of the escarpment. At most sites the coarse-clastic deposits compose the lowest of three genetic components of the regional Quaternary section.

Subsidence continued locally, creating closed basins as much as 2.5 km (1.5 mi) in diameter. These basins became perennial lakes owing to humid conditions during the late Wisconsinan stage. Water levels within the lakes probably were maintained by a high ground-water table in the underlying permeable sands and gravels. The lakes gradually filled with deposits of autochthonous fossiliferous calcareous clay, which form the middle component of the Quaternary section. The quantity of allochthonous sediment and runoff entering the small karstic basins was minimal, as indicated by the lateral uniformity of beds and near absence of coarse-grained sediment from the

lacustrine deposits. The lakes and contiguous subaerial environments supported a diverse molluscan fauna including several species no longer regionally extant. Remains of calcareous algae, diatoms, ostracodes, fish, amphibians, and turtles also are present, as are allogenic shells of terrestrial mollusks and bones and teeth of Rancholabrean mammals.

Subsidence persisted throughout the late Quaternary Period. But by Holocene time, the climate had become relatively dry, so that the number, size, and permanence of lakes in the region were reduced. Holocene strata principally consist of fluvial and eolian sands and silts, thin discontinuous pond deposits, and paleosols. These deposits constitute all or most of the upper component of the Quaternary section. Chronologic control for Quaternary studies in the region is afforded by more than 50 finite radiocarbon dates primarily from analyses of Holocene soil humates and Pleistocene and early Holocene lacustrine material. Paleoindian and Archaic artifacts have been recovered from a few sites including Bison-hunting and -butchering areas.

INTRODUCTION

Previously unrecognized Quaternary deposits extend eastward as much as 50 km (30 mi) from the foot of the Eastern Caprock Escarpment, from Briscoe and Hall Counties southward to Garza County, Texas (Caran and Baumgardner, 1984a) (fig. 1). The deposits thin to the east, abut the escarpment on the west, and are truncated on the north by the headwaters of the Little Red River in southeastern Briscoe County. Originally these sediments may have covered an area of 7,800 km^2 (3,000 mi^2) or more between the valleys of the Little Red River to the north and the Double Mountain Fork of the Brazos River south of Post, Texas. The areal extent of this sedimentary complex has been reduced by erosion during the middle and late Holocene Epoch; at present as little as

1,660 km^2 (640 mi^2) may remain. Thin remnants cover most of the major modern drainage divides, and thick sections are preserved in undissected areas. Similar deposits are found farther east and south, and to the north as well, in the valley of the Prairie Dog Town Fork of the Red River. However, the relation of these sediments to the Quaternary sequence in the study area has not been demonstrated.

Measured sections at more than 100 sites and driller's logs from more than 300 water wells in Briscoe, Floyd, Hall, and Motley Counties were studied to determine the lateral boundaries and thickness of this sedimentary sequence. Logs from wells south of Motley County also were reviewed, but the mapped extent of deposits in the southern part of the study area is based solely on limited field reconnaissance. Over much of the region the maximum thickness of Quaternary strata is approximately 40 m (130 ft). However, the section thickens to more than 76 m (250 ft) locally. The thickest deposits lie within closed basins or deep troughs on the Permian or Triassic subcrop. In these areas intrastratal dissolution of Permian evaporites apparently resulted in karstic subsidence contemporaneous with deposition of the sediments. Paleoclimatic changes during the late Pleistocene and Holocene Epochs probably affected subsidence rates and modified paleoenvironments. In this way both the sites of deposition and the types of deposits reflect paleoclimatic conditions.

PREVIOUS INVESTIGATIONS

Several investigators have described elements of the Pleistocene geology of the area east of the High Plains, including Gould (1906), Frye and others (1948), Frye and Leonard (1957; 1963), Van Siclen (1957), Dalquest (1964a and b; 1965) and Johnson and others (1982). Van Siclen (1957) investigated Quaternary deposits on the Rolling Plains south of Garza County, and Dalquest

(1965) described a new formation and local paleofauna in Hardeman County farther east (beyond area covered by fig. 1). These strata may be genetically similar and time-equivalent in part with those in the present study area. However, relations among the Quaternary sequences in these areas have not yet been demonstrated.

Gould (1906), Frye and Leonard (1957; 1963), and Dalquest (1964a) were the first to discuss the Quaternary strata and fauna of the present study area. Gould (1906) mentioned these deposits only briefly. He and the other authors named based their investigations on data from only a few outcrops and interpreted the deposits as local fluvial terraces. None of these investigators recognized the enormous and essentially continuous extent of the deposits nor their complex origin. The purported age of the sedimentary sequence also is in question. Frye and Leonard (1957; 1963) regarded most of the Quaternary deposits of the Rolling Plains of Texas to be at least partly time equivalent with the Pleistocene Meade Formation of Kansas. Frye and others (1948) reported that the Meade Formation in central and southwestern Kansas "fill(s) deep valleys cut below the Ogallala surface or fill(s) solution-subsidence or down-faulted areas" (p. 522). They considered the Meade Formation to be Kansan in age on the basis of stratigraphic criteria. Subsidence features are common in the western Rolling Plains (Gustavson and others, 1982) just as they are in Kansas, and likewise tend to localize deposition. But most of the resulting Quaternary strata on the Rolling Plains are much younger than the Kansan-age Meade Formation (Caran and Baumgardner, 1985), although deposits roughly isochronous with the Meade have been found farther east. Dalquest (1964b) described the paleofauna of a Pleistocene terrace in northwestern Childress County, east of Hall County. Based on the presence of mammoth remains and the absence of Bison material, Dalquest concluded that the deposit was Kansan or Yarmouthian in age. Geomorphic evidence indicates this high-terrace remnant may be older than the strata exposed farther west (in the present study area). Caran and Baumgardner (1985) summarized and evaluated more than 50 finite radiocarbon dates from deposits in the study area. These dates indicate that the Quaternary strata probably are diachronous but no older than late Pleistocene and Holocene. Radiocarbon dates and Paleoindian artifacts from the Lake Theo archeological site in Briscoe County (Johnson and others, 1982; Caran and Neck, 1984) (fig. 2) support this conclusion.

DETAILED STRATIGRAPHY AND MAPPING

Recent investigations (Baumgardner and Caran, 1984; Caran and Baumgardner, 1984a and b) have defined the stratigraphic framework of Quaternary deposits in the western Rolling Plains where more than 100 sections have been measured and described. A 53.7 m (176 ft) representative section was measured at one outcrop and a nearby water well. This section contains three principal genetic elements: a basal, upward-fining, fluvial component (17 m, 55 ft thick); a middle, argillaceous, lacustrine component (2.7 m, 9 ft thick); and an upper component consisting of a complex series of fluvial and eolian deposits interrupted by pedogenic horizons (35 m, 114 ft thick). These lithofacies and thicknesses are typical of the regional Quaternary sequence.

The representative section combines data from a well log and a measured section. The outcrop is on the H. E. Blair, Jr. farm in Briscoe County, Texas, 15 m (50 ft) west of Farm-to-Market Road (FM) 1065, on the north side of Los Lingos Creek (Red River drainage basin), 6.0 km (3.7 mi) south of the intersection of State Highway 86 and FM 1065 in Quitaque (fig. 2). The site is a deep, steep-walled, northward-cutting gully more than 370 m (1,200 ft) long that formed when drainage was diverted from FM 1065. Late Quaternary sediments are exposed throughout the gully. The cumulative thickness of these strata is approximately 12 m (40 ft) (figs. 3 and 4). Units highest in this composite section are exposed near the northern end of the gully. Erosion has cut more deeply to the south, exposing progressively lower units.

A water well was drilled in May 1983 on the Blair farm, 1.5 km (0.95 mi) east of the site just described (fig. 2). The first 7.6 m (25 ft) of this well were completed before sample logging began, and no samples from this interval had been saved. However, the rest of the well was logged and sampled to its total depth of 56.7 m (186 ft) (fig. 3). The Quaternary section at the well site is 53.7 m (176 ft) thick. The composite section measured in the gully west of FM 1065 probably is representative of the 7.6 m (25 ft) interval omitted from the well log.

Measured Section

The section shown in figure 3 combines shorter sections measured at five sites within the gully (inset map, fig. 3). Quaternary strata exposed here represent a succession of depositional facies. Cross-bedded, poorly sorted, fluvial deposits of sand and gravel (units 6 through 10 of the measured section, fig. 3; see note in caption, fig. 3) occupy the lowest 7.8 m (23 ft) of the exposed section. Units 7 through 10 are very much alike. Unit 6 is horizontally bedded in part and contains a few large tabular rip-up clasts of clay to 0.3 m (1 ft) in maximum diameter. This unit probably was deposited in a swale in which water stood quietly after floods. Sediment composing units 6 through 10 is very similar to deposits in modern streams throughout the region. The environment of deposition likely was a broad, braided alluvial channel such as that of Quitaque Creek in northern Motley County (figs. 1 and 2). Pedogenesis or other alteration of these deposits was very weak, indicating that sediment accumulated rapidly with limited subaerial exposure between periods of significant discharge.

Two of these units contain the fossil remains of mammals. Poorly preserved teeth and partly articulated bone fragments of a rodent, probably a prairie dog (Cynomys ludovicianus), were found in unit 6, and a well-preserved, incomplete premolar (?) of a Pleistocene horse, Equus cf. E. conversidens, was found in unit 9 (determinations confirmed by E. L. Lundelius, personal communication, 1983). The horse tooth was lying at the base of a small depression scoured into the top of unit 10, but is worn and probably was reworked from older deposits elsewhere. The rodent remains do not appear to have been worn by transport. However, they may have occupied a burrow and thus could be considerably younger than the unit in which they were preserved.

Overlying unit 6 in the measured section is unit 5 (fig. 3), a clayey, very fine to fine sandy silt containing discrete lenses of well-sorted, fine and coarse sand. In addition to the small lenses among these strata, unit 5 as a whole is lenticular and laterally discontinuous. Faint, horizontal bedding through much of the unit is almost masked by strong, blocky, pedogenic structure; whereas the intercalated sandy lenses are structureless. This deposit probably formed within an abandoned channel that received suspended load and small amounts of bed load during floods. The sediment remained water-saturated (aquic or even peraquic soil-forming conditions) for extended periods following deposition. Pedogenic structure probably was established soon after the unit accreted. Vertically elongate, calcareous concretions are common in the upper part of the unit, representing a later stage of pedogenesis following burial. The upper boundary is abrupt and irregular, probably because of erosion prior to deposition of unit 4.

Unit 5 is overlain unconformably by unit 4 (fig. 3). Unit 4 and all succeeding units are well sorted, fine and medium sands and clayey sands with weak to moderate blocky and columnar soil structure. Units 2 to 4 retain faint, horizontal laminae. Accretion of all four units composing the upper part of this section was gradual. All show evidence of pedogenesis which strengthens upward through the section. Units 2 through 4 appear to have been deposited on a floodplain where the frequency of inundation decreased through time. A change in channel geometry or the timing and volume of discharge through the contributing drainage system is the most likely cause of this trend. The trend is a continuation of the reduction in fluvial contributions that is evident in units 7 through 5.

Caran and Baumgardner (1985, table 1 and fig. 1) reported two radiocarbon dates from analyses of soil humates in samples from this outcrop. Samples were collected 10 to 20 cm and 20 to 30 cm beneath the top of unit 3. Dates were corrected for ^{13}C and were, respectively, 1,350 $\pm$ 100 yr before 1950 (b.p.) and 280 $\pm$ 110 yr b.p. The obvious discrepancy in these dates probably resulted from pedogenic contamination of the deeper sample. Analysis of this sample was disproportionally imprecise over the 68-percent confidence interval. The older date is consistent with analyses of shallow buried soils at other sites in the region (Caran and Baumgardner, 1985), and may be representative of the actual age of the unit. A sample from unit 5 also was analyzed but contained insufficient organic carbon for dating. Material similar to that of unit 5 was collected at a site approximately 2.4 km (1.5 mi) northwest of the measured section at the Blair farm. Radiocarbon analysis of this sample (sample 2, Henson farm section 15B of Caran and Baumgardner, 1985, table 1) yielded a corrected date of 1,950 $\pm$ 80 yr b.p.

Fluvial deposition at the Blair farm (gully) site apparently ceased altogether soon after depositon of unit 2. The top of unit 2 is eroded and irregular. The superjacent unit, number 1, is a well-sorted, fine sand with low-angle cross-bedding resulting from eolian sedimentation. One or two buried A horizons of paleosols are included in this depositional unit which has weak to moderate blocky soil structure.

A small limnic deposit, not included in the measured section, is exposed in the eastern wall of a roadcut along FM 1065, approximately 30 m (100 ft) southeast of site A in the inset map of figure 3. This deposit appears to be in the stratigraphic position of unit 1 or 2 (fig. 3). Ponding on uplands became increasingly localized and ephemeral throughout the region after the climate shifted toward drier conditions 5,000 to 8,000 years ago (Caran and Neck, 1984). Previously, ponds and small lakes had been the dominant landforms across the western Rolling Plains (Caran and Baumgardner, 1984a and b) under humid conditions that persisted from the late Pleistocene perhaps to the early or middle Holocene Epoch (Caran and McGookey, 1983). The present dry climate restricts the retention of water in basins, thereby generally preventing establishment of a perennial lacustrine environment.

Well Log

The strata measured in outcrop represent only part of the Quaternary section in the area. A complete section (except for the first 7.6 m or 25 ft) was logged at a water well approximately 1.5 km (0.95 mi) east of the outcrop described previously. The well section comprises all three of the principal genetic components of late Quaternary deposits throughout the region. The basal component, represented by unit 7 of the well log shown in figure 3 (see note in caption, fig. 3), unconformably overlies Permian and Triassic strata. Unit 7 itself is an upward-fining fluvial deposit 17 m (55 ft) thick on the irregular Permian Quartermaster Formation. The thickness of this as well as the other Quaternary components varies widely from place to place (fig. 5). Coarseness of the basal sediment and its provenance along the Caprock Escarpment (fig. 1) here as elsewhere indicate deposition within a bajada, a coalescing suite of alluvial fans.

Overlying the basal sand and gravel is an argillaceous lacustrine deposit. This component of the regional section is represented in the well log by unit 6 which is 2.7 m (9 ft) thick (fig. 3). Unit 6 is organic-rich (sapropelic) and highly fossiliferous (pelecypods, gastropods, and ostracodes). Correlative strata (seen in outcrop at sites throughout the region) consist of very thick yet discontinuous lenses. Although these lenses are discrete they are everywhere similar and have a common origin. They occupy a consistent stratigraphic position defining the middle of the Quaternary section. Locally, these deposits attain a thickness of 13 m (40 ft) or more (Caran and Baumgardner, 1984a and b). Finite radiocarbon dates on samples from correlative lacustrine deposits at several sites range from 8,560 ± 290 yr b.p. to 23,240 ± 2,330 yr b.p. (Caran and Baumgardner, 1985, table 1). Infinite dates greater than 38,000 yr b.p. were obtained from analyses of samples from the base of one thick lacustrine section.

The upper part of the regional Quaternary section, overlying the lacustrine deposits, is a series of fluvial and eolian deposits. These consist of stacked cycles of upward-fining strata interrupted by pedogenic horizons and small, thin, widely separated lenses of limnic clay and silt. At the Blair farm the upper component of the Quaternary sequence is represented by units 1 through 5 of the well log and the entire section measured in the gully (fig. 3). Collectively these strata are 35 m (114 ft) thick. The complete composite section (well and outcrop) is approximately 55 m (180 ft) thick and appears to be representative of the regional Quaternary section of the westernmost Rolling Plains.

PALEOENVIRONMENTAL RECONSTRUCTION

The stratigraphic record of the late Quaternary Period in the western Rolling Plains comprises a complex suite of overlapping lithofacies and erosional surfaces. Environments of deposition and denudation shifted principally in response to progressive climatic change. Therefore, stratigraphic and associated paleontologic evidence is a proxy indicator of climatic conditions in the geologic past.

Across much of the region, karstic subsidence and resulting adjustments of base level also affected sedimentation and erosion. Intrastratal dissolution of Permian halite caused both regional and local differential downwarp. This nontectonic deformation trapped sediment within the zone of subsidence. Climate may have influenced the timing and rate of deformation and sediment accumulation. Precipitation and evaporation would have moderated the amount of surface water available for aquifer recharge and storage. Movement of unsaturated ground water in turn effected dissolution of evaporites at depth, and may have enhanced subsidence during wet periods.

Fluvial systems adjust to dissolution-induced subsidence by downcutting at the margins of a structural basin and aggrading within its center. If the climate is moist and subsidence is rapid, the center of the basin might become a lake: runoff would be impounded or the floor of the basin would drop below the water table. Under dry conditions karstic subsidence may have been slowed or restricted areally, and generally would not have produced perennial lacustrine environments. In a region where evaporites lie at relatively shallow depth, climate and subsidence would interact to influence most geomorphic processes.

This dual mechanism produced the three-part Quaternary stratigraphic sequence of the western Rolling Plains (fig. 5). In most areas the basal component is a sheet of weakly consolidated, coarse clastic sediment. Conformably overlying these sands and gravels are lenses of calcareous, silty clay. Although the argillic lithosomes are discrete they occupy a consistent medial position in the regional Quaternary section. Typically, they are unconformably overlain by a series of sandy gravels and clayey silts (some of which were modified pedogenically) that constitute the uppermost component of the section. For purposes of this discussion, the three stratigraphic elements are here informally designated 1, 2, and 3, respectively, from oldest to youngest. The environments of deposition of these components and the climatic conditions that existed during deposition can be inferred from available stratigraphic evidence.

Component 1: Basal Coarse-Grained Deposits

The basal, coarse-grained component of the regional Quaternary section consists of sands and gravels dominated by lithoclasts of Ogallala caliche. These deposits form a wedge along the flank of the Caprock Escarpment, resting unconformably on Permian, Triassic, and (locally) Tertiary strata (figs. 1 and 2). The wedge of Quaternary sediment tapers to the east but extends several tens of kilometers across the Rolling Plains. Large-scale sedimentary structures commonly are preserved. They, together with the geometry of the deposit, indicate primary paleotransport from the west. However, sediment sources to the west are largely restricted to the escarpment itself. Only a few, widely separated canyons cut through the escarpment into the interior of the High Plains. Drainage through these canyons alone could not have transported all of the coarse sediment that blanketed the Rolling Plains. Evidently, most of this basal detritus was deposited by alluvial fans that originated at the escarpment when it occupied positions east of its present location. Sediment was conveyed from this proximal source as the escarpment retreated westward. The fans coalesced laterally, eventually forming a broad bajada. Thus, although sediment constituting component 1 was transported eastward, or normal to the regional strike, the deposit as a whole constitutes a strike-oriented lithologic unit.

The thickness of the basal components varies, reflecting irregularity of the largely Permian subcrop. Deposits as much as 40 m (130 ft) thick occupy low areas on this paleosurface. Some lows are sinuous and broaden to the east, and probably represent former channels and valleys; whereas closed basins and troughs characterize areas of karstic subsidence. Within erosional lows only component 1 should be overthickened. Other components generally would not reflect the irregularity of the subjacent bedrock surface. In contrast, subsidence caused differential thickening of the basal sediments at some sites but also accentuated deposition of other stratigraphic elements. Subsidence controlled environments of deposition as well, most often by creating lakes (resulting in deposition of component 2). In addition, many of the deposits filling subsidence basins were faulted and downwarped (Baumgardner and Caran, 1984).

High points on the erosional surface beneath the Quaternary section were buried thinly, or remained partly exposed and comprised sediment sources. Complete sections, incorporating all three stratigraphic components of the regional section, are found on many of these highs. But there, the Quaternary sequence generally is thin, composing an attenuated but correlative counterpart of more representative sections off the highs. The deposits even cover most of the major modern drainage divides, and existing channels and valleys cut into these older strata.

At some sites, shells of aquatic mollusks are abundant within the basal clastic unit. The diversity of taxa generally is low and most of the species represented tolerate a wide range of ecologic conditions. None of these species is a diagnostic paleogeographic or paleoclimatic indicator. Remains of vertebrates also have been recovered at a few localities, including the type area of the Quitaque local fauna (Dalquest, 1964b). But the scarcity of microvertebrates and absence of restricted megafauna at these sites prevents refinement of this part of the paleoclimatic record beyond that already inferred from regional syntheses and local studies elsewhere in the area (Caran and McGookey, 1983; Caran and Neck, 1984). However, no evidence contradicting these interpretations has been found.

The fauna does provide some chronostratigraphic data. All of the large mammals represented in collections from the basal clastic unit appear to be part of the Rancholabrean faunal association. Therefore, the deposits containing these fossils certainly are younger than 600,000 yr old (Kurten and Anderson, 1980, p. 5), and probably are much younger. Beds of clay conformably overlying the fossil-bearing sands at the Quitaque fauna site have been dated by radiocarbon analyses (Dalquest, 1964b; Caran and Baumgardner, 1985). The age of organic humates from these argillic strata exceeds 38,000 yr. Finite radiocarbon dates as old as 25,000 yr were obtained higher in a correlative section nearby (Caran and Baumgardner, 1985, table 1). These dates provide an estimate of the age of the unit, which is corroborated by regional projections of minimum rates of escarpment retreat (Gustavson and others, 1980), and the inferred stratigraphic position of the deposits relative to others containing older faunas farther east (Dalquest, 1964a). In most areas the basal clastic component probably is more than 40,000 yr old but less than 100,000 yr old. The age of this deposit probably increases to the east where some strata may be older than 100,000 yr, and decreases to the west, perhaps to less than 40,000 yr.

Component 2: Medial Fine-Grained Deposits

Overlying the basal coarse-clastic component of the regional Quaternary sequence are lenticular lithosomes of argillaceous sediment. These lenses of clay and silt are discrete and were deposited in small closed basins that contained perennial lakes. The basins filled with laminated, highly fossiliferous, calcareous clay, then were buried beneath coarser clastic units of fluvial and eolian origin (component 3). The modern drainage network has incised through the Quaternary sequence, providing excellent exposures of some of the lacustrine deposits and basins as well as the other two principal components of the sedimentary complex.

Lacustrine deposits crop out at numerous sites as much as 50 km (30 mi) east of the Caprock Escarpment. The largest lakes occupied structural depressions 2.5 km (1.5 mi) in diameter. These basins apparently formed by karstic subsidence following dissolution of Permian (Ochoan and Guadalupian) salt 90 to 180 m (300 to 600 ft) beneath the Quaternary section. Some basins continued to subside as they filled with sediment. The resulting stress produced minor tensional fractures and dips of 10 to 16 degrees in laminae that were deposited horizontally. Subsidence also enhanced deposition, resulting in locally thickened sections. Lacustrine sequences within these basins are 12 m (40 ft) or more in maximum thickness and consist of calcareous clays and silty clays. Much of this sediment was autochthonous, either biogenic or authigenic. The virtual absence of coarse sediment, and the textural homogeneity of deposits at basin margins and centers, indicate little overland transport, thereby implying limited local runoff. Allochthonous constituents were carried by wind and by centripetal drainage from watersheds only a slightly larger than the lakes themselves. The fine sediment settled into quiet water probably below wave base. No desiccation features have been found, but root traces throughout these deposits indicate water depths did not exceed the photic limit (presumably 5 m or less).

Most of the water in these lakes almost certainly was emergent ground water. The floor and lower flanks of the subsidence basins likely dipped beneath the water table as the beds warped downward. The zone of saturation would have been relatively high because of humid conditions in the area at the time (Caran and McGookey, 1983, fig. 90). The conclusion that these were water-table lakes is supported by several lines of indirect evidence, the most compelling being the absence of coarse sediment or sedimentary zonation indicative of significant runoff into the small lacustrine basins. Similar water-table lakes are found today within sinkholes in the Pecos River Valley of New Mexico and at a few locations in the Rolling Plains.

The lakes supported diverse aquatic molluscan faunas as well as ostracodes, diatoms, and the benthic macrophytic alga Chara which produced abundant calcareous sediment. Allochthonous shells of terrestrial mollusks also are common among the fossils of these lakes. All molluscan taxa are extant, but most are absent from the region's modern fauna. These disjunct taxa serve as important paleoclimatic indicators. Skeletal remains of terrestrial and aquatic vertebrates have been recovered from lacustrine strata in a few areas. But none of the vertebrate species represented provides significant information regarding the prevailing paleoenvironment. The megafauna appears to be Rancholabrean, although very little Bison material has been found in place. Radiocarbon analyses of organic humates from lacustrine beds are consistent with the limited biochronologic evidence. Ages range from 25,000 to about 8,500 or perhaps 6,500 yr, and a nearly continuous series of late Pleistocene to early Holocene dates were obtained from one vertical series (Caran and Baumgardner, 1985, table 1 and fig. 1). Conditions favoring the existence of perennial lakes appear to have deteriorated after about 8,000 yr ago (fig. 5).

Component 3: Uppermost Heterogeneous Deposits

The uppermost Quaternary stratigraphic component informally recognized in the western Rolling Plains is a polymodal textural suite of fluvial and eolian deposits, punctuated with paleosols at various horizons. These deposits contrast sharply with the underlying lacustrine sediments from which they generally are separated by erosional unconformities. Such a marked, regionally extensive replacement of one major environment of deposition by others undoubtedly resulted from climatic change and associated geomorphic adjustments. Progressive regional desiccation began in early Holocene time (Caran and McGookey, 1983; Caran and Neck, 1984), and it is with this interval that the break in the stratigrahic record appears to coincide. Drier conditions also would have reduced recharge and the elevation of the water table. Dissolution subsidence may have been affected as well although subsidence has continued to the present. These factors, in combination, probably caused the great reduction in size, permanence, and number of lakes that is evident in the stratigraphic record.

Under the relatively dry conditions of early Holocene time, small meandering and braided streams scoured and truncated preexisting deposits and buried them beneath thin-bedded sands and gravels. These coarse clastic deposits preserved small-scale sedimentary structures and individual channel forms. Directions of paleotransport were dominantly eastward but highly variable. Channels were shallow and short-lived or laterally unstable. This indicates intermittent flow across a surface of low gradient, with bedloads approaching stream capacity. Much of component 3 consists of an aggrading, cut-and-fill sequence. The thickness of this component varies but can exceed 30 m (100 ft).

In addition, component 3 includes extensive, fine-grained, eolian deposits. The eolian material probably was winnowed from local stream beds and floodplains during dry seasons. This process has remained active throughout the region. Stable and slowly aggrading surfaces developed relatively strong, thick soils. Some of these soils were later buried and can now be traced as far as 2 km (3.2 mi). But no satisfactory stratigraphic markers of more than local extent have been recognized within component 3.

Despite problems of internal correlation, the chronostratigraphy of these deposits is reasonably well known (fig. 5). Most of the radiocarbon dates applicable to the regional Quaternary section are based on analyses of samples from this uppermost component. The dated material was collected at relatively few locations (Caran and Baumgardner, 1985). Therefore, the dates can only partly reinforce correlations among sections, but do provide a good indication of the age of the deposits overall. None of the dates is older than early to middle Holocene. However, deposition of component 3 was discontinuous locally, and some strata may have accumulated during the latest Pleistocene. Yet, in general, component 3 appears to be the lithostratigraphic record of the Holocene Period (fig. 5).

Little fossil material has been recovered from these deposits. Poorly preserved skeletal debris from both large and small mammals has been found at a few localities, but some of this undoubtedly was reworked from older strata.

Molluscan faunas also are not well represented except locally. The most important record of latest Pleistocene and Holocene mollusks is that from the Lake Theo archeological site (number 41BI70) in Briscoe County (fig. 2). Excavations near Lake Theo, an artificial impoundment on Holmes Creek, revealed artifacts of Paleoindian and Archaic cultures, and a large molluscan fauna (Neck, 1978; Johnson and others, 1982). Radiocarbon dates bracket each of the major genetic and pedogenic units composing this section (Caran and Neck, 1984). Nearly continuous deposition at this site preserved a diverse terrestrial molluscan faunal sequence, as well as a limited number of aquatic and amphibious forms. All of the represented taxa are extant, but more than half are absent from the modern local fauna. The disjunct faunal elements are ideal paleoclimatic indicators, and reveal a gradual warming and desiccation culminating in the warm, dry conditions of today (fig. 5).

SUMMARY

Representative sections through the Quaternary deposits denote a fining-upward sequence from fluvial sand and gravel at their base (on underlying Triassic and Permian red beds) to eolian sand and silt at the surface, with lenses of lacustrine clay interposed (Caran and Baumgardner, 1984a and b) (fig. 5). The basal, coarse-grained sediments probably were deposited by alluvial fans spreading eastward from the retreating Caprock Escarpment. At a few sites this coarse-clastic component contains Rancholabrean faunal remains, indicating that the deposits are less (probably much less) than 600,000 years old (Kurten and Anderson, 1980, p. 5) and more than 5,000 years old (Johnson and others, 1982, p. 131).

Overlying these basal gravels, near the middle of the Quaternary sequence, is a zone of fossiliferous argillaceous strata. The fine silt and clay composing these deposits accumulated in closed basins containing ponds and small lakes. These perennial-water bodies provided suitable habitat for aquatic gastropods, pelecypods, and ostracodes, including several species no longer extant regionally. A few microvertebrates and the benthic macrophytic alga <u>Chara</u> also are represented at some sites, as are allochthonous remains of terrestrial mollusks and large vertebrates. Lenses of lacustrine deposits are discrete but widespread, and constitute important stratigraphic markers within the regional Quaternary section.

In some areas, accumulation of these lake deposits was enhanced by subsidence. Locally, the Quaternary section includes thick sequences of lacustrine and fluvial sediment filling closed structural depressions. Some of these deposits are tilted and faulted; individual laminae thicken across some faults whereas other strata are merely offset, indicating that subsidence occurred episodically (Baumgardner and Caran, 1984). Gustavson and others (1982) demonstrated that subsidence was active historically in Hall and Briscoe Counties, producing sinkholes and broad basins. The subsidence features formed as a result of dissolution of Permian evaporites 120 to 240 m (400 to 800 ft) below the surface (Gustavson and others, 1982), or 90 to 180 m (300 to 600 ft) beneath the Quaternary deposits. Before the basins were isolated from external sediment sources, they trapped fluvial sands and gravels transported eastward from the escarpment. These coarse-clastic deposits constitute important fresh-water aquifers. Leakage of unsaturated ground water from these aquifers may have effected additional dissolution of subjacent evaporites, thereby promulgating karstic subsidence.

The same process appears to have produced comparable features throughout late Pleistocene and Holocene time. During much of this interval, subsidence may have been even more widespread than today because of the wetter climate and presumably higher rates of infiltration and movement of ground water (Caran and McGookey, 1983; Caran and Neck, 1984). The moist climate of the late Pleistocene turned sinkholes and subsidence basins into perennial ponds or lakes, the largest of which probably were maintained by phreatic discharge. Although subsidence has continued to the present, most of the lacustrine deposits occupy a stratigraphically consistent position in the middle of the Quaternary section, corresponding to the period of greatest available moisture (Caran and Baumgardner, 1984a and b). Later, the climate became increasingly arid with the result that eolian and intermittent fluvial processes were dominant and contributed most of the sediment composing the upper part of the section. Many of these upper deposits have been modified pedogenically, implying slower accumulation of sediment overall.

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FIGURE CAPTIONS

Figure 1. Preliminary estimate of the distribution of Quaternary sedimentary deposits along the flank of the Eastern Caprock Escarpment, on the western Rolling Plains of Texas. The area shown in figure 2 lies in the northeastern part of the region represented in figure 1, in Briscoe, Hall, Floyd, and Motley Counties.

Figure 2. Geologic map of part of the western Rolling Plains. Sites mentioned in this paper are denoted symbolically. Map is based on Barnes (1968) but has been revised extensively, particularly with regard to Quaternary deposits.

Figure 3. Representative sections through late Quaternary deposits of the western Rolling Plains. See figure 4 for explanation of symbols. Inset map indicates the approximate locations at which parts of the composite measured section were described. Note: Stratigraphic units in the two sections illustrated (outcrop and well) are numbered separately. Units defined at the outcrop are not necessarily correlative with units of the same number in the well section.

Figure 4. Symbols used to represent stratigraphic and pedogenic features of the sections illustrated in figure 3.

Figure 5. Generalized composite section, paleoenvironmental interpretation, and approximate chronology of late Quaternary deposits, western Rolling Plains.

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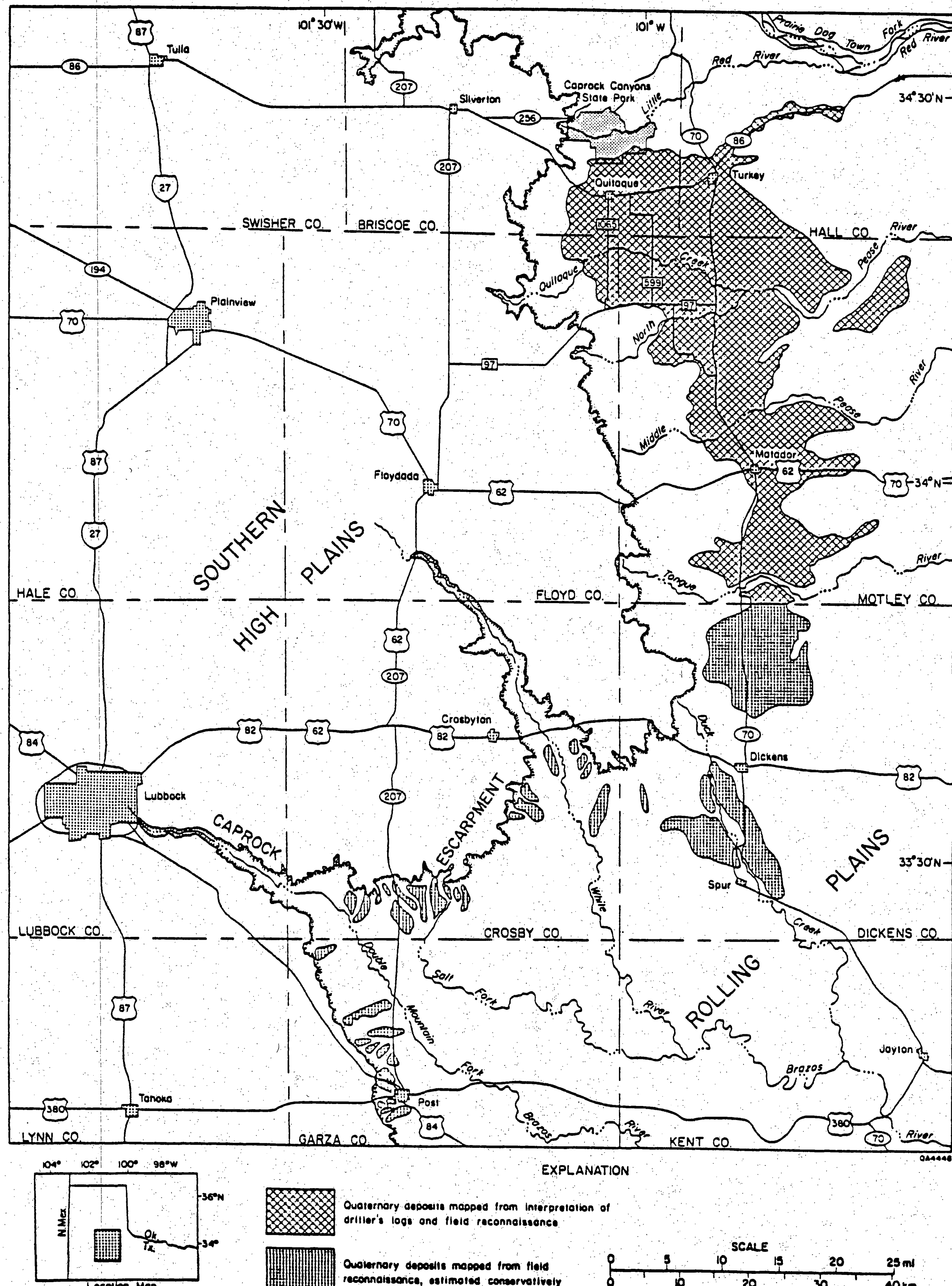


101° 30'W
101° W
34° 30'N
34° N
33° 30'N
Tulia
Silverton
Caprock Canyons State Park
Quitaque
Turkey
Plainview
Floydada
Matador
Crosbyton
Lubbock
Dickens
Spur
Jayton
Tahoka
Post
SWISHER CO.
BRISCOE CO.
HALL CO.
HALE CO.
FLOYD CO.
MOTLEY CO.
LUBBOCK CO.
CROSBY CO.
DICKENS CO.
LYNN CO.
GARZA CO.
KENT CO.
SOUTHERN HIGH PLAINS
CAPROCK ESCARPMENT
ROLLING PLAINS
Prairie Dog Town Fork Red River
Red River
Little Red River
Quitaque Creek
North Pease River
Middle Pease River
Pease River
Tongue River
Duck Creek
White River
Salt Fork
Double Mountain Fork Brazos River
Brazos River
EXPLANATION
Quaternary deposits mapped from interpretation of driller's logs and field reconnaissance
Quaternary deposits mapped from field reconnaissance, estimated conservatively
SCALE
0 5 10 15 20 25 mi
0 10 20 30 40 km
104° 102° 100° 98°W
36°N
34°
N.Mex.
Ok.
Tx.
Location Map

Fig. 1

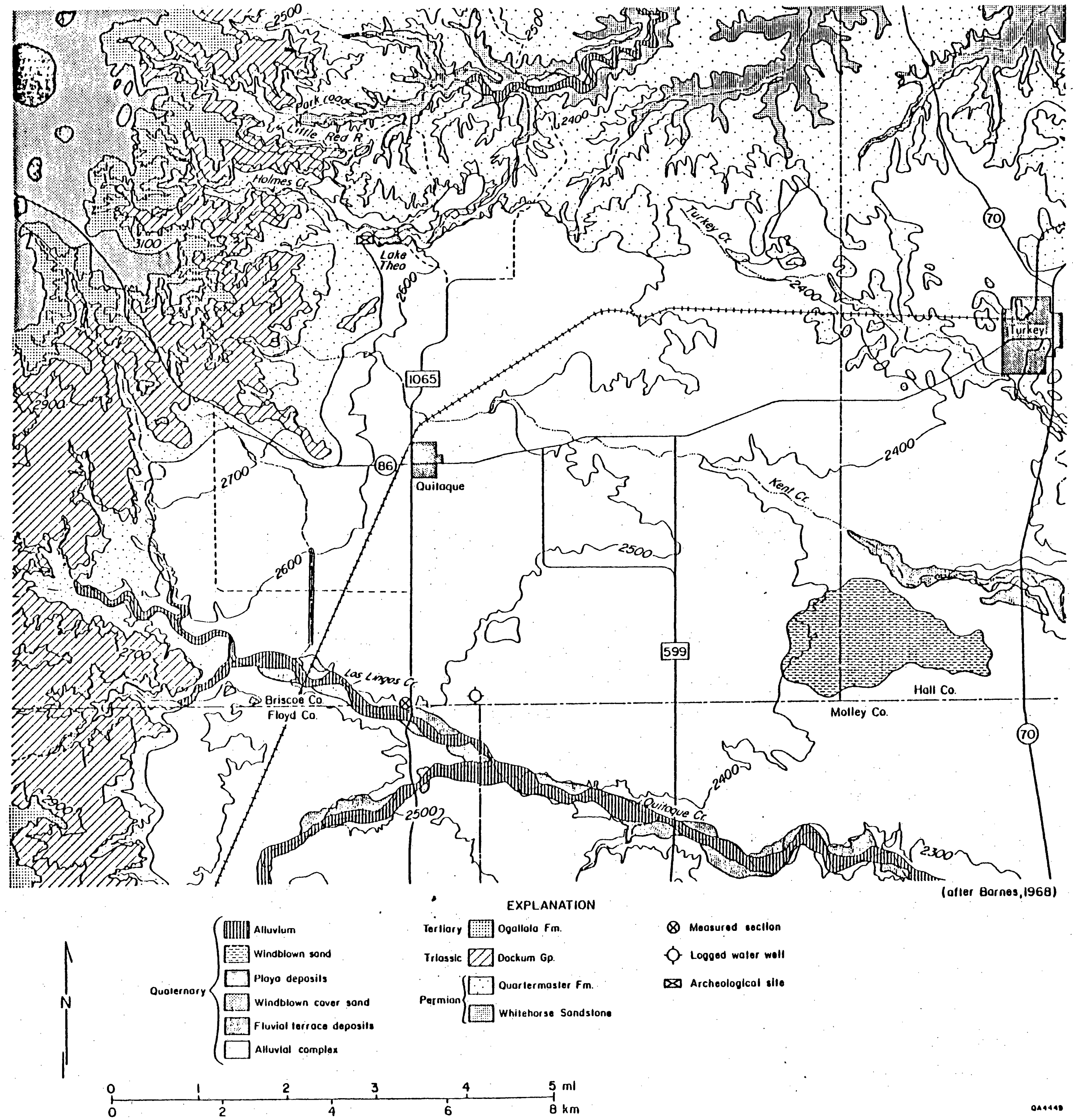
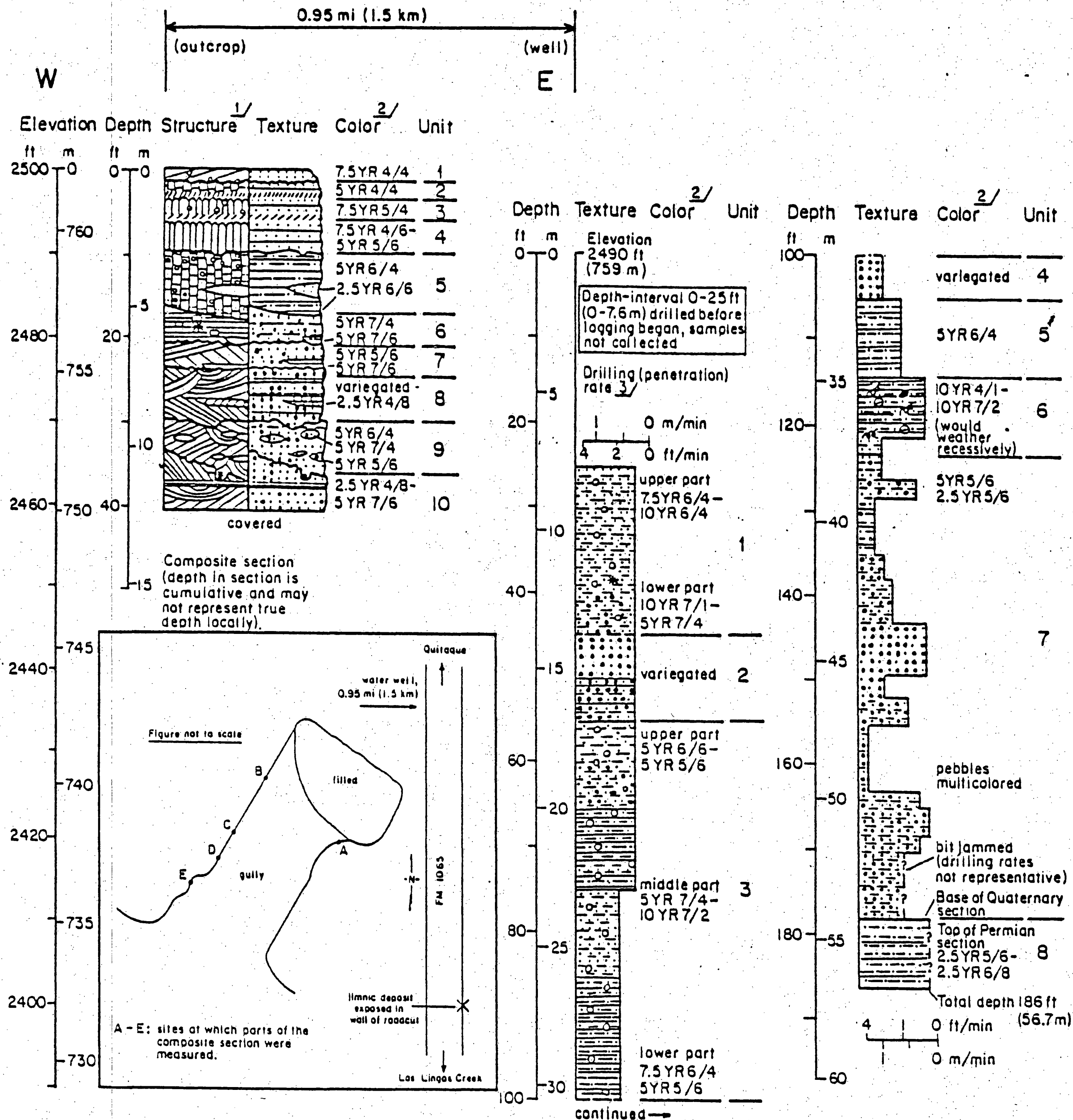

2500
Park Loop
Little Red R.
Holmes Cr.
2400
3100
Lake Theo
2600
Turkey Cr.
2400
70
Turkey
1065
2900
86
Quitaque
2700
2400
Kent Cr.
2500
2600
599
Las Lingos Cr.
Briscoe Co.
Floyd Co.
Hall Co.
Motley Co.
70
2400
Quitaque Cr.
2500
2300
(after Barnes, 1968)
EXPLANATION
Quaternary
Alluvium
Windblown sand
Playa deposits
Windblown cover sand
Fluvial terrace deposits
Alluvial complex
Tertiary
Ogallala Fm.
Triassic
Dockum Gp.
Permian
Quartermaster Fm.
Whitehorse Sandstone
Measured section
Logged water well
Archeological site
N
0 1 2 3 4 5 mi
0 2 4 6 8 km
QA4449

Fig. 2



1/ Sedimentary, compactional, and pedogenic structures and fossils.

2/ Munsell color, determined on fresh, dry surface.

3/ In general, drilling rate is inversely related to hardness of rock. Graph of changes in drilling rate with depth is comparable to weathering profile, except where noted.

Fig. 3

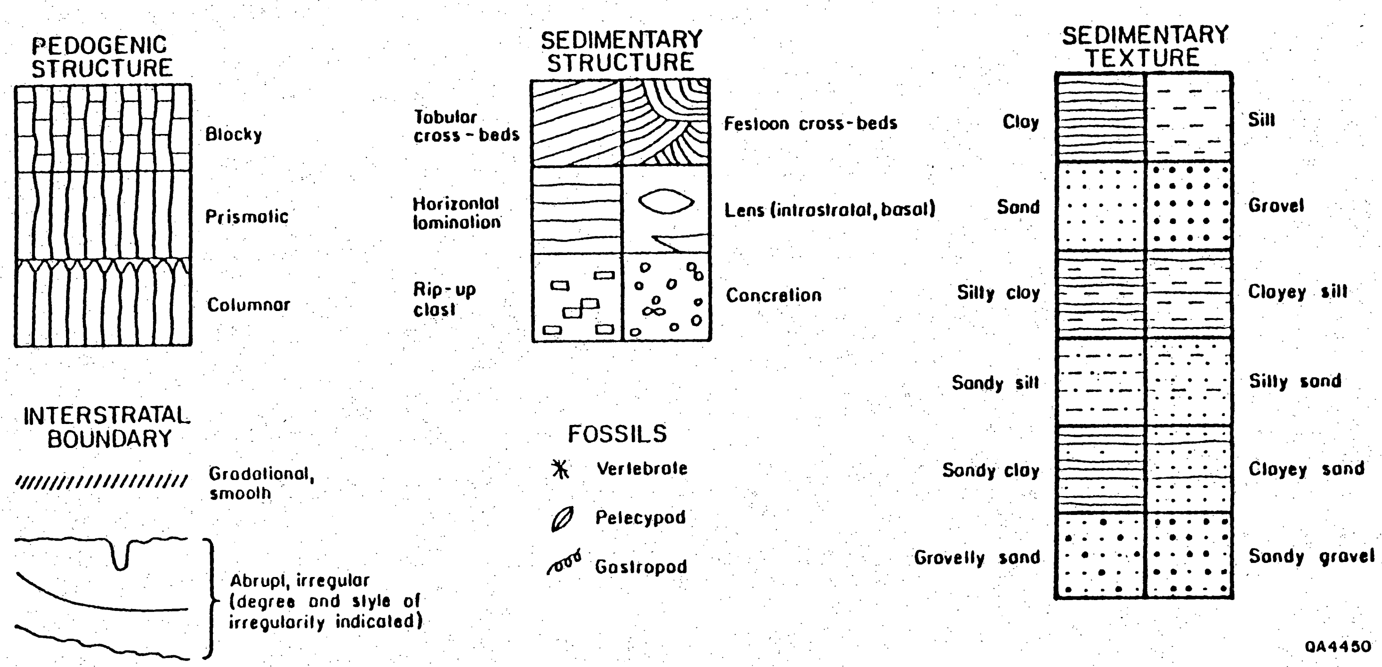

PEDOGENIC STRUCTURE
Blocky
Prismatic
Columnar
INTERSTRATAL BOUNDARY
Gradational, smooth
Abrupt, irregular (degree and style of irregularity indicated)
SEDIMENTARY STRUCTURE
Tabular cross-beds
Festoon cross-beds
Horizontal lamination
Lens (intrastratal, basal)
Rip-up clast
Concretion
FOSSILS
Vertebrate
Pelecypod
Gastropod
SEDIMENTARY TEXTURE
Clay
Silt
Sand
Gravel
Silty clay
Clayey silt
Sandy silt
Silty sand
Sandy clay
Clayey sand
Gravelly sand
Sandy gravel
QA4450

Fig. 4

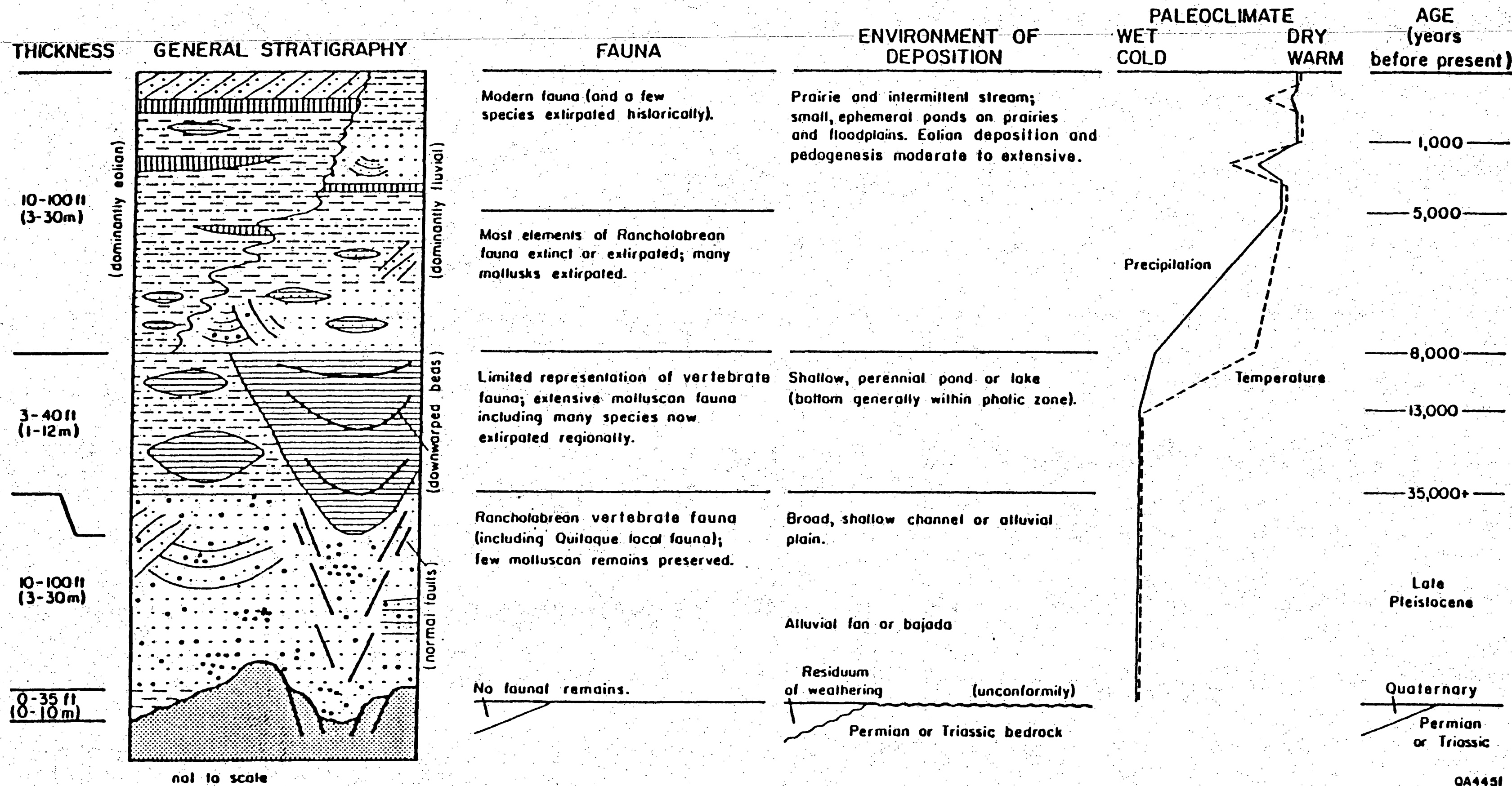

THICKNESS
GENERAL STRATIGRAPHY
FAUNA
ENVIRONMENT OF DEPOSITION
PALEOCLIMATE
WET COLD
DRY WARM
AGE (years before present)
10-100 ft (3-30m)
(dominantly eolian)
(dominantly fluvial)
Modern fauna (and a few species extirpated historically).
Prairie and intermittent stream; small, ephemeral ponds on prairies and floodplains. Eolian deposition and pedogenesis moderate to extensive.
1,000
5,000
Most elements of Rancholabrean fauna extinct or extirpated; many mollusks extirpated.
Precipitation
8,000
3-40 ft (1-12m)
(downwarped beds)
Limited representation of vertebrate fauna; extensive molluscan fauna including many species now extirpated regionally.
Shallow, perennial pond or lake (bottom generally within photic zone).
Temperature
13,000
35,000+
Rancholabrean vertebrate fauna (including Quitaque local fauna); few molluscan remains preserved.
Broad, shallow channel or alluvial plain.
10-100 ft (3-30m)
(normal faults)
Late Pleistocene
Alluvial fan or bajada
Residuum of weathering
(unconformity)
0-35 ft (0-10m)
No faunal remains.
Quaternary
Permian or Triassic bedrock
Permian or Triassic
not to scale
QA4451

Fig 5