URANIUM RESOURCE EVALUATION
LUBBOCK QUADRANGLE
TEXAS

J. H. McGowen, S. J. Seni, R. L. Andersen, and J. E. Thurwachter

Bureau of Economic Geology
The University of Texas at Austin
University Station, Box X
Austin, Texas 78712

Work performed under Bendix Field Engineering Corporation,
Grand Junction Operations, Subcontract No. 78-133-E,
and Bendix Contract No. DE-AC13-76GJO1664

March 1980

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO 81502

FIGURE CAPTIONS

Figure 1. Location of Lubbock Quadrangle.

Figure 2. Major structural elements, late Paleozoic (after Erxleben, 1975).

Figure 3. Stratigraphic column with lithologic descriptions.

Figure 4. South to north cross section, Guadalupe and Ochoa Series, western part of Lubbock Quadrangle (after Maher, 1960).

Figure 5. Sediment dispersal system (Dockum) during humid climate conditions: meandering streams (A-A' and B-B'); large distributary channel (C-C'); small distributary channel, channel mouth bar, and delta front (D-D'); delta front, prodelta, and lacustrine (E-E'); crevasse channel (F-F'); and crevasse splay (G-G') (after McGowen, Granata, and Seni, 1979).

Figure 6. Sediment dispersal system (Dockum) during arid climatic conditions: valley fill (A-A'); braided feeder channel (B-B'); delta platform, delta foresets, delta front, and lacustrine (section parallel to sediment transport, (C-C'); and same facies as (C-C') except section is perpendicular to sediment transport (D-D') (after McGowen, Granata, and Seni, 1979).

Figure 7. Sedimentary features, Caprock locality.

Figure 8. Sedimentary features, Yellow Cub locality.

page 2 - figure captions

Figure 9. Sedimentary features, Hillside locality. Crevasse splay (splay delta of McGowen, Granata, and Seni, 1979); greenish-gray slightly calcitic fine-grained sandstone with lenses of sandy granule to pebble mud-clast conglomerate; and trough crossbeds, foreset crossbeds, horizontal laminae, and parallel-inclined laminae are the primary sedimentary structures.

Figure 10. Sedimentary features, MacArthur locality.

Figure 11. Sedimentary features, Red Mud locality.

Figure 12. Subsurface sandstone distribution patterns and outcrop directional trends (lower Dockum) (after McGowen, Granata, and Seni, 1979).

Figure 13. Depositional systems, Duncan Sandstone Member, San Angelo Formation (after Smith, 1974).

Figure 14. Depositional systems, Flowerpot Member, San Angelo Formation, and lower part of Blaine Formation (after Smith, 1974).

Figure 15. Structural elements that influenced deposition of the San Angelo Formation (after Smith, 1974).

Figure 16. Sand isolith map of the San Angelo Formation (after Smith, 1974).

Figure 17. Evaporative pump mechanism operative during San Angelo deposition (after Smith, 1974).

Figure 18. Influence of Ogallala ground-water system on uranium mineralization within Permian and Triassic strata.

CONTENTS

ILLUSTRATIONS

ABSTRACT

Uranium resources of the Lubbock Quadrangle, Texas, were evaluated to a depth of 1500 m using available surface and subsurface geological information. Uranium occurrences reported in the literature and in reports of the Atomic Energy Commission were located, sampled, and described. Areas of anomalous radioactivity, interpreted from aerial radiometric survey, and geochemical anomalies, interpreted from hydrogeochemical and stream-sediment reconnaissance, were also investigated. Areas of uranium favorability in the subsurface were evaluated using gamma-ray well logs and driller's logs. Nine areas of uranium favorability were delineated within the quadrangle. Delineation was based on both surface and subsurface data. Several occurrences are present within some of these areas. Five subsurface areas are considered to be favorable for uranium deposits: one area in the San Angelo Formation (a delta system), three areas in the Dockum Group (consisting of fluvial, delta, and lacustrine systems), and one area in the Ogallala Formation (a wet alluvial-fan system). Favorable areas in outcrop are lacustrine facies of the Tule Formation and fluvial-deltaic facies of the Dockum Group. Geologic units considered to be unfavorable include Recent and Pleistocene deposits that blanket the High Plains, parts of the Ogallala Formation, Cretaceous strata, parts of the Dockum Group, and most of the Permian units, except the deltaic deposits within the San Angelo Formation. Recommendations for improving the evaluation of the Lubbock Quadrangle include an aerial radiometric survey with more closely spaced flightlines, a detailed ground-water study, and a coring/logging program to document subsurface uranium occurrences.

INTRODUCTION

PURPOSE AND SCOPE

The Lubbock NTMS Quadrangle, Texas, was evaluated to identify and delineate areas and geologic units that exhibit characteristics favorable for the occurrence of uranium. All geologic formations to a depth of 1500 m were evaluated by means of surface and subsurface investigations. Each stratigraphic entity was categorized as favorable, unfavorable, or not evaluated for uranium deposits, on the basis of the study of significant uranium districts worldwide (Mickle and Mathews, 1978).

ACKNOWLEDGMENTS

Chemical analyses of rock and soil samples were conducted under the supervision of Dr. Clara Ho (Mineral Studies Laboratory, Bureau of Economic Geology). Drafting was supervised by James W. Macon. Initial typing was by Ginger Zeikus. Manuscript processing was supervised by Lucille Harrell. Editing was by Michelle Pemberton. Dr. L. F. Brown, Jr., coordinated the project and reviewed the manuscript. Douglas Ratcliff and Dianne Sullivan managed the project. Computerization of the chemical data was performed by Mark McClelland.

Criteria for recognition of uranium occurrences in the field and classification of uranium deposits were provided by Mathews, Jones, Pilcher, and D'Andrea (1979).

This research was funded by Bendix Field Engineering Corporation (subcontract number 78-133-E) under prime contract to the U.S. Department of Energy (contract number DE-AC13-76GJO1664).

PROCEDURES

Uranium potential of the Lubbock Quadrangle was evaluated by examination of the rocks in outcrop and in subsurface. Surface geologic procedures include (1) locating and determining the source of aerial radiometric anomalies (Geodata International, 1975), (2) checking areas with geochemical anomalies shown by results of the Hydrogeochemical and Stream-Sediment Reconnaissance (HSSR) Program (Butz and others, 1979), and (3) making a general reconnaissance of the geologic environments exposed in outcrop. In conjunction with the outcrop work, rock and soil samples were collected and submitted to the Mineral Studies Laboratory of the Bureau of Economic Geology at Austin for chemical analysis. Descriptions of the stratigraphic units from which samples were taken include mineralogy, lithology, and primary sedimentary structures. A portable scintillometer, the geoMetrics Model GR-101A, was used to measure gross gamma counts of all sampled horizons and to determine the characteristic background radiation level for the area from which the samples were collected. Uranium content of rock and soil samples was by fluorometric method (Ho and Dupre, 1980). Determination of the concentration of the other 30 elements (App. B) contained in rock and soil samples was made by the inductively coupled plasma emission spectrometer (Ho, Calvo, and Tweedy, 1980). Evaluation of the subsurface geologic environments was made by examining geophysical, lithologic, and water well driller's logs.

Subsurface maps of the Ogallala Formation were constructed using closely spaced water well driller's logs. All subsurface maps and cross sections of units below the Ogallala were constructed from gamma-ray, sonic, and resistivity logs.

Some of the plates accompanying this report are on graticules provided by BFEC. These graticules are not at the same scale; therefore, when transparencies are superimposed, the discrepancies are obvious. Other plates are on the same base as the Bureau of Economic Geology's Geologic Atlas, Lubbock Sheet.

GEOLOGIC SETTING

The Lubbock 1° by 2° Quadrangle, an area of 21,280 km^2, is located in northwest Texas between lat 33°N. and 34°N. and long 100°W. and 102°W. (Fig. 1). The Lubbock Quadrangle lies within two physiographic provinces. The western 40% of the area lies within the Southern High Plains, and the eastern 60% of the area lies within the Osage Plains of the Central Lowland Province. The Caprock Escarpment, an erosional escarpment with up to 61 m of relief, forms the boundary between these two physiographic provinces.

The survey area lies almost entirely within the late Paleozoic Midland Basin (Fig. 2). Part of the area is underlain by the Matador Arch (Nicholson, 1960; Salisbury, 1960). Midland Basin was filled with sedimentary rocks ranging in thickness from 3963 m in Lynn County to 2744 m in Lubbock County (Maher, 1960). Stratigraphic nomenclature and generalized lithologic descriptions are summarized in Figure 3.

Precambrian crystalline rocks were encountered in the subsurface within the Midland Basin at depths of 3354 to 3963 m, and along the Matador Arch at depths of about 2744 m. Igneous rocks are unconformably overlain by Ordovician rocks (Ellenburger Group), ranging in thickness from about 122 to 396 m and consisting mostly of dolomite that grades into sandstone and conglomerate near the Matador Arch. Mississippian rocks comprising 46 to 259 m of limestone, dolomite, and shale unconformably overlie the Ellenburger.

The base of the Pennsylvanian represents another major unconformity. Pennsylvanian sediments are represented by a wide range of lithologic types, including locally prominent reefing. Basin lithologies are predominantly sandstone, shale, and shaly limestone. Eastern Shelf (platform) rocks are mostly limestone and dolomite; terrigenous clastics make up a minor part of the section.

In ascending order, Pennsylvanian strata are designated Caddo (Bend), Strawn, Canyon, and Cisco Groups. Distribution of facies within the Pennsylvanian System resulted from tectonism in the Ouachita Structural Belt and concurrent development of depositional basins. During the Atoka, massive limestone accumulated south of the Matador Arch and granite wash accumulated north of the arch prior to development of a shelf, slope, and basin system. Strawn, Canyon, and Cisco Groups are characterized by: (1) fluvial-deltaic sandstones and mudstones, (2) platform carbonates and shelf-margin reefs, (3) slope limestone, sandstone, and mudstone, and (4) basinal limestone, sandstone, and mudstone (Galloway and Brown, 1972; Erxleben, 1975; Cleaves, 1975). Near the western limit of the Lubbock Quadrangle, Pennsylvanian rocks are 120 m thick above the Matador Arch and 500 m thick near the center of the Midland Basin.

During the Permian, basins slowly subsided, water was shallow, and sedimentation rates were slow. Permian section, consisting of Wolfcamp, Leonard, Guadalupe, and Ochoa Series, attains thicknesses of 1980 to 2440 m near the western limit of the Lubbock Quadrangle. The Wolfcamp is mostly shale and dense limestone in the basin areas and predominantly carbonates with some anhydrite in shelf areas. Reef carbonates developed along some shelf edges. In the Midland Basin, rocks of the Leonard Series are mostly marine sandstones and dense limestones. Rocks of the Guadalupe Series are chiefly evaporites and red shale, except for the San Andres

Formation, which is mostly dolomite (Fig. 4). In outcrop, part of the San Angelo and all of the Blaine Formation are equivalent to the San Andres. Ochoa Series (Salado Halite, Rustler Anhydrite, and Dewey Lake Red Beds) is represented by evaporite deposits similar to those of the Guadalupe Series, with the exception of the Dewey Lake Red Beds, which consist of sandstone, siltstone, and mudstone.

Tectonism that created the Gulf of Mexico (Kehle, 1972; Belcher, 1979) rejuvenated certain Paleozoic structural elements, brought about climatic changes, and initiated fluvial-deltaic sedimentation that produced the Triassic Dockum Group (McGowen, Granata, and Seni, 1979). Physical evidence of an unconformity does not exist between Permian and Triassic rocks in most of the Lubbock Quadrangle. Dockum Group crops out along the Caprock Escarpment (Pl. 7) and dips westward beneath the High Plains. Dockum Group consists of about 61 to 488 m of fluvial, deltaic, and lacustrine deposits. Lithologically, the Dockum consists of conglomerate, sandstone, siltstone, and mudstone, along with minor amounts of dolomite and chert. Reddish-brown color dominates the Dockum, although drab colors are locally predominant.

Triassic rocks are unconformably overlain by Cretaceous shale, sandstone, and limestone represented by Trinity and Fredericksburg Groups and part of the Washita Group. Post-Cretaceous erosion removed most of these deposits. Erosional remnants of the Cretaceous are up to 46 m thick (Barnes, 1967).

Prior to deposition of the Pliocene Ogallala Formation, erosion had removed large areas of Cretaceous strata, and streams had scoured southeastward-trending valleys, up to 76 m deep, into Triassic and Permian rocks. Ogallala Formation, a wet alluvial-fan system, consists of conglomerate, sand, silt, clay, and a few limestone beds (Seni, in press). Terrigenous clastics were derived from the Rocky Mountains.

The Ogallala, capped by caliche, is exposed in the cliffs of the Caprock Escarpment. In the northwestern quarter of the map area, the Ogallala outcrop belt ranges from 1.6 to 16 km wide (Pl. 7). The Ogallala dips to the southeast at about 1 m per km.

During the Pleistocene, numerous lakes formed on the Ogallala surface. Lakefill consists of up to 26 m of gravel, sand, silt, clay, limestone, and bentonite. Other Pleistocene deposits are cover sands, playa sands, silts, and clays, and fluvial gravel, sand, and silt.

Recent deposits include windblown sheet and dune sand and silt, and gravel and sand along present stream courses (Pl. 7).

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

The Lubbock Quadrangle includes nine areas containing environments favorable for uranium (Pls. 1A and B). Most of the environments include channel-controlled peneconcordant deposits (Subclass 243, Mathews and others, 1979). Two of the environments (Tule and San Angelo Formations) are unclassified. One area is in the Pleistocene Tule Formation; one is in the Pliocene Ogallala Formation; six are in the Triassic Dockum Group; and one is in the Permian San Angelo Formation. Numerous small occurrences of uranium have been reported in the Dockum (Finch, 1975; Hayes, 1956; McGowen, Granata, and Seni, 1979; and Wright, 1969). Low concentrations of uranium and copper have been reported for the San Angelo Formation (Smith, 1974).

TULE FORMATION

One area (Area A, Pl. 1A) in the Tule Formation is favorable for uranium deposits of an unclassified type because (1) the Tule Formation contains a uranium occurrence; (2) the median fluorometric value of rock samples from the Tule

Formation is the highest among all rock units in Lubbock Quadrangle; (3) uranium source rocks include the Pleistocene Pearlette ash, which was concentrated and preserved in the lacustrine fill of the Tule Formation; and (4) uranium that was leached from volcanic ash was retained in lacustrine fill by reducing conditions at the sediment/water interface.

Stratigraphy and Structure

The Pleistocene Tule Formation occupies a partly filled depression in the Ogallala Formation and covers 25 to 40 km^2 along the Caprock Escarpment in eastern Lynn and western Garza Counties (Evans and Meade, 1944; Frye and Leonard, 1957; Reeves, 1963). Ogallala deposits thin below the depression, which occurs along a Pleistocene drainage valley. The depression formed by caprock breaching resulted from stream (Frye and Leonard, 1957) and/or wind erosion (Reeves, 1963). The Tule is overlain by Quaternary stream gravels, eolian cover sands, Tahoka Clay (Wisconsinan), and soil.

Lithology

The Tule Formation ranges in thickness from a few meters to 26 m. It consists of (1) red, gray, greenish-gray, and light brown fine to medium sands, sandstone, and granule to pebble conglomerate; (2) white, light gray, yellowish-gray, and greenish-gray clays; (3) thin limestones; (4) irregularly distributed caliche; and (5) volcanic ash. The texture and lithology of Tule deposits change vertically and laterally (Pl. 11). In general, the texture of the Tule deposits fines upward. Coarse terrigenous clastics, composed of fine to medium sand and sandstone and limestone- and caliche-clast granule to pebble conglomerate are concentrated at the margins of the deposit and in the lower third of the sequence. The coarse clastics occur in lenses 0.3 to 2.0 m thick.

Horizontal to slightly inclined parallel laminae and convolute laminae are common. The upper two-thirds of the sequence is predominantly gray clay containing varve-like laminations (Reeves, 1963). According to Reeves (1963), the clay is bentonitic and represents altered volcanic ash. Sample MIW-318 is unaltered ash from a bed 5.0 cm thick. Sporadic lenses of caliche 0.05 to 2.0 m thick occur at the top of the sequence.

Depositional Environment

The lacustrine origin of the depression fill is evidenced by thin limestones, clay-rich varve-like laminations, marginal, locally derived coarse terrigenous clastics around the periphery, and lithologic and physiographic similarities between Tule deposits and other early Pleistocene lacustrine deposits, such as Rita Blanca Beds (Evans and Meade, 1944; Anderson and Kirkland, 1969), Blanco Beds (Evans and Meade, 1944; Izett and others, 1970, 1972), and Tule Beds in Briscoe County, Texas (Evans and Meade, 1944).

Although ash from the Tule Formation in Lynn County has not been dated, it probably is related to the Pearlette ashes, ranging in age from 0.6 to 3.2 m.y.

The abundance of gray sands and clays suggests that reducing conditions prevailed during deposition of the Tule. The presence of reducing conditions at the sediment/water interface, distinct varve-like laminations, and lack of benthonic fauna indicate meromictic or chemically stratified lacustrine conditions in which lake bottom waters were seasonally oxygen deficient.

During the early Pleistocene, the Tule may have drained a 3000 km^2 area, providing a mechanism to concentrate and preserve uraniferous ash and to fix the uranium through reducing conditions.

Uranium Mineralization

One uranium occurrence was found in the Tule Formation outcrop area (Pl. 12). The highest uranium concentrations in this formation (MIW-336, 125 ppm; MIW-337, 128 ppm) occur in gray and light brown fine sands and sandstones. Anomalous uranium values also occur in gray mudstones (30 to 40 ppm). Below the Tule, some Tertiary Ogallala conglomerates also show elevated uranium values (MIW-319, 26 ppm). Although no uranium minerals were detected, a black, pore-filling cement was present in the two Tule samples having the highest uranium values.

The source of uranium is believed to be the Pearlette-type ashes. Most of the gray clay in the upper two-thirds of the sequence may also represent altered volcanic ash.

Hydrology

Little information exists on ground water in the Tule Formation. Ground water normally is not produced from the Tule because of the abundance of relatively impermeable lacustrine clays. Results from the Hydrogeochemical and Stream-Sediment Reconnaissance sampling program (Butz and others, 1979) indicate that anomalous concentrations of uranium and associated trace elements (As, Cu, Mo, Se, and V) occur in the Ogallala ground water in the vicinity of the Tule Formation. Ground water in thin sandstones at the base of the Tule is expected to show similar uranium and trace-element associations.

Favorable Area

Area A. The entire outcrop of the Tule Formation is considered favorable for uranium deposits (Area A, Pl. 1A). The subsurface extent of the Tule is estimated to cover 24 km^2. If the formation averages 10 m in thickness, and if half of the volume of the Tule were removed by erosion, the remaining volume of Tule rocks is 0.24 km^3 or 2.4 x $10^8 m^3$. The volume of rock having more than 100 ppm U is estimated at 300 m^3. Amount of U_3O_8 is 0.1 t.

Radioactivity and chemical data for all Quaternary rock samples are summarized in Appendix D. Fluorometric U_3O_8 values for Quaternary rocks are graphically represented in frequency histograms and cumulative-probability curves (Pl. 13). The choice of symbols and concentration intervals is based on conventions established by the NURE program. The median fluorometric U_3O_8 values from the probability curve of Quaternary rock samples are the highest among all rock units in the Lubbock Quadrangle (Pl. 5).

The uranium occurrences in Area A are categorized as peneconcordant sandstone-type uranium deposits (Subclass 243), with uranium deposition occurring as a lacustrine fill.

OGALLALA FORMATION

One area (Area B, Pl. 1A) in the Ogallala Formation is favorable in the subsurface for uranium deposits in sandstone Subclass 244 (Mathews and others, 1979) because (1) favorable sandstone host-rock characteristics exist, (2) there is a source of uranium in overlying Pleistocene deposits, (3) overlying Pleistocene deposits contain a uranium occurrence, (4) Ogallala strata are enriched in uranium below Pleistocene uranium occurrences, and (5) Ogallala ground water is enriched in uranium, arsenic, molybdenum, selenium, and vanadium.

Stratigraphy and Structure

The Ogallala Formation consists of clay, silt, sand, and gravel deposited in a widespread, wet alluvial-fan system (Seni, in press). Multiple pedogenic (soil) caliche horizons cap the sequence (Reeves, 1966). Sand and gravel are concentrated at the base of the formation, but also occur sporadically throughout the section.

The Ogallala ranges in thickness from a few meters to more than 130 m and rests unconformably on an eroded surface of Cretaceous and Triassic strata (Pl. 14). A structure contour map of the base of the Ogallala (Pl. 15) shows that the Ogallala is thickest along valleys cut into the pre-Ogallala surface. Regional basement structures affecting Permian strata deposited along the western edge of the Eastern Shelf apparently do not affect Ogallala sedimentation (Pls. 16 and 17).

Lithology

The lithology of the Ogallala Formation in the Lubbock Quadrangle can be broadly divided into coarse-grained and fine-grained lithofacies. The coarse-grained lithofacies, concentrated at the base of the formation, is sand and gravel. The sand and gravel consists of medium to coarse sand, granules, pebbles, and cobbles of quartz, quartzite, limestone clasts, minor chert, igneous rock, metamorphic rock, and clay balls. The clay balls and limestone clasts were locally derived from underlying Triassic and Cretaceous strata; the more durable clasts were derived from the Rocky Mountains. The fine-grained lithofacies are composed of clay, silt, sand, and caliche. Clay and silt dominate the upper parts of the formation. Caliche forms the resistant caprock and is locally absent. Early Pleistocene fluvial and lacustrine deposits fill depressions in the caprock.

Depositional Environment

The Ogallala is an alluvial apron extending east of the Rocky Mountains that was deposited by coalescent, low-gradient, wet alluvial fans (Seni, in press). In the Lubbock Quadrangle, subsurface studies indicate that coarse-grained lithofacies occur in the medial- and distal-fan facies, defined by broad sheets, and digitate belts of thick net sand, respectively. Medial-fan facies are characterized by broad, thick, lobate sheets of sand and gravel. Distal-fan facies are defined by (1) digitate, high percentage sand and gravel and (2) thick sand and gravel belts occurring downdip from medial-fan facies. Fan processes and braided fluvial systems were dominant in the lower part of the Ogallala, whereas lacustrine, soil, and eolian processes were dominant in the upper part. Ogallala deposits thin over erosional remnants of Cretaceous strata in Hale, Lubbock, Lynn, and Garza Counties.

Uranium Mineralization

Although no uranium occurrences containing greater than 100 ppm U_3O_8 or any reductants were recognized in Ogallala outcrops, anomalous uranium concentrations (less than 100 ppm U_3O_8; greater than 95th percentile) are associated with indurated caliche and silicified zones in the upper part of the caliche caprock (Pl. 18). Anomalous uranium concentrations in Ogallala sand and gravel occur beneath uranium occurrences in Pleistocene lacustrine deposits.

Two uranium occurrences in the Ogallala caliche east of Lubbock, described by Finch (1975), were sampled. Thin zones (0.03 to 0.6 m thick) and pods of highly indurated caliche, at the top of the caliche horizon, contain uranium 10 to 20 times greater than the concentrations in the adjacent slightly lithified caliche (MIW-362, 1.0 ppm; MIW-363, 17.0 ppm; MIW-364, 1.5 ppm; MIW-365, 19.0 ppm). A similar pattern of 10 to 20 times increase in uranium occurred in other indurated caliche samples (MIW-150, 1.3 ppm; MIW-151, 13.0 ppm) (Pl. 18).

Uranium in indurated caliche is apparently related to increases in carbonate cement that completely filled the interstices. Petrographic studies from samples of both caliche types indicate little difference, except with regard to increased carbonate micrite cement. A similar mechanism of uranium concentration that may occur in caliche is reported by Zielinski (1979). He states that uranium concentrations in sedimentary silicates (opal and chalcedony cements) are greater than the uranium concentration in associated ground waters by a factor of 400 to 1,000.

Pedogenic caliche in the Ogallala Formation has little in common with the highly uraniferous caliche at Yeelirrie, Western Australia (Carlisle and others, 1978). Differences in ground-water flow patterns and open-basin hydrologic conditions make the Ogallala caliche an environment unfavorable for uranium occurrences. The low grade of uranium in indurated caliche and the spotty distribution also indicate poor uranium favorability.

Hydrology

Ogallala Formation ground water is under declining water table conditions over most of the survey area (Taylor, 1979) as discharge exceeds recharge. Regionally, ground water in the Ogallala flows from northwest to southeast, following the regional dip of the pre-Ogallala surface and the regional slope of the upper surface of the Ogallala. Open-basin hydrologic conditions in the Ogallala aquifer occur over the survey area, but flow conditions are influenced by the topography of the pre-Ogallala surface. The topography of the pre-Ogallala surface is modified by deep pre-Ogallala valleys and erosional remnants of Cretaceous strata.

Within pre-Ogallala valley systems, the Ogallala is thicker (up to 130 m) than adjacent strata, and contains thicker net sand and gravel and higher percentage sand and gravel (Pl. 19). Ogallala strata are thin (less than 65 m) and contain lower net and percentage sand and gravel over erosional remnants of Cretaceous strata. These differences allow ground water to move more rapidly through porous valley-fill systems than through less permeable strata over erosional remnants. Open-basin hydraulic conditions are unfavorable for preservation of uranium deposits in Ogallala strata. Flushing would be slower in the thinner Ogallala sections because of the lower porosities and the thinner saturated section.

Hydrogeochemical and Stream-Sediment Reconnaissance data for the Lubbock Quadrangle (Butz and others, 1979) indicate a large group of anomalous Ogallala ground-water samples in eastern Lynn and Lubbock Counties and in western Garza County. In this area, uranium is associated with the following trace elements: As, Mo, Se, and V. The area of anomalous Ogallala ground water coincides with the area of Ogallala underlain by Cretaceous strata. Pleistocene fluvial and lacustrine deposits (Tahoka Lake, Tule Formation) overlie the Ogallala in parts of this area.

Favorable Area

Area B. The favorable part of the Ogallala referred to as Area B (Pl. 1A) outlines the area where the Ogallala is underlain by a broad plateau of Cretaceous strata and where Ogallala ground water contains anomalous uranium values. Although rock samples from surface exposures do not indicate a high degree of uranium favorability, Hydrogeochemical and Stream-Sediment Reconnaissance data (Butz and others, 1979) indicate favorable recognition criteria based on anomalous uranium and trace element concentrations.

In Area B, Ogallala deposits cover approximately 3000 km^2 and range from a few meters to more than 70 m thick. The favorable volume of rock is approximately 440 km^3.

Pleistocene deposits are especially abundant in Area B, and they contain the highest median uranium value for rock samples. Leaching of uranium occurrences in Pleistocene strata by oxidizing ground water has resulted in the partial redistribution of uranium into Ogallala rocks. For example, the two highest uranium values for Ogallala rocks (MIW-319, 26.0 ppm; MIW-328, 21.0 ppm), are below the uranium occurrence in the Tule Formation.

The source of uranium in Pleistocene strata is believed to be the Pearlette-type ashes. Uranium associated with caliche is also thought to originate from Pleistocene ashes. Meteoric waters percolating through ash-bearing soil zones leached uranium and redeposited uranium in the caliche zone. Post-Pleistocene and Pleistocene lacustrine deposits (Tahoka, Guthrie, Double, and Twin Lakes, and Tahoka and Tule Formations) are abundant in Area B, in part because of the lower permeabilities and porosities of Ogallala deposits in this area. The formation of large (up to 1000 km^2) drainage basins associated with these lacustrine systems provides a mechanism to collect and concentrate ash and uranium in the lacustrine fill. The reducing nature of the lacustrine deposit limits the mobility of uranium. Continual contact with slow-moving and oxidizing Ogallala ground water, however, remobilizes and redistributes some uranium into Ogallala ground water and strata. The mechanisms of uranium emplacement, preservation, and concentration indicate that the most likely sandstone-type uranium deposits in the Ogallala Formation would occur in nonchannel (Subclass 244) environments.

Drainage, Generalized Land Status, and Culture

Drainage is poorly developed in Area B. The High Plains surface is dotted with abundant playas that collect surface runoff from the immediate area. The drainage basins of individual playas range from less than 2.0 to 20 km^2. Playas are strongly aligned in a northwest-southeast orientation in the southern part of the study area. Incipient drainage develops by overland flow between the aligned playas. In the same area, wind and current erosion (Reeves, 1966) have enlarged playas to form pluvial lake basins, such as Double Lakes, Twin Lakes, Guthrie Lake, and Tahoka Lake. In the northwestern part of the area, drainage is developed along Yellow House and Blackwater Draws, which form the headward reaches of the North Fork of the Double Mountain Fork of the Brazos River. The land in Area B is under private ownership and predominantly consists of small, highly productive farms. The main city in the region, Lubbock, is located in Area B, at the confluence of the Yellow House and Blackwater Draws.

DOCKUM GROUP

Six areas (C, D and E in outcrop and F, G and H in subsurface--see Pl. 1B) in the Dockum Group are favorable for uranium in sandstone Subclass 243 (Mathews and others, 1979) because (1) there is a sandstone host rock; (2) there is a source of uranium in the overlying Pleistocene deposits; (3) uranium was leached from volcanic ash in the Pleistocene; (4) uranium-bearing ground waters of the Ogallala Formation invaded the sandstones of the Dockum Group; and (5) uranium was deposited upon encountering a reducing environment within the Dockum sandstones.

Stratigraphy and Structure

The Dockum Group in the Lubbock Quadrangle consists of 60 to 395 m (Pl. 20) of terrigenous clastic rocks ranging from mudstone to conglomerate. Distribution of coarse clastics is shown on Plate 21. The Dockum Group, which accumulated in a slowly subsiding continental basin, has traditionally been subdivided into three units:

the basal Tecovas Formation, middle Trujillo Formation, and upper Chinle Formation. These formations are not recognizable in the Lubbock Quadrangle, and the Dockum has been arbitrarily divided into a lower and an upper unit (McGowen, Granata, and Seni, 1979). Only the lower unit is exposed in outcrop.

The basin was filled with a maximum of 600 m of fluvial, deltaic, and lacustrine deposits. Sediment was derived chiefly from Paleozoic sedimentary rocks that surrounded the basin. Deposits initially sloped from all sides toward the basin center. The Dockum in the Lubbock Quadrangle slopes 1.0 to 3.0 m per km to the west.

Lithology

The Dockum Group is made up of mudstone, siltstone, sandstone, and conglomerate and rare chert, gypsum, dolomite, and impure coal. Reddish-brown siltstone, the dominant rock type, encases all other rock types, either lenticular or tabular bodies. The ratio of coarse-to-fine-grained sedimentary rocks varies laterally and vertically within the Dockum. Where fluvial and deltaic systems are dominant, coarse-grained sedimentary rocks may make up 80 to 90% of the section, whereas in interdeltaic positions, fine-grained sedimentary rocks may make up 80 to 90% of the section.

Sandstones and siltstones are made up of a combination of quartz (plus feldspar) and sedimentary rock fragments. In the stratigraphically lower parts of the Dockum, conglomerates are made up of several varieties of quartz and chert. In the upper parts of the Dockum, conglomerates consist mostly of calcareous material (caliche), mudstone, siltstone, and sandstone clasts.

Depositional Environments

Rejuvenation of Paleozoic structural elements plus alternating humid and arid climatic cycles determined the depositional style of the Dockum. During humid cycles, lake area and depth were maximum. Highly meandering fluvial systems transported sediment to the lake margin, where shallow-water lobate deltas were constructed (Fig. 5). Basinward beyond the delta front, silt and mud settled to the lake floor. During arid cycles, lake area and depth diminished; at this time valleys were scoured into older Dockum deposits. Depositional environments operative during the arid cycles were braided streams, fan deltas (Fig. 6), mudflats, and shallow ephemeral lakes.

In outcrop, a generalized vertical sequence of strata that accumulated under humid conditions is: (1) reddish-brown, massive- to parallel-laminated prodelta or lacustrine mudstone; (2) grayish-green, horizontally laminated and ripple cross-laminated delta-front siltstone and very fine-grained sandstone; (3) reddish-brown to grayish-green trough crossbedded and horizontally laminated distributary channel fill; and (4) orange to grayish-green, upward-fining meanderbelt sandstones (these sandstone bodies are up to 26 m thick).

Arid-climate deposits are predominantly reddish-brown mudstone to conglomerate, mostly derived from older Triassic deposits. Mudstones accumulated in lacustrine and mudflat environments and are thin, massive, or parallel laminated, and commonly burrowed or desiccated; some desiccated mudstones contain gypsum crystals and salt hoppers. Siltstones are reddish-brown to greenish-gray, ripple cross laminated and parallel laminated; they are components of delta foresets and bottomsets. Sandstone and conglomerate make up delta-foreset and delta-platform facies of small fan deltas.

Uranium Mineralization

A total of 564 rock samples from the Dockum Group were analyzed for uranium (Pl. 22) and 30 other elements (App. B). Uranium content ranges from 0.2 ppm to

8,375 ppm. Only 15 samples, from six localities, contained more than 100 ppm uranium. Where uranium values are 100 ppm, or greater, vanadium values are high; the highest concentrations of vanadium (highest value is 8,034 ppm) are about equal to those of uranium.

Uranium and vanadium were emplaced in Dockum sandstones by a ground-water flow system that developed subsequent to accumulation of Pleistocene volcanic ash. Uranium and vanadium were leached from ash contained in the Pleistocene and transported by oxygenated Ogallala ground waters into the Dockum, where reducing conditions were encountered, resulting in uranium concentration.

Hydrology

Ground-water movement through Dockum sandstones in the Lubbock Quadrangle is to the west and southwest. Ground water derived from the Dockum directly beneath the Ogallala is high in bicarbonate (as is the Ogallala), and in general exhibits the same chemistry as the Ogallala (McGowen, Granata, and Seni, in preparation). Similarly, ground water derived from the Dockum near its contact with Permian strata is high in sulfate, chloride, and dissolved solids; these properties are also characteristic of Permian waters.

Ground-water yield from the Dockum is generally very low (Cronin and Follett, 1963), indicating low permeability.

Dockum ground water changes from very shallow fresh water to very saline water at depth. Sodium, sulfate, chloride, and dissolved solids increase irregularly with depth.

Favorable Areas (Outcrop)

Area C. The favorable Area C (southwest Garza County, Pl. 1B) includes the Caprock Prospect (locality 1)and the Yellow Cub Prospect (locality 2; see App. A, B, and C).

The Caprock Prospect uranium (sandstone Subclass 243; Mathews and others, 1979) occurs in the upper part of the lower Dockum Group (McGowen, Granata, and Seni, 1979).

Four depositional units compose the section at the Caprock locality (Fig. 7). These are (1) delta-front sandstone, (2) distributary channel-fill sandstone, (3) crevasse channel-fill sandstone and delta-plain siltstone and mudstone, and (4) meander-belt sandstone. Sample MIW-541 was taken from muddy sandstone near the erosional base of the channel; however, most of the channel fill is moderately sorted fine sand. The uranium mineral is carnotite. Scintillometer reading was 1,000 counts per second. Related elements are V, Cu, Mo, Co, Ni, As, and Fe. Samples MIW-542 and MIW-543 were taken near the erosional base and about 2.0 m above the base of a meandering stream deposit. Rock type is moderately sorted conglomeratic medium sandstone at the base and moderately sorted fine- to medium-grained sandstone 2.0 m above the base. The uranium mineral is carnotite. Scintillometer readings were 2,135 to 4,600 counts per second. Related elements are V, Cu, Mo, Co, Ni, As, and Fe.

Geochemical anomalies (Pl. 4) ranging from 24 to 36 ppb lie to the northwest of the Caprock locality. A radiometric anomaly (Pl. 3) occurs within the area of the Caprock locality and the geochemical anomalies. Also within the area of the Caprock locality are uranium occurrences ranging from 4.0 to 11.0 ppm (Pl. 22).

Sample MIW-541 (U_3O_8 content 475 ppm) occurs in a muddy sandstone (Fig. 7). Surface area of the mineralized sandstone is 0.9 m^2, and estimated volume of mineralized rock is 2.7 m^3. Estimated amount of U_3O_8 in the muddy sandstone is 0.15 t.

Samples MIW-542 and MIW-543 (U_3O_8 content 240 and 2,000 ppm, respectively) are from the lower part of a conglomeratic fine- to medium-grained sandstone (Fig. 7). Combined surface area of these two mineralized zones is 0.9 m^2 and estimated volume of mineralized rock is 1.24 m^3. Estimated amount of U_3O_8 from the two mineralized zones is 0.64 t.

Mineralized zones at the Caprock locality are overlain by approximately 60 m of Dockum, Cretaceous, and Pliocene sedimentary rock.

Locality 2 (Area C) is the Yellow Cub Prospect (Pl. 1B, App. A, B, and C). Uranium occurs in sandstone Subclass 243 (Mathews and others, 1979). The geologic unit is the upper part of the lower Dockum Group (McGowen, Granata, and Seni, 1979).

Four depositional units (Fig. 8) are recognizable in the Dockum at the Yellow Cub Prospect. These are (1) floodplain mudstone and siltstone, (2) crevasse channel-fill conglomerate, sandstone, siltstone, and mudstone, (3) a covered interval (assumed to be floodplain and lacustrine mudstone and siltstone), and (4) crevasse-splay conglomerate and sandstone. Sample MIW-537 was taken from a medium gray, friable to calcitic, muscovitic, moderately sorted fine- to medium-grained sandstone about 1.0 m above the base of the crevasse-splay unit. The uranium mineral was not identifiable in the field (reported to be carnotite by Butler and others, 1962; Bement and others, 1977). Scintillometer readings were 250 to 1,800 counts per second, and the related elements are V, Cu, Mo, Zn, Co, Ni, As, Cd, Mn, and Fe.

An examination of Plates 3, 4, and 22 shows that there are no radiometric anomalies, geochemical anomalies, or other uranium occurrences within the area of the Yellow Cub Prospect.

Sample MIW-537 contained 362 ppm U_3O_8 and 813.6 ppm V. The area of the mineralized zone is 1.8 m^2. The estimated volume of mineralized rock is 5.4 m^3. Estimated amount of U_3O_8 is 0.23 t.

Area D. Area D (Pl. 1B) in northwestern Garza County has three localities with occurrences greater than 100 ppm U_3O_8. Two localities (Hillside and Twin Rattler Prospects, App. A, B, and C) are on the Long Ranch. The other locality is on the Eubank Ranch (App. A, B, and C).

On the Long Ranch (shown as Area D on Pl. 1B) uranium occurs in sandstone Subclass 243 (Mathews and others, 1979). The sandstone is in the upper part of the lower Dockum Group (McGowen, Granata, and Seni, 1979).

Both the Hillside and Twin Rattler Prospects lie in an area characterized by fluvial, deltaic, and lacustrine depositional systems (McGowen, Granata, and Seni, 1979). Sandstones exposed at the Hillside and Twin Rattler Prospects accumulated as crevasse splays. Characteristics of crevasse-splay deposits are shown in Figure 9. Uranium concentrations mostly occur in fine-grained quartz sandstone and carbonaceous, mud-clast-bearing, fine-grained quartz sandstone. The uranium mineral is carnotite. Scintillometer readings ranged from 900 to 10,000 counts per second. Related elements are V (greater than 8,000 ppm), Cu, Mo, Zn, Co, Ri, As, Cd, Mn, and Fe.

Geochemical anomalies occur to the southwest of Hillside and Twin Rattler localities, where ground-water samples (Pl. 4) contained 39 to 140 ppb uranium. Flightlines did not cross this area; therefore no radiometric anomalies were indicated (Pl. 3). Uranium occurrences within the area of Hillside and Twin Rattler localities range from 3.3 to 20.7 ppm (Pl. 22).

Three samples were collected at the Hillside Prospect (MIW-552, 525 ppm U_3O_8; MIW-553, 950 ppm U_3O_8; MIW-554, 7,375 ppm U_3O_8), and three samples were collected at the Twin Rattler Prospect (MIW-555, 600 ppm U_3O_8; MIW-556, 198 ppm U_3O_8; MIW-557, 8,375 ppm U_3O_8). Although some of these values are high, the outcrop areas of these mineralized zones are extremely small. At the Hillside Prospect, total area of the mineralized zones is 8.6 m^2; estimated volume of mineralized rock is 35.2 m^3; estimated amount of U_3O_8 is 10.5 t. At the Twin Rattler Prospect, total area of these mineralized zones is 16.1 m^2; estimated volume of mineralized rock is 83.9 m^3; estimated amount of U_3O_8 is 5.014 t.

The geologic setting, depositional environment, type of uranium mineral and associated elements of the Eubank Prospect (Area D on Pl. 1B; App. A, B, and C) are similar to the Hillside and Twin Rattler localities. Samples MIW-558 and MIW-559 contained 1,275 ppm U_3O_8 and 1,800 ppm U_3O_8, respectively. Total outcrop area of the two mineralized zones is 1.26 m^2; estimated volume of mineralized rock is 1.404 m^3; estimated amount of U_3O_8 is 0.244 t.

Geochemical anomalies are present within the area east, north, and west of the Eubank Prospect, where ground-water samples (Pl. 4) contained 12 to 67 ppb uranium. A radiometric anomaly (Pl. 3) occurs in the area of the Eubank Prospect. Also within the vicinity of the Eubank Prospect are uranium occurrences ranging from 3.5 to 28.8 ppm.

Area E. Area E (Pl. 1B), at the juncture of Crosby, Dickens, Kent, and Garza Counties, contains two uranium prospects (MacArthur Ranch and Red Mud Prospects). Only the MacArthur Ranch Prospect yielded samples containing more than 100 ppm. At MacArthur Ranch, uranium occurs in sandstone Subclass 243 (Mathew and others, 1979). The geologic unit is the basal part of the Dockum Group, which accumulated in a coarse-grained meanderbelt fluvial system (McGowen and Garner, 1970). This system is characterized by trough crossbedded and foreset crossbedded, calcitic, conglomeratic, fine- to medium-grained sandstone (Fig. 10). These fluvial deposits contain wood casts and silicified wood. Carnotite was associated with wood casts (MIW-549). Related elements are V, Cu, Mo, Zn, Co, Ni, As, Cd, Mn, and Fe.

Geochemical anomalies are not particularly evident from ground-water samples (Pl. 4) in which uranium content ranged from 2.2 ppb to 17 ppb; values are highest to the west and southwest. Radiometric anomalies (Pl. 3) were not indicated for the MacArthur Prospect (Geodata International, 1975). Within the area of the MacArthur Prospect there are several uranium occurrences (all less than 100 ppm).

Three uranium occurrences (MIW-549, 281 ppm U_3O_8; MIW-550, 131 ppm U_3O_8; MIW-551, 105 ppm U_3O_8) are found in the upper 4.6 m of the outcrop (Fig. 10). Scintillometer readings ranged from 1,000 to 1,200 counts per second. The total area of the mineralized zones is 5.4 m^2; estimated volume of mineralized rock is 25 m^3; estimated amount of U_3O_8 is 0.24 t. At the MacArthur Prospect, the uranium-bearing strata cap small outliers, but immediately to the south the Dockum is overlain by at least 3 m of Recent windblown sand.

The Red Mud Prospect occurs within Area E (Pl. 1B). The highest value of 56 ppm places the Red Mud area in a marginal category. A progradational, lacustrine delta system is indicated for this basal Dockum sequence (Fig. 11), which immediately overlies the Permian Quartermaster Formation. Delta-front sandstone is the host of the 56 ppm U_3O_8 occurrence (sandstone Subclass 243, Mathews and others, 1979). This occurrence covers an area of about 3.6 m^2 and the volume of rock estimated to contain U_3O_8 at 56 ppm is 216 m^3. Estimated amount of U_3O_8 is 0.14 t.

Carnotite is the probable uranium mineral, although it was not observed in the outcrop. Geochemical and radiometric anomalies, and other uranium occurrences, are the same as for the MacArthur Prospect area.

Of the uranium occurrences in the Dockum outcrop, those in Areas C and D appear to be the most promising because (1) they have the highest U_3O_8 content as determined from analyses of rock samples; (2) occurrences are coincident with radiometric anomalies (where flightlines crossed the areas of occurrence); (3) highest uranium content in ground waters generally occurs downdip from the areas in which uranium content is high in outcrop, as indicated by analyses of rock samples; and (4) these areas have only recently, in terms of geologic time, been stripped of their Ogallala Formation cover (volcanic ash in the Pleistocene is the only plausible source of uranium).

Favorable Areas (Subsurface)

Uranium occurrences in the Dockum outcrop, although locally exhibiting high U_3O_8 content, are small and are the remnants of larger mineralized zones. Geochemical gradients (based on uranium content of ground-water samples) indicate an increase in uranium content in the subsurface. This suggests that uranium was mobilized in the oxidizing outcrop environment and has been concentrated in the subsurface.

Subsurface trends of the sands in the lower Dockum (McGowen, Granata, and Seni, 1979) in the Lubbock Quadrangle are to the southwest (Fig. 12). These sandstone trends, in conjunction with geochemical data, suggest that uranium-bearing ground waters have moved generally to the southwest.

Area F. Area F (as well as Areas G and H, Pl. 1B) is favorable for uranium in sandstone Subclass 243 (Mathews and others, 1979) because of (1) the presence of subsurface sandstones the counterparts of which (depositional facies) in outcrop contain uranium; (2) the southwest trend of geochemical anomalies, which corresponds with subsurface sandstone trends (Pls. 4 and 21); and (3) the presence of subsurface radiometric anomalies, at several stratigraphic positions, that are distributed over broad areas (Pls. 23 and 33).

Area F, having an area of 260 km^2, lies downdip from the Caprock Prospect (Pl. 1B). Thickness of the Dockum in Area F is 305 to 395 m; the Dockum consists of 10 to 20% sand (Pl. 21). One hundred percent of the well logs in the area displayed gamma-ray anomalies. Ground water in Area F contains 10 to 100 ppb U_3O_8. The volume of sandstone contained in Area F is 9.1 km^3, and the estimated volume of U_3O_8 (concentration of 50 ppm) is 5.0 x 10^7 t.

Area G. Area G, having an area of 575 km^2, lies to the north and west of outcrop Area D (Pl. 1B). Thickness of the Dockum in Area G is between 260 and 305 m; the Dockum consists of 15 to 20% sandstone (Pl. 21). A large area--including (1) the subsurface Dockum beneath outcrop Areas D and E, and (2) subsurface Area G--is characterized by 100% of well logs indicating gamma-ray anomalies. Ground water in Area G contains 10 to 100 ppb U_3O_8. The volume of sandstone contained in Area G is about 27 km^3, and the estimated volume of U_3O_8 (concentration of 50 ppm) is 15.2 x 10^7 t.

Area H. Area H, having an area of 1980 km^2, lies in the northwest part of the Lubbock Quadrangle (Pl. 1B), and is the southern extension of Favorable Area C of the Plainview Quadrangle (Amaral, 1979). The Dockum of Area H ranges from about 170 to 430 m thick (Pl. 20). Sandstone constitutes 20 to 40% of the Dockum in Area H (Pl. 21). Sandstone trend is northeast-southwest; highest percentage sandstone lies to the northeast, indicating that the sediment source lay to the northeast. Part of Area H has been penetrated by wells whose logs indicate no radiometric anomalies, whereas in other parts of Area H, each log has one or more anomalies (Pl. 23); more than 50% of the wells have gamma-ray anomalies. Ground-water data in Area H are mostly from the Ogallala Formation. In general, U_3O_8 in ground water is less than 20 ppb; one significant anomaly of greater than 100 ppb U_3O_8 (Pl. 4) lies at the southern tip of Area H where the Dockum is 400 to 425 m thick (Pl. 20) and the section consists of 40% (160 to 170 m) of sandstone (Pl. 21). Gamma-ray anomalies are present in 100% of the well logs in the southern tip of Area H. The volume of sandstone contained in Area H is about 48 km^3, and the estimated volume of U_3O_8 (concentration of 50 ppm) is 1.3×10^9 t.

Drainage, Generalized Land Status, and Culture

Area C and F are transected from northwest to southeast by the Double Mountain Fork of the Brazos River (Pl. 6). The northwestern part of the area is underlain by the flatlands of the High Plains. The 61 m Caprock Escarpment separates the High Plains from the hills, to the east, formed by dissection of the Dockum Group. Areas C and F are entirely in the private sector (Pl. 9). The area is traversed from north to south by Farm Road 62. Numerous paved and dirt roads are situated on the High Plains (Pl. 10). Water wells and oil fields are scattered across the area. The hamlets of Grassland and Draw are within Area A.

Areas D and G are traversed from northwest to southeast by McDonald Creek, the Salt Fork of the Brazos River, and the North Fork of the Double Mountain Fork of the Brazos River (Pl. 6). The area is underlain by the flatlands of the High Plains and by the Dockum Group (Pl. 7), which forms east-facing escarpments dissected by streams. The lands of Areas D and G are privately owned (Pl. 9). The area is traversed from north to south by Farm Road 62 and from northwest to southeast by U.S. Highway 84; numerous paved and dirt roads lie within the area (Pl. 10). Numerous water wells and oil wells are situated in the area. The major towns near the area are Post and Slaton.

Area E is traversed from north to south by the White River (Pl. 6). The area is characterized by east-facing escarpments formed in Dockum strata, by flat to hummocky sandy areas formed of Recent windblown sand, and by relatively flat areas underlain by the Permian Quartermaster Formation. The state-owned White River Reservoir and Park is in Area D; the remaining part of the area is held by the private sector (Pl. 9). Paved farm roads cross the center of the area from east to west and parallel the west shore of the White River Reservoir (Pl. 10). A few water wells and oil wells are scattered across the area.

Area H occurs entirely within the flatlands of the High Plains. Yellow House and Blackwater Draws trend in a southeasterly direction across the area to just north of Lubbock where they join to form the North Fork of the Double Mountain Fork of the Brazos River. The area is heavily dotted with playa lakes. Most of the surface is covered with Pleistocene windblown sand. The Ogallala Formation is exposed along some of the drainage systems (Pl. 7). The lands of Area H are privately owned (Pl. 9). Numerous highways and railroads traverse the area. Numerous water wells and oil wells are in Area H. Major towns within the area are Lubbock, Abernathy, and Idalou.

SAN ANGELO FORMATION

The San Angelo Formation is judged, by geologic inference, to be an unclassified favorable sandstone type for uranium occurrence because (1) a widespread sandstone unit exists in the subsurface in Stonewall County; (2) uranium and copper occurrences have been reported from equivalent rocks in north Texas and Oklahoma; (3) uranium and other metals were concentrated in brines in sabkha deposits that grade laterally into the deltaic deposits, and that overlie and underlie the deltaic deposits; and (4) reductants occur in the fluvial and distributary sediments of the San Angelo Formation.

Stratigraphy and Structure

The San Angelo Formation (Fig. 3) is divided into a lower sandstone (Duncan Sandstone Member) and an upper mudstone (Flowerpot Mudstone Member). Smith (1974) delineated two delta systems and an intervening tidal-flat system in the Duncan Sandstone Member (Fig. 13) and a tidal-flat system in the Flowerpot Member (Fig. 14).

The San Angelo Formation prograded westward across a restricted shelf, which formed the eastern margin of the Midland Basin (Fig. 15). During Guadalupian time, the shelf was shallow and lacked a distinct shelf edge. The Ouachita Foldbelt and Wichita-Arbuckle Mountains bordered the coastal plain to the east and north, respectively. In southern Stonewall County, regional dip of the San Angelo is about 5.6 m per km.

The San Angelo Formation extends from the first sandstone bed that rests conformably or unconformably on the Choza Formation and extends upward to the first regionally extensive gypsum bed at the base of the Blaine Formation. The San Angelo grades upward and downdip into the Blaine.

The Duncan Sandstone Member attains a thickness of about 20 m in outcrop and pinches out in the subsurface in Stonewall County (Fig. 16). Upper half of the San Angelo, the Flowerpot Member, is 10 to 20 m thick.

Lithology

In southern Stonewall County the Duncan Sandstone is slightly conglomeratic sandstone. The sandstone is generally poorly sorted and is cemented by calcite, silica, or gypsum. Bedding includes large-scale trough crossbeds, horizontal bedding, ripple cross-laminae, and flaser bedding. Mudstones of the Duncan Member are reddish-brown, silty to sandy; clay is chiefly illite.

Gypsum nodules in the Flowerpot Mudstone Member distinguish these mudstones from those in the Duncan Member.

Depositional Environment

The San Angelo Formation in the Lubbock Quadrangle is dominated by a fluvial-deltaic system. The Choza Formation, representing subtidal, tidal flat, and sabkha deposits, underlies the San Angelo Formation. Red- and gray-banded mudstones, thin channel-fill siltstone and sandstone, thin dolomite beds with gypsum nodules, and salt hoppers compose the Choza Formation. Succeeding the fluvial-deltaic deposits of the San Angelo are (1) tidal-flat and sabkha deposits of the Blaine Formation, consisting of laterally continuous gypsum beds (sabkha) and (2) reddish-brown, brown, and gray mudstone containing minor amounts of dolomite and sandstone.

The San Angelo fluvial-deltaic system underlies most of Stonewall County and extends southward into Fisher County. The delta prograded westward about 48 km where it terminates (Fig. 16). The sheetlike geometry of the fluvial-deltaic system indicates reworking of a shoal-water delta by marine processes. In Stonewall County the delta covers an area of approximately 1800 km^2, and the approximate volume of sandstone contained in the Duncan is about 11 km^3.

Uranium Mineralization

Most of the uranium values from samples taken from the San Angelo Formation (Pl. 24) are comparable to average values for shale (Krauskopf, 1967). Uranium values range from 1.2 to 8.5 ppm. Copper values range from 1.3 to 2,674 ppm. Most of the values for copper are below the average for shale. Vanadium values range from 10.04 to 91.37 ppm. Most of the vanadium values fall below the average value for shale (130 ppm). In general, as uranium concentration increased there was an increase in vanadium content.

Origin of uranium and copper deposits in Permian strata is related to an evaporitic process (Fig. 17) whereby metals are concentrated in ground water then transported within the brine to a reducing environment.

Hydrology

Permian rocks generally have low permeability, and water quality is commonly poor. The San Angelo Sandstone yields small quantities of slightly saline (1,000 to 3,000 ppm dissolved solids) to moderately saline (3,000 to 10,000 ppm dissolved solids) water (Cronin and Follett, 1963). Waters are generally high in chloride and sulfate. Brine springs issue from the San Angelo and Blaine Formations within the Brazos River drainage system in southern King and northern Stonewall Counties.

Regional ground-water movement is postulated to be to the east. The water table surface mimics the topography of the overlying land surface (Butz and others, 1979).

Favorable Area

Area I. Although the San Angelo Formation is unfavorable in outcrop it is considered to be favorable in subsurface (Area I, Pl. 1B). The Duncan Member of the

San Angelo Formation is a sand-rich fluvial-delta system (Smith, 1974) covering an area of approximately 1800 km^2, with an average thickness of 6.0 m. Total volume of potential host rock is 11 km^3. The Duncan Sandstone Member is underlain, overlain, and grades laterally into rocks that accumulated in tidal flat and sabkha environments. The Duncan Sandstone Member was virtually encased in brine-saturated sediments. The brine contained a high concentration of metals. Compaction and dewatering of tidal flat - sabkha deposits and migration of brines into the Duncan Sandstone provided a source of uranium and other metals. Upon encountering a reducing environment, copper and uranium were concentrated. Dunsmore (1977a; 1977b) proposed such a mechanism for concentration of uranium in Permo-Carboniferous deposits of Canada. According to Dyck and others (1976) one should not expect rock outcrops to be more highly or extensively mineralized than their subsurface equivalents; in fact, the opposite should be true.

Uranium content of San Angelo ground water (Butz and others, 1979) ranges from 3.4 to 61 ppb. Ground-water data were collected from wells that were drilled within the San Angelo outcrop area, and therefore are not indicative of uranium or copper mineralization in the deeper subsurface.

Drainage, Generalized Land Status, and Culture

Area I is transected from west to east by the Salt Fork of the Brazos River (north of Aspermont). The Double Mountain Fork of the Brazos River flows to the northeast near the southern boundary of the quadrangle (Pl. 6). North of Aspermont the area is highly dissected by the drainage system of the Salt Fork of the Brazos; the area south of Aspermont is less severely dissected. Area I is characterized by numerous east-facing escarpments that are capped by dolomite or gypsum beds.

Area I is entirely in the private sector (Pl. 9).

Most of the area is traversed by a network of paved and unpaved roads (Pl. 10). Fort Worth and Denver Railroad crosses the area from east to west. The towns and communities of Ford, Swenson, Peacock, Aspermont, and Old Glory are within Area I. Oil fields and water wells are scattered across Area I.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

Several rock units within the Lubbock Quadrangle are considered unfavorable environments for uranium deposits (Fig. 3; Pls. 7, 25, 26, 27, 28, 29, and 30). Unfavorable environments include (1) all Pleistocene units excluding the Tule Formation; (2) the Ogallala Formation outside the area of favorability, (3) the Dockum Group outside the area of favorability, (4) the Permian units between the Dockum Group and the San Angelo Formation (Quartermaster, Whitehorse - Cloud Chief, and Blaine Formations), and (5) the Choza Formation.

PLEISTOCENE AND YOUNGER UNITS

Pleistocene cover sands (Illinoian), the Tahoka Formation (Wisconsinan), playa deposits (Wisconsinan to Recent), sediment underlying terraces, alluvium, and windblown sand were judged to be environments unfavorable for uranium deposits because of limited thickness and areal extent and low uranium values from rock and soil samples. With the exceptions of the Tahoka Formation and clayey playa sediments, these surficial deposits are characterized by high transmissivities and oxidizing conditions. Any contained uranium (exclusive of uranium associated with resistate minerals) would be mobilized and redistributed downdip by infiltrating meteoric waters.

Although a number of airborne radiometric anomalies are associated with Pleistocene Tahoka Formation and playa deposits, they were also considered unfavorable for uranium deposits because of the limited thickness and extent. The airborne radiometric anomalies are caused by the contrast in background radiation between the cover sands (10 to 20 counts per second) and the higher (30 to 50 counts per second) clay-rich sediments in the Tahoka Formation and playa deposits.

OGALLALA FORMATION

Areas of the Ogallala Formation outside the area of favorability shown in Plate 1 were judged to be unfavorable for uranium deposits because of the following combination of characteristics: (1) open-basin hydraulic conditions, which allow oxidizing ground water to flush highly transmissive, porous sands and gravels; (2) lack of reductants; (3) low uranium values in Ogallala Formation rock samples; and (4) the presence of pedogenic caliche (Carlisle and others, 1978).

In order to better understand factors controlling uranium distribution in the Ogallala Formation, subsurface maps were prepared. These maps include Ogallala isopach (Pl. 14) and net sand and gravel (Pl. 19). Strike and dip cross sections were also prepared (Pls. 16 and 17).

Rock samples from along the Ogallala escarpment were analyzed (Pls. 5 and 18; App. B). No anomalous uranium values occurred in the unfavorable area. The maximum uranium value of Ogallala Formation rock samples in the unfavorable area is 8.0 ppm (MIW-096).

DOCKUM GROUP

The Dockum Group was judged to be unfavorable outside the areas of favorability (Pl. 1B) because (1) uranium content of rock samples was generally low;

(2) ground water contained low values of uranium; (3) radiometric anomalies were absent; (4) a large volume of oxidized fine-grained deposits occurs in these areas; and (5) there is no reducing environment. Scattered uranium occurrences are found throughout the Dockum outcrop belt (Pl. 22). Most of these are volumetrically small. For example, burrows are filled with sandstone in some of the lacustrine mudstones. The sandstones are cemented with calcite and mineralized with copper and uranium; the mineralized materials probably constitute a volume of less than 0.027 m^3. Some occurrences are in highly permeable sandstone bodies that have been repeatedly flushed with oxidizing ground water. Other occurrences are represented by a thin carnotite rind on carbonized plant debris. Uranium occurrences in outcrop (including those in the favorable areas) are remnants of extensive occurrences; uranium in outcrop was oxidized, mobilized, and transported downdip by ground water, or away from the outcrop by surface water.

Uranium occurrence is judged to be sparse in those areas of subsurface Dockum where no anomalies were indicated on gamma-ray logs.

PERMIAN FORMATIONS

Permian strata, in outcrop, that lie between the San Angelo Formation and the Dockum Group are predominantly red beds and evaporites. Permian strata are considered unfavorable for uranium because (1) the depositional environment was oxidizing, (2) reductants are rare, (3) few permeable strata (host rock) are present other than sandstones in the Whitehorse - Cloud Chief Formations, (4) U_3O_8 content is low in rock samples, and (5) U_3O_8 content in ground water is generally low.

The Blaine Formation has numerous thin, laterally continuous dolomite beds, some of which contain numerous pelecypods. Other dolomite beds were initially oolite beds that were later dolomitized. Some are thinly laminated and are disrupted by desiccation cracks. The Blaine accumulated in a shallow, subtidal-intertidal-supratidal environment; sandstones or siltstones are rare. Although evaporation functioned to concentrate elements in brine (Pendery, 1962; Smith, 1974) the environment was oxidizing, reductants were negligible, and there was no apparent uranium source other than seawater or ground water from the Ogallala. Uranium values for the Blaine Formation are shown on Plate 31.

The Whitehorse - Cloud Chief and Quartermaster Formations consist of red-bed - evaporite sequences, which accumulated in an oxidizing environment. In the subsurface, halite is an additional facies component. The environments are considered unfavorable for uranium deposits, on the basis that they were oxidizing and that there was no apparent source material (other than brines generated during the Permian and ground water derived from the Ogallala Formation). Rather widespread eolian sands are interspersed with gypsum in the Whitehorse - Cloud Chief Formation; these sands are highly permeable and were potential host rocks. Uranium values for the Whitehorse - Cloud Chief Formation are shown on Plate 32. A potential volcanic uranium source was present in Mexico during accumulation of the Quartermaster Formation (Miller, 1955); the Quartermaster contains some hollow sanadine grains. Uranium values are shown on Plate 31.

The Choza Formation (Clear Fork Group), which occurs below the San Angelo Formation, is the product of the same kinds of depositional processes that produced the facies of the Permian above the San Angelo Formation. The Choza is judged to be an unfavorable environment for uranium deposits for the same reasons given for the Permian section between the San Angelo Formation and Dockum Group.

UNEVALUATED ENVIRONMENTS

Three stratigraphic units, all in subsurface and mostly within the eastern part of the Lubbock Quadrangle, were not evaluated. These units are the Canyon, Cisco, and Wichita-Wolfcamp Groups (Pls. 25, 26, and 27). Time constraints and the fact that the facies present within these units generally are not favorable environments for uranium deposits are the reasons that low priorities were given to these units.

The Canyon Group in the eastern part of the Lubbock Quadrangle consists of shelf-edge reef, slope, and basin deposits (Erxleben, 1975). Canyon environments favorable for uranium deposits lie to the east of the Lubbock Quadrangle.

Most of the Cisco Group in the subsurface within the Lubbock Quadrangle is represented by shelf, shelf-edge, slope, and basin deposits (Galloway and Brown, 1972); each of these facies is considered an unfavorable environment for uranium deposits. The Cisco shelf edge lies roughly along a north-south line defined by long 100°15'W.

The Wolfcamp-Wichita Group consists mostly of marine shales and carbonates. Shales and dense limestone make up the slope and basin facies. Reefs constitute shelf edge facies, and dolomites and evaporites make up the backreef and shelf facies. These rock types are considered to be unfavorable environments for uranium deposits.

INTERPRETATION OF RADIOMETRIC AND GEOCHEMICAL DATA

RADIOMETRIC DATA

During May and June 1975, an aerial radiometric and total magnetic field survey was flown over the Lubbock NTMS Quadrangle by Geodata International, Incorporated (1975). The survey was flown in an east-west direction along lines 4.8 km (3 mi) apart and at a mean terrain clearance of 122 m (400 ft). North-south tielines were flown at 19-km (12-mi) intervals at the same terrain clearance. Aircraft speed averaged 224 kmh (140 mph).

Radiometric instrumentation consisted of a 256-channel spectrometer and 3,320 cubic inches of Na(Tl) crystal volume. An additional 415-cubic-inch Na(Tl) crystal was partially shielded to monitor ^{214}Bi radiation coming from the upper 2 π solid angle. Energy ranges used to detect potassium (^{40}K), thorium (^{208}Th), and uranium (^{214} Bi) were 1.322 to 1.638, 2.410 to 2.796, and the sum of 1.053 to 1.322 and 1.638 to 2.410 MeV, respectively.

All data used in this report were corrected for instrument live time, aircraft background radiation, and atmospheric ^{214}Bi, and then were adjusted to an equivalent terrain clearance of 122 m (400 ft).

Corrected data were statistically analyzed by Geodata using their in-house data processing techniques. The statistically reduced data were interpreted by the Bureau of Economic Geology following the procedure of Saunders and Potts (1978). Favorable areas for uranium occurrence were indicated by significantly high readings for U, U/Th, and U/K. Possibly favorable areas were delineated where U/Th and U/K were significantly anomalous. Both categories are shown in Plate 3.

Anomalies in the windblow cover-sand unit Qcs (Pls. 3 and 7; Areas 1-15) generally occur where a flightline crosses a paved road. All Qcs anomalies are interpreted to be uraniferous asphalt and other cultural materials having relatively high uranium levels that contrast with the very low uranium content of the windblown sand.

Double Lakes and Tahoka Lake (Areas 16 and 17) show significantly high uranium readings in the Tahoka Formation. Uranium leached from Pleistocene ash beds could be accumulated in lacustrine clays.

Uranium anomalies in the Ogallala Formation (Areas 18 through 26) result from the concentration in ground water of uranium derived from ash beds within the Pleistocene.

The anomalies showing the greatest potential for commercial quantities of uranium are within the Triassic Dockum Group (Areas 28 through 36). Most of the anomalies are at the base of the Dockum. Area 27 contains anomalies in the uppermost Quartermaster Formation near its contact with the Dockum Group.

Permian strata in the eastern half of the quadrangle are mostly red beds that lack the chemically reducing conditions normally considered favorable for uranium concentration. The scattered anomalies detected in the Whitehorse and Blaine Formations (Areas 38 through 52) reflect uranium concentration by processes other than precipitation of oxidized uranium in a reducing environment. Sabkha evaporation in Permian time concentrated uranium and other minerals from seawater. Another mechanism for concentration is ground-water flushing of uranium from the High Plains into the Permian beds. Subsequent investigation within the delineated anomalous areas should consider both processes.

GEOCHEMICAL DATA

Hydrogeochemical and stream sediment data were provided via a draft Hydrogeochemical and Stream-Sediment Reconnaissance report by Oak Ridge Gaseous Diffusion Plant (Butz and others, 1979). Their raw data, on uranium content of ground water, were plotted and contoured for the purpose of depicting any trends in uranium content (Pl. 4). Ground waters of a large part of the area are characterized by uranium content in the range of 2.0 to 10 ppb; this seems to be the background upon which the higher values are superposed. Two trends are obvious--one in the eastern quarter of the quadrangle and one that covers roughly one-quarter of the quadrangle in the western half of the area. The first area trends north-south and includes the upper part of the Blaine and lower part of the Whitehorse - Cloud Chief Formations; this trend includes a small area underlain by the San Angelo Formation in the southeast corner of the Lubbock Quadrangle, as well as westward extensions across the Whitehorse - Cloud Chief Formation, and locally into the Quartermaster Formation. Values of U_3O_8 in ground waters within this trend range from 10 to 100 ppb. Ground waters in the second trend, which is oriented northwest-southeast, are contained in the Dockum Group and Ogallala Formation. The high concentrations of uranium in the Dockum and Ogallala have similar trends, suggesting that their respective aquifers are physically connected and that the waters are genetically related. Values of U_3O_8 in ground waters within the second trend range from 10 ppb to greater than 100 ppb. In the central part of the quadrangle, approximately between long 100°35'W. and long 101°10'W., there are four smaller areas with ground waters containing 10 ppb to greater than 100 ppb U_3O_8; as mapped, these areas are elongate and oriented roughly east-west (although the area that lies in Crosby, Dickens, and Kent Counties has a stellate pattern). These smaller anomalies are contained in ground waters in the Quartermaster Formation and Dockum Group.

Uranium contained in most of the ground waters in the Lubbock Quadrangle was derived from volcanic ash within the Pleistocene deposits. Ground water, charged with uranium, moved downward from the Pleistocene through the Ogallala into

Dockum and upper Permian strata. Upon reaching upper Permian strata, ground water moved updip through permeable sandstones and siltstones; brines derived from solution of salts within the Permian are currently being discharged into present drainage systems. The north-south trending ground-water anomaly is the result of uranium-bearing Ogallala ground water moving updip through the sandstones and siltstones of the Whitehorse - Cloud Chief Formation.

By approximately 600,000 years B.P., the time when the Pearlette Ash was accumulating, the Ogallala had been eroded westward approximately to the middle of Kent County (Fig. 18). Eastward beyond that point, ash fell upon Permian outcrops. The present area of the discontinuous anomalies was overlain 600,000 years B.P. by the Ogallala Formation. Lakes that formed on the Ogallala surface were sites of uranium concentration. The present patchy distribution of ground-water anomalies probably reflects the position of those lakes; ground-water movement from the lakes was downward into Dockum and Permian strata. Another factor affecting patchy distribution in the Dockum is that the thicker Dockum sandstone bodies are narrow north-south and elongate east-west.

The very broad anomalies in the western part of the quadrangle coincide with the present distribution of the Ogallala or with areas that recently were covered by the Ogallala. Oxidizing ground waters of the Ogallala are mobilizing, and, in places, transporting uranium. High values of U_3O_8 in the Dockum ground waters generally occur in an area to the west or southwest of uranium occurrences.

A comparison of ground-water anomalies and radiometric anomalies indicates that the two types of anomalies are not always coincident. Areas where ground-water and radiometric anomalies coincide are (1) along the north-south ground-water trend that spans the Blaine and Whitehorse - Cloud Chief boundary, (2) in the south central part of the quadrangle in the Quartermaster Formation and Dockum Group (southwestern Kent County), between long 100°45'W. and long 101°01'W., (3) in the Quartermaster Formation north of Spur, (4) in the Dockum Group in southwestern Garza County (in the area of the Caprock Prospect), and (5) in the Ogallala Formation in Blanco and Yellow House Canyons.

Some uranium occurrences are coincident with U_3O_8 anomalies in ground water. In the San Angelo Formation there is a ground-water anomaly (Pl. 4), but no uranium occurrence as determined from rock samples (Pl. 24). Within the area of the north-south trending ground-water anomaly there is no uranium occurrence as determined from rock samples (Pls. 31 and 32). The ground-water anomaly in southwest Kent County (Quartermaster Formation and Dockum Group) has no corresponding surface uranium occurrence as determined from rock samples. The large stellate ground-water anomaly in Crosby, Dickens, and Kent Counties underlies the area of the Red Mud and MacArthur Prospects where sandstone percentage is high (Pl. 21). The area of the Eubank Prospect and ground-water anomaly in south central Crosby County coincide. In the western part of Garza County, the broad ground-water anomaly roughly parallels the Ogallala outcrop (or the Caprock Escarpment); ground-water anomalies generally lie to the southwest of Dockum outcrops containing the highest uranium values. Ground water with the high U_3O_8 content underlies most of the Ogallala that is situated to the west and south of Yellow House Canyon (Pl. 6). Ogallala in this area contains ground water with 10 to 20 ppb U_3O_8. Transecting the area from northwest to southeast are yet higher U_3O_8 values; this trend continues into the Dockum aquifers. Ground-water anomalies (10 to 20 ppb U_3O_8) correspond with uranium occurrences along Yellow House Canyon. Also on the High Plains, ground-water anomalies occur within the areas of Tahoka Lake and Twin Lakes.

Ground-water, radiometric, and rock data all indicate that the Dockum Group and the Ogallala and Tule Formations contain appreciable amounts of U_3O_8. Within the Permian section, the San Angelo Formation (by geologic inference) contains uranium deposits.

RECOMMENDATIONS TO IMPROVE EVALUATION

Several methods could be used to improve the evaluation of the Lubbock Quadrangle. The proposed methods are more detailed than the reconnaissance study recently made to evaluate the Lubbock Quadrangle.

Airborne radiometric surveys failed to indicate the presence of some uranium occurrences in the Dockum that were detected by field investigations (rock sampling and ground-water sampling have shown high U_3O_8 content in these areas). More closely spaced flightlines, particularly in the areas underlain by the Dockum Group and Ogallala Formation, would enhance the evaluation.

A detailed ground-water study is needed in order to document the relationships among the various aquifers. Data analyzed to date indicate that volcanic ash within the Pleistocene units on the High Plains is the source for most of the uranium occurrences in the Lubbock Quadrangle, and that the uranium was transported to older stratigraphic units by Ogallala ground water. Delineation of ground-water flow systems is requisite for understanding the mechanism of uranium mobilization, transportation, and concentration.

Highest U_3O_8 values in the Lubbock Quadrangle occur in Dockum outcrops in western Garza County. Ground-water anomalies in the same area are highest downdip from these occurrences. Uranium in outcrop obviously has been mobilized and is being transported by ground water into the deeper subsurface. Also within the subsurface Dockum are numerous anomalies as indicated by gamma-ray logs (Pl. 1B; Areas F, G, and H). The reconnaissance study of the Lubbock Quadrangle clearly indicates areas that merit additional subsurface study. It is recommended that coring and detailed geophysical logging be conducted immediately to the west of Areas A, C, and D (Pls. 1A and 1B). It is also recommended that the Dockum subsurface section in Areas F, G, and H be investigated by the same methods.

The Ogallala and Tule Formations in Area A (Pl. 1A) should be cored and logged to verify their favorability as uranium hosts. The subsurface investigation in this area should also include the entire Dockum section; this investigation would establish the relationships among uranium occurrences within Tule and Ogallala Formations and the underlying Dockum Group. This area and the proposed methods are recommended because obvious relationships exist between uranium occurrences in the Tule and Ogallala Formations and in the Dockum Group.

Area B (Pl. 1A) is underlain by broad U_3O_8 anomalies in Ogallala ground water and by radiometric anomalies. Coring and logging is recommended for this area.

SELECTED BIBLIOGRAPHY

Amaral, E. J., 1979, National Uranium Resource Evaluation, Plainview Quadrangle, Texas: Bendix Field Engineering Corporation, Grand Junction Operations GJQ-001(79), 34 p.

Anderson, R. Y., and Kirkland, D. W., eds., 1969, Paleoecology of an early Pleistocene lake on the High Plains of Texas: Geological Society of America Memoirs 113, 215 p.

Barnes, V. E., and Eifler, G. K., 1967, Geologic atlas of Texas, Lubbock sheet: The University of Texas at Austin, Bureau of Economic Geology, scale 1:250,000.

Belcher, R. C., 1979, Depositional environments, paleomagnetism, and tectonic significance of Huizachal red beds (Lower Mesozoic), Northeastern Mexico: Ph.D. dissertation, The University of Texas at Austin, 276 p.

Bement, T. R., Susco, D. V., Whiteman, P. E., and Ziegler, R. K., 1977, Geostatistical project for the NURE program, January-March 1977: Los Alamos Science Lab, New Mexico, GJBX-50(77).

Butler, A. P., Finch, W. I., and Twenhofel, W. S., 1962, Epigenetic uranium in the United States, exclusive of Alaska and Hawaii: U.S. Geological Survey Mineral Investigations Resource Map MR-21, scale 1:3,168,000.

Butz, T. R., Minkin, S. C., Pritz, P. M., Rutledge, D. A., Joyner, J. D., Helgerson, R. N., and Switek, J., 1979, Hydrogeochemical and stream sediment reconnaissance basic data for Lubbock NTMS Quadrangle, Texas: Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Report No. K/UR-129, 37 p.

Carlisle, Donald, Merifield, P. M., Orme, A. R., Kohl, M. S., and Kolker, Oded, 1978, The distribution of calcretes and gypcretes in southwestern United States and their uranium favorability based on a study of deposits in western Australia and South West Africa (Namibia): U.S. Energy Research and Devel. Adm., GJBX-29(78), Open-File Rept., 274 p.

Cleaves, A. W., II, 1975, Upper Desmoinesian - lower Missourian depositional systems (Pennsylvanian), North-Central Texas: The University of Texas at Austin, Ph.D. dissertation, 256 p.

Cronin, J. G., Follett, C. R., Shafer, G. H., and Rettman, P. L., 1963, Reconnaissance investigation of the ground-water resources of the Brazos River basin, Texas: Texas Water Commission Bulletin 6310, 152 p.

Dunsmore, H. E., 1977a, A new genetic model for uranium-copper mineralization, Permo-Carboniferous Basin, Northern Nova Scotia: Geological Survey of Canada, Paper 77-1B, 7 p.

__________ 1977b, Uranium resources of the Permo-Carboniferous Basin, Atlantic Canada: Geological Survey of Canada, Paper 77-1B, 8 p.

Dyck, W., Chatterju, A. K., Gemmell, D. E., and Murricane, K., 1976, Well water trace element reconnaissance, eastern Maritime Canada, Journal Geochemical Exploration, v. 6, p. 139-162.

Erxleben, A. W., 1975, Depositional systems in Canyon Group (Pennsylvanian System), North-Central Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations 82, 75 p.

Evans, G. L., and Meade, G. E., 1944, Quaternary of the Texas High Plains: University of Texas Publication 4401, p. 485-507.

Finch, W. I., 1975, Uranium in West Texas: U. S. Geological Survey Open-File Report 75-356, 20 p.

Frye, J. C., and Leonard, A. B., 1957, Studies of Cenozoic geology along eastern margin of Texas High Plains, Armstrong to Howard Counties: University of Texas, Austin, Bureau of Economic Geology Report of Investigations No. 32, 62 p.

Galloway, W. E., and Brown, L. F., Jr., 1972, Depositional systems and shelf-slope relationships in upper Pennsylvanian rocks, North-Central Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations 75, 62 p.

Geodata International, Inc., 1975, Aerial radiometric and magnetic survey of the Lubbock and Plainview national topographic maps, NW Texas: U.S. Energy Research and Development Administration Open-File Report GJO-1654, 3 volumes.

Hayes, W. C., Jr., 1956, Uranium prospects in West Texas: West Texas Geological Society Guidebook, April 1956, p. 69-72.

Ho, C. L., and Dupre, B., 1980, A rapid method for U_3O_8 measurement using fluorometric method (abs.): Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, March 13, 1980, Atlantic City, N.J.

Ho, C. L., Calvo, J., and Tweedy, S., 1980, Analysis of 30 elements in geological materials using inductively coupled plasma emission spectrometer (abs.): Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, March 13, 1980, Atlantic City, N.J.

Izett, G. A., Wilcox, R. E., Powers, H. A., and Desborough, G. A., 1970, The Bishop ash bed, a Pleistocene marker bed in the western United States: Quaternary Res., vol. 1, p. 121-132.

Izett, G. A., Wilcox, R. E., and Borchardt, G. A., 1972, Correlation of a volcanic ash bed in Pleistocene deposits near Mt. Blanco, Texas, with Guaje pumice bed of the Jemez Mountains, New Mexico: Quarternary Res., vol. 2, p. 554-578.

Kehle, R. O., 1972, Gulf coast structure: origin of the Gulf of Mexico: The University of Texas at Austin, Department of Geological Sciences, Lecture Notes, 152 p.

Krauskopf, K. B., 1967, Introduction to geochemistry: New York, McGraw-Hill Book Co., 721 p.

Maher, J. C., ed., 1960, Stratigraphic cross section of Paleozoic rocks, West Texas to northern Montana: American Association of Petroleum Geologists, 18 p., 7 plates.

Mathews, G. W., Jones, C A., Pilcher, R. C., and D'Andrea, R. F., Jr., 1979, Preliminary recognition criteria for uranium occurrences: A field guide: Bendix Field Engineering Corporation, GJBX-32 (79), 41 p.

McGowen, J. H., and Garner, L. E., 1970, Physiographic features and stratification types of coarse-grained point bars: Modern and ancient examples: Sedimentology, v. 14, p. 77-111.

McGowen, J. H., Granata, G. E., and Seni, S. J., 1979, Depositional framework of the lower Dockum Group (Triassic), Texas Panhandle: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 97, 60 p.

__________ in preparation, Depositional systems, uranium occurrence, and postulated ground-water history of the Triassic Dockum Group, Texas Panhandle - eastern New Mexico.

Mickle, D. G., ed., 1978, A preliminary classification of uranium deposits: Bendix Field Engineering Corporation, GJBX-63 (78), 77 p.

Mickle, D. G., and Mathews, G. W., eds., 1978, Geologic characteristics of environments favorable for uranium deposits: Bendix Field Engineering Corporation, GJBX-67 (78), 250 p.

Miller, D. N., Jr., 1955, Petrology of Pierce Canyon Red Beds, Delaware Basin, Texas and New Mexico: University of Texas, Austin, Ph.D. dissertation, 148 p.

Nicholson, J. H., 1960, Geology of the Texas Panhandle, _in_ Aspects of the geology of Texas, a symposium: University of Texas, Austin, Bureau of Economic Geology Publication No. 6017, p. 51-64.

Pendery, E. C., III, 1962, Stratigraphy and carbonate petrography of the Blaine Formation, North-Central Texas: M.S. Thesis, Texas Technological College, 163 p.

Reeves, C. C., Jr., 1963, Origin of Spring Creek Beds, Garza and Lynn Counties, Texas: Texas Journal of Science, v. 15, p. 322-338.

___________ 1966, Pluvial lake basins in west Texas: Journal of Geology, v. 74, p. 269-291.

Renfro, A. R., 1974, Genesis of evaporite associated stratiform metalliferous deposits -- a sabkha process: Economic Geology, v. 69, no. 1, p. 33-45.

Salisbury, G. P., 1960, Remarks on Permian Basin tectonics: Union Oil of California, Geology Department, Midland, Texas, 33 p.

Saunders, D. F., and Potts, M. J., 1978, Manual for the application of NURE 1974-1977 aerial gamma-ray spectrometer data: U.S. Energy Research and Development Administration, GJBX-13 (78), Open-File Report, 74 p.

Seni, S. J., in press, Depositional systems and sand-body geometry of the Ogallala formation (Neogene), Texas: The University of Texas at Austin, Bureau of Economic Geology Geological Circular.

Smith, G. E., 1974, Depositional systems, San Angelo Formation (Permian), North Texas -- Facies control of red-bed copper mineralization: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 80, 69 p.

Taylor, H. D., 1979, Water-level data from observation wells in the Southern High Plains of Texas, 1971-77: Texas Department of Water Resources Report 228, 484 p.

Wright, J. C., 1969, Stratigraphic position of uranium deposits, Triassic rocks, western Texas and eastern New Mexico, in Geological Survey Research: U.S. Geological Survey Professional Paper 650-A, p. A15-56.

Zielinski, R. A., 1979, Uraniferous silica: conditions of formation (abs.): Geological Society of America, Abstracts with Programs, v. 11, no. 9, p. 546.

URANIUM-OCCURRENCE

REPORT

Quad Name A90 Lubbock

Quad Scale A100 |2,5,0,0,0,0|

Deposit No. B40 4

Deposit Name A10 < Lott Ranch >

Synonym Name(s) A11 < >

District or Area A30 < Osage Plains >

Country A40 <U S> |U S|

State Texas

State Code A50 <4 8> |48|
(Enter code twice from List D)

County A60 < Garza >

Position from Prominent Locality A82 < 5.5 miles west of Post, Tx on Hwy 360; 4.0 miles south on Hwy 399; 0.5 miles west on county road; 3.0 miles south and west on county road. >

Field Checked G1 <79 | 09> Yr Mo

By G2< Seni, Steven J > Last name, First, Initial

Latitude A70 <33 - 05 - 20 N> Deg Min Sec

Longitude A80 <101 - 30 - 00 W> Deg Min Sec

Township A77 < | > N/S

Range A78 < | > E/W

Section A79 < >

Meridian A81 < >

Altitude A107 < > FT/M

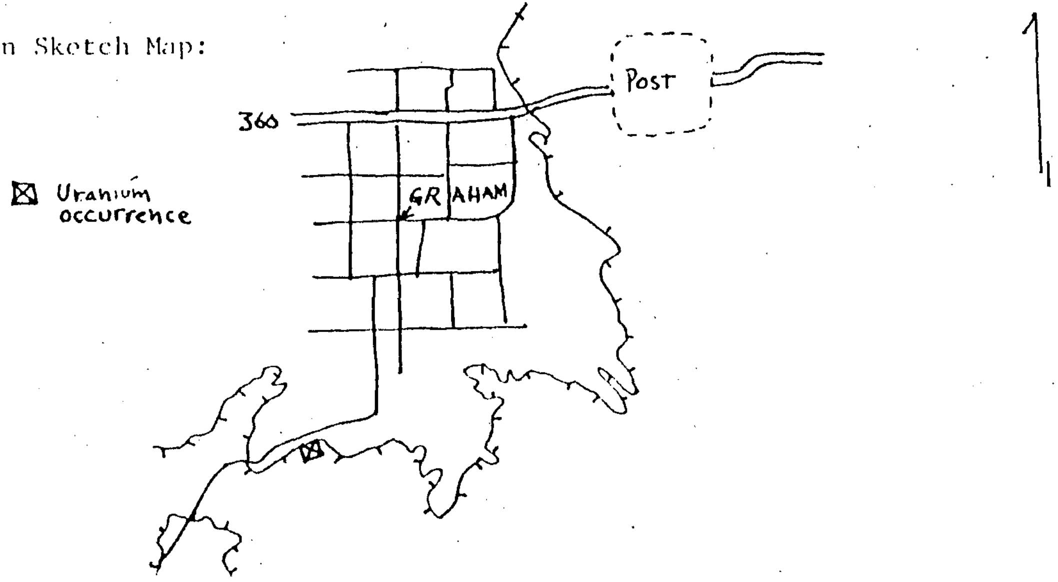
Quad Scale A91 <2,4,0,0,0> (7½' or 15' quad)

Quad Name A92 < Grassland SE >

Physiographic Province A63 <0 7> | Great Plains > (List K)

Location Comments A83 < Occurrence is south of county road >

Location Sketch Map:



BFE 1236
4/19/78

URANIUM-OCCURRENCE Quad Name Lubbock

REPORT Deposit No. 4

Commodities Present:
C10 <U >

Commodities Produced:
MAJOR < > COPROD < >

MINOR < > BYPROD < >

Potential Commodities:
POTEN < > OCCUR <U >

Commodity Comments C50 < >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < >

Property is A21 (Active) [✓ A22] (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< >

Cumulative Uranium Production PROD YES [✓ NO] SML MED LGE (circle)

DH2
accuracy thousands of lb. years grade
G7<U| > G7A< > G7B<LB> G7C< > G7D< % U308>

Source of Information D9 < >

Production Comments D10 < >

Reserves and Potential Resources

EH
accuracy thousands of lb. year of est. grade
E1<U|ES T> E1A<0 0 0 . 2 2 2 > E1B<LB> E1C<1 9 8 0> E1D< 0.01 % U308>

Source of Information E7 < Seni S.J., this report >

Comments E8 < >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 4

Deposit Form/Shape M10 < Irregular dissemination >

FT/M

Length M40 < > M41< >

Width M50 < > M51< >

Thickness M60 < > M61< >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U3O8

A 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < Eastern-slope, Midland Basin >

Local Structures N70 < Host rock is a lacustrine-fill of a High Plains basin. Lacustrine-fill covers approximately 15 square miles. >

Host-FM. Name U1 < TULE FM > Member U2 <

Host Rock K1 < PLEISTOCENE soil zone; sandstone, light gray.
(Age) (Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.) >

Host-Rock Environment U3 < Lacustrine; basal clastic fill; recent soil zone
(Sed. dep. environ., metamorphic facies, ign. environ.)

Comments on
Associated Rocks U4 < Host rock is underlain and laterally bound by Ogallala Formation >

Ore Minerals C30 < No uranium minerals observed >

Gangue Minerals K4 < No gangue minerals observed >

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 4

Alteration N75 < No alteration observed >

Reductants U5 < Reductants are probably related to microscopic organic material preserved from oxidization by the meromictic (chemically stratified) nature of lake >

Analytical Data (General) C43 < >

Radiometric Data (General) U6 < Max 40x background over 10 ft x 10 ft area.
(No. times background and dimensions) >

Ore Controls K5 < Uranium occurrence is controlled by nature of lacustrine-fill. Uranium enrichment has occurred in clays and sandstones. Sandstones at base of lacustrine-fill are most radioactive. Recent soil developed on sandstones are also radioactive. Ash also occurs in lacustrine-fill and is the probable source of uranium. >

Deposit Class C40 < Lacustrine-sandstone > Class No. U7 <2 4 4>

Comments on Geology N85 < >

URANIUM-OCCURRENCE

REPORT

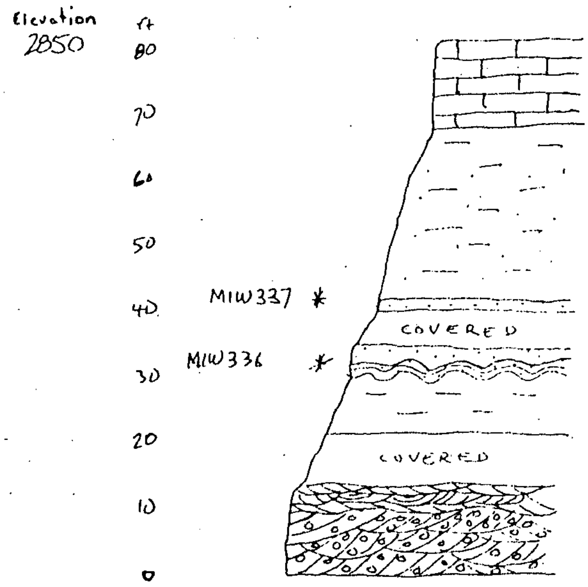
Quad Name Lubbock

Deposit No. 4

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MIW336	Gray and brown fine sandstone: calcitic, moderately sorted, convoluted at base	125ppm
MIW337	Gray fine sand: sandy recent soil zone friable	128ppm

Geologic Sketch Map and/or Section, with Sample Locations:



References:

F1 < >

F2 < >

F3 < >

F4 < >

URANIUM-OCCURRENCE

REPORT

Lubbock

4

Continuation from p. 1-5

Label

SFE 1232
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name A90 Lubbock

Quad Scale A100 |1:2,5,0,0,0,0|

Deposit No. B40 5

Deposit Name A10 < Caprock Prospect >

Synonym Name(s) A11 < Slaughter Ranch >

District or Area A30 < Llano Estacado >

Country A40 <U S> |U S| State Texas

State Code A50 <4 8> |4 8| (Enter code twice from List D) County A60 < Garza >

Position from Prominent Locality A82 <

Field Checked G1 <7 9|1 1> (Yr Mo) By G2 < Thurwachter (Last name), Jeffrey (First) E. (Initial) >

Latitude A70 <33|00|20 N> (Deg Min Sec) Longitude A80 <101|29|00 W> (Deg Min Sec)

Township A77 < | > (N/S) Range A78 < | > (E/W) Section A79 < >

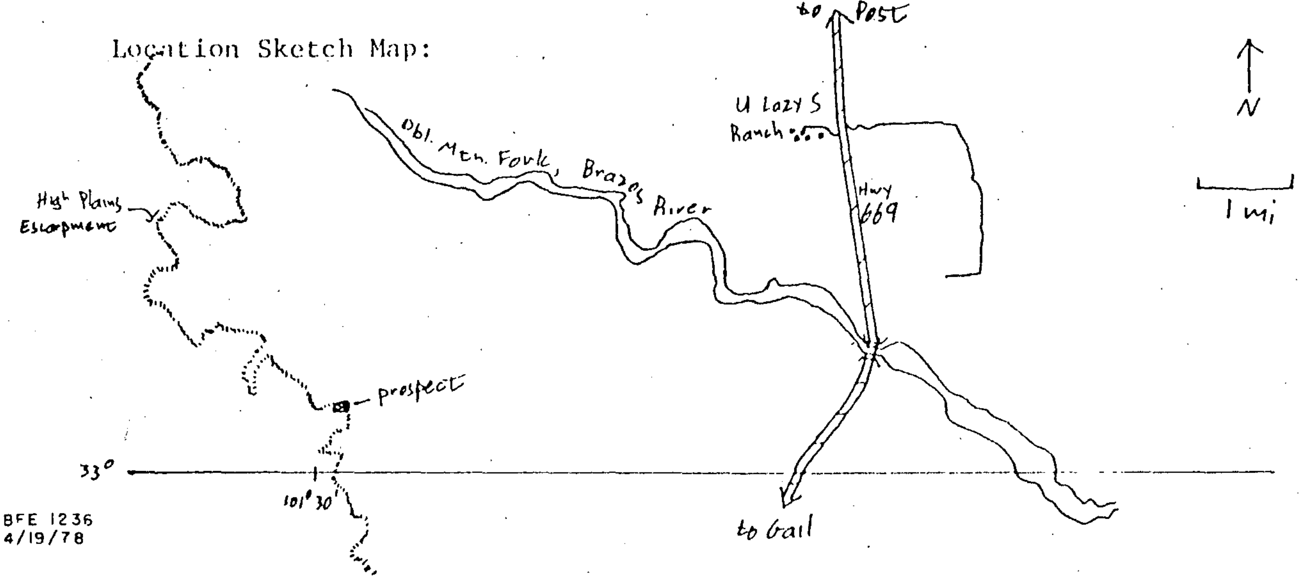
Meridian A81 < > Altitude A107 < > FT/M

Quad Scale A91 < 24000> (7½' or 15' quad) Quad Name A92 < Middle Creek >

Physiographic Province A63 <07| (List K) | Great Plains >

Location Comments A83 < >

Location Sketch Map:



URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 5

Commodities Present:
C10 < U S S T >

Commodities Produced:
MAJOR < > COPROD < >

MINOR < > BYPROD < >

Potential Commodities:
POTEN < > OCCUR < U >

Commodity Comments C50 < >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < No past development >

Property is A21 (Active) [✓ A22] (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< No workings >

Cumulative Uranium Production [✓ PROD] YES [✓ NO] SML MED LGE (circle)

DH2
accuracy thousands of lb. years grade
G7< U > G7A< > G7B<LB> G7C< > G7D< % U308>

Source of Information D9 < >

Production Comments D10 < >

Reserves and Potential Resources

EH
accuracy thousands of lb. year of est. grade
E1< U E S T > E1A< 0 0 0 0 0 1 8 7 8 > E1B<LB> E1C< 1 9 8 0 > E1D< 0.02 to 0.2 % U308>

Source of Information E7 < McGowen and Thurwachter, this report >

Comments E8 < >

BFE 1236
4/19/78

APPENDIX A. URANIUM OCCURRENCES IN THE LUBBOCK QUADRANGLE

Table 1A. Visited Uranium Occurrences in the Lubbock Quadrangle

Occurrence no.	Name	County	Location						Host rock formation/member	Deposit class or sub-class (no.)	Production[a]	Reference
			¼ Sec.	Sec. (S)	Twp. (S)	Rng. (W)	Lat. (N)	Long. (W)				
1	Benson Lake anomaly	Lubbock					33 32 18	101 44 27	Ogallala Fm.	Evaporative precipitate (220)*	a	Bement, et al. 1977; Finch, W. I., 1975; Flawn and Anderson, 1955 This report
2	Forrest Ranch	Crosby					33 26 24	101 32 25	Quaternary terrace deposit	Sandstone (240)*	a	This report; UT BEG Open File Report; (A.E.C. LTR 4/6/65)
3	Unnamed	Garza					33 04 11	101 32 26	Tule Fm.	Sandstone (243)**	a	This report; Finch, W. I., 1975
4	Lott	Garza					33 05 00	101 30 45	Tule Fm.	Sandstone (243)**	a	This report
5	Caprock Prospect	Garza					33 00 20	101 29 00	Dockum Gp.	Sandstone (243)**	a	This report; Bement, et al. 1977; Butler, et al., 1962
6	Yellow Cub	Garza					33 07 36	101 21 33	Dockum Gp.	Sandstone (240)*	a	This report; Bement, et al. 1977; Butler, et al., 1962
7	Long Ranch Twin Rattler Site	Garza					33 19 29	101 24 25	Dockum Gp.	Sandstone (240)	a	This report; Bement. et al. 1977; Butler, et al., 1962

Table 1A. Lubbock (cont.)

			Location									
Occurrence no.	Name	County	¼ Sec.	Sec. (S)	Twp. (S)	Rng. (W)	Lat. (N)	Long. (W)	Host rock formation/member	Deposit class or subclass (no.)	Production[#]	Reference
8	Long Ranch Hillside Site	Garza					33 19 07	101 24 06	Dockum Gp.	Sandstone (240)	a	This report; Bement, et al. 1977; Butler, et al., 1962
9	Eubank Ranch	Crosby					33 23 49	101 18 33	Dockum Gp.	Sandstone (240)*	a	This report; Bement, et al. 1977; Butler, et al., 1962
10	MacArthur Prospect	Kent					33 23 36	101 02 06	Dockum Gp.	Sandstone (243)**	a	This report; Bement, et al. 1977; Butler, et al., 1962
11	Red Mud	Dickens					33 25 44	100 59 57	Dockum Gp.	Sandstone (240)*	a	This report; Finch, W. I., 1975

*Jones, C. A., 1978.

[#] Production categories: a. 0 to 20,000 lb. U_3O_8 (no uranium production reported from these occurrences).

**Austin and D'Andrea, 1978.

Table A2. Uranium Occurrences Searched For But Not Found in the Lubbock Quadrangle

Occurrence no.	Name	County	Location						Host rock formation/member	Deposit class or subclass (no.)	Production#	Reference
			¼ Sec.	Sec. (S)	Twp. (S)	Rng. (W)	Lat. (N)	Long. (W)				
X12	Libesay V-8 Ranch	Lubbock					33 32 30 (approximate)	101 47 -	Ogallala Fm.	Evaporative precipitate (220)*	a	UT BEG Open File Report (A.E.C. LTR 4/6/55)
X13	Wood Ranch	Crosby					33 29 -	101 29 30	Ogallala Fm.	Evaporative precipitate (220)*	a	This report; Bement, et al 1977; Finch, W. I., 1975
X14	Unnamed	Garza					33 19 - (approximate)	101 28 10	Dockum Gp.	Sandstone (240)*	a	Finch, W. I., 1975
X15	Unnamed	Crosby					33 24 - (approximate)	101 14 -	Dockum Gp.	Sandstone (240)*	a	Finch, W. I., 1975

---

*Jones, C. A., 1978.

#Production categories: a. 0 to 20,000 lb. U_3O_8 (no uranium production reported from these occurrences).

**Austin and D'Andrea, 1978.

Table A3. Occurrences Not Visited in the Lubbock Quadrangle

Occurrence no.	Name	County	Location						Host rock formation/member	Deposit class or subclass (no.)	Production#	Reference
			¼ Sec.	Sec. (S)	Twp. (S)	Rng. (W)	Lat. (N)	Long. (W)				
Y16	Negro Hill	Crosby					33 31 -	101 10 -	Dockum Gp.	Sandstone (240)*	a	Bement, et al. 1977; Finch, W. I., 1975
Y17	Swenson Ranch	Garza					33 21 -	101 15 -	Dockum Gp.	Sandstone (240)*	a	Bement, et al. 1977; Butler, et al., 1962
Y18	Salt Fork (Adams) Prospect	Garza					33 18 -	101 08 30	Dockum Gp.	Sandstone (240)*	a	Finch, W. I., pers. comm.; Hayes, W.C., 1956; UT BEG Open File Rep
Y19	Sanderson Ranch	Garza					33 17 -	101 08 -	Dockum Gp.	Sandstone (240)*	a	Bement, et al. 1977; Butler, et al., 1962
Y20	Unnamed	Garza					33 17 30 (approximate)	101 04 10	Dockum Gp.	Sandstone (240)*	a	Finch, W. I., 1975
Y21	Roddy Ranch	Garza					33 14 -	101 11 -	Dockum Gp.	Sandstone (240)*	a	Bement, et al. 1977; Butler, et al., 1962
Y22	Adams Prospect	Garza					33 07 -	101 07 -	Dockum Gp.	Sandstone (240)*	a	Bement, et al. 1977; Finch, W. I., 1975

---

*Jones, C. A., 1978.

#Production categories: a. 0 to 20,000 lb. U_3O_8 (no uranium production reported from these occurrences).

**Austin and D'Andrea, 1978.

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 5

Deposit Form/Shape M10 < Irregular dissemination >

FT/M

Length M40 < ? > M41< FT >

Width M50 < 5 > M51< FT >

Thickness M60 < 1.5 > M61< FT >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

[✓ A] 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < Eastern slope, Midland Basin >

Local Structures N70 < >

Host-FM. Name U1 < Dockum Gp. > Member U2 < >

Host Rock K1 <|T|R|I| | | | | | | | | |b| Orange, calcareous, micaceous, fine
(Age) (Rock type, texture, composition, color,

to medium quartz arenite.
alteration, attitude, geometry, structure, etc.) >

Host-Rock Environment U3 < Fluvial meanderbelt & distributary channel sands
(Sed. dep. environ., metamorphic facies, ign. environ.)

Comments on
Associated Rocks U4 < Underlain by fluvial deltaic units >

Ore Minerals C30 < Minor scattered patches of yellow uranium mineral. >

Gangue Minerals K4 < None observed. >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 5

Alteration N75 < None observed >

Reductants U5 < None observed >

Analytical Data (General) C43 < 240 to 2000 ppm U_3O_8 >

Radiometric Data (General) U6 < 28 x BG(1 x 10 FT); 61 x BG (1 x 3 FT); 131 x BG (1.5 x 5 FT) >
(No. times background and dimensions)

Ore Controls K5 < >

Deposit Class C40 < Sandstone > Class No. U7 <2414>

Comments on Geology N85 <Progradational sequence (from base to top): Delta front ss; Distributary channel ss (anomalous in part); Crevasse channel ss; Delta plain mdst & sltst; Meanderbelt sandstone (anomalous in part) >

URANIUM-OCCURRENCE REPORT

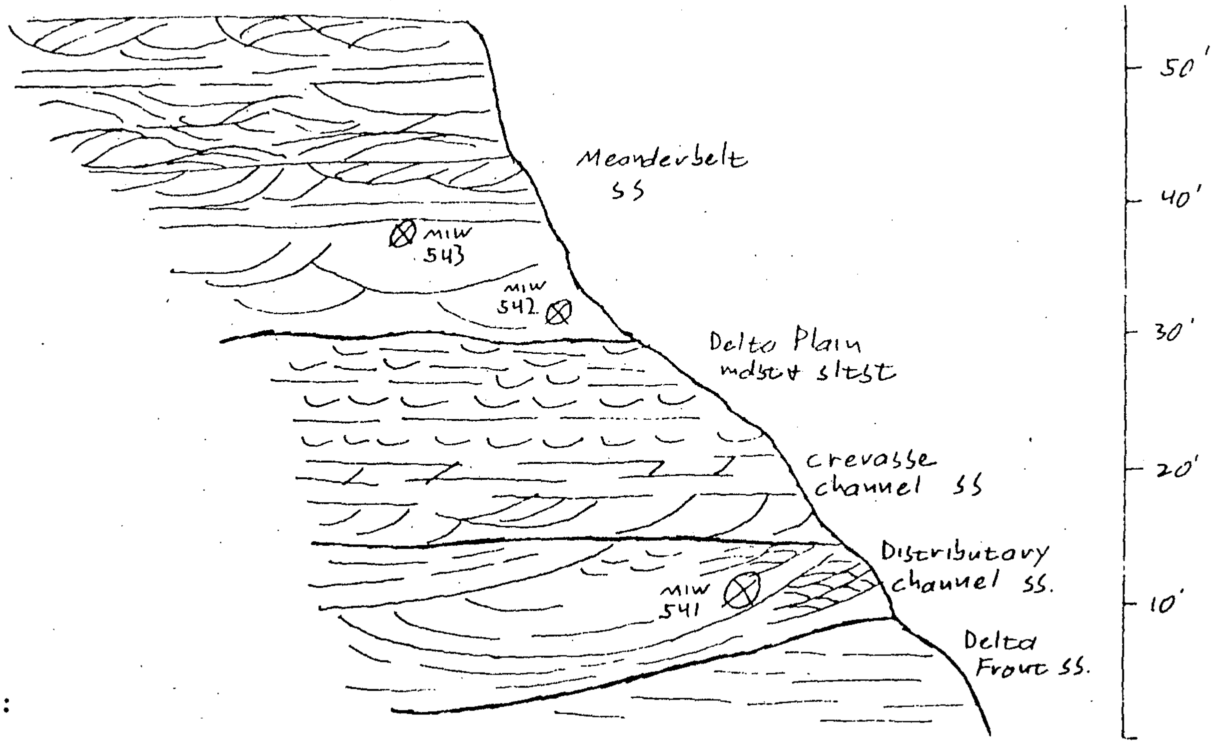
Quad Name Lubbock

Deposit No. 5

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MIW541	Chip sample, 'hot' mdy ss lens in distributary channel ss	475 ppm U_3O_8
MIW542	Chip sample from hot zone in basal meander-belt ss	240 ppm U_3O_8
MIW543	Chip sample from hot zone in lower meander-belt ss	2000 ppm U_3O_8

Geologic Sketch Map and/or Section, with Sample Locations:



References:

F1 <

>

F2 <

>

F3 <

>

F4 <

>

BFE 1236
6/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 5

Continuation from p. 1-5:

<u>Label</u>

GFE 1232
4/19/78

URANIUM-OCCURRENCE

REPORT

Quad Name A90 Lubbock

Quad Scale A100 |2,5,0,0,0,0|

Deposit No. B40 6

Deposit Name A10 < Yellow Cub Mine >

Synonym Name(s) A11 < Kirkpatrick Ranch >

District or Area A30 < Osage Plains >

Country A40 <U S> [U S] State Texas

State Code A50 <4 8> [4 8] County A60 < Garza >
(Enter code twice from List D)

Position from Prominent Locality A82 < 0.45 miles due south from Nathan Little tank.

Field Checked G1 <7 9|1 1> By G2< Thurwachter, Jeffrey E. >
Yr Mo Last name First Initial

Latitude A70 <3 3|0 7|3 6 N> Longitude A80 <1 0 1|2 1|3 3 W>
Deg Min Sec Deg Min Sec

Township A77 < > Range A78 < > Section A79 < >
N/S E/W

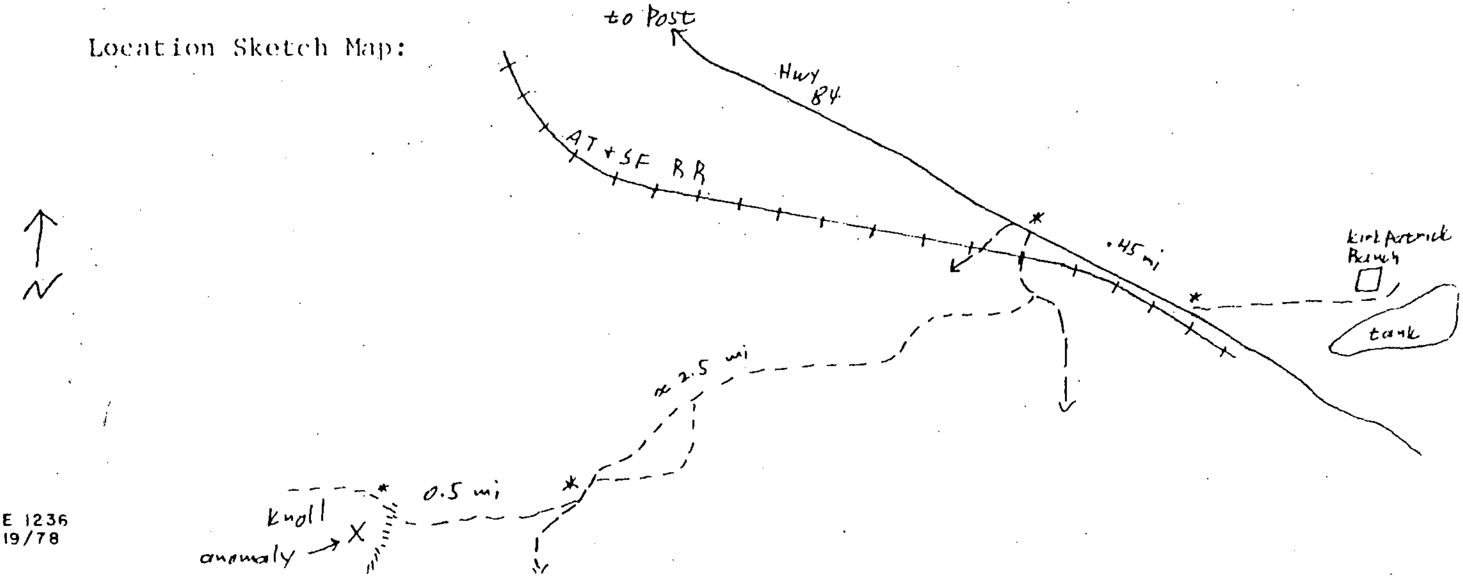
Meridian A81 < > Altitude A107 < > FT/M

Quad Scale A91 < 2 4 0 0 0> Quad Name A92 < Post East >
(7½' or 15' quad)

Physiographic Province A63 <0 7| [Great Plains >
(List K)

Location Comments A83 < >

Location Sketch Map:



BFE 1236
4/19/78

URANIUM-OCCURRENCE　　　　Quad Name　Lubbock

REPORT　　　　Deposit No.　6

Commodities Present:
C10 <U SST CLY QTZ>

Commodities Produced:
MAJOR <　> COPROD <　>

MINOR <　> BYPROD <　>

Potential Commodities:
POTEN <　> OCCUR <U>

Commodity Comments C50 <　>

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < Shipped 186 tons at 0.43% U_3O_8 >

Property is A21 (Active)　[✓ A22] (Inactive)　(Circle appropriate labels)

Workings are M120 (Surface)　M130 (Underground)　M140 (Both)

Description of Workings M220< No workings >

Cumulative Uranium Production　PROD　YES　[✓ NO]　[✓ SML]　MED　LGE　(circle)

DH2
accuracy　thousands of lb.　years　grade
G7< U| EST> G7A< 0 0 1 5 9 . 9 6> G7B<LB> G7C< before 1960 G7D< 0.43 % U308>

Source of Information D9 < Bement, et al., 1977 Geostats of NURE >

Production Comments D10 < No production, just minor exploration >

Reserves and Potential Resources

EH
accuracy　thousands of lb.　year of est.　grade
E1< U| EST> E1A< 00 00 . 512> E1B<LB> E1C< 19 80> E1D< .0362 % U308>

Source of Information E7 < McGowen and Thurwachter, this report >

Comments E8 <　>

BFE 1236
4/19/78

URANIUM-OCCURRENCE
REPORT

Quad Name Lubbock

Deposit No. 6

Deposit Form/Shape M10 < Elongate area of anomalous radioactivity (surface)

FT/M

Length M40 < 20 > M41< FT >

Width M50 < 8 > M51< FT >

Thickness M60 < appx 4 > M61< FT >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

[✓ A] 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < Eastern slope, Midland Basin >

Local Structures N70 < >

Host-FM. Name U1 < Dockum Gp. > Member U2 < >

Host Rock K1 < TRI b Medium grey, micaceous, friable fine to med. grained qtz ss, mod to well sorted & rounded. >
(Age) (Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.)

Host-Rock Environment U3 < Fluvial - deltaic >
(Sed. dep. environ., metamorphic facies, ign. environ.)

Comments on
Associated Rocks U4 < >

Ore Minerals C30 < No uranium minerals observed. >

Gangue Minerals K4 < None observed. >

URANIUM-OCCURRENCE Quad Name Lubbock

REPORT Deposit No. 6

Alteration N75 < None observed

>

Reductants U5 < None observed

>

Analytical Data (General) C43 < 362 ppm U_3O_8

>

Radiometric Data (General) U6 < 7 x BG(20 x 8 ft) 40 x BG(2 x 2 ft)
(No. times background and dimensions)

>

Ore Controls K5 <

>

Deposit Class C40 < Sandstone > Class No. U7 <2 4 4>

Comments on Geology N85 < Crevasse splay deposit

>

URANIUM-OCCURRENCE

REPORT

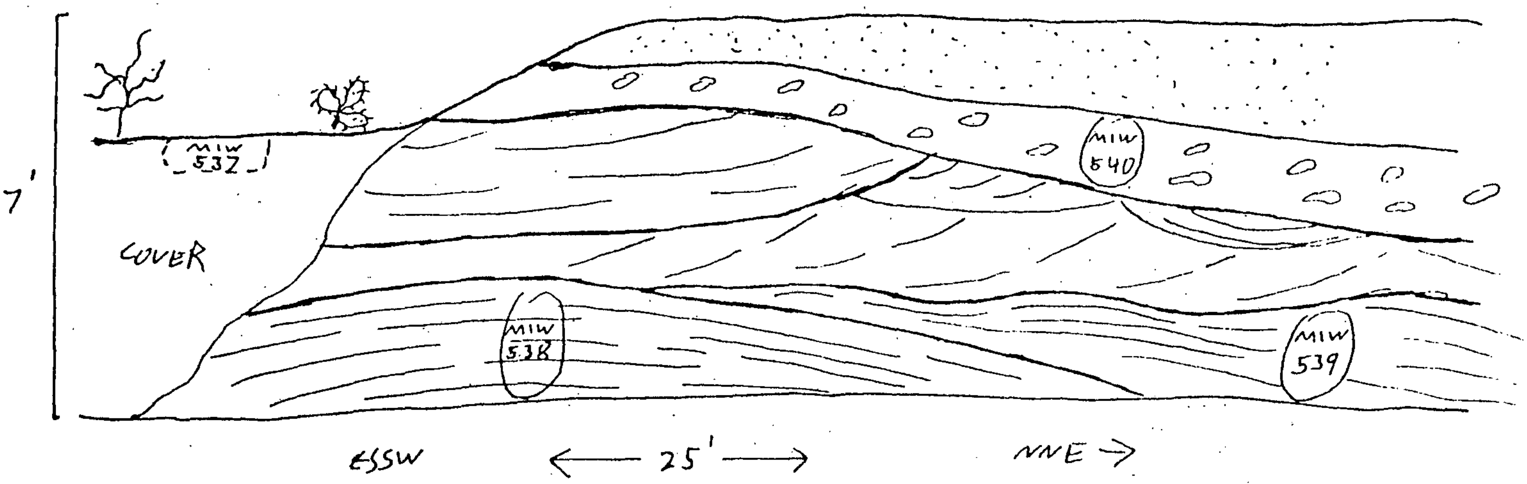
Quad Name Lubbock

Deposit No. 6

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MIW537	Sample from shallow hole (2x2x2 ft) in hottest zone	362 ppm U_3O_8
MIW538	from fine to v. fine micaceous ss	2.3 ppm U_3O_8
MIW539	fine to med. micaceous ss	1.5 ppm U_3O_8
MIW540	sdy pebble to cobble congl	3.3 ppm U_3O_8

Geologic Sketch Map and/or Section, with Sample Locations:



References:

F1 < Bement, T.R., et al., Geostatistical project of the NURE program, Jan-March 1977: Los Alamos Science Lab, N.M. GJBX-50(77)>

F2 <

>

F3 <

>

F4 <

>

URANIUM-OCCURRENCE Quad Name Lubbock

REPORT Report No. 6

Continuation from p. 1-5:

Label

URANIUM-OCCURRENCE

REPORT

Quad Name A90 Lubbock

Quad Scale A100 |2,5,0,0,0,0|

Deposit No. B40 7

Deposit Name A10 < Long Ranch >

Synonym Name(s) A11 < Twin Rattler Site >

District or Area A30 < Osage Plains >

Country A40 <U S> |U S| State Texas

State Code A50 <4 8> |48| County A60 < Garza >
(Enter code twice from List D)

Position from Prominent Locality A82 < 3200 ft west of the confluence of South Dokegood Creek and the North Fork, Double Mtn. Fork, Brazos River. >

Field Checked G1 <7 9|1 1> By G2< Thurwachter, Jeffrey E. >
Yr Mo Last name First Initial

Latitude A70 <3 3-1 9-2 9 N> Longitude A80 <1 0 1-2 4-2 5 W>
Deg Min Sec Deg Min Sec

Township A77 < > N/S Range A78 < > E/W Section A79 < >

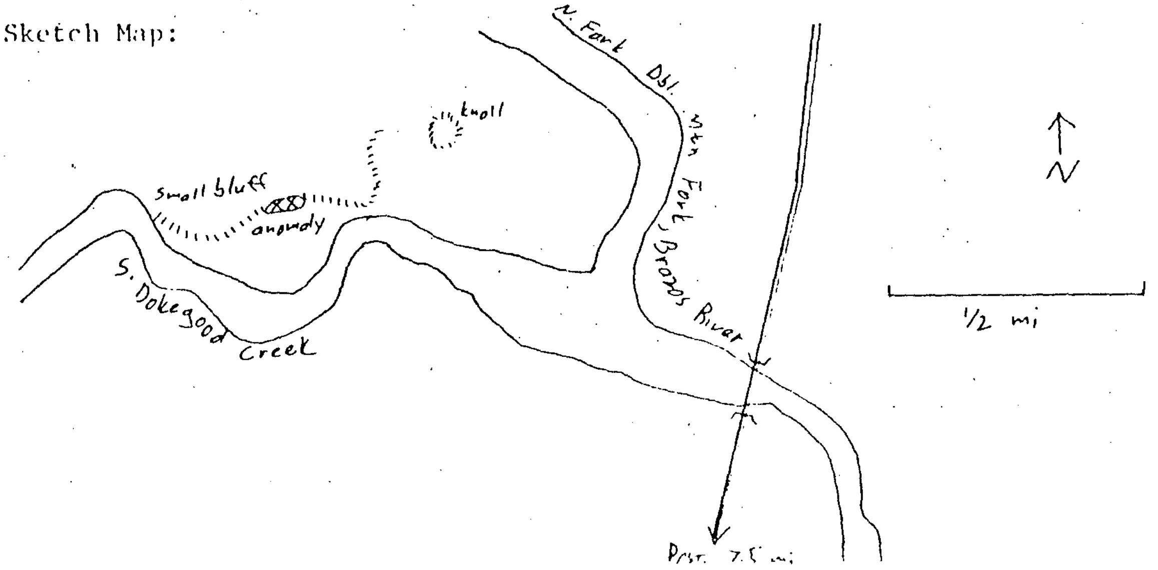
Meridian A81 < > Altitude A107 < > FT/M

Quad Scale A91 < 2 4 0 0 0> Quad Name A92 < So. Dokegood Creek >
(7½' or 15' quad)

Physiographic Province A63 <0 7> | Great Plains >
(List K)

Location Comments A83 < >

Location Sketch Map:



BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 7

Commodities Present:
C10 <U | SDG | SST | QTZ | | | | >

Commodities Produced:
MAJOR < | | | > COPROD < | | >

MINOR < | | | > BYPROD < | | >

Potential Commodities:
POTEN < | | > OCCUR <U | | >

Commodity Comments C50 < >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < shipped 133 tons @ 0.14% U_3O_8 >

Property is A21 (Active) [✓ A22] (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< No workings >

Cumulative Uranium Production PROD YES [✓ NO] [✓ SML] MED LGE (circle)

DH2 accuracy thousands of lb. years grade
G7<U|EST> G7A<000037.2> G7B<LB> G7C<before 1960 G7D< 0.14 % U308>

Source of Information D9 < Bement, et al., 1977, Geostats of NURE.* >

Production Comments D10 < No production, just minor exploration >

Reserves and Potential Resources

EII accuracy thousands of lb. year of est. grade
E1<U|EST> E1A<00011.14> E1B<LB> E1C<1980> E1D<.02 to .84 U308>

Source of Information E7 < McGowen and Thurwachter, this report >

Comments E8 < >

BFE 1236
4/19/78

URANIUM-OCCURRENCE

REPORT

Quad Name Lubbock

Deposit No. 7

Deposit Form/Shape M10 < Irregular dissemination >

FT/M

Length M40 < appx. 25 > M41< FT >

Width M50 < ? > M51< >

Thickness M60 < appx. 3 > M61< FT >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

[✓ A] 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < Eastern slope, Midland Basin >

Local Structures N70 < >

Host-FM. Name U1 < Dockum Gp. > Member U2 < >

Host Rock K1 <|T|R|I| | | | | | | | |b| Greenish-grey, calcitic in part,
(Age) (Rock type, texture, composition, color,

micaceous, mud-clast-granule bearing, silty, fine to v. fine qtz ss,
alteration, attitude, geometry, structure, etc.)

showing parallel laminae and minor cross-bedding. Contains minor amts of organic debris. >

Host-Rock Environment U3 < Fluvial-deltaic >
(Sed. dep. environ., metamorphic facies, ign. environ.)

Comments on
Associated Rocks U4 < >

Ore Minerals C30 < Scattered small patches of yellow uranium mineral. >

Gangue Minerals K4 < None observed. >

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 7

Alteration N75 < None observed >

Reductants U5 < Minor amounts of organic matter >

Analytical Data (General) C43 < 600 ppm U_3O_8; 8375 ppm U_3O_8 >

Radiometric Data (General) U6 < 14 to 170 times BG (40 x 10 ft)
(No. times background and dimensions)
25 to over 285 times BG (20 x 7 ft) >

Ore Controls K5 < >

Deposit Class C40 < sandstone > Class No. U7 <2 4 4>

Comments on Geology N85 < Probable crevasse splay deposit. >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

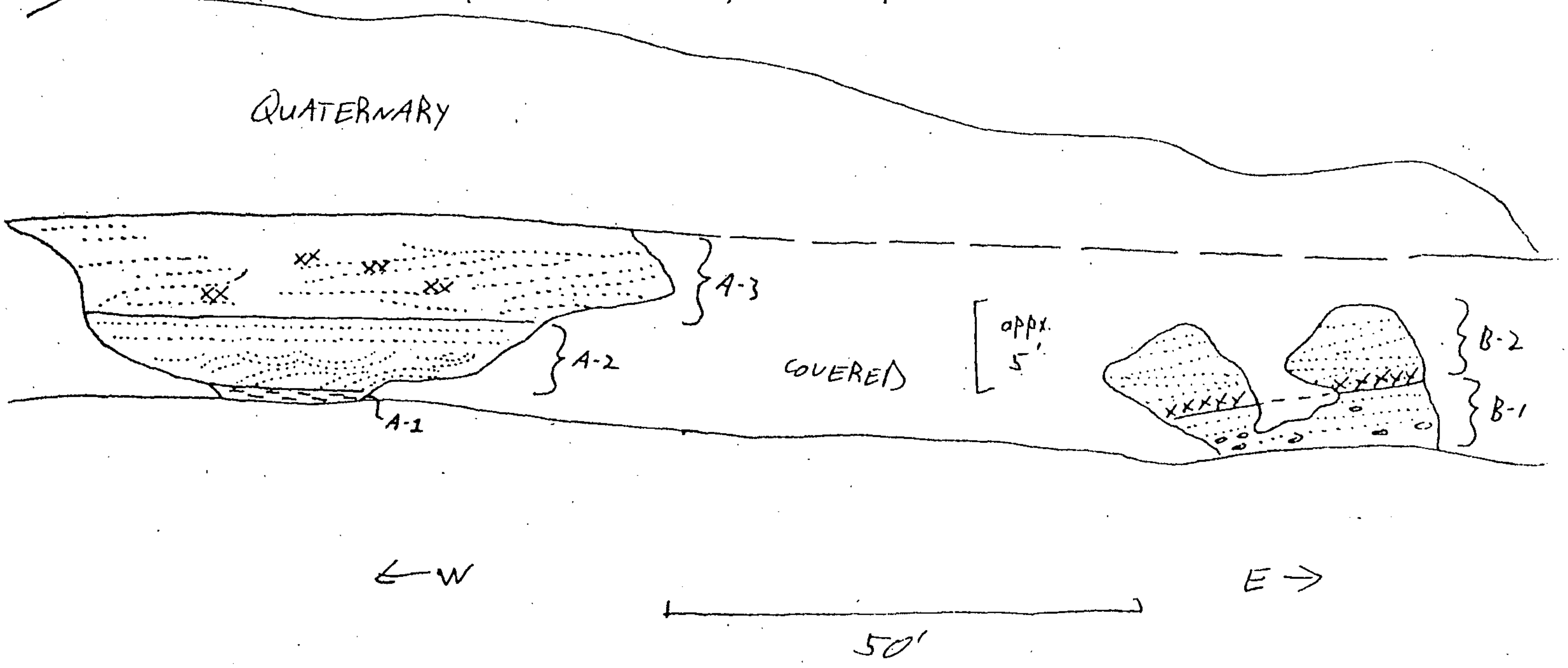
Quad Name Lubbock

Deposit No. 7

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MIW555	chip sample from hot part of unit A-3	600 ppm U_3O_8
MIW556	chip sample from unit B-1	198 ppm U_3O_8
MIW557	chip sample from hot part (base) of unit B-2 where yellow U minerals were observed	8375 ppm U_3O_8

Geologic Sketch Map and/or Section, with Sample Locations:



References:

F1 <Bement, et al., 1977, Geostatistical project of the NURE program, Jan-March 1977: LASL, N.M. GJBX-50(77)>

F2 <Butler, et al., 1962, Epigenetic uranium in the U.S., exclusive of Alaska and Hawaii: USGS Min. Inv. Res. Map MR-21, scale 1:3,168,000>

F3 <>

F4 <>

URANIUM-OCCURRENCE REPORT [illegible] Lubbock

[illegible] 7

Continuation from p. 1-5.

Label

D9 < 1962, Epigen. U in U.S.

D9 Butler, et al.

GFE 1237
4/12/78

URANIUM-OCCURRENCE

REPORT

Quad Name A90 Lubbock

Quad Scale A100 |_,_,2,5,0,0,0,0|

Deposit No. B40< 8

Deposit Name A10 < Long Ranch >

Synonym Name(s) A11 < Hillside Site >

District or Area A30 < Osage Plains >

Country A40 <|U, S|> |U, S| State Texas

State Code A50 <|4, 8|> |4, 8| County A60 < Garza >
(Enter code twice from List D)

Position from Prominent Locality A82 < 2200 ft nw from the confluence of South Dokegood Creek and the North Fork, Double Mtn. Fork, Brazos River

Field Checked G1 <|7, 9| |1, 1|> By G2< Thurwachter, Jeffrey E. >
Yr Mo Last name First Initial

Latitude A70 <|3, 3|-|1, 9|-|0, 7, N|> Longitude A80 <|1, 0, 1|-|2, 4|-|0, 6, W|>
Deg Min Sec Deg Min Sec

Township A77 <|_,_,_|_|> Range A78 <|_,_,_|_|> Section A79 <|_,_|>
N/S E/W

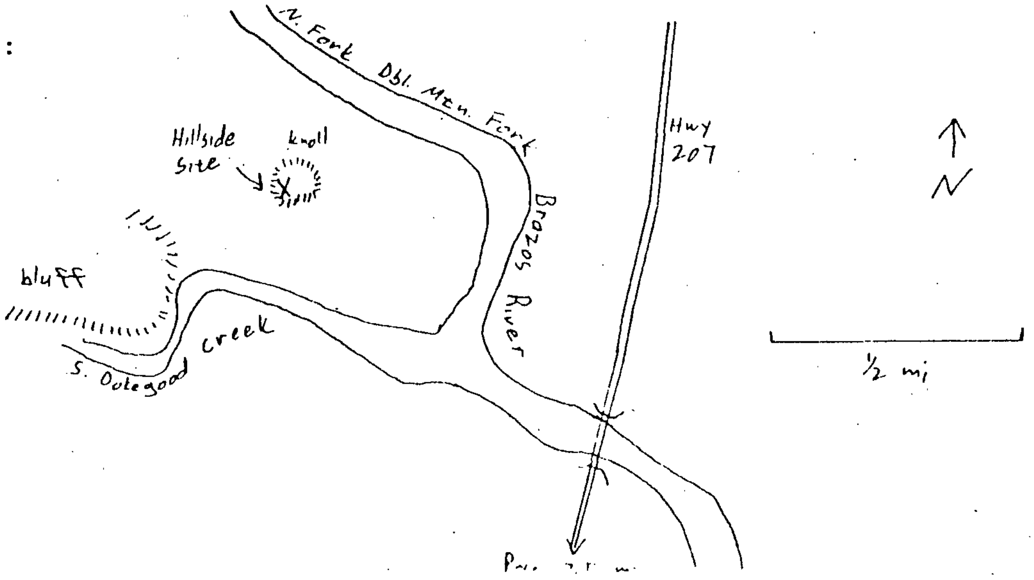
Meridian A81 < > Altitude A107 < > FT/M

Quad Scale A91 <|_,_,2,4,0,0,0|> Quad Name A92 < South Dokegood Creek >
(7½' or 15' quad)

Physiographic Province A63 <|0, 7| | Great Plains >
(List K)

Location Comments A83 < >

Location Sketch Map:



BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 8

Commodities Present:
C10 <U | SST | CLY | QTZ | | | | >

Commodities Produced:
MAJOR < | | | | > COPROD < | | | >

MINOR < | | | | > BYPROD < | | | >

Potential Commodities:
POTEN < | | | > OCCUR <U | | | >

Commodity Comments C50 < >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < shipped 38 tons @ 0.2% U_3O_8 >

Property is A21 (Active) [✓ A22] (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< No workings >

Cumulative Uranium Production PROD YES [✓ NO] [✓ SML] MED LGE (circle)

DH2 accuracy thousands of lb. years grade
G7< U | EST > G7A< 0 0 0 0 1 5 . 2 > G7B<LB> G7C< before 1960 G7D< 0.2 % U308>

Source of Information D9 < Bement, et al., 1977, Geostats of NURE. * >

Production Comments D10 < No production, just minor exploration. >

Reserves and Potential Resources

EH accuracy thousands of lb. year of est. grade
E1< U | EST > E1A< 0 0 0 2 3 . 3 8 > E1B<LB> E1C< 1 9 8 0 > E1D< .05 to .74 U308 >

Source of Information E7 < McGowen and Thurwachter, this report >

Comments E8 < >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 8

Deposit Form/Shape M10 < Irregular dissemination >

Length M40 < 15 > M41< FT > (FT/M)

Width M50 < ? > M51< >

Thickness M60 < 0.75 > M61< FT >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

A 0 - 20,000

[✓ B] 20,000 - 200,000

C 200,000 - 2 million

D 2 million - 20 million

E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < Eastern slope, Midland Basin >

Local Structures N70 < >

Host-FM. Name U1 < Dockum Gp > Member U2 < >

Host Rock K1 < TRI b Grey and green, calcitic, micaceous, mud clast granule and pebble bearing, v. fine qtz ss, with minor amounts of organic material. >

(Age) (Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.)

Host-Rock Environment U3 < Fluvial-deltaic >

(Sed. dep. environ., metamorphic facies, ign. environ.)

Comments on Associated Rocks U4 < >

Ore Minerals C30 < Scattered small patches of yellow uranium mineral. >

Gangue Minerals K4 < None observed. >

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 8

Alteration N75 < None observed >

Reductants U5 < Minor amounts of organic material observed. >

Analytical Data (General) C43 < 525 ppm U_3O_8; 950 ppm U_3O_8;
7375 ppm U_3O_8 >

Radiometric Data (General) U6 < 43 x BG (20 x 0.75 ft)
(No. times background and dimensions)
286 x BG (2 x 0.75 ft) >

Ore Controls K5 < >

Deposit Class C40 < sandstone > Class No. U7 <2 4 4>

Comments on Geology N85 < Probable crevasse splay deposit. >

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

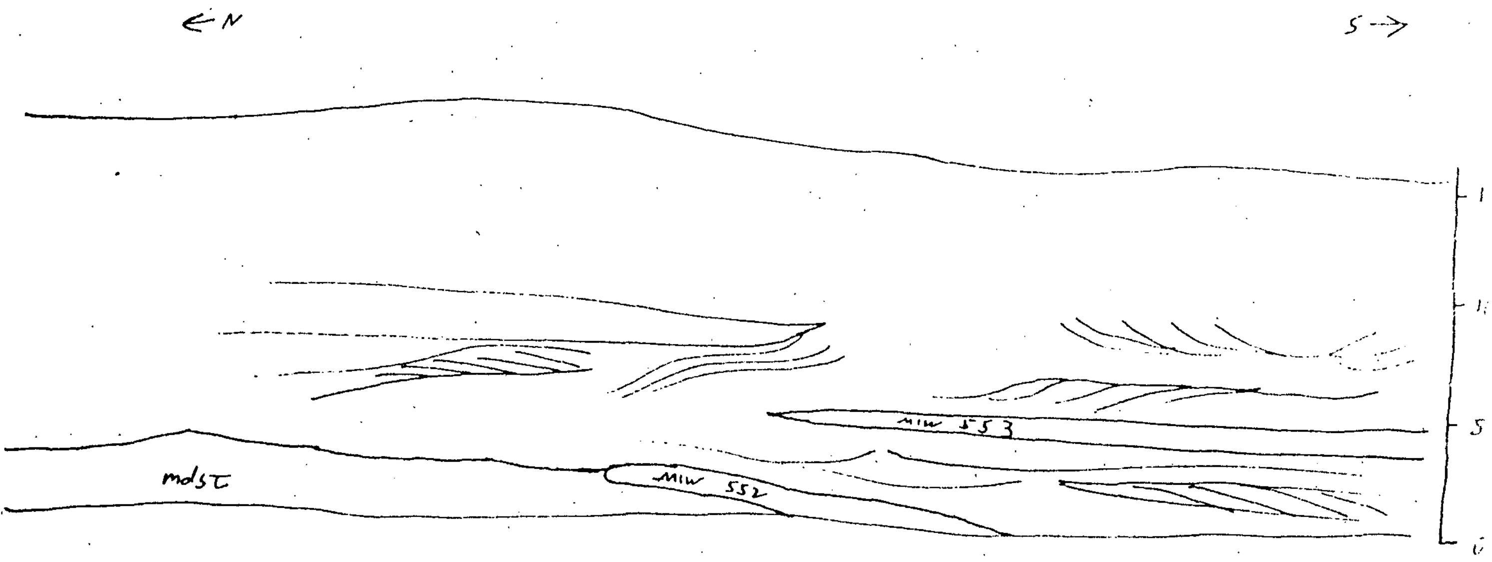
Deposit No. 8

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MIW552	chip sample from hottest zone in unit 1	525 ppm U_3O_8
MIW553	chip sample from hottest zone in unit 3	
	very fine quartz arenite	950 ppm U_3O_8
MIW554	chip sample from sdy congl showing scattered	
	yellow uranium minerals & organic debris	7375 ppm U_3O_8

Geologic Sketch Map and/or Section, with Sample Locations:

west side of Hill



References:

F1 <~~Bement, et al., 1977, Geostatistical project of the NURE program~~, Jan-March, 1977: Los Alamos Science Lab., N.M. GJBX-50 (77)>

F2 <Butler, et al., 1962, Epigenetic uranium in the U.S., ~~exclusive~~ of Alaska and Hawaii: USGS Min. Inv. Res. Map MR-21, scale 1:3,168,000>

F3 <

>

F4 <

>

BFE 1236
4/19/79

Continuation from p. 1-5.

Label

D9 Butler, et al., 1962, Epigenetic U in the U.S.

URANIUM-OCCURRENCE REPORT

Quad Name A90 Lubbock

Quad Scale A100 |2,5,0,0,0,0|

Deposit No. B40 9

Deposit Name A10 < Eubank Ranch >

Synonym Name(s) A11 < >

District or Area A30 < Osage Plains >

Country A40 <|U S|> |U S|

State Texas

State Code A50 <|4 8|> |4 8|

(Enter code twice from List D)

County A60 < Crosby >

Position from Prominent Locality A82 < 1.5 mi East of Canyon Valley Community

Field Checked G1 <|7 9| |1 1|> Yr Mo

By G2< Thurwachter, Jeffrey E. > Last name First Initial

Latitude A70 <|3 3|-|2 3|-|4 9 N|> Deg Min Sec

Longitude A80 <|1 0 1|-|1 8|-|3 3 W|> Deg Min Sec

Township A77 <| | |> N/S

Range A78 <| | |> E/W

Section A79 <| |>

Meridian A81 < >

Altitude A107 < > FT/M

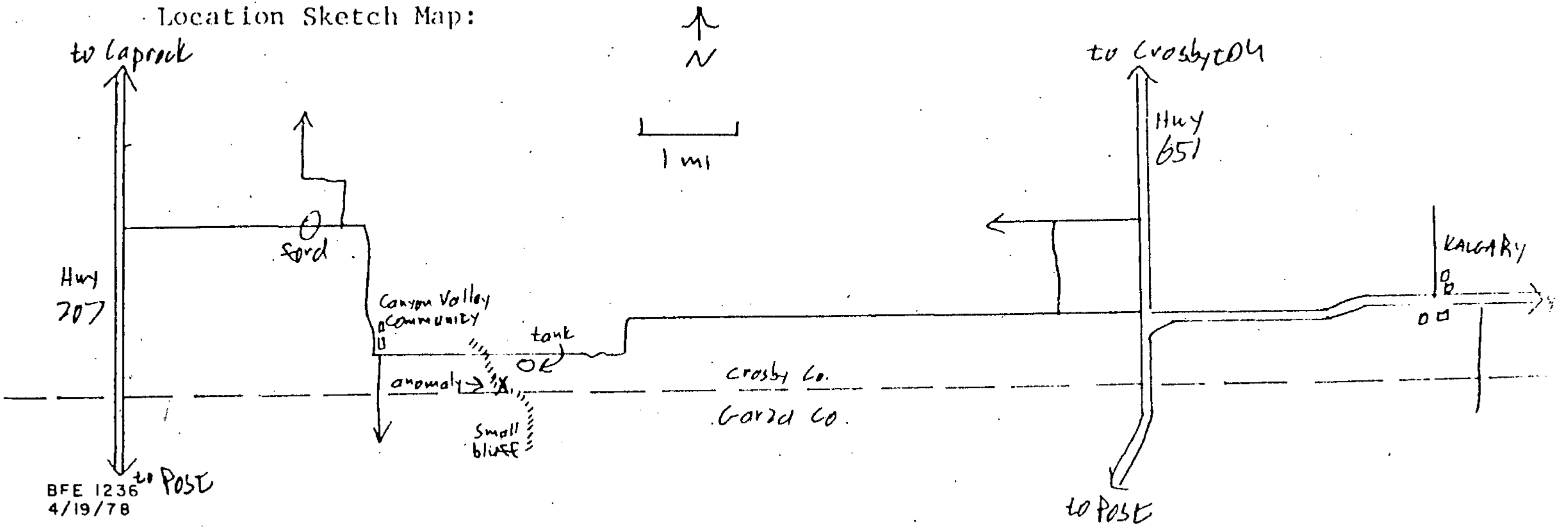
Quad Scale A91 <|2 4 0 0 0|> (7½' or 15' quad)

Quad Name A92 < Canyon Valley >

Physiographic Province A63 <|0 7| | Great Plains > (List K)

Location Comments A83 < >

Location Sketch Map:



BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 9

Commodities Present:
C10 <U SST>

Commodities Produced:
MAJOR < > COPROD < >

MINOR < > BYPROD < >

Potential Commodities:
POTEN < > OCCUR <U>

Commodity Comments C50 < >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < shipped approx. 365 tons at 0.11% U_3O_8 >

Property is A21 (Active) [✓ A22] (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< No workings >

Cumulative Uranium Production [✓ PROD] YES NO SML MED LGE (circle)

DH2
accuracy thousands of lb. years grade
G7<U EST> G7A<00008 0 .3> G7B<LB> G7C<before 1960 G7D< 0.11 % U308>

Source of Information D9 <Bement, et al., 1977. Geostats of NURE >

Production Comments D10 < No production, just minor exploration. >

Reserves and Potential Resources

EH
accuracy thousands of lb. year of est. grade
E1<U EST> E1A<0000 . 608> E1B<LB> E1C<1980> E1D<.13 - .18% U308>

Source of Information E7 < McGowen and Thurwachter, this report >

Comments E8 < >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 9

Deposit Form/Shape M10 <Circular areas of anomalous radioactivity >

Length M40 < 70 > M41< FT >

Width M50 < 100 > M51< FT >

Thickness M60 < ? > M61< >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

[✓ A] 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < Eastern slope, Midland Basin >

Local Structures N70 < >

Host-FM. Name U1 < Dockum Gp > Member U2 < >

Host Rock K1 <|T|R|I| | | | | | | | |b| Dirty grey, micaceous, mostly friable, minor mud-clast-granule bearing fine to very fine qtz ss, moderate to well sorted, well rdd. >
(Age) (Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.)

Host-Rock Environment U3 < >
(Sed. dep. environ., metamorphic facies, ign. environ.)

Comments on Associated Rocks U4 < >

Ore Minerals C30 < Scattered small patches of yellow uranium mineral. >

Gangue Minerals K4 < None observed. >

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 9

Alteration N75 < None observed >

Reductants U5 < None observed >

Analytical Data (General) C43 < 1275 ppm U_3O_8; 1800 ppm U_3O_8 >

Radiometric Data (General) U6 < 10 x BG (70 x 100 ft) 100 x BG (1 x 2 ft)
(No. times background and dimensions)
200 x BG (4 x 3 ft) >

Ore Controls K5 < >

Deposit Class C40 < sandstone > Class No. U7 <2|4|4>

Comments on Geology N85 < Area is covered & overgrown with vegetation to the extent of making geologic interpretations impossible >

URANIUM-OCCURRENCE

REPORT

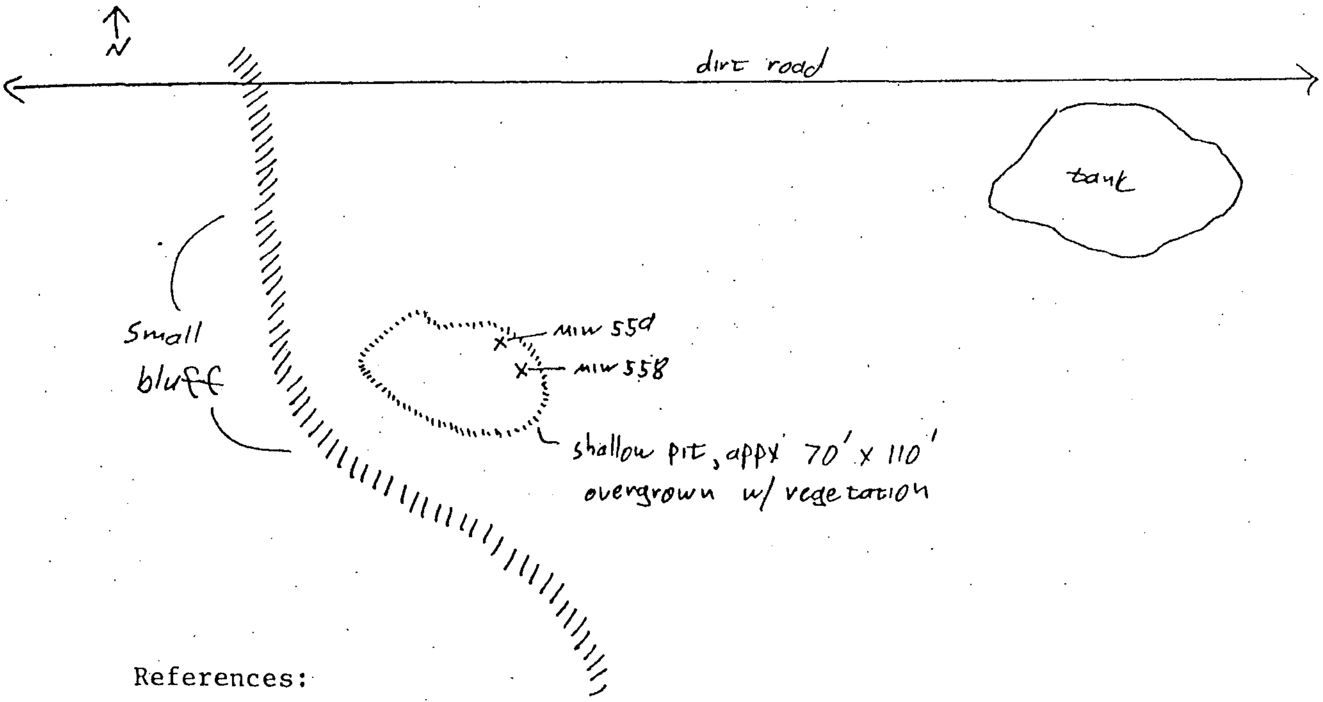
Quad Name Lubbock

Deposit No. 9

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MIW558	channel sample, hot patch showing yellow U minerals	1275 ppm U_3O_8
MIW559	channel sample, hot patch showing yellow U minerals	1800 ppm U_3O_8

Geologic Sketch Map and/or Section, with Sample Locations:



References:

F1 < Bement, et al., 1977, Geostatistical project of the NURE program, Jan-March, 1977: LASL, N.M. GJBX-50(77) >

F2 < >

F3 < >

F4 < >

BFS 1236
4/19/79

URANIUM OCCURRENCE REPORT

[illegible] Lubbock

[illegible] 9

Continuation from p. 1-4

Label

[illegible]FE 1237
4/12/78

URANIUM-OCCURRENCE

REPORT

Quad Name A90 Lubbock

Quad Scale A100 <250000>

Deposit No. B40 < 10 >

Deposit Name A10 < MacArthur Prospect >

Synonym Name(s) A11 < >

District or Area A30 < Osage Plains >

Country A40 <US> US

State Texas

State Code A50 <48> 48
(Enter code twice from List D)

County A60 < Kent >

Position from Prominent Locality A82 < >

Field Checked G1 <79|11> By G2< Thurwachter, Jeffrey E. >
Yr Mo Last name First Initial

Latitude A70 <33-23-36 N> Deg Min Sec

Longitude A80 <101-02-06 W> Deg Min Sec

Township A77 < > N/S

Range A78 < > E/W

Section A79 < >

Meridian A81 < >

Altitude A107 < > FT/M

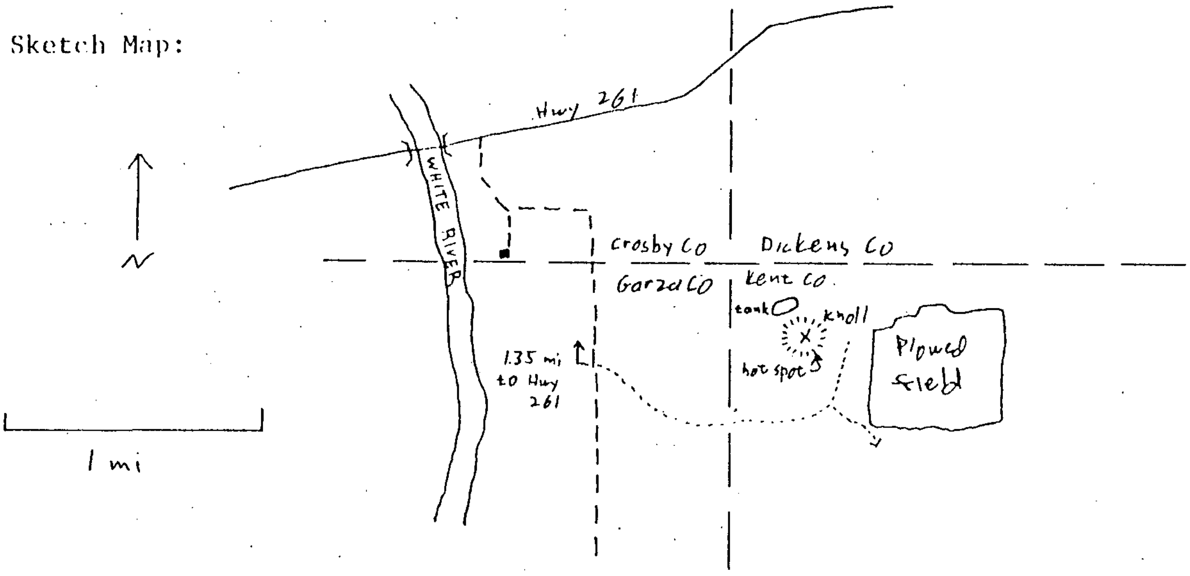
Quad Scale A91 <24000>
(7½' or 15' quad)

Quad Name A92 < Smith Tank >

Physiographic Province A63 <07> Great Plains >
(List K)

Location Comments A83 < >

Location Sketch Map:



BFE 1236
4/19/78

URANIUM-OCCURRENCE Quad Name Lubbock

REPORT Deposit No. 10

Commodities Present:
C10 <U S S T S D G Q T Z >

Commodities Produced:
MAJOR < > COPROD < >

MINOR < > BYPROD < >

Potential Commodities:
POTEN < > OCCUR <U >

Commodity Comments C50 < >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < shipped 33 tons @ 0.01% U_3O_8 >

Property is A21 (Active) [✓ A22] (Inactive) (Circle appropriate labels)

Workings are [✓ M120] (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< Top of knoll was blown up and several tons were hauled away. Otherwise, no workings >

Cumulative Uranium Production [✓ PROD] YES [✓ NO] [✓ SML] MED LGE (circle)

DH2
accuracy thousands of lb. years grade
G7<U E S T> G7A<0 0 0 0 0 . 6 0> G7B<LB> G7C<before 1960 G7D< 0.01 % U308>

Source of Information D9 < Butler, et al., Epigenetic uranium in U.S. * >

Production Comments D10 < No production, just minor exploration. >

Reserves and Potential Resources

EH
accuracy thousands of lb. year of est. grade
E1<U E S T> E1A<0 0 0 0 . 1 5 3 4> E1B<LB> E1C<1 9 8 0> E1D<.01-.028 % U308>

Source of Information E7 < McGowen and Thurwachter, this report >

Comments E8 < >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 10

Deposit Form/Shape M10 < Circular (?) area of anomalous radioactivity >

Length M40 < 200 > M41< FT > (FT/M)

Width M50 < 200 > M51< FT >

Thickness M60 < appx 15 > M61< FT >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

[✓ A] 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < Eastern slope, Midland Basin >

Local Structures N70 < >

Host-FM. Name U1 < Dockum Gp > Member U2 < >

Host Rock K1 <|T|R|I| | | | | | | | |b| Grey and tan, calcitic, micaceous, fossil wood-bearing, fine to very fine qtz ss and sed rock frag-qtzite-chert pebble congl. >
(Age) (Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.)

Host-Rock Environment U3 < Fluvial >
(Sed. dep. environ., metamorphic facies, ign. environ.)

Comments on Associated Rocks U4 < >

Ore Minerals C30 < Very sparse, minor scattered small patches of yellow uranium mineral. >

Gangue Minerals K4 < None observed. >

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 10

Alteration N75 < None observed >

Reductants U5 < None observed >

Analytical Data (General) C43 < 105 to 281 ppm U_3O_8 >

Radiometric Data (General) U6 < 6 to 24 times BG (200 x 200 ft) >
(No. times background and dimensions)

Ore Controls K5 < >

Deposit Class C40 < sandstone > Class No. U7 <2 4 4>

Comments on Geology N85 < Possibly a coarse-grain meanderbelt deposit. Good exposures are too rare to make accurate geologic interpretations. >

URANIUM-OCCURRENCE REPORT

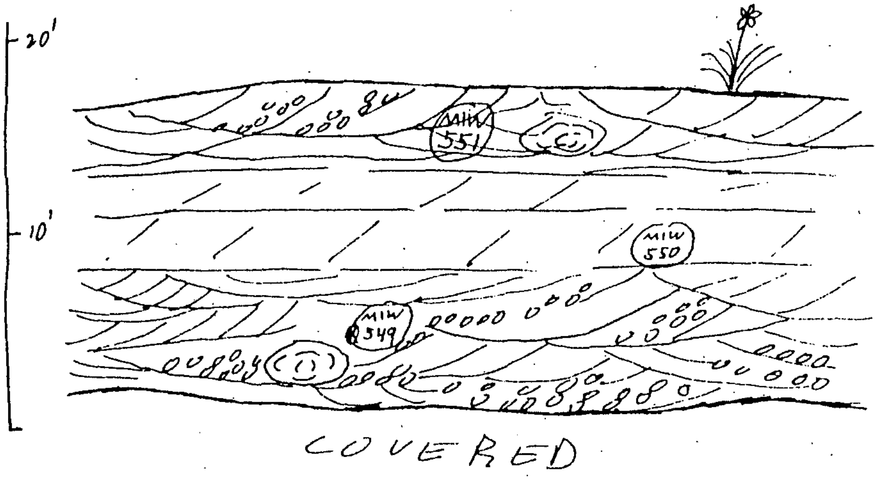
Quad Name Lubbock

Deposit No. 10

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MIW549	chip sample from north side of knoll	281 ppm U_3O_8
MIW550	chip sample from near north side of knoll	131 ppm U_3O_8
MIW551	chip sample from center of knoll	105 ppm U_3O_8

Geologic Sketch Map and/or Section, with Sample Locations:



References:

F1 < Bement, T.R., et al., 1977, Geostatistical Project of the NURE Program, Jan-March, 1977: Los Alamos Science Lab Report GJBX-50(77) >

F2 < Butler, A.P., Jr., et al., 1962, Epigenetic U in the U.S., exclusive of Alaska and Hawaii: USGS Min. Inv. Res. Map MR-21 >

F3 < >

F4 < >

BFE 1235
4/19/79

Page

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 10

Continuation from p. 1-5

Label

D9 Bement, et.al., 1977, Geostats of NURE project.

[illegible]FE 123[illegible]
[illegible]/12/78

URANIUM OCCURRENCE

REPORT

Quad Name A90 Lubbock

Quad Scale A100 ⊢ 2,5,0,0,0,0 ⊣

Deposit No. B40 11

Deposit Name A10 < Red Mud Prospect >

Synonym Name(s) A11 < Unnamed >

District or Area A30 < Osage Plains >

Country A40 <U S> U S　State Texas

State Code A50 <4 8> 4 8　County A60 < Dickens >
(Enter code twice from List D)

Position from Prominent Locality A82 < Approx. 750 ft north of Red Mud(?) Cemetery.

Field Checked G1 <7 9 | 1 1> By G2< Thurwachter, Jeffrey E. >
Yr Mo　Last name　First　Initial

Latitude A70 <3 3 | 2 5 | 4 4 N> Deg Min Sec　Longitude A80 <1 0 0 | 5 9 | 5 7 W> Deg Min Sec

Township A77 < > N/S　Range A78 < > E/W　Section A79 < >

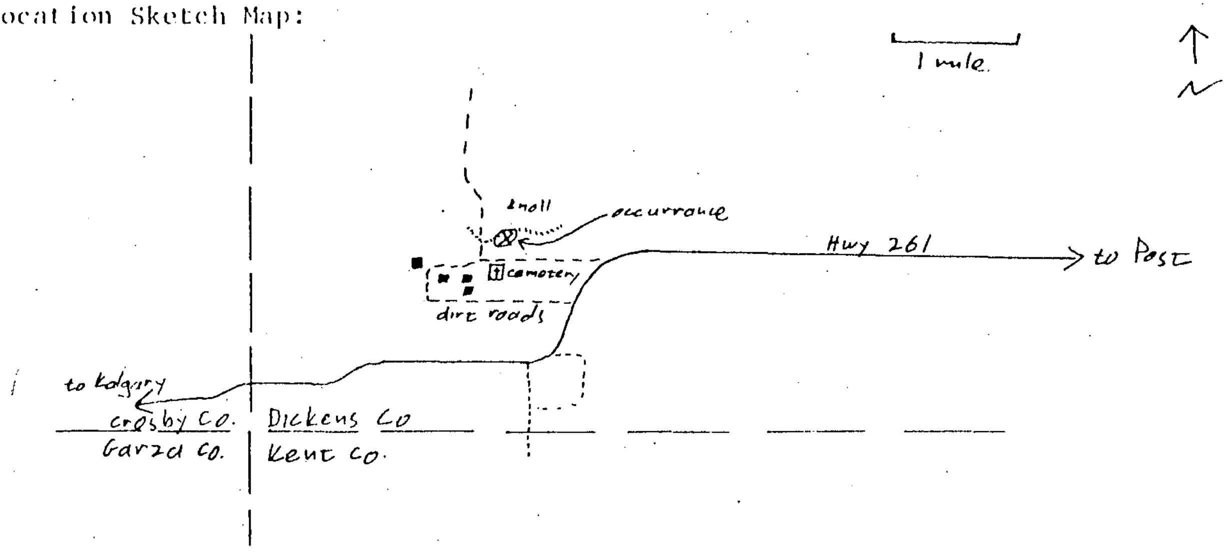
Meridian A81 < > Altitude A107 < > FT/M

Quad Scale A91 < 2 4 0 0 0 > (7½' or 15' quad)　Quad Name A92 < Spur, NW >

Physiographic Province A63 <0 7> (List K) Great Plains >

Location Comments A83 < >

Location Sketch Map:



BFE 1236
4/19/78

URANIUM-OCCURRENCE Quad Name Lubbock

REPORT Deposit No. 11

Commodities Present:
C10 < U SDG CLY >

Commodities Produced:
MAJOR < > COPROD < >

MINOR < > BYPROD < >

Potential Commodities:
POTEN < > OCCUR < U >

Commodity Comments C50 < >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < No past development >

Property is A21 (Active) [✓ A22] (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< No workings >

Cumulative Uranium Production [✓ PROD] YES [✓ NO] SML MED LGE (circle)

DH2

accuracy	thousands of lb.		years	grade
G7< U >	G7A< >	G7B<LB>	G7C< >	G7D< % U308>

Source of Information D9 < >

Production Comments D10 < >

Reserves and Potential Resources

EH

accuracy	thousands of lb.		year of est.	grade
E1< U EST >	E1A< 0000,312 >	E1B<LB>	E1C< 1980 >	E1D< 0.005 % U308>

Source of Information E7 < McGowen & Thurwachter, this report >

Comments E8 < Grade of 0.005% is the maximum at this locality >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 11

Deposit Form/Shape M10 < A few scattered circular areas of anom radioactivity

Length M40 < 50 > M41< FT/M FT>

Width M50 < 20 > M51< FT>

Thickness M60 < 2? > M61< FT>

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

[✓ A] 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < Eastern slope, Midland Basin >

Local Structures N70 < >

Host-FM. Name U1 < Dockum Gp > Member U2 < >

Host Rock K1 <|T|R|T| | | | | | | | |~~b~~| Orange, fine-grained, qtz ss, friable,
(Age) (Rock type, texture, composition, color,

well sorted, well rdd.
alteration, attitude, geometry, structure, etc.) >

Host-Rock Environment U3 < Delta front ss unit >
(Sed. dep. environ., metamorphic facies, ign. environ.)

Comments on Associated Rocks U4 < Underlain by a prodelta siltstone unit (15')
Overlain by braided stream (fan delta) conglomerate and ss sequence
(18') >

Ore Minerals C30 < None observed >

Gangue Minerals K4 < None observed >

URANIUM-OCCURRENCE REPORT

Quad Name Lubbock

Deposit No. 11

Alteration N75 < None observed >

Reductants U5 < None observed >

Analytical Data (General) C43 < 10 to 56 ppm U_3O_8 >

Radiometric Data (General) U6 < Appx 7 times BG (20 x 50 ft)
(No. times background and dimensions) >

Ore Controls K5 < >

Deposit Class C40 < sandstone > Class No. U7 <2 4 4>

Comments on Geology N85 < >

URANIUM-OCCURRENCE

REPORT

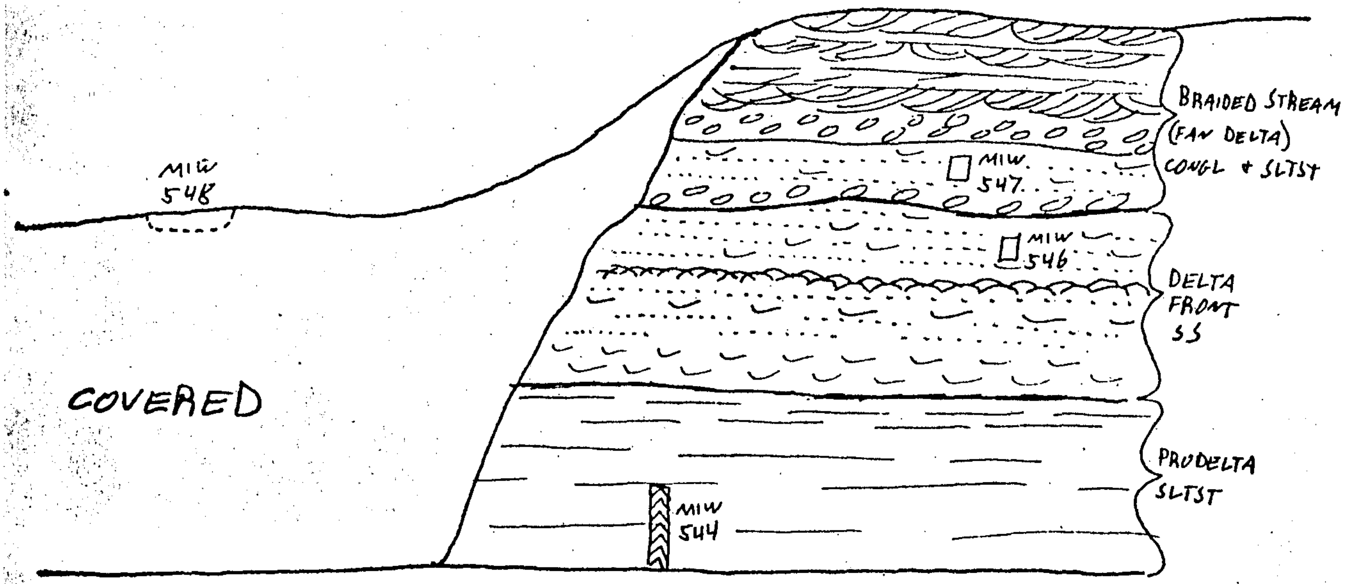
Quad Name Lubbock

Deposit No. 11

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MIW544	channel sample from prodelta sltst	10.3 ppm U_3O_8
MIW546	chip sample from upper delta front ss	16 ppm U_3O_8
MIW547	chip sample from lower braided stream	
	(fan delta) congl	11 ppm U_3O_8
MIW548	channel sample near center of anomalous	
	area, equivalent to upper delta front ss	56 ppm U_3O_8

Geologic Sketch Map and/or Section, with Sample Locations:



References:

F1 < Finch, W.I., 1975, Uranium in West Texas: USGS Open File Report 75-356 >

F2 < >

F3 < >

F4 < >

URANIUM-OCCURRENCE

REPORT

Quad Name Lubbock

Deposit No. 11

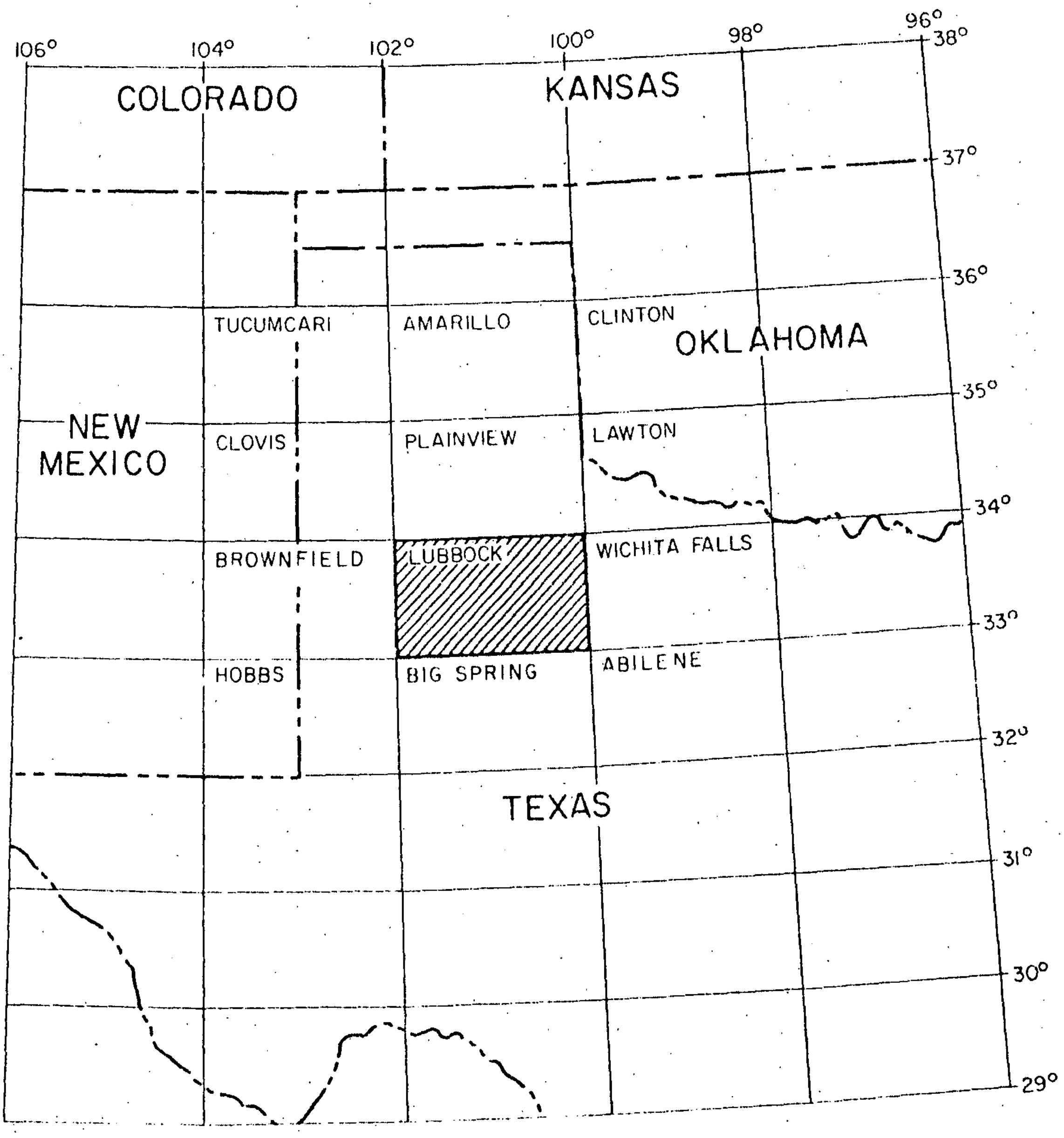
Continuation from p. 1-5:

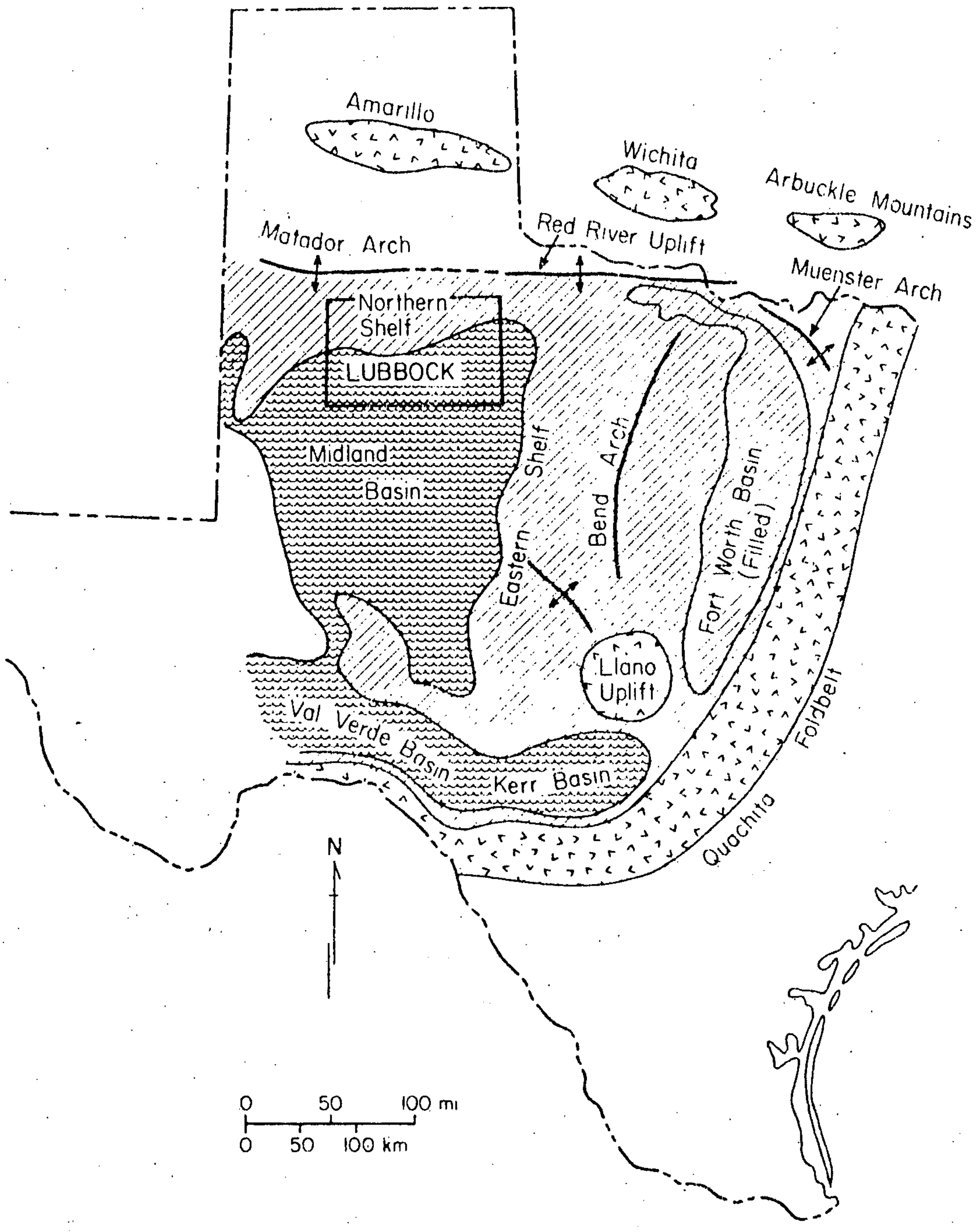
Label

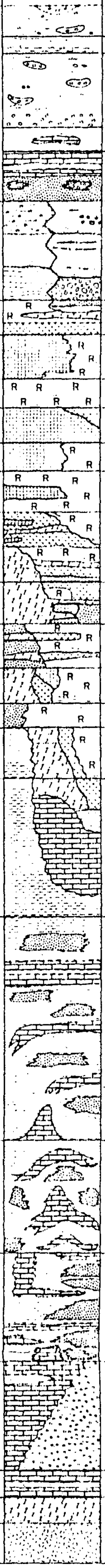
PFE 123C
4/18/78

APPENDIX D. Quaternary geochemical rock samples

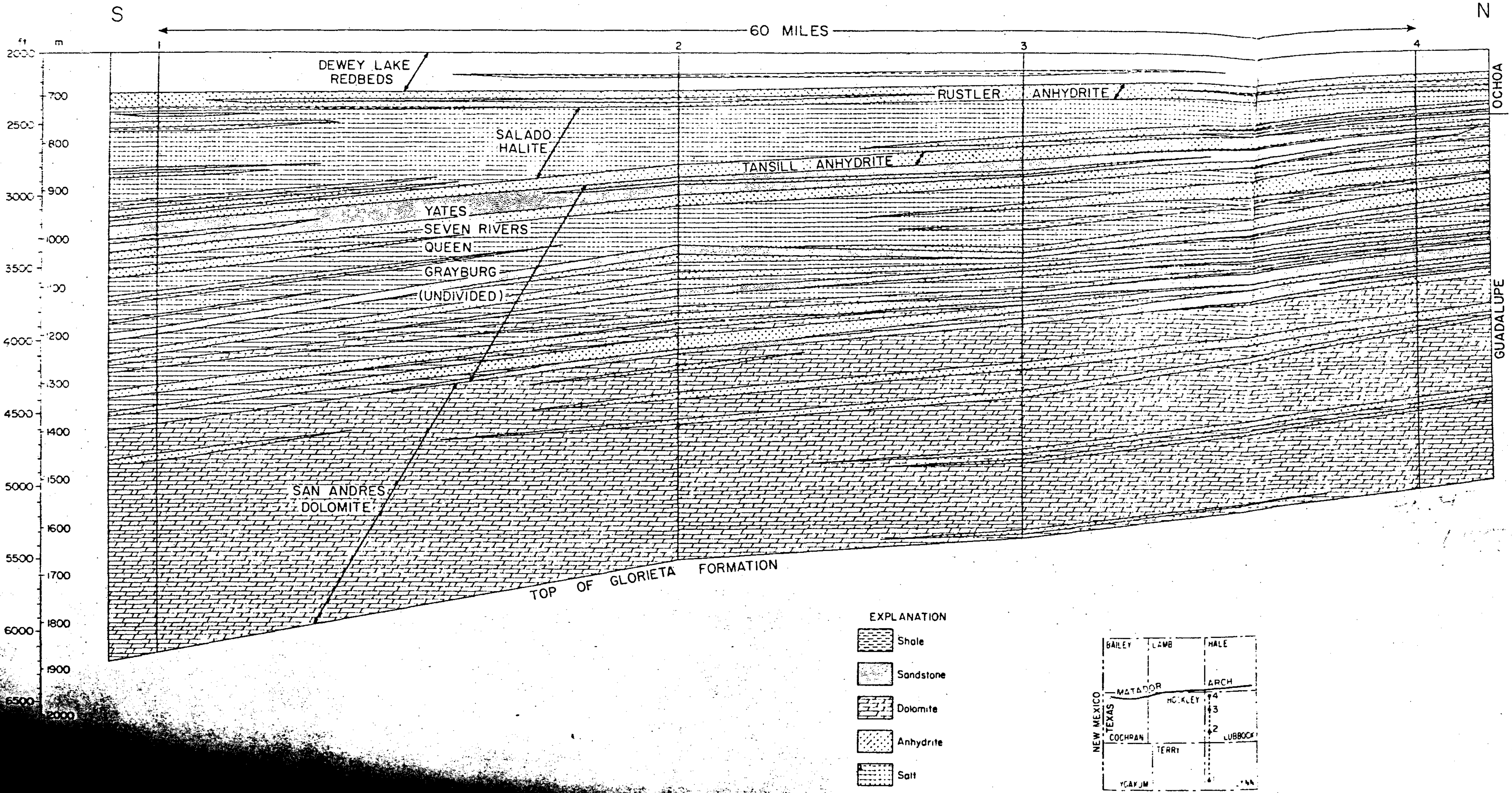
Sample No. M/W	Total Gamma Ray CPS	U_3O_8(FI) ppm	Th ppm	U/Th	V ppm	V/U
169		40	> 5	> 8.0	95.5	23.9
170		30.0	> 5	> 6.0	100.7	3.4
171		30.0	> 5	> 6.0	111.3	3.7
172		14.0	> 5	> 2.8	65.3	4.7
173		19.0	< 5	> 3.8	43.3	2.3
174		3.8	< 10	> 0.08	39.7	10.4
175		1.5	< 5	> 0.3	24.1	16.1
316		6.0	< 5	> 1.2	82.0	13.7
317		7.0	6.6	1.1	109.1	15.7
318		4.5	34.1	0.13	40.6	9.0
320		10.0	< 5	> 0.5	32.6	3.3
321		42.5	< 10	> 0.24	144.9	3.4
322		2.0	< 5	> 0.4	76.0	13.0
323		6.3	< 10	> 0.6	911.1	152
324		13.3	< 10	> 1.3	16.7	13
329		7.0	< 5	> 1.4	49.8	7.1
330		9.3	< 5	> 1.9	27.6	3.0
331		3.0	< 5	> 0.6	30.9	10.3
332		4.8	< 5	> 1.0	44.4	9.3
333		2.0	< 5	> 0.4	26.8	13.4
334		3.8	< 5	> 0.8	20.9	5.5
335		2.5	< 5	> 0.5	31.4	12.6
336		125	< 10	> 12.5	100.2	0.8
337		128	< 10	> 12.8	25.4	0.20
338		27	< 10	> 2.7	123.6	4.6
341	45	15.0	< 5	> 3.0	65.0	4.3
339		10.7	< 5	> 2.1	65.1	6.1
342		5.0	< 5	> 1.0	43.7	8.7
343		17.8	< 10	> 1.8	66.3	3.7
344	50	6.0	< 5	> 1.2	61.0	10.2
097		1.5	< 5	> 0.3	51.6	3.4
354		1.5	< 5	> 0.3	112.4	74.0
355		1.8	< 5	> 0.36	65.2	36.2
356		7.3	< 5	> 1.5	90.4	12.4
357		3.5	8.1	0.4	90.8	25.9
358		2.3	< 5	> 0.5	55.9	24.3
359		3.0	< 5	> 0.6	20.2	6.7
360		1.0	< 5	> 0.2	38.7	38.7
361		2.3	7.3	0.32	60.6	26.3
135		4.0	< 5	> 0.8	48.0	12.0
370	275	50.0	< 5	> 10.0	141.5	2.8
372	500	60.0	< 5	> 12.0	222.4	3.7
373	270	80.0	< 5	> 16.0	151.4	1.9


106°
104°
102°
100°
98°
96°
38°
37°
36°
35°
34°
33°
32°
31°
30°
29°
COLORADO
KANSAS
OKLAHOMA
NEW MEXICO
TEXAS
TUCUMCARI
AMARILLO
CLINTON
CLOVIS
PLAINVIEW
LAWTON
BROWNFIELD
LUBBOCK
WICHITA FALLS
HOBBS
BIG SPRING
ABILENE

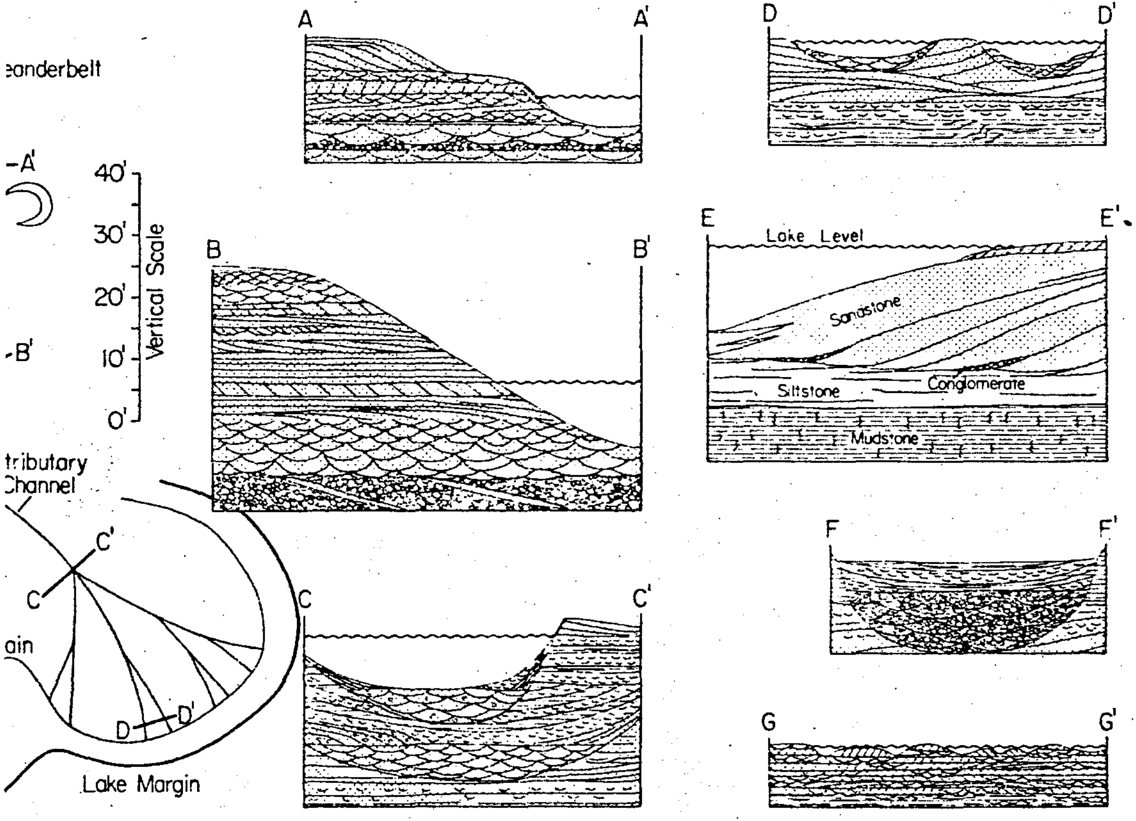

Amarillo
Wichita
Arbuckle Mountains
Matador Arch
Red River Uplift
Muenster Arch
Northern Shelf
LUBBOCK
Midland Basin
Eastern Shelf
Bend Arch
Fort Worth Basin (Filled)
Llano Uplift
Val Verde Basin
Kerr Basin
Quachita Foldbelt
N
0 50 100 mi
0 50 100 km



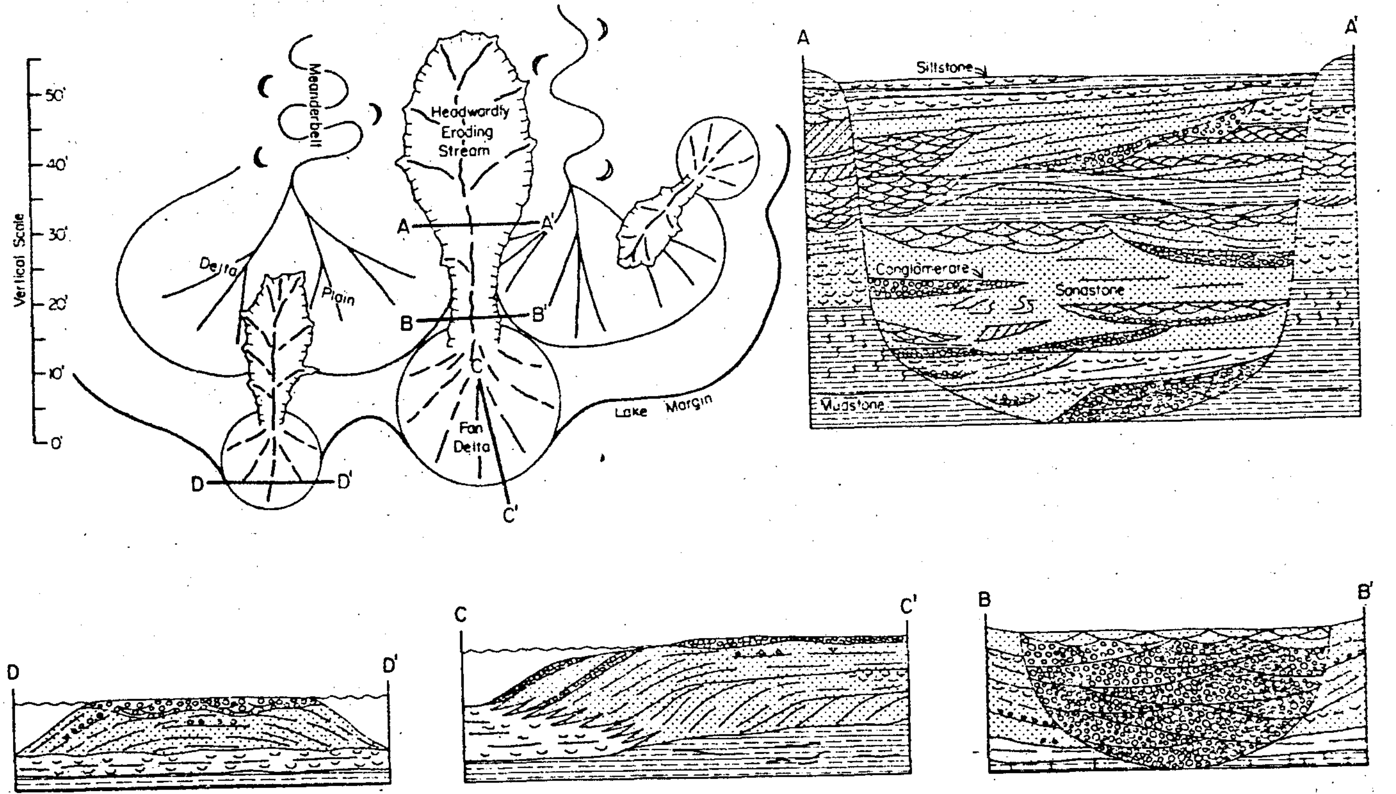
ERA	SYSTEM	SERIES	SURFACE GROUP OR FORMATION	SUBSURFACE GROUP OR FORMATION	COLUMNAR SECTION	DESCRIPTION
CENOZOIC	Quaternary	Holocene	Quaternary deposits			Windblown sand and silt Fluvial terrace and floodplain deposits
		Pleistocene				Playa silts and clays, lacustrine clay, silt, sand, and gravel
			Tule/Blanco *			Lacustrine clays, sands, and limestone. Vocanic ash
	Tertiary	Pliocene	Ogallala *			Fine to coarse grained sand, gravel, clay, silt, with caliche caprock
MESOZOIC	Cretaceous	Lower	Duck Creek Sh. Kiamichi Sh			Interbedded shale, sandstone and limestone
			Edwards Ls Comanche Pk Ls Walnut Antlers Sd			Thick to massive, white to yellow-brown, "Rudistid" limestone with thin shale and sandstone interbeds Sandstone and Conglomerate
	Triassic	Upper	Dockum *	Dockum		Fine to coarse-grained sand, conglomerate, and interbedded clay
PALEOZOIC	Permian	Guadalupe	Quartermaster	Dewey Lake		Shale, sandstone, gypsum, dolomite interbedded Mostly red beds
				Alibates		Anhydrite
			Whitehorse Sandstone and Cloud Chief Gypsum	Salado		Salt to northwest, becoming red beds on the east side of the quadrangle
				Yates		Red beds; sand, shale, gypsum, and dolomite
				Upper Seven Rivers		Salt with mud and anhydrite Anhydrite where salt has been disolved by ground water
				Lower Seven Rivers		Salt and red beds
				Queen-Grayburg		Salt and red beds
			Blaine	Upper San Andres		Dolomite, anhydrite, salt, red beds
			San Angelo *	Lower San Andres		Dolomite, anhydrite, sandstone, salt, red beds
				Glorietta		Red beds interbedded with anhydrite Sandstone, dolomite
		Leonard	Choza	Upper Clear Fork		Dolomite with anhydrite, salt, red beds
				Tubb		Sandstone and red beds
				Lower Clear Fork		Shale, dolomite with anhydrite, and red beds Shelf margin
		Wolfcamp		Wichita-Wolfcamp		Shale, limestone, dolomite with anhydrite
	Pennsylvanian	Virgil		Cisco		Updip thin shallow marine limestone to downdip thick shelf limestone cycle Fluvial deltaic and slope clastics Sands and shales Local thick reef limestone.
		Missouri		Canyon		High constructive deltaic sands and shales Cycles of discontinuous platform, shelf limestone, local reefs
		Desmoines		Strawn		Bank, platform, or shelf limestones, local reefs Fluvial and deltaic sands and shales
		Atoka		Caddo		Massive limestone with some shale Granite wash north of Matador arch
	Mississippian	Chester-Kinderhook		Mississippian undiff.		Limestone and shale
	Ordovician	Canadian		Ellenburger		Dolomite
Precambrian				Precambrian		Granite, gneiss and rhyolite

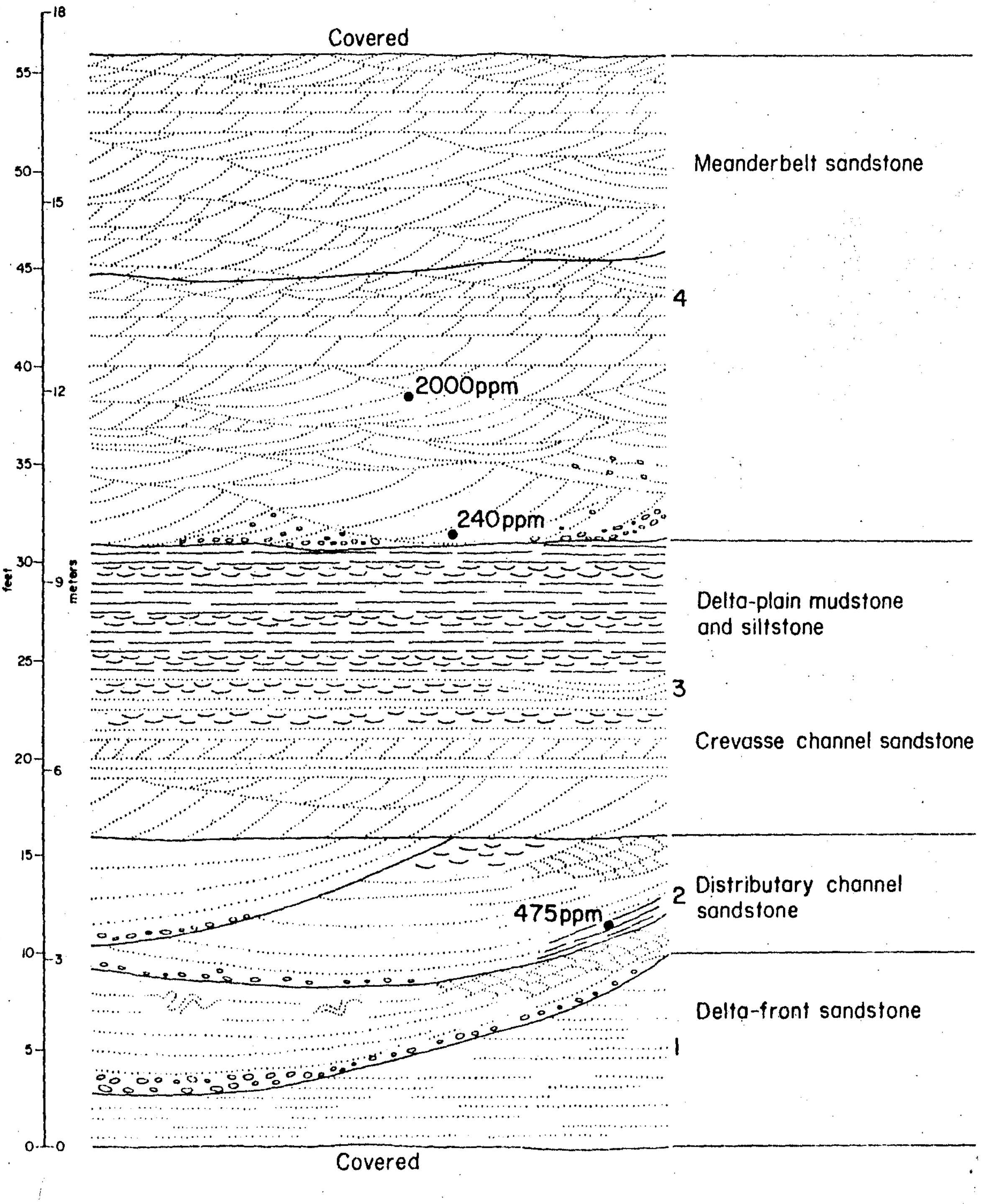

S
N
60 MILES
1
2
3
4
ft
m
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
DEWEY LAKE REDBEDS
RUSTLER ANHYDRITE
SALADO HALITE
TANSILL ANHYDRITE
YATES
SEVEN RIVERS
QUEEN
GRAYBURG
(UNDIVIDED)
SAN ANDRES DOLOMITE
TOP OF GLORIETA FORMATION
OCHOA
GUADALUPE
EXPLANATION
Shale
Sandstone
Dolomite
Anhydrite
Salt
BAILEY
LAMB
HALE
MATADOR
ARCH
HOCKLEY
4
3
2
NEW MEXICO
TEXAS
COCHRAN
TERRY
LUBBOCK
YOAKUM
LYNN

FACIES DEVELOPED AT HIGH STAND

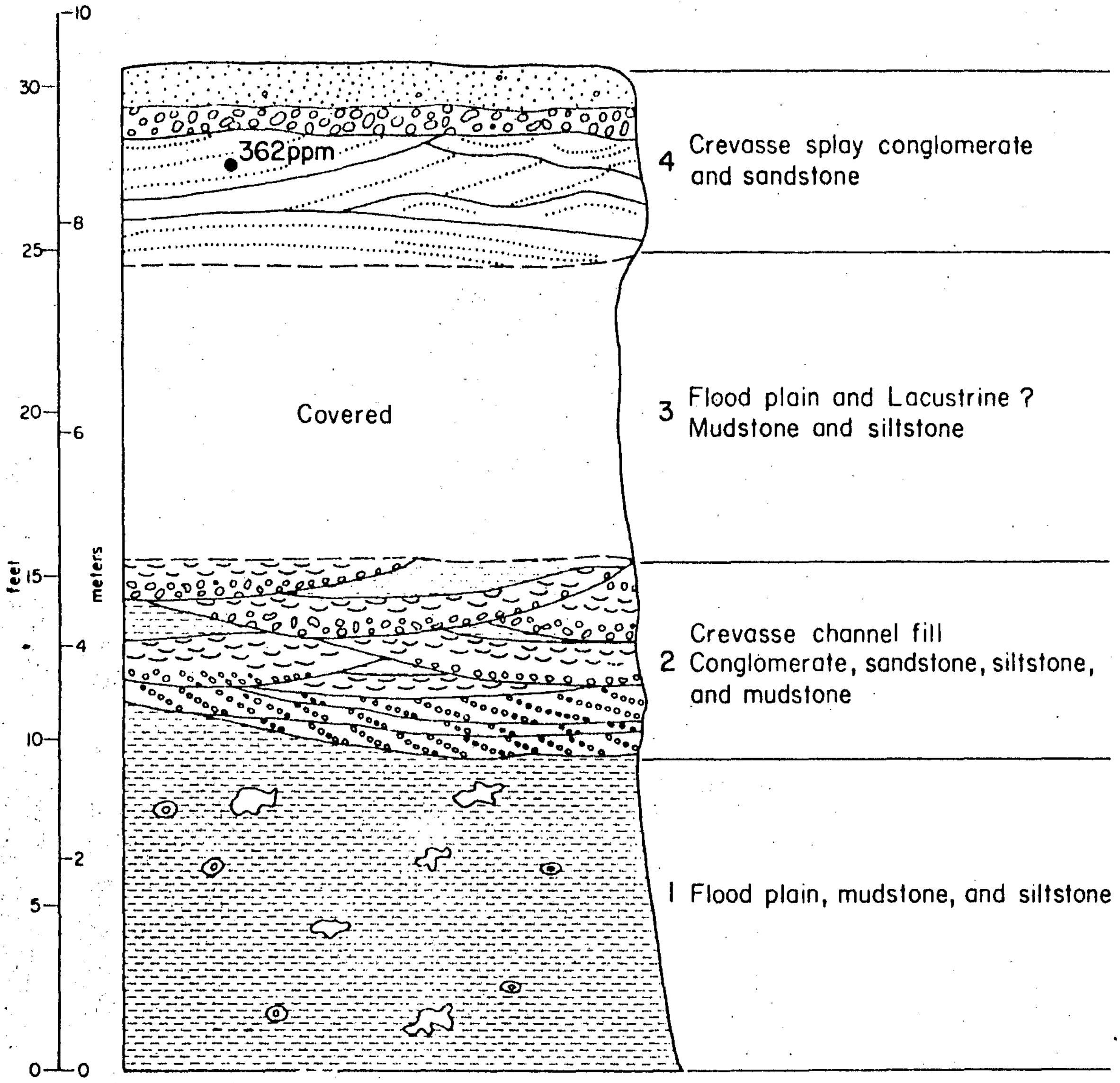


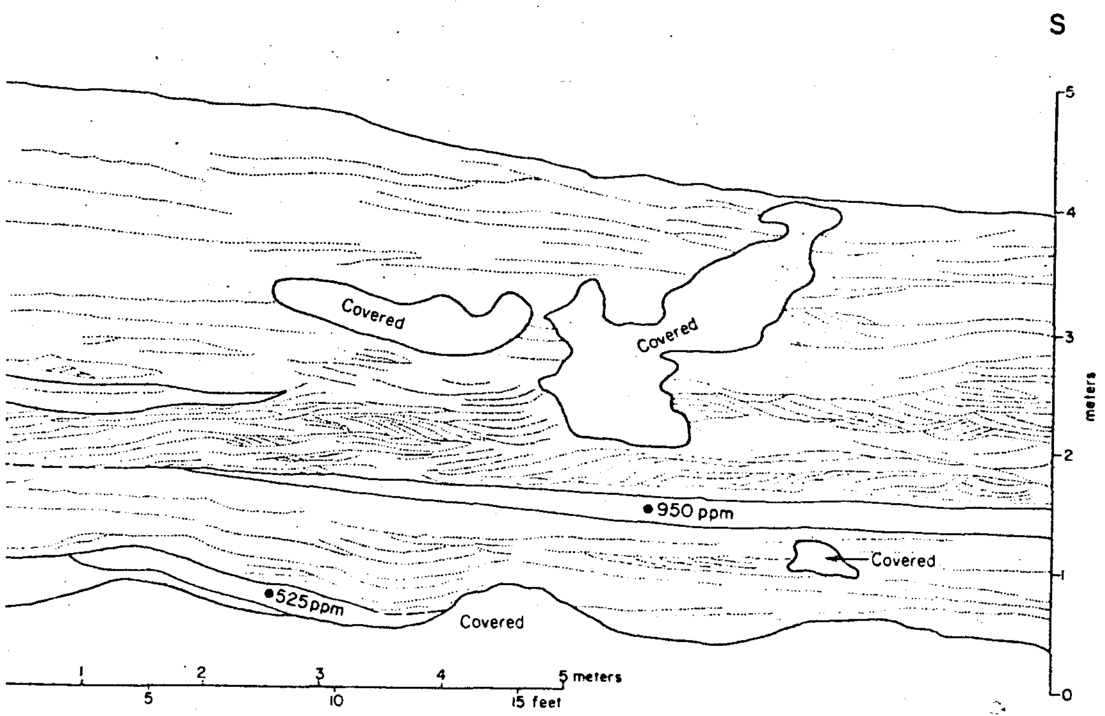
FACIES DEVELOPED AT LOW STAND

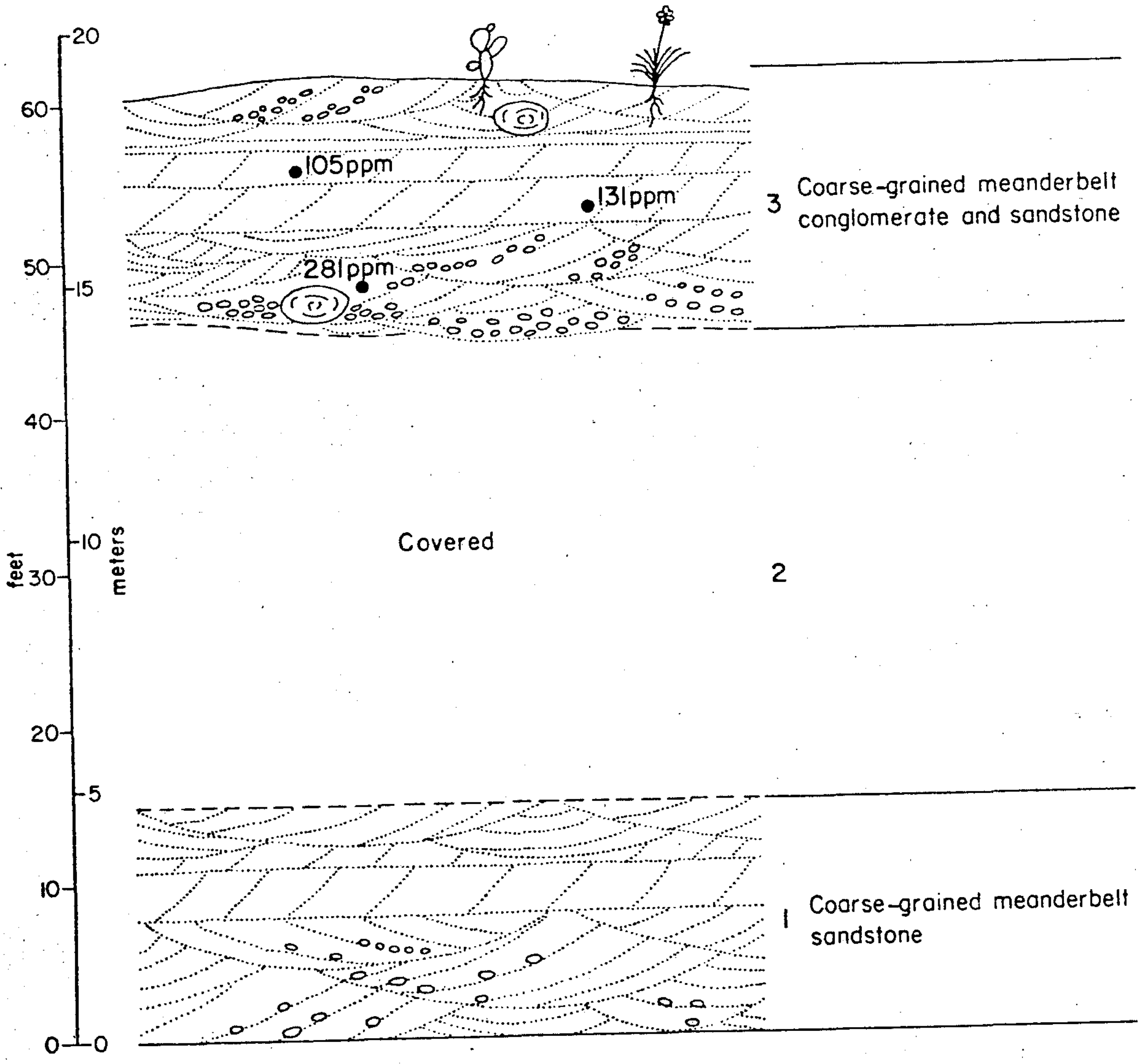


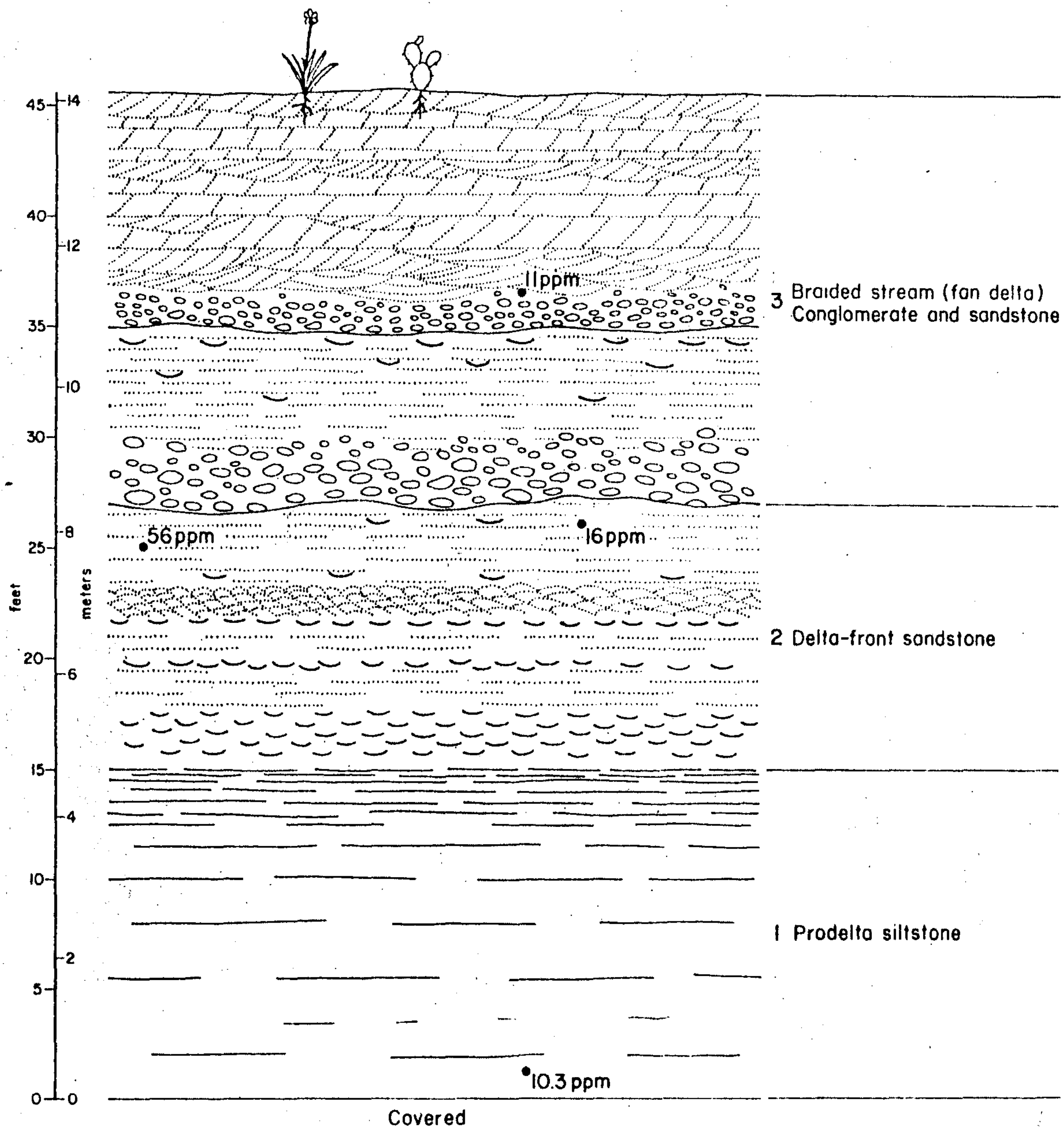


Covered
Meanderbelt sandstone
4
2000ppm
240ppm
Delta-plain mudstone
and siltstone
3
Crevasse channel sandstone
Distributary channel
sandstone
2
475ppm
Delta-front sandstone
1
Covered
feet
meters
55
50
45
40
35
30
25
20
15
10
5
0
18
15
12
9
6
3
0

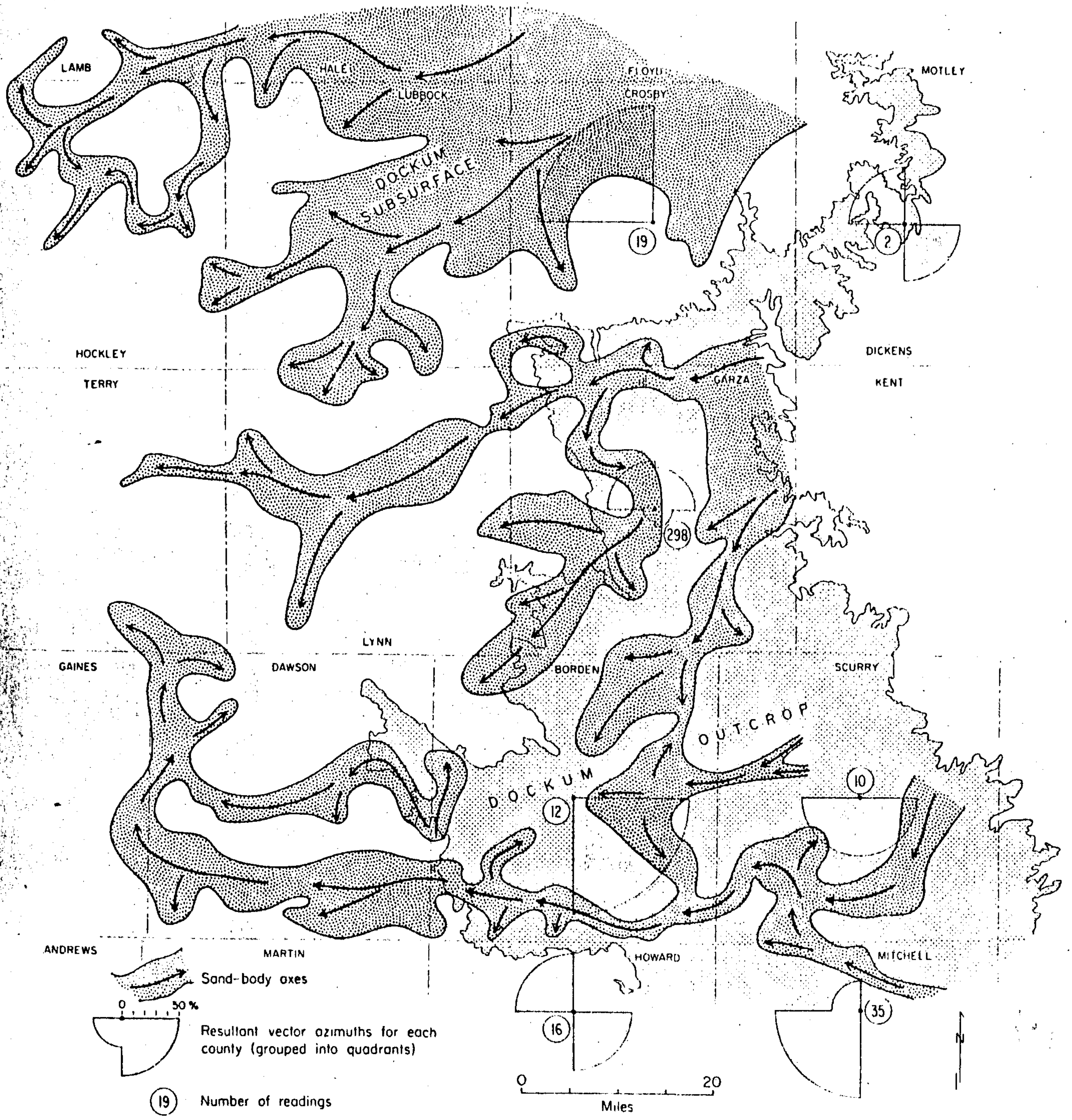

10
30
8
25
20
6
feet
meters
15
4
10
2
5
0
0
362ppm
Covered
4 Crevasse splay conglomerate and sandstone
3 Flood plain and Lacustrine ? Mudstone and siltstone
2 Crevasse channel fill Conglomerate, sandstone, siltstone, and mudstone
1 Flood plain, mudstone, and siltstone

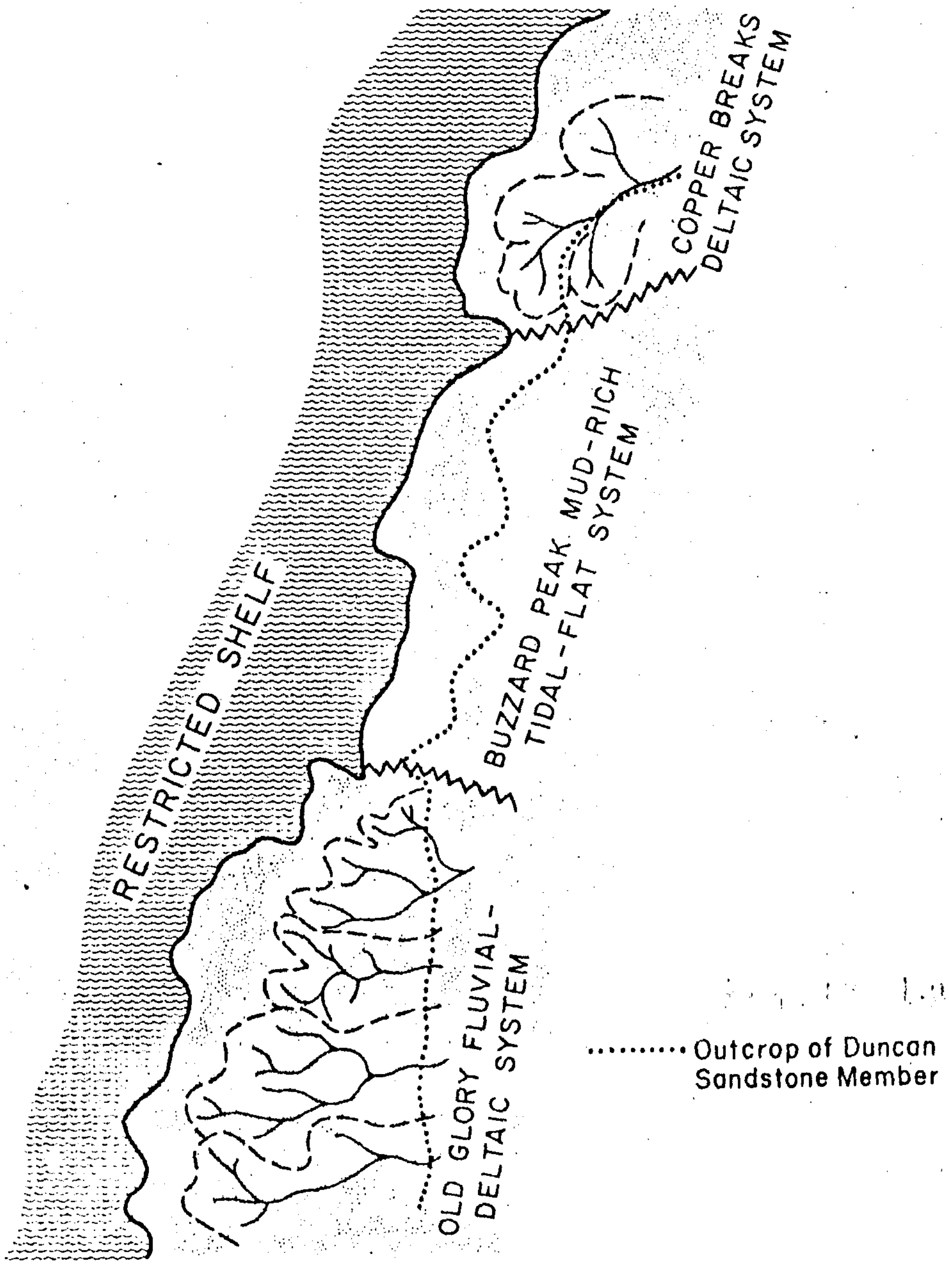

S
Covered
Covered
950 ppm
Covered
525 ppm
Covered
0
1
2
3
4
5
meters
1
2
3
4
5 meters
5
10
15 feet

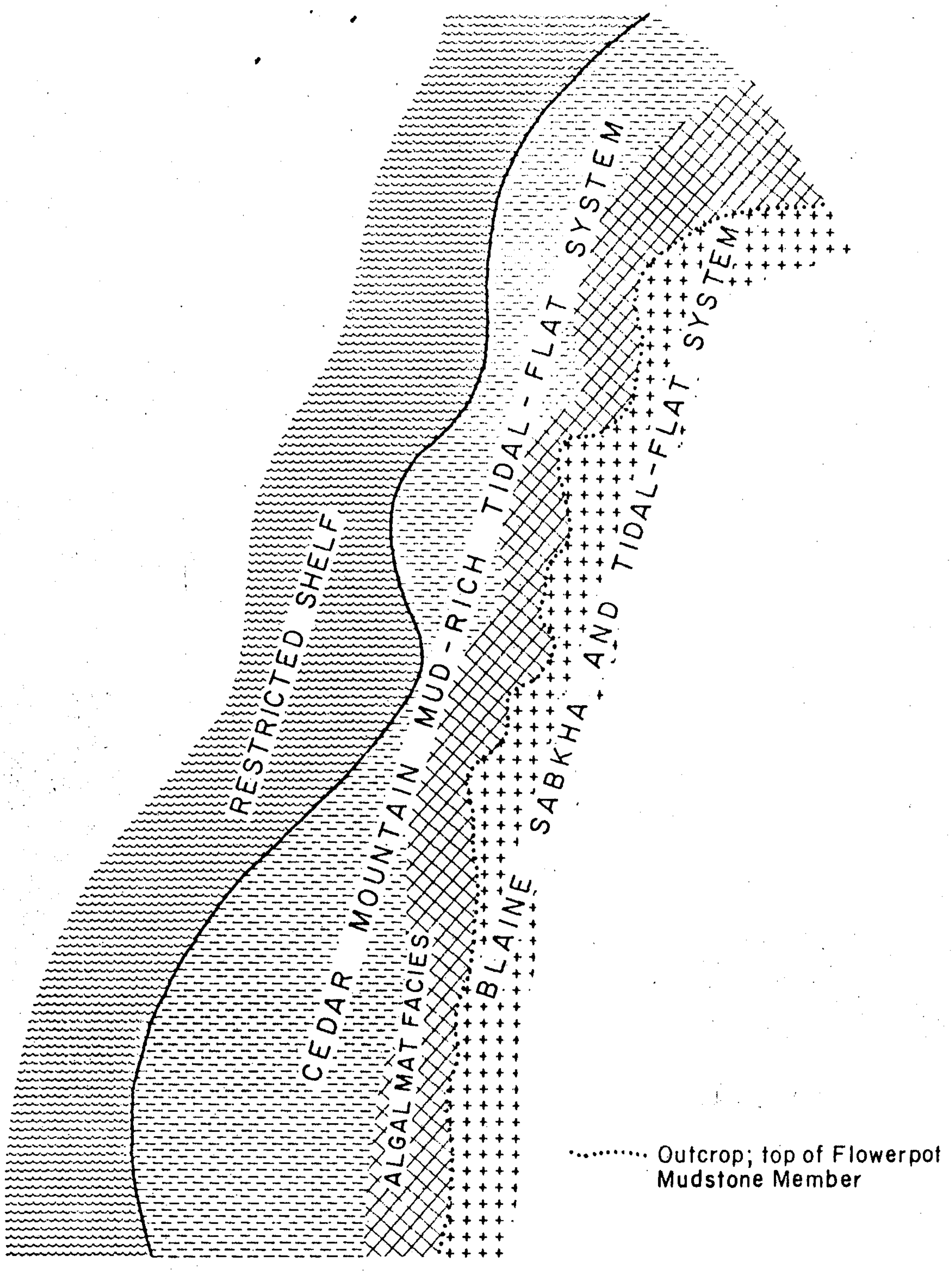

feet
meters
0
10
20
30
40
50
60
0
5
10
15
20
105ppm
131ppm
281ppm
3 Coarse-grained meanderbelt conglomerate and sandstone
Covered
2
1 Coarse-grained meanderbelt sandstone


45
40
35
30
25
20
15
10
5
0
feet
14
12
10
8
6
4
2
0
meters
11ppm
3 Braided stream (fan delta)
Conglomerate and sandstone
56ppm
16ppm
2 Delta-front sandstone
1 Prodelta siltstone
10.3 ppm
Covered

SUBSURFACE SANDSTONE-DISTRIBUTION PATTERN AND OUTCROP DIRECTIONAL TRENDS




RESTRICTED SHELF
COPPER BREAKS DELTAIC SYSTEM
BUZZARD PEAK MUD-RICH TIDAL-FLAT SYSTEM
OLD GLORY FLUVIAL-DELTAIC SYSTEM
Outcrop of Duncan Sandstone Member



RESTRICTED SHELF
CEDAR MOUNTAIN MUD-RICH TIDAL-FLAT SYSTEM
ALGAL MAT FACIES
BLAINE SABKHA AND TIDAL-FLAT SYSTEM
Outcrop; top of Flowerpot Mudstone Member

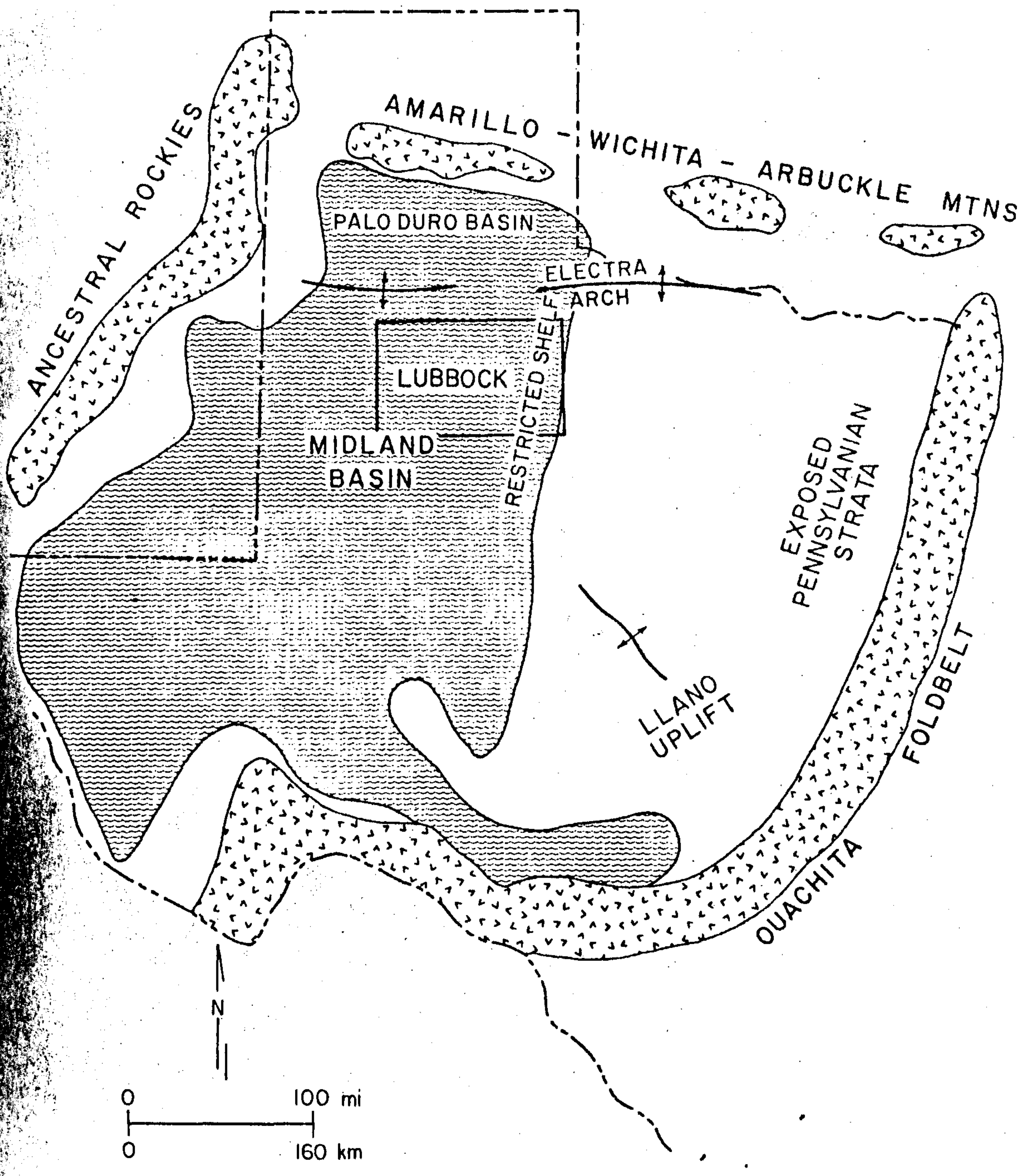
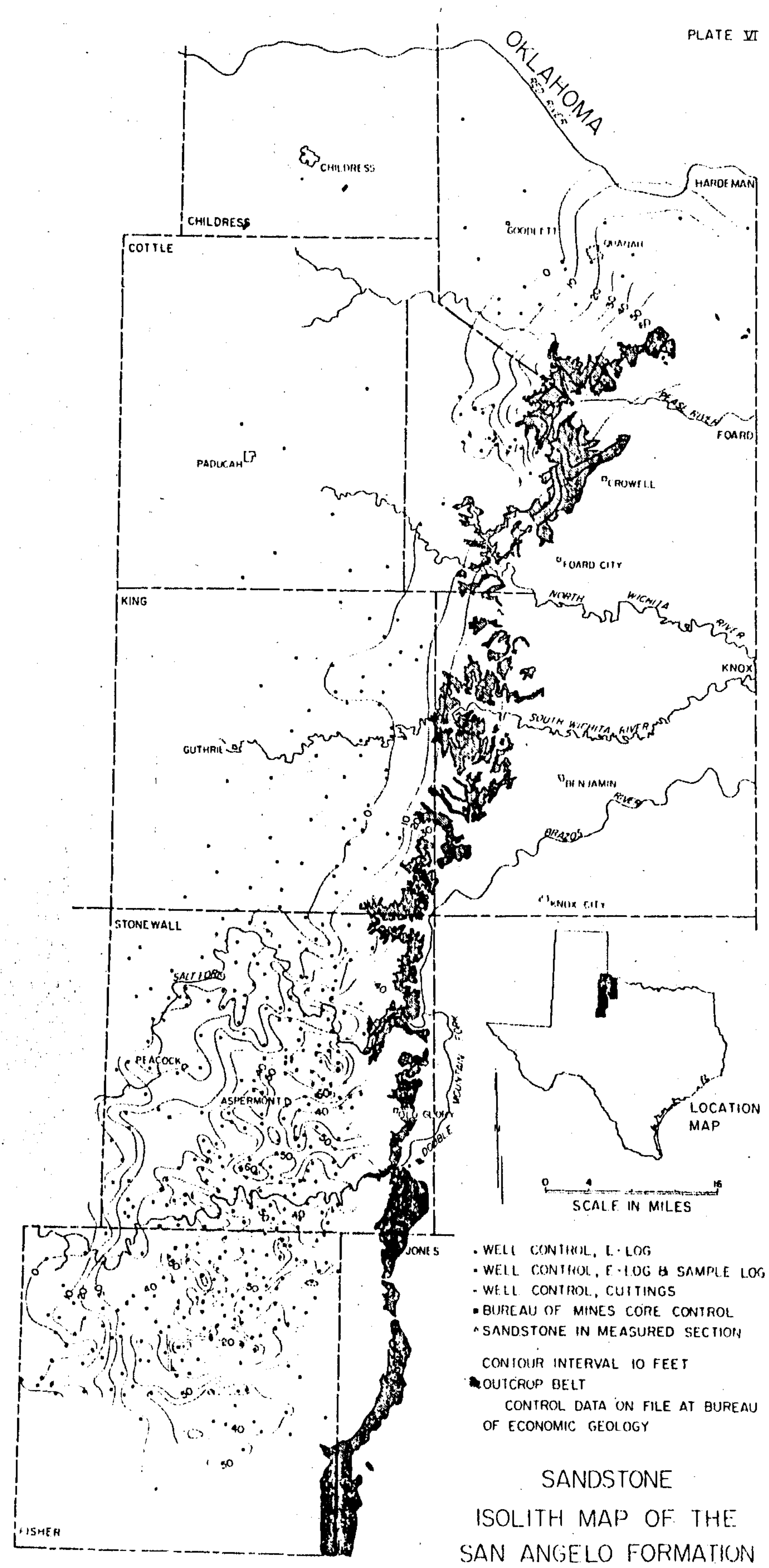
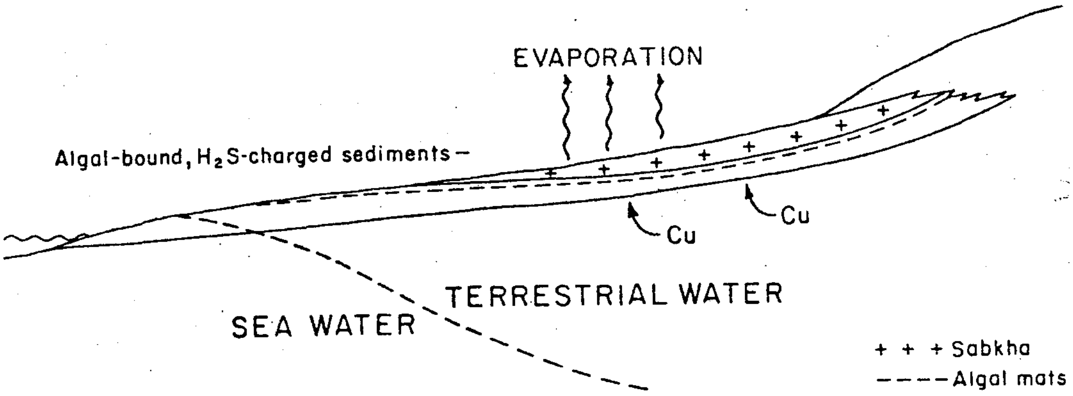
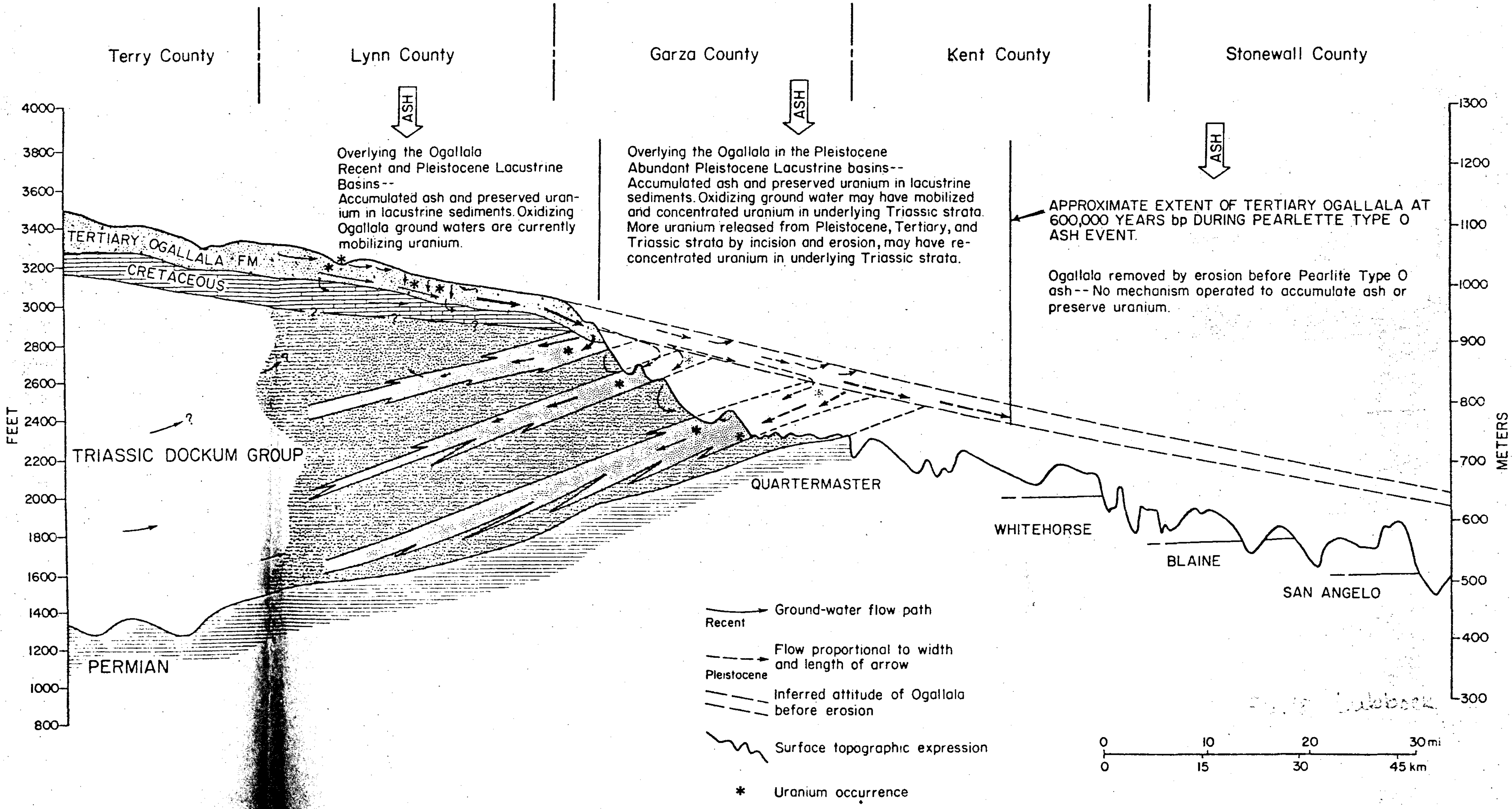

AMARILLO - WICHITA - ARBUCKLE MTNS
ANCESTRAL ROCKIES
PALO DURO BASIN
ELECTRA ARCH
LUBBOCK
RESTRICTED SHELF
MIDLAND BASIN
EXPOSED PENNSYLVANIAN STRATA
LLANO UPLIFT
OUACHITA FOLDBELT
N
0
100 mi
0
160 km

PLATE VI



SANDSTONE
ISOLITH MAP OF THE
SAN ANGELO FORMATION


EVAPORATION
Algal-bound, H_2S-charged sediments
Cu
Cu
TERRESTRIAL WATER
SEA WATER
+ + + Sabkha
- - - - Algal mats



Overlying the Ogallala
Recent and Pleistocene Lacustrine Basins--
Accumulated ash and preserved uranium in lacustrine sediments. Oxidizing Ogallala ground waters are currently mobilizing uranium.

Overlying the Ogallala in the Pleistocene
Abundant Pleistocene Lacustrine basins--
Accumulated ash and preserved uranium in lacustrine sediments. Oxidizing ground water may have mobilized and concentrated uranium in underlying Triassic strata. More uranium released from Pleistocene, Tertiary, and Triassic strata by incision and erosion, may have re-concentrated uranium in underlying Triassic strata.

APPROXIMATE EXTENT OF TERTIARY OGALLALA AT 600,000 YEARS bp DURING PEARLETTE TYPE O ASH EVENT.

Ogallala removed by erosion before Pearlite Type O ash--No mechanism operated to accumulate ash or preserve uranium.