URANIUM RESOURCE EVALUATION
PALESTINE QUADRANGLE
TEXAS AND LOUISIANA

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FIGURE CAPTIONS

Palestine captions, cont.

Figure 14. Net sand isopach of Upper Catahoula Formation (Galloway, 1977)

Figure 15. Net sand isopach of Lower Catahoula Formation (Galloway, 1977)

Figure 16. Lacustrine sequence in Catahoula Formation illustrating uranium enrichment

Sequence A: Base level of pit sequence of parallel-laminated muds and claystone with some interlaminae of silt; claystone is greenish gray to light gray, waxy, carbonaceous; at contact of sequences A and B pyrite nodules occur

Sequence B: Yellowish gray, slightly micaceous, parallel laminated mudstone with some interlaminae of silt and sand; ripples and desiccation cracks present; scattered ironstone nodules; rare root tracings

Sequence C: Crudely bedded, light gray, slightly micaceous siltstone with mudstone clasts

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ABSTRACT

The uranium resource potential of the Palestine Quadrangle, Texas and Louisiana, was evaluated to a depth of 1500 m (5,000 ft) using criteria established for the National Uranium Resource Evaluation (NURE) program. Data derived from geochemical analyses of surface samples (substrate, soil, and stream sediment) in conjunction with hydrochemical data from water wells were used to evaluate geologic environments as being favorable or unfavorable for the occurrence of uranium deposits. The Palestine Quadrangle lies in the northeastern part of the Texas Gulf Coastal Province; structurally it is located within the southern part of the East Texas Embayment. Rock units, to depths less than 1500 m (5,000 ft), range in age from Early Cretaceous to Recent. Tertiary strata compose approximately 90 percent of the total surface area of the quadrangle. Cretaceous strata are restricted to the subsurface, except over shallow salt domes (Butler, Keechi, and Palestine), where undifferentiated Cretaceous sandstones, mudstones, and marls are exposed. Two favorable environments have been identified in the Palestine Quadrangle: (1) potential deposits of modified Texas roll-type in fluvial channels and associated facies within the Yegua Formation, and (2) potential occurrences along mineralization fronts associated with the Elkhart Graben and Mount Enterprise fault system. Unfavorable environments include: (1) Cretaceous shales and limestones, (2) Tertiary fine-grained marine sequences, (3) Tertiary sandstone units that exhibit favorable host-rock characteristics but fail to show significant syngenetic or epigenetic mineralization, and (4) Quaternary sands and gravels. Unevaluated units include the Woodbine Group (Upper Cretaceous), Jackson Group (Tertiary) and Catahoula Formation (Tertiary). The subsurface interval

of the Jackson Group and Catahoula Formation contains depositional facies that may represent favorable environments; however, the evaluation of these units is inconclusive because of the general lack of shallow subsurface control and core material. The Woodbine Group, restricted to the subsurface except for a small exposure over Palestine Dome, occurs above 1500 m (5,000 ft) in the northwest quarter of the quadrangle. The unit exhibits favorable host-rock characteristics, but the paucity of gamma logs and cores as well as the lack of Hydrogeochemical and Stream-Sediment Reconnaissance (HSSR) data make evaluation of the unit difficult.

INTRODUCTION

PURPOSE AND SCOPE

The Palestine Quadrangle, Texas and Louisiana, was evaluated to identify geologic environments within mappable rock units and to delineate areas favorable for the occurrence of uranium deposits. The evaluation encompassed surface exposures and subsurface units to a depth of 1500 m (5,000 ft). Geologic environments are identified on the basis of their similarity to the classification of uranium deposits established by Mickle and Mathews (1978) and then categorized as favorable, unfavorable, or unevaluated.

Evaluation of the Palestine Quadrangle was conducted by the Bureau of Economic Geology under subcontract to Bendix Field Engineering Corporation for the National Uranium Resource Evaluation program managed by the Grand Junction Office of the U.S. Department of Energy. Work on Phase I was initiated April 1, 1978, and completed September 30, 1978; Phase II began October 1, 1978, and was completed March 31, 1980.

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PROCEDURES

Data derived from geochemical analyses of surface samples (950 substrate, 404 soil, 120 stream sediment, and 51 water) in conjunction with the Hydrogeochemical and Stream-Sediment Reconnaissance Survey (Union Carbide, 1979) were used to evaluate geologic environments as being favorable for the occurrence of uranium deposits (Pls. 1, 4, 5 and 6). Plots of the ground-water geochemical analyses showed elevated uranium concentration values clustered in a few of the geologic formations, indicating areas favorable for uranium mobilization and mineralization in the Palestine Quadrangle (Pl. 4). Similar plots of stream-sediment geochemical analyses produced a random pattern of uniformly low uranium concentration values, and therefore did not indicate favorable areas (Indelicato, 1980). A preliminary aerial radiometric report for the Palestine Quadrangle (Texas Instruments, Incorporated, 1979) was available February 7, 1980. Time did not allow for detailed interpretation or field checking of radioactive anomalies; however, generalized conclusions derived from the report are included. Forty-nine anomalies were recorded, thirty-five of which were categorized as first priority. First-priority anomalies are defined as "those showing simultaneous statistically valid equivalent uranium, equivalent uranium/equivalent thorium, and equivalent potassium anomalies" (Texas Instruments, Incorporated, 1979).

Samples of rock, soil, stream sediment, and water were collected and submitted for geochemical analyses to the Mineral Studies Laboratory of the Bureau of Economic Geology under the supervision of Dr. Clara Ho (Pls. 5 and 6). Detailed geologic descriptions were made for each outcrop, including mineralogy, lithologies, and sedimentary structures. A Geometrics Model GR-101A portable scintillometer was used to measure gamma-ray counts for each sample and the background for each outcrop.

Subsurface data for Tertiary units in the Palestine Quadrangle were derived largely from earlier detailed studies of the Wilcox (Fisher and McGowen, 1967, 1969; Kaiser, 1974); Carrizo (Fisher, 1972); Queen City (Guevara and Garcia, 1972); Sparta, Cook Mountain (Ricoy, 1976); Yegua (Fisher, 1969; Kaiser and others, in press); Jackson (Fisher, and others, 1970; Kaiser, 1974) and the Catahoula (Galloway, 1977; Galloway and Kaiser, 1979). These investigations include regional cross sections, identification of principal depositional facies, and the construction of net sand or percent sand maps.

Additional cross sections were constructed specifically for the Palestine Quadrangle (Pls. 10-16; Appendix D). These sections, in conjunction with data derived from off-section wells, were used to construct a structure map on top of the Wilcox Group (Pl. 18). The Hydrogeochemical and Stream-Sediment Reconnaissance Survey was used largely to identify environments favorable for uranium enrichment in the subsurface. Gamma-ray logs and cores are unavailable for most wells in this quadrangle.

A preliminary interpretation of the hydrogeochemical and stream-sediment data was performed by Bendix Field Engineering Corporation Data Integration Group and reported by Indelicato (1980). Methods used include frequency distributions and cumulative probability curves and the multivariant statistical techniques of principal-component analysis and correlation coefficients. The results were used in the final interpretation and integration of Hydrogeochemical and Stream-Sediment Reconnaissance data in the quadrangle evaluation.

Laboratory procedures used by the Bureau of Economic Geology Mineral Studies Lab in geochemical analyses of rocks, stream-sediment, and soil samples follow: (1) Rocks (2.5 kg) were first crushed and ground to less than 30-mesh size. A small portion (about 250 g) of the crushed sample was pulverized to less than 100-mesh for all subsequent chemical analyses. (2) Stream-sediment and soil samples were air-dried and pulverized slightly using a mortar and pestle. The less than 100-mesh fine fraction was separated by sieving through a polyethylene nylon sieve.

The following analytical procedures were used to determine total uranium concentrations:

(1) Total U_3O_8 in rocks -- Sample was fused with Li-tetraborate at 1050°C for 20 minutes. The flux was dissolved in 10 percent distilled HNO_3. An aliquot of the

solution was extracted with trioctylphosphine oxide (TOPO) dissolved in cyclohexane. Total uranium was complexed by TOPO and partitioned into the cyclohexane layer. A small aliquot of the latter was pipetted onto a NaF + KF (98:2) pellet. After fusing the pellet over a rotating multiple Fisher's burner, U_3O_8 fluorescence was measured on a Jarrell-Ash fluorometer (Ho and Dupre, 1980).

(2) Total U_3O_8 in stream sediments and soils -- Sample was digested with 50 percent distilled HNO_3 at 140°C on a Technicon BD-40 heating unit for 2 hours. The sample was then diluted with distilled water to make a final HNO_3 concentration of about 10 percent. U_3O_8 was then extracted in the same manner as that described for total U_3O_8.

(3) Total U_3O_8 in water samples -- Appropriate amount of water was evaporated to a 5-ml volume in presence of 10 percent HNO_3. Total uranium was then extracted and measured in exactly the same manner as that described above (Ho and Dupre, 1980).

Multiple-element analyses were accomplished by Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES). The instrument used in the Mineral Studies Laboratory (MSL) was the ARLQA-137 (Applied Research Laboratory) equipped with a minicomputer for data storage and processing. The instrument has the capability of analyzing 30 elements (Na, K, Mg, Ca, Al, Fe, Ti, Co, Cr, Cu, Mn, Ni, V, Zn, As, Cd, Mo, Pb, Sb, Se, Sn, Li, Be, Sr, Ba, Zr, U, Th, B, and P) simultaneously in less than 3 minutes' time per sample.

The sample was first digested with a mixture of concentrated HNO_3 + H_2SO_4 at 150°C followed by further dissolution with HCl. Supernatant was separated on centrifuge. The residue was decomposed with HNO_3 + HF followed by dissolution with a HNO_3 + HCl mixture. The supernatant and dissolved residue were combined and analyzed by ICP-AES.

GEOLOGIC SETTING

The Palestine 1° by 2° Quadrangle, an area of 20,000 km^2, is located between lat 31°00'00"N. and 32°00'00"N. and long 94°00'00"N. and 96°00'00"W. (Fig. 1). Physiographically the quadrangle lies within the northeastern part of the Texas Gulf Coastal Plain Province. Rock units to depths less than 1500 m (5,000 ft) range in age from Early Cretaceous to Recent (Fig. 2, Pl. 9).

Structurally, the Palestine Quadrangle lies within the southern part of the East Texas Embayment. The western and northern limits of the embayment are the Mexia-Talco fault system; the eastern boundary is the Sabine Uplift; and the southern margin is the Angelina-Caldwell Flexure (Fig. 3). There is a general basinward dip of sediments in the basin from the Mexia-Talco fault system on the north and west and from the Sabine Uplift on the east. Structural elements within the southern part of the embayment include the Elkhart Graben - Mount Enterprise fault system and salt domes restricted to the deeper, more central part of the embayment (Fig. 4).

The Elkhart Graben - Mount Enterprise fault system is a zone of complex faulting coincident with a hinge line that runs subparallel to and north of the Angelina-Caldwell Flexure (Nichols and others, 1968). This hinge line marks the southern limits of the East Texas salt dome province (Agagu and others, 1980a).

Gravity and seismic studies suggest that structures within the East Texas Basin are controlled by salt movement rather than major basement elements (Agagu and others, 1980a). Within the central parts of the basin, salt mobilization was initiated with the first major influx of terrigenous clastics during the Late Jurassic-Early Cretaceous (Shuler and Travis Peak Formations). Salt was squeezed from areas of major sedimentation creating salt ridges in the intervening areas. Salt movement around the margins of the basin preceded Shuler - Travis Peak deposition (Agagu and others, 1980a). The initial salt ridges were the precursors of salt diapirs and associated faulting in the basin.

Approximately 10,000 m (33,400 ft) of Mesozoic and Cenozoic sediment have been penetrated in the central part of the East Texas Embayment (Agagu and others, 1980b). These deposits overlie metamorphosed Paleozoic sediments of the Ouachita system, which probably represents a continuation of the Appalachian foldbelt (Lyons, 1957; Wood and Walper, 1974; McGookey, 1975).

The Glen Rose Formation (Early Cretaceous) is the oldest unit to occur within 1500 m (5,000 ft) of the surface in the Palestine Quadrangle. The Early Cretaceous units underlying the quadrangle are composed of marine shales and carbonates (Granata, 1963; Fig. 2). Late Cretaceous sedimentation was initiated by an uplift of marginal areas of the East Texas Basin concomitant with Cenomanian lowering of sea level. The Woodbine Group, composed of sandstones and mudstones, marks the peak of clastic influx, and the Eagle Ford Formation, consisting predominantly of shales, marks the waning phase (Agagu and others, 1980b). Woodbine - Eagle Ford sedimentation was followed by a dominantly marine sequence composed of more than 1000 m (3,000 ft) of shelf muds and carbonates (Fig. 2). Minor influxes of terrigenous clastics are documented but are restricted to the northern part and flanks of the basin. The Tertiary deposits of the basin include a complex sequence of superposed fluvial, deltaic, marginal-strandplain (including lagoonal) deposits with minor occurrences of shelf deposits.

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

Favorable environments in the Palestine Quadrangle include (1) potential deposits of modified Texas roll-type (Subclass 242, Austin and D'Andrea, 1978), epigenetic occurrences associated with local concentrations of carbonaceous debris in crevasse-splay deposits coincident with an alteration front (Galloway, 1977, and Galloway and Kaiser, 1979), and (2) occurrences along mineralization fronts associated with faulting (Subclass 242, Austin and D'Andrea, 1978) (Pl. 1).

FAVORABLE AREA A -- YEGUA FORMATION

The subsurface interval of the Yegua Formation is considered a favorable area because characteristics of the fluvio-deltaic complex fulfill criteria established for Sandstone Subclass 242 -- Texas roll-type deposits (Austin and D'Andrea, 1978).

Surface exposures of the Yegua Formation include only the updip fluvial elements of the deltaic complex. The facies continues into the shallow subsurface and is composed of channel-fill sands and mud-rich interfluvial basin deposits. Dip-oriented sands form belts, 48 km (30 mi) wide and over 60 m (200 ft) thick (Fisher and others, 1970), which provide excellent conduits for ground-water flow (Pl. 17). The Yegua fluvial sequence grades downdip into a delta-plain complex composed of elongate, distributary channel-fill sands, interdistributary muds, and abundant plant debris and lignite. Thin beds of volcanic ash are reported in some areas (Sellards and others, 1932). Cross sections B-B' and F-F' (Pls. 12 and 16) show the subsurface delta-plain sequence of interbedded sands and muds and thicker distributary sand channels. The Yegua Formation extends from the surface to a depth of 475 m (1,568 ft) in the southern part of the quadrangle and attains a maximum thickness of 364 m (1,200 ft).

The presence of uranium enrichment within the Yegua is suggested by geochemical data from surface samples of the unit in conjunction with preliminary data from the aerial radiometric survey, which delineates nine first-priority anomalies associated with the Yegua Formation (Fig. 5). Total uranium concentrations in channel sands in outcrop are characteristically low; however, overbank muds and interdistributary deposits show higher concentrations, generally coincident with carbonized plant debris and lignites. Maximum concentrations of U_3O_8 are 52.5 ppm in carbonaceous overbank muds of the Yegua Formation (Fig. 5). The presence of U_3O_8, in the above concentrations, in mud-rich sequences probably suggests that syngenetic mineralization occurred within these facies. The extremely low levels of U_3O_8 associated with sands suggest that any available uranium resulting from diagenesis and alteration of volcanic ash was leached and mobilized downdip by ground-water flow systems. Oxidizing ground waters coming in contact with reducing environments of organic-rich, crevasse-splay sands could produce mineralization fronts resulting in deposition of uranium. Concentrations of carbonized plant debris and lignite would serve as reductants. Crevasse splays interfinger with highly carbonaceous and lignitic muds that provide permeability barriers and geochemical gradients favorable for precipitation of uranium. The model for this kind of uranium mineralization is described by Galloway and Kaiser (1979) for a Catahoula uranium deposit in Fayette-Washington Counties (Fig. 6). The deposit occurs along an alteration front within a crevasse-splay sand body downdip from a fluvial channel. Uranium mineralization of ore grade appears to occur in pods along an alteration front in areas adjacent to high concentrations of organic material. The deposit is compared to "trash pile" accumulations of the Colorado Plateau; however, in this case, the deposit is coincident with a well-defined mineralization front.

Of a total of 155 ground-water samples collected from the Yegua Formation, 15 samples contain uranium concentrations greater than the 0.44 ppb mean. These samples also have higher than average uranium-conductivity ratio values. The elevated geochemical values are clustered in three anomalous areas (Pl. 4) that delineate possible uranium occurrences.

The first area is located in eastern Houston County (Pl. 4) and contains five samples ranging in concentration from ≥ 1.70 to ≥ 20 but < 50 ppb. The depth of the producing horizons ranges from 4 m (13 ft) to 74 m (244 ft), with deeper wells containing the lower geochemical values. The second anomalous area, in southeastern Houston and northwestern Trinity Counties, contains five samples from the Yegua Formation, ranging in uranium concentration from ≥ 0.50 to ≥ 6 but < 10 ppb. The depth range for these samples is 8 m (26 ft) to 77 m (254 ft), with higher geochemical values occurring predominantly in the shallower wells. The third area is a cluster of four samples in central Angelina County that range in uranium concentration from ≥ 0.80 to ≥ 3.50 but < 6.00 ppb. Samples from this area range in depth from 6 m (20 ft) to 31 m (102 ft); however, there does not appear to be a correlation between depth and geochemical values. All three anomalous areas have moderate uranium/conductivity ratios, which suggest that the samples are slightly saline in character. The elevated uranium concentrations are believed to be a function of an increase in the total dissolved solids content (Indelicato, 1980). However, tuffaceous material is indigenous to the Yegua Formation, and where favorable geohydrologic environments exist, minor accumulations of uranium may occur. Downdip of the anomalous areas, the uranium concentrations and the uranium/conductivity ratios are observed to diminish. Here the uranium concentration in the ground water appears to be inversely related to the total dissolved solids content. It should be noted that as the salinity of ground water increases, the concentration of ionic species capable of interfering with uranium analyses also increases. Thus uranium concentration values and uranium/conductivity values of brines are not reliable. However, available Texas Department of Water Resources data (Peckham and others, 1963; Tarver, 1966, 1968; Anders, 1967; and Guyton and Associates, 1970) indicate that the ground water of the Yegua Formation is fresh to slightly saline in the outcrop area and a few miles in the downdip direction. In areas directly downdip of the anomalies, uranium could be precipitating in suitable geologic environments rather than being flushed downdip into the brines. Onlap of tuffaceous deposits of the Jackson Group and Catahoula Formation over the Yegua Formation may have served as a source for downward-percolating, enriched ground waters.

A core 10.3 m (34 ft) in length was taken from the Yegua Formation in Houston County (Fig. 5). The core penetrated a sequence of interchannel laminated muds and silts with thin interbeds of sand. One lignite bed approximately 2 m (6 ft) thick was encountered. The core was sampled selectively to determine total uranium, particularly in the lignite and highly carbonaceous units. Concentrations ranged from 1.5 to 9.8 ppm. Total uranium in the carbonaceous zones and lignite bed ranged from 4.3 to 7.3 ppm, respectively. The interface between the lignite and overlying unconsolidated sand unit was not sampled because the material was lost in coring. The highest concentration (9.8 ppm) occurred in a burrowed sequence of interlaminated mudstone and siltstone at a depth of approximately 10 m (33.3 ft). The uppermost 60 cm (2 ft) of core penetrated the B and C soil horizons. The A horizon, a very loose sand, could not be recovered. Total U_3O_8 concentrations in the soil range from 4.5 to 6.3 ppm.

The highest concentration occurred at a depth of approximately 43 cm (1.5 ft) in the C or bedrock horizon. The median concentration occurred in an oxidized ironstone horizon at a depth of approximately 20 cm (0.7 ft).

Approximately one half of the Palestine Quadrangle overlying the subsurface Yegua Formation section is privately owned. The remaining half falls within the Davy Crockett and Angelina National Forests. For exact boundaries, refer to Plate 21.

FAVORABLE AREA B -- ELKHART GRABEN - MOUNT ENTERPRISE FAULT SYSTEM

The Elkhart Graben - Mount Enterprise fault system is considered a favorable area for uranium enrichment because characteristics of the system and faulted rock units within the subsurface fulfill criteria established for Subclass 242 -- Texas roll-type deposits (Austin and D'Andrea, 1978). The preliminary aerial radiometric report for the Palestine Quadrangle (Texas Instruments, Incorporated, 1979) indicated five first-priority anomalies aligned northeast-southwest along the Elkhart Graben and four first-priority anomalies showing a similar alignment, along the Mount Enterprise fault system in the northeastern part of the quadrangle (Fig. 7).

Evidence of uranium mineralization related to faulting in the Palestine Quadrangle is suggested from geochemical analyses of rock samples collected from the Queen City Formation 10 km (6 mi) south of Jacksonville, Cherokee County, on Highway 69. Laminated, highly glauconitic mudstones of the Weches Formation are faulted against interlaminated mudstones and siltstones and thinly-bedded, cross-stratified sands of the Queen City Formation. Uranium concentrations attain a maximum value of 11.8 ppm within thin-bedded, cross-stratified sands found in approximately the lower 2 m (6 ft) of the outcrop. Concentrations decrease rapidly upward in the interlaminated mudstones and siltstones and average 3 ppm. Scintillometer counts also increase from 52 counts per second to 120 counts per second within the lower sands, but decrease rapidly to background levels in areas away from the fault zone. Typical low U_3O_8 concentrations in substrate samples collected from the Queen City Formation at other sample locations suggest that the low-level enrichment recorded south of Jacksonville is structurally rather than facies related. More significant concentrations may occur within the subsurface coincident with the fault.

Faults can produce vertical flow paths that cross less permeable facies and allow upward migration of uranium enriched fluids or extrinsic reductants in the form of sulfide rich fluids or H_2S gas associated with hydrocarbon accumulations. Examples of uranium deposits coincident with faulting occur in the Catahoula Formation (Galloway, 1977) and Jackson Group (Fisher and others, 1970) in South Texas.

All of the land overlying the subsurface section of the Elkhart Graben - Mount Enterprise fault system is privately owned.

The Elkhart Graben - Mount Enterprise fault system (Figs. 4 and 7) and other structural features such as salt domes have not been adequately evaluated in the Palestine Quadrangle as potential areas for uranium mineralization, especially in the subsurface. Surface exposures are generally limited and of poor quality, and gamma-ray well logs are not readily available to aid in recognizing radioactive anomalies within the subsurface. A reconnaissance survey of the fault zone and Keechi, Palestine, and Butler salt domes yielded scintillation counts of 20 to 40 counts per second with no significant increases near structural features.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

Unfavorable environments within the Palestine Quadrangle include (1) Cretaceous shales and limestones (Classes 130 and 230, Jones, 1978); (2) Tertiary fine-grained marine deposits (Class 130, Jones, 1978); (3) Tertiary sandstone units that exhibit favorable host-rock characteristics but fail to show significant syngenetic or epigenetic uranium mineralization; and (4) sands and gravels of Quaternary age.

CRETACEOUS SHALES AND LIMESTONES

Lower and Upper Cretaceous marine shales and carbonates (Fig. 2) are restricted to the subsurface, except over Keechi, Butler, and Palestine salt domes, where undifferentiated Cretaceous sandstones, mudstones, and marls have been mapped (Powers, 1920; Lahee, 1933; Hightower, 1958; Ebanks, 1965; Barnes, 1967). In the subsurface, Cretaceous units occur above 1500 m (5,000 ft) in the northern half of the quadrangle and on the southwestern flank of the Sabine Uplift (Pls. 11 and 15). Marine shales (Class 130, Jones, 1978) probably experienced some syngenetic mineralization; however, occurrences of this type would represent very low grade resources. The depth of occurrence in the subsurface would eliminate these units from further consideration. Cretaceous limestones (Class 230, Jones, 1978) represent environments that were not conducive to uranium mineralization.

TERTIARY DEPOSITS

Unfavorable environments of Tertiary age include fine-grained marine deposits of the Claiborne Group (Reklaw Formation, Weches Formation, and Cook Mountain Formation) and fluvial-deltaic sequences that exhibit excellent host-rock characteristics but fail to show significant syngenetic or epigenetic uranium enrichment (Carrizo Formation - Wilcox Group, Queen City Formation, and Sparta Sand) (Fig. 2).

Marine sequences of the Claiborne Group are dominated by fine-grained shelf deposits composed of glauconitic mudstones exhibiting abundant whole and fragmented shell material. Geochemical data show no evidence of uranium mineralization in these geologic units. An aerial radiometric anomaly was reported in the Weches Formation just north of San Augustine (Atomic Energy Commission, Preliminary Reconnaissance Report, File No. 2487) (Pl. 2). The area was relocated in the field and sampled extensively. Scintillometer readings are slightly elevated above background; however, U_3O_8 concentrations ranged from 2.5 to 4.4 ppm. The anomaly may be related to the presence of locally occurring ironstone ledges within the Weches Formation.

Those geologic units exhibiting favorable host-rock characteristics but no significant uranium enrichment include the fluvial-deltaic complexes of the Carrizo Formation - Wilcox Group, Queen City Formation, and Sparta Sand (Figs. 8, 9, and 10). Component facies of these units have been described and mapped by Fisher and McGowen (1967, 1969), Fisher (1972), Guevara and Garcia (1972), and Ricoy (1976). Depositional facies include fluvial and distributary channel sands, crevasse splays, and highly organic interdistributary muds and lignites--all analogous to environments considered favorable in the Yegua Formation. Wilbert and Templain (1978) conducted a preliminary regional evaluation of uranium favorability of the Wilcox and Claiborne Groups in Texas and concluded that no mineralization had occurred.

Criteria used to determine unfavorability of geologic environments in this study relied heavily upon hydrogeochemical data from the Hydrogeochemical and Stream-Sediment Reconnaissance Survey. The multivariant statistical analysis performed by the Bendix Field Engineering Corporation Data Integration Group delineates potentially favorable areas on the basis of elevated, clustered uranium concentrations and uranium conductivity values of stream-sediment and ground-water samples (Indelicato, 1980). There are no elevated, clustered values for the Carrizo Formation - Wilcox Group, Queen City Formation, or Sparta Sand. Most values for these geologic units are < 0.30 ppb uranium. However, there are two isolated ground-water samples collected in the area of the Wilcox Group outcrop that contain uranium concentrations of > 10 but < 20 ppb and > 3.5 but < 6.0 ppb. The values are at least a magnitude greater than those values calculated for samples from water wells in the vicinity.

Geochemical analyses of substrate samples indicate low uranium concentrations associated with surface exposures of the Carrizo Formation - Wilcox Group, Queen City Formation, and Sparta Sand. The absence of intrinsic volcanic detritus was probably the main factor contributing to the absence of uranium enrichment in these units. However, volcanic-rich clastics of the Yegua Formation, Jackson Group, and Catahoula Formation probably overlapped the Wilcox and Claiborne Groups prior to Pleistocene time, thus providing a source for epigenetic mineralization by uranium enriched ground waters. The efficiency of this proposed enrichment process would have been hindered by a humid paleoclimate (Fisher and others, 1970; Galloway, 1977). Studies of Modern shallow aquifers in Jasper and Newton Counties indicate that approximately one-third to one-half of the potential recharge is rejected (Wesselman, 1967). Dilution of the uranium cycle by recharge rejection concomitant with continued flushing would have placed extreme limitations on the potential for epigenetic enrichment. In addition, erosion of the Yegua, Jackson, and Catahoula deposits during Pleistocene sea-level changes removed these possible sources for uranium.

QUATERNARY DEPOSITS

Sands and gravels associated with Recent alluvial and Pleistocene terrace deposits show little potential for uranium enrichment. Stream-sediment analyses from the Hydrogeochemical and Stream-Sediment Reconnaissance Survey and this study indicate low uranium concentration values that range from 0.0 to 4.10 ppm.

UNEVALUATED ENVIRONMENTS

Unevaluated units of the Palestine Quadrangle include the Woodbine Group (Upper Cretaceous), Jackson Group (Tertiary), and Catahoula Formation (Tertiary) (Fig. 2). The subsurface interval of the Jackson Group and Catahoula Formation contains depositional environments that exhibit characteristics favorable for uranium enrichment; however, the evaluation of these units is inconclusive because of the general lack of shallow subsurface control and core material.

WOODBINE GROUP

The Woodbine Group has the greatest uranium resource potential of all the Upper Cretaceous units; however, it remains largely unevaluated. The formation is restricted to the subsurface except for a small exposure over Palestine Dome (Hightower, 1958) (Pl. 19). It occurs above 1500 m (5,000 ft) in the northwest quarter of the quadrangle, attains a maximum thickness in the north in synclinal areas adjacent to salt domes, and is thinnest at the pinch-out in the east along the Sabine Uplift. There is no hydrogeochemical data available for the Woodbine Group.

Four criteria favorable for uranium mineralization are present in the Woodbine Group:

(1) An indigenous uranium source, provided by an extensive volcanic ash deposit, exists in the Woodbine (Ross and others, 1928).

(2) A geologic framework providing suitable component facies and lithologies is present within the Woodbine. According to Oliver (1971), the Woodbine Group in the study area is dominated by the coastal-barrier and channel-mouth-bar facies of the high-destructive Freestone Delta System. [Descriptions of representative facies are based on surface exposures and well cuttings (Oliver, 1971).] The coastal-barrier facies strikes east-west and is composed largely of well sorted sands interbedded with dark gray to brown shales with some sands containing marine fossils, glauconite, and finely divided carbonaceous materials. Landward, coastal-barrier sands are interbedded with lagoonal or marsh-type muds; offshore they grade into shelf- and prodelta muds. Areas of maximum sand thickness are perpendicular to major fluvial axes and exhibit well-sorted, low-angle crossbeds, parallel beds, ripple cross-stratification, and horizontal laminations. Channel-mouth-bar facies are limited to an area underlying northeast Anderson County. The sand of this facies is commonly finer than fluvial sands, is well sorted and exhibits ripple marks and scattered glauconitic, carbonaceous and fossil material. The sands of the channel-mouth-bar facies are laterally transitional, with flanking coastal-barrier sands. Thus, the sands of these facies provide a fairly continuous, permeable environment favorable for oxidation, leaching, and transportation of uranium during depositional and early postdepositional times.

(3) A hydrologic flow system and possible favorable geochemical conditions exist in the Woodbine Group. The ground water is confined and under great artesian

pressure. Discharge occurs by the process of upward leakage through confining beds (Peckham, 1963) and fault planes. The ground water is considered to be too mineralized to be useful and no water wells in the Palestine Quadrangle tap Cretaceous water (Guyton and Associates, 1972). Brooks (1960) suggests that compaction of sediments in the East Texas Basin has forced chemically reducing waters from underlying shales through the Woodbine Group. If this is the case, then these waters may have enhanced the mineralization activity of indigenous reducing waters and introduced a reducing environment in previously oxidized areas of the Woodbine sands.

(4) Faults and salt domes cause interruptions and alternating thinning and thickening of Woodbine sediments, creating traps in some areas and conduits in others for ground-water and hydrocarbon movement. The Woodbine Group in the study area is faulted by the Mount Enterprise system and Elkhart Graben -- both areas associated with known hydrocarbon production. Possible occurrences of uranium mineralization may exist wherever the Woodbine overlies or pinches out against salt domes. Known hydrocarbon production occurs in the Woodbine in the vicinity of Brushy Creek, Boggy Creek, and Butler Domes (Pl. 18), where upward migration of H_2S and other reductants could create a favorable environment for mineralization. Such an occurrence is found in the Goliad Sand overlying Palangana Dome of South Texas (The Southern Interstate Nuclear Board, 1969).

JACKSON GROUP

The Jackson Group in East Texas is part of the larger Fayette fluvial-deltaic system described by Fisher and others (1970). East of the Angelina River, the fluvial-deltaic system grades laterally into the Yazoo - Moodys Branch shelf system.

Within the outcrop belt of the Jackson Group, all four (fluvial, delta-plain, delta-front and prodelta) facies of the fluvial-deltaic complex are recognized (Fisher and others, 1970) (Fig. 12). The component facies of the system are approximately coextensive with the four formations of the group: the Whitsett represents the fluvial facies, the Manning represents delta-plain deposits, the Wellborn represents delta-front sequence, and the Caddell represents prodelta muds (Fisher and others, 1970). The Jackson Group ranges in thickness from around 121 to 273 m (400 to 900 ft), attaining maximum thickness in the subsurface.

The fluvial facies is composed of channel-fill sands and interchannel muds. Sands are generally tuffaceous, fine- to medium-grained, and contain lignitic fragments, silicified wood, and angular mud clasts. Typical sedimentary structures include several cross-stratification types: moderate- to large-scale trough and foreset crossbeds, small- to moderate-scale tabular crossbeds, and current-rippled cross-laminae. Interchannel overbank muds are generally gray to dark brown and carbonaceous or lignitic. Altered ash beds occur locally. Dominant sand axes are dip-oriented as illustrated in Figure 11.

Delta-plain deposits of the Jackson Group (Manning Formation) are composed of alternating sands, muds, and lignites. Distributary-channel sands are generally fine-grained and trough cross-stratified. Interdistributary muds are laminated to thin-bedded and carbonaceous. Discontinuous, tabular lignite beds are characteristic of this facies. Crevasse-splay deposits and levee deposits are commonly associated with distributary channel-fill sequences.

The delta-front facies generally represents the Wellborn Formation and consists of two types of sand units: thick-bedded cross-stratified sands and thin-bedded flaggy sands. Fisher and others (1970) interpret the thicker sands to be dominantly shoal-water, channel-mouth bars and the thinner sands to represent the more distal margins of the delta-front sequence. Updip this facies grades into delta-plain deposits and downdip, into marine muds.

The fourth component facies -- prodelta and shelf muds -- comprises the Caddell Formation. This facies consists of thick sequences of dark, laminated glauconitic mudstones. The mudstones contain finely disseminated organic material, shell material, and foraminifers.

East of the Angelina River the fluvial-deltaic system of the Jackson Group grades laterally into the Yazoo - Moodys Branch shelf system, represented by a sequence of predominantly marine muds. Only a small area of this system is located within the Palestine Quadrangle.

Geochemical analyses of rock samples from the Jackson Group indicate that uranium enrichment has occurred within the unit. In general, total uranium concentrations are low in channel sands but show higher concentrations in organic-rich overbank muds and interdistributary deposits (Fig. 12). Maximum concentrations (37.5 ppm) of U_3O_8 occur within the delta-plain facies (Manning Formation) of the Jackson Group. Characteristically low total U_3O_8 concentrations associated with channel sands suggest that any available uranium resulting from argillation of volcanic ash was leached by ground water and migrated downdip by ground-water flow systems. Oxidizing ground waters within the main fluvial channels coming in contact with reducing environments of organic-rich, crevasse-splay sands, could produce mineralization fronts resulting in deposition of uranium. The subsurface interval of the Jackson Group in the Palestine Quadrangle is largely unevaluated because of a lack of shallow subsurface data.

CATAHOULA FORMATION

The Catahoula Formation of northeast Texas is part of the Chita-Corrigan fluvial system as defined by Galloway (1977) and Galloway and Kaiser (1979) in their detailed regional studies of the formation. Galloway (1977) and Galloway and Kaiser (1979) compare and contrast this system to the Gueydan fluvial system of South Texas where uranium production occurs. The system is composed of stacked channel-fill sequences and associated crevasse-splay sands alternating with mud-rich facies of well-drained floodplain muds and silts and interchannel lacustrine muds, clays, and sands. Altered volcanic ash is a dominant component of crevasse-splay and interchannel facies. The formation outcrops in the southeastern part of the quadrangle and ranges in thickness from 91 to 183 m (300 to 600 ft) (Fig. 13). The beds thicken and dip basinward at less than 1° and grade downdip into an equivalent wave-modified, lobate-delta system of the Frio Formation.

Channel-fill sequences in the easternmost part of the Chita-Corrigan system tend to spread out laterally rather than stack vertically as in the central and western part of the system. Thus interchannel mudstones and claystones become a more important facies. Net sand maps of the Upper Catahoula and Lower Catahoula intervals demonstrate this relationship (Figs. 14 and 15) (Galloway, 1977).

The change in sand distribution pattern has an important influence on the ground-water flow system. The more permeable channel-fill sands of the Lower Catahoula, which are laterally separated by the less permeable interchannel mudstones and claystones, behave as conduits for ground-water flow. In the central and western part of the Chita-Corrigan system, the vertical stacking of channel-fill sands creates the hydrologic continuity between Upper and Lower Catahoula, which allows upward discharge of ground water as well as enhancing influx from the updip recharge area. In the easternmost area of the system, the overlying laterally continuous claystone and mudstone interchannel deposits are effectively an aquitard capping the Lower Catahoula sands. The aquitard restricts the upward discharge of ground water and likewise the downward percolation of ground-water recharge. The outcrop exposure of the aquitard reduces the surface area of the recharge zone, thus reducing the volume of ground-water influx.

Dominant framework facies include channel-fill sands and crevasse-splay deposits. Channel-fill sequences are generally composed of moderately to well sorted, very fine to medium sand with local lenses of mudstone and muddy sandstone. Mud clast conglomerates are common as channel-lag deposits; clay pellets and chips are common in the upper part of the sequence. Ferruginous nodules and fragments of silicified wood are common. Sedimentary structures include medium- to large-scaled, low- to high-angle trough cross-stratification and scour features. Planar beds and foreset crossbeds are common locally. Occurrence of ripples, mud drapes, and root structures is also noted. Channel-fill units average 11 to 14 m (35 to 45 ft) in thickness.

Crevasse-splay sequences, commonly associated with channel-fill deposits, are characterized by a variety of bedding structures and textures. Sequences of laminated to thickly and poorly bedded sands and sandstones, muddy sands, siltstones, and mudstones typically compose crevasse-splay deposits. Ripples, climbing ripples, mud drapes, desiccation cracks, rooted zones, and dewatering structures are common; sands are locally cross-stratified. Ironstone nodules, carbonized or siliceous wood fragments, and local concentrations of plant debris are common accessory features. Vuggy textures are commonly associated with mudstone units.

Crevasse-splay deposits interfinger laterally with floodplain and lacustrine mudstones and siltstones. Deposits typically form coalescing aprons that thin away from the channel axes. Crevasse-splay sequences are commonly 10 km (63 mi) wide and reach a maximum thickness of 9 m (30 ft).

Interchannel lacustrine deposits represent the major nonframework facies in the Palestine Quadrangle; floodplain deposits are a minor facies. Lacustrine basin deposits are typically massive, olive to gray, bentonitic claystones that grade vertically upward and laterally into beds of tuffaceous muds, silts, and fine sands. Organic material in the form of disseminated plant debris and large wood fragments is common to abundant. Silts and fine sands are typically laminated, with climbing ripple cross-lamination and medium- to small-scale trough cross-stratification occurring locally. Burrowed zones, root casts, clay drapes, dewatering structures, and desiccation cracks are common. Galloway (1977) describes the following typical progradational sequence for the lacustrine facies: (1) massive homogenous claystone, (2) massive to poorly bedded mudstone containing root traces and burrows, and (3) thick- to medium-bedded, highly root-disturbed silty mudstone to muddy sandstone. Lacustrine deposits are commonly tens of meters thick and stacked sequences may be several hundreds of meters thick. Lateral dimensions are variable.

Well-drained floodplain sequences are not as well developed in the eastern part of the Chita-Corrigan system as they are to the west. Deposits are generally tuffaceous mud, silt, and clay. Common accessory features include ironstone and calcareous nodules with local occurrences of gypsum veins. Rooted zones and vuggy textures are commonly associated with the mudstones.

Sands of the Catahoula consist of quartz with subequal amounts of orthoclase, plagioclase, and rock fragments (Galloway, 1977). Kaolinite is the dominant clay mineral in interchannel floodbasin and lacustrine mudstones and claystones. The absence of detrital illite, chlorite, or their mixed layer variants suggests that the clays are primarily derived from altered airborne volcanic ash rather than from older rock units. On the basis of gross mineralogy, Galloway (1977) suggests that from 70 to 90 percent of the clay in the Chita-Corrigan system was derived from volcanic ash. Volcanic detrital material served as the source of uranium released into the system during argillation of the ash. Total U_3O_8 concentrations associated with highly carbonaceous lacustrine basin clays are probably syngenetic in origin. Available uranium, released during early diagenesis, was probably adsorbed by finely disseminated carbonaceous plant debris in the lake basins.

Hydrogeochemical and stream-sediment reconnaissance data are available only for that portion of the Catahoula that lies within the Palestine Quadrangle. A total of 12 ground-water samples were collected and analyzed. The uranium concentration values are generally very low, ranging from 0.0 to 0.50 ppb, with an average value of 0.14 ppb. The depth range of the producing horizons was 6 to 123 m (18 to 369 ft), with six of the wells producing from horizons less than 9 m (30 ft) in depth. Plots of the uranium and trace element concentrations and uranium/conductivity ratios indicate there is little uranium in the ground water. Low uranium concentrations in surface sand deposits and ground-water samples suggest that most of the uranium once present in these more permeable deposits has been leached and mobilized. Favorable environments for the precipitation of uranium in the shallow subsurface of the Catahoula may exist downdip in the region covered by the Beaumont Quadrangle.

The following two environments are categorized as favorable for potential uranium mineralization within the Catahoula Formation; however, both are unevaluated because of a lack of shallow subsurface data:

(1) Potential deposits of modified Texas roll-type (Subclass 242, Austin and D'Andrea, 1978), restricted to the subsurface of the Catahoula Formation -- The model is based on a uranium deposit in the Chita-Corrigan fluvial system in Fayette-Washington Counties described by Galloway and Kaiser (1979) (Fig. 6). Uranium occurs along an alteration front within a crevasse-splay sand body that lies downdip from a fluvial channel. Uranium mineralization of ore grade appears to occur in pods along an alteration front related to areas of high organic concentration.

(2) Unclassified lacustrine basin syngenetic deposits containing anomalous total uranium concentrations -- An example of this type of occurrence is located in a road material pit located approximately one-half mile east of the town of Browndell (Fig. 13). This location is east of the Palestine-Alexandria Quadrangle boundaries; however, it is included in this report because analogous occurrences are likely to be present in the shallow subsurface of the Palestine Quadrangle. This Catahoula depositional sequence can be subdivided into three units (Fig. 16). Anomalous occurrences of U_3O_8, indicated by geochemical analysis of substrate samples, is associated with sequence A, a sequence of greenish gray to light gray, parallel-laminated, waxy claystones with minor amounts of silt. Finely disseminated plant debris is common. These claystones are interpreted to be lacustrine basin deposits and are overlain by sequence B, consisting of yellowish gray, slightly micaceous, parallel-laminated mudstones and siltstones. The presence of root tracings, ripples, and desiccation cracks suggests that this sequence was deposited in a lacustrine-margin environment that was subject to

periods of subaerial exposure. Sequence B is overlain by poorly bedded siltstone with common mudstone clasts scattered throughout the interval. The level of U_3O_8 decreases markedly upward through the overlying lake-margin muds and silts (Fig. 16). The base level of the pit bottoms in the lacustrine clays; thus the thickness of sequence A is unknown. Galloway (1977) reports that lacustrine deposits in the Chita-Corrigan system are of variable width and typically tens of meters or feet thick.

Within the same area, in an adjoining abandoned pit east of sample number MGR-012, a sample was taken from a partially silicified log. Geochemical analyses indicate a U_3O_8 level of 45 ppm; concentrations in the surrounding mudstones and siltstones are appreciably lower. Galloway (1977) also reports U_3O_8 levels of 41 ppm and 36 ppm in lacustrine deposits sampled in Jasper (same area as sample MGR-012) and Walker Counties, respectively.

A uranium deposit of ore grade associated with Miocene lacustrine deposits in western Arizona is described by Sherborne and others (1979). Sherborne and others suggest that uranium-bearing fluids expelled during subsequent compaction of these sediments came in contact with a strongly reducing environment causing precipitation and fixation of uranium. Concentrations of U_3O_8 range from 0.03 to 0.10 percent, with an average of 0.07 percent.

Based on detailed regional studies, Galloway (1977; Fig. 31) speculates that uranium deposits that may occur in the Catahoula Formation in East Texas will range from small (10^5 lbs U_3O_8) to medium (10^6 lbs U_3O_8). These figures are based on size categories established for uranium deposits in the Catahoula of South Texas.

Approximately two-thirds of the Catahoula Formation subsurface section underlies the Angelina National Forest (Pl. 21). The remaining third is privately owned.

RECOMMENDATIONS TO IMPROVE EVALUATION

Potential favorable environments on the Palestine Quadrangle are restricted to the subsurface (Yegua Formation, Jackson Group, Catahoula Formation, and the Elkhart Graben - Mount Enterprise fault system). Thus the evaluation of the quadrangle would be greatly enhanced through a selective coring program. Three drilling programs are suggested:

(1) A coring program of the lacustrine basin deposits in Jasper County (Catahoula Formation) (Fig. 13), which contain anomalous occurrences of total uranium, would determine the lateral and vertical extent of the sequence. Analogous deposits should occur within the subsurface section of the Catahoula Formation underlying the Palestine Quadrangle. Knowledge of the size of lacustrine basin deposits would aid in evaluating their importance as a potential favorable environment for low-grade uranium deposits.

(2) Kaiser and others' (in press) sand percent map (Pl. 17) of the Yegua Formation, which shows the distribution of major channel sands, could be used as a model for coring marginal areas of the high sand trends to locate genetically associated crevasse-splay deposits, which represent an environment favorable for uranium mineralization.

(3) A paucity of shallow subsurface data within the fluvial facies of the Jackson Group on the Palestine Quadrangle would make an analagous coring program for this group more difficult.

(4) A coring program along the Elkhart Graben - Mount Enterprise fault trend, particularly in those areas where first-priority radioactive anomalies occur, would aid

in evaluating the possibility of uranium deposits coincident with faulting in the quadrangle.

In conclusion, a more complete evaluation of favorable environments within the Yegua Formation, Jackson Group, and Catahoula Formation could be made by the collaboration of data from the Palestine and adjoining Beaumont Quadrangle to the south. The Beaumont Quadrangle is currently being evaluated by Bendix Field Engineering Corporation, Austin office.

Cross-referencing ground-water wells sampled for the Hydrogeochemical and Stream-Sediment Reconnaissance Survey with those ground-water wells on file at the Texas Department of Water Resources would improve the interpretation of geochemical data and thus the evaluation of the Palestine Quadrangle.

Additional, pertinent data are available for many of the Hydrogeochemical and Stream-Sediment Reconnaissance wells and have been published in county ground-water resources reports by the Texas Department of Water Resources. There are six such reports covering eleven counties in the Palestine Quadrangle. Also it would be helpful for the National Uranium Resource Evaluation project researchers if hydrogeochemical and stream-sediment data contained standard definitions of fresh, brackish, and saline water.

SELECTED REFERENCES

Agagu, O. K., Harris, D. W., and Wood, D. H., 1980a, Tectonic evolution of the East Texas Basin: The University of Texas at Austin, Bureau of Economic Geology unpublished manuscript.

Agagu, O. K., Guevara, E. H., and Wood, D. H., 1980b, Stratigraphic framework of the East Texas Basin: The University of Texas at Austin, Bureau of Economic Geology unpublished manuscript.

Anders, Robert B., 1967, Ground-water resources of Sabine and San Augustine Counties, Texas: Texas Water Development Board Report No. 37, 123 p.

Atomic Energy Commission, Preliminary Reconnaissance Report, File No. 2487.

Austin, S. R., and D'Andrea, R. F., 1978, Sandstone-type uranium deposits, in Mickle, D. G., and Mathews, G. W., eds., Geologic characteristics of environments favorable for uranium deposits: Bendix Field Engineering Corporation, Grand Junction Office, Contract No. EY-76-C-13-1664, p. 87-114.

Barnes, V. E., project director, 1967, Palestine sheet: The University of Texas at Austin, Bureau of Economic Geology Geologic Atlas of Texas, scale 1:250,000.

Brooks, F. A., 1960, Trace and minor elements in Woodbine subsurface waters of the East Texas basin: Geochemica et Cosmochimica Acta, volume 20, p. 199-214 (Pergamon Press Ltd., Northern Ireland).

Ebanks, G. R., 1965, Structural geology of Keechi Salt Dome, Anderson County, Texas: University of Texas, Austin, M.A. Thesis, 83 p.

Fisher, W. L., 1969, Facies characterization of Gulf Coast basin delta systems, with some Holocene analogues: Gulf Coast Geological Societies Transactions, v. XIX, p. 239-261.

_________ 1972, Depositional systems of the Carrizo-Wilcox of Texas and their relation to the occurrence of oil and gas (abs.): South Texas Geological Society, vol. 13, p. 11-13.

Fisher, W. L., and McGowen, J. H., 1967, Depositional systems in the Wilcox Group of Texas and their relationship to occurrence of oil and gas: Transactions of the GCAGS, v. 17, p. 105-125.

_________ 1969, Lower Eocene lagoonal systems in the Texas Gulf Coast Basin: Lagunas Costeras, Un Symposio. Mem. Simp. Intern. Lagunas Costeras, UNAM-UNESCO, Nov. 28-30, 1967, Mexico, D.F., p. 263-274.

Fisher, W. L., Proctor, C. V., Galloway, W. E., and Nagle, J. S., 1970, Depositional systems in the Jackson Group of Texas -- their relationship to oil, gas and uranium, in Gulf Coast Assoc. Geol. Socs. Trans., v. 20, p. 234-261.

Galloway, W. E., 1977, Catahoula Formation of the Texas Coastal Plain: depositional systems, composition, structural development, ground-water flow history and uranium distribution: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 87, 59 p.

Galloway, W. E., and Kaiser, W. R., 1979, Catahoula Formation of the Texas Coastal Plain: origin, geochemical evolution and characteristics of uranium deposits: The University of Texas at Austin, Bureau of Economic Geology Contract Report No. 77-063-E, prepared for Bendix Field Engineering Corporation, 139 p.

Granata, W. H., 1963, Cretaceous stratigraphy and structural development of the Sabine Uplift area, Texas and Louisiana, in Report on selected north Louisiana and south Arkansas oil and gas fields and regional geology, Reference Volume V: Shreveport Geological Society, 201 p.

Guevara, E. H., and Garcia, R., 1972, Depositional systems and oil-gas reservoirs in the Queen City Formation (Eocene), Texas: GCAGS Trans., v. 22.

Guyton, William F., and Associates, 1970, Ground-water conditions in Angelina and Nacogdoches Counties, Texas: Texas Water Development Board Report 110, 167 p.

__________ 1972, Ground-water conditions in Anderson, Cherokee, Freestone, and Henderson Counties, Texas: Texas Water Development Board Report 150, 335 p.

Hightower, M. L., 1958, Structural geology of the Palestine salt dome, Anderson County, Texas: University of Texas, Austin, unpublished M.A. Thesis, 84 p.

Ho, C. L., and Dupre, B., 1980, A rapid method for U_3O_8 measurement using fluorometric method: unpublished paper presented to Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, March 13, 1980, Atlantic City, New Jersey.

Indelicato, G. J., 1980, An interpretation for the Hydrogeochemical and Stream-Sediment Reconnaissance data for the Palestine Quadrangle: Data Integration Group, Geology Division, Bendix Field Engineering Corporation, Grand Junction, Colorado.

Jones, C. A., 1978, Uranium occurrences in sedimentary rocks exclusive of sandstone, in Mickle, D. G., and Mathews, G. W., eds., Geologic characteristics of environments favorable for uranium deposits: Bendix Field Engineering Corporation, Grand Junction Office, Contract No. EY-76-C-13-1664, p. 1-86.

Kaiser, W. R., 1974, Texas lignite: near-surface and deep-basin resources: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 79, 70 p.

Kaiser, W. R., Ayers, W. B., Jr., and LaBrie, L. W., in press, Lignite resources in Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations.

Lahee, F. H., 1933, Keechi and Palestine salt domes: 16th International Geological Congress, Guidebook 6, p. 72-82.

Lyons, R. L., 1957, Geology and geophysics of the Gulf of Mexico: Gulf Coast Association of Geological Societies, Transactions, vol. VII, p. 1-10.

McGookey, D., 1975, Gulf Cenozoic sediments and structure: an excellent example of extra-continental sedimentation: Gulf Coast Association of Geological Societies, Transactions, vol. XXV, p. 104-120.

Mickle, D. G. and Mathews, G. W., eds., 1978, Geologic characteristics of environments favorable for uranium deposits: Bendix Field Engineering Corporation, Grand Junction Office, Contract No. EY-76-C-13-1664, 250 p.

Nichols, P. H., Peterson, G. E., and Wercestner, C. E., 1968, Summary of subsurface geology of northeast Texas: in Beebe, B. W., and Curtis, B. F., eds., Natural gases of North America: American Association of Geological Societies Memoir 9, vol. 2, p. 982-1004.

Oliver, William B., 1971, Depositional systems in the Woodbine Formation (Upper Cretaceous), Northeast Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 73, 28 p.

Peckham, Richard C., Sowders, Vernon L., Dillard, Joe W., and Baker, Bernard B., 1963, Reconnaissance investigation of the ground-water resources of the Trinity River Basin, Texas: Texas Water Commission, 110 p. (2nd printing, 1973, by Texas Water Development Board, Bulletin No. 6309).

Powers, S., 1920, The Butler salt dome, Freestone County, Texas: American Journal of Science, v. 49, p. 133-136.

Ricoy, J. U., 1976, Depositional systems in the Sparta Formation (Eocene) Gulf Coast Basin of Texas: The University of Texas at Austin, M.S. Thesis, 98 p.

Ross, C. S., Mirer, H. D., Stephenson, L. W., 1928, Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas: U.S. Geological Survey Professional Paper 154-F, p. 175-202.

Sellards, E. H., Adkins, W. J., and Plummer, F. B., 1932, The geology of Texas: Volume I, Stratigraphy: University of Texas Bulletin No. 3232, 1007 p.

Sherborne, J. E., Jr., Buckovick, W. A., Dewitt, D. B., Hellinger, T. S., and Pavlak, S. J., 1979, Major uranium discovery in volcaniclastic sediments, Basin and Range Province, Yavapai County, Arizona: American Association of Petroleum Geologists Bulletin, vol. 63, p. 621-646.

The Southern Interstate Nuclear Board, 1969, Uranium in the southern United States: prepared for Division of Raw Materials, United States Atomic Energy Commission, 229 p.

Tarver, George E., 1966, Ground-water resources of Houston County, Texas: Texas Water Development Board Report 18, 89 p.

__________ 1968, Ground-water resources of Polk County, Texas: Texas Water Development Board Report 82, 113 p.

Texas Instruments, Incorporated, 1979, Aerial radiometric and magnetic reconnaissance survey of a portion of Texas' Beaumont and Palestine Quadrangles, final report, vol. 1 and vol. 2B, Palestine Quadrangle: work performed under Bendix

Field Engineering Corporation, Grand Junction Operations, Grand Junction, Colorado, Subcontract 79-285-6 and Bendix Contract EY-76-C-13-1664, prepared for U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado.

Union Carbide Corporation, 1979, Hydrogeochemical and Stream-Sediment Reconnaissance basic data for Palestine NTMS Quadrangle, Texas: National Uranium Resource Evaluation Program, Union Carbide Corporation Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, United States Department of Energy, W-7405 eng 26, 35 p.

Wesselman, J. B., 1967, Ground-water resources of Jasper and Newton Counties, Texas: Texas Water Development Board Report 59, 167 p.

Wilbert, W. P., and Templain, C. J., 1978, Preliminary study of uranium favorability of the Wilcox and Claiborne Group (Eocene), in Texas: Bendix Field Engineering Corporation, U.S. Department of Energy Open-File Report GJBX-7 (78).

Wood, M. L., and Walper, J. L., 1974, The evolution of the interior Mesozoic basins of the Gulf of Mexico: Gulf Coast Association of Geological Societies Transactions, v. XXIV, p. 31-41.

Occurrence no.	Name	County	Location ¼ Sec.	Sec. (S)	Twp. (S)	Rng. (W)	Lat. (N)	Long. (W)	Host rock formation/member	Deposit class or subclass (no.)	Production#	Reference**
1	San Augustine	San Augustine					31 34 36	98 08 12	Weches Fm.	Marine Shale(130)*	a	PRR (2487)

*Austin and D'Andrea, 1978.

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

**PRR: U.S. Atomic Energy Commission Preliminary Reconnaissance Report, open filed.

URANIUM-OCCURRENCE

REPORT

Quad Name A90 Palestine

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

Deposit No. B40 1

Deposit Name A10 < San Augustine Occurrence >

Synonym Name(s) A11 < >

District or Area A30 < San Augustine >

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

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

Position from Prominent Locality A82 < North of San Augustine

>

Field Checked G1 <7,8|1,0> By G2< Rose , Floyd G. >
Yr Mo Last name First Initial

Latitude A70 <3,1|3,4|3,6,N> Longitude A80 <0,9,6|0,8|1,2,W>
Deg Min Sec Deg Min Sec

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

FT/M

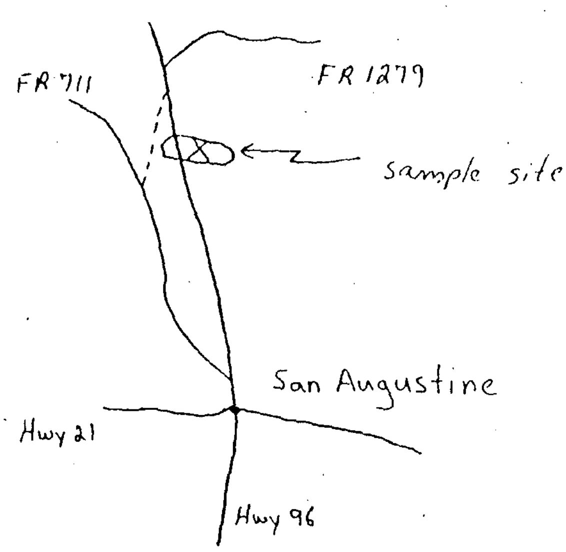
Meridian A81 < > Altitude A107 < 490 ft. >

Quad Scale A91 < 6,2,5,0,0,0> Quad Name A92 < San Augustine >
(7½' or 15' quad)

Physiographic Province A63 <0,3| | Coastal Plain >
(List K)

Location Comments A83 < small hill just south of intersection of Hwy 96 and FR 1279 >

Location Sketch Map:



BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Palestine

Deposit No. 1

Commodities Present:
C10 <U>

Commodities Produced:
MAJOR < > COPROD < >

MINOR < > BYPROD < >

Potential Commodities:
POTEN < > OCCUR <U >

Commodity Comments C50 < 4.4 ppm U_3O_8 >

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> < > E1A< > E1B<LB> E1C< > E1D< % U308>

Source of Information E7 < >

Comments E8 < >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Palestine

Deposit No. 1

Deposit Form/Shape M10 < Circular area of anomalous activity >

Length M40 < 20 > M41 < M > (FT/M)

Width M50 < 13.5 > M51 < M >

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 < Coastal Plain >

Major Regional Structures N5 < >

Local Structures N70 < >

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

Host Rock K1 < E O C E N E | b̸ | Dark green glauconitic marl with some shell fragments
(Age) (Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.) >

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

Comments on Associated Rocks U4 < >

Ore Minerals C30 < None >

Gangue Minerals K4 < None >

BFE 1236
4/19/78

URANIUM-OCCURRENCE REPORT

Quad Name Palestine

Deposit No. 1

Alteration N75 < None >

Reductants U5 < None >

Analytical Data (General) C43 < >

Radiometric Data (General) U6 < 2 X BG (30 X 150 ft)
(No. times background and dimensions) >

Ore Controls K5 < reduction in ground water pH >

Deposit Class C40 < Marine shale > Class No. U7 <11310>

Comments on Geology N85 < >

URANIUM-OCCURRENCE

REPORT

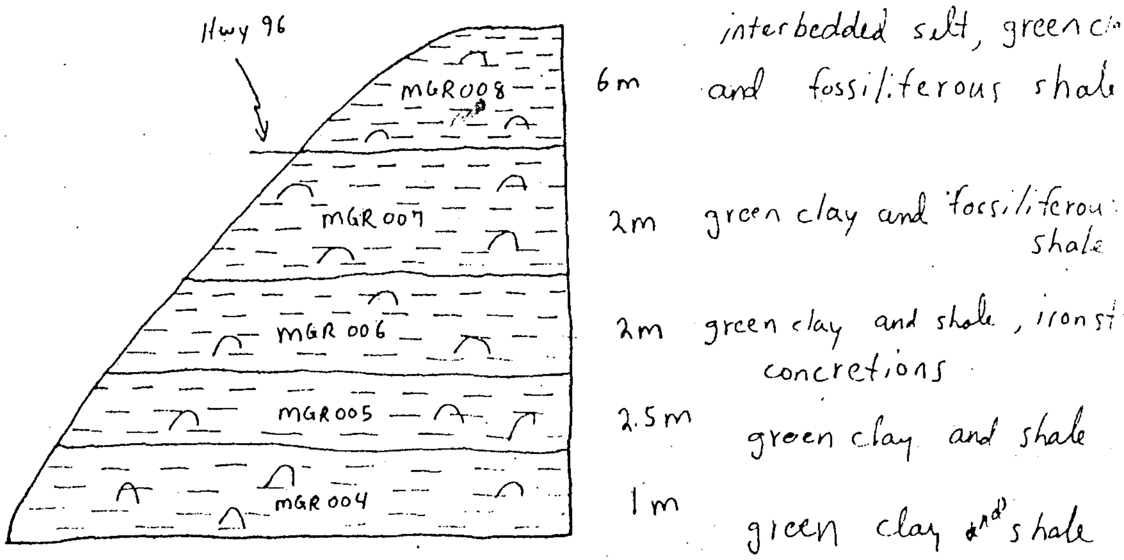
Quad Name Palestine

Deposit No. 1

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MGR 004	Grab sample of glauconitic shale	4.4 ppm U_3O_8
MGR 005	Grab sample of glauconitic shale	4.3 ppm U_3O_8
MGR 006	Grab sample of glauconitic shale	2.9 ppm U_3O_8
MGR 007	Grab sample of glauconitic shale	2.5 ppm U_3O_8
MGR 008	Grab sample of glauconitic shale	3.5 ppm U_3O_8

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



References:

F1 < AEC Preliminary Reconnaissance Report
File #2487, Open filed >

F2 < >

F3 < >

F4 < >

URANIUM-OCCURRENCE Palestine

REPORT 1

Continuation from p. 1-5:

Label

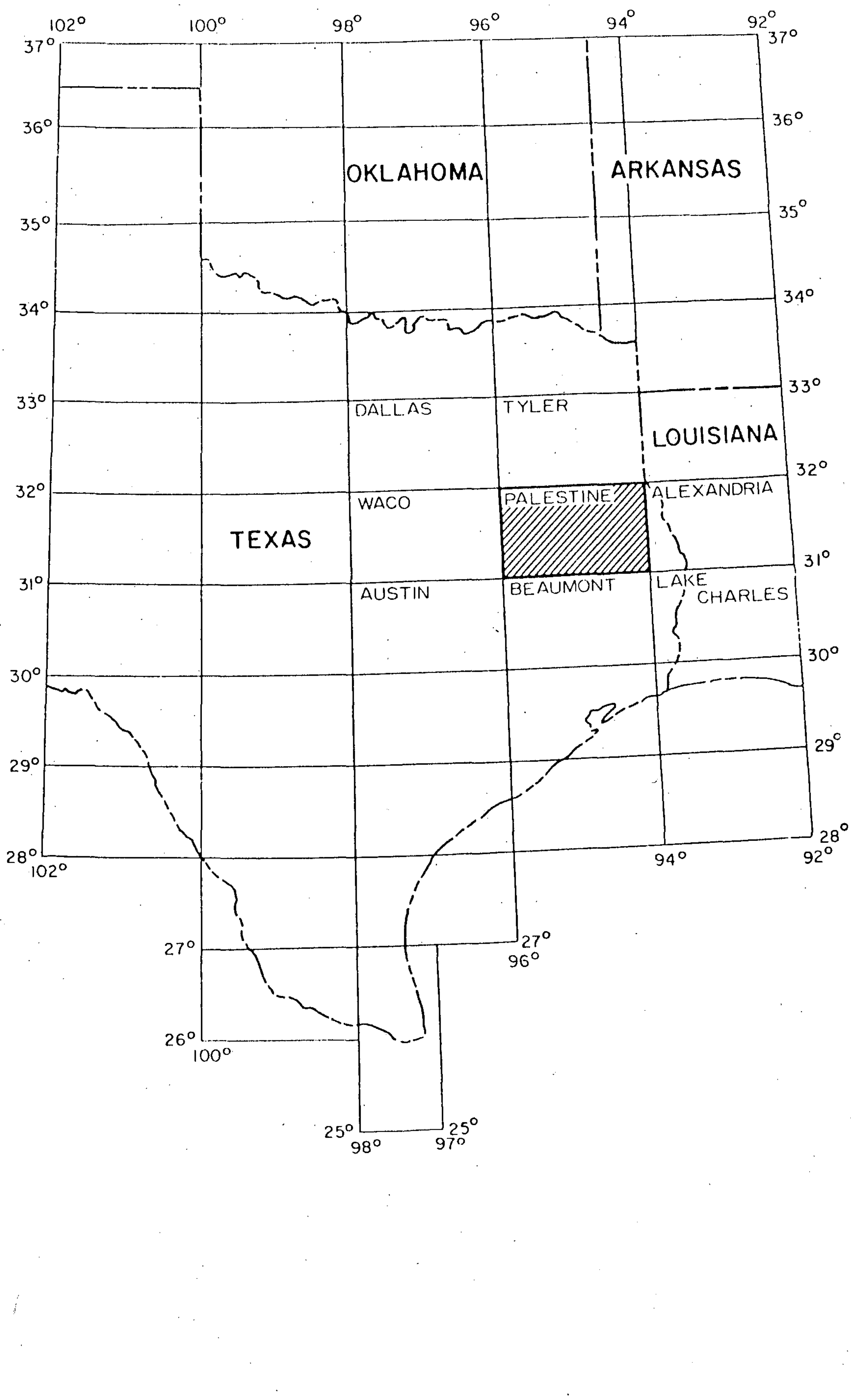
SFE 1230
1/12/79

APPENDIX D. Cross-Section Wells

Well Code #	Company and Well Name	County
A-1	Stroube & Strobe; J. D. Bearden #1	Cherokee
A-2	Humble Oil; H. L. Carter #13	Anderson
A-3	Jack Phillips; Royal Nat'l Bank #1	Anderson
A-4	Ridley & Locklin; So. Pine Lumber Co. #1	Anderson
A-5	Michael; Mallerd Estate #1	Anderson
A-6	Talbert and Gulley; Pine Lodge Club #1	Anderson
A-7	La Coastal Petroleum; J. W. Bridges	Anderson
A-8	F. R. Jackson; A. P. Matthews #1	Houston
A-9	Humble Oil; Dailey #1	Houston
A-10	McMurrey; Murray #1	Houston
A-11	Barnwell Drilling Co; Swift Estate #1	Leon
A-12	E. C. Johnston; Swift #1	Leon
A-13	Mobile Oil; Newson #1	Leon
A-14	D. H. Byrd; Leathers #1	Leon
A-15	Delta Drilling; Moore #1	Leon
A-16	Harvey Park; F. L. Wilson Estate #1	Leon
A-17		Madison
A-18	Cico Oil & Gas; Ferguson #1	Madison
A-19	Standard of Texas; Winne Hightower Colwell #1	Madison
A-20	Mitchell & Assoc.; Standlet #1	Madison
B-1	Trentman Oil; L. R. Evans #1	Rusk
B-2	Tex-Harvey Oil; S. N. Coleman #2	Cherokee
B-3	R. J. Caraway; Walker #1	Cherokee
B-4	Humble Oil; Reklaw Gas Unit #3, Well #2	Cherokee
B-5	Hughey & Perryman; McDonald #1	Cherokee
B-6	Coats Drilling; Sally Starr McGee #1	Houston
B-7	Marine Gathering; J. C. Merriweather #1	Houston
B-8	C-1 Comp; Houston County Timber Comp #1	Houston
B-9	Humble; Curry #1	Houston
B-10	Killam; Houston County Coal Company #1	Houston
B-11	Humble Oil; J. M. Moore #1	Trinity
B-12	Pan American Oil; Texas Long Leaf #1	Trinity
B-13	J. D. Davis; J. B. Gibson #1	Trinity
C-1	P. H. Pewitt, Rushing #1	Panola
C-2	P. H. Pewitt, Pickering #2	Shelby
C-3	Southern Prod. Co., Childress #2	Shelby
C-4	P. H. Pewitt, Pickering #1	Shelby
C-5	Barnhill Bros., Clark #1	Shelby
C-6	Anderson & Bernard, Bartle #2	Shelby
C-7	HIWS, Inc., Cordray #1	Shelby
C-8	Strandlind Oil & Gas Co., Parker #A-1	Shelby
C-9	Davis, Johnson #1	San Augustine
C-10	H. L. Poole; Pickering #1	San Augustine

C-11	H. L. Poole, Cousins #1	San Augustine
C-12	Lester & Culbertson, Childers #1	San Augustine
C-13	Roper, Long Bell #2	San Augustine
D-1	Conoco; Carrol #1	Anderson
D-2	Texaco; Rutledge #1	Anderson
D-3	Ridley & Locklin; Southern Pine Lumber Co. #1	Anderson
D-4	Jackson; Sherman #1	Cherokee
D-5	Lake; Spence & Watburn Jones #1	Cherokee
D-6	Tipton; Cowalt #1	Cherokee
D-7	R. J. Caraway; Walker #1	Cherokee
D-8	Colston; Dedman #2	Nacogdoches
D-9	Humble Oil & Refining Co.; Trawick #48	Nacogdoches
D-10	Humble Oil & Refining Co.; Trawick #52	Nacogdoches
D-11	Humble Oil & Refining Co.; Trawick #3	Nacogdoches
D-12	Humble Oil & Refining Co.; McKnight & Rosen #1	Shelby
D-13	Humble Oil & Refining Co.; Harris #1	Shelby
D-14	Trans-American; Hurst #1	Shelby
D-15	Anderson & Bernard, Bartle #2	Shelby
E-1	Fisher & Davidson; Lee #1	Leon
E-2	Happy Gist; Plate #1	Leon
E-3	Humble Oil; Daily #1	Houston
E-4	Humphrey & Sunray, Daily #1	Houston
E-5	Delta & Parsley, Southland #1-A	Houston
E-6	Marine Gathering; Merriwether #1	Houston
E-7	Kirby; Williams #1	Houston
E-8	Byrd, Angelina #1	Angelina
E-9	Placid; Fairchild	Angelina
E-10	Layne Texas Co.; City of Lufkin #9	Angelina
E-11	E. L. Kurth?; Henderson #1	Angelina
E-12	Carter Jones Drilling Co.; Long Bell Petroleum Co. #1	San Augustine
E-13	Union Carbide Petroleum Corp.; G. W. Lewis #1	San Augustine
F-1	J. R. Parten, Greenbrier Ranch #1	Madison
F-2	Texas Oil & Gas; Hightower Colwell #1	Madison
F-3	Perryman Oper.; Andrews #5-6	Madison
F-4	Humble Oil & Refining Co.; Harrison #1	Madison
F-5	Humble Oil & Refining Co.; Forrest #1	Madison
F-5	Pure Oil Co.; Steven Stock Farm #10	Houston
F-7	Pure Oil Co.; Bruton #2	Houston
F-8	Pure Oil Co.; Maples #1	Houston
F-9	Humble Oil & Refining Co.; Stevens #1	Houston
F-10	Blalock; Southland Paper Mills #1	Houston
F-11	Bradley Prod. Corp.; Crouch-Drilling Unit #1	Trinity
F-12	Humble Oil & Refining Co.; Thompson Bros. #2	Trinity
F-13	Pan American Prod. Co.; Texas Long Leaf #1	Trinity
F-14	Bellville Prod. Co.; Cameron #1	Trinity
F-15	Watburn, Bolton #1	Trinity
F-16	Burnet, Trinity (Libr)	Trinity

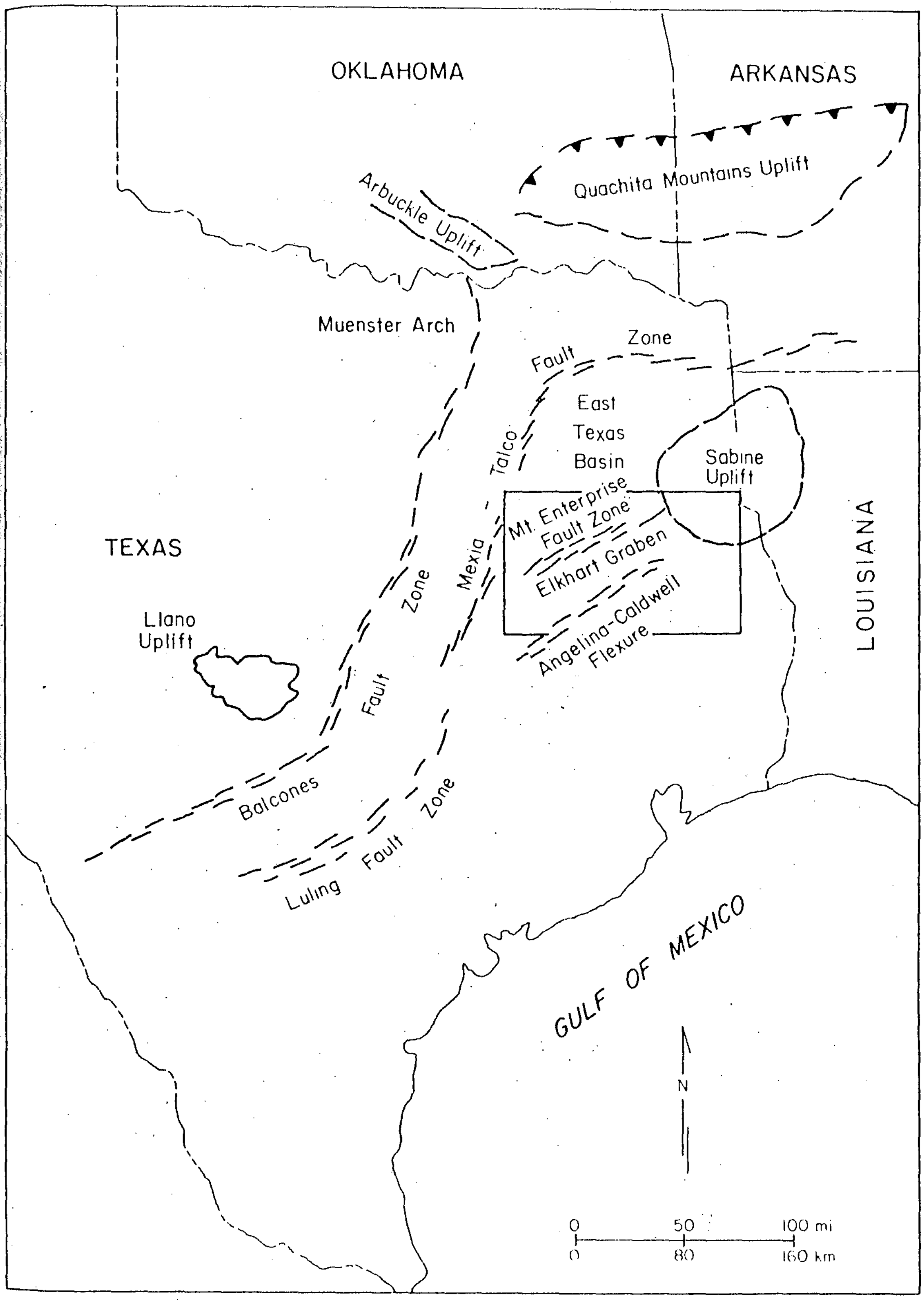
F-17	J. C. Roberts, Bane #1	Trinity
F-18	Palm Petroleum Co., Cameron #3	Trinity
F-19	Palm Petroleum Co.; Cameron #4	Trinity
F-20	Placid, Dorrance #1	Polk
F-21	Lightfoot; Davidson #1	Polk
F-22	Arkansas Fuel Oil Co.; Carter #1	Angelina
F-23	Mudge; Fairchild #1	Angelina
F-24	General Crude; Wilson #1	Tyler
F-25	Bonharn, Wilson #1	Tyler
F-26	Humble Oil & Refining Co.; Denkman-Kountze #1	Tyler
F-27	General Crude, Matteur #1	Tyler
F-28	ARCO; Milner #1	Jasper



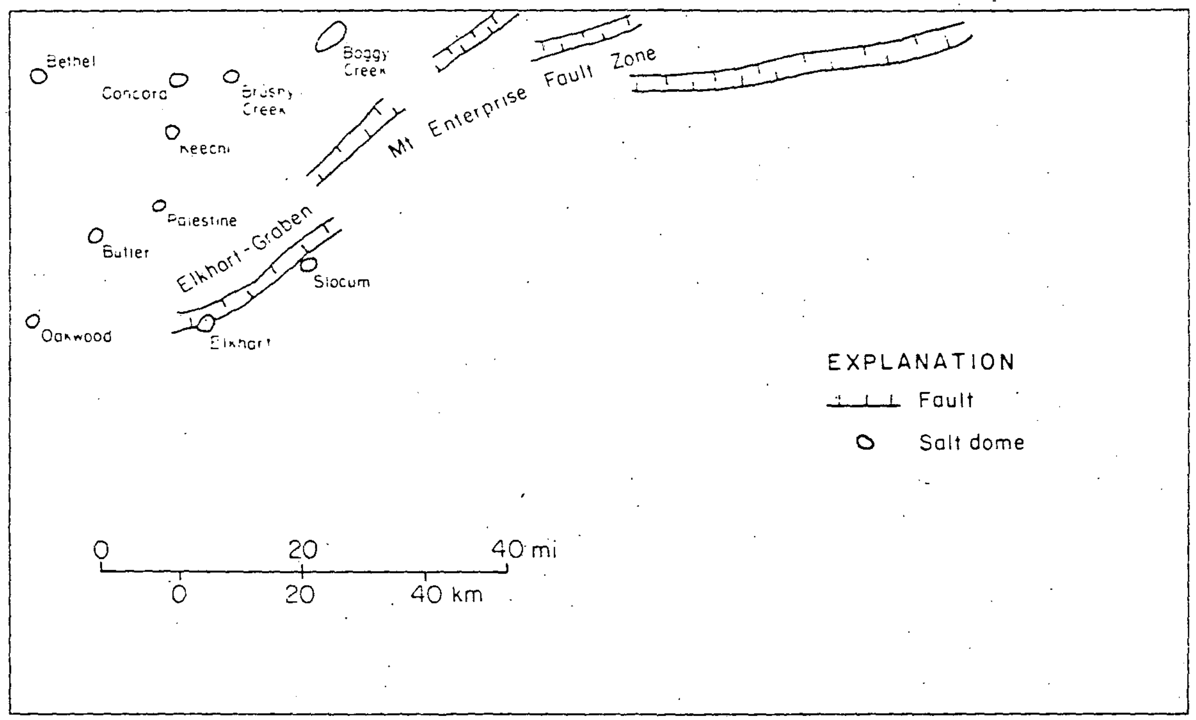
102°
100°
98°
96°
94°
92°
37°
36°
35°
34°
33°
32°
31°
30°
29°
28°
27°
26°
25°
97°
OKLAHOMA
ARKANSAS
LOUISIANA
TEXAS
DALLAS
TYLER
WACO
PALESTINE
ALEXANDRIA
AUSTIN
BEAUMONT
LAKE
CHARLES

A	SYSTEM	SERIES	GROUP	FORMATION	LITHOLOGY	DESCRIPTION
CENOZOIC	QUATERNARY	HOLOCENE				Alluvium, clay, silt, and sand
		PLEISTOCENE		Deweyville		Sand, silt, and clay, some gravel
						Fluviatile terrace deposits: gravel, sand, and silt
				Beaumont		Clay, silt, and sand
				Willis		Clay, silt, sand, pebble-size gravel
	TERTIARY	MIOCENE	FLEMING	Fleming		Clay, silt, and sand. Clay commonly calcareous, calcareous concretions. Sand often cross-bedded (at surface on Alexandria Quadrangle)
			CATAHOULA	Catahoula		Tuffaceous mudstone and sand
		OLIGOCENE OR EOCENE	JACKSON	Whitsett-Nash Creek		Whitsett: Quartz sand, locally tuffaceous, fossil wood Nash Creek: Bentonitic clay and sand
		EOCENE		Manning / Wellborn (Yazoo)		Manning: Quartz sand, clay, lignite, tuffaceous Wellborn: Sand, glauconite, locally tuffaceous, lignite, marine fossils Yazoo: Interbedded sand and clay, glauconite, marine fossils
				Caddell-Moodys Br		Caddell: Clay and quartz sand, locally tuffaceous, lignite, glauconite Moodys Branch: Marl and clay, glauconite, marine fossils
			CLAIBORNE	Yegua *		Clay, quartz sand, shaley sand, and lignite
				Cook Mountain		Clay, marl, glauconite, ironstone, and marine fossils
				Sparta Sand		Quartz sand commonly with silt or lignitic clay partings
				Weches (Mt. Selman)		Glauconite, glauconitic marl, quartz sand, clay, abundant marine megafossils
				Queen City Sand (Mt. Selman)		Quartz sand, thin irregular interbeds of clay, a few glauconitic lentils
				Reklaw (Mt. Selman)		Clay and silt, carbonaceous lentils of clay ironstone. Quartz sand interbedded with clay
				Carrizo Sand		Quartz sand. Clay and silt interbeds in upper part
			WILCOX (UNDIVIDED)	Wilcox		Quartz sand, glauconite, silt, clay and lignite. Interbeds of silt and clay, sandstone concretion in lower part
		PALEOCENE	MIDWAY	Midway		Clay and marl with concretions in lower part
MESOZOIC	CRETACEOUS	UPPER / GULFIAN	NAVARRO	Navarro		Clay, silt, calcareous, marine fossils
			UPPER TAYLOR	Pecan Gap Chalk		Calcareous clay, glauconite, interbedded limestone, marine fossils
			LOWER TAYLOR			Fine grained sand, silt, marine fossils, mudstone, clay, and glauconite
			AUSTIN	Austin		Massive chalk with interbeds of calcareous clay, marl
			EAGLE FORD	Eagle Ford		Shale, selenitic, calcareous concretions, marine fossils
			WOODBINE	Woodbine		Shale, lenses of sand, glauconitic, marine fossils, sandstone, tuffaceous clay, calcareous
		LOWER / COMANCHEAN	WASHITA	Maness Shale		Calcareous shale
				Buda Limestone		Limestone
				Grayson Marl		Sandy, fossiliferous marl
				Mainstreet Limestone		Limestone
				Weno-Pawpaw		Calcareous shale and limestone
				Denton Clay		Clay and shale
				Fort Worth Limestone		Chalky limestone
				Duck Creek		Dense limestone and interbedded shale
				Kiamichi		Shale, marl, and chalky limestone
			FREDERICKSBURG	Goodland Limestone		Massive limestone, marl [illegible] at base
				Walnut		Shale and marl
			TRINITY	Glen Rose (undifferentiated)		Clastic limestone, pellets, aggregates of pellets and marine fossils

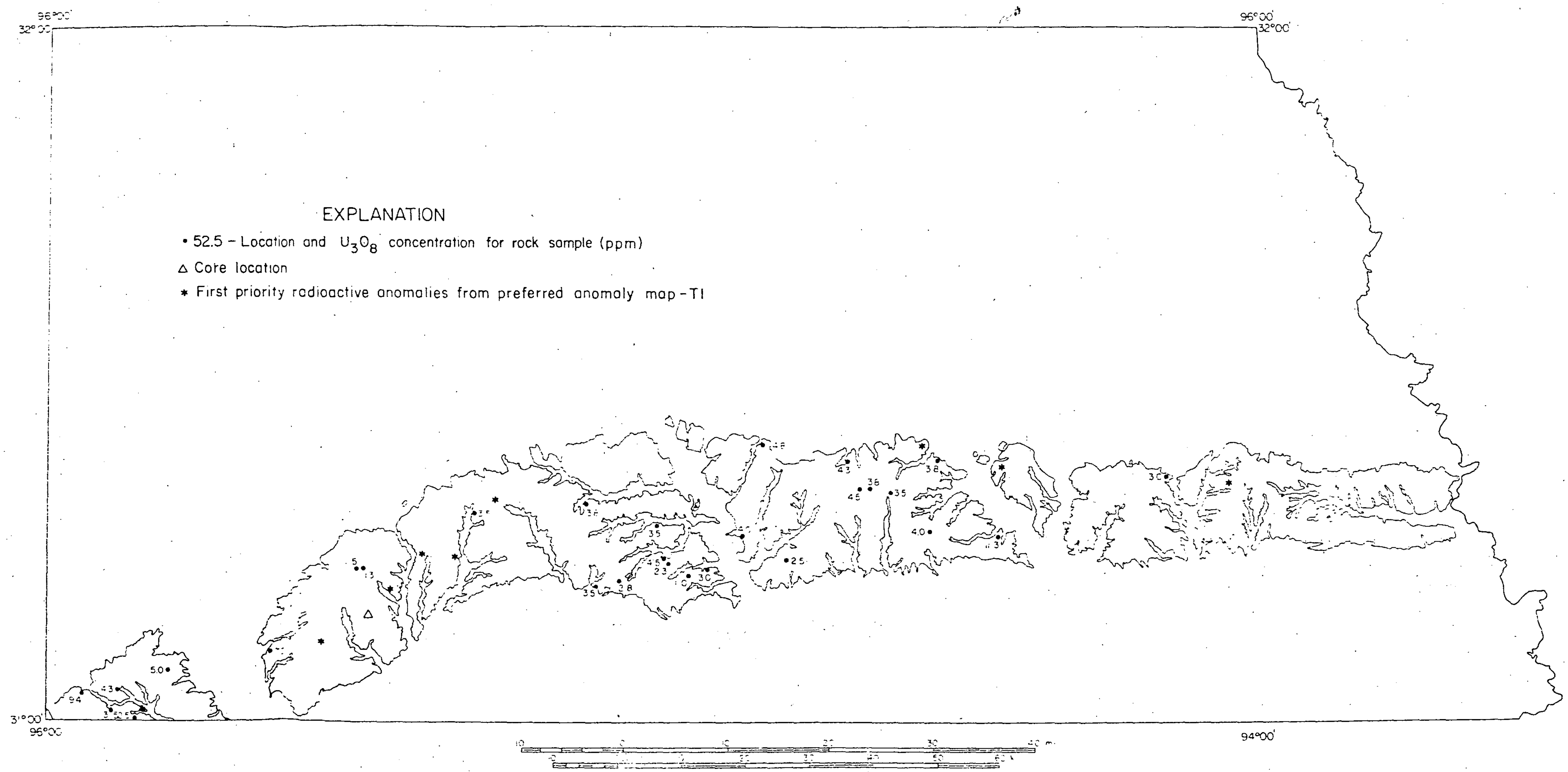
*Favorable for uranium deposits



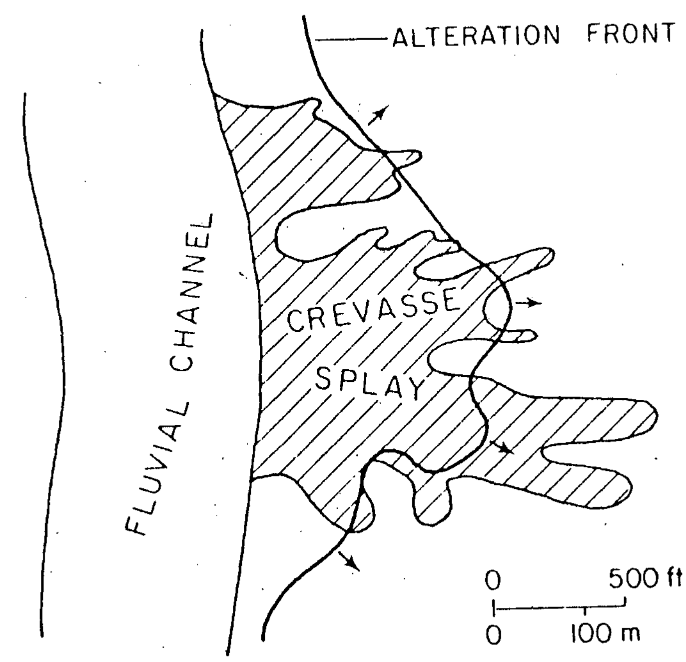
OKLAHOMA
ARKANSAS
Quachita Mountains Uplift
Arbuckle Uplift
Muenster Arch
Fault Zone
East Texas Basin
Sabine Uplift
Talco
Mt. Enterprise Fault Zone
Elkhart Graben
Angelina-Caldwell Flexure
Mexia
TEXAS
LOUISIANA
Llano Uplift
Zone
Fault
Balcones
Luling Fault Zone
GULF OF MEXICO
N
0 50 100 mi
0 80 160 km

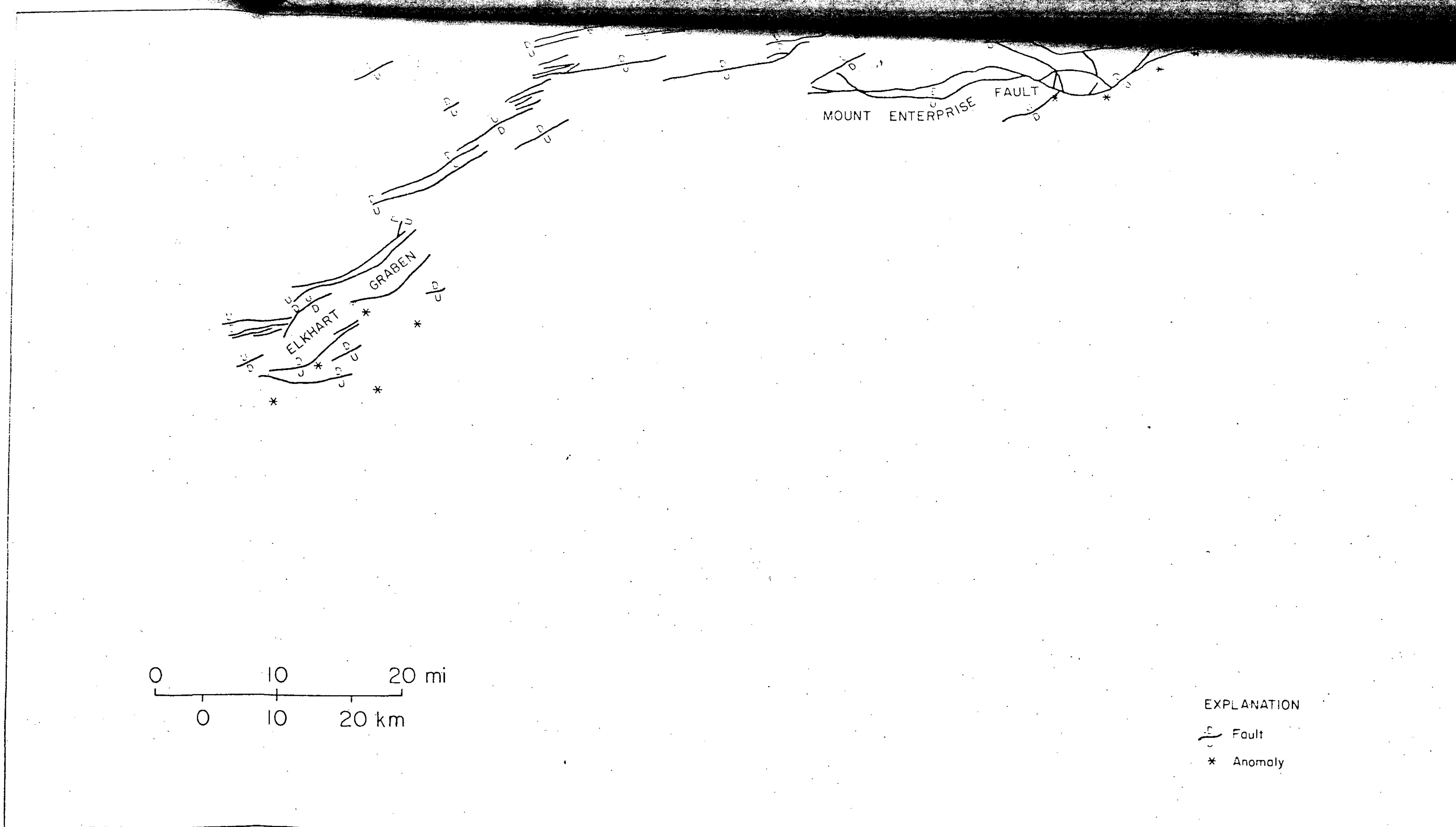


Palestine Quadrangle

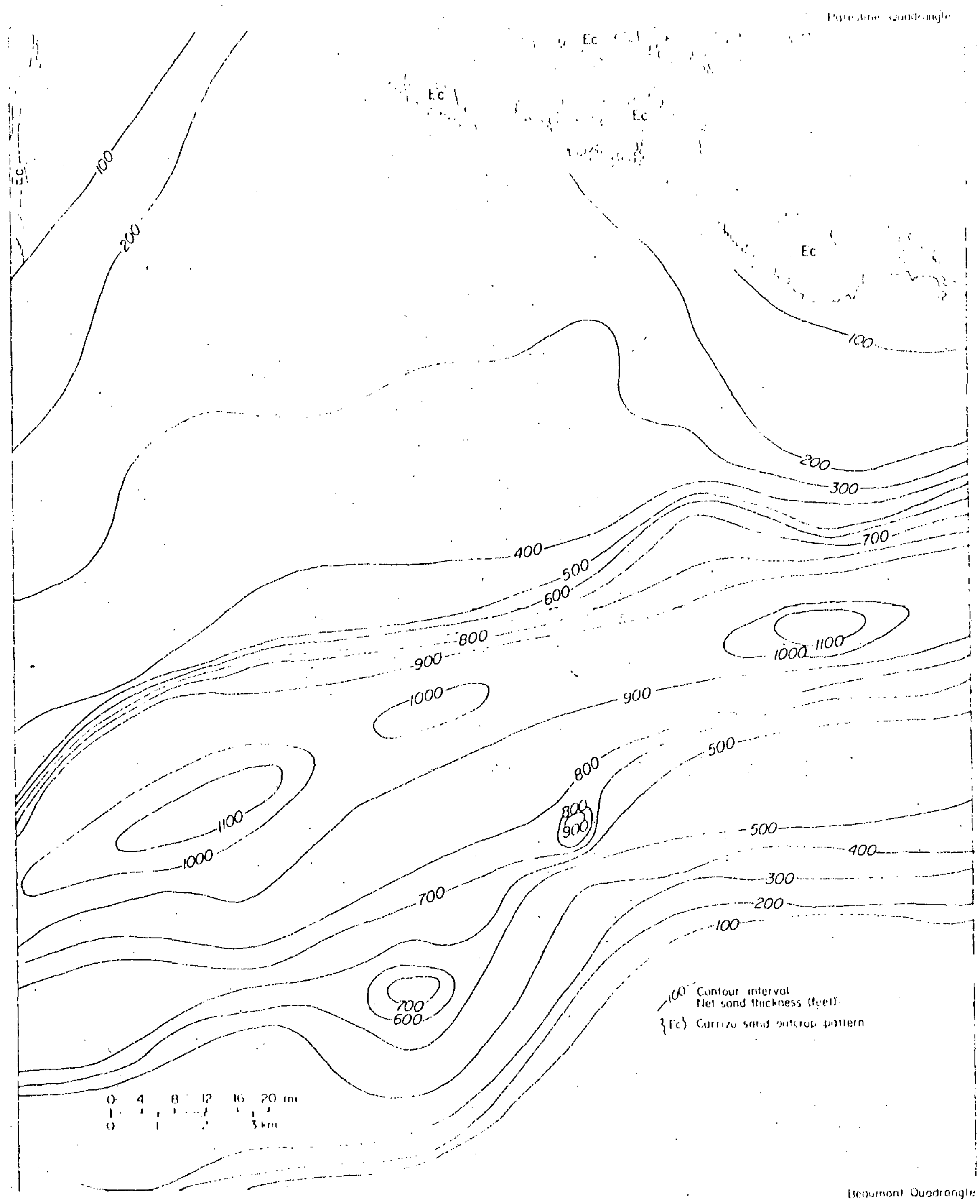


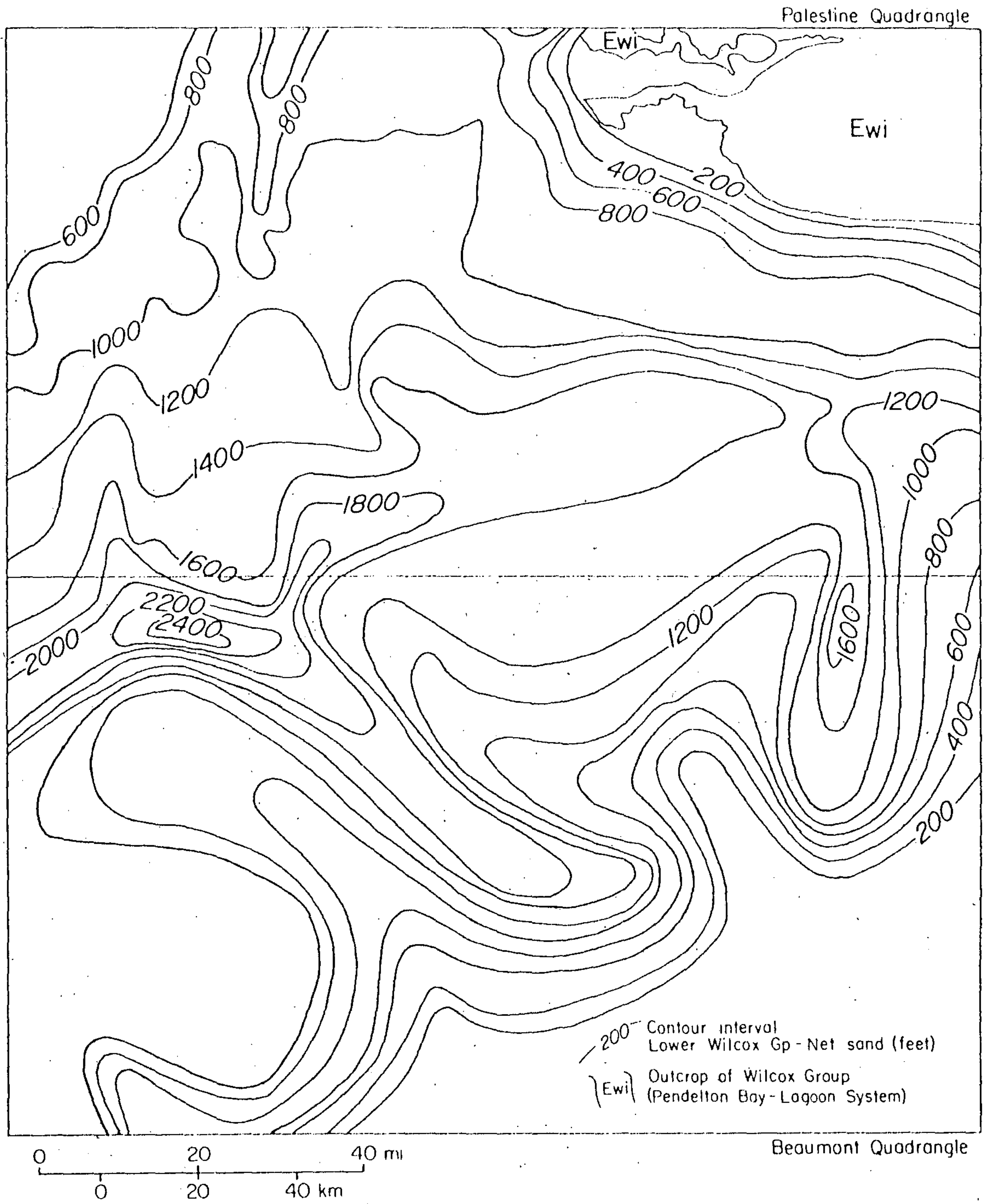
EXPLANATION
• 52.5 – Location and U_3O_8 concentration for rock sample (ppm)
△ Core location
* First priority radioactive anomalies from preferred anomaly map-TI
96°00'
32°00'
31°00'
94°00'
5.0
4.3
9.4
5
13
35
2.8
4.5
2.3
1.0
3.0
3.6
2.5
4.3
3.6
4.5
3.5
3.8
4.0
3.0


ALTERATION FRONT
FLUVIAL CHANNEL
CREVASSE
SPLAY
0
500 ft
0
100 m

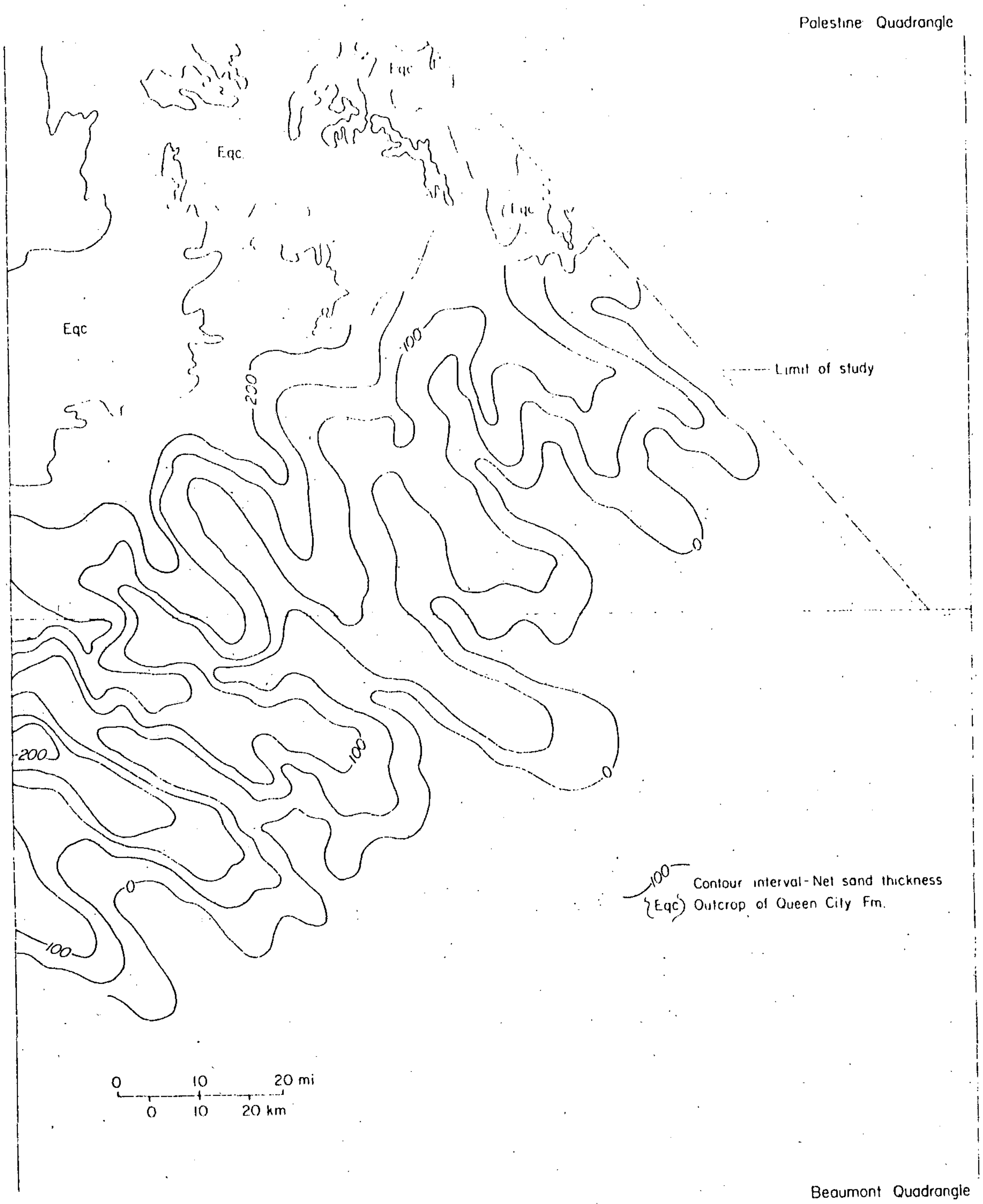


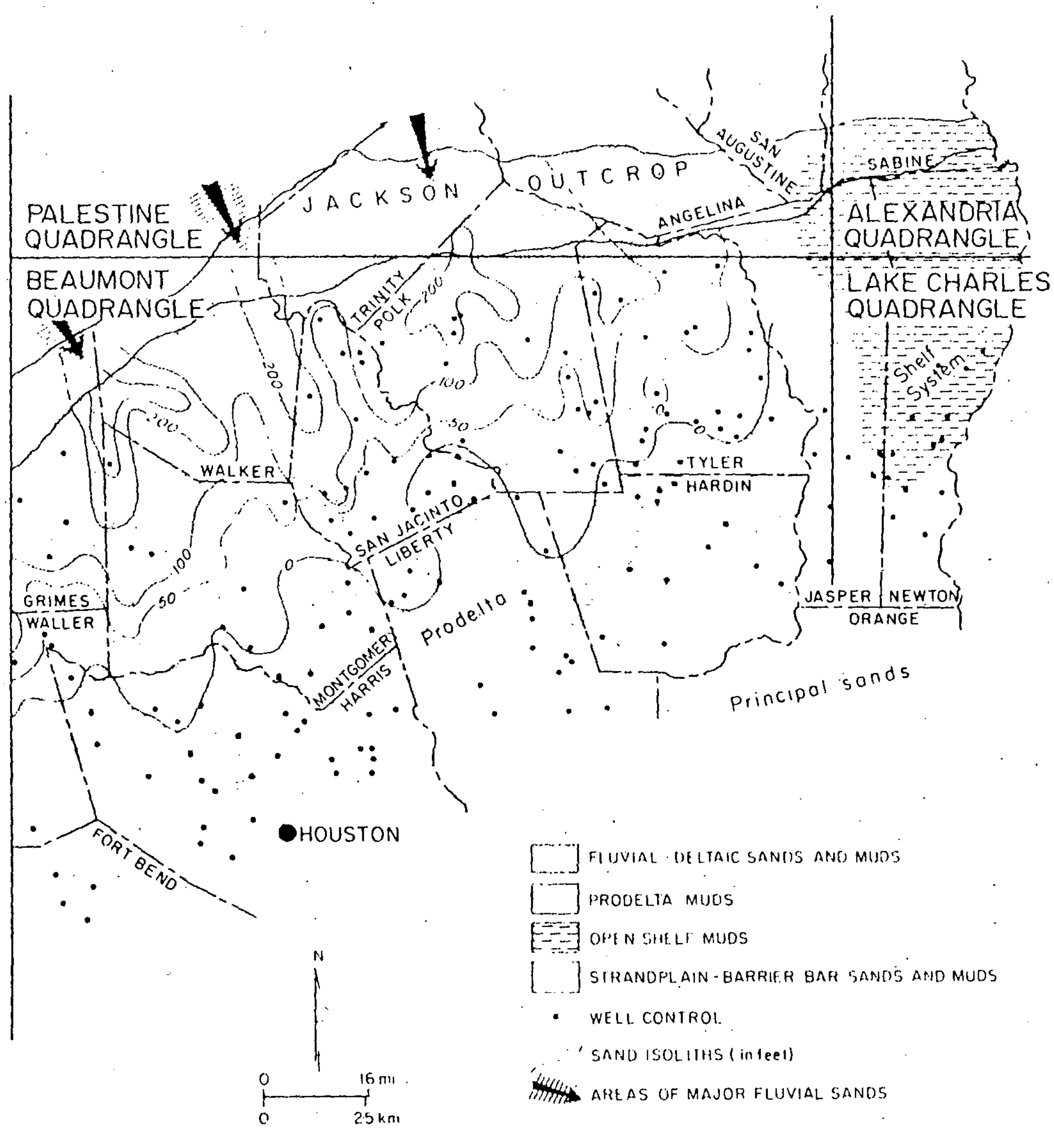
Palestine Quadrangle

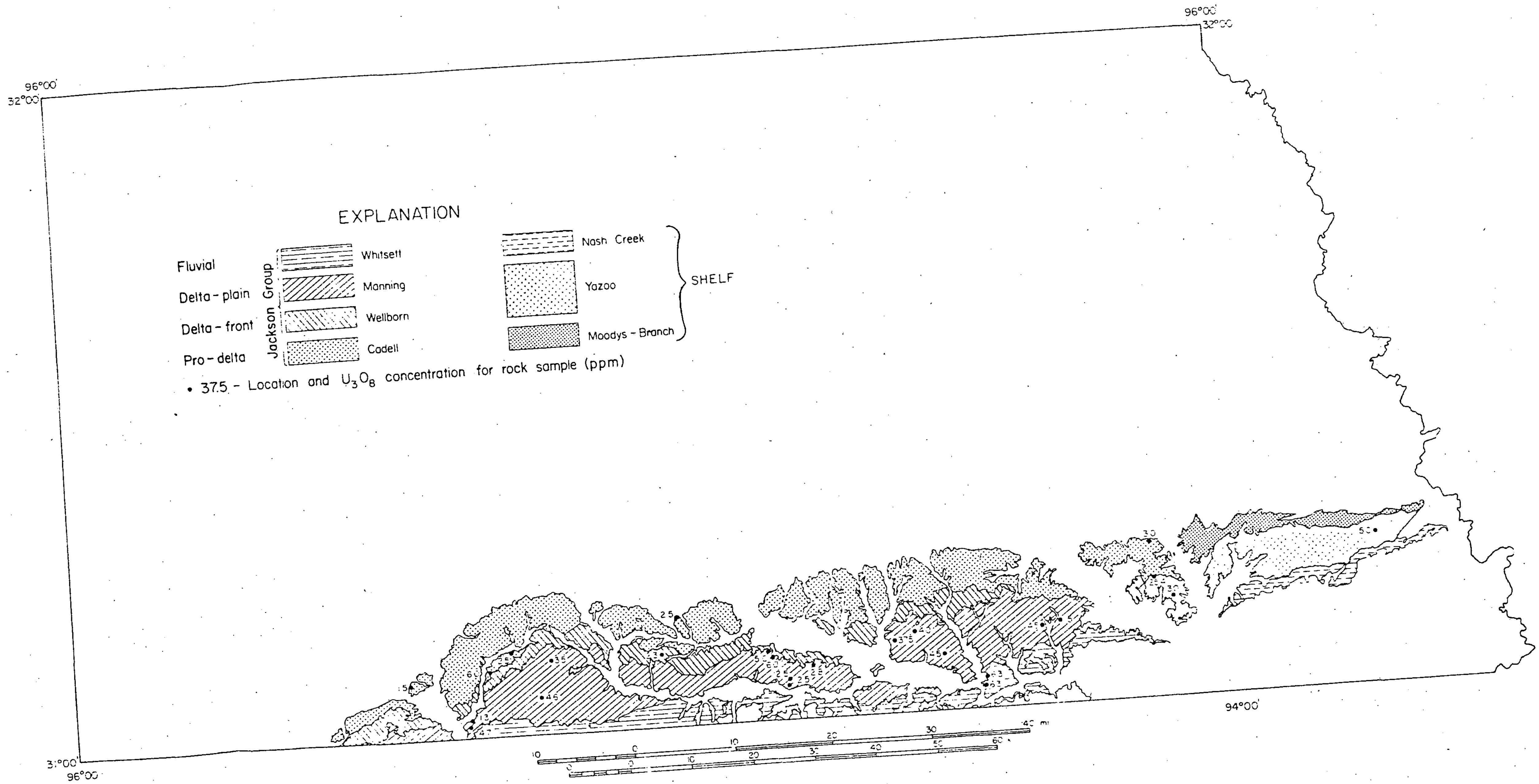

Palestine Quadrangle
Ec
100
200
300
400
500
600
700
800
900
1000
1100
Contour interval
Net sand thickness (feet)
Carrizo sand outcrop pattern
0 4 8 12 16 20 mi
Beaumont Quadrangle



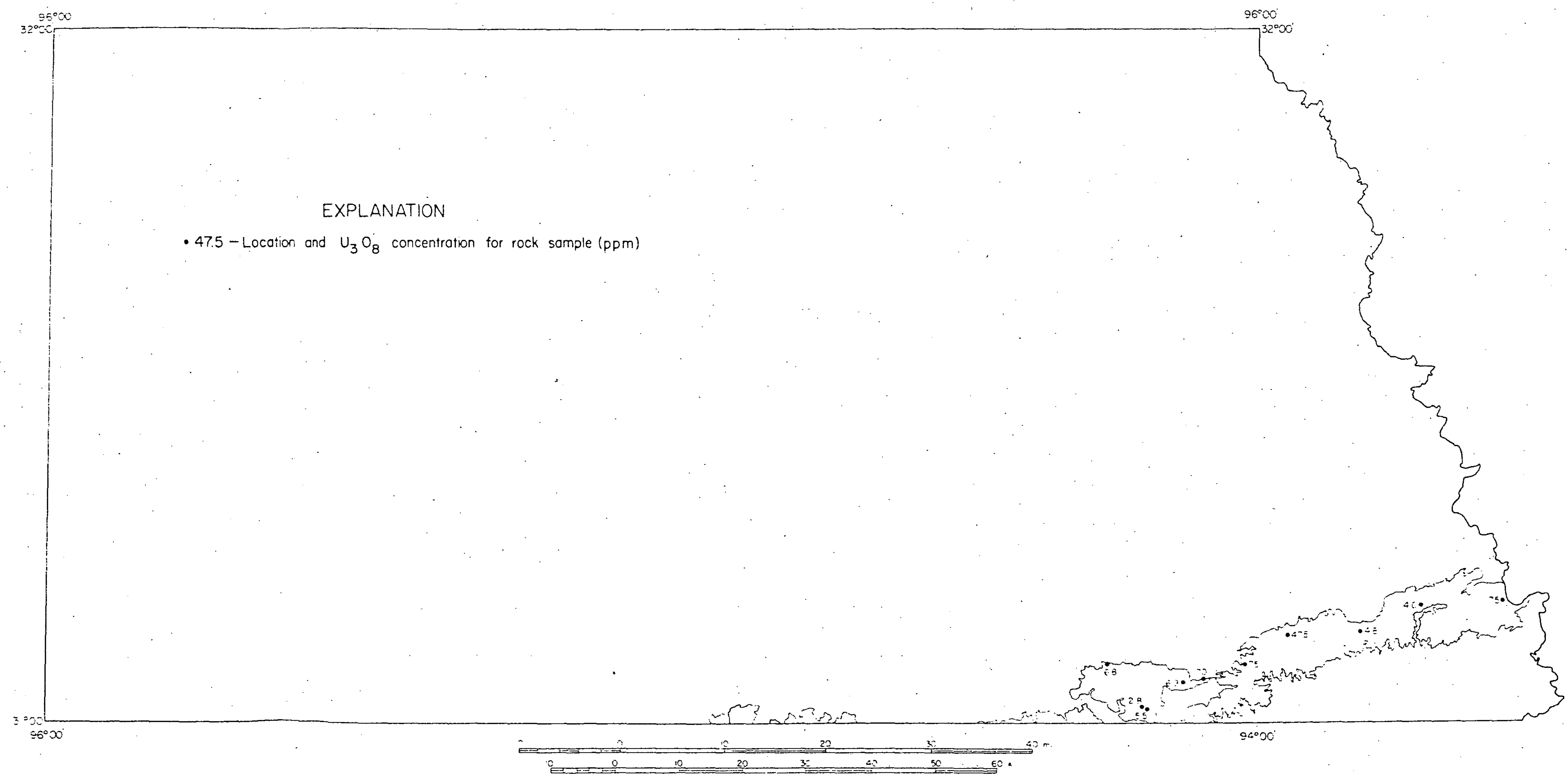
Palestine Quadrangle
Ewi
Ewi
800
800
600
400
200
600
800
1000
1200
1400
1800
1600
1200
1000
800
2200
2400
2000
1200
1600
600
400
200
200 Contour interval
Lower Wilcox Gp - Net sand (feet)
Ewi Outcrop of Wilcox Group
(Pendelton Bay - Lagoon System)
Beaumont Quadrangle
0 20 40 mi
0 20 40 km


Palestine Quadrangle
Eqc
Eqc
Eqc
Eqc
Limit of study
100
200
0
0
100
200
0
100
100 Contour interval - Net sand thickness
Eqc Outcrop of Queen City Fm.
0 10 20 mi
0 10 20 km
Beaumont Quadrangle

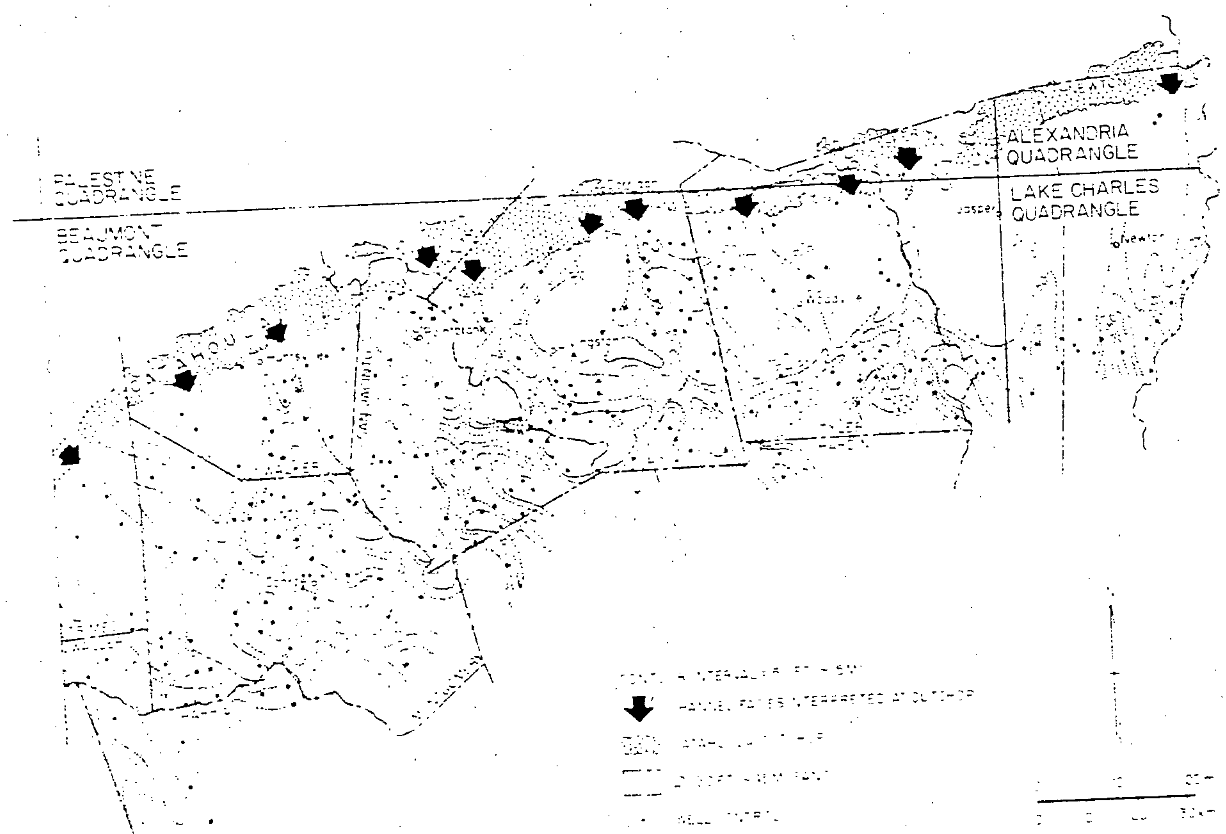

PALESTINE QUADRANGLE
BEAUMONT QUADRANGLE
JACKSON OUTCROP
ALEXANDRIA QUADRANGLE
LAKE CHARLES QUADRANGLE
SAN AUGUSTINE
SABINE
ANGELINA
TRINITY
POLK
WALKER
TYLER
HARDIN
SAN JACINTO
LIBERTY
Shelf System
JASPER
NEWTON
ORANGE
GRIMES
WALLER
MONTGOMERY
HARRIS
Prodelta
Principal sands
HOUSTON
FORT BEND
200
100
50
0
N
0 16 mi
0 25 km
FLUVIAL - DELTAIC SANDS AND MUDS
PRODELTA MUDS
OPEN SHELF MUDS
STRANDPLAIN - BARRIER BAR SANDS AND MUDS
WELL CONTROL
SAND ISOLITHS (in feet)
AREAS OF MAJOR FLUVIAL SANDS

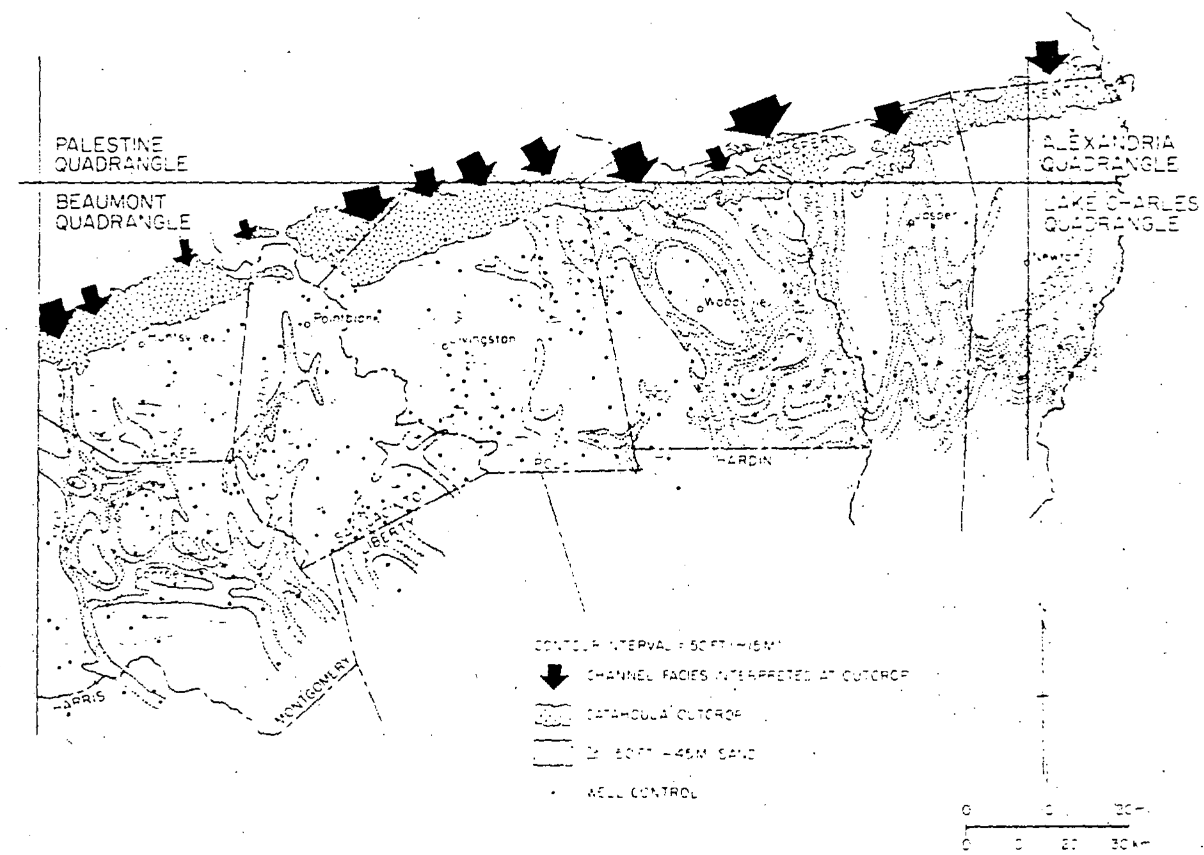


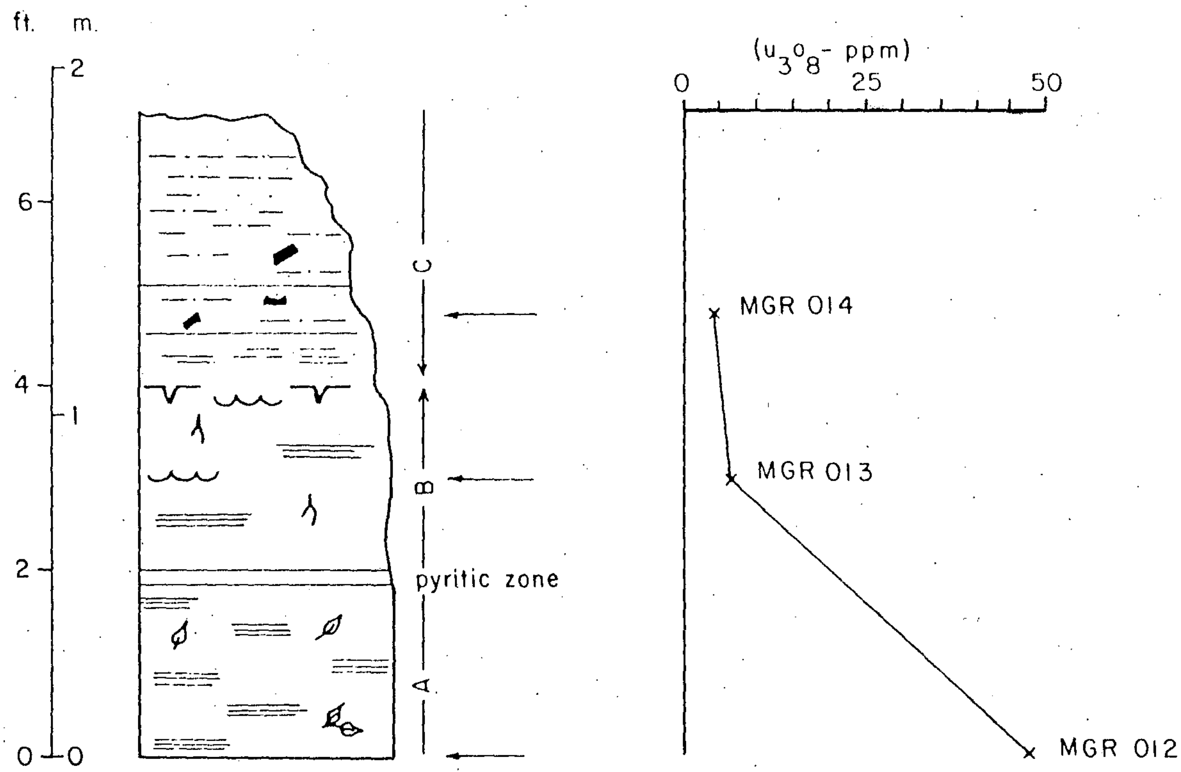
96°00'
32°00'
EXPLANATION
Fluvial
Delta - plain
Delta - front
Pro - delta
Jackson Group
Whitsett
Manning
Wellborn
Cadell
Nash Creek
Yazoo
Moodys - Branch
SHELF
• 37.5 - Location and U_3O_8 concentration for rock sample (ppm)
94°00'
31°00'
96°00'



96°00'
32°00'
EXPLANATION
• 47.5 – Location and U_3O_8 concentration for rock sample (ppm)
94°00'


ALEXANDRIA QUADRANGLE
LAKE CHARLES QUADRANGLE
BEAUMONT QUADRANGLE


PALESTINE QUADRANGLE
BEAUMONT QUADRANGLE
ALEXANDRIA QUADRANGLE
LAKE CHARLES QUADRANGLE
HARDIN
LIBERTY
MONTGOMERY
HARRIS
CHANNEL FACIES INTERPRETED AT OUTCROP
CATAHOULA OUTCROP
WELL CONTROL



ft.
m.
2
6
4
1
2
0
0
C
B
A
pyritic zone
(u_3o_8- ppm)
0
25
50
MGR 014
MGR 013
MGR 012