DESCRIPTION AND INTERPRETATION OF TEST CORES - BROOKS AND ADJACENT COUNTIES, SOUTH TEXAS

by

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CONTENTS

Figures

Tables

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INTRODUCTION

This report reviews the results of an examination of approximately 700 feet of core collected during a regional drilling program conducted under the National Uranium Resource Evaluation Program. Location of cored test borings is shown in Figure 1. Core depths ranged from 380 to 2905 feet, and included portions of the Catahoula (Oligocene), Oakville/Fleming (Miocene) and Goliad (Pliocene) Formations, all of which are significant uranium hosts in the South Texas Uranium Province.

Objectives of the examination included:

1. Description and interpretation of sedimentologic features.
2. Description and interpretation of alteration facies.
3. Mineralogic analysis of selected representative samples.
4. Correlation of drill logs and core intervals within the framework developed in the course of regional stratigraphic studies.
5. Geochemical analysis of selected samples to assess alteration mineralogy and trace metals content.

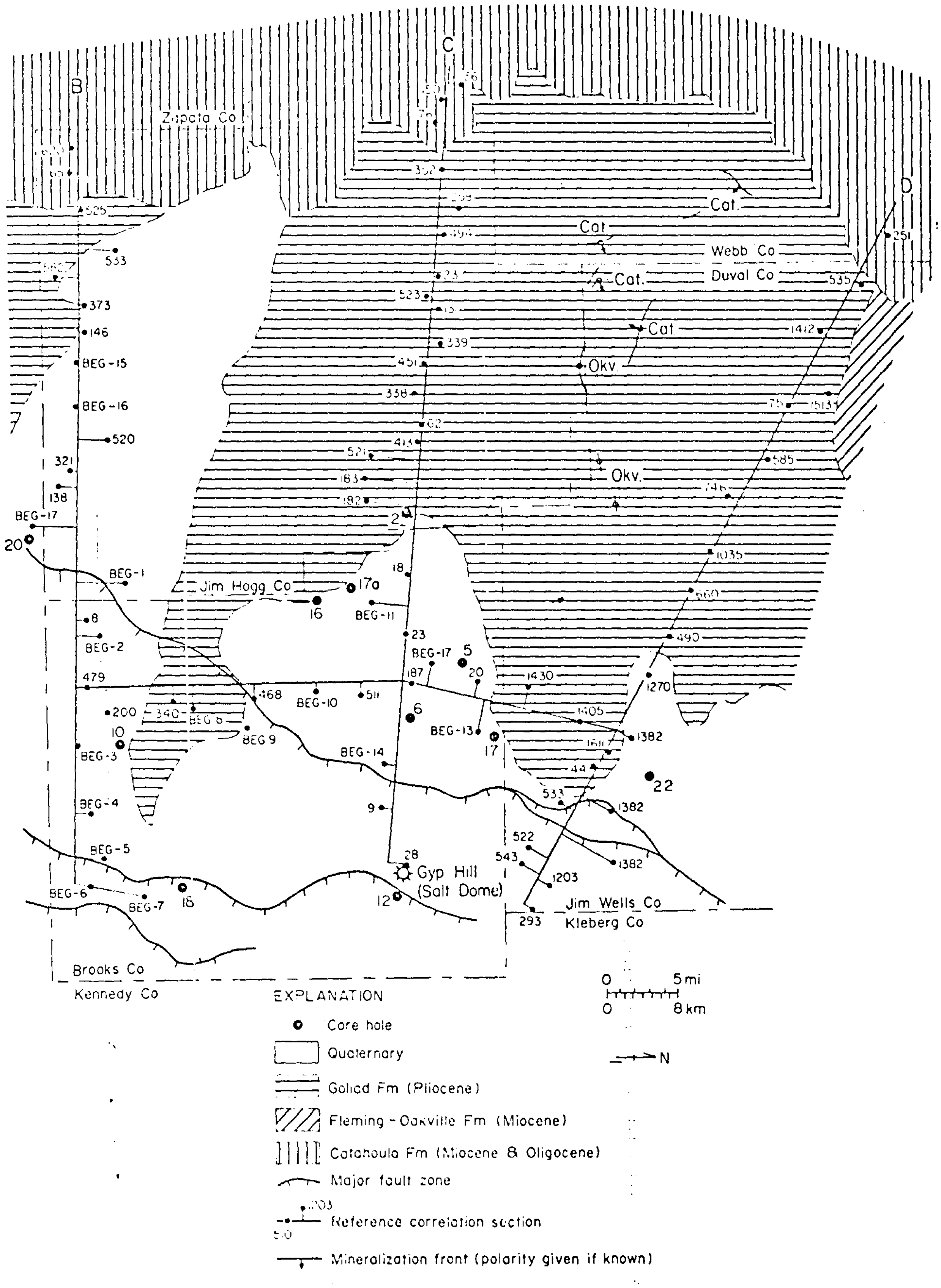


Figure 1. Index map showing location of core holes with respect to major structural features, reference correlation sections, known uranium deposits, and mapped outcrop patterns.

CORE DESCRIPTION AND CORRELATION

Regional correlation sections (on open file at the Bureau of Economic Geology) were augmented with additional strike cross sections constructed using petroleum logs (figure 1). Petroleum wells closely adjacent to each core hole were used to establish correlations within the regional framework developed in earlier stratigraphic studies (Galloway, 1977; Galloway and others, in press). Resultant formation tops are shown in table 1. Depth intervals for cores, and the formation sampled, are also shown in the table. Individual summary core lithologic descriptions are reproduced as table 2. Original core description forms, which include information on lithologic sequence, bed contact types, primary sedimentary structures, descriptive alteration characteristics, color (based on the G.S.A. color chart), cements, estimated porosity and permeability, and notes on minor components or other attributes, are included in Appendix A.

Composition of cores ranged from cobble conglomerate to mudstone, micritic limestone, and bedded gypsum. Muddy sandstone to sandy mudstone constitute the principal lithologies in most cores. Mudstones are characterized by massive, churned, root or burrow-disturbed textures. Most sands contain considerable detrital, mechanically infiltrated, and authigenic clay and micritic carbonate cement.

Alteration Facies

The geochemistry, mineralogy, geometry, and internal zonation of both oxidizing and reducing alteration events that are preserved within the South Texas uranium-bearing aquifers record the successive flushing by ground waters

Table 1. Summary of formation tops based on correlations with Bureau of Economic Geology regional sections and interpreted depositional and alteration facies for described core intervals.

Well No.	Formation Tops (log depth, ft) Goliad	Fleming	Oakville	Catahoula	Core Interpretations Core Interval (ft)	Formation BEG (Bendix)	Depositional Facies	Alteration
2		440	1226	2200	380-425	Goliad-Fleming	Eolian and/or floodplain; paleosoil horizons	Dominantly syndepositional oxidation with some epigenetic (?) oxidation
					1170-1182	Fleming (Oakville)	Bedload alluvial channel fill	Weak epigenetic oxidation
					2883-2905	Catahoula	Bedload alluvial channel fill	Weak epigenetic oxidation
5		620	1538	2406	No core	recovered		
6		640	1530		600-640	Goliad	Floodplain and crevasse splay	Syndepositional oxidation
					2220-2317	Oakville	Crevasse splay or minor tributary	Syndepositional oxidation
10		880	1782		947-990	Fleming (Goliad)	Crevasse splay or ephemeral flood run off channel	Weak reduction alternating with weak epigenetic oxidation
					2493-2523	Oakville	Floodplain and crevasse splays (?)	Sands-weak epigenetic (?) oxidation Mud/silt-weak syndepositional oxidation

Table 1. (continued)

Well	Formation Tops (log depth, ft)				Core Interpretations			
No.	Goliad	Fleming	Oakville	Catahoula	Core Interval (ft)	Formation BEG (Bendix)	Depositional Facies	Alteration
12		920	2040		795-851	Goliad	Floodplain with possible eolian units	Epigenetic sulfidic reduction
					2755-2766	Oakville	Lake basin/local pond	Sulfidic reduction
					2810-2817	Oakville	Floodplain	Syndepositional oxidation
16		564	1400		2020-2040	Oakville (Catahoula)	Floodplain mudstone	Syndepositional oxidation
					2080-2133	Oakville (Catahoula)	Channel fill sequence grading up into overbank, levee and/or crevasse splay deposits	Sulfidic (top) to gley reduction (base)
17		612	1540		2140-2241	Oakville (Oakville-Catahoula)	Channel fill overlying floodplain/crevasse splay deposits	Probable weak epigenetic oxidation within syndepositionally oxidized finer-grained sediments
17A		586			614-700	Fleming	Floodplain sequence including possible shallow pond/lake beds and paleosoil horizons	Syndepositional oxidation with thin zone of early sulfidic reduction (670-672') related to former presence of plant debris and some bounding epigenetic oxidation

Table 1. (continued)

Well	Formation Tops (log depth, ft)				Core Interpretations			
No.	Goliad	Fleming	Oakville	Catahoula	Core Interval (ft)	Formation BEG (Bendix)	Depositional Facies	Alteration
18		860	2470		750-806½	Goliad	Coastal playa lake	Slightly sulfidic to gley reduction
					2700-2737½	Oakville	Nondiagnostic-possible major channel fill	Syndepositional oxidation
20		440	1215		750-850	Fleming	Thin channel fill and crevasse splay sandstone overlying muddy flood plain with distal splay/eolian sandstone	Syndepositional oxidation and possible minor epigenetic oxidation
22		660	1680	2294	620-660	Goliad (Goliad-Fleming)	Fine grained flood plain and distal splay sequence	Dominantly syndepositional oxidation
					2420-2478	Catahoula (Oakville)	Splay and flood plain deposits overlying fluvial channel fill	Sulfidic reduction with basal gley reduction

Table 2.

CORE SUMMARY INTERPRETATION

WELL OG-2

DEPTH INTERVAL 380-480

FORMATION (BEG) 380-440 Goliad 440-480 Fleming

(Bendix) 380-432 Goliad 432-480 Fleming

GEOCHEMICAL SAMPLE(S) 410

THIN SECTION(S) 410

LITHOLOGY: Goliad: Very fine to fine sandstone with interspersed clay mottles.

Fleming: Basal 24 feet of siltstone overlain by clay/mudstone. Siltstone contain clay mottles, caliche mottles, caliche zone, and organics. Mudstone contains minor organics.

DEPOSITIONAL ENVIRONMENT(S):

Floodplain muds and paleosoil (Fleming) overlain by floodplain muddy sand and silt (Goliad). Intense root and animal bioturbation and syndepositional oxidation reflect an inter-channel floodplain setting for both units.

ALTERATION:

Goliad: Mixed syndepositional and some epigenetic (?) oxidation

Fleming: Syndepositional oxidation

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL OG-2

DEPTH INTERVAL 1170-1182

FORMATION (BEG) Fleming

(Bendix) Oakville

GEOCHEMICAL SAMPLE(S) 1175

THIN SECTION(S) 1175

LITHOLOGY: Basal 6½ feet of conglomerate overlain by sandstone and clay-rich sandstone. Basal conglomerate composed of unsorted clasts ¼ inch to 5 inch diameter of chert and quartzite in a fine sand/siltstone matrix. Sandstone fines upward from slightly conglomeratic medium sandstone to fine sandstone. Clay-rich sandstone contains limonitic clay clasts and oxidized plain stems.

DEPOSITIONAL ENVIRONMENT(S):

Upper portion of bed-load alluvial channel fill.

ALTERATION:

Weak epigenetic oxidation with top 2 feet of clay-rich sand showing strong epigenetic (?) oxidation.

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL OG-2

DEPTH INTERVAL 2883-2905

FORMATION (BEG) Catahoula (Soledad Member)

(Bendix) Catahoula (Soledad Member)

GEOCHEMICAL SAMPLE(S) 2890

THIN SECTION(S) 2890

LITHOLOGY: Basal 5 feet of conglomerate overlain by fine sandstone with minor stringers of fine conglomerate. Basal conglomerate composed of rounded clasts ¼ inch to 4 inches in diameter of chert and volcanic rock in a fine sandstone matrix. Sandstone is crossbedded and reflects lithotypes present in basal conglomerate. Minor green (reduced) clay blebs and organic matter occur near top of section.

DEPOSITIONAL ENVIRONMENT(S):

Upper portion of bed-load alluvial channel fill. Well location lies in a major sand belt near the axis of the Gueydan (Catahoula) fluvial system.

ALTERATION:

Weak epigenetic oxidation. Gray tint due to abundance of detrital rock fragments.

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 6

DEPTH INTERVAL 600-609; 620-636

FORMATION (BEG) Fleming

(Bendix) Goliad

GEOCHEMICAL SAMPLE(S) --

THIN SECTION(S) --

LITHOLOGY:

Interbedded siltstone and claystone overlain by medium to fine sandstone. Siltstone is clay rich and churned. Claystone is churned and contains fine sand and silt grains along fractures. Sandstone contains hematite, magnetite, and rounded to irregular shaped clay clasts ¼ inch to 1 inch in diameter.

DEPOSITIONAL ENVIRONMENT(S):

Floodplain grading up into crevasse splay deposits. Fine, churned, oxidized sediments typify floodplain sequence. More abundant sand in fining-up sequences with mud clasts and ripple lamination suggest influx of sediment during flood events.

ALTERATION:

Syndepositional oxidation

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 6

DEPTH INTERVAL 2220-2222; 2260-2273; 2277-2317

FORMATION (BEG) Oakville

(Bendix) Oakville

GEOCHEMICAL SAMPLE(S) 2299

THIN SECTION(S) 2299

LITHOLOGY: Alternate beds of medium to fine sandstone, clay-rich siltstone and claystone. Sandstone contains hematite grains, limonite grains, and rounded clay clast stringers. Siltstone contains some clay matrix, possible laminations and caliche blebs. Claystone contains caliche clasts, contorted to broken lamina (ripup clasts?) and burrows. Sequences tend to fine upward.

DEPOSITIONAL ENVIRONMENT(S):

Crevasse splay or minor tributary deposits. Diagnostic features include alternating lithologies, fine grain sizes, numerous zones of mudclasts, pedogenic caliche nodules, and limited root mottling. Core lies within the downdip extent of the Hebbronville (Oakville) fluvial axis.

ALTERATION:

Syndepositional ozidation

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 10

DEPTH INTERVAL 947-990

FORMATION (BEG) Fleming

(Bendix) Goliad

GEOCHEMICAL SAMPLE(S)

THIN SECTION(S)

LITHOLOGY: Sequence of thin bedded, alternating medium to very fine sandstone, siltstone, and claystone overlain by massive, very fine sandstone. Sandstone contains mud clasts 1 inch in diameter, some silt in matrix, out of phase climbing ripples and micrograding. Siltstone is cross laminated. Claystone is silty and contains hematite, magnetite, and clay intraclasts resulting from burrowing and/or current rip-up. The massively bedded very fine sand contains silt, thin mottles of light brown clay, and clay clasts up to 1 inch in diameter.

DEPOSITIONAL ENVIRONMENT(S):

Splay or ephemeral flood run-off channel. Diagnostic features include alternation and micro-grading of fine and coarse grain sizes, multiple zones of rip-up clasts, biogenic churning, and small-scale structures.

ALTERATION:

Weak reduction alternating with weak epigenetic oxidation

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 10

DEPTH INTERVAL 2493-2533

FORMATION (BEG) Oakville

(Bendix) Oakville

GEOCHEMICAL SAMPLE(S)

THIN SECTION(S)

LITHOLOGY:

Siltstone overlain by a thin (<6 inch) layer of claystone and capped by medium to fine silty sandstone. Siltstone contains clay matrix and is churned. Claystone contains small gypsum crystals and rare pyrite. Sandstone is unsorted and contains magnetite drapes over current ripples and possible burrows.

DEPOSITIONAL ENVIRONMENT(S):

Possible playa floodplain facies with splay sands. Core recovery insufficient for detailed interpretation.

ALTERATION:

Sands - weak epigenetic (?) oxidation
Mud and siltstone - weak syndepositional oxidation

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 12

DEPTH INTERVAL 795-851

FORMATION (BEG) Goliad

(Bendix) Goliad

GEOCHEMICAL SAMPLE(S) 800, 831, 846

THIN SECTION(S) 800, 831, 846

LITHOLOGY: Interbedded fine to very fine sandstone with siltstone (beds approximately 7 feet thick). Minor beds of claystone present. Sandstone has silt/clay-rich matrix and contains pyrite. Siltstone has clay-rich matrix and contains pyrite. It is occasionally cross laminated and/or rippled. Claystone contains abundant microcrystals of pyrite.

DEPOSITIONAL ENVIRONMENT(S):

Floodplain, possible aeolian units?

ALTERATION:

Epigenetic sulfidic

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 12

DEPTH INTERVAL 2755-2766; 2810-2817

FORMATION (BEG) Oakville

(Bendix) Oakville

GEOCHEMICAL SAMPLE(S)

THIN SECTION(S)

LITHOLOGY:

Shallow core - Highly churned claystone.

Deeper core - Clay-rich siltstone overlain by very fine sandstone. Siltstone contains pyrite. Sandstone is cross laminated and contains distinct horizontal burrows and pyrite.

DEPOSITIONAL ENVIRONMENT(S):

Shallow core - Floodplain

Deeper core - Possible lake basin or local pond. Sandstone with distinct burrows overlying clay is suggestive, as is the thin, coarsening-upward cycle observed on the log.

ALTERATION:

Shallow core - Syndepositional oxidation

Deeper core - Epigenetic sulfidic reduction

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 16

DEPTH INTERVAL 2020 - 2040

FORMATION (BEG) basal Oakville

(Bendix) Catahoula

GEOCHEMICAL SAMPLE(S)

THIN SECTION(S)

LITHOLOGY:

Claystone with indistinct burrows and rare blebs of reduced clay.

DEPOSITIONAL ENVIRONMENT(S):

Massive floodplain mudstone

ALTERATION:

Syndepositional oxidation

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 16

DEPTH INTERVAL 2080-2133

FORMATION (BEG) basal Oakville

(Bendix) Catahoula

GEOCHEMICAL SAMPLE(S) 2083, 2103, 2130

THIN SECTION(S) 2083, 2103, 2130

LITHOLOGY: Medium sandstone grading upward to very fine sandstone. Overlain by a sequence of interbedded silty sandstone, siltstone, and claystone. Sandstone is cross laminated and becomes clay rich up section. Silty sandstone has a clay matrix and contains magnetite. Up section it becomes pyritic and is interbedded with coaly seams and plant debris. Siltstone contains a clay matrix and reduced clay blebs. Claystone contains sulfide crusts, pyrite and clay clasts approximately 2 inches in diameter.

DEPOSITIONAL ENVIRONMENT(S):
Small channel-fill sequence (~2100) grading up into associated top strata of overbank, levee, and/or splay deposits, which include abundant preserved, carbonaceous plant debris in thin lenses and layers. Interpretation fits best with a correlation as Oakville as core hole lies on the south margin of the coarse, conglomeratic Hebbronville (Oakville) axis. The Gueydan (Catahoula) axis is mapped directly through this location.

ALTERATION:
Sulfidic (top) to gley reduction (bottom)

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 17

DEPTH INTERVAL 2140-2208, 2230-2241

FORMATION (BEG) Oakville

(Bendix) Oakville, Catahoula

GEOCHEMICAL SAMPLE(S) 2153, 2193

THIN SECTION(S) 2153, 2193

LITHOLOGY: Sandy siltstone and mudstone overlain by medium to fine sandstone. Sandy siltstone has a clay matrix and contains abundant clay clasts. Mudstone/claystone is silty and burrowed. Sandstone is parallel to cross laminated and contains wood fragments, caliche clasts, and abundant clay clasts 1 inch to 2 inches in diameter.

DEPOSITIONAL ENVIRONMENT(S):

Thick, well-developed crudely upward-fining coarse mixed load or bed load channel fill overlying oxidized floodplain and splay sequence of silt and mudstone.

ALTERATION:

Probable weak epigenetic oxidation within syndepositionally oxidized finer-grained sediments.

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 17A

DEPTH INTERVAL 614-641, 660-700

FORMATION (BEG) Fleming

(Bendix) ?

GEOCHEMICAL SAMPLE(S) 671, 695

THIN SECTION(S) 671, 695

LITHOLOGY: Massively bedded (10 feet thick) alternations of claystone, fine sandstone and siltstone overlain by paleosoil horizons. Claystone is highly burrowed and contains plant remains, and very minor pyrite. Sandstone is well sorted with a clay matrix. Siltstone has a clay matrix and is highly churned and burrowed. Paleosoil horizons consist of a fining-upward sequence of burrowed, root-mottled sandstone, siltstone with caliche nodules, and churned, root-mottled claystone.

DEPOSITIONAL ENVIRONMENT(S):

Floodplain sequence including possible shallow pond/lake beds (660-690) and paleosoil horizons (635-640).

ALTERATION: Syndepositional oxidation with thin zone of early sulfidic reduction (670-72 feet) related to the former presence of plant debris and some bounding epigenetic oxidation.

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 18

DEPTH INTERVAL 750-766; 770-786, 790-806½

FORMATION (BEG) Goliad

(Bendix) Goliad

GEOCHEMICAL SAMPLE(S) 753, 777, 802

THIN SECTION(S) 753, 777, 802

LITHOLOGY: Thin interbeds of fine sandstone, siltstone, claystone, and gypsum. Gypsum beds predominate in lower 27 feet. Core becomes sandier up section. Sandstone is cross laminated to parallel laminated. Siltstone has a clay matrix and contains floating gypsum crystals $<$ 1/8 to 3/4 inches long, molds of gastropods, pelecypods, ostrocods, and some pyrite. Claystone is terrigenous to micritic. Individual beds range from $\leq$1 to 4 inches and are highly dessicated. Gypsum beds are 1/8 inch thick and exhibit wavy (algal?) laminations.

DEPOSITIONAL ENVIRONMENT(S):

Coastal playa lake. Gypsum (bedded and intrastratal rosettes and laths), micrite, fine scale lamination, abundant dessication cracks, and intraformational rip-up clasts all indicate this unique coastal plain environment.

ALTERATION:

Slightly sulfidic to gley reduction

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 18

DEPTH INTERVAL 2700-2712, 2720-2737½

FORMATION (BEG) Oakville

(Bendix) Oakville

GEOCHEMICAL SAMPLE(S)

THIN SECTION(S)

LITHOLOGY: Fining upward sequence of very fine sandstone, siltstone, and claystone overlain by fine sandstone. Very fine sandstone is well sorted and massive. Siltstone is clay rich and churned. Claystone is sandy and also churned. Overlying fine sandstone contains limonite, hematite, magnetite, and occasional pebbles less than ¼ inch in diameter. The sandstone is cross laminated and rippled.

DEPOSITIONAL ENVIRONMENT(S):

Nondiagnostic - possibly minor channel fill or splay/floodplain sequences.

ALTERATION:

Syndepositional oxidation

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 20

DEPTH INTERVAL 750-758½, 770-775, 790-827, 830-850

FORMATION (BEG) Fleming

(Bendix) Fleming

GEOCHEMICAL SAMPLE(S) 817

THIN SECTION(S) 817

LITHOLOGY: Section dominantly siltstone with occasional interbeds of claystone and minor fine sandstone units. Siltstone is churned and contains clay blebs and plant remains. Claystone is highly churned/burrowed. Sandstone is well sorted and contains floating clay clasts and very minor hematite and magnetite.

DEPOSITIONAL ENVIRONMENT(S):

Thin channel-fill and splay sands overlying a thick sequence of floodplain mud and siltstone with thin distal splay or aeolian sands.

ALTERATION:

Syndepositional oxidation and possible minor epigenetic oxidation.

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 22

DEPTH INTERVAL 620-632, 640-660

FORMATION (BEG) Goliad

(Bendix) Goliad, basal 4 feet top Fleming

GEOCHEMICAL SAMPLE(S) 645

THIN SECTION(S) 645

LITHOLOGY: Interbedded very fine sandstone and siltstone. Sandstone contains cross laminations, possible ripples, interbedded clay drapes 1/8 inch thick. Siltstone is horizontally laminated and contains micrograded beds and occasional clay drapes. Up section the units become churned.

DEPOSITIONAL ENVIRONMENT(S):

Fine-grained floodplain and distal splay sequence.

ALTERATION:

Dominantly syndepositional oxidation

Table 2. (continued)

CORE SUMMARY INTERPRETATION

WELL 22

DEPTH INTERVAL 2420-2456, 2460-2478

FORMATION (BEG) Catahoula

(Bendix) Oakville

GEOCHEMICAL SAMPLE(S) 2435, 2447½, 2470

THIN SECTION(S) 2435, 2447½, 2470

LITHOLOGY: Fine sandstone overlain by interbedded clay-rich sandstone, siltstone, and minor claystone. Sequence is capped by 12 feet of clay-rich siltstone. Fine sandstone is crossbedded and contains pebbles 1 inch in diameter, clay clasts, and pyritized clay drapes. Siltstone contains pyrite nodules. Claystone contains pyritic and other sulfide mineral phases. Overlying clay-rich siltstone contains clay, fine sand grains, and pyrite nodules.

DEPOSITIONAL ENVIRONMENT(S):

Fluvial channel fill (2450-2480) overlain by aggrading splay and floodplain deposits.

ALTERATION:

Sulfidic reduction

derived from different reservoirs. Shmariovich (1973) described and contrasted idealized epigenetic alteration patterns produced by the flux of sulfidic, reducing waters and by oxidizing waters through an aquifer. Not all of the geochemical zones described by Shmariovich are recognized in upper Tertiary sediments of South Texas; however, analogous epigenetic reduction and oxidation events are apparent (figure 2), and include syndepositional oxidation, epigenetic oxidation, and epigenetic sulfidization.

Syndepositional oxidation is characterized by hematitic alteration of iron minerals. Presence of hematite implies either long-term, kinetically slow dehydration of original ferric oxyhydroxides formed by oxidation and hydrolysis of ferrous iron minerals in water-saturated media, or rapid dehydration due to periodic desiccation at warm temperatures (Langmuir, 1971). Indeed, features of many hematitic samples are suggestive paleosoil formation under subarid conditions. Hematitic alteration is commonly described as "primary oxidation" by geologists working in the South Texas uranium province. The implication that much of the Catahoula through Goliad is therefore a primary red-bed sequence is confirmed by core and sample examination. Fluvial deposits of the Catahoula, Oakville, and Goliad Formations appear to have been thoroughly oxidized and dehydrated by syndepositional and earliest diagenetic processes.

Epigenetic oxidation is defined by limonitic alteration of iron minerals. Presence of ferric oxyhydroxides indicates comparative youth relative to hematitic oxidation. Two variations are recognized. Phreatic oxidation occurs above the modern water table in shallowest, outcropping portions of each unit. More extensive tongues of limonitic alteration extend far below the water table into permeable sands. Epigenetic oxidation necessitates a pre-existing reducing rock matrix.

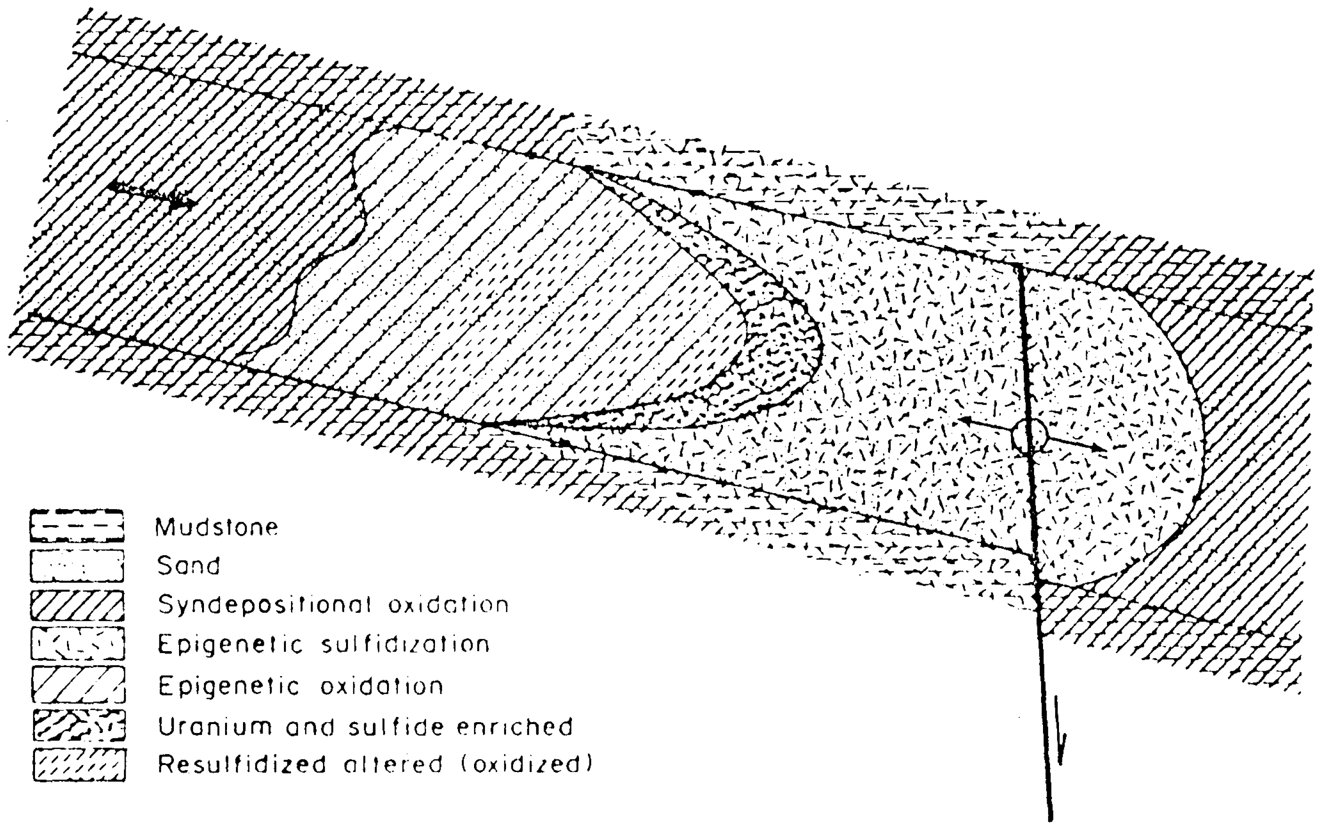


Figure 2. Diagrammatic alteration zonation produced by successive episodes of epigenetic sulfidic reduction, punctuated by mineralizing epigenetic oxidation within a syndepositionally oxidized aquifer.

Epigenetic sulfidization is recognized by the presence of well crystallized to finely dispersed iron disulfide (primarily pyrite) and consequent gray color imparted to the rock matrix. Reduction of the South Texas fluvial aquifers appears to be characterized by importation of additional sulfide. Gley (sulfide-deficient) alteration, though present, appears to be comparatively minor. Spatial distribution relative to mineralization fronts (figure 2) as well as detailed mineralogy of the sulfide phases indicates regional epigenetic sulfidization may be superimposed on both syndepositionally and epigenetically oxidized ground (Goldhaber and others, 1979a; Galloway and others, in press). The latter situation, which is a common attribute of many South Texas uranium deposits, is commonly called "rereduction".

INTERPRETED DEPOSITIONAL AND ALTERATION FACIES

Specific depositional environments, which could be interpreted with reasonable certainty by comparison of composition, bedding, and primary structures with previously studied mine or outcrop exposures of equivalent strata, have been interpreted and are listed in table 1. All cores, with the possible exception of 18:750-806, record depositional sequences typical of an arid to subarid coastal plain fluvial system. Common facies include floodplain mudstone and interspersed paleosoil horizons, sandy to silty crevasse splays deposited marginal to main fluvial channels, possible small tributary stream deposits, and bed-load to mixed-load channel fill sandstone and conglomerate. Minor facies include possible eolian fine sand and siltstone and interchannel lake or pond mud and claystone. The shallow Goliad core in well 18 may be interpreted as either an inland or coastal (marine-influenced) hypersaline playa sequence. In either case, the occurrence of significant bedded gypsum in the upper Tertiary of South Texas has not previously been documented.

Catahoula Formation

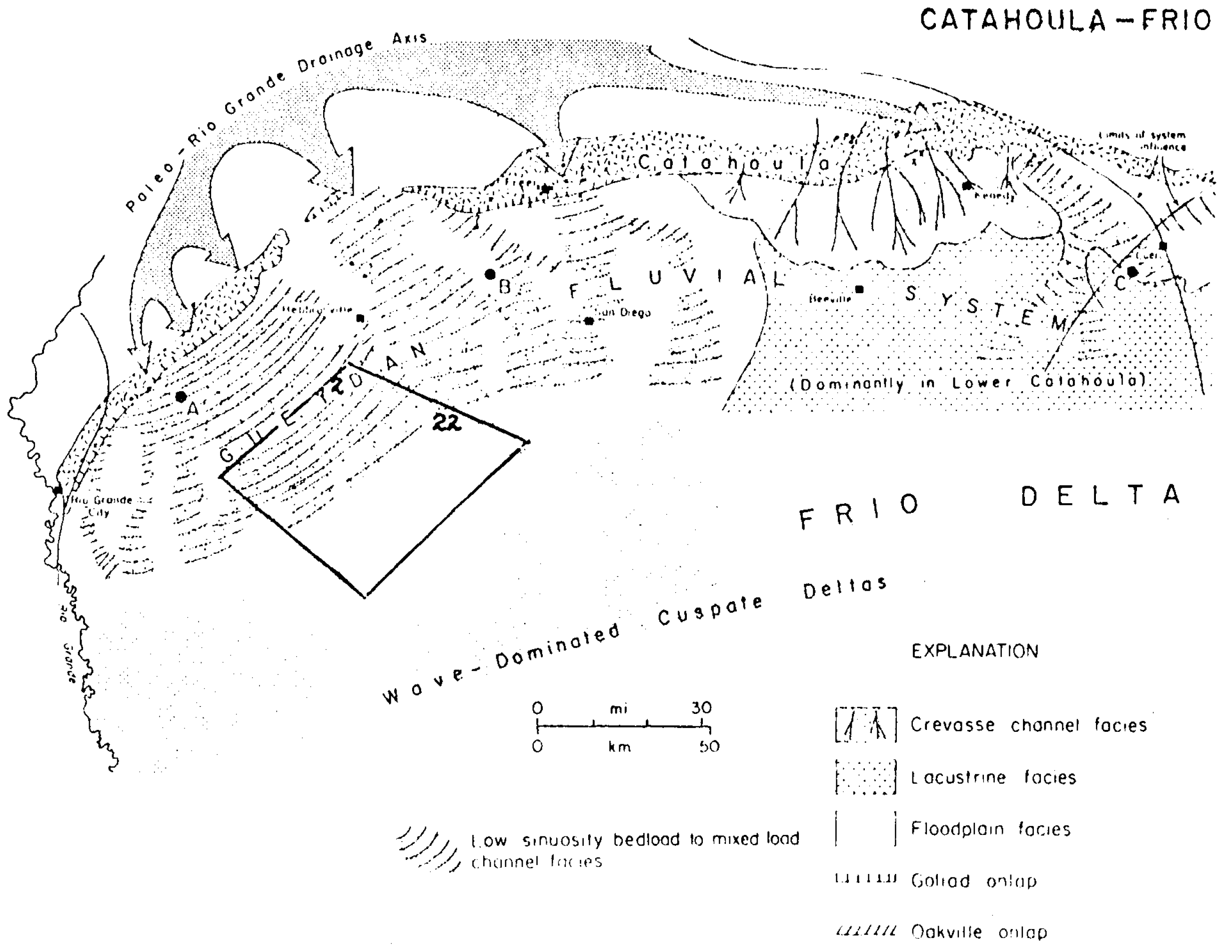
The Catahoula Formation of the study area consists of deposits of the Gueydan fluvial system, a major bed-load fluvial system that drained along the axis of the Rio Grande embayment (Galloway, 1977). Two cores are interpreted to have sampled Catahoula deposits (figure 3; table 1). Well 2 penetrated 22 feet of conglomeratic fine to medium sandstone deposited as part of a bed-load channel fill sequence. Rounded volcanic clasts are typical of the Gueydan system. Their presence in this core indicates that coarse fluvial facies, typical of major uranium mineralization districts, persist to considerable depth along the axis of the Gueydan system (figure 3). Well 22 penetrated 58 feet of floodplain and splay deposits grading at their base into possible channel-fill coarse sandstone.

Compositionally, the Catahoula sands are plagioclase and volcanic rock fragment-rich litharenites typical of the Gueydan system (figure 4; Appendix B).

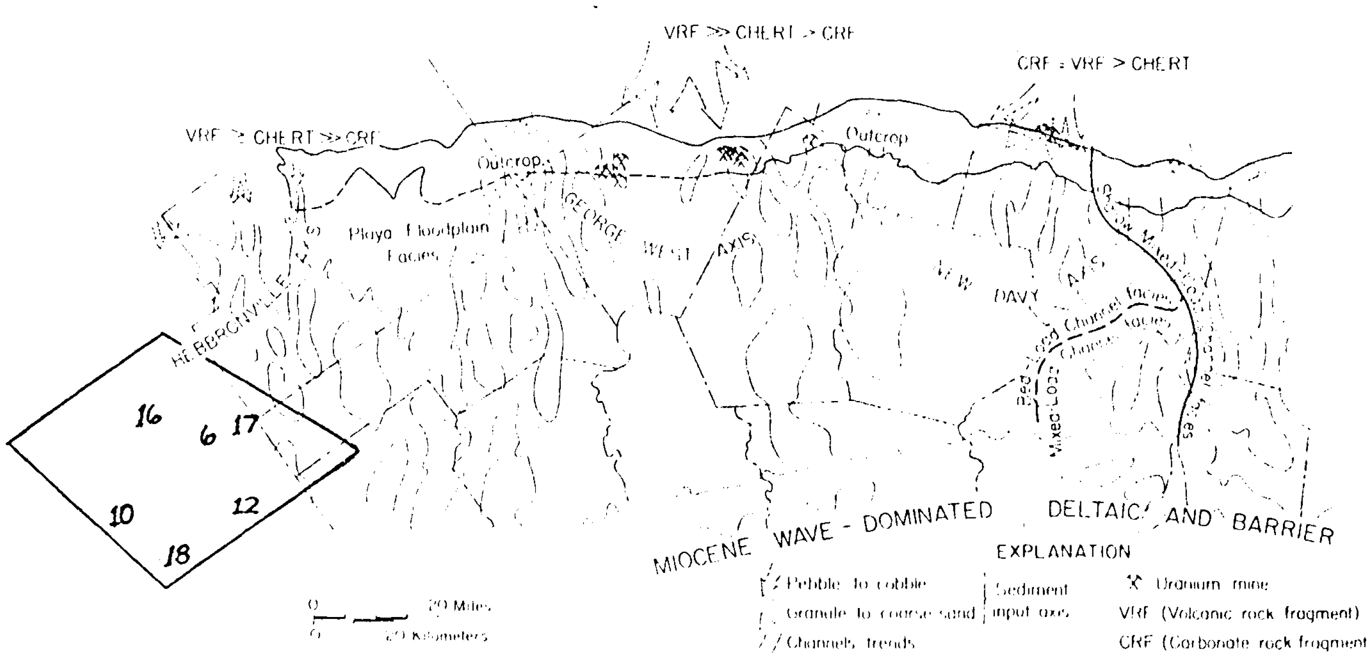
Alteration facies include weak epigenetic oxidation in well 2, and well-developed sulfidic epigenetic reduction in well 22. The strong reduction lies approximately 4 miles updip of the Vicksburg Flexure, a major regional growth fault system.

Oakville/Fleming Formation

The Oakville Formation was sampled by eight cores in six different wells (table 1). Four cores in four wells are sufficiently shallow to be correlated with the Fleming. As noted in earlier work, however, the boundary between the Oakville and Fleming is often rather arbitrary. The core sites lie within and



A.



B. Figure 3. Approximate location of study area, and appropriate core holes relative to major depositional elements of the Catahoula Gueydan (A) and Oakville (B) fluvial systems. Core holes lie within or marginal to highly favorable bed-load fluvial belts.

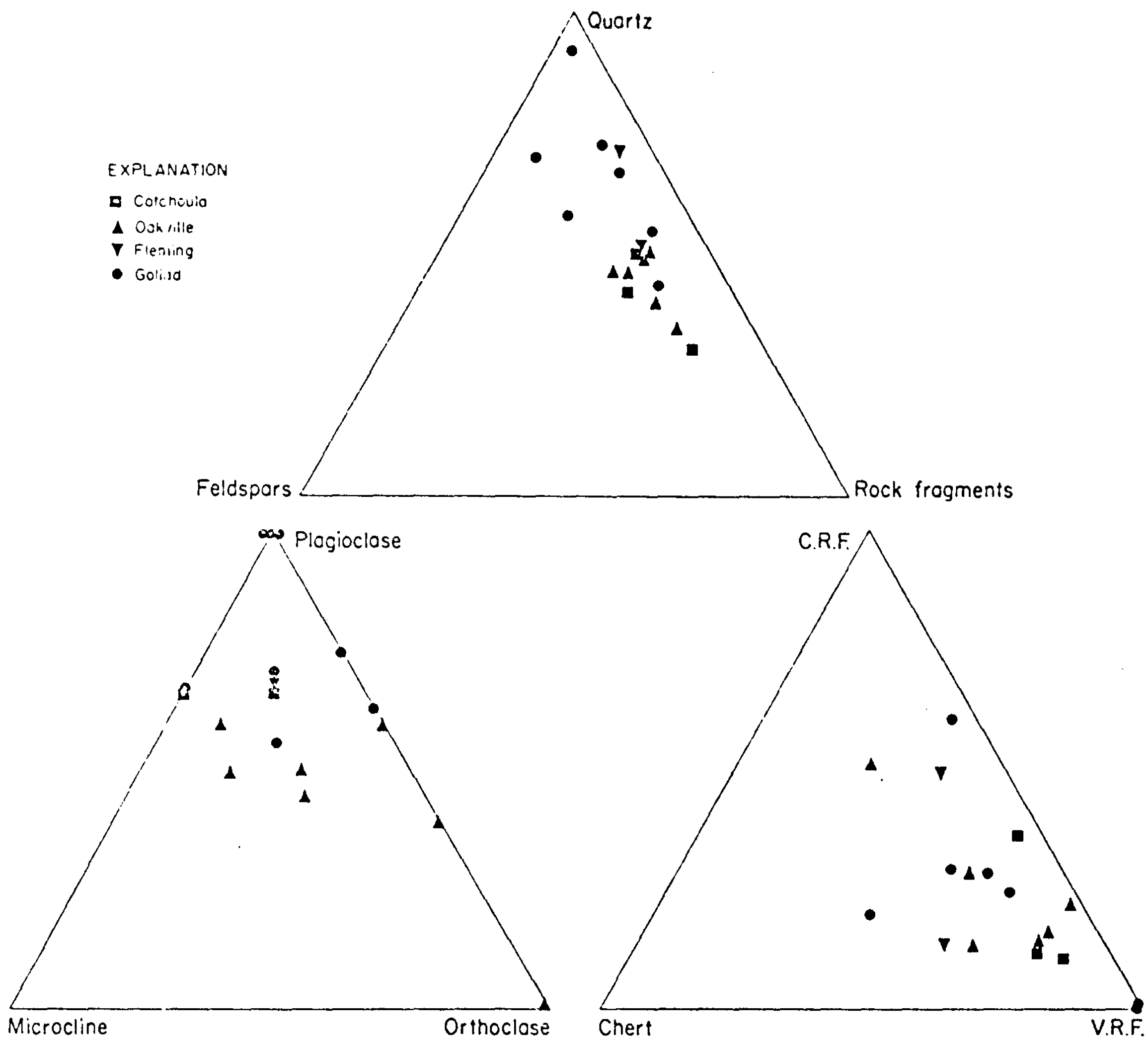


Figure 4. Sand composition plots of selected representative core samples. C.R.F. = carbonate rock fragments. V.R.F. = volcanic rock fragments.

along the southern margin of the Hebbronville fluvial axis of the Oakville system (figure 3) as outlined by Galloway and others (in press). Unpublished mapping suggests that this fluvial axis persists vertically into the Fleming, though it is less well-defined, and mapping does not extend south of Duval County.

Cores 16:2020-2133 and 17:2140-2241 display well-developed fluvial channel fill sequences consisting of medium to fine sandstone containing common zones of mudclasts and small pebbles. Replaced or carbonaceous plant debris also occurs in this facies. Sandstones are cross bedded, and a crude fining-upward sequence is indicated. Channel fill units are surrounded by massive to bedded, commonly highly leached and oxidized floodplain, levee, and crevasse splay mudstone, siltstone, and sandstone. Sequences resemble those of the better documented Oakville George West fluvial axis; however, analogous coarse conglomeratic and sand-rich channel fill sequences that core the updip portions of the George West trend are not present within the cores. Their presence is inferred updip, and they may also extend through the study area along thickest channel axes.

Fleming cores are characteristically finer grained sequences containing a variety of features, including zones of intense root mottling, dessication cracks, burrowing, and churned, pedal (soil-like) structures indicative of floodplain, intermittent pond, and splay deposition punctuated by paleosoil development. Core 2:425-480 contains two such paleosoils. Cores 17A:660-700 displays burrowed mudstone containing leaf imprints suggestive of pond deposition. Presence of local, coarse channel-fill units is suggested by core 2:1170-1182, which contains 12 feet of conglomerate with a fine sandy to silty matrix. Plant or leaf debris or oxidized imprints are common to most of the sequences.

Oakville and Fleming sandstones are characteristically smectitic plagioclase-bearing volcanic litharenites and are compositionally similar to Oakville sandstones of the George West fluvial axis (Galloway and others, in press). Carbonate rock fragments and micritic (caliche?) cement are ubiquitous. Minor authigenic and infiltrated clay permeates most sands, particularly those of floodplain and splay origin. Permeabilities can, however, be quite high.

Fine-grained facies commonly display intense syndepositional oxidation, broken locally by thin reduced plant debris-bearing zones containing early diagenetic sulfide that may be partially epigenetically oxidized (table 1). Several sandier intervals are characterized by light yellow to brown colors suggestive of weak epigenetic oxidation, which would imply earlier more extensive development of epigenetic sulfidic alteration. Cores from wells 12 and 16 retain good intervals of sulfidic reduction. Core 16 lies almost 10 miles from major faulting; 12 is near Gyp Hill salt dome.

Goliad Formation

Although a regional stratigraphic study of the Goliad is incomplete, preliminary data, published maps (Brogdon and others, 1977) and similarities with underlying fluvial sequences provide a basis for interpretation of cores. In all, five cores from five of the test wells contain strata correlated with the Goliad Formation. Although the Goliad appears very sand-rich on electrical logs, all of the cores contain fine-grained floodplain, possible eolian, and playa facies interbedded with thin, probably local channel fill and splay deposits (table 1). If the cores are representative, the Goliad of the Brooks County area may lie marginal to principal, coarser fluvial axes that typically support larger scale mineralization in the underlying Oakville and Catahoula Formations. The unique bedded gypsum and fossiliferous micritic limestone facies penetrated by core 18:750-806 supports the interpreted trend (possibly interrupted during Fleming deposition) of increasing aridity in South Texas in latest Tertiary time. The facies penetrated are directly analogous, both compositionally and in terms of primary structures, to those forming today in broad exposed wind tidal flats of Laguna Madre (Fisk, 1959). However, extrapolation of Goliad environments defined by Solis (1980) indicates the core location to be far inland of marine influenced facies. Similar gypsiferous facies form in playas (Hardie and others, 1978) suggesting a probable alternative interpretation.

In part because of finer grain size, Goliad arenites are more quartz rich than the older sandstones (figure 4). Quartz content may also be increased by carbonate replacement of the accessory feldspar and rock fragments. Carbonate cement and micritic mud matrix are particularly abundant within Goliad samples.

Goliad cores are dominated by syndepositional oxidation as would be expected of floodplain and eolian sequences. Pervasive sulfidic reduction occurs in core 12:795-851 (located near Gyp Hill), and weakly sulfidic to gley-type early diagenetic reduction typifies the gypsiferous playa sequence penetrated by well 18.

IMPLICATIONS FOR MINERALIZATION POTENTIAL

In addition to interpreted alteration and depositional facies, geochemical analyses of selected samples (Appendix C) combined with indicated radioactivity anomalies provide the basis for evaluating the overall mineralization potential of the study area.

Regional facies mapping shows Brooks County and environs to lie within or adjacent to major Oakville and Catahoula fluvial axes. Potential host fluvial facies are also present in the Fleming. Cored sequences are analogous to facies that are productive to the north in Duval (figure 1) and Live Oak Counties. Cores of Goliad are equivocal; a regional stratigraphic study is in progress.

Alteration facies include the areal and stratigraphic mix of syndepositional oxidation, epigenetic sulfidic reduction, and epigenetic oxidation zones that typify uranium mineralization in Catahoula and younger hosts of the South Texas uranium province (Goldhaber and others, 1978; Galloway, in press). Most sediments, particularly fine-grained overbank deposits were thoroughly oxidized soon after deposition, though a few pockets of syngenetic reduction produced by carbonaceous trash (core 17A, Fleming; core 16, Oakville,; core 2, Catahoula) or local playa sedimentation (core 18, Goliad) survived. Epigenetic sulfidization, resulting in pyrite formation, reduced large islands of Catahoula (core 22), Oakville (core 16) and Goliad (core 12) sandstones. Strong sulfidic reduction occurs near and some miles from major structural features. Several cores exhibit a weak limonitic color suggesting periods of post-sulfidization epigenetic oxidation, which is necessary for development of a roll front. Limonitic oxidation of detrital organic material (core 20, Fleming Formation) is good evidence for postdepositional intrusion of potentially mineralizing, oxidizing waters.

Two samples produced significant trace metal anomalies. Weakly radioactive carbonaceous sand and mud at the top of an Oakville channel fill (core 16) contained 29 and 262 ppm of Mo and As, respectively. These metals are commonly associated with uranium, and along with possible trace uranium (below detection limits of the ICP method) are strongly indicative of passage of mineralizing ground waters through a dominantly oxidized sand before final epigenetic sulfidization. A more unusual Cu, V, Zn, Pb, Li, Sr anomaly occurs in a thin lens of sulfide-replaced plant debris within oxidized, floodplain or lacustrine Fleming mudstone (core 17A). Weak to moderate radioactivity anomalies, noted on the gamma ray logs, occur in all drilled formations, including the Fleming. Radioactivity anomalies are noted in table 3.

Using the criteria discussed in Galloway (1977, p. 47) mineralization potential of the study area for each formation is assessed as follows:

Catahoula Formation - moderate to high potential for development of medium to large (10^6 to 10^7 lbs U_3O_8 reserve) deposits.

Oakville Formation - moderate to high potential for development of medium (10^6 lbs U_3O_8 reserves) deposits.

Fleming Formation - low to moderate potential for development of small to medium (10^5 to 10^6 lbs U_3O_8 reserves) deposits.

Goliad Formation - moderate potential for development of small to medium (10^5 to 10^6 lbs U_3O_8 reserves) deposits.

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Table 3: Radioactivity anomalies indicated by natural gamma-ray logs.

Well No.	Stratigraphic Position
2	Weak basal Oakville anomaly Strong upper Catahoula anomaly
5	Weak basal Oakville and Catahoula anomalies
6	Weak basal Oakville anomalies
10	Fleming and upper Catahoula anomalies
12	Very weak Fleming anomaly
16	Multiple Fleming anomalies Weak anomaly at top of Oakville channel fill; corresponds to As and Mo anomalies
17	Goliad anomaly
17A	Very weak anomaly in Goliad playa sequence
18	Weak anomaly in Goliad playa sequence
20	Weak Goliad anomaly Numerous upper Oakville and one lower Oakville anomalies
22	Goliad anomaly Upper Oakville anomaly

REFERENCES

Brogdon, L. D., Jones, C. A., and Quick, J. V., 1977, Uranium favorability by lithofacies analysis, Oakville and Goliad Formations, South Texas: Gulf Coast Association of Geological Societies Transactions, v. 27, p. 32-40.

Fisk, H. N., 1959, Padre Island and the Laguna Madre flats, coastal South Texas: Second Coastal Geography Conference, Coastal Studies Institute, Louisiana State University, p. 103-152.

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 87, 59 p.

Galloway, W. E., in press, Fluid flow histories and resultant epigenetic zonation of uranium-bearing fluvial aquifer systems, South Texas Uranium Province: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations.

Galloway, W. E., Henry, C. D., and Smith, G. E., in press, Depositional framework, hydrostratigraphy and uranium mineralization of the Oakville Sandstone (Miocene), Texas Coastal Plain: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations.

Goldhaber, M. B., Reynolds, R. L., and Rye, R. O., 1978, Origin of a South Texas roll-type uranium deposit: II. Petrology and sulfur isotope studies: Economic Geology, v. 73, no. 8, p. 1690-1705.

Goldhaber, M. B., Reynolds, R. L., and Rye, R. O., 1979, Formation and resulfidization of a South Texas roll-type uranium deposit: U.S. Geological Survey Open-File Report 79-1651, 41 p.

Hardie, L. A., Smoot, J. P., and Eugster, H. P., 1978, Saline lakes and their deposits: a sedimentological approach, in Modern and ancient lake sediments: International Association of Sedimentologists Special Publication No. 2, p. 7-42.

Langmuir, Donald, 1971, Particle size effect on the reaction goethite = hematite + water: American Journal of Science, v. 271, p. 147-156.

Shmariovich, Y. M., 1973, Identification of epigenetic oxidation and reduction as impositions on sedimentary rock: International Geology Review, v. 15, no. 11, p. 1333-1340.

Solis, R. F., 1980, Late Tertiary and Quaternary depositional systems in the subsurface of Central Coastal Texas: The University of Texas at Austin, Ph.D. dissertation, 155 p.

APPENDIX A

Core description work forms in back pocket.

LOGGING SYMBOLS

LITHOLOGY

	conglomerate
	sand
	silt
	claystone/mudstone
	caliche hardground or paleosoil
GGG	bedded gypsum/anhydrite

CONTACT

S	sharp
G	gradational
IR	irregular
?	unknown due to core break or missing interval

CEMENT

	calcite, calcareous
CLAY	clay: diagenetic and/or depositional
Q	quartz

STRUCTURES

	planer crossbeds
	trough crossbeds
	parallel laminations
	parallel wavey laminations
	cross laminations
	ripples
CH	churned or contorted/mottled bedding possibly due to burrowing or plant roots
CH	as above, indistinct
OR	burrow
	root, rootlet
	leaves
	stems & wood fragments (plant)
	clasts, usually composed of clay
	gypsum crystals
	graded bedding and/or micro-graded laminations
UUU	dessication marks
	dewatering structures (contorted bedding)
	solution cavity with breccia

APPENDIX B

Petrographic work sheets.

Sample No. G2-410 Section: 440-425

Formation: Goliad Environment: floodplain

Rock name: very fine sand: submature, organic, calcareous, argillaceous litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
1%	22%	5%	1%	few rare grains seen <1%	chlorite present on some altered grains (VRF)
Musc.	**VRF**	**SRF**	**Chert**	**Ash Clast**	**Shard**
	8%	carbonate clayclast 14%	1%		
Minor	**#1 Cem.**	**#2 Cem.**	**Pore**	**A. organics**	**B. magnetite**
	carbonate/clay 34%	authigenic smectite 1%	5%	4%	3%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 53% Porosity-orig./Pres.: -/15%

Q	F	RF
43%	13%	44%

Fabric: (H/P/O) churned grains float in detrital pseudo-matrix, no evidence of compaction

Grain Shape/Sorting: subangular to subrounded/moderately well sorted

Clay Mineralogy:

Sample No. G2-2890

Section: 2883-2905

Formation: Catahoula-Soledad Member

Environment: Upper portion of bed-load alluvial channel fill

Rock name: fine sand: immature, calcareous, smectitic volcanic feldspathic litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl. grains
7%	20%	8% mostly albite	2%	2%	1%
Musc.	VRF	SRF carbonate	Chert	Ash Clast	Shard volcanic glass
	13%	5%	4%		2%
Minor hematite grains present	#1 Cem.	#2 Cem.	Pore	A. chlorite cement/alter.	B. one grain calcedony seen in slide
	14% calcite	8% smectite	13%	1%	

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 64%

Porosity-orig./Pres.: -/13%

Q	F	RF
42%	19%	39%

Fabric: (H/P/O) laminated, preferential zones of porosity vs. cement, very minor alignment of grains, no obvious compaction

Grain Shape/Sorting: angular/moderately well sorted

Clay Mineralogy: strong smectite peak; trace kaolinite, trace illite

Sample No. G6-2299

Section: 2220-2317

Formation: Oakville

Environment: crevasse splay or minor tributary deposit

Rock name: medium sand size: mature, calcareous, argillaceous volcanic rock fragment-bearing litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag. (albite)	Orth./San.	Micro.	Bio/Chl.
composite 5%	20%	6%	1% (?)	3%	
Musc.	VRF intermediate composition with albite phenocrysts common 19%	SRF carbonate 7% sand/silt stone 3%	Chert 6%	Ash Clast	Shard
Minor MRF (Quartzite) 2%	#1 Cem. carbonate 5%	#2 Cem. illite coats 3%	Pore 19%	A. limonite 1%	B. hematite grains present, chlorite grain seen

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 73%

Porosity-orig./Pres.: -/19%

Q	F	RF
34%	14%	52%

Fabric: (H/P/O) no obvious grain orientation, sample previously compacted

Grain Shape/Sorting: angular to well rounded/well sorted

Clay Mineralogy: strong smectite peak; possible clinoptilolite

Sample No. G12-800 Section: 795-851

Formation: Goliad Environment: flood plain

Rock name: very fine sand: immature, calcareous, argillaceous, pyritic quartzose lithic arkose

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San. (orthoclase)	Micro.	Bio/Chl.
1%	25%	5%	3%		
Musc.	VRF	SRF	Chert	Ash Clast	Shard
	3%				
Minor grains re-placed by carbonate	#1 Cem. 47%	#2 Cem. chloritic 1%	Pore less than 1% apparent	A. Matrix calcareous mud 47%	B. sericite 1% pyrite 4%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 37% Porosity-orig./Pres.: -/<1%

Q	F	RF
70%	22%	8%

Fabric: (H/P/O) no obvious packing or orientation of grains, however, some faint laminations due to alignment of more clay-rich zones

Grain Shape/Sorting: angular to rounded/very poorly sorted (approximates bimodal distribution of medium sand vs. silt)

Clay Mineralogy:

Sample No. G12-831 Section: 795-851

Formation: Goliad Environment: floodplain

Rock name: fine sand: immature, calcareous, argillaceous, pyritic feldspathic litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag. albite	Orth./San.	Micro.	Bio/Chl.
3%	20%	5%	2%	2%	
Musc.	**VRF**	**SRF carbonate replaced grains**	**Chert**	**Ash Clast**	**Shard**
	5%	2%	1%		
Minor matrix rip-up clasts	**#1 Cem.**	**#2 Cem.**	**Pore**	**A. Matrix: calcareous mud**	**B. pyrite**
10%		organics 1%	6%	36%	8%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 40% Porosity-orig./Pres.: -/6%

Q	F	RF
58%	22%	20%

Fabric: (H/P/O) no obvious orientation of grains, however, intraclasts resulting from matrix rip-up are aligned with their long axis parallel to bedding; no obvious compaction

Grain Shape/Sorting: angular to subrounded/poorly sorted

Clay Mineralogy:

Sample No. G12-846 Section: 795-851

Formation: Goliad Environment: flood plain

Rock name: coarse silt: immature, calcareous, argillaceous, pyritic sublitharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
2%	20%	1%			
Musc.	VRF	SRF	Chert	Ash Clast	Shard
	1%				
Minor heavy minerals rutile 1%	#1 Cem.	#2 Cem. authigenic chlorite 1%	Pore 2%	A. Matrix: calcareous organics 64%	B. pyrite 8%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 33% Porosity-orig./Pres.: -/2%

Q	F	RF
92%	4%	4%

Fabric: (H/P/O) no evidence for grain orientation or compaction, grains float in mud/carbonate matrix

Grain Shape/Sorting: angular to sub-angular/poorly sorted

Clay Mineralogy:

Sample No. G16-2083 Section: 2080-2133

Formation: Oakville Environment: overbank/splay deposits

Rock name: medium sand: submature, calcareous, pyrite/organic-rich feldspathic litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag. albite	Orth./San.	Micro.	Bio/Chl.
3%	23%	6%	4%		
Musc.	**VRF**	**SRF**	**Chert**	**Ash Clast**	**Shard**
	14	carbonate 3% clay 1%	2%		
Minor	**#1 Cem.** calcite	**#2 Cem.** clay coats (smectite?)	**Pore**	**A.**	**B.**
pyrite 6%	17%	1%	17%		(coaly) organics present

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 59% Porosity-orig./Pres.: -/17%

Q	F	RF
46%	20%	34%

Fabric: (H/P/O) possible very faint laminations (based on occurrence of pyrite), no obvious compaction

Grain Shape/Sorting: subangular to rounded/poorly sorted

Clay Mineralogy:

Sample No. G16-2103 — Section: 2080-2133

Formation: Oakville — Environment: overbank/levee/splay

Rock name: very fine sand to silt: immature, calcareous, argillaceous, hematitic litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
4%	17%	2%	3%		
Musc.	**VRF**	**SRF**	**Chert**	**Ash Clast**	**Shard**
	12%	clay 2% carbonate 2%	1%		
Minor	**#1 Cem.**	**#2 Cem. (cement & alt.)**	**Pore**	**A. Matrix: calcareous mud**	**B. hematite**
		chlorite 4%	2%	47%	4%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 43% — Porosity-orig./Pres.: -/27%

Q	F	RF
49%	12%	39%

Fabric: (H/P/O) appears muddy and churned, no obvious orientation of grains or evidence for compaction

Grain Shape/Sorting: angular to rounded/poorly sorted

Clay Mineralogy:

Sample No. G16-2130 Section: 2080-2133

Formation: basal Oakville Environment: channel fill

Rock name: medium sand: submature to mature, calcareous, argillaceous, hematitic litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag. untwinned & albite	Orth./San.	Micro.	Bio/Chl.
4%	20%	4%	3%	2%	
Musc.	VRF 20% total (3%± is volcanic glass)	SRF clay 2% carbonate 2%	Chert 3%	Ash Clast	Shard
Minor	#1 Cem. calcite 21%	#2 Cem. clay coat (illite) 3%	Pore 13%	A. authigenic chlorite 1%	B. magnetite hematite 1%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 60% Porosity-orig./Pres.: -/13%

Q	F	RF
40%	15%	45%

Fabric: (H/P/O) very faint lamination (parallel orientation) of large grains, no obvious compaction

Grain Shape/Sorting: angular to subrounded (dominately angular)/moderately well sorted.

Clay Mineralogy: strong smectite peak; trace clinoptilolite

Sample No. G17-2153 | Section: 2153-2208

Formation: Oakville | Environment: mixed load or bed load channel fill

Rock name: fine sand: submature, calcareous, argillaceous, volcanic rock-bearing feldspathic litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
27%	25%	5%	3%	2%	
Musc.	VRF	SRF	Chert	Ash Clast	Shard
	11%	calcareous clay 5%	5%		
Minor	#1 Cem. 12%	#2 Cem.	Pore	A.	B.
MRF (quartzite or schist) 1%	calcite (includes carbonate replaced grains)	clay coat smectite 4%	20%	magnetite 3%	hematite 1% chlorite 1%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 59

Porosity-orig./Pres.: -/20%

Q	F	RF
46%	17%	37%

Fabric: (H/P/O) no obvious orientation of grains, fabric appears churned, remnants of "slight" previous compaction

Grain Shape/Sorting: angular to subrounded/moderately sorted to poorly sorted

Clay Mineralogy:

Sample No. G17-2193 | Section: 2153-2208

Formation: Oakville | Environment: mixed load or bed load channel fill

Rock name: very fine sand: submature, calcareous, argillaceous quartzose litharenite

Composition:

Com. Qtz. 3%	Volc. Qtz. rutilated quartz seen 26%	Plag. albite 3%	Orth./San. 1% highly vacu-olised	Micro. 2%	Bio/Chl.
Musc.	VRF 13% one granite grain seen	SRF gastropod and mollusk frag. seen; cal-careous clay 3%	Chert 5%	Ash Clast	Shard
Minor MRF (quartzite) 1%	#1 Cem. calcite-cement & grain replace 11%	#2 Cem. clay coat 4% chlorite 3%	Pore 12%	A. pseudo-matrix 6%	B. hematite 3% limonite 2% organics 2%

Minor | #1 Cem. | #2 Cem. | A. | B.

grain of magnetite, calcedony, schist (?) also seen

Total Detrital Grains: 57% | Porosity-orig./Pres.: --

Q	F	RF
51%	11%	38%

Fabric: (H/P/O) very faint grain alignment although no major orientation; sediment originally compacted: smashed mica, clay rich RF's & close, conforming grain boundaries seen

Grain Shape/Sorting: angular to rounded/very poorly sorted, grain size ranges from coarse sand to coarse silt, $\bar{x}$ = very fine sand

Clay Mineralogy:

Sample No. G17A-671 Section: 660-700

Formation: Fleming Environment: floodplain

Rock name: mud or claystone

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
Musc.	VRF	SRF	Chert	Ash Clast	Shard
Minor	#1 Cem.	#2 Cem.	Pore	A.	B.

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: Porosity-orig./Pres.:

Q F RF

Fabric: (H/P/O) no obvious orientation of fabric or compaction

Grain Shape/Sorting:

Clay Mineralogy:

Sample No. G17A-695 Section: 660-700

Formation: Fleming Environment: floodplain

Rock name: fine sand: submature, calcareous, argillaceous quartzose litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
2%	24%	4%	1%	1%	1%
Musc.	VRF 6% IRF 2%	SRF carbonate (gastropod seen) 8%	Chert 2%	Ash Clast	Shard
Minor one schist grain seen	#1 Cem. calcite to mudsized carbonate 12%	#2 Cem. clay coat (illite) 4%	Pore 33%	A.	B.

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 51% Porosity-orig./Pres.: -/33%

Q	F	RF
51%	12%	37%

Fabric: (H/P/O) no obvious orientation or packing but possible indication of very faint laminations?

Grain Shape/Sorting: angular to rounded/moderately sorted

Clay Mineralogy: strong smectite peak; minor kaolinite

Sample No. G18-753

Formation: Goliad

Section: 752-766 (752-806½ inclusive)

Environment: coastal playa lake

Rock name: fine sand size: immature, calcareous, argillaceous, pyritic quartzose litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
1%	some rutilated 31%	4%			
Musc.	VRF	SRF	Chert	Ash Clast	Shard
	5%	calcareous clay 3%	2%		
Minor	#1 Cem.	#2 Cem.	Pore	A. Matrix:	B. pyrite
MRF 1% (?) IRF 1% (?)		calcite cement, replaced grains 5%	10%	calcareous mud 36%	1%

Minor	#1 Cem.	#2 Cem.	A.	B.
one chlorite grain seen				

Total Detrital Grains:

Porosity-orig./Pres.: -10%

Q	F	RF
67%	8%	25%

Fabric: (H/P/O) fabric appears highly churned (possibly burrowed) no preferred alignment of grains, no evidence for compaction

Grain Shape/Sorting: angular to rounded/moderate sorting

Clay Mineralogy: strong illite peak; possible trace vermiculite/chlorite mixed layer phase

Sample No. G18-777 Section: 770-786 (752-806½ inclusive)

Formation: Goliad Environment: coastal playa lake

Rock name: limestone; burrowed mudstone (microspar)

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
Musc.	VRF	SRF	Chert	Ash Clast	Shard
Minor	#1 Cem.	#2 Cem.	Pore	A.	B.

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: Porosity-orig./Pres.:

Q F RF

Fabric: (H/P/O) churned

Grain Shape/Sorting:

Clay Mineralogy:

Sample No. G18-802

Formation: Goliad

Section: 790-806½ (752-806½ inclusive)

Environment: coastal playa lake

Rock name: coarse silt: immature, calcareous, argillaceous quartzose litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
present	21%	2% twinned & untwinned		highly altered 1%	
Musc.	VRF	SRF	Chert	Ash Clast	Shard
	8%	carb. cement (radial/fibrous clay clasts) 4%	2%		
Minor	#1 Cem.		14		
Pyrite 2%		carb/clay clast 3%	Pore 7%	A. Matrix: calcareous mud 51%	B. magnetite 1% organics 1%

Minor	#1 Cem.	#2 Cem.	A.	B.
one gypsum crystal seen				

Total Detrital Grains: 38%

Porosity-orig./Pres.: -/7%

Q	F	RF
55%	8%	37%

Fabric: (H/P/O) inclined (low angle) laminations w/vertical burrows, laminations not distinct and are a result of variability of amount of mud in matrix.

Grain Shape/Sorting: subangular to subrounded/poor to moderately sorted

Clay Mineralogy:

Sample No. G20-817 Section: 795-827

Formation: Fleming Environment: splay

Rock name: coarse silt: immature calcareous, argillaceous quartzose litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
2%	20%		2%		Mica seen
Musc.	IRF (one contains mica) 4%	SRF (1 gastropod seen) clay clast 1% calcareous	Chert 2%	Ash Clast	Shard
Minor Chlorite 5%	#1 Cem.	#2 Cem. calcite & re-placed grains 16%	Pore 1%	A. Matrix: calcareous mud 44%	B. hematite 1% limonite 2%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 31% Porosity-orig./Pres.: -/1%

Q	F	RF
71%	6%	23%

Fabric: (H/P/O) highly churned, no obvious grain orientation or compaction

Grain Shape/Sorting: angular to rounded/moderately sorted

Clay Mineralogy:

Sample No. G22-645

Section: 640-660 (620-660 inclusive)

Formation: Goliad

Environment: floodplain splays

Rock name: very fine sand: immature, calcareous, argillaceous quartzose feldspathic litharenite

Composition:

Com. Qtz. 2%	Volc. Qtz. 34%	Plag. 3%	Orth./San. highly weathered 1%	Micro.	Chl. Grains 1%
Musc.	VRF 2% IRF 2%	SRF calc. clay clast 1%	Chert 2%	Ash Clast	Shard
Minor	#1 Cem.	#2 Cem.	Pore 11%	A. Matrix: calcareous mud 41%	B. magnetite, organics, hematite present

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 49%

Porosity-orig./Pres.: -/11%

Q	F	RF
73%	8%	18%

Fabric: (H/P/O) faint horizontal lamination, no obvious compaction

Grain Shape/Sorting: angular to subrounded/well sorted

Clay Mineralogy: strong illite peak; mixed layer smectite phase

Sample No. G22-2435

Section: 2420-2456 (2420 to 2478 inclusive)

Formation: Catahoula

Environment: splay on flood plain

Rock name: fine to very fine sand: immature, calcareous, argillaceous, pyritic quartzose litharenite

Composition:

Com. Qtz.	Volc. Qtz.	Plag. twinned & untwinned	Orth./San.	Micro.	Chl. rims & replaced grains
7%	17%	6%			3% (1% grains)
Musc.	**VRF**	**SRF**	**Chert**	**Ash Clast**	**Shard**
Minor	**#1 Cem.**	**#2 Cem.**	**Pore**	**A. Matrix:**	**B.**
IRF 1% MRF (Qtzile) 1%		calcite replaced grains 10%	4%	calcareous mud 27%	organics 2% pyrite 6%

Minor	#1 Cem.	#2 Cem.	A.	B.
percentage of IRF & MRF actually lower in sample				

Total Detrital Grains: 48%

Porosity-orig./Pres.: -/4%

Q	F	RF
50%	13%	38%

Fabric: (H/P/O) no obvious orientation or grains, minor compaction with deformation of soft RF's noted.

Grain Shape/Sorting: angular to rounded/poor sorting

Clay Mineralogy:

Sample No. 622-2447½

Formation: Catahoula

Section: 2420-2456 (2420-2478 inclusive)

Environment: splay on floodplain

Rock name: Pyritic, silty, claystone

Composition:

Com. Qtz.	Volc. Qtz.	Plag.	Orth./San.	Micro.	Bio/Chl.
Musc.	VRF	SRF	Chert	Ash Clast	Shard
Minor	#1 Cem.	#2 Cem.	Pore	A.	B.

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains:

Porosity-orig./Pres.:

Q ____ F ____ RF ____

Fabric: (H/P/O) burrowed or root churned

Grain Shape/Sorting:

Clay Mineralogy:

Sample No. G22-2470

Formation: Catahoula

Section: 2460-2478 (2420 to 2478 inclusive)

Environment: fluvial channel fill

Rock name: fine sand: submature, calcareous, VRF-rich litharenite

Composition:

Com. Qtz. 1%	Volc. Qtz. some rutilated 21%	Plag. (twinned & untwinned) 6%	Orth./San. sanidine seen 3%	Micro.	Bio/Chl.
Musc.	VRF 32%	SRF some sand/silt seen, calc. clay 5%	Chert 3%	Ash Clast hematite	Shard 4% minor clay
Minor	80 #1 Cem. calcite cement & grain replacement 11%	#2 Cem.	Pore 8%	A. limonite hematite 4%	B. chlorite & minor clay 2%

Minor	#1 Cem.	#2 Cem.	A.	B.

Total Detrital Grains: 71%

Porosity-orig./Pres.: -/8%

Q	F	RF
31%	13%	56%

Fabric: (H/P/O) no obvious grain orientation, evidence for previous grain compaction (CRF squashed, minor cracked grains)

Grain Shape/Sorting: rounded to angular/poorly sorted

Clay Mineralogy:

APPENDIX C

ICP-AES Multi-Element Analysis - $HNO_3/H_2SO_4/HCL$ Soluble

(Results are reported in microgram/gram of solid)

Note: < Indicates that the result is less than the given value

* Indicates that the result is near the detection limit and must be interpreted accordingly

Date of Analysis: 11-21-80

Sample	Na	K	Mg	Ca	Al	Fe	Ti	Mn	Co	Cr	Cu	Ni	V	Zn
Blank	*0.246	<0.200	<0.100	*0.058	<0.200	<0.010	<0.050	<0.010	<0.020	<0.020	<0.020	<0.050	<0.050	0.053
Agv-1 (Standard)	1,041	678.9	3,556	7,696	4,461	44,633	6,269	566.2	<1.00	6.354	52.04	13.61	117.5	75.92
2-410'	935.6	6,986	8,031	34,990	29,572	15,781	1,797	184.6	45.79	21.14	9.219	9.922	46.78	34.76
2-1175'	1,965	9,658	6,856	36,194	39,258	28,319	2,455	660.6	31.60	31.05	9.547	13.87	68.11	62.61
2-2890'	3,398	3,456	3,808	31,849	21,257	13,030	1,865	382.2	287.8	14.30	6.970	8.183	46.87	36.40
6-2299'	1,712	2,934	2,272	32,054	11,636	12,895	1,776	232.3	118.0	11.71	4.956	*5.808	31.16	25.91
12-800'	1,626	7,517	5,194	38,076	20,924	17,003	2,192	289.4	117.2	22.19	8.120	12.17	59.09	48.62
12-831'	1,318	7,315	5,167	36,522	22,105	15,088	1,862	264.2	50.79	20.33	8.822	11.25	58.34	53.79
12-846'	1,562	9,532	6,317	37,779	31,316	20,608	2,562	382.8	60.77	26.38	12.35	16.88	80.15	68.12
Blank	0.326	<0.200	<0.100	*0.095	<0.200	<0.010	<0.050	<0.010	<0.020	<0.020	<0.020	<0.050	<0.050	0.050
Agv-1	1,002	657.6	3,316	7,871	4,339	40,893	6,359	534.3	<1.00	6.113	51.11	12.12	115.3	73.84
16-2083	2,584	4,037	3,771	36,357	20,306	35,308	2,053	424.0	107.5	16.77	5.630	8.823	41.50	24.41
16-2103	4,012	7,613	8,025	36,035	41,351	25,172	3,046	326.1	21.55	24.16	7.636	9.959	55.14	54.71
16-2130	2,555	3,135	2,188	36,647	12,313	10,311	1,977	572.6	77.74	11.21	2.922	*4.338	25.08	27.79
17-2153	2,006	3,195	2,304	35,632	12,408	13,965	2,570	371.1	121.1	15.61	4.598	6.471	43.43	41.14
17-2193	2,339	3,436	3,160	34,194	15,583	16,167	2,367	361.1	79.64	16.45	5.918	7.892	47.14	33.31
17A-671	2,113	11,544	12,826	41,549	65,717	20,992	2,867	202.2	126.6	51.99	86.86	74.37	150.3	138.3
17A-695	339.3	2,044	2,997	35,236	9,359	4,562	580.1	156.7	<1.00	6.586	2.646	*3.182	24.50	11.71
18-753	2,294	3,718	18,146	34,179	13,298	5,839	1,003	238.8	215.6	11.80	18.36	*5.458	18.81	20.26
Blank	0.309	*0.373	<0.100	0.182	<0.200	<0.010	*0.053	<0.010	<0.020	<0.020	<0.020	<0.050	<0.050	0.053
18-777	313.9	1,312	21,391	40,181	5,523	3,940	368.7	307.6	44.82	5.285	4.013	*2.960	11.42	14.49
18-802	1,683	3,671	36,868	35,568	12,927	7,980	1,282	297.1	61.73	10.60	7.484	*6.088	22.33	25.11
20-817	2,050	8,522	5,914	37,260	33,401	21,186	2,859	260.6	152.5	33.09	13.60	16.62	76.78	53.06
22-2435	3,097	3,785	3,242	26,302	15,514	153,425	2,550	221.3	38.91	14.36	7.652	27.50	37.75	60.44
22-2447	4,945	14,543	9,219	48,260	48,912	49,551	2,729	297.1	<1.35	33.69	5.803	19.62	80.04	82.50
22-645	1,806	6,326	20,826	26,519	22,938	12,862	1,935	156.7	58.79	21.56	7.086	10.76	36.98	35.60
22-670	4,253	3,948	3,244	37,497	13,712	23,296	5,639	669.0	105.5	43.30	5.728	6.351	73.30	57.24

APPENDIX C

(continued)

Sample	As	Cd	Mo	Pb	Sb	Se	Sn	Li	Be	Sr	Zr	U	Th	B	P
Blank	<0.100	<0.020	<0.050	<0.200	<0.200	*0.268	<0.050	<0.020	<0.005	<0.005	<0.020	<0.100	<0.100	0.574	<0.500
Agv-1 (Standard)	<5.00	*1.163	<2.50	*14.90	<10.0	<12.5	<2.50	*2.482	<0.250	34.29	61.45	<5.00	*6.117	<10.0	2,111
2-410'	<5.00	<1.00	<2.50	<10.0	<10.0	<12.5	<2.50	13.94	*0.506	110.4	20.37	<5.00	<5.00	<10.0	156.7
2-1175'	<5.00	*1.349	<2.50	<10.0	<10.0	<12.5	<2.50	15.64	1.087	149.4	33.33	<5.00	<5.00	<10.0	497.6
2-2890'	<5.00	*1.297	*2.542	<10.0	<10.0	<12.5	<2.50	9.649	<0.250	155.5	18.09	<5.00	<5.00	<10.0	294.8
6-2299'	<5.00	*1.041	<2.50	<10.0	<10.0	<12.5	<2.50	4.874	<0.250	145.5	31.82	<5.00	<5.00	<10.0	384.1
12-800'	<5.00	*1.052	<2.50	<10.0	<10.0	<12.5	<2.50	11.63	*0.590	124.8	37.91	<5.00	<5.00	<10.0	349.2
12-831'	<5.00	<1.00	<2.50	<10.0	<10.0	<12.5	<2.50	9.129	*0.601	97.72	33.47	<5.00	<5.00	<10.0	352.4
12-846'	<5.00	*1.555	<2.50	<10.0	<10.0	<12.5	<2.50	17.04	0.922	165.8	52.40	<5.00	<5.00	<10.0	576.9
Blank	<0.100	<0.020	<0.050	<0.200	<0.200	*0.356	<0.050	<0.020	<0.005	<0.005	*0.025	<0.100	*0.103	0.612	<0.500
Agv-1	<5.00	*1.159	<2.50	*14.51	<10.0	<12.5	<2.50	*2.357	<0.250	33.93	60.36	<5.00	<5.00	<10.0	2,089
16-2083	262.0	*1.841	28.99	<10.0	<10.0	<12.5	<2.50	11.40	*0.621	143.4	39.23	<5.00	<5.00	<10.0	425.3
16-2103	<5.00	*1.135	<2.50	<10.0	<10.0	<12.5	<2.50	21.34	1.181	215.1	58.53	<5.00	<5.00	<10.0	379.8
16-2130	<5.00	<1.00	<2.50	<10.0	<10.0	<12.5	<2.50	5.366	*0.377	104.3	40.21	<5.00	<5.00	<10.0	314.1
17-2153	<5.00	*1.010	<2.50	<10.0	<10.0	<12.5	<2.50	5.797	<0.250	142.7	28.64	<5.00	<5.00	<10.0	361.6
17-2193	<5.00	<1.00	<2.50	<10.0	<10.0	<12.5	<2.50	8.686	*0.283	183.8	31.56	<5.00	<5.00	<10.0	357.9
17A-671	<5.00	2.892	<2.50	*13.52	<10.0	<12.5	<2.50	39.97	1.559	570.5	49.05	<5.00	<5.00	*11.37	521.1
17A-695	<5.00	<1.00	<2.50	<10.0	<10.0	<12.5	<2.50	5.669	<0.250	180.7	7.093	<5.00	<5.00	<10.0	130.0
18-753	<5.00	3.151	*3.771	<10.0	<10.0	<12.5	<2.50	10.98	<0.250	1,150	21.78	<5.00	<5.00	<10.0	252.1
Blank	<0.100	<0.020	<0.050	<0.200	<0.200	*0.252	<0.050	<0.020	<0.005	<0.005	*0.025	<0.100	*0.104	0.620	<0.500
18-777	<5.00	<1.00	<2.50	<10.0	<10.0	<12.5	<2.50	6.155	<0.250	27.64	2.575	<5.00	<5.00	<10.0	130.2
18-802	<5.00	<1.00	<2.50	<10.0	<10.0	<12.5	<2.50	13.82	<0.250	62.84	18.40	<5.00	<5.00	<10.0	268.7
20-817	<5.00	2.797	*2.565	<10.0	*15.79	<12.5	<2.50	21.89	*0.621	189.9	29.48	<5.00	<5.00	<10.0	549.8
22-2435	<5.00	4.647	<2.50	<10.0	<10.0	<12.5	<2.50	11.01	0.628	183.2	43.38	<5.00	<5.00	<10.0	343.5
22-2447	<6.76	<1.35	<3.38	<13.5	*15.04	<16.9	<3.38	27.52	1.949	292.1	44.54	<6.76	<6.76	<13.5	401.5
22-645	<5.00	<0.999	<2.50	<9.99	<10.0	<12.5	<2.50	20.98	*0.458	203.1	22.49	<5.00	<5.00	<9.99	581.1
22-670	<5.00	*1.332	<2.50	<9.99	<10.0	<12.5	<2.50	9.769	0.740	147.8	83.79	<5.00	<5.00	<9.99	916.5