Uranium Geology and Mines, South Texas

BY D. HOYE EARGLE, GEORGE W. HINDS,
AND ALICE M. D. WEEKS

GUIDEBOOK NUMBER 12

THE UNIVERSITY OF TEXAS AT AUSTIN
BUREAU OF ECONOMIC GEOLOGY
W. L. FISHER, DIRECTOR

COVER: View toward the southwest along the uranium-mining trend in western Karnes County, Texas. Galen (or Pawelek) pit in foreground, followed successively by the Butler and Weddington pits of Susquehanna-Western, Inc., and lastly by Tenneco's Weddington pits. Mining on Conoco-Pioneer Nuclear's leases is projected farther to the southwest. Photographed in March 1971 by Mitchell Photography, Kenedy, Texas.

BUREAU OF ECONOMIC GEOLOGY
The University of Texas at Austin
W. L. FISHER, *Director*

Guidebook 12

Uranium Geology and Mines, South Texas

By

D. Hoye Eargle, George W. Hinds, and Alice M. D. Weeks

June 1971

FOREWORD

In recent years exploration and mining of uranium have become a significant part of the Texas mineral scene with Texas emerging as a leading uranium-producing state. At the end of 1970, Texas ranked third in reserves among the states with ore reserves of 6.6 million tons. Continuation of recent high level of exploration is shown by the 6.1 million feet of drilling in Texas during 1970, surpassed only by drilling activity in Wyoming.

This guidebook is a reprinting of a field trip guidebook originally printed by the Houston Geological Society for the annual meeting of the American Association of Petroleum Geologists held in Houston, April 1971. This field guide should serve as a valuable reference to the important uranium mineral district in South Texas.

W. L. FISHER
Director

CONTENTS

ILLUSTRATIONS

URANIUM GEOLOGY AND MINES, SOUTH TEXAS

FIELD TRIP OF THE HOUSTON GEOLOGICAL SOCIETY FOR THE AAPG CONVENTION IN HOUSTON, TEXAS, APRIL 1-2, 1971[1/]

by D. Hoye Eargle, Geologist, U.S. Geological Survey, Austin, Tex., George W. Hinds, Geologist, Photogravity Co., Inc., Houston, Tex., and Alice M. D. Weeks, Head, Department of Geology, Temple University, Philadelphia, Pa., and Geologist, U.S. Geological Survey

PRELIMINARY STATEMENT[2/]

The geologic section to be traversed during the first part of the trip, from Houston to Goliad, will be chiefly on the nearly flat Pleistocene coastal terraces that still preserve essentially their depositional surfaces (fig. 1, pl. 1). No stops are planned for this stretch, but from Goliad northwestward the trip will cross the erosional surface of the Gulf Coastal Plain. The outcropping Tertiary rocks that will be crossed in sequence are shown on figure 2. Although it will not be possible to study all units, some of their distinguishing features can be seen along the roads the field trip will follow.

For several decades and until recently, the Pleistocene has been considered two formations: the Lissie Formation (older) and the Beaumont Clay (younger) (Plummer, 1932). Terrace deposits formerly considered Lissie are now included in the Bentley and Montgomery Formations (Texas Univ. Bur. Econ. Geology[3/], 1968a, 1968b); the Deweyville Formation, whose surface forms low terraces along modern streams near the coast, has been separated from the Beaumont. The Willis Sand has been placed by some in the Pliocene(?) or (by Doering, 1956) in the Pliocene-Pleistocene interval. It is shown as Pleistocene on sheets of the Geologic Atlas of Texas (Texas Univ. Bur. Econ. Geol., 1968a, 1968b).

1/Publication authorized by the Director, U.S. Geological Survey. Names used are not necessarily in conformity with U.S.G.S. standards.

2/Some of the material in this guidebook has been taken and in part revised from previous guidebooks (Eargle and Foust, 1962; Eargle and Weeks, 1961b; South Texas Geological Society, 1958; Corpus Christi Geological Society, 1968; Gulf Coast Association of Geological Societies, 1967).

3/Permission has been granted by Dr. Virgil E. Barnes, Project Director, Geologic Atlas of Texas, to use information from sheets of that series. The Pleistocene was mapped for the Atlas by Dr. Saul Aronow.

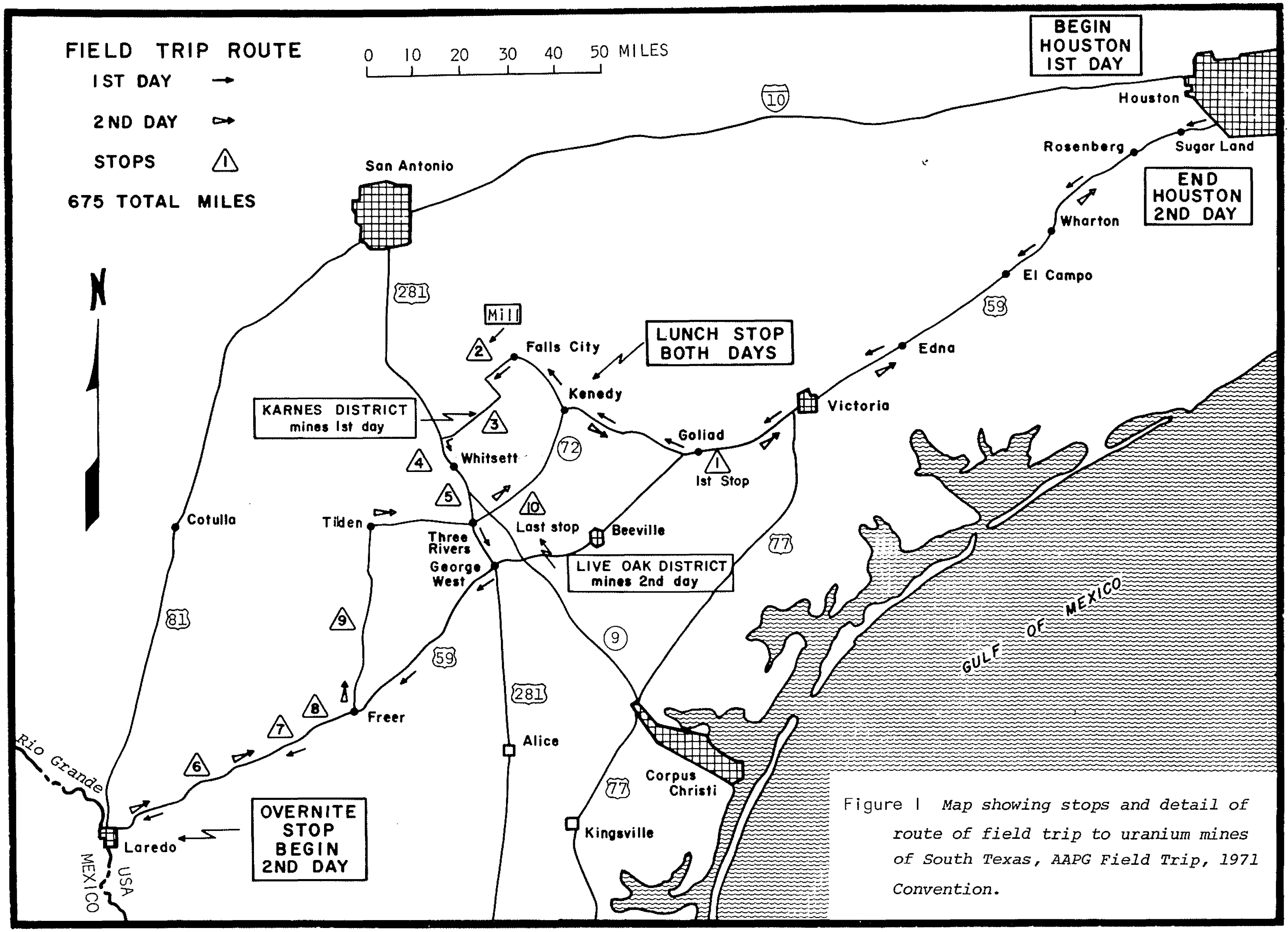


Figure 1 *Map showing stops and detail of route of field trip to uranium mines of South Texas, AAPG Field Trip, 1971 Convention.*

The terraces are divided on the basis of age (therefore, on the basis of exposure to erosion, extent of leaching, and depth of soil development), of seaward dip or slope of the surface, and, to some extent, differences in lithologic character. These differences have produced some distinctive geographic features that affect the terraces, drainage, soil characteristics, adaptability to various aspects of land use, and character of vegetation. Many of these features will be noted by the field-trip leaders as we proceed on the trip.

The terraces consist mainly of fine-grained clastics, sand, silt, and clay, with some gravel in the older deposits. Facies changes are minor but easily observable. A few differences in lithology between the terraces of different ages can be observed. The beds dip only a few feet per mile, approximately paralleling the land surface.

In many places the terraces merge into one another or are separated by low scarps. Two indistinct scarps have been mapped in Harris County in the vicinity of Houston; one at 100 feet, and another at 60 feet above sea level. Some scarps are erosional; some are low fault scarps. Most geologists consider the deposits nonmarine, deltaic, or coalescing fluvial, with some intervening swamp or minor near-shore lagoonal deposits.

Since deposition, the terrace surfaces have been modified only by limited sheet and chemical erosion, by shallow trenching by streams that cross them, by deposition of fluvial sedimentary land forms, and by limited and local diastrophic movements. Diastrophic movements include general slight displacement, local subsidence (following withdrawal of water, hydrocarbons, and sulfur from beneath the plains), and gentle arching of the surface (resulting from recent upward movement of salt) over a few of the salt domes.

In the vicinity of Goliad the Goliad Sand (Pliocene), which preserves some of its original depositional surface, will be seen at its type locality.

From Goliad to the mines of Karnes County the route of the trip is generally northwestward and traverses the truncated or beveled edge of each outcropping Tertiary formation from Pliocene to upper Eocene. The coastal plain of this region is an erosional plain of gently rolling

Trip	System	Series	Group	Geologic Unit		Description
FIRST DAY'S TRIP	QUATERNARY	Holocene		Flood-plain alluvium		Sand, gravel, silt, clay.
				Fluvial terrace deposits		Sand, gravel, silt, clay.
		Pleistocene		Pleistocene Deweyville[1] Formation, Beaumont Clay, Montgomery Formation, Bentley Formation, and Pliocene(?) Willis Sand.		Sand, gravel, silt, clay. Montgomery and Bentley comprise Lissie Formation of older reports. Willis Sand not seen on this trip.
	-?	?-				
	TERTIARY	Pliocene		Goliad Sand		Fine to coarse sand and conglomerate. Medium to fine sandstone; gray to pink calcareous clay; basal medium to coarse sandstone. Strongly calichified.
		Miocene		Fleming Formation		Calcareous clay and sand, gray to pink, red, light brown.
FIRST DAY'S TRIP / SECOND DAY'S TRIP				Oakville Sandstone		Calcareous, crossbedded, coarse sand. Some clay and silt and reworked sand and clay pebbles near base.
				Catahoula Tuff (Gueydan Formation of some authors)	Chusa Tuff Member	Light-gray to pink calcareous tuff; bentonitic clay; some gravel and varicolored sand near base. Soledad near middle in Duval County grades into sand lenses in northern Duval and adjacent counties.
					Soledad Volcanic Conglomerate Member	
					Fant Tuff Member	
		Oligocene(?)		Frio Clay (Southwest of Karnes County)		Light-gray to green clay; overlapped by Catahoula Tuff northeast of Live Oak County. Occasional sand-filled channels.
			Jackson	Whitsett Formation	Fashing Clay Member	Chiefly marine clay; some lignite, sand, *Corbicula* coquina, oysters.
		Eocene			Tordilla Sandstone Member. Calliham Sandstone Member west of Karnes County.	Shallow marine very fine sand.
					Dubose Member	Silt, sand, clay, lignite.
					Deweesville Sandstone Member	Mostly fine sand; some carbonaceous silt and clay.
					Conquista Clay Member	Carbonaceous clay.
					Dilworth Sandstone Member	Fine sand, abundant *Ophiomorpha*.

1/Names used are not necessarily in conformity with U.S.G.S. standards.

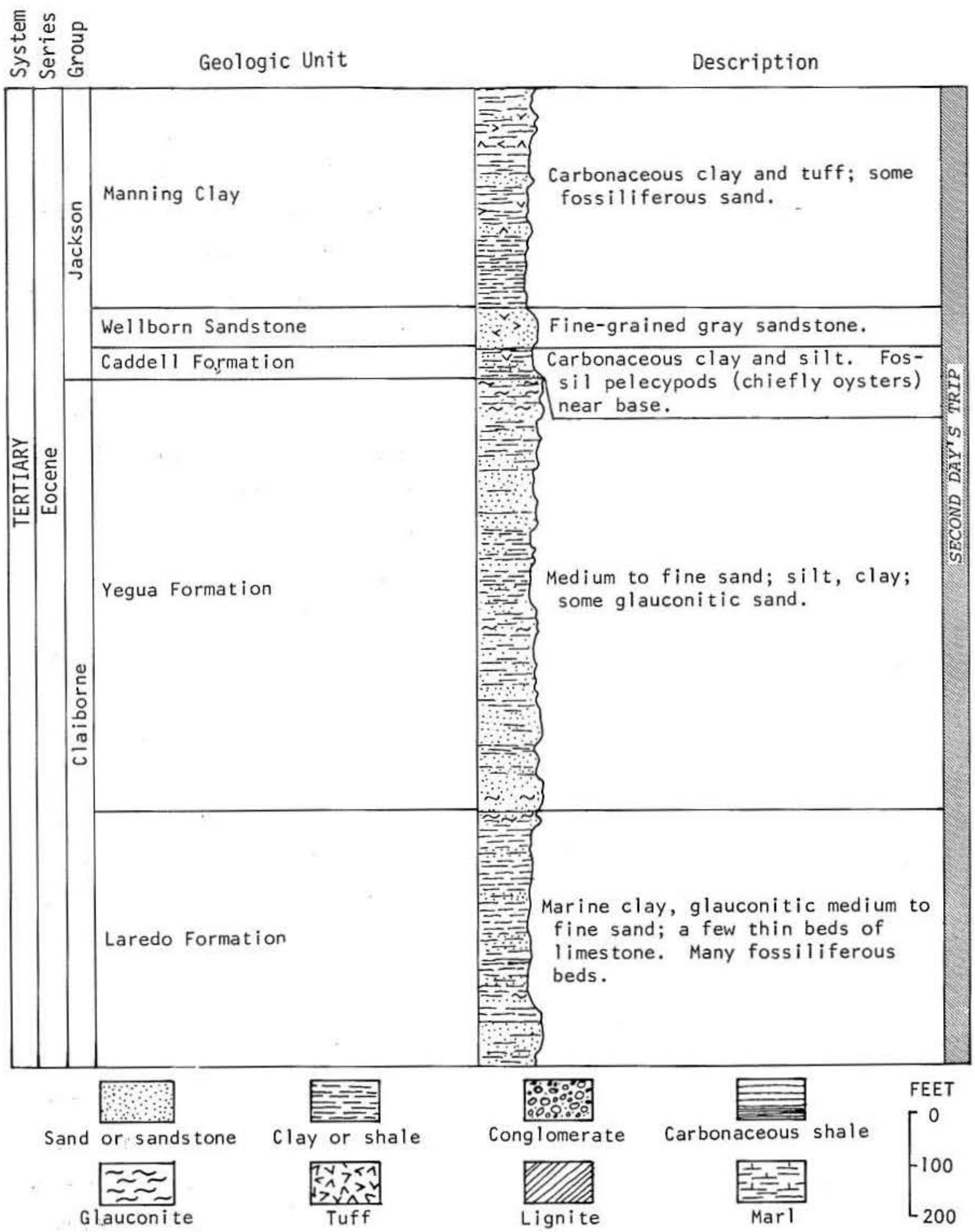


Figure 2 *Generalized stratigraphic section, middle Eocene (Claiborne Group) to Holocene. Revised from Moxham and Eargle (1961). Nomenclature modified from Geologic Atlas of Texas (Texas Univ. Bur. Econ. Geology, 1968b; in press).*

topography, but in a few places, as from the vicinity of the Karnes uranium mines southwestward for at least 75 miles, cuestas supported by resistant rocks are conspicuous features of the landscape. These cuestas have steep frontal scarps that face northwestward and topographic relief of 100 to 150 feet. Major streams have cut valleys as much as 200 feet below the general level of the plain in the higher parts of the Coastal Plain, but elsewhere the valleys are shallower. Some reaches of both major and minor streams parallel the trends of the cuestas, but the general flow of the streams is to the southeast.

OIL PRODUCTION

The route traverses several trends of oil production from different zones of the subsurface. From Houston to Goliad, along the coastal area but not necessarily along the route of the trip, the production is from stratigraphic or structural traps in the downdip Oligocene or Miocene, including beds that do not crop out at the surface, and from local salt-dome structures. In northwestern Goliad County near the Karnes County line, most of the production is from sands of Wilcox age (lower Eocene), downdip sections of which include beds equivalent to the Carrizo Sand of the overlying Claiborne Group. Production from the Wilcox in this area ranges in depth from 7,500 to 9,000 feet. Near the Karnes-Goliad line, several down-to-the-coast faults form a trend many miles long that has provided traps for oil and gas, not only from the Wilcox, but also from the shallower Pettus sand and other sands of the subsurface of the Yegua Formation (middle Eocene). This zone is especially productive in Bee County and to the southwest.

About 15 miles north of this fault trend we cross the Edwards Limestone (Lower Cretaceous) reef trend. This reef trend, which produces sour oil and gas, extends for 250 miles from near the Rio Grande northeastward to the vicinity of Hallettsville in Lavaca County. Depths of producing zones range from 10,000 to 14,000 feet. In some places downdip from the Edwards trend the lowermost Cretaceous and Jurassic are being explored to depths of nearly 20,000 feet.

In northern Karnes, eastern Atascosa, and Wilson Counties several fault-line fields 20 years old or more are producing from the Carrizo Sand and Wilcox Formation. Some of the faults are up-to-the-coast, antithetical to the more common down-to-the-coast faults and are generally productive of sweet oil. The trends in the region of this trip are coastward from those of the Luling fault-zone trend. One such up-to-the-coast fault, the Fashing fault in Atascosa County, will be crossed in the vicinity of the Karnes uranium deposits. Fields along this fault produce sweet oil from the Wilcox and also sour gas and some oil from the Edwards reef zones.

In Live Oak County early production was from the Jackson Group and younger beds; oil and gas occur along the Oakville fault zone, the same zone along which extensive uranium deposits were found. Deeper production, chiefly of gas, comes from the Wilcox here as in Karnes and other counties along a wide belt of the central part of the Coastal Plain. In Duval County prolific production has been found in sands of the Jackson and Claiborne, where stratigraphic traps combined with faulting have been largely responsible. The Government Wells field (fig. 18), through which we will pass in the vicinity of Freer, is typical of these fields. Production from salt domes is minor in the South Texas region, but several domes have produced considerable amounts of oil. The route of the trip takes us near small Moca dome in eastern Webb County and across tremendous Pescadito dome (figs. 16, 17, pl. 2), believed to be the largest dome in Texas. Production from Pescadito dome has been only slight up to the present time (see p. 45).

URANIUM

History of Operations

Texas is the most recent State in the Nation to become a major producer of uranium. (That it is a major producer is a fact that may not be commonly known.) Although uranium had been mined and processed as a source of atomic energy in several western States--chiefly in arid and semiarid climates--since the early 1940's, early exploration in western Texas did not reveal significant deposits. Ore was discovered in Texas, however, late in 1954, in an environment previously considered unfavorable--the more humid Coastal Plain of South Texas--and extensive exploration soon proved the existence there of commercial uranium deposits. Within 2 years as many as 25 prospects were discovered along a 300-mile strip of upper Eocene to Pliocene rocks that extends from east-central to

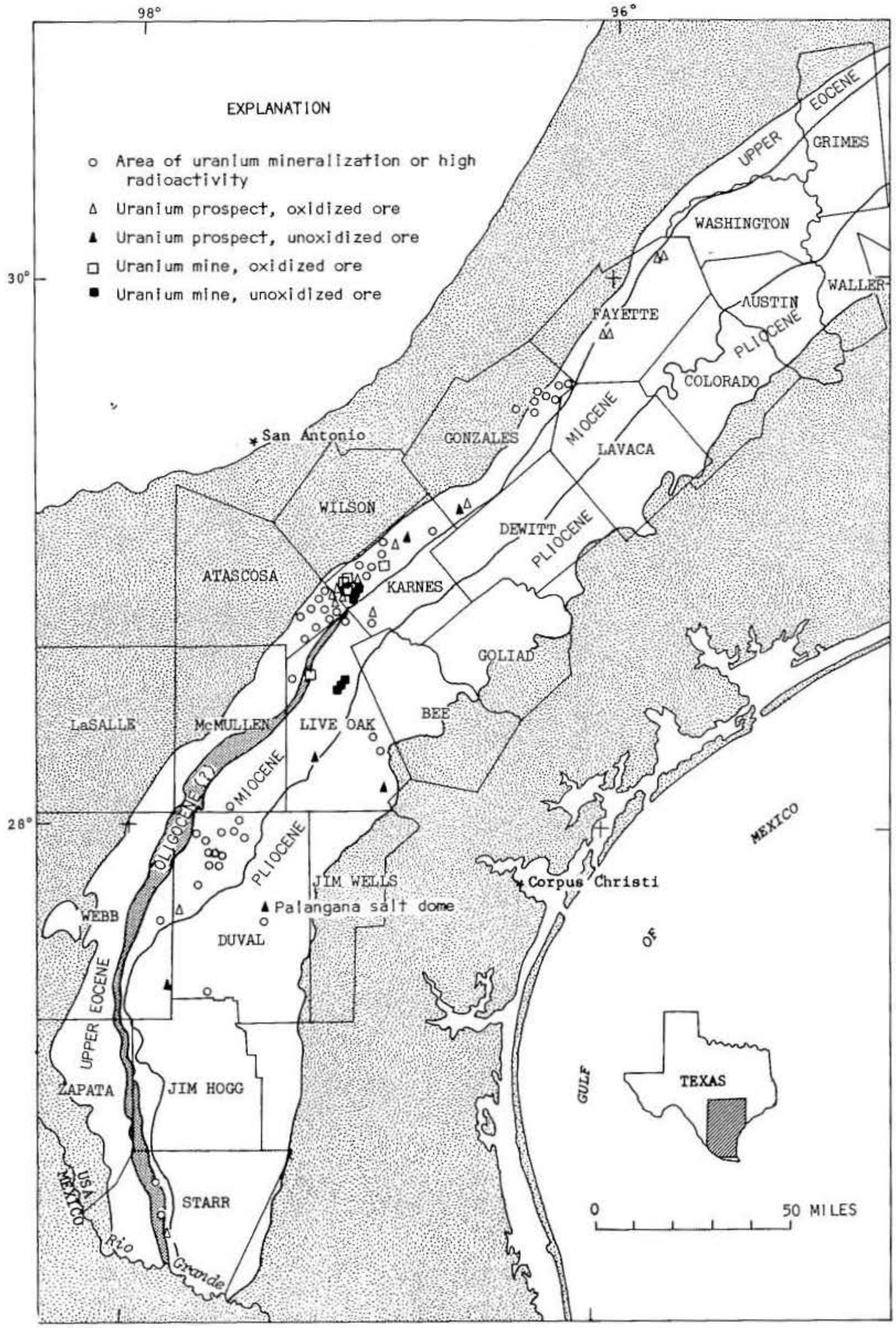


Figure 3 *Map showing areas of mineralization, prospects, and uranium mines in the Coastal Plain of South Texas. Revised from Eargle (1970).*

southernmost Texas (fig. 3). The first production was 100,000 tons of approximately 0.20-percent ore mined in 1959 and 1960 by a subsidiary of Climax Molybdenum Company from the Nuhn lease at Deweesville, an abandoned community center in western Karnes County about 9 miles southwest of Falls City (fig. 9). A mill with a capacity of about 200 tons per day, built by Susquehanna-Western, Inc., to process this ore and ore to be mined subsequently, began operation in April 1961 (fig. 4). Susquehanna-Western's

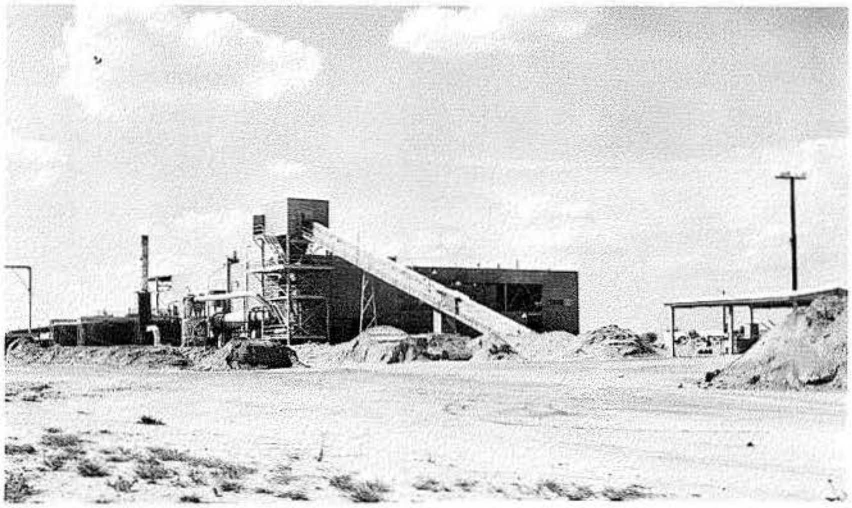


Figure 4 *Photograph showing Susquehanna-Western's uranium mill at Deweesville. This photograph was taken before the mill was enlarged to more than twice its original capacity.*

mining in the Deweesville area began that year, and since 1961 the company has mined a dozen or more properties and has explored many more in the region. After fulfilling its contract with the AEC in 1965, Susquehanna-Western contracted to supply uranium for nuclear-power production to the government of West Germany, reportedly the first contract negotiated between a United States company and a foreign government for the sale of uranium outside the country. Other contracts followed and in 1967 Susquehanna enlarged its mill capacity to 1,000 tons per day. Because the ore of the Karnes district is essentially noncalcareous, the mill utilizes an acid-leach process for extracting the uranium.

In 1969 Tenneco, the second company to mine in the region, with its Weddington mine continued exploitation of the ore trend established by earlier mining. The company began mining in August 1969, feeding its ore to Susquehanna's Falls City (Deweesville) mill.

Late in 1970, Continental Oil Company and Pioneer Nuclear Corporation, which own extensive properties in both the district and the whole South Texas region, prepared the ground for construction of another 1,750-ton-per-day mill about 8 miles southwest of Falls City and 1 1/2 miles east of Deweesville on Farm Road 791 (fig. 9).

Texas' second district, the Live Oak district, was opened in 1967, when Susquehanna started mining ore from the Marrs McLean property in eastern Live Oak County (early in the 1960's the company had mined the Mabel New deposit of shallow oxidized ore in the western part of the county). The large deposit on adjoining Felder property, extensively explored by the Humble Oil and Refining Company, is now in production. Susquehanna-Western is mining and milling the Felder deposit, which is expected to produce about 5 million pounds of refined U_3O_8 (Klohn and Pickens, 1970), and has built a second mill at Ray Point, 6 miles northeast of Three Rivers (figs. 5, 19) to process ores of the Live Oak district. This

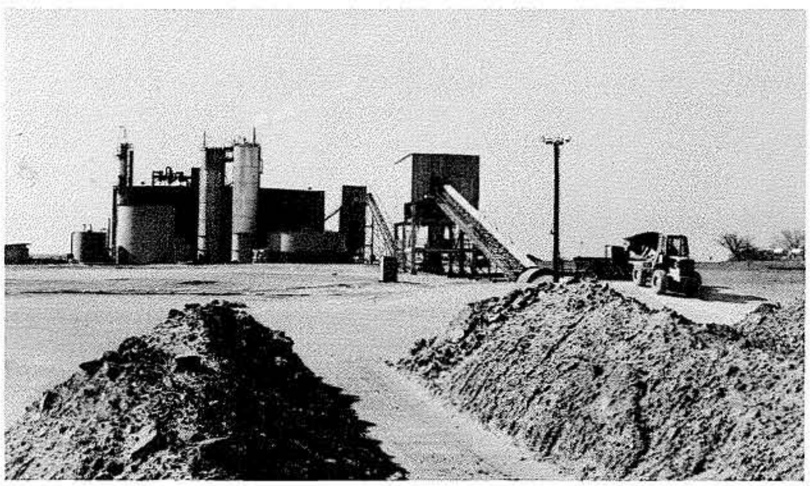


Figure 5 *Photograph showing Susquehanna-Western's uranium mill at Ray Point, January 16, 1971. Note ore piles in foreground.*

1,000-ton-per-day operation began in the spring of 1970, utilizing a carbonate-leach direct-precipitation process to extract the uranium from the calcareous ores of this district. The final product has a low sodium content.

Within the past 4 years more than 20 companies have been active in exploring the region. The impetus came in 1966 when reactor design reached the point where the use of nuclear fission for generation of electric power was considered competitive in several respects with fossil fuels, and the market was opened for purchase of uranium by private companies. Texas is now being extensively explored because it has large areas that are considered favorable but relatively unexplored in comparison to other productive regions. The ore that is being mined is at shallow depth, unconsolidated, easy to strip and mine, and highly amenable to milling and processing. On the other hand, most of the deposits of the Coastal Plain of Texas are relatively small, although exploration probably has not yet progressed far enough to permit definite determination of the limitations of the region. The more recently discovered deposits are fairly high in lime content and, in addition, are so deep that they require subsurface mining, a method in which the unconsolidated host rocks (an advantage in open-pit mining) and the high level of hydrogen sulfide in the rocks are serious disadvantages. Experiments in underground leaching of ore in place have been conducted in the region, but little has been announced concerning the feasibility of this process.

Exploration

Many different exploration methods have been employed in the Coastal Plain of Texas. Much of the country has been covered by airborne radiometric surveys. Both airplanes and helicopters were used early in the exploration of the region, but airplanes were used for most work, which was done on behalf of oil, mining, and exploration companies. The U.S. Geological Survey covered about 70,000 square miles in an airborne survey that centers on the Karnes district and published both airborne and surface radiometric maps that relate to the geology of the area (Brown, Eargle, and Moxham, 1961a, b; Eargle and Moxham, 1961; Eargle, Brown, and Moxham, 1961; Eargle, Trumbull, and Moxham, 1961a, b, c; Moxham and Eargle, 1961; Trumbull, Eargle, and Moxham, 1961). Other types of exploration have included airborne side-looking radar imagery; geochemical surveys of soil, air, and water; trenching by bulldozer; and boring and logging. Geologic mapping of the region has progressed, and photo interpretation has been made from both color and black-and-white photographs.

However, most exploration is by boring, logging, and sampling. Although some holes have been drilled to about 1,000 feet, most exploratory holes in wildcat areas have been bottomed at 600 feet or less (one of the principal factors limiting depth of drilling is the need to use expensive methods of hole completion on all holes that penetrate the fresh water-salt water interface, in order to protect the fresh-water aquifers from pollution). Logging is chiefly by gamma-ray and induction-electrical methods. Other types of logging, for redox potential, salinity, and other characteristics, have been introduced, but none are in general use.

Usually, samples from the rotary drilling are studied and lithologic characteristics determined in the field. Because water is used in most of the drilling, most samples are not reliable for analysis of uranium content. When highly anomalous radioactivity is indicated on gamma-ray logs, offset holes are usually drilled, and solid cores of the anomalous section are taken for analysis.

Host Rocks

Host rocks of the South Texas region are chiefly sands and sandstones that contain volcanic ash and are of relatively high permeability. The sands are interbedded with bentonitic clays and tuffaceous silts that locally are almost pure volcanic ash. Most of the volcanic material has been diagenetically altered by weathering and soil-forming processes that probably took place during periods of dry climate (Weeks and Eargle, 1963).

The Eocene rocks of the Karnes area contain considerable amounts of carbonaceous material and thin beds of impure lignite. The sands there are shallow-marine, deltaic-lagoonal, and strand-plain barrier-bar deposits laid down near the shores of gentle slopes and extending out to continental shelves. These are cyclic deposits, however, interbedded with near-shore carbonaceous swamp deposits and with beds of almost pure ash of acid volcanics, generally water laid and of fine texture. The sands are generally fine to very fine grained; only a few beds of medium or coarse grains--generally channel deposits--are found. They have a relatively high percentage of lithic (volcanic-rock) fragments and contain quartz, feldspar, and a small amount of mica. Some of the beds are thin coquinas of limited numbers of species; some, of thin-shelled pelecypods such as

Corbula or *Corbicula*, others, of large, thick-shelled *Ostrea*. Shells of *Mesalia*, a gastropod that is lower spired than *Turritella*, are found in a few beds with predominantly thin-shelled pelecypods. The preponderance of thin-shelled fossil assemblages of few species indicates a brackish lagoonal environment of low energy and restricted circulation, similar to many of the bays and lagoons of the modern coast.

The host rocks of the Live Oak district are fluvial sands, which, interbedded with silts and clays, extend laterally along the strike from a central alluvial system (Klohn and Pickens, 1970). The system, about 300 feet thick, extends southeastward through central Live Oak County, nearly normal to the strike of the Oakville Sandstone. Thus the host rocks are flood-plain deposits that grade laterally into finer grained deposits. It is believed that the circulation of ground water is restricted in this stratigraphic setting, giving ample opportunity for the precipitation of uranium from solution.

The deposits are located near fault lines where there is seepage of oil and gas that contain hydrogen sulfide (Eargle and Weeks, 1961a). Thus, abundant materials are provided for creation of a reducing environment in which the uranium is precipitated.

Ore Deposits

The first mining in the region was of oxidized ores from relatively shallow pits that averaged 40 feet in depth. The ore occurred in pods, and was usually out of radiometric equilibrium (that is, the radioactivity measurement did not give a true estimate of the uranium content). The chief ore minerals were uranyl phosphates and silicates. Vanadates were of minor importance, and oxides were found in only a few places. Downdip deposits that constitute the more recent mining are unweathered, reduced uranium oxides and silicates, found characteristically in rolls or along chemical boundaries between oxidized and reduced host rocks. The two deposits to be seen on this trip are unoxidized ores, and the nature of the roll, or rounded crescentic shape of the oxidized front, will be demonstrated.

ROAD LOG

First Day, Houston to Laredo

Mileage		
Total	Interval	
		Houston. The route of this trip, following US 59 from Houston to Goliad (pl. I, fig. I), parallels the main oil- and gas-productive trends of the Tertiary of the Gulf Coast of Texas. The Frio and Vicksburg trends are on the left (SE) toward the coast, and the Wilcox trend is a few miles to the northwest, on the right. Because US 59 lies between these trends, it crosses only a few oil and gas fields.
0.0	0.0	Log begins 21 miles southwest of downtown Houston, at the traffic light in Sugar Land (elev 80 ft above sea level; all elevations shown on this log are approximate); Oyster Creek, just behind us, is 70 to 75 ft above sea level. Tall building on your right is the refinery of the Imperial Sugar Co., which has a daily capacity of 2 million pounds and is the only sugar refinery in Texas.
7.8	7.8	Brazos River bridge, US 90A and 59; river elev 65 to 70 ft. The Brazos starts in the panhandle of northern Texas and empties into the Gulf of Mexico about 70 miles southeast of here near Freeport. At one time the river was called Brazos de Dios. Several legends account for the name, and it seems fairly certain that the names of the Colorado and Brazos were interchanged by cartographic error. Entering Richmond, elev 90 ft, county seat of Fort Bend County, named for the fort that was a military post of Stephen F. Austin's colony on the Brazos.
11.3	3.5	Rosenberg, traffic light on Main Street, elev 100 ft.
12.0	0.7	Junction of US 90A, Texas 36, and US 59; bear left on US 59.
19.0	7.0	Beasley (blinker light), elev 109 ft; Orchard dome 6 miles to the northwest: depth to caprock, 285 ft; to salt, 375 ft; the production of sulfur from 1,000 to 3,200 ft is deepest use of Frasch process.
24.5	5.5	Kendleton, elev 94 ft.

26.1 1.6 San Bernard River bridge, river elev 70 to 75 ft. Fort Bend-Wharton county line.

36.8 10.7 Junction US 59 and Texas 60 in Wharton, elev 105 ft; county seat of Wharton County, which has a large output of cotton, rice, cattle, oil, and sulfur.

37.0 0.2 Colorado River bridge, river elev 65 ft.

44.6 7.6 Pierce, area very flat, elev 100 to 105 ft; Pickett Ridge oil field, at left (S) of highway and just west of town, is productive from the updip Frio at a depth of 4,600 ft (fig. 6).

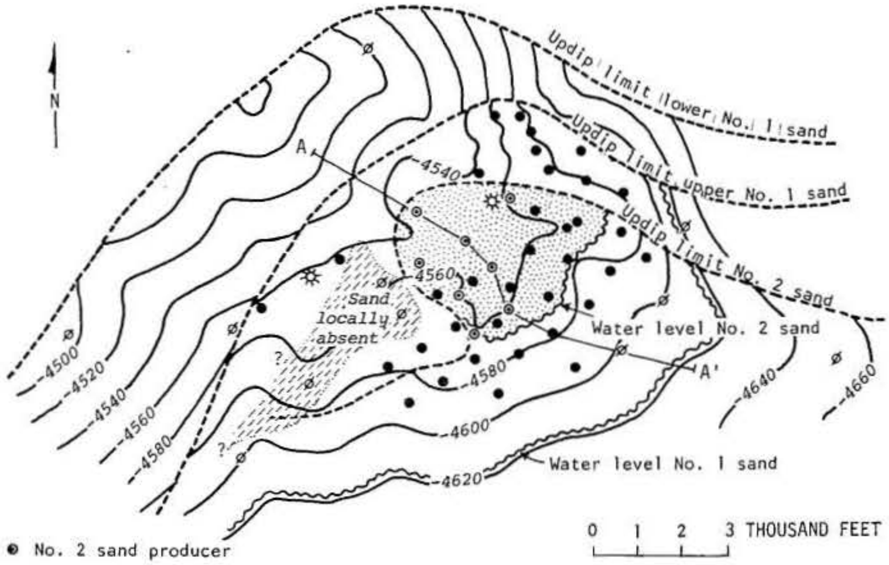


Figure 6 *Map showing areas of producing sands in Pickett Ridge oil field, Wharton County, Texas. The low arch and the facies change from sands to shales updip form the traps in this multiple-pool field. Contour interval 20 feet. Section A-A' across the field is shown in figure 7. Redrawn from Houston Geological Society (1941).*

The field was discovered in June 1935, and is significant in that it represents one of the first stratigraphic traps found in the area. The field is updip from most Frio production and produces from sands that pinch out on a gentle structural nose (fig. 7). As of January 1, 1970, this field had produced 14,645,836 barrels of oil and 28,872 million cubic feet of gas from 105 wells. Forty-one wells are still productive.

49.4 4.8 El Campo, area very flat, elev 105 ft.
Junction US 49 and Texas 71; rice granaries and rice fields.

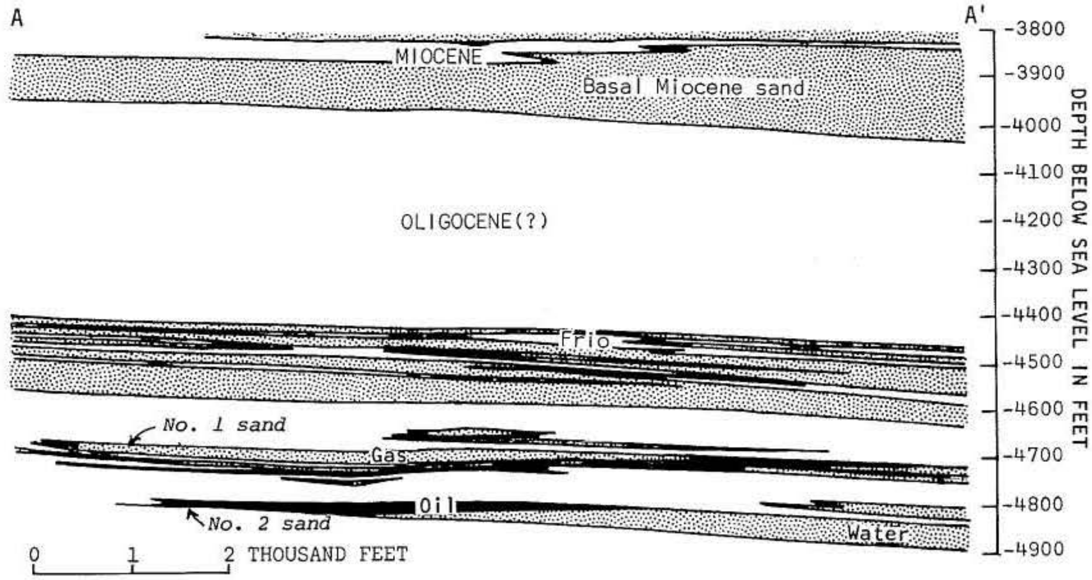


Figure 7 *Cross section A-A' across the Pickett Ridge oil field, Wharton County, Texas, showing the pinch-out of the two productive sandstones. Redrawn from Houston Geological Society (1941).*

54.8 5.4 Hillje.

59.7 4.9 Louise, elev 83 ft; rest area on right.

63.8 4.1 Mustang Creek bridge, creek elev 45 ft; land nearby, 70 ft.

67.3 3.5 Ganado, elev 65 ft; junction US 59 and Texas 172. Sandy Creek and Harmon oil fields can be seen on both sides of the road. These fields produce from Frio sands between 4,500 and 6,500 ft. The fields are separated by a down-to-the-coast normal fault that parallels the highway. The structure is an anticline cut by faulting. Harmon field was discovered in May 1942 and as of January 1, 1970, it had produced 2,562,941 barrels of oil and 5,156 million cubic feet of gas. Sandy Creek field was discovered in February 1948 and as of January 1, 1970, it had produced 1,906,873 barrels of oil and 2,385 million cubic feet of gas.

69.8 2.5 Navidad River, elev 15 to 20 ft; bridge elev 43 ft. Borings made about 4 miles downstream by the U.S. Bureau of Reclamation show that alluvium extends to about 35 feet below sea level. The alluvium filled an old channel in the Beaumont Clay cut to that depth in late Pleistocene and Holocene times.

76.1 6.3 Edna, elev 65 ft; large rice granaries; junction US 59 and Texas 111. Edna, the county seat of Jackson County, was squarely in the path of hurricane Carla, which hit in the fall of 1961.

78.8 2.7 Lavaca River bridge, river elev 40 to 45 ft.

84.9 6.1 Arenosa Creek.

86.1 1.2 Inez (junction with Farm Road 444).

88.0 1.9 Garcitas Creek. About half a mile beyond Garcitas Creek, 2 miles southwest of Inez, the highway climbs from the Beaumont terrace (elev here about 65 ft) to the Montgomery terrace (elev more than 75 ft).

92.9 4.9 Junction US 59 and Texas Loop 175, loop around Victoria to US 77 and Corpus Christi. Stay on US 59, bear right.

94.8 1.9 Victoria County Airport (old Foster Field) on right is on the Bentley terrace, elev 100 ft.

Junction US 77 and US 59 in Victoria. Victoria was a district under Mexican government in 1832, became a municipality in 1835, and the county seat when Victoria County was created under the Republic of Texas in 1836. Mission de Nuestra Señora del Espiritu Santo de Zuñiga was first located here in 1722.

Fort Saint Louis, on Garcitas Creek at the head of Lavaca Bay 25 miles east of here in Victoria County, was founded by LaSalle in 1685 (the foundation of the old fort remains today). Here the French flag was first raised over Texas. LaSalle had landed here after passing by the mouth of the Mississippi, for which he was searching. Following several years of exploration of the lower Gulf Coast, he was beset with many difficulties, including mutiny, and is thought to have been murdered by his own men near Navasota on the Brazos River, 100 miles north of here.

101.7 1.4 Guadalupe River, elev 45 to 50 ft; flood-plain elev 50 to 55 ft.

103.1 1.4 Gravel pits in terrace deposits off to right.

104.0 0.9 Rise to higher terrace at junction of US 77 and US 59.

105.4 1.4 Montgomery terrace, higher relief with huisache vegetation dominant.

108.5 3.1 Goliad Sand outcrop in stream bottom at left.

110.5 2.0 Coleto Creek bridge; bridge elev 110 ft. Beyond Coleto Creek we rise to the Montgomery terrace, elev here, 115 ft.

114.7 4.2 Goliad Sand outcrop in stream bank at right.

116.9 2.2 Fannin; the road to the left leads to Fannin State Park, site of the battle where Colonel Fannin and his men were defeated by the Mexican army under General Urrea. The 12-ton battlefield monument, half a mile south of the highway, was blown from its base by hurricane Carla in the fall of 1961.

118.9 2.0 Foster Field Auxiliary, elev 153 ft, probably on Bentley terrace; valleys are cut into Goliad Sand (Pliocene).

122.5 3.6 Manahuilla Creek; rolling topography in this area is typical of Bentley terrace surface.

126.1 3.6 Goliad; junction of US 59, 77A, and 183 South. Turn left (S) on 77A and 183.

This part of Goliad, with its old town square and well preserved houses along shady streets, belies the violent events of its past.

The town of Goliad is the outgrowth of the Presidio of Nuestra Señora de Loreto and the Mission of Espiritu Santo Zuñiga, together known as La Bahia, about a mile to the south on the San Antonio River. The Presidio was one of a series of forts built by the Spanish to further their plans for colonization and territorial expansion and for protection from the hostile Karankawa Indians, who were then occupying the Coastal Plain of Texas. It was built originally in 1722 on Garcitas Creek near the head of Lavaca Bay (whence the name La Bahia) east of Victoria, on the site of LaSalle's Fort Saint Louis. A few years later the fort was moved to Mission Valley (on the Guadalupe River below Victoria), and in 1749 it was moved to Goliad, a more strategic location. The Mission of Espiritu Santo Zuñiga was established near the Presidio, and in it the Indians were offered instruction in religion, the rudiments of farming, and common skills, but the ministry to the Karankawa was not very successful.

After the Spanish soldiers had left the region and the Anglo-American settlements were established, the buildings of La Bahia fell into ruin, although the Presidio was occasionally used by people seeking protection and was occupied during three military expeditions organized to assist the Mexicans in their struggle for freedom from Spain: under Gutierrez-Magee in 1812, Henry Perry in 1817, and Dr. James Long in 1821. In October 1835, Texan forces under George M. Collinsworth and Ben Milam, seeking independence from Mexico, captured La Bahia (then called Goliad) from the resident Mexican garrison, and the Goliad Declaration of Texan Independence was signed there on December 22, 1835. The most tragic incident of the Texas Revolution was the execution here of Colonel James W. Fannin and 330 of his men on March 27, 1836, following their surrender at Coleto Creek, 10 miles to the east.

126.4 0.3 Underpass, Southern Pacific RR. Excellent exposure of the Goliad Sand, thick-bedded, coarse-grained sandstone containing thin lenses of gray clay.

126.8 0.4 Memorial auditorium at left. On front panels are inscriptions that give a brief summary of the events that make Goliad so important historically.

126.9 0.1 Goliad State Park entrance, Mission Espiritu Santo Zuñiga, and Museum at right (W).

127.3 0.4 San Antonio River (elev 90 to 100 ft).

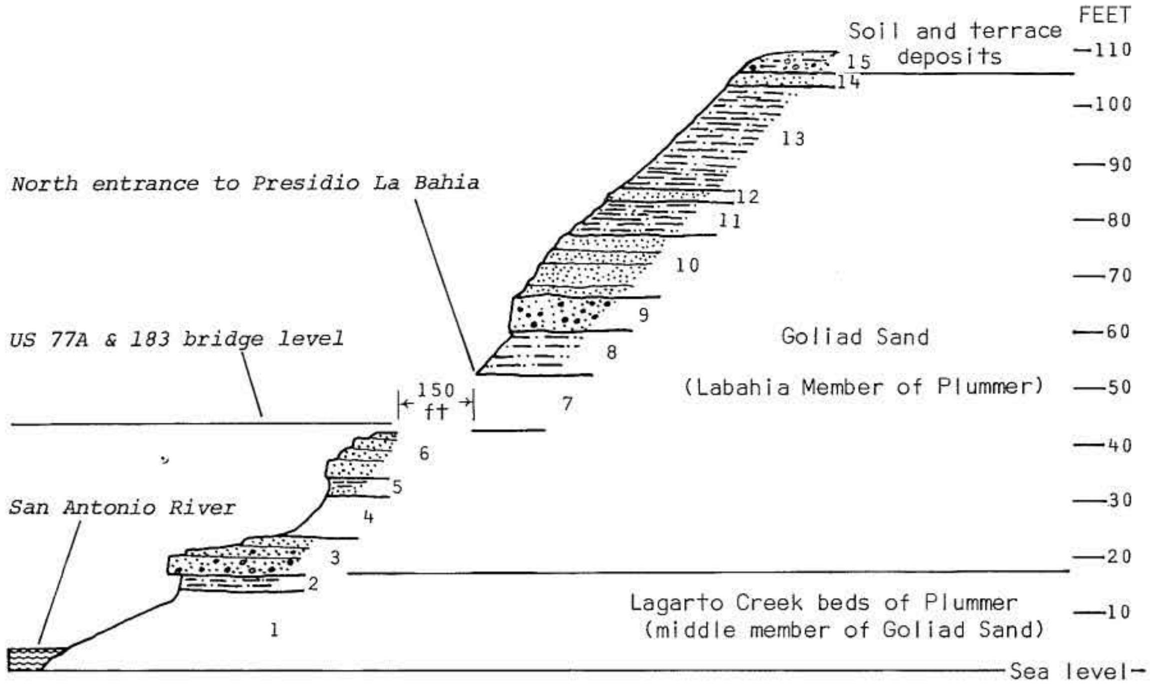


Figure 8 *Cross section at Stop 1, type locality of Goliad Sand in road-cut on US 77A near Presidio La Bahia, Goliad County, Texas. Numbers refer to measured section on page 21.*

127.4 0.1 STOP 1, at Loop 71. At left is the entrance to Presidio La Bahia. Type locality of the Goliad Sand is in cuts along the highway here (fig. 8). Fossils of Pliocene age found in the Goliad Sand near the bridge here in Goliad State Park have been studied by Wilson (1956, p. 2234) and Quinn (1955, p. 70), who termed this assemblage the La Bahia Mission local fauna of middle Pliocene age. An older fauna, the Lapara Creek fauna, has been found extensively in basal sands of the Goliad in Live Oak, Bee, and Goliad Counties. Although the Lapara Creek fauna has been termed Miocene, Dr. Wilson stated (oral commun., 1962) that the assemblage is on the border between Miocene and Pliocene. A detailed description of beds exposed here follows on page 21.

Section measured from the San Antonio River up the hill to the south, along US 77A at Presidio La Bahia. [Numbers at left refer to numbered beds in figure 8.]

	Feet
Soil and terrace deposits	
15. Caliche and gravelly sandy soil, contains terrace gravel........	3
Goliad Sand (Labahia Member of Plummer)	
14. Sand, white, coarse..	2
13. Clay, sandy, white; sand fraction fine. About..................	18
12. Sand, clayey, white, medium....................................	2
11. Clay, sandy, white, somewhat fissile, fine to medium............	5.5
10. Sandstone, gray, coarse-grained, medium-bedded; grades upward into sandy clay containing sand lenses..........................	11
9. Sandstone, conglomeratic, very light gray, coarse-grained to granular conglomeratic; contains round clay balls and has a clay matrix; irregular to medium bedded.........................	6
8. Clay, sandy, white, hard but not indurated; sand fraction fine to medium, contains some red and black grains; upper 2 feet is strongly vertically jointed, forming columnar structure. Opposite lower entrance to Presidio La Bahia....................	8
7. Covered..	10
6. Sandstone, gray, semi-indurated, crossbedded; contains lenses of abundant clay balls. Base at 33 feet on stream gage. This and underlying bed exposed under bridge.........................	8
5. Sand, very fine, and silt, gray, slightly stained yellow, soft..	3
4. Covered..	8
3. Sandstone, gravelly, gray; subrounded pebbles, mostly chert and clay balls, some as long as an inch; indurated, forms overhang in west ditch. Undersurface appears somewhat fluted but fairly level. Crossbedded, but forms solid 3-foot ledge, with overlying beds forming other benches above. Sand is subrounded, red and black grains less than 10%, fine to coarse. Contact with underlying sandy clay is at 17 feet on gage staff...............	6
Lagarto Creek beds of Plummer (middle member of Goliad Sand)	
2. Clay, sandy, gray, stained yellow in upper foot. Sand is coarse to fine, subrounded; some dark grains, sticky; contains indurated nodules in upper few inches and one flattened smooth clay boulder (3 x 10 in). Under overhang of bed above.......................	3
1. Covered with alluvium of San Antonio River......................	10

Beds 1 through 6 measured from water surface 3.8 feet above datum of staff of USGS stream-gage. Level of bridge is 44 feet above datum (datum is 91.085 feet above sea level). High water during hurricane Beulah, July 23, 1967, was 53.7 feet above datum.

127.6 0.2 Turn left on Loop 71.

127.8 0.2 Grave of Colonel James W. Fannin and troops.

Colonel Fannin, who occupied La Bahia in February 1836, was ordered by General Sam Houston to proceed to San Antonio to assist in the defense of the Alamo, but the Alamo fell before he was able to leave. Houston then ordered him to retreat to Victoria, but Fannin delayed, waiting for the return of two of his detachments that had been sent to relieve besieged settlers in Refugio. Because he had delayed so long and because his army could move only as fast as the slow-moving oxcarts that supplied it, he and his men were surrounded and captured by General Jose Urrea in a one-sided battle 10 miles east of here on the plains of the Coleto, and were returned to Goliad.

Although the captured soldiers were told they would be treated as prisoners of war, the conditions of surrender were dictated by General Santa Anna, whose policy to execute all rebels as pirates was well known. Although Urrea petitioned for clemency, Santa Anna's orders remained unchanged, and the men were divided into three groups, were led a short distance from the fort, and were shot. Their bodies were stripped of clothing and burned. Later their remains were gathered and buried in a trench above which the Fannin Monument now stands.

Turn left and proceed to front of Presidio La Bahia.

128.1 0.3 Presidio La Bahia, museum entrance.

Return to junction of US 77A and Loop 71.

128.2 0.1 Turn right onto US 77A and 183. Return to Goliad, intersection with US 59. (Turn left two blocks before intersection for tour of picturesque town square.)

129.6 1.4 Blinker light; go left on US 59 and Texas 239.

131.4 1.8 Turn right onto Texas 239 toward Kenedy.

132.7 1.3 Wide terraces of San Antonio River on left.

133.1 0.4 Caliche (used for road building) pit in Goliad Sand at right, easily seen from road.

137.6 4.5 Caliche formed in Goliad Sand exposed in roadcut, forms high scarp overlooking valley of San Antonio River to west. Clay of Goliad Sand exposed below caliche. Base of Goliad a tenth of a mile ahead and about 50 feet lower.

139.8 2.2 Angel City, elev 223 ft; Farm Road 2043 at left (S). Continue on Texas 239.

140.2 0.4 Albrecht gas field on a down-to-the-coast fault. Numerous faults extend northeastward through this area in the subsurface.

141.9 1.7 On left are terraces of San Antonio River developed on soft Fleming (Miocene) clay.

144.6 2.7 Keep left on Texas 239; Farm Road 81 to Runge (pronounced Rungy) on right. Weather records have been kept continuously in Runge since early times.

145.1 0.5 Charco, elev 242 ft, on a terrace of the San Antonio River.

146.6 1.5 Roadcut at left side of road, east bank of San Antonio River, exposes gravelly sand of the Fleming Formation under terrace gravels.

146.8 0.2 San Antonio River (elev 205 ft) bridge. At flood plain elevation is 150 to 160 ft.

147.9 1.1 Roadcut at left side of road exposes coarse, crossbedded pink sand and silt of Fleming Formation.

151.3 3.4 Sign at road on right: ***Shell Atkinson No. 1, 20,000-ft well to test Lower Cretaceous Sligo Formation.*** The well is about 200 yds to the right (N) of highway. Depth, 19,250 ft on August 21, 1970, now abandoned.

153.0 1.7 Choate.

156.7 3.7 Pink, tuffaceous sands of Fleming Formation poorly exposed in road cut.

159.2 2.5 Junction, Texas 239 and 72; turn left onto Texas 72 toward Kenedy. Roadcut at left in Oakville Sandstone.

160.8	1.6	Kenedy. Stop sign at intersection with Farm Road 743 at east edge of town. Stay on Texas 72. Kenedy is the center of petroleum and flax production for this region.
160.9	0.1	Turn right onto Business US 181 in Kenedy. Note storage tanks for flax and other grains. The flax industry of this part of Texas centers here. The seeds are used for linseed oil, and the stalks were used for linen paper until the paper plant in Karnes City burned down several years ago. The principal manufacturing plant in Kenedy is a guar plant, said to be one of two in the world, owned by General Mills. The beans from which guar is made, formerly grown here, are now brought in from northern Texas and Pakistan. Uses of the product, a water-soluble white flour, are many; in the food industry they include cake mixes, pie fillings, ice cream, and instant whips. Industrial uses include drilling muds and hydrofrac gums.
161.4	0.5	Turn left, staying on Business US 181, at traffic light in downtown Kenedy.
161.5	0.1	Turn right at blinker light, staying on Business US 181.
161.9	0.4	Escondido Creek bridge, in Kenedy. Creek flooded frequently until 10 upstream dams were built.
162.1	0.2	Join US 181. Continue straight ahead on 181.
162.4	0.3	Barth's Restaurant at left on US 181. LUNCH STOP. All South Texas uranium geologists eventually meet at Barth's. From Barth's go north on US 181 toward Falls City.
165.4	3.0	Texas 123 to San Marcos on right. Continue on 181.
165.8	0.4	Basal Oakville (Miocene) in fields.
166.8	1.0	Farm Road 99 goes left to Coy City, Fashing, and Whitsett. Continue on US 181.
167.3	0.5	Farm Road 1144 at left. Continue on US 181. For descriptions of significant exposures of Catahoula Tuff and of the caliche that caps it 6 miles west of here, see Eargle and Foust (1962, p. 241-243). Samples from the thick, massive caliche into which modern soils are developing and which had been partly

destroyed by tree roots and animal burrows, were dated by the Radiocarbon Laboratory, The University of Texas at Austin, at approximately 18,000 years (Valastro and Davis, 1970). Caliche veins in the tuff slightly downhill showed ages ranging from 13,750 to nearly 17,000 years. The former arid climate indicated by caliche development is believed to have had an important part in the weathering and leaching of the uranium from the tuffaceous bedrock.

169.7 2.4 Outcrop of Catahoula Tuff in creek at right.

173.1 3.4 Approaching Hobson; a deep-seated up-to-the-coast fault in subsurface traps hydrogen sulfide-bearing gas and oil in the Edwards Limestone, 11,000 to 12,000 feet below the surface. Fields producing sour oil and gas extend almost continuously across northern Karnes County and southwestward into Atascosa County.

174.3 1.2 Tuff of Whitsett Formation exposed in "caliche" pit at right of road.

175.4 1.1 Deweesville Sandstone Member of the Whitsett in roadcut.

175.8 0.4 San Antonio River.

176.3 0.5 Falls City. At blinker light turn left onto Farm Road 791. Winding road for several miles.

180.0 3.7 Obscure farm road at left to Conquista Bluff on San Antonio River, type locality of the Conquista Clay Member of the Whitsett Formation, where one of the best exposures of beds of the Jackson Group (outside of the uranium mines) can be seen. For detailed description of beds exposed there see South Texas Geological Society (1958), a guidebook to the oil- and uranium-producing areas of this region, written before the downdip unoxidized ores were discovered.

180.1 0.1 San Antonio River.

181.4 1.3 Scared Dog Creek. Exposures of Dilworth Sandstone Member near here (figs. 9, 10).

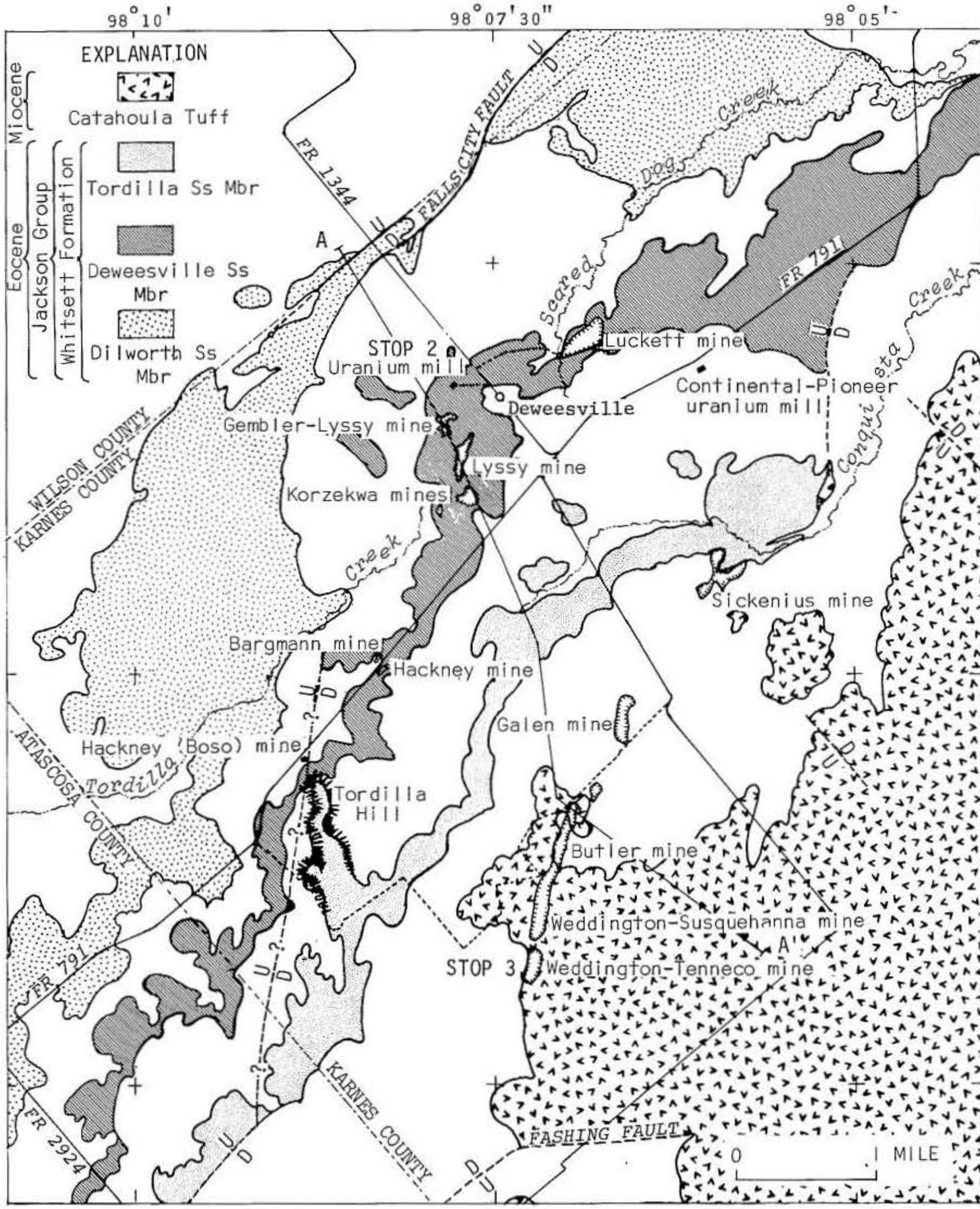


Figure 9 *Map showing distribution of sandstone in the Whitsett Formation of the Karnes district. Section A-A' is shown on figure 10. Revised from Eargle and Weeks (1968).*

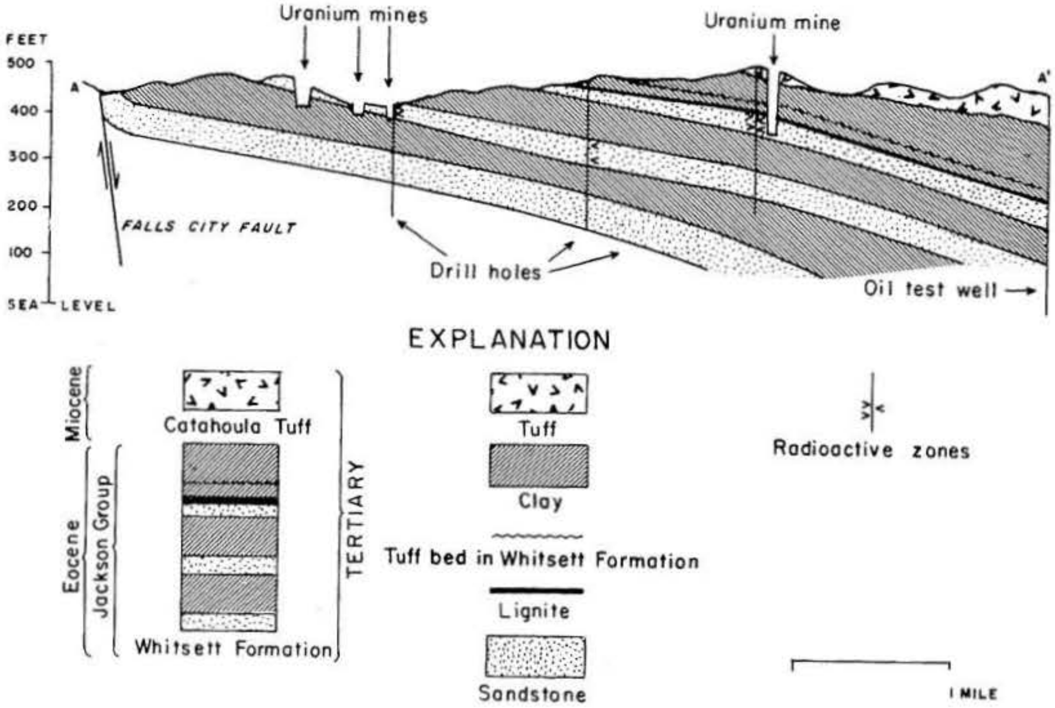


Figure 10 *Cross section A-A' through the uranium-mining area of Karnes County. From Eargle and Weeks (1968).*

182.0 0.6 Good exposure, type locality of Deweesville Sandstone Member, in roadcuts. This sandstone was the host rock for most of the early-discovered oxidized uranium deposits in this region.

182.6 0.6 North-trending fault crosses road in this small valley. For some distance ahead we will be traveling on the back slope of the cuesta supported by the Deweesville.

183.3 0.7 Tordilla Sandstone Member supports cuesta at distant left.

184.3 1.0 Site of the new Conquista uranium mill of Continental Oil Co. and Pioneer Nuclear, Inc.

184.8 0.5 Fossil leaves of deciduous trees were found in sandstone outcrops of Dubose Member, Whitsett Formation, in the roadcuts.

185.3 0.5 Turn right onto Farm Road 1344.

185.8 0.5 Site of Deweesville, a community center that once had a post office, cotton gin, and dance hall; abandoned in the early 1930's.

186.0 0.2 Entrance to Susquehanna-Western, Inc., uranium mill. Turn

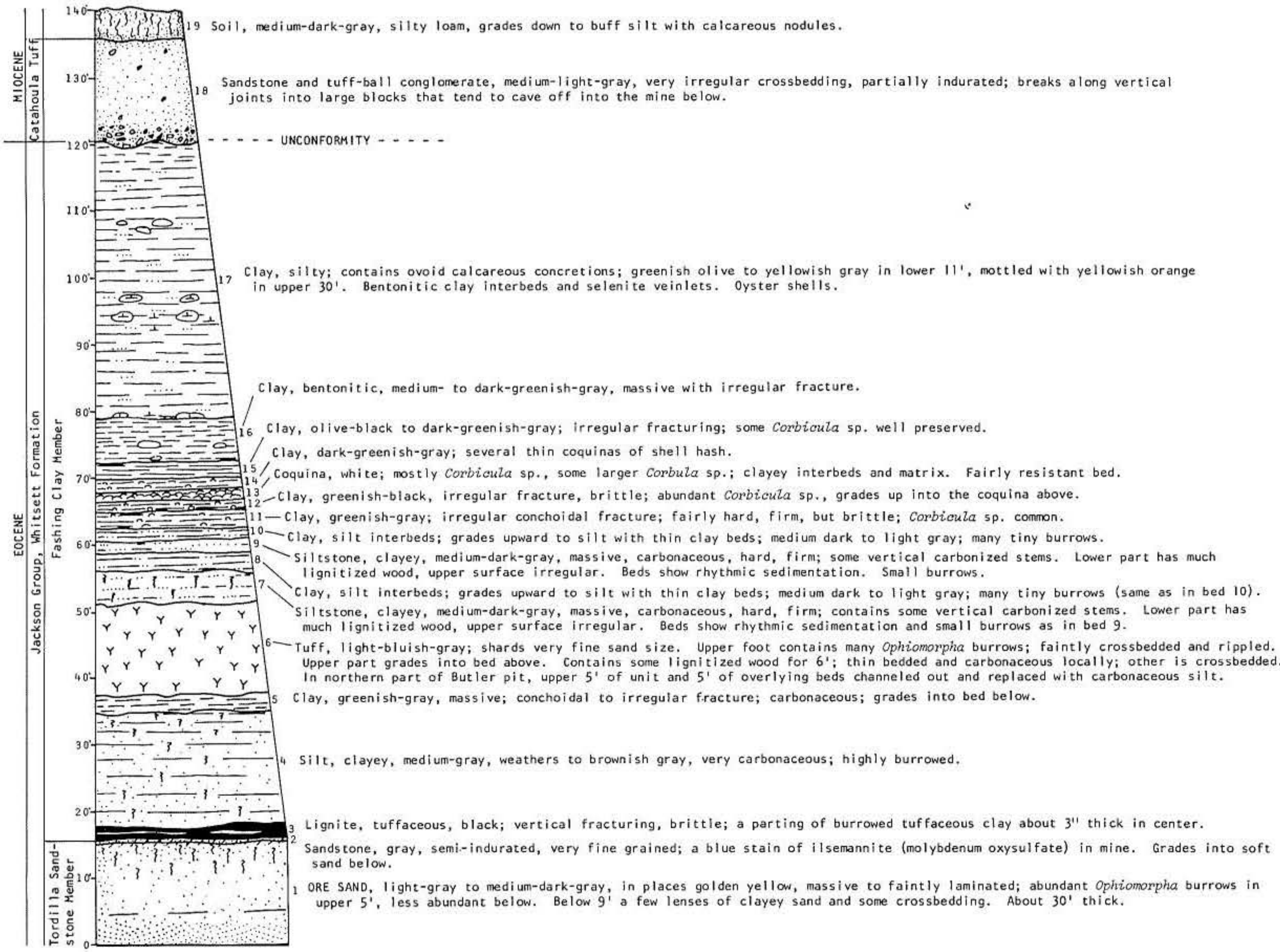


Figure 11 *Diagrammatic cross section at Stop 3. Beds 7 to 19 measured in haulageway in southwest end of Weddington pit; beds 1 to 6 measured in the northeastern part of the Butler pit, 11 miles southwest of Falls City, Texas. Revised from Corpus Christi Geological Society (1968).*

left at mill entrance, proceed into mill yard.

STOP 2, Susquehanna-Western, Inc., uranium mill. Brief discussion of milling processes.

186.4 0.4 Return to mill entrance. Office of exploration geologist and engineers at right. Turn right onto Farm Road 1344.

187.2 0.8 Turn right onto Farm Road 791. Through this area along both sides of road are old pits in oxidized ores of the Deweesville. Korzekwa pit on the right at 2 o'clock.

190.0 2.8 North foot of Tordilla Hill. The first discovery of uranium minerals in this region was here. Abandoned Hackney (Boso) mine in Deweesville at left.

190.6 0.6 Gate to Weddington mine. Turn left onto mine road.

191.4 0.8 Road turns left, up hill.

191.5 0.1 Outcrop of Tordilla Sandstone Member.

192.0 0.5 Right turn.

192.6 0.6 Left turn.

193.0 0.4 Right turn toward pits of Tenneco's Weddington mine.

193.2 0.2 Old ramp into Susquehanna-Western's Weddington and Butler pits.

193.8 0.6 STOP 3, Tenneco's Weddington mine. See figure 11 for a typical measured section of the overburden and ore sand. For bird's-eye views see figures 12 and 13. Tenneco's operations began on March 10, 1969, and mining began on August 1 of that year. Stripping overburden from a typical pit takes about 5 or 6 months, and mining the ore, about 7 to 9 months. Mining is accomplished in open-pit units that vary in size, but a typical one is about 300 to 400 feet wide and about 1,000 feet long at the mine floor. Average depth of the pits, to bottom of ore, is about 135 feet. The average tenor of the ore is about 0.20 percent U_3O_8. Ore minerals are sooty pitchblende (uraninite, UO_2) and coffinite ($USiO_4$), which coat the sand grains. The ore occurs as a roll, the front of which is an oxidation-reduction boundary, crescentic in cross section and concave updip. The ore is thickest and richest just downdip

Figure 12 *Oblique aerial photograph showing Susquehanna-Western's Butler-Weddington mine. The ore is at a depth of 100 to 130 feet along the bottom of the long trench. Some of the overburden is piled in high mounds at the sides of the trench; some has been back-filled as mining has progressed. (Photograph by Mitchell Photography, Kenedy, Texas.)*

from the front and is 20 to 30 feet thick, gradually diminishing in tenor and thickness downdip.

Return to Farm Road 791 over same road on which we entered.

197.0 3.2 Turn left onto Farm Road 791, Cuestas ahead are supported by indurated layers of Deweesville Sandstone Member.

197.6 0.6 Atascosa-Karnes County line.

198.8 1.2 Roadcut in Conquista Clay Member, capped by bed of fossiliferous sandstone in the Conquista.

199.3 0.5 Left turn onto Farm Road 2924 toward Fashing.

199.9 0.6 Outcrop of Conquista Clay Member capped by fossiliferous sandstone. At left is cuesta capped by indurated Deweesville Sandstone Member.

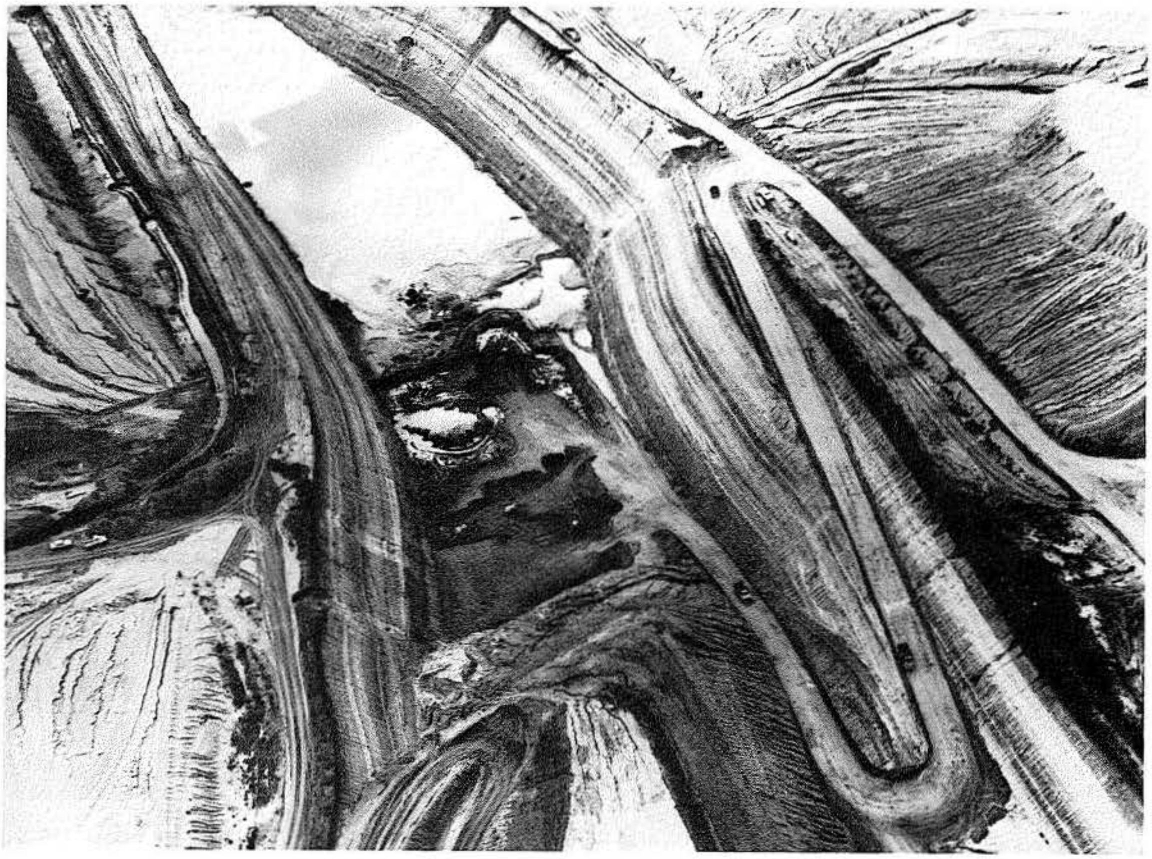


Figure 13 *High-angle aerial photograph showing mining operations in the dark ore of the Butler mine, November 17, 1967. (Photograph by Mitchell Photography, Kenedy, Texas.)*

200.4	0.5	Crossbedded coarse-shardy tuffaceous sand in the Deweesville.
200.5	0.1	Fashing-Edwards gas field. Sour gas is produced from the Edwards Limestone at about 11,000 feet. Trap is the Fashing fault.
201.9	1.4	Old Fashing or Weigang oil field in the Carrizo Sand at about 3,800 feet. Trap is again the Fashing fault.
202.2	0.3	Surface exposure of the Fashing fault is in small draw.
202.4	0.2	Cuesta capped by thin Tordilla. Fashing Clay Member, near the type locality, is on the back slope. Town of Fashing in distance ahead.
202.6	0.2	Turn right on paved road (road to Campbellton), unmarked.
203.5	0.9	Somico tank farm.

204.2	0.7	Warren and Lone Star gas processing plants at right. Distillate and sulfur are stripped from gas here.
207.0	2.8	Deweesville Sandstone Member in roadcuts.
207.8	0.8	Junction with Farm Road 1099. Continue straight ahead.
210.1	2.3	Gate to Hacienda de la Tordilla, Spanish-styled mansion formerly owned by Smith and Mowinkle, now by the H. R. Smith estate, at right. Fossiliferous sandstone in the Conquista supports this cuesta. High hills at 11 o'clock are Lipan Hills, supported by indurated sandstones of the Whitsett Formation. Road ahead is over these sandstones and interbedded softer clays and silts.
211.8	1.7	Basal sand of the Whitsett Formation. Slope and valley of Lipan Creek ahead are in Manning Clay.
213.2	1.4	Junction of Farm Road 1099 with US 281. Turn left onto US 281.
214.3	1.1	Bridge over Lipan Creek. Hills ahead are on basal sandstones of the Whitsett Formation.
215.3	1.0	Base of sandstone that Ellisor (1933) termed "Stone's Switch sand," actually correlative with her Dilworth, the type locality of which is 85 miles northeast of here in Gonzales County. Type locality of her "Stone's Switch" is in this ridge, about a mile to the right at about 2 o'clock. Ellisor, reporting Sam Houston's field work in the area, believed the clay in the slope of this cuesta, below the sandstone that caps it, to be the "Falls City shale" (Conquista Clay Member of this report), and the Dilworth to be hidden in the valley of Atascosa Creek below. Correlations to the east were based on the section measured in these hills. Detailed mapping in this region (Horne, 1964) has proved this correlation erroneous, and acceptance of this work before the detailed mapping was done has resulted in miscorrelations of the uranium-bearing beds in the Karnes area.
216.9	1.6	STOP 4, Whitsett section (fig. 14) and discussion. View from crest of Lipan Hills shows beds that can be traced by following the cuestas they support for many miles through this

region, These sandstones in the lower part of the Whitsett are considered strand-plain and barrier-bar deposits near the shore of the Jackson Sea. North of here, across the fence and 50 yards off the road to the east, is a small quarry in indurated sandstones of the Whitsett.

218.6 1.7 Whitsett Bluff, type locality of the Whitsett Formation half a mile to the right. The sandstone that caps this bluff is now considered the correlative of the Deweesville Sandstone Member in the Karnes uranium district.

221.2 2.6 Whitsett. Texas 99 crosses US 281 here. Stay on 281.

222.3 1.1 Olmos Creek. Whitsett-Frio contact said to be under bridge; not verified by current mapping.

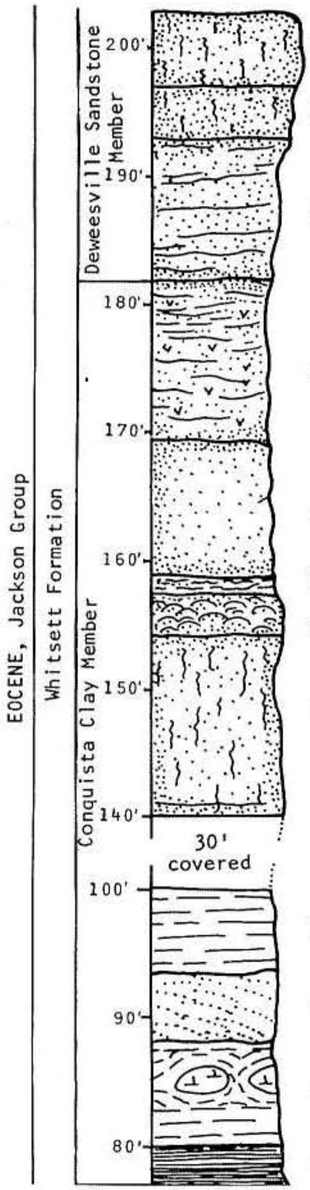
225.9 3.6 Suniland, formerly Fant City, site of land scandal in 1928, in which the promoter who organized what he called "the largest turkey ranch in the world" was sent to prison for using the mails to defraud.

226.2 0.3 STOP 5. Type locality of the Fant Member of the Catahoula Tuff (fig. 15), named by T. L. Bailey (1926) (Bailey's name for the Catahoula was Gueydan Formation). This is the basal member of the Catahoula Tuff and lies on the Frio Clay, type locality of which is also in this vicinity, although the Frio River, for which it is named, is about 10 miles to the south. (The original Frio included both the Catahoula Tuff and the clay that we now call Frio.) Typical exposures of the Frio in badlands across the road from this locality and in gullies about two-tenths of a mile ahead along Weedy Creek. For a detailed description of beds at this locality, see McBride, Lindemann, and Freeman (1938, p. 53).

This is the last stop for today. The group will proceed to Laredo, a distance of about 125 miles, to spend the night at La Posada Motor Hotel.

226.5 0.3 Weedy Creek, called San Cristoval (also spelled San Christobal) on many maps. Pink and olive Frio Clay, overlain by thin beds of Fant Member, Catahoula Tuff, in gullies at right.

226.6 0.1 Intersection with Farm Road 2049. To the left this road



23 Sandstone, massive, fine, light-gray to olive-gray; some limonite staining; burrowed; zeolite and opal cemented. Caps Whitsett Bluff.

22 Sandstone, very fine to fine, light- to olive-gray, crossbedded; soft to well-indurated thin beds.

21 Sandstone and interbedded silty sandstone and carbonaceous shale, light- to olive-gray to light-chocolate-brown.

20 Claystone, interbedded with siltstone and sandstone. Claystone is bentonitic, weathers light gray.

19 Sand, very fine to fine, light-gray, olive-gray, and reddish-yellow; crossbedded to thinly bedded; *Corbicula* shells in upper part.

18 Claystone, bentonitic, olive-gray; concentrations of *Corbicula* shells and a few small gastropods; fibrous calcite concretions.

17 Shell bed with sand matrix, light-gray, olive-gray, reddish-yellow, moderately hard; chiefly *Corbicula* shells, a few small gastropods; fine to medium sand.

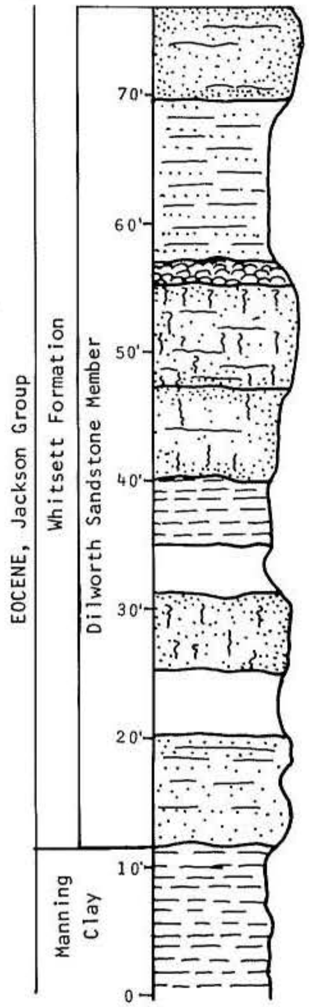
16 Sand, light-gray to reddish-yellow, crossbedded; soft lenses of chocolate-brown bentonitic claystone; scattered *Corbicula*.

15 Clay, olive, bentonitic.

14 Siltstone, buff, soft, finely crossbedded.

13 Clay, pale-brown, weathers yellowish gray, fissile, wavy-bedded; contains calcareous concretions as large as 3' x 8' and prismatic calcite; upper part grades into siltstone above.

12 Siltstone, pale-brown, very carbonaceous, thinly bedded.



11 Sandstone, gray, with yellow-orange staining, massive, thick but irregularly bedded to lenticular; contains plant-root impressions. Gradational upper and lower contacts. Lipan Hills Sandstone Member of Horne (1964).

10 Clay and silt, thinly interbedded and finely crossbedded; some *Ophiomorpha* burrows; contains some prismatic calcite lenses and concretions as large as 6" x 18". Lower part is mostly covered.

9 Sandstone, gray, weathers yellow to orange, very fossiliferous, lenticular.

8 Sandstone, gray, coarsely and irregularly bedded, occasional ash beds as much as 6" thick; moderately well indurated; fine to medium; abundant *Ophiomorpha* burrows in upper half, fewer burrows and more ashy in lower half.

7 Sandstone, gray, salt-and-pepper appearance; similar to bed above, but fewer burrows and more ashy.

6 Claystone, buff to yellow-tan, obscurely bedded, well-indurated, locally silty to sandy; minor ash.

5 Covered.

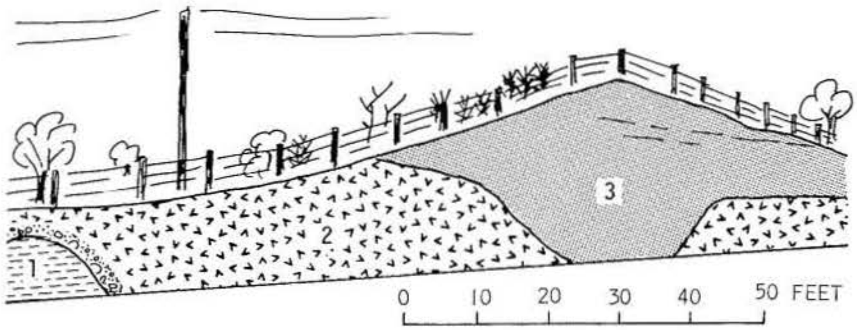
4 Sandstone, gray-stained with iron oxide, moderately well indurated near top, very friable near base; fine-grained; abundant large *Ophiomorpha* burrows, horizontal and vertical.

3 Covered.

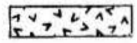
2 Sandstone, gray to greenish-gray, thinly bedded and interbedded with clayey sand, clay, and ash; some beds show minor crossbedding; slabby.

1 Clay, light- to dark-brown, weathers gray to almost white. Finely but obscurely bedded; conchoidal fracture.

Figure 14 *Measured section at Stop 4. Beds 1 through 15 measured on northwest face of Lipan Hills in railroad cut about 4 miles south of Campbellton by Jerry D. Horne (written commun., 1961). Beds 16 through 23 measured in Whitsett Bluff, 1 7/10 miles northwest of Whitsett on the Atascosa River, by Clyde R. Seewald (written commun., 1966). Both parts are revised from South Texas Geological Society (1958).*



Bed 1.--Pale-olive-green, massive, slightly indurated and bedded bentonitic clay.



Bed 2.--Pale-olive, slightly indurated massive tuff that is channeled into the underlying clay and has a basal conglomerate of bentonitic clay balls that are similar to the clay of bed 1.

Bed 3.--Very pale bluish gray, friable, mealy tuff that weathers white, is generally massive, but is slightly bedded near the top and fills a deep channel cut into the underlying bed.

Figure 15 *Diagrammatic cross section of Catahoula Tuff at Stop 5, in a cut on US 281, 9 miles north of Three Rivers and 5 miles southeast of Whitsett, Live Oak County, Texas.*

leads toward uranium mines and mill of the Live Oak district near Ray Point, which this field-trip group will visit tomorrow.

230.9 4.3 Intersection; Texas 9 goes to left. Continue straight on US 281.

234.6 3.7 Junction with Texas 72 at northern edge of Three Rivers. Here we join the route of tomorrow's field trip, which will turn eastward at this point.

235.3 0.7 At traffic light in Three Rivers, Texas 72 turns westward to Tilden. Tomorrow's trip will come into Three Rivers on this road. Continue straight ahead on US 281.

237.4 2.1 Nueces River bridge, main channel. Several bridges are required to carry the highway across this wide flood plain.

237.7 0.3 Oakville fault, downthrown to southeast, just beyond railroad underpass near site of old railroad siding named for Kittie West. Oakville Sandstone up hill to south.

239.3	1.6	Mobil's Kittie gasoline plant on left.
241.0	1.7	Sand and gravel pits in this area are in massive channel sands of the Oakville. The uranium deposits of Live Oak County are believed to occur not in fluvial channels, but in adjacent flood-plain deposits where sands interfinger with silts and clays (Klohn and Pickens, 1970).
244.2	3.2	Houston Pipeline Co. gasoline plant on left. Base of Goliad Sand is approximately here.
244.7	0.5	George West, county seat of Live Oak County. US 59 joins US 281 at traffic light.
245.2	0.5	Bear right on US 59 toward Freer.
250.8	5.6	Roadcut exposes sands of the Goliad overlain by 15 feet of windblown sand.
252.9	2.1	Roadcut exposes Goliad Sand.
253.4	0.5	Atlantic-Richfield's Clay West uranium prospect is beyond hill on the right. The uranium ore is in the Oakville Sandstone along an up-to-the-coast fault and extends down to as much as 500 feet below the surface. Cities Service's Burns prospect on the left.
255.8	2.4	The hills at the left (S) are in the Goliad Sand. They are capped with caliche except where the caliche has been eroded or destroyed by leaching and soil development.
258.1	2.3	Caliche in Goliad Sand is exposed in road cut.
260.8	2.7	Farm Road 1359 enters from left. Caliche caps hills in distance on left. The hills are in the upper part of the Goliad Sand.
262.6	1.8	Rest area on left. Basal sand of Goliad is exposed in ditch.
263.0	0.4	Road to Dougherty Ranch No. 1 at right.
264.2	1.2	Brush-covered terrane on Goliad Sand.
265.0	0.8	Farm Road 624. Continue straight ahead on US 59.
266.1	1.1	Live Oak-McMullen County boundary.
266.7	0.6	Campana Ranch.
269.6	2.9	McMullen-Duval County boundary. Goliad Sand at top of ridge at far right.
271.1	1.5	San Cajita, a butte capped with upper sand of Goliad, off to

left at 11 o'clock.

271.6 0.5 Seven Sisters, hills in distance at right, are siliceous knobs developed along a fault.

274.4 2.8 Roadcuts in crossbedded basal sands of the Oakville for the next mile. These are the southernmost exposures of Oakville along this highway. They form a conspicuous northwest-facing scarp.

277.4 3.0 Farm Road 2350, to Seven Sisters Post Office.

282.3 4.9 Humble gasoline plant on right. The plant is located near the pinch-out of the Oakville Sandstone north of Freer. The hill straight ahead in the distance is Loma Novilla (Loma Novia of local usage), capped by the Goliad Sand. A bench of caliche developed in pink, calcareous tuffs of the Catahoula surrounds the hill.

285.2 2.9 Dos Hermanitas, two distant knobs at left (11 o'clock), capped with Goliad and possibly Oakville Sandstone of a facies found south of Freer.

285.6 0.4 Pit in Catahoula Tuff on right at pistol range. Boulders of vesicular basalt measuring as much as 2 feet in diameter are in the Catahoula. The boulders were transported here by streams from the Big Bend-Davis Mountain area, about 300 miles to the west.

287,2 1.6 Traffic light, junction with Texas 44. Bear right on US 59 and Texas 44 to Freer.

288.4 1.2 Freer. Traffic light where Texas 16 crosses US 59. Proceed straight, toward Laredo.

289.4 1.0 Chusa (uppermost) Member of Catahoula Tuff exposed in roadcut.

290.7 1.3 Soledad Creek bridge.

291.3 0.6 Texas 44 goes right to Encinal. Continue on US 59.

292.4 1.1 Lundell oil field.

292.9 0.5 Soledad Volcanic Conglomerate Member of Catahoula Tuff exposed in ditch.

293.9 1.0 Quarry in Soledad near its type locality. Site of Stop 8 tomorrow.

294.9 1.0 Colmena Creek. Soledad Hills at left.

295.2	0.3	Road on left to Lykes Bros. Ranch, the southern part of the Duval County Ranch Company's holdings.
298.1	2.9	Sarnosa Knobs, silicified knobs along faults in distance at left; Parrilla Hills at far left on horizon. Basal Goliad gravels and underlying Miocene tuffs have a few uranium shows. These hills are supported by the Goliad Sand, indurated along faults, and by caliche.
299.0	0.9	Catahoula-Frio contact exposed in roadcuts.
301.2	2.2	Duval-Webb County line.
302.6	1.4	Road to Moca dome on right. Produces oil from the Mirando sand (the subsurface equivalent of the Wellborn Sandstone, Jackson Group, on the outcrop in the Karnes region) at about 900 feet. Salt was encountered in one well at 6,320 feet.
304.1	1.5	Farm Road 2050 to Bruni at left.
307.1	3.0	Tal Vez oil field at right.
308.1	1.0	Note gravel cover exposed in roadcuts through this area. The gravel is believed to have come from an ancestral Rio Grande system that at one time extended from west to east through this region.
316.1	8.0	White tuffaceous zeolitic sandstone of Jackson Group in cuts in west-facing scarp. Site of Stop 7 tomorrow.
316.6	0.5	Farm Road 2895 joins US 59. Pit at right in zeolitized ash.
317.3	0.7	Caliche Creek bridge. Zeolitized tuffs exposed.
318.5	1.2	Rest area on left, near Gato Creek.
322.6	4.1	Salado Creek bridge. Lake at left.
333.1	10.5	Crossing central part of northern half of Pescadito dome.
339.9	6.8	Tios Creek.
345.9	6.0	Laredo AFB at right.
347.5	1.6	Laredo. Traffic light and junction of US 59 and US 81, US 83, and IH 35. Turn left beyond underpass onto IH 35. Go straight south beyond end of IH 35 to Zaragosa Ave., approximately 2 miles from US 49 and IH 35 junction. Turn right on Zaragosa and continue two-tenths of a mile to La Posada Hotel at corner of Zaragosa and San Agustin.
349.8	2.3	End of first day's trip.

ROAD LOG

Second Day, Laredo to Houston

Mileage		
Total	Interval	
0.0	0.0	Laredo, La Posada Hotel, Zaragosa Ave. and San Agustin Ave. Go north on San Agustin.
0.2	0.2	Police Dept. on left.
0.4	0.2	Houston Street. Webb County Courthouse. Turn right (E).
0.5	0.1	San Dario Street; turn left (N).
0.9	0.4	Join IH 35.
1.9	1.0	Note exit sign for US 59 to Houston.
2.1	0.2	Turn right onto US 59.
3.8	1.7	Laredo AFB entrance on left.
4.8	1.0	Casa Blanca Lake entrance on left.
5.3	0.5	Chacon Creek bridge. Creek is outlet for Lake Casa Blanca. Outcrop just west of bridge, on right (S) side of highway, is chocolate, silty, gypsiferous clay of Laredo Formation.
5.7	0.4	Drive-in theater on right (S) side of highway.
6.3	0.6	Rounded bend to left. Highly fossiliferous, calcareous sandstone with large oyster shells, Laredo Formation, appears to dip about 1° to 5° E.
7.6	1.3	Bend to left. Outcrop in roadcut on right (SE) side is light-gray to buff silty, gypsiferous clay, completely friable.
7.8	0.2	La Esperanza Ranch on right.
8.3	0.5	Roadcut on right (S) side; friable gray sandy silt covered with loose oyster shells washed down from top of slope. Laredo Formation.
8.5	0.2	Continuous outcrop, slightly friable, buff sandy silt, the basal bed of the Yegua Formation.
9.2	0.7	Just before bend in the highway, power line from south crosses road and from there extends northwestward.
9.6	0.4	Highway here extends east-northeastward. Outcrop on right (S) side, about a tenth of a mile west of Tios Creek, has

calcareous concretions in friable silty clay of the Yegua Formation.

9.7 0.1 Tios Creek bridge.

11.7 2.0 High point on highway. On left (N) side is outcrop of friable silty sand of the Yegua.

13.8 2.1 Another high point on highway. On left (N) is outcrop of same silty sand.

14.3 0.5 Power line crosses highway, extending east-southeastward.

14.7 0.4 STOP 6. Rest area and Pescadito dome (fig. 16, pl. 2). From this point on the northwestern flank, a broad panorama of the northern part of the dome can be seen. Looking eastward, toward the radio telephone tower, a dip slope of about 5° to 8° can be seen dipping toward the observer. Major faults, downthrown to the east, trend northward in the valleys at both sides of Stop 6. At the north and west, subdued hogbacks or cuestas can be seen dipping away from the observer.

In the roadcut on the right (S) side of Stop 6 is an outcrop of an inlier of the Laredo Formation, apparently brought to the surface by faulting. Note the many oyster shells and reddish-brown soil. The sand enclosing the shell fragments is medium to coarse grained, gray to light rusty brown; contains angular to subrounded quartz, dark chert, lithic fragments, light-green glauconite rounded grains, and a few brown to bleached biotite "books."

To the south, beyond the roadcut, can be seen the Ginther-Warren I-C Killam gas well, the only producing well now operating on the dome.

Although mapping has made details of the dome familiar, one can cross it on US 59 without being aware of its presence because incompetent rocks and a thick gravel cover obscure most of the structural details along the highway.

EXPLANATION

A - Highway US 59 between Freer and Laredo, about 10 miles from Laredo.

B - Stop 6, rest area and Ginther-Warren No. 1-C Killam gas well.

C - Telephone relay tower and gravel pit; a field dip of 5° WNW measured here.

D - Strongly expressed dip-slope facets, with dip of about 4° to 10°.

Photograph courtesy of Aero Service Corporation (a division of Litton Industries).

Photogeologic interpretation by Photogravity Company, Inc.

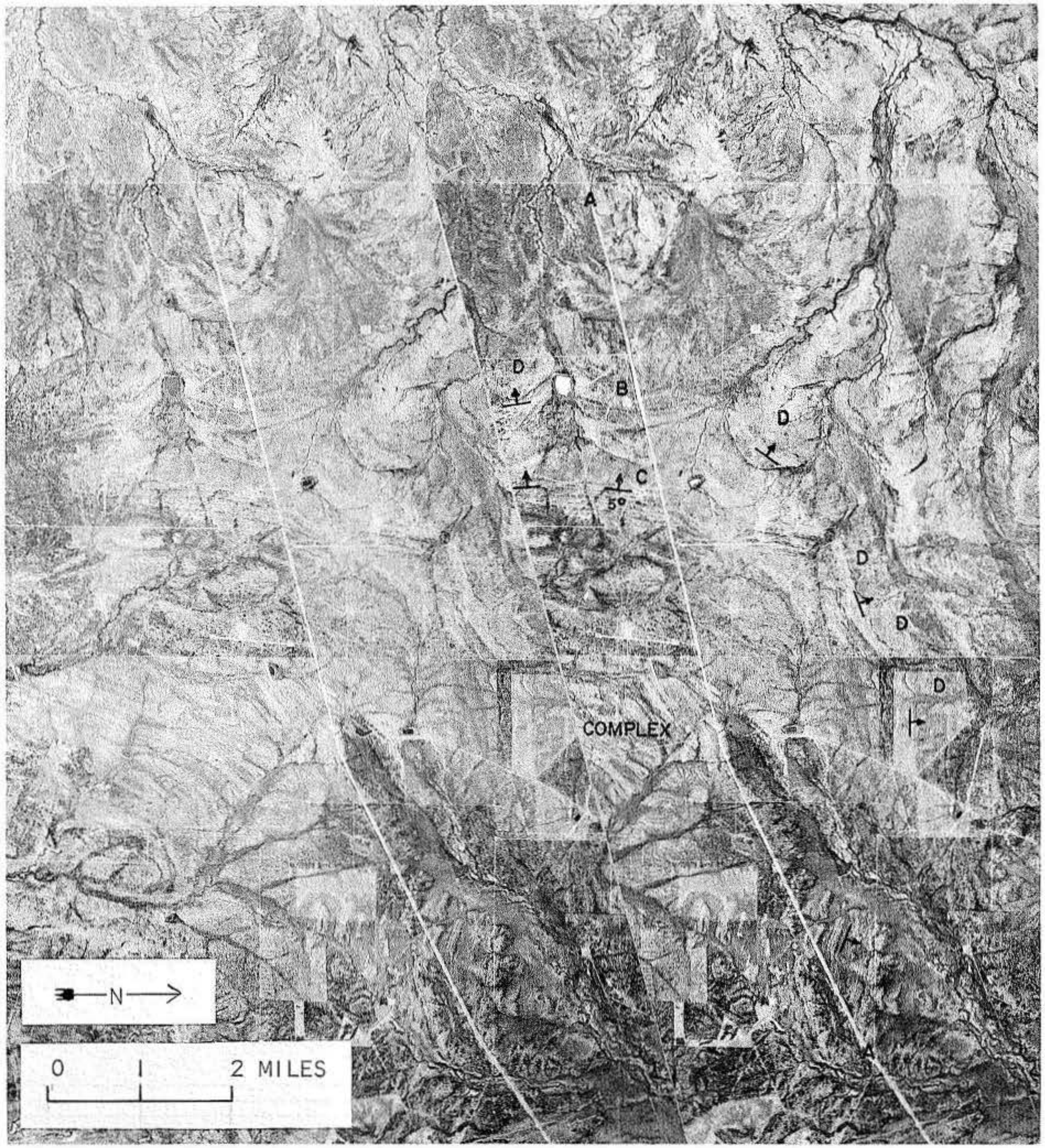


Figure 16 *Stereogram of northwestern flank of Pescadito dome, showing much of the structure of the dome in spite of low relief and surface cover. RC-9 photograph. Vertical exaggeration 6X.*

(ROAD LOG CONTINUES ON PAGE 45)

Pescadito Dome

by George W. Hinds

General.--Pescadito dome is the largest salt dome in Texas, covering an area of more than 100 square miles. It is an ovate domal structure measuring at the surface 8 to 10 miles from east to west and 10 to 12 miles from north to south.

The surface of the dome rises to a prominent topographic high at an elevation of nearly 750 feet, a rise of more than 200 feet from Laredo.

The existence of Pescadito dome has been known for many years. In early surface mapping it was traced by following key oyster beds (Stapp, 1957). The structure has also been mapped more recently by gravity, subsurface, seismic, and radiometric methods, as well as by photogeologic methods, which show it very well.

Surface rocks.--Surface rocks are of Eocene age and include inliers of the Laredo Formation (equivalent to the Cook Mountain Formation and Sparta Sand to the north) surrounded by the Yegua Formation on the flanks. Rock units are generally soft and poorly exposed. A mantle of terrace gravel and a veneer of windblown silt cover much of the dome, particularly the southern part.

While preparing this report the authors of the guidebook spent about 2 days exploring the dome along limited access roads and trails. The only good exposure found in which dip and strike data could be measured was about 15 to 20 feet of the upper part of the Yegua in the huge borrow pit half a mile south of US 59, just south of the prominent relay tower. There, a dip of 5° WNW was measured. Even the roadcuts along US 59 generally show only the blanket of surficial cover. Very few exposures of bedrock can be found, either near the center or around the flanks of the dome, but a few hints toward identification of the outcropping beds can be found beside several water tanks or dams on the dome, in seismic shot-hole tailings, and in general observation of the gentle cuesta slopes and the soil cover and texture where Holocene erosion has stripped the surficial materials. The Laredo Formation is typically brownish clays or reddish sands, in many places containing oyster shells. The Yegua Formation weathers to ochre, and its sandy soils are slightly more coarse and resistant than are those derived from adjacent formations.

Surface form.--The surface form of Pescadito dome, as mapped by photogeologic methods, is a reasonably well defined structure, outlined by dips that appear to range from about 4° to 10° (pl. 2). The northwestern flank is particularly well shown on figure 16. Surface faults extend from north to south across the dome forming a graben about 4 miles wide. The crest of the structure is half a mile south of US 59 and about 3 miles east of Stop 6. The crest is of complex structure and appears to contain many local faults and folds. Surface closure is probably about 300 to 350 feet.

Subsurface.--The subsurface structure is generally similar to the surface, with faulting across the crest (fig. 17). Structural relief is more than 1,000 feet on the middle Wilcox marker. The dome apparently has

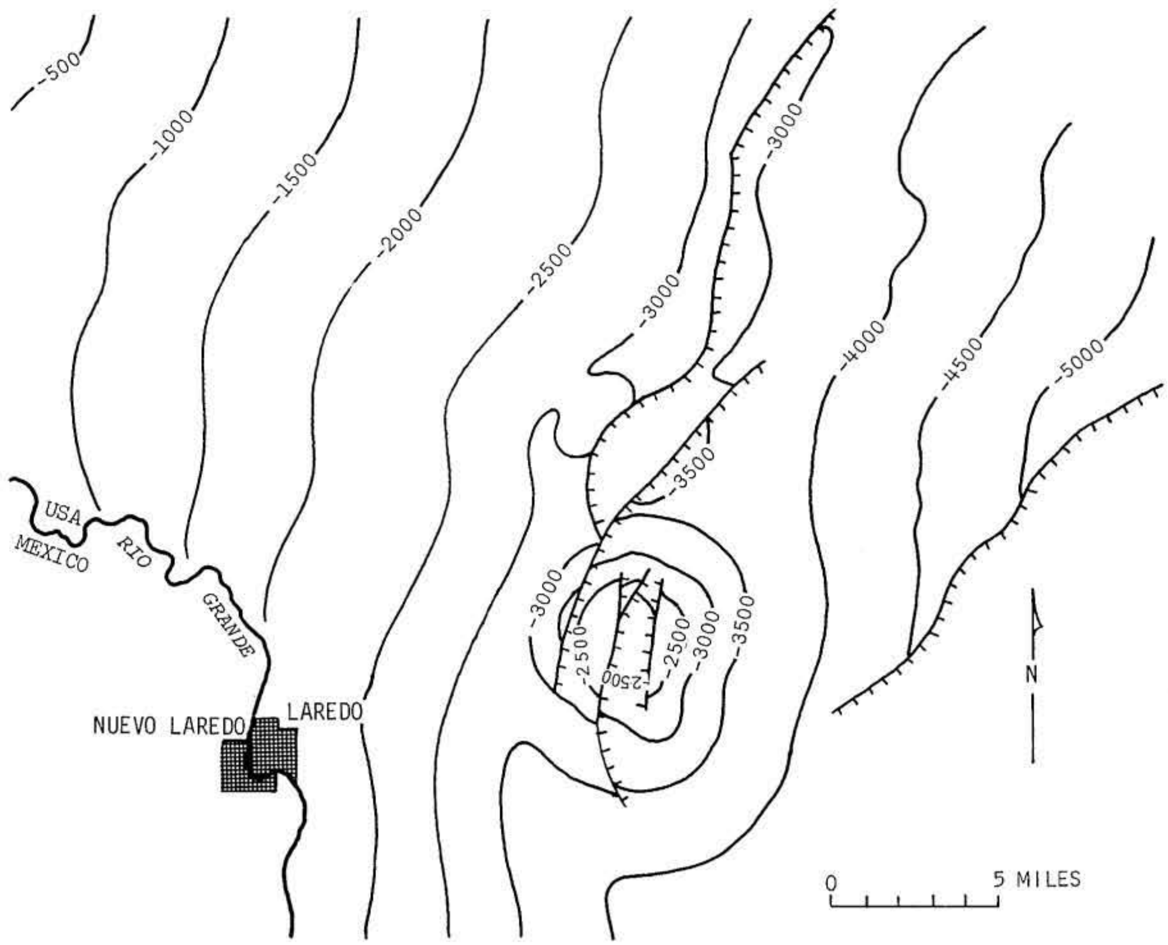


Figure 17 *Map showing structure on top of the Wilcox Formation, Pescadito dome. Contour interval 500 feet. Map furnished by Humble Oil and Refining Company.*

a very large core of salt or shale or both. Salt was reported at about 14,400 feet in a well, as mentioned below, located about 2 miles east of Stop 6 of this field trip.

The subsurface section from the surface through the Wilcox-Midway is well defined and includes about 1,000 feet of sands and shales of the Yegua and Laredo Formations, 300 feet of sand of the Sparta equivalent, 400 feet of shale of the El Pico (Weches and Queen City equivalent), 3,300 feet of sand and shale of the Wilcox (subsurface Wilcox probably includes Bigford and Carrizo), and 3,700 feet of shale of the Midway.

The sequence below the Midway is more difficult to interpret and correlate, due to tremendous thicknesses of shale and limey shale. The pre-Tertiary section in the Brewster and Bartle et al. No. 1 Killam well, 2 miles east-northeast of Stop 6, is about as follows: Navarro, -6,802; Taylor, -7,878; Austin, -11,495; Eagle Ford, -12,106; Buda, -12,316; Del Rio, -12,436; Georgetown, -12,568.

Exploration for oil and gas.--Thirty-two test wells, most of which are shallow, have been drilled on and around the structure. Many shows of oil and gas have been logged, and there have been three producing gas wells. The Ginther-Warren 1-C Killam, the only commercial well at present, produces from the Wilcox at a depth of about 6,000 feet.

Only four deep tests have been drilled. The Brewster and Bartle et al. No. 1 Killam was the first deep test, drilled in 1950 on the northwest flank to a depth of 13,704 feet, penetrating to the Georgetown (upper part of the Lower Cretaceous). The Ginther-Warren No. 1 Killam, located about a mile to the south of the first deep test, was drilled to 15,107 feet, reaching salt at 14,394 feet. The Ginther-Warren No. 1-A Killam, located farther west on the northwest flank, reached 19,503 feet, penetrating the Hosston (Lower Cretaceous). The most recent deep test was the Humble No. 1 Benavides, drilled in October 1968 to 19,852 feet, on the east or southeast flank of the dome, probably penetrating pre-Cretaceous carbonates. It is reported to be significantly high and may stimulate further drilling.

Exploratory efforts have not yet paid off at Pescadito dome, and the reasons are not entirely clear. Perhaps enough tests have been made in the Wilcox to indicate that it probably will not be a big producer. The dome is located many miles downdip from the more prolific and typical Wilcox production, and it seems reasonable to postulate that much of the hydrocarbons formed in this productive shelf environment could not migrate the necessary distance to Pescadito dome, and that even if migration was possible, the dome probably was formed late, after significant migration occurred.

The deeper horizons are probably still a good possibility, although very thick shale sections occur in many of the deeper units, making them somewhat less attractive than might be desired.

The real reason for lack of production on Pescadito dome may be the fact that only four deep tests have been made on the 100-square-mile area. This leaves much unexplored ground on the Texas giant. It is hoped that the Spanish word pescadito, which means little fish, is not an omen for Pescadito dome.

The author is grateful to Don McNamee, of Union Texas Petroleum, and George Clement, of Ginther-Warren Inc., for supplying information about the dome.

ROAD LOG, *Continued*

Mileage		
Total	Interval	
15.6	0.9	Relay tower on right (S) side of highway; house and earthen tank on left (N) side. Pit behind relay tower exposes sands characteristic of the Yegua.
16.5	0.9	Shallow roadcut with many oyster shells. Inlier of Laredo Formation.
17.6	1.1	Gate on left (N) side to Zachry Co. Hunting Lodge. View from highway of curving outcrop dipping away to northwest. Also a gate on right (S) side of highway, with possible soil on the Yegua exposed.
18.9	1.3	Gravel and mantle, locally reddish, with a few oysters.
19.7	0.8	On small rise beside highway, outcrop of olive silty clay with many small contraction cracks.
20.7	1.0	C. Y. Benavides and Sons Yugo Ranch road on right (S) side.

On left (N) side is olive clay, weathering to mottled brownish green; possibly a soil on the Yegua.

21.6 0.9 Right (S) side of highway, outcrop of white to pale-gray, tuffaceous, fine-grained, silty sandstone; appears to be zeolitized. Interpreted as either Jackson (occurring on the northeastern side of the dome, possibly in a fault block or syncline) or a tuffaceous unit of the Yegua.

22.6 1.0 Gentle rise on highway. Roadcut has gravel cover partially obscuring friable, dry, puffy, pale-chocolate altered ash. Continues for several tenths of a mile.

27.6 5.0 Salado Creek bridge. Creek dammed to south for large, shallow reservoir on two branches.

28.2 0.6 Piedra Parada Ranch road on right (S). Roadcut 10 feet deep; gravel has slid down over pale, friable silt.

28.4 0.2 Gentle rise with gravel cover.

30.8 2.4 Gentle broad valley bottom.

31.7 0.9 Gato Creek bridge. Rest area on right (S), east of creek.

33.0 1.3 Caliche Creek bridge.

33.6 0.6 Aguilares road to right (S); 18 miles to Aguilares. Road to left (N) is surfaced locally with zeolitized tuffaceous fine-grained sandstone of Jackson Group.

34.0 0.4 STOP 7. Roadcut (new in August 1970) exposes white zeolitized tuffaceous fine-grained sandstone of the uppermost part of the Jackson Group. A group of samples from this outcrop show that the proportion of sand grains to altered tuffaceous matrix ranges from 20:80 to 70:30. Most of the samples show very thin, faint bedding, commonly crossbedded. The sand fraction is very fine to fine grained and consists of subangular to angular clear quartz, feldspar, biotite flakes, and lithic grains.

Rock that had been used as surface material on the road north from the Aguilares road is whiter, more massive, shows less indication of bedding, has a rough conchoidal fracture, and is more altered than the rock here at Stop 7.

34.5 0.5 Similar material in shallower cut.

34.7	0.2	Friable and puffy buff-colored clay.
35.4	0.7	Buff montmorillonitic clay, exposed in roadcuts.
36.0	0.6	More buff clay on right (S) side.
36.4	0.4	Left (N) side, contemporaneous slumping (or contortion) in thin-bedded buff montmorillonitic ash.
36.9	0.5	Look ahead to broad valley on Frio Clay; at 2 o'clock note Las Hermanas (knobs) capped with basal Goliad, 10 miles to the southeast on the Billings Ranch.
37.8	0.9	Ranch road (cattleguard) on right (S) side.
38.8	1.0	Unpaved ranch road on right (S) to Oilton via Frost's De Spain Ranch.
39.0	0.2	On right (S) side, Frio Clay, chocolate, puffy, sandy.
40.6	1.6	Frio Clay on gentle rise.
41.0	0.4	Black Creek crossing (no sign).
41.8	0.8	Frio exposed on right (S) side, weathers almost white.
46.3	4.5	Farm Road 2050 to Bruni (25 miles) at right (S). Note basal Catahoula in distant ridge at 2 o'clock.
47.9	1.6	Moca dome on left (N) side about 5 miles to the north; can see white road on dome. Produces oil from Mirando sand of the Jackson at 900 feet and from deeper sands of the Yegua. Production to the present has been about 3 million barrels of oil. Salt was encountered at 6,320 feet in a well drilled in 1950 by Quintana Oil Company.
49.1	1.2	Webb-Duval County line (N-S) and Arroyo de Charco Escondido bridge. Watch for basal Catahoula on Frio Clay in rise ahead.
51.4	2.3	Exposure of basal sand of Catahoula on Frio Clay. Soledad Hills at 2 o'clock.
55.3	3.9	Lykes Brothers Ranch road on right (S) (Duval County Ranch Co. land).
57.0	1.7	STOP 8. Gate to road-material pit on left (N) side. Pit exposes Soledad Volcanic Conglomerate Member (middle member) of Catahoula Tuff; contains boulders of volcanic rock, tuff pebbles, and many grains of volcanic material. This quarry is one of the better and fresher exposures of the Soledad

in the area of its type locality, the Soledad Hills to the south. The conglomerate is made up of rounded boulders and pebbles of volcanic rocks and vesicular amygdaloidal lava that probably originated in western Texas and northern Mexico. Some rock types have been related to specific stocks and flows in the Big Bend and Davis Mountains by geologists who are familiar with those regions. A large proportion of the pebbles are rounded balls of tuffaceous clay derived from penecontemporaneous erosion of local deposits or from the underlying Fant Tuff Member. The boulders of these deposits, some measuring as much as a foot in diameter, are believed to have been transported to this locality along channels during times of flood, when streams were slurries of volcanic ash and pebbles. The boulders are chiefly trachyte, trachyandesite, and andesite, and the tuffs are brown to dark gray. The unit weathers to green and brown soil materials. The volcanic conglomerate is found chiefly in Duval County; the outcrop is cut off by faulting south of the Soledad Hills. To the north the boulders diminish in size, and dark-gray lenticular sands occupy this stratigraphic position.

An excellent--and also the most recent--study of the Catahoula is one by McBride, Lindemann, and Freeman (1968).

57.6 0.6 Roadcuts of Soledad conglomerate and tuff, interbedded.

58.3 0.7 Lundell oil field. Rest area on right (S). Look ahead to Freer in the midst of large Government Wells and Loma Novia fields.

59.7 1.4 Texas 44 goes northwestward to Encinal.

60.3 0.6 Soledad Creek crossing. Beyond is Chusa Tuff (upper) Member of Catahoula.

62.5 2.2 Traffic light in Freer. Turn left onto Texas 16. Government Wells field, which has produced more than 90 million barrels of oil, extends throughout the Freer area (fig. 18). The Bordas escarpment cuts through this region at the left (W).

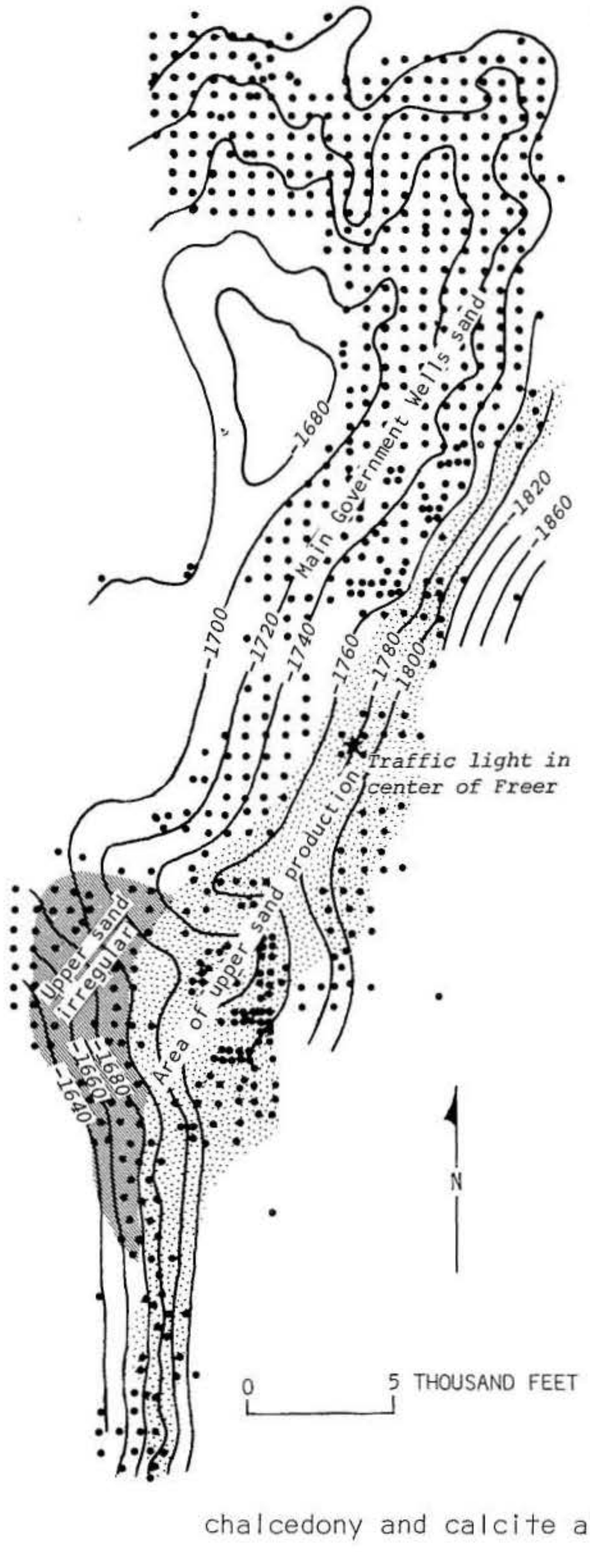


Figure 18 *Map of the Government Wells field, Duval County, Texas, showing structure of the lower sand of the Government Wells sand, Jackson (Eocene), and, where it is absent, on its projected position. The upper and lower sands pinch out updip. The wells outline the producing area of the lower or main producing sand. The map shows also the updip pinch out of the lower sand. Contour interval 20 feet. Redrawn from Trenchard and Whisenant (1936).*

65.4 2.9 Old Encinal road, on the left, goes to an early uranium prospect on the Wiederkehr lease in the North Government Wells field.

65.7 0.3 Exposure of conglomerate of Soledad on left (W) side of road.

66.7 1.0 Mobil oil camp.

67.4 0.7 Radioactive anomaly along a small fault where road bends to right (NNE).

68.0 0.6 At 10 o'clock note hills along Eagle Hill fault.

69.7 1.7 Rest area on right (E) side.

70.9 1.2 STOP 9. Eagle Hill. Roadcut on right (E) side has chalcedony and calcite along northeast-trending fault; altered Chusa on southeast side and altered Soledad on northwest side.

Note Seven Sisters (siliceous knobs) near three large cylindrical tanks on eastern horizon. Los Picachos are siliceous knobs on the Eagle Hill fault.

71.2 0.3 Loma Alta ahead, mesa capped with basal Oakville Sandstone.

72.9 1.7 Mobil Hagist Ranch gasoline plant.

74.6 1.7 Duval-McMullen County line (E-W).

77.5 2.9 Resistant type volcanic sandstone of Soledad forms rise on right side of road.

79.7 2.2 Farm Road 624. Stay on Texas 16. Basal Catahoula exposed 1 mile west of here at rest area on Farm Road 624. Chusa Hills off to right, capped with Oakville rocks.

86.2 6.5 Top of rise; approximate base of Catahoula. View toward Nueces valley and Kings Hills to left (NW).

86.9 0.7 Farm Road 1962 on right. Stay on Texas 16.

88.2 1.3 Arrowhead Ranch on right (E) side. Ahead our low-lying route crosses Nueces River bottom land on Frio Clay for about 5 miles.

91.6 3.4 Nueces River bridge; flood plain here several miles wide.

92.7 1.1 Frio Clay exposed in cuts through this area.

94.0 1.3 Upper laminated clay in Whitsett Formation of Jackson Group.

95.3 1.3 Upper sands in Whitsett Formation.

98.0 2.7 Transcontinental Gas Pipeline plant on right (E) side. Upper of two sand sequences in lower part of Whitsett (erroneously mapped by Darton, Stephenson, and Gardner ([1937]) as basal Jackson instead of basal Whitsett). We are traveling diagonally up dip slopes through here.

101.3 3.3 Tilden, southern city limit. Base of Whitsett sands. Tilden was a cowboy center of early days.

102.1 0.8 Center of Tilden. Note county courthouse on right and "Old Rock Store" (former saloon) on left. On Texas 16 go one block north of intersection with Texas 72, turn right, and go one block to Boot Hill Cemetery. Turn right again and go one block to join Texas 72. Turn left (E) on Texas 72; old jail across street lost roof in hurricane Celia.

103.5 1.4 Basal sandstone of Whitsett.

104.6 1.1 Cross a broad hollow on Conquista Clay Member of Whitsett.

106.4	1.8	At top of rise is the top of the second sand sequence (Deweesville) of the lower part of the Whitsett Formation. This member is the host rock for the early discovered Karnes district oxidized uranium deposits.
108.6	2.2	Farm Road 1106 on right (S).
113.9	5.3	Calliham; town is on terrace cover that overlies Frio-Jackson contact. Old Calliham oil field on north side of town; type locality of Calliham Sandstone Member of Whitsett at old bridge 1 mile north of town. Many old oil-field relics can be seen in this area.
114.7	0.8	Farm Road 99 on left (N) side, to Whitsett. Stay on Texas 72.
119.3	4.6	Basal Catahoula Tuff with hard tuff balls, a basal conglomerate overlying Frio Clay in roadcut on right (S).
119.9	0.6	"Rise" is capped by lithic sand of Catahoula containing much volcanic detritus.
120.7	0.8	Traveling on terraces of Frio and Nueces Rivers; town of Three Rivers can be seen (note water tower) 3 miles to the east. The third river is the Atascosa, which joins the Frio just north of Three Rivers.
123.6	2.9	Frio River bridge. Tips State Park.
124.1	0.5	Three Rivers. Turn left (N) on Texas 72 and US 281.
124.7	0.6	Turn right (NE) onto Texas 72 (toward Kenedy), en route to Felder mine.
127.3	2.6	Cross Texas 9 at blinker light and continue on Texas 72 (fig. 19).
128.7	1.4	Approximate base of Oakville Sandstone (Miocene).
129.3	0.6	Turn right on Farm Road 1358 toward Ray Point.
130.4	1.1	New uranium mill of Susquehanna-Western on left. Uses an alkali-leach process.
130.9	0.5	Uranium mill entrance.
131.2	0.3	Ray Point. Turn sharp right at intersection. Note country store, Ray Point Mercantile, on left.
132.3	1.1	Sulphur Creek bridge. On right note large piles of overburden stripped from Felder mine.
132.7	0.4	STOF 10, Felder mine (figs. 20, 21). The following abstract

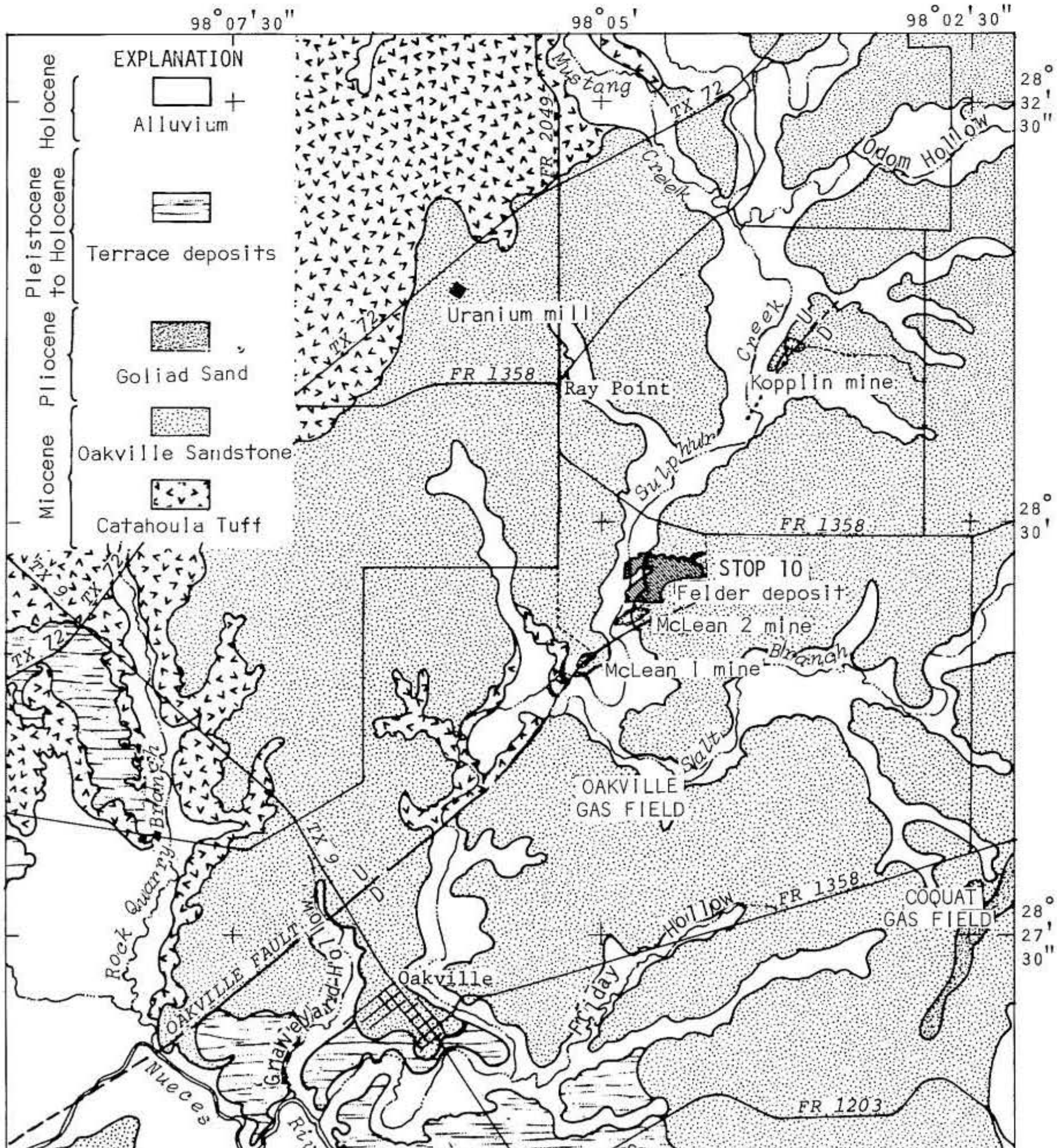


Figure 19 *Map showing geology of the Ray Point area and locations of uranium mines. Revised from Eargle, Stanford, and Davis (1966).*

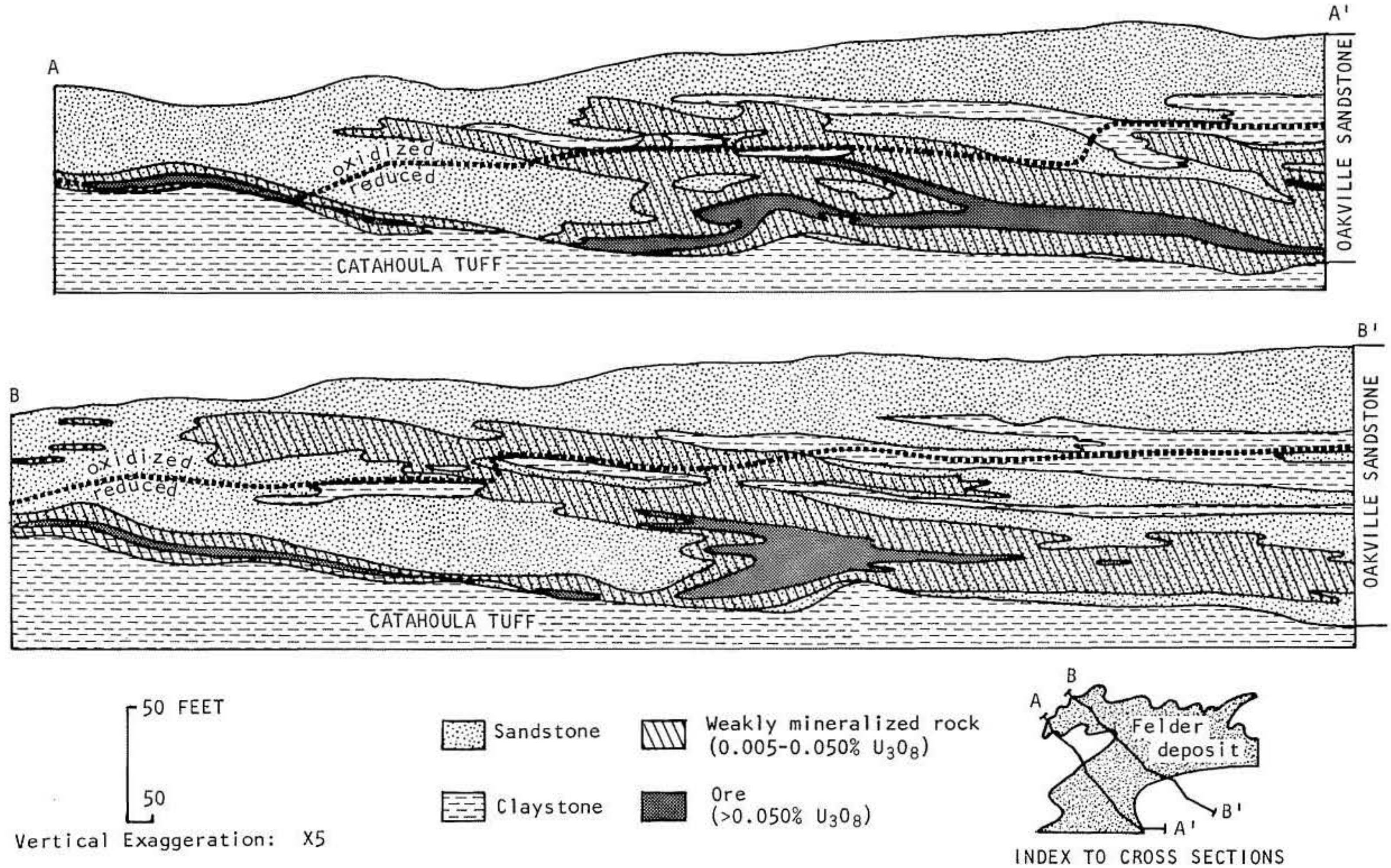


Figure 20 *Cross sections A-A' and B-B' through the Felder uranium mine. From Klohn and Pickens (1970).*

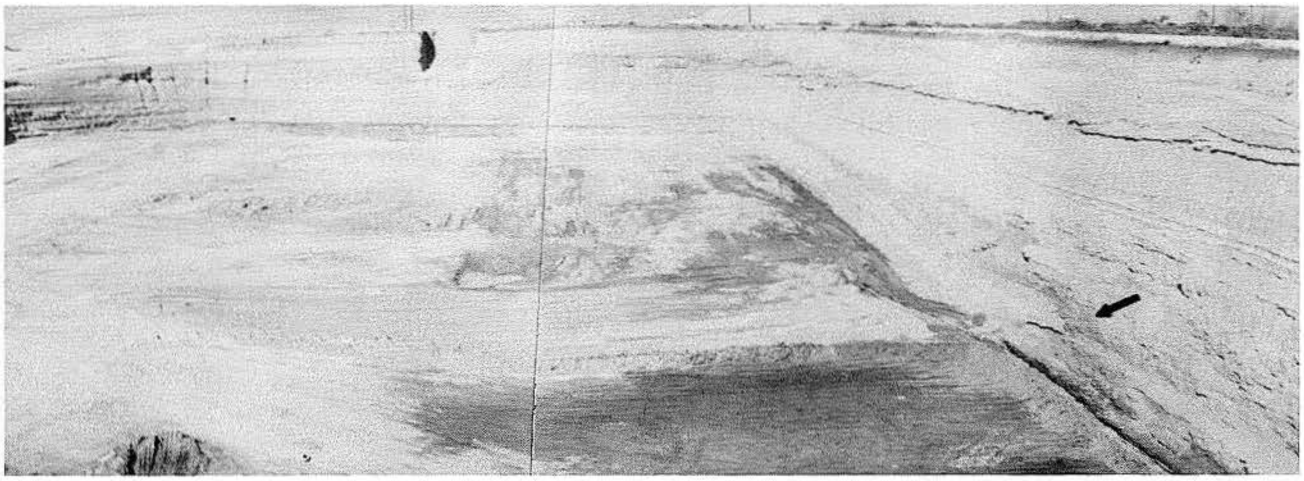


Figure 21 *Photograph showing northeast part of Humble's Felder uranium mine from south wall, January 1971. Arrow points to roll front.*

(Klohn and Pickens, 1970) summarizes the main features of the Felder ore deposit.

> *"The Felder ore deposit is a 5,000,000-pound uranium deposit in the South Texas Coastal Plain. It occurs in the basal sand of an Oakville Formation (Miocene) alluvial system. The host sand is a carbonate-rich arkose which contains virtually no carbonaceous debris and has been reduced by the local introduction of hydrogen sulfide. The ore lies well within the reduced zone and occurs as coffinite and uraninite that fill interstices and coat and replace grains.*
>
> *"The overall geometric configuration of the ore is that of a winged, crescentic ore roll. Weak mineralization extends the wings of the ore roll and gives greater expression to the roll character. Departures from the shape are controlled by discontinuities in bedding and by proximity of the ore to the surface. Associated with the uranium is a broad halo of anomalous molybdenum.*
>
> *"Subsidiary mineralized trends suggest a pre-existing up-dip position for the main roll. Oxidation from the surface largely destroyed this previous roll by solubilization of uranium. Uranium subsequently migrated into favorably reduced sand and reprecipitated at the present roll position."*

A radioactive anomaly a mile southwest of the Felder mine in the faulted sandstone wall of Sulphur Creek led to the discovery of uranium ore in this area. Susquehanna-Western drilled the area to the north and east and began mining in 1967 in the McLean 2 mine that abuts the Felder property to the south. The company opened the McLean 1 mine in 1968.

The Oakville fault cuts the McLean 1 mine, but apparently lies just to the south of McLean 2. The fault trends about N.65°E. The faults and general structure of this area have been mapped and described by Thomas S. West, Sr. (South Texas Geological Society, 1958).

In 1969, Susquehanna-Western opened its Kopplin mine 2 miles to the north in ore along and updip from a fault that trends N.45°E., approximately paralleling the local trend of Sulphur Creek.

Geologists of Humble Oil and Refining Co. outlined the Felder deposit by extensive prospecting in 1968, and Susquehanna-Western began mining and milling the ore in 1970.

A non-ore sample of the Oakville Sandstone from the Felder mine is described as follows: gray sandstone, firmly cemented with calcareous cement; medium grained; is a lithic sand with grains of many different colors--black, gray, pink, buff, green. Overall color is grayish-green buff with a sprinkling of "black pepper" effect. Very faint bedding, nearly massive. It has microscopic pyrite interstitial to the sand grains.

133.0 0.3 Return to road, turn left, cross Sulphur Creek.

134.3 1.3 Ray Point Mercantile, turn left and pass mill.

136.1 1.8 Junction with Texas 72. Turn right.

137.6 1.5 Good view of Susquehanna-Western uranium mill.

138.5 0.9 Farm Road 2049 to Suniland on left. Continue on Texas 72.

143.2 4.7 Travel for several miles on Oakville and Fleming (Miocene).

144.8 1.6 <u>Oaks</u>. Note cotton gin and grain mill. On skyline at 2 o'clock note low scarp formed by the basal Goliad. At right of road is high-pressure sour-gas field of Shell Oil Co. producing from deep-seated Edwards reef at depth of more than 14,000 feet.

148.1 3.3 Pawnee. Pass Farm Road 798 and continue on Texas 72 to Kenedy. In this area the Oakville makes excellent farm land.

162.3 14.2 Kenedy, outskirts., Junction with US 181; continue on Texas 72.

162.8 0.5 Intersection with Business US 181.

This completes the log.

Field trip group will proceed to Barth's Restaurant for lunch, after which the buses will return to Houston, about 170 miles, or ~3 hours.

REFERENCES

Bailey, T. L., 1926, The Gueydan, a new middle Tertiary formation from the southwestern Coastal Plain of Texas: Texas Univ. Bull. 2645, 187 p.

Brown, R. D., Jr., Eargle, D. H., and Moxham, R. M., 1961a, Preliminary aeroradioactivity and geologic map of the Falls City NE quadrangle, Karnes and Wilson Counties, Texas: U.S. Geol. Survey Geophys. Inv. Map GP-250, scale 1:31,680.

_______ 1961b, Preliminary aeroradioactivity and geologic map of the Falls City NW quadrangle. Atascosa, Karnes, and Wilson Counties, Texas: U.S. Geol. Survey Geophys. Inv. Map GP-249, scale 1:31,680.

Corpus Christi Geological Society; Eargle, D. H.,; Quigley, Galen; Dempsey, R. J., 1968, South Texas uranium--Field trip, 1968: Corpus Christi, Tex., Corpus Christi Geol. Soc., 62 p.

Darton, N. H., Stephenson, L. W., and Gardner, J. A., 1937, Geologic map of Texas: U.S. Geol. Survey, 4 sheets.

Doering, J. A., 1956, Review of Quaternary surface formations of Gulf Coast region: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 8, p. 1816-1862.

Eargle, D. H., 1970, Uranium in Texas: Houston Geol. Soc. Bull., v. 13, no. 2, p. 18-27.

Eargle, D. H.,; Brown, R. D., Jr.; and Moxham, R. M., 1961, Preliminary aeroradioactivity and geologic map of the Falls City SW quadrangle, Atascosa, Karnes, and Live Oak Counties, Texas: U.S. Geol. Survey Geophys. Inv. Map GP-252, scale 1:31,680.

Eargle, D. H., and Foust, R. T., Jr., 1962, Tertiary stratigraphy and uranium mines of the southeast Texas Coastal Plain, Houston to San Antonio via Goliad, Field excursion no. 4, *in* Geology of the Gulf Coast and central Texas and guidebook of excursions, Geol. Soc. America, 1962 Ann. Mtg.: Houston, Tex., Houston Geol. Soc., p. 225-253.

Eargle, D. H., and Moxham, R. M., 1961, Preliminary aeroradioactivity and geologic map of the Falls City SE quadrangle, Atascosa, Karnes, and Live Oak Counties, Texas: U.S. Geol. Survey Geophys. Inv. Map GP-253, scale 1:31,680.

Eargle, D. H., Stanford, J. F., Jr., and Davis, B. O., 1966, Preliminary geologic map of the Live Oak County area, Texas: U.S. Geol. Survey open-file map.

Eargle, D. H., Trumbull, J. V. A., and Moxham, R. M., 1961a, Preliminary aeroradioactivity and geologic map of the Floresville SE quadrangle, Karnes and Wilson Counties, Texas: U.S. Geol. Survey Geophys. Inv. Map GP-246, scale 1:31,680.

________ 1961b, Preliminary aeroradioactivity and geologic map of the Karnes City NW quadrangle, Karnes County, Texas: U.S. Geol. Survey Geophys. Inv. Map GP-251, scale 1:31,680.

________ 1961c, Preliminary aeroradioactivity and geologic map of the Stockdale SE quadrangle, Karnes, De Witt, and Wilson Counties, Texas: U.S. Geol. Survey Geophys. Inv. Map GP-248, scale 1:31,680.

Eargle, D. H., and Weeks, A. D., 1961a, Possible relation between hydrogen sulfide-bearing hydrocarbons in fault-line oil fields and uranium deposits in the southeast Texas Coastal Plain, Art. 295: U.S. Geol. Survey Prof. Paper 424-D, p. D7-D9.

________ 1961b, Uranium-bearing clays and tuffs of south-central Texas, *in* Folk, R. L., and others, Field excursion, central Texas: Texas Univ. Bur. Econ. Geology Guidebook no. 3, p. 19-31.

Eargle, D. H., and Weeks, A. M. D., 1968, Factors in the formation of uranium deposits, Coastal Plain of Texas: South Tex. Geol. Soc. Bull., v. 9, no. 3, 12 p.

Ellisor, A. C., 1933, Jackson Group of formations in Texas with notes on Frio and Vicksburg: Am. Assoc. Petroleum Geologists Bull., v. 17, no. 11, p. 1293-1350. Reprinted *in* Gulf Coast Oil Fields: Am. Assoc. Petroleum Geologists, 1936, p. 470-527.

Gulf Coast Assoc. Geol. Socs.; Eargle, D. H.; Welder, Frank; Rives, J. S.; His, George; Eubanks, L. L., Jr. (leaders), 1967, Field trip of the 17th annual meeting, San Antonio, Tex., 1967 [guidebook]: San Antonio, Tex., Gulf Coast Assoc. Geol. Socs., 105 p.

Horne, J. D., 1964, A stratigraphic revision within the Jackson Group in south central Texas: Gulf Coast Assoc. Geol. Socs. Trans., v. 14, p. 277-283.

Houston Geological Society, 1941, An introduction to Gulf Coast oil fields, prepared for the 1941 convention of the American Association of Petroleum Geologists: 22p. [Houston, Texas, 1941.]

Klohn, M. L., and Pickens, W. R., 1970, Geology of the Felder uranium deposit, Live Oak County, Texas: Paper presented at the AIME ann. mtg. Denver, Colo.--Feb. 15-19, 1970, Soc. Mining Engineers Preprint No. 70-I-38, New York, N.Y., Soc. Mining Engineers, 19 p.

McBride, E. F., Lindemann, W. L., and Freeman, P. S., 1968, Lithology and petrology of the Gueydan (Catahoula) Formation in South Texas: Texas Univ. Bur. Econ. Geology Rept. Iny. no. 63, 122 p.

Moxham, R. M., and Eargle, D. H., 1961, Airborne radioactivity and geologic map of the Coastal Plain area, southeast Texas: U.S. Geol. Survey Geophys. Inv. Map GP-198, scale 1:250,000.

Plummer, F. B., 1932, Cenozoic systems in Texas, part 3 *in* The Geology of Texas, Vol. I, Stratigraphy: Texas Univ. Bull. 3232, p. 519-818 [1933].

Quinn, J. H., 1955, Miocene Equidae of the Texas Gulf Coastal Plain: Texas Univ. Pub. no. 5516, 102 p.

South Texas Geological Society (Eargle, D. H., and others, leaders), 1958, [Guidebook] 1958 field trip, Eocene-Miocene, oil-uranium, Falls City, Tordilla Hill and Fashing areas, Wilson, Karnes and Atascosa Counties, Texas, December 5, 1958: 67 p. San Antonio.

Stapp, W. L., 1957, Notes on Pescadito structure, Webb County, Texas, *in* Corpus Christi Geol. Soc. Ann. Field Trip, Apr. 1954, p. 31-32; reprinted, Ann. Field Trip, Apr. 1957, p. 18-19, 1957.

Texas Univ. Bur. Econ. Geol., 1968a, Geologic atlas of Texas, Beaumont Sheet--Harold Norman Fisk Memorial Edition: Austin, Tex., Univ. Texas Bur. Econ. Geology, scale 1:250,000.

________ 1968b, Geologic atlas of Texas, Houston Sheet--Paul Weaver Memorial Edition: Austin, Tex., Univ. Texas Bur. Econ. Geology, scale 1:250,000.

________ in press, Geologic atlas of Texas, Seguin and Beeville Sheets: Austin, Tex., Univ. Texas Bur. Econ. Geology, scale 1:250,000.

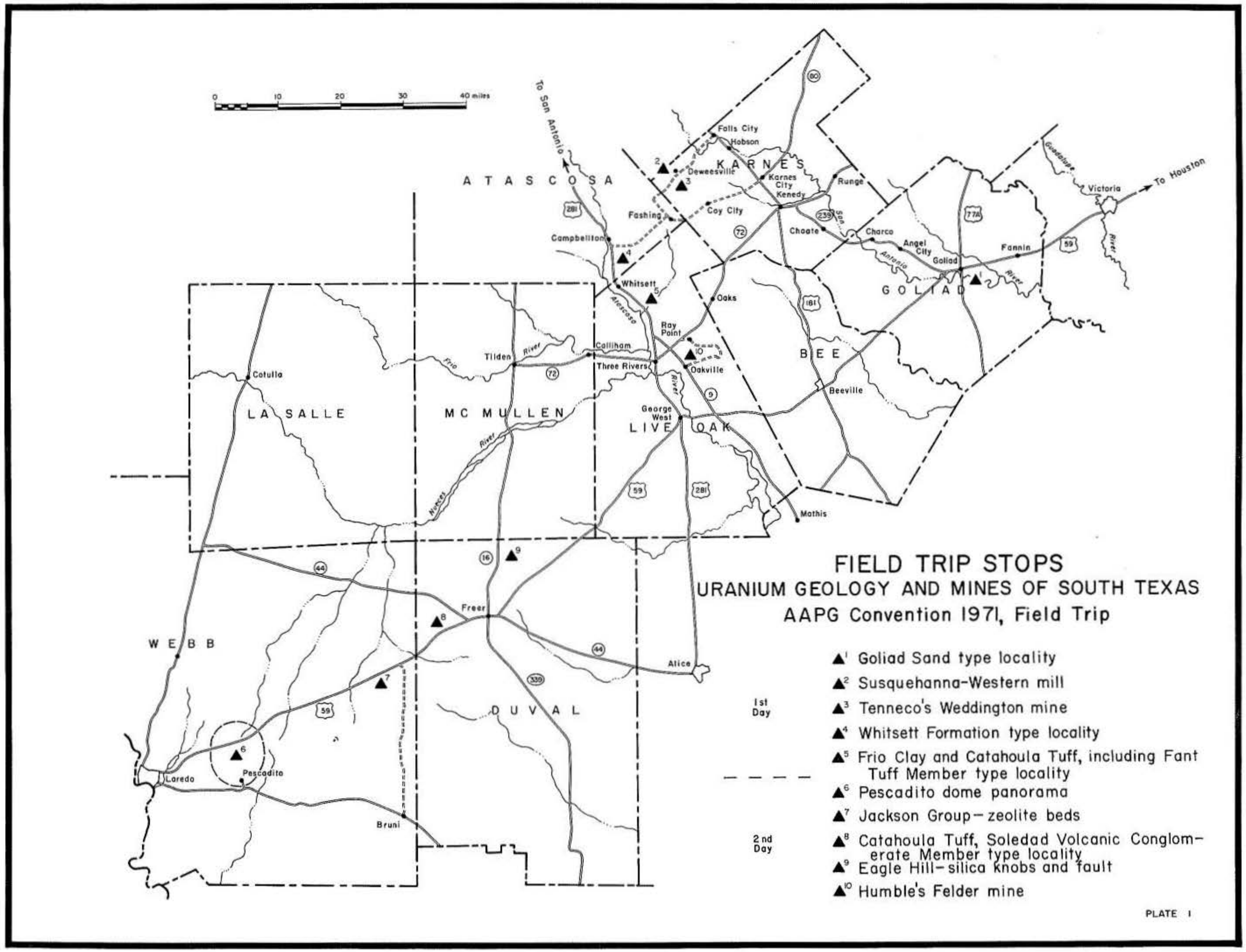
Trenchard, John, and Whisenant, J. B., 1936, Government Wells oil field, Duval County, Tex.: Am. Assoc. Petroleum Geologists Bull., v. 19, no. 8, p. 1131-1147, reprinted in Gulf Coast Oil Fields, 1936, p. 631-647.

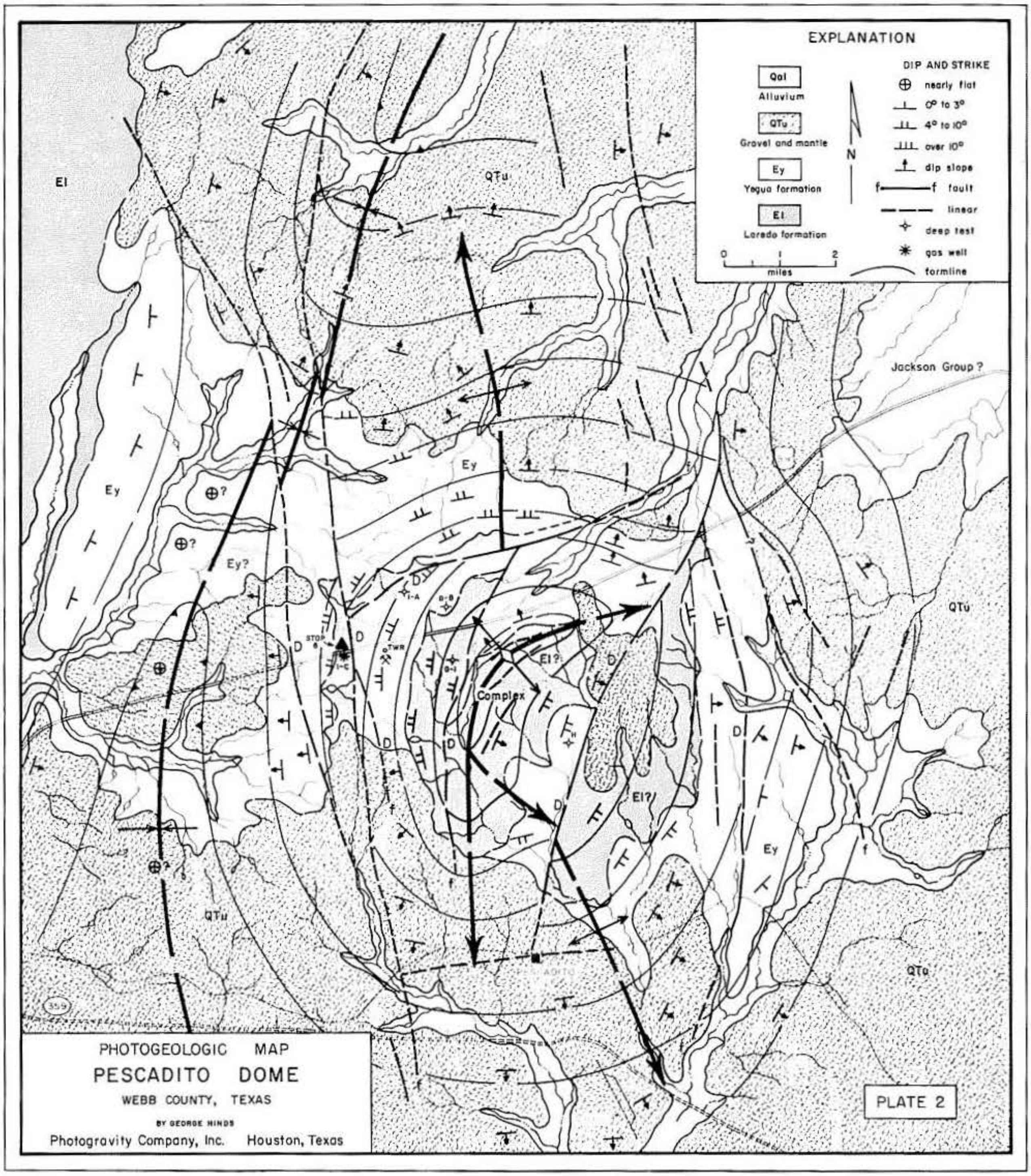
Trumbull, J. V. A., Eargle, D. H., and Moxham, R. M., 1961, Preliminary aeroradioactivity and geologic map of the Stockdale SW quadrangle, Karnes and Wilson Counties, Texas: U.S. Geol. Survey Geophys. Inv. Map GP-247, scale 1:31,680.

Valastro, Salvatore, Jr., and Davis, E. M., 1970, University of Texas at Austin radiocarbon dates VIII: Radiocarbon, v. 12, no. 2, p. 617-639.

Weeks, A. D., and Eargle, D. H., 1963, Relation of diagenetic alteration and soil-forming processes to the uranium deposits of the southeast Texas Coastal Plain, *in* Clays and clay minerals, V. 10--Natl. Conf. Clays and Clay Minerals, 10th, 1961, Proc.: New York, Macmillan Co. (Internat. Ser. Mons. Earth Sci., v. 12), p. 23-41.

Wilson, J. A., 1956, Miocene formations and vertebrate biostratigraphic units, Gulf Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 9, p. 2233-2246.


0 10 20 30 40 miles
To San Antonio
To Houston
ATASCOSA
KARNES
GOLIAD
BEE
LIVE OAK
LA SALLE
MC MULLEN
WEBB
DUVAL
Falls City
Hobson
Deweesville
Karnes City
Kenedy
Runge
Fashing
Coy City
Campbellton
Choate
Charco
Angel City
Goliad
Fannin
Victoria
Whitsett
Oaks
Ray Point
Calliham
Tilden
Three Rivers
Oakville
Cotulla
George West
Beeville
Mathis
Freer
Alice
Laredo
Pescadito
Bruni
Frio River
Nueces River
Atascosa River
San Antonio River
Guadalupe River
FIELD TRIP STOPS
URANIUM GEOLOGY AND MINES OF SOUTH TEXAS
AAPG Convention 1971, Field Trip
1st Day
2nd Day
▲1 Goliad Sand type locality
▲2 Susquehanna-Western mill
▲3 Tenneco's Weddington mine
▲4 Whitsett Formation type locality
▲5 Frio Clay and Catahoula Tuff, including Fant Tuff Member type locality
▲6 Pescadito dome panorama
▲7 Jackson Group – zeolite beds
▲8 Catahoula Tuff, Soledad Volcanic Conglomerate Member type locality
▲9 Eagle Hill – silica knobs and fault
▲10 Humble's Felder mine
PLATE I


EXPLANATION
Qal
Alluvium
QTu
Gravel and mantle
Ey
Yegua formation
El
Laredo formation
DIP AND STRIKE
nearly flat
0° to 3°
4° to 10°
over 10°
dip slope
fault
linear
deep test
gas well
formline
N
miles
Jackson Group ?
Complex
PHOTOGEOLOGIC MAP
PESCADITO DOME
WEBB COUNTY, TEXAS
BY GEORGE HINDS
Photogravity Company, Inc. Houston, Texas
PLATE 2