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National Uranium Resource Evaluation

LAREDO QUADRANGLE TEXAS

Bendix Field Engineering Corporation
Grand Junction, Colorado

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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Nuclear Energy
Grand Junction Area Office, Colorado

This report is a result of work performed by Bendix Field Engineering Corporation, Operating Contractor for the U.S. Department of Energy, as part of the National Uranium Resource Evaluation. NURE was a program of the U.S. Department of Energy's Grand Junction, Colorado, Office to acquire and compile geologic and other information with which to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the United States.

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NATIONAL URANIUM RESOURCE EVALUATION
LAREDO QUADRANGLE
TEXAS

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August 1982

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION AREA OFFICE
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This is the final version of the subject-quadrangle evaluation report to be placed on open file. This report has not been edited. In some instances, reductions in the size of favorable areas on Plate 1 are not reflected in the text.

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*Published geologic map available from: University of Texas at Austin, Bureau of Economic Geology

ABSTRACT

The Laredo Quadrangle, Texas, was evaluated to a depth of 1500 m to identify environments and delineate areas favorable for the occurrence of uranium deposits. The areas were delineated in accordance with criteria established by the National Uranium Resource Evaluation program sponsored by the U.S. Department of Energy. Surface studies included investigations of uranium occurrences described in the literature, location of aerial radiometric anomalies, outcrop studies, and followup of hydrogeochemical and stream-sediment reconnaissance data. Subsurface evaluation of selected geologic units was accomplished by using electric and gamma-ray well logs to construct maps and cross sections.

An environment favorable for Texas roll-type sandstone uranium deposits is identified in 62 areas in the Goliad, Oakville, Catahoula, Frio, and Whitsett Formations. The Midway Group; the Reklaw, Weches, Cook Mountain, Caddell, Wellborn, Manning, Vicksburg, and Anahuac Formations; the Chusa Member of the Catahoula Formation; the Fleming, Uvalde, Lissie, and Beaumont Formations; and river-terrace deposits and deposits of Recent age are considered unfavorable. The Yegua, Sparta, Laredo, and Queen City Formations; the El Pico Clay; the Bigford and Carrizo Formations; the Wilcox Group; and the Escondido, Olmos, and San Miguel Formations were examined but not evaluated.

INTRODUCTION

PURPOSE AND SCOPE

The Laredo Quadrangle, Texas (Fig. 1), was evaluated to a depth of 1500 m (5,000 ft) to identify geologic environments and delineate areas that exhibit characteristics favorable for the occurrence of uranium deposits. Favorable environments, as determined by surface and subsurface investigations, are those that could contain uranium deposits of at least 100 tons U_3O_8 in rocks with an average grade not less than 100 ppm U_3O_8. Selection of a favorable environment is based on the similarity of its geologic characteristics to those of environments that contain known uranium deposits (recognition criteria) as described in Mickle and Mathews (eds., 1978). This study was conducted by Bendix Field Engineering Corporation (BFEC) for the National Uranium Resource Evaluation (NURE) program, managed by the Grand Junction Office of the U.S. Department of Energy (DOE).

The evaluation began November 1, 1978, and ended June 13, 1980. Time spent in literature search, field work, evaluation of data and preparation of the final report totaled approximately 2.2 man-years by the authors and other BFEC personnel of the Austin field office.

ACKNOWLEDGMENTS

The authors are grateful to the many ranchers and mining companies who allowed sampling on their land and provided a wealth of information. Gratitude is also extended to the numerous government employees, both local and state, for their aid in locating landowners. Special thanks are extended to William E. Galloway and Christopher Henry of the University of Texas Bureau of Economic Geology (BEG) for the time and knowledge they shared.

PROCEDURES

In order to properly evaluate the uranium potential of the Laredo Quadrangle, an examination of the surface and subsurface geology was necessary. The surface geologic investigations involved preparatory literature research, examination of all uranium occurrences previously reported in Preliminary Reconnaissance Reports (PRR's) of the U.S. Atomic Energy Commission (Pl. 2; App. A and C), and evaluation of aerial radiometric anomalies (Geodata International, 1975 and 1979) (Pl. 3). Data from the Hydrogeochemical and Stream-Sediment Reconnaissance (HSSR) program (Oak Ridge Gaseous Diffusion Plant [ORGDP], 1980) were received too late for proper evaluation (Pl. 4), but partially evaluated anomalies are outlined on Plate 46. Geologic environments exposed in surface outcrops were visited and sampled where and when possible. Samples of rock and water (Pl. 5 and 38-43; App. B) were collected and submitted for chemical analysis to Core Laboratories, Inc., Corpus Christi, Texas, and to BFEC laboratories in Grand Junction, Colorado. A Mt. Sopris Model SC-132 portable scintillometer was used in all surveys of outcrops, uranium occurrences, and aerial radiometric anomalies. When possible, a specific ion meter, Model 407 A/F, manufactured by Orion Research, was used to measure Eh and pH of water samples.

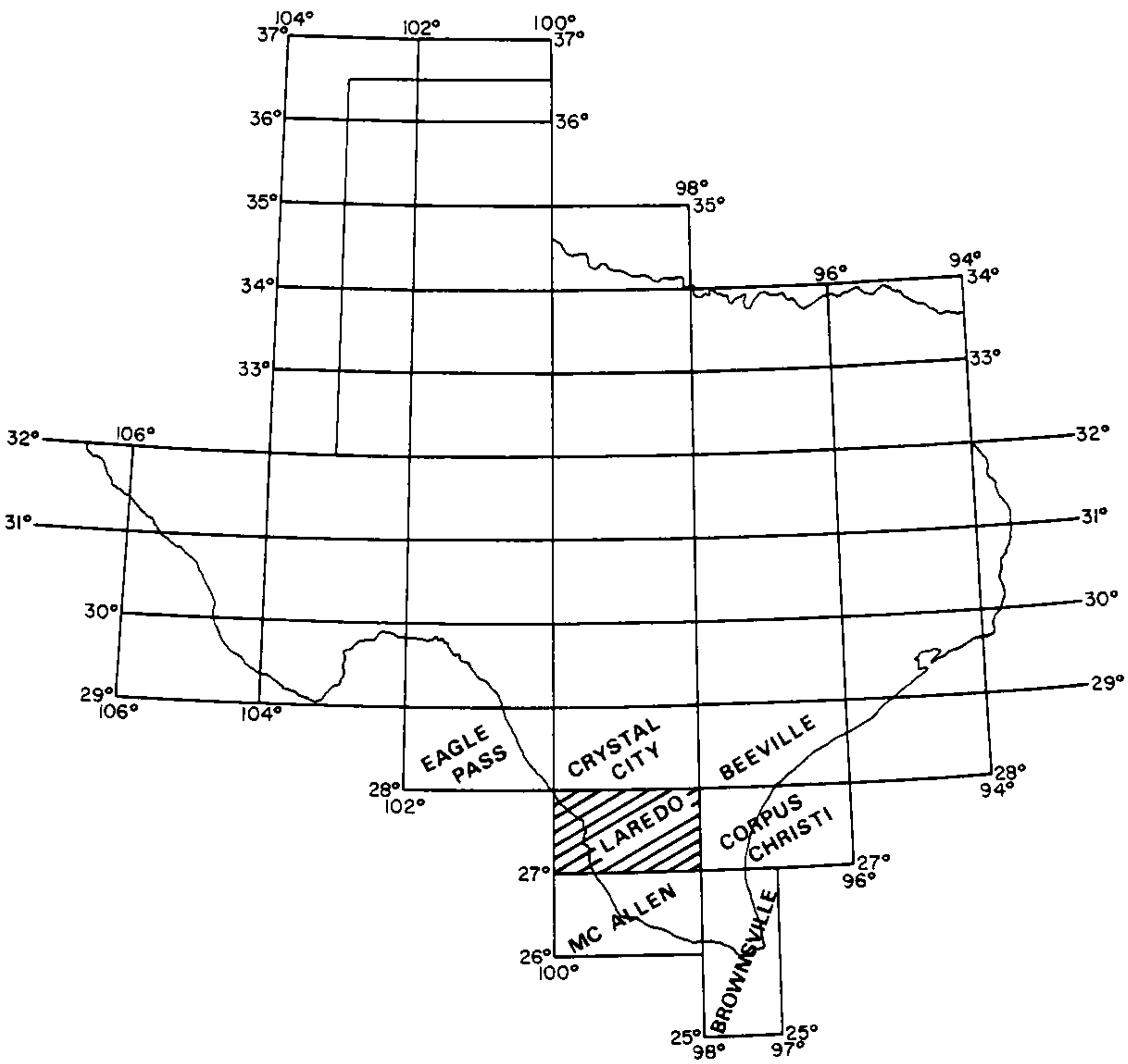

Figure 1. Quadrangle location map

The subsurface evaluation of the Laredo Quadrangle was based on the work of Quick and others (1977), on the examination of electric well logs (Pl. 36; App. D), and on the examination of gamma-ray well logs (Pl. 37; App. E) obtained from Petroleum Information Service and the Texas Water Development Board. Subsurface anomalies were located using the gamma-ray well logs; whereas, the subsurface geologic environments were evaluated by using spontaneous potential (SP) and resistivity (RES) curves of the electric well logs. Cross sections (Pl. 26-35), structure maps (Pl. 19-24), total-thickness maps (Pl. 8-12), and total-sandstone-thickness maps (Pl. 13-18) were constructed. A map illustrating the major subsurface fault zones was also prepared (Pl. 25).

A total of 46 plates accompanies this report; 36 are folio-sized maps, and 10 are stratigraphic cross sections. The plates showing drainage (Pl. 6) and culture (Pl. 45) were obtained from the U.S. Geological Survey, and the geologic map (Pl. 7) is a publication of the University of Texas BEG (1976).

GEOLOGIC SETTING

The Laredo Quadrangle, an area of 17,660 km^2 (6,820 mi^2), is in a portion of the South Texas Gulf Coastal Plain between lat 27°00'00"N. and 28°00'00"N. and long 98°00'00"W. and 100°00'00"W. (Fig. 1). A portion of Mexico occupies the western end of the quadrangle (Pl. 44). The elevation is slightly over 50 ft above sea level in the southwestern portion and over 800 ft in the western portion of the quadrangle. Physiographic features include cuestas, domal structures, siliceous knobs, escarpments, and modern eolian sand sheets that cover most of Brooks County.

The quadrangle lies within the Rio Grande Embayment, a depositional basin that has existed since the Tertiary (Fig. 2). The basin is bounded by uplifts on three sides: the San Marcos Arch on the northeast, the Devil's River Uplift on the northwest, and the Salado-Tamaulipas Arch to the southwest. The regional dip of sediments of Tertiary age is approximately 1° to the southeast toward the Gulf of Mexico.

Sediments of the embayment have been affected by structural features active since Jurassic time (Corpus Christi Geological Society, 1975). Data indicate numerous subsurface fault zones trending northeast but indicate few that extend to the surface. Many of the faults are syndepositional, and some show evidence of more than one growth period (Bornhauser, 1979). Normal movement along the faults has resulted in an abrupt thickening of sediments on the downthrown side. Other faults are associated with the emplacement of several salt domes and domal features present at the surface and in the subsurface. Many oil- and gas-producing regions in the quadrangle are fault controlled, which is also the case for most of the known uranium deposits (Pl. 46).

Stratigraphy

At depths less than 1500 m, the oldest geologic unit in the study area is the Taylor Group (Fig. 3), which was deposited during Late Cretaceous time. Carbonates dominated in Cretaceous time through the deposition of the Austin

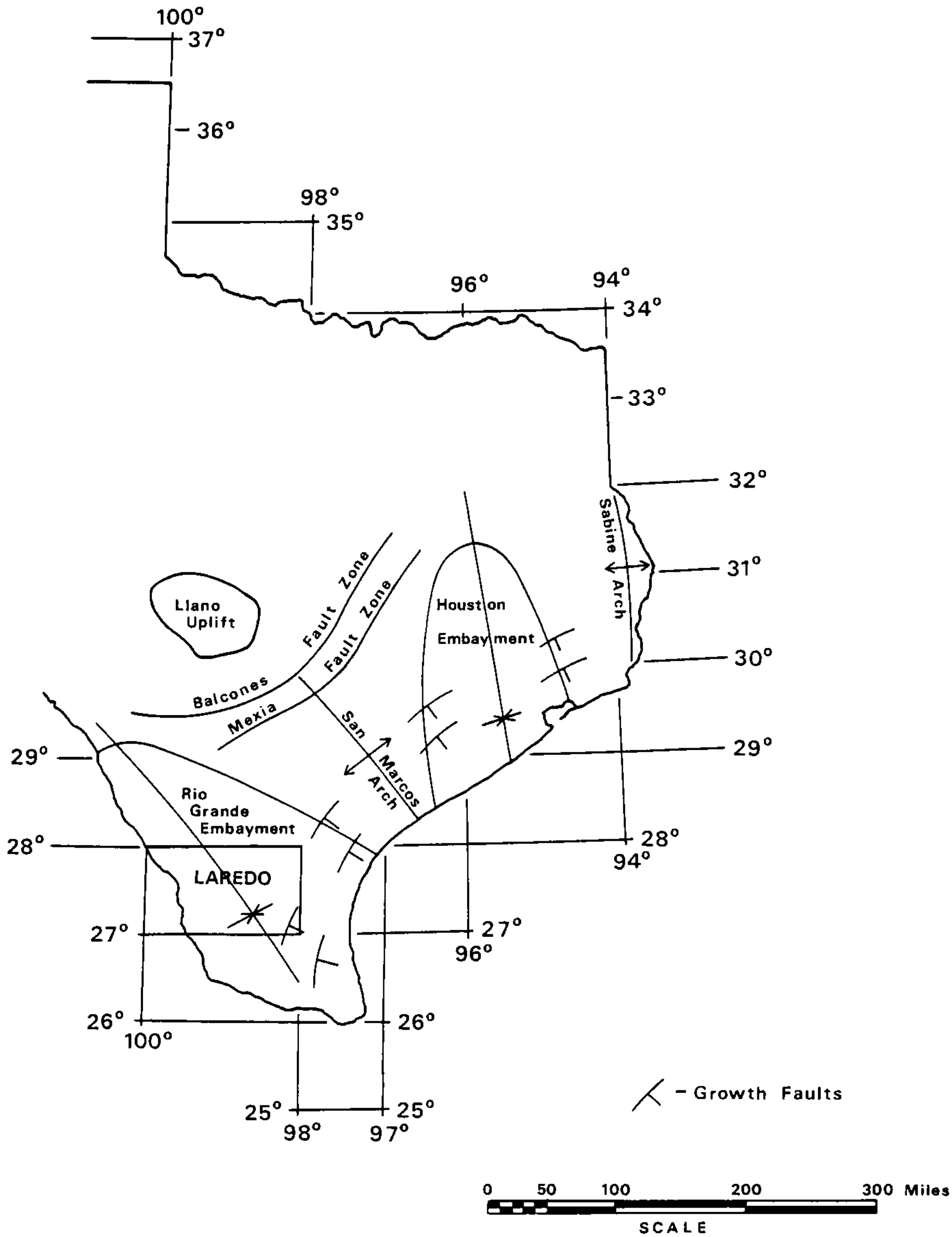

Figure 2. Structural setting

SYSTEM	SERIES	GROUP		FORMATION	LITHOLOGY	DESCRIPTION
QUATERNARY	HOLOCENE			ALLIVIUM		Clay, silt, sand, gravel and organic matter
				WINDBLOWN DEPOSITS		Clay-sand dunes and silt sheets
	PLEISTOCENE			RIVER TERRACE DEPOSITS		Sand, silt, clay and gravel; iron oxide in weathered zones
				BEAUMONT		
				LISSIE		
TERTIARY	PLEISTOCENE OR PLIOCENE			UVALDE		Well-rounded chert pebbles and cobbles
	PLIOCENE			GOLIAD*		Calcitic, medium- to very coarse-grained sandstone and conglomerate; marl and limestone
	MIOCENE			FLEMING		Gray, calcitic mudstone
				OAKVILLE*		Thick-bedded, medium-grained sandstone
				CATAHOULA*		Varicolored, massively bedded, tuff and tuffaceous mudstone, sandstone and clay; loosely cemented, coarse volcanic conglomerate
	?			ANAHUAC		Subsurface only. Green-to-gray clay with guartzose and glauconitic sand
	OLIGOCENE			FRIO		Massive, greenish-gray clay with minor sandstone
		VICKSBURG				Subsurface only. Greenish-gray clay and sandstone with volcanic rock fragments
	EOCENE	JACKSON*		WHITSETT*		Fine- to coarse-grained, fossiliferous, laminated and crossbedded sandstone; sandy, calcitic clay with abundant fossil wood; some volcanic ash beds
				MANNING		
				WELLBORN		
				CADDELL		
		CLAIBORNE		YEGUA		Lignitic, bentonitic, silty, brown clay and fine-grained, calcareous, glauconitic sandstone with some fossil wood
			LAREDO	COOK MOUNTAIN		Thin-bedded, fine-grained sandstone overlain by clay and sandstone
				SPARTA		
			EL PICO	WECHES		Clay, fine-grained sandstone, and coal, interfingering to the northeast with fine-grained sandstone and shale overlain by clay
				QUEEN CITY		
			BIGFORD	REKLAW		Calcareous, gypsiferous clay and sandy clay; thin- to thick-bedded coarse-grained sandstone; lignite
				CARRIZO		Massive, fine- to coarse-grained sandstone and minor shale
	PALEOCENE-EOCENE	WILCOX		INDIO		Thin-bedded, fine-grained, carbonaceous sandstone; sandy shale; lignite
		MIDWAY		KINCAID		Dark gray shale and sandstone
CRETACEOUS	UPPER CRETACEOUS	NAVARRO		ESCONDIDO		Clay, sandstone, siltstone and limestone
		TAYLOR		OLMOS		Clay, sandstone and coal
				SAN MIGUEL		Sandstone and shale

*Favorable for uranium deposition; also contains uranium ore deposits

Figure 3. Stratigraphic column with lithologic descriptions

Group, which underlies the Taylor Group. However, with the advent of Taylor Group deposition, clastics began to prevail because of tectonic activity to the west and northwest. The three units of Cretaceous age are the San Miguel and Olmos Formations of the Taylor Group and the overlying Escondido Formation of the Navarro Group. These formations are composed of wave-dominated, deltaic sands deposited during a period of marine transgression. After deposition of the Escondido sands, tectonic activity subsided; and a period of relative quiescence dominated until deposition of the Claiborne Group in middle Eocene time.

Resting unconformably on the Escondido Formation are the sediments of the Kincaid Formation of the Midway Group that consist of marine, dark-gray, fossiliferous shale occasionally interbedded with thin sandstone. Sediments of the Kincaid Formation grade upward into the Indio Formation of the Wilcox Group, which is a series of deltaic and strand plain--barrier bar sands and muds. The sediments of the Midway and Wilcox Groups have not been further subdivided for this quadrangle. The Wilcox Group is overlain by the Carrizo Formation of the Claiborne Group, which consists of medium- to coarse-grained fluvial sands. All of these units are of Eocene age.

The oldest exposed unit in the quadrangle, the Bigford Formation of the Claiborne Group, consists of sands, thin beds of fossiliferous silts and shale, and several coal beds (Lonsdale and Day, 1937). The Bigford Formation exists only on the surface and in the shallow subsurface. Downdip, a facies change occurs that separates it into the Reklaw (shale) Formation on the bottom and the lower portion of the Queen City (sand) Formation on the top (Guevara and Garcia, 1972). This facies change is shown in cross sections on Plates 27, 30, and 32. These sediments represent a highly destructive delta system composed of meander-belt and stacked coastal--barrier bar facies (Guevara and Garcia, 1972).

Overlying the Bigford Formation is the El Pico Clay. It consists of clays, sands, and thin coal beds (BEG, 1976) that represent lagoonal facies genetically related to the highly destructive, wave-dominated deltas of the prograding Queen City Formation to the northeast (Guevara and Garcia, 1972). The El Pico Clay is the name used by the University of Texas BEG on the geologic map (Pl. 7). However, in the western portion of the quadrangle, a facies change can be recognized that divides the El Pico Clay into the Weches (clay) Formation and the upper portion of the Queen City (sand and clay) Formation (Guevara and Garcia, 1972). This is shown in cross sections on Plates 27, 30, and 32.

The Laredo Formation overlies the El Pico Clay and consists of thick sand beds (in part glauconitic), gypsiferous clay, impure limes, and lignite (BEG, 1976; Ricoy and Brown, 1977). This formation represents a marine regressive-transgressive sequence (Eargle, 1968). Sedimentary structures indicate a highly destructive, wave-dominated delta system with its associated lagoonal facies followed by a marine transgression, which resulted in shelf-mud deposition (Ricoy and Brown, 1977). The Laredo Formation is the name used by the University of Texas BEG on the geologic map (Pl. 7). However, in the subsurface in the western portion of the quadrangle, a facies change can be recognized that divides the Laredo Formation into the Sparta (sand) Formation and the Cook Mountain (clay) Formation (Guevara and Garcia, 1972). This facies change is shown in cross sections on Plates 27, 30, and 32. The relationships of the Bigford, El Pico, and Laredo Formations are shown on the stratigraphic column (Fig. 3).

Overlying the Laredo Formation is the Yegua Formation, the uppermost unit of the Claiborne Group. Sediments of the Yegua Formation were deposited in environments similar to those in which the Laredo Formation was deposited (Ricoy and Brown, 1977). The Yegua Formation is composed mainly of varicolored, gypsiferous, carbonaceous and sandy clay with thin beds of grayish sand and concretionary limes (Lonsdale and Day, 1937). Data from electric well logs indicate that, in a downdip direction, this formation becomes an almost continuous series of stacked sands that grade into clay at the base of the formation.

The Jackson Group, of Eocene age, conformably overlies the Yegua Formation on the surface and is composed of interbedded sand, mud, and lignite deposited in the upper portion of a major progradational cycle that includes the underlying Yegua Formation (White and Galloway, 1977). At the base of the Jackson Group is the Caddell Formation, a sequence of marine sands that is overlain by a sequence of strand plain--barrier bar sands of the Wellborn Formation. Overlying the Wellborn Formation are the lagoonal muds of the Manning Formation and sands of the Whitsett Formation (Fisher and others, 1970). In the subsurface, near the Webb and Duval county line, the lower Jackson Group becomes a sequence of thick sands that is difficult to distinguish from the sands of the Yegua Formation due to similar electric well-log characteristics. Subsurface maps constructed by Quick and others (1977) and by the authors do not agree with the outcrop thickness of the Jackson Group as shown on the geologic map (Pl. 7). Therefore, cross sections B' to B" and D' to D" (Pl. 28 and 33) and the total-thickness map for the Jackson Group (Pl. 9) show a thinner sequence of Jackson sediments in the north-central portion of the quadrangle than would be expected from an examination of the geologic map.

The Vicksburg Group is a marine wedge consisting of gray, slightly calcareous clay with some sandy clay and local lenses of very fine-grained sand (Sellards and others, 1932). This unit is found only in the subsurface at locations where it separates the Jackson Group from the Frio Formation (Fig. 3).

Overlying the Jackson Group is the Frio Formation. The Frio consists of dark greenish gray, massive clay with some gypsum and concretions (Barnes, 1976). There are some sands present downdip, but they occur erratically. This formation, deposited during Oligocene time, is marked by the absence of volcanic ash, which is present in both the underlying Jackson Group and overlying Catahoula Formation (Shafer, 1974).

The Anahuac Formation is a marine sandstone and shale wedge that is present only in the subsurface and which has no known exposure to ground-water exchange. It separates the Frio and Catahoula Formations in the subsurface (Fig. 3).

The Catahoula Formation, of predominantly Miocene age, overlies the Frio Formation and was deposited in the Gueydan fluvial system described by Galloway (1977). The recognized members of this formation are the Fant Tuff, Soledad Conglomerate, and Chusa Tuff (Bailey, 1926). Coarse clastics are concentrated in, but not confined to, the Soledad Conglomerate. These clastics form broad, lenticular units of intermixed sandy conglomerates and fine- to coarse-grained sands. They represent channel-fill and crevasse-splay facies, which are interbedded with lenticular units of mud and clay that have subordinate amounts of tuff and silt. The Fant Tuff and Chusa Tuff represent flood-plain deposited tuffaceous muds and coastal lacustrine tuffaceous muds and clays (Galloway, 1977). On the geologic map (Pl. 7), the University of Texas BEG made no distinction between the Frio and Catahoula Formations in the southern portion of the quadrangle. Therefore, they are not shown separately on the surface extension of the cross sections (Pl. 30). Air-fall volcanic ash, together with fluvial sands composed of plagioclase feldspar and volcanic rock fragments, indicate a western sedimentary source for the Catahoula Formation (Galloway, 1977).

During Miocene time, uplift along the Balcones Fault Zone, located to the north, resulted in termination of Catahoula deposition. Erosion of the Edwards Plateau and Llano Uplift contributed sediments to the fluvial Oakville Formation, which overlies the Catahoula Formation (Eargle and others, 1975). Predominant lithologies in the Oakville Formation are carbonate-rich, fine- to medium-grained arkoses; also included are bentonitic clays that contain volcanic rock fragments and detrital iron minerals (Klohn and Pickens, 1970; Shafer, 1974).

Overlying the Oakville Formation is the Fleming Formation, also of Miocene age, which is made up of yellow to green calcareous clay with thin lenticular seams of fine- to coarse-grained sand and gravel (Shafer, 1974). The Fleming Formation commonly has a higher percentage of clay than does the Oakville Formation, but it is so lithologically similar that establishing formational contacts is difficult, particularly in the subsurface (Mason, 1963; Baker, 1978).

The Goliad Formation overlies the Fleming Formation and in some areas also overlaps the Fleming, Oakville, Frio, and Whitsett Formations. The Goliad Formation was deposited under arid climatic conditions during Pliocene time by streams originating in West Texas, New Mexico, and possibly the Rocky Mountain region (Eargle and others, 1975). Sediments of the Goliad Formation are sands interbedded with layers of gravel and clay and extensive and distinctive deposits of caliche (Mason, 1963). The Uvalde Formation, of late Pliocene or early Pleistocene age, occurs in the western portion of the quadrangle as isolated deposits of sand, gravel, and caliche that are similar in lithology to the Goliad Formation (Lonsdale and Day, 1937).

Overlying the Goliad and Uvalde Formations are the Lissie and Beaumont Formations and the river-terrace deposits. These units are fluvial sediments of continental origin that were deposited during Pleistocene time. They consist of interbedded sand, silt, clay, and marl with minor amounts of gravel. The facies changes are rapid both laterally and vertically (Mason, 1963).

Deposits of Recent age include alluvium in and along present-day rivers and windblown deposits that cover large areas of the Laredo Quadrangle, especially in the east, the southeast, and, to a lesser extent, the southwest. The eolian units were deposited by easterly winds that carried sand from the beaches east of the study area (Wood and others, 1963). Most of the eolian deposits are stabilized, but active sand dunes are present in the southeastern portion of the quadrangle (Barnes, 1976).

Uranium Deposits

The tuffaceous Catahoula Formation is considered the dominant source of uranium for deposits occurring in the South Texas coastal region. Uranium has been shown to have been leached from the tuffs shortly after they were deposited (Duex, 1971). The uranium was carried to reducing environments in the Catahoula, Frio, and Whitsett Formations by oxidizing meteoric ground waters. Galloway (pers. comm., 1980) believes the Catahoula tuffs had once overlain formations as old as Cretaceous and possibly older. If this did in fact occur, then the uranium leached from the Catahoula may have been transported into the more sandy and permeable formations (Yegua, Sparta, Queen City, Carrizo-Wilcox, Escondido, Olmos, and San Miguel) and deposited in reducing environments. Uranium in the Oakville Formation was derived from either intraformational volcanic ash or was leached from older uranium-bearing formations. Uranium leached from older formations is the probable source for uranium in the Goliad Formation. Reductants, in the form of lignites and carbonaceous trash, are present within these formations. Another possible source of reductants is H_2S gas from underlying petroleum and natural-gas accumulations along fault zones and in permeable formations (Eargle and Weeks, 1961). For additional information, see Galloway (1977) and Galloway and Kaiser (1979).

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

SUMMARY

In the Laredo Quadrangle, 63 areas contain an environment favorable for epigenetic uranium deposits that are Texas roll-type (Subclass 242; Austin and D'Andrea, 1978). The first group is all areas with channel-controlled deposits in sand. Areas A_1, A_2, and B_1 through B_{15} have favorable environments in the Soledad and Fant Members of the Catahoula Formation. Area C has an environment in the Oakville Formation. Areas D_1 through D_5 have environments in the Goliad Formation. Area E has an environment in the Whitsett Formation of the Jackson Group. Areas F_1 through F_4 have environments in the Frio Formation.

Areas of the next group are all in major fault-controlled sand deposits. These are less well defined sands that are displaced by major fault trends, which form aquitards and that provide an avenue by which reductants enter the system. Areas G_1 through G_5 have favorable environments in the Soledad and Fant Members of the Catahoula Formation. Areas H_1 through H_5 have environments in the Oakville Formation. Areas I and J have environments in the Whitsett Formation of the Jackson Group.

Areas of the final group have environments related to domal structures. Areas K and N_1 through N_5 have environments in the Goliad Formation; Areas L_1 through L_5, in the Soledad and Fant Members of the Catahoula Formation;

Areas M_1 through M_6, in the Oakville Formation; Areas P_1 through P_5, in the Frio Formation; and Area O, in the Whitsett Formation of the Jackson Group.

CHANNEL-CONTROLLED SAND DEPOSITS

Fluvial channel-margin facies are favorable for Texas roll-type uranium deposits in the Soledad and Fant Members of the Catahoula Formation (Areas A_1, A_2, and B_1 through B_{15}), the Oakville Formation (Area C), the Goliad Formation (Areas D_1 through D_5), the Whitsett Formation of the Jackson Group (Area E), and the Frio Formation (Areas F_1 through F_4). The dimensions of the favorable areas are presented in Table 1 at the end of this section.

Areas A_1, A_2, and B_1 through B_{15}

Areas A_1, A_2, and B_1 through B_{15} (Pl. 1a and 1c) each contain an environment favorable for Texas roll-type uranium deposits of Subclass 242 in fluvial channel-margin facies of the Soledad and Fant Members of the Catahoula Formation. These areas lie along the South Texas uranium trend in the Duval uranium district. The areas delineate fluvial channel margins as defined by sand "thicks" and "thins" in Plate 16 and by channel systems (Fig. 4) mapped by Galloway and others (1979). The downdip favorability of the formation ends as increasing sand thickness and lack of subsurface control prevent further delineation of fluvial channels.

The Soledad and Fant Members are lithologically described in the geologic setting. Both members contain enough tuffaceous material and fluvial sands to be considered potentially favorable. There are faults associated with oil and gas fields in the favorable areas that would provide solution conduits, as well as carbonaceous material in the units to account for the reductants, necessary to precipitate uranium. The tuffaceous material in these members is more than ample to supply the uranium necessary to form deposits; clay beds, less permeable sands, and faults could act as aquitards. Anomalous amounts of elements normally associated with uranium deposits, especially molybdenum and vanadium, are present in the formation (ORGDP, 1980). Other HSSR (ORGDP, 1980) and aerial radiometric anomalies (Geodata International, 1975 and 1979) are aligned with fault zones (Pl. 46).

Area A_1 includes the Bruni-Hebbronville mining area, which has four producing in-situ leach mines and one mine under development (Y15-Y19, Pl. 2; App. A and C). There are two anomalous gamma-ray well logs present in the area (No. 2041 and 20701, Pl. 37; App. E) as well as anomalous HSSR well-water samples (ORGDP, 1980) that contain up to 86.09 ppb U_3O_8 (Pl. 46).

Area A_2 is mostly an interchannel facies; but since no sand maps are available for the broad western area, a margin along a less sandy to more sandy zone had to be implied. In the northwest portion of Area A_2 are two proposed uranium mines that are due to begin operations soon. One (Y3) was to be the only open-pit mine in the quadrangle but has, of late, been changed to an in-situ leach mine. The other (Y1) is an in-situ leach project that was

TABLE 1. AREA, THICKNESS, VOLUME, AND DEPTH OF FAVORABLE AREAS RELATED TO CHANNEL-CONTROLLED SAND DEPOSITS

Favorable Area	Description	Area (km^2)	Average Thickness	Volume	Depth from Surface
A_1	Soledad and Fant Members	404.13	152.40	61.58	Shallow subsurface to 701
A_2	Soledad and Fant Members	689.50	45.72	31.52	Shallow subsurface to 710
B_1	Soledad and Fant Members	189.25	152.40	28.84	Shallow subsurface to 427
B_2	Soledad and Fant Members	33.32	91.44	3.05	152 to 488
B_3	Soledad and Fant Members	151.66	152.40	23.11	442 to 1,219
B_4	Soledad and Fant Members	313.99	152.40	47.85	Shallow subsurface to 610
B_5	Soledad and Fant Members	245.21	91.44	22.42	15 to 623
B_6	Soledad and Fant Members	22.21	45.72	1.02	52 to 253
B_7	Soledad and Fant Members	78.18	91.44	7.15	168 to 442
B_8	Soledad and Fant Members	154.22	60.96	9.40	40 to 436
B_9	Soledad and Fant Members	205.06	91.44	18.75	152 to 732
B_{10}	Soledad and Fant Members	91.42	152.40	13.93	244 to 771
B_{11}	Soledad and Fant Members	157.64	91.44	14.41	244 to 771
B_{12}	Soledad and Fant Members	35.46	213.36	7.57	198 to 488
B_{13}	Soledad and Fant Members	40.58	198.12	8.04	610 to 930

TABLE 1. AREA, THICKNESS, VOLUME, AND DEPTH OF FAVORABLE AREAS RELATED TO CHANNEL-CONTROLLED SAND DEPOSITS (Continued)

Favorable Area	Description	Area km^2	Average Thickness	Volume	Depth from Surface
B_{14}	Soledad and Fant Members	56.82	121.92	6.93	610 to 869
B_{15}	Soledad and Fant Members	211.89	152.40	32.09	869 to 1,524
C	Oakville Formation	3,030.56	91.44	277.11	Shallow subsurface to 1,067
D_1	Goliad Formation	296.90	60.96	18.10	Shallow subsurface to 244
D_2	Goliad Formation	214.88	60.96	13.10	Shallow subsurface to 244
D_3	Goliad Formation	302.46	76.20	23.05	Shallow subsurface to 396
D_4	Goliad Formation	86.72	91.44	7.93	Shallow subsurface to 268
D_5	Goliad Formation	176.86	45.72	8.09	Shallow subsurface to 76
E	Whitsett Formation	289.64	60.96	17.66	Shallow subsurface to 640
F_1	Frio Formation	1,628.06	30.48	49.62	Shallow subsurface to 1,524
F_2	Frio Formation	1,179.07	60.96	71.87	Shallow subsurface to 1,524
F_3	Frio Formation	613.03	45.72	28.03	Shallow subsurface to 1,524
F_4	Frio Formation	319.97	60.96	19.51	Shallow subsurface to 1,524

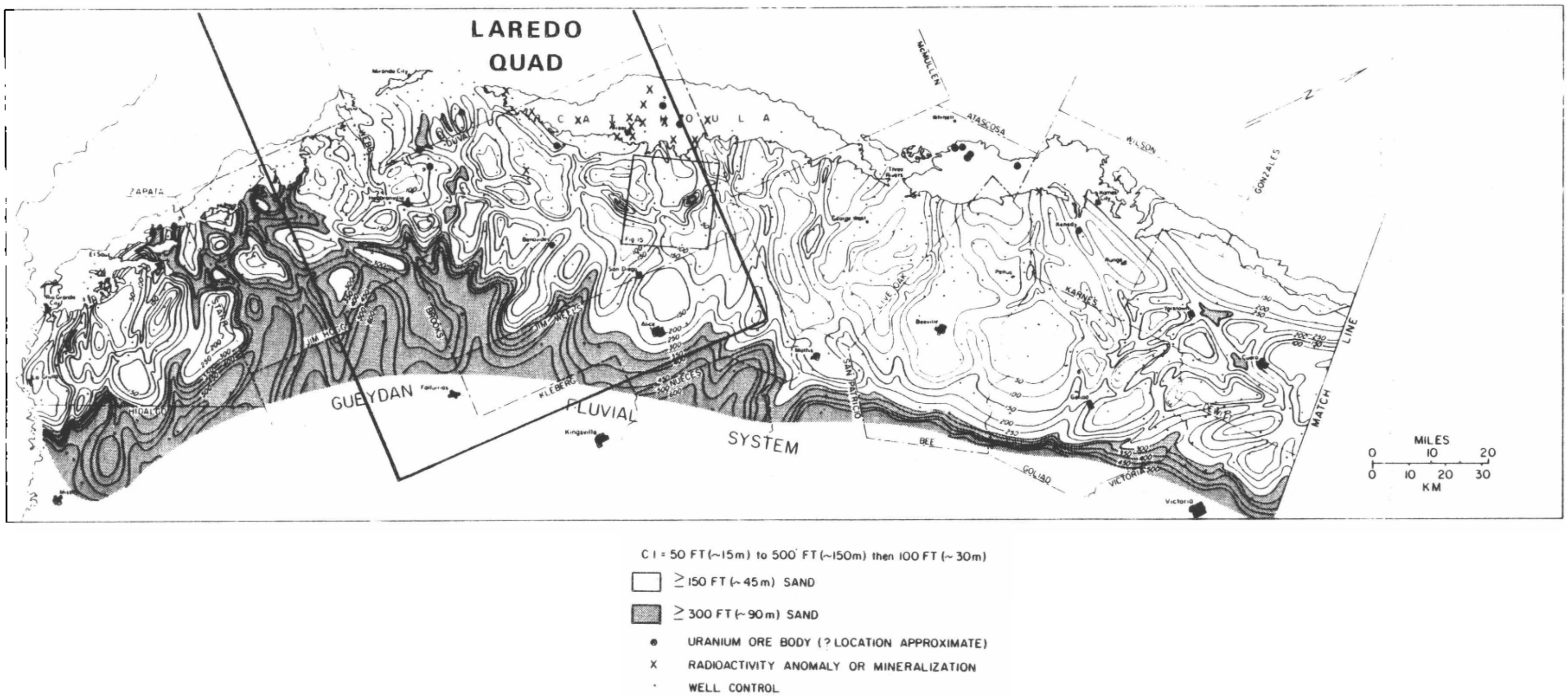

Figure 4. Sand-isolith map of Gueydan fluvial system-Catahoula Formation.

due to begin operations by the end of 1979 and is near the border of the Crystal City Quadrangle. Both are a few miles north of Freer, Texas (Pl. 2; App. A and C).

Two detailed geochemical sampling areas containing anomalous surface samples are shown on Plates 41 and 46 (MJP 001-005, 007, and 008; App. B-1). Followup investigations of reported uranium occurrences (Pl. 2; App. A) were done in these areas north of Freer. Occurrences Y2, Y3, and Y4 were not accessible. Occurrence Y2 is reported to have readings as high as 1.2 MR/hr, Occurrence Y3 has a high of 0.2 MR/hr, and Occurrence Y4 has up to 0.06 MR/hr. Occurrence Y5 was not found, but it is reported to have readings as high as 0.25 MR/hr and 0.007% eU_3O_8.

Two samples from uranium Occurrence 6 (Pl. 2; App. A and C) contain 365 and 299 ppm U_3O_8 (No. MJP 002 and 003; App. B). There are also anomalous molybdenum and vanadium values present. This occurrence is in the Soledad Member of the Catahoula Formation. The PRR for the occurrence reports concentrations as high as 5.8% eU_3O_8.

Uranium Occurrence 7 (Pl. 2; App. A and C) is also in the Soledad Member, and one sample contains 55 ppm U_3O_8 (MJP 001; App. B). The PRR for this occurrence reports concentrations of 0.275% eU_3O_8 for this locality.

Areas B_1 through B_{14} are all similar. Area B_1 has one anomalous gamma-ray well log (No. 28101; Pl. 37; App. E) and several HSSR (ORGDP, 1980) well-water anomalies (Pl. 46). Area B_2 has an anomalous gamma-ray well log (No. 11505; Pl. 37; App. E). Area B_3 has one anomalous gamma-ray well log (No. 18401; Pl. 37; App. E). Areas B_4 and B_5 each have three HSSR well-water anomalies (ORGDP, 1980) (Pl. 46). Areas B_6 through B_{14} have no anomalies associated with them.

Area B_{15} (Pl. 1a and 1c) is the easternmost extension, from the Corpus Christi Quadrangle, of a large fluvial-channel system of sands of the Catahoula Formation, which is favorable for Texas roll-type uranium deposits of Subclass 242. Area B_{15} is very similar to the previously described areas of the Catahoula Formation in that it has faults with related oil and gas fields and similar lithology. The only difference is that the area seems to be in a more broad and larger fluvial-channel-system facies than is evident in Areas B_1-B_{14} (Pl. 16; Fig. 5). A larger, more broad channel system may provide a larger transition zone from more sandy to less sandy areas and may be an environment more favorable for larger deposits.

The Soledad and Fant Members of the Catahoula Formation contain the favorable environment of Area B_{15}. Large quantities of uranium have been leached out of the Catahoula Formation in the past; this makes it reasonable to assume that uranium was available to have formed deposits further downdip and deeper than presently known deposits. There are two anomalous gamma-ray well logs (No. 5; 17601 and 18401; Pl. 37; App. E) in a linear west to east pattern (Pl. 37 and 46).

Most of the land is used for ranching and oil and gas exploration and production. Uranium exploration and production has been increasing lately in many of the areas.

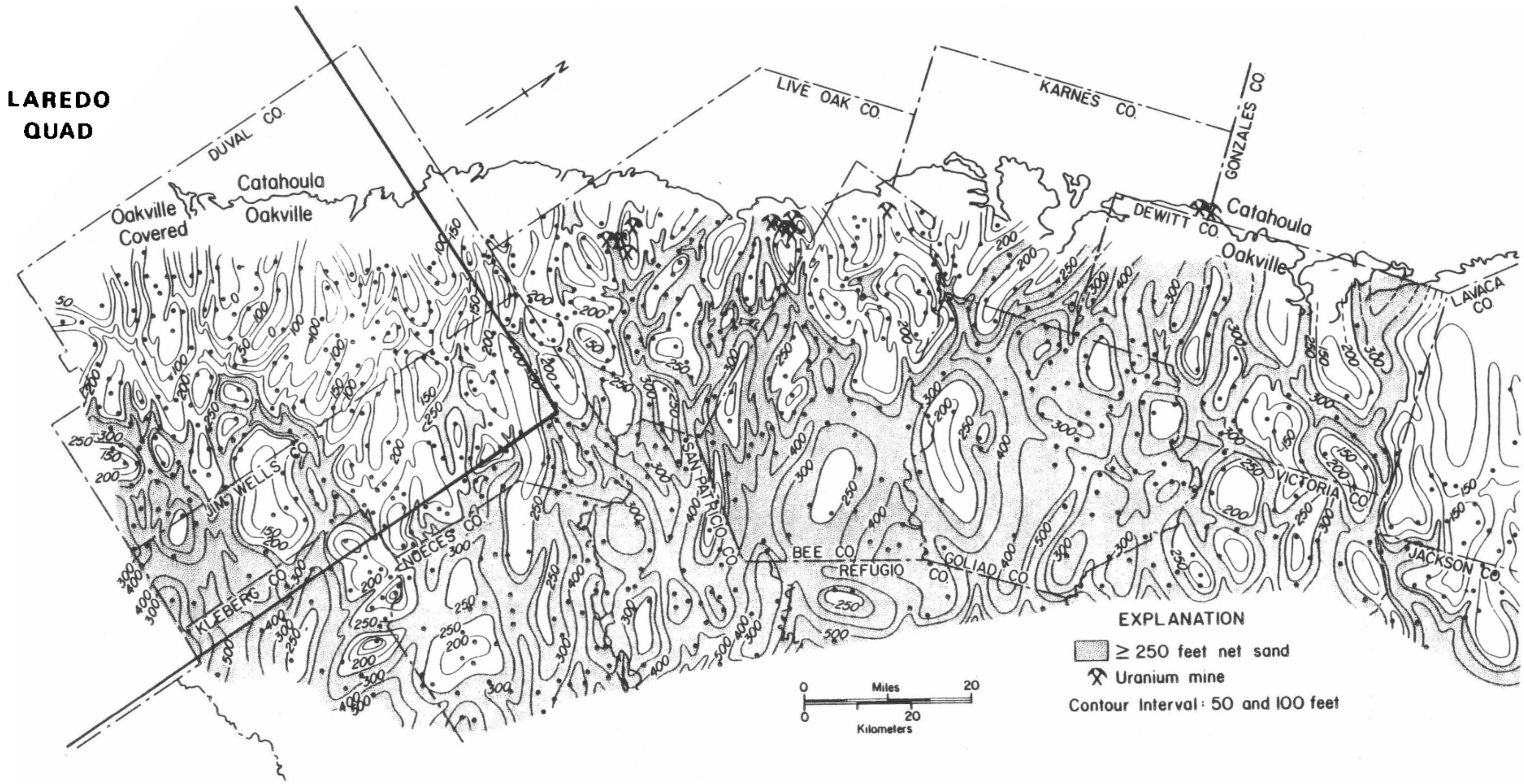

Figure 5. Net-sandstone isolith map of the Oakville Formation (Galloway, Finley and Henry, 1979)

Area C

Area C (Pl. 1a and 1b) has an environment favorable for Texas roll-type uranium deposits of Subclass 242 in the fluvial-channel-margin sands of the Oakville Formation. The sands are thick bedded, medium grained, and calcareous. Carbonaceous matter is mostly in the less sandy, clayey areas along the channel margins. This carbonaceous matter, along with numerous fault-related oil and gas fields, are the main source of reductants.

Fluvial-channel systems are noticeable on Pl. 17, but Galloway and others (1979), Figure 5 of this report, show a more detailed map of the channel-system sands. Galloway's isolith map was used to trace fluvial-system margins and outline much of the favorable area. The western limit of this favorable area is the extent of the isolith map. Further mapping could extend the favorability a few hundred feet.

Although there are no known uranium mines in the Oakville Formation in the Laredo Quadrangle, the Crystal City Quadrangle just to the north has numerous such mines in Live Oak County. The source of uranium is either from the tuffaceous ash present in the Oakville Formation or from the underlying Catahoula tuffs. Both contain enough uranium to act as source rocks for Oakville deposits. Sandstone-to-shale ratios of 1:1 to 4:1 for the areas (Quick and others, 1977) are also favorable.

The southern portion of the Area C environment is totally subsurface along a northwest-southeast trending fluvial-channel system. Quick and others (1977) suggest a large east-west trending fluvial-channel system roughly following the Duval-Brooks county line. Insufficient data on Plate 17 prevented the authors from extending the system further east. The northern portion of this area is adjacent to an Oakville playa-flood-plain facies described by Galloway and others (1979). There is one anomalous gamma-ray well log (No. 18901; Pl. 37 and 46; App. E) present near the Sejitas dome, along with exploration drilling north of Hebbronville.

The middle portion of Area C is a west-east trending fluvial-channel system. The channel margins in the west are smaller and less well defined than the larger ones to the east. This portion is similar in characteristics to the southern portion except that it partially crops out updip. There are two anomalous gamma-ray well logs present, and both are along the southernmost channel system (No. 18103 and 17106; Pl. 37 and 46; App. E). There are also two HSSR anomalies (ORGDP, 1980) and two aerial radiometric anomalies (Geodata International, 1975) (Pl. 46) over the area of outcrop.

The northern portion of Area C represents fluvial-channel margins trending northwest to southeast. The extent of this portion of the area is influenced by the playa-flood-plain facies mentioned earlier. Many small fluvial channels are present in this facies, but none are large enough to map. This portion of Area C has characteristics similar to those of the rest of the area and is totally in the subsurface. There is one anomalous gamma-ray well log (No. 1101; Pl. 37 and 46) in the upper east corner, but it may be in the lowest sand of the Fleming Formation. However, since the Oakville and Fleming Formations are undifferentiated on the geologic map and are difficult to differentiate on electric well logs, it is reasonable to suppose that this anomaly may be related to the Oakville Formation. This portion of Area C is also closest to the Live Oak County uranium mines in the Oakville Formation to the north.

It is suggested by Galloway and others (1979) that the margins of the larger fluvial-channel systems are most favorable for uranium deposition. However, with the presence of so many favorable sands and good shale breaks to act as aquitards throughout the Oakville Formation, the authors consider all fluvial-channel-system margins as favorable. Ranching, farming, and gas production and exploration dominate surface activity in the area.

Areas D_1 through D_5

Areas D_1 through D_5 (Pl. 1a) contain an environment favorable for Texas roll-type deposits of Subclass 242 in the fluvial-channel sands of the Goliad Formation. They are delineated by channel and interchannel sand trends (Pl. 18). These sands and conglomerates are calcitic and medium to very coarse grained with good clay breaks between the sands to act as aquitards. There are numerous fault systems throughout four of the areas (Area D_5 shows few faults); all have related oil and gas fields and provide a source of reductants needed to precipitate uranium. Remobilized uranium or reworked tuffaceous sediments from older formations are the most likely source of uranium.

A portion of Area D_1 was considered favorable by Quick and others (1977). They believed the sandstone-to-shale ratio (1:1 to 4:1) of the area was favorable. A few miles to the northeast in the Beeville Quadrangle is the Mt. Lucas site, which is a uranium deposit in fluvial sandstone of the Goliad Formation (Droddy and Hovorka, 1981).

There are three aerial radiometric anomalies in Area D_1 (Geodata International, 1975 and 1979; Pl. 2) and five HSSR well-water anomalies (Pl. 46) with 30.56, 20.69, 18.68, 15.74, and 15.16 ppb U_3O_8. HSSR sampling (ORGDP, 1980) detected stream sediments anomalous in thorium and favorable thorium-to-vanadium and uranium-to-specific conductance ratios. Followup sampling of water wells produced samples containing between 10 and 13 ppb U_3O_8 inclusive (MJP 502, 520, and 522; Pl. 38; App. B-2). Vanadium concentrations were also high in this area and show an average of at least 8 times background.

Area D_2 also has an area considered favorable by Quick and others (1977) with favorable sandstone-to-shale ratios of 1:1 to 4:1. Results of HSSR sampling (ORGDP, 1980) in this area include well-water samples containing as much as 106 ppb U_3O_8 (Pl. 46). Stream-sediment samples from the same study show high uranium-to-arsenic ratios, plus high vanadium and thorium-to-uranium ratios.

Area D_3 has one HSSR well-water sample (ORGDP, 1980) containing 107 ppb U_3O_8 (Pl. 46). In addition, there is a favorable uranium-to-specific conductivity ratio from HSSR stream-sediment samples.

Area D_4 has sandstone-to-shale ratios considered favorable by Quick and others (1977). There are two aerial radiometric anomalies (Geodata International, 1975) on the western edge of the area.

Area D_5 has a lithology that is similar to that of Areas D_1 through D_4. No apparent fault zones or oil and gas fields lie in the area, but there are large fault trends updip, downdip, and possibly smaller ones in between. The area is also surrounded by small gas fields.

The source for uranium may be the Oakville and Catahoula Formations. Along the Webb-Duval county line, the Fleming clays nearly pinch out and leave a thin Oakville sand separating the Goliad and Catahoula Formations. If aquifer mixing took place, uranium-rich waters from the Oakville and/or Catahoula Formations would have flowed into the Goliad sands and then downdip to the area. The uranium mines of the Bruni-Hebbronville area (Pl. 2) are updip of the area, and migrating ground water could have carried uranium into the area from these deposits. There are aerial radiometric anomalies (Geodata International, 1975) along the western border (Pl. 46), and one HSSR well-water anomaly (ORGDP, 1980) of 40 ppb U_3O_8 is downdip of Area D_5. Most land is used for ranching, farming, and oil and gas exploration and production.

Area E

Area E (Pl. 1a and 1d) contains an environment favorable for Texas roll-type uranium deposits of Subclass 242 in fluvial-channel-system facies of the Whitsett Formation of the Jackson Group. A paleoenvironment map (Quick and others, 1977) shows this area to be at the mouth of a channel system that crosses a lagoonal system into a strand plain--barrier bar system. The downdip extension of the area is limited by a fault with associated gas accumulations, which could act as a reductant source. Throughout most of the outcrop area, the Frio Formation overlies the Jackson Group. In Area E, the Jackson Group is unconformably overlain by the Goliad and Catahoula Formations. The Frio Formation is mostly clay, which acts as an aquitard and which prevents uranium-rich solutions from the Goliad and Catahoula Formations from entering aquifers of the Jackson Group. Any uranium leached out of the Goliad and Catahoula Formations would go into the sands of the Whitsett Formation and probably would be deposited near channel margins in fault zones. In the Karnes uranium district in the Crystal City Quadrangle, the Catahoula Formation unconformably overlies the Jackson Group in the areas of the uranium deposits, as in Area E.

There are a few aerial radiometric anomalies (Geodata International, 1975 and 1979) updip, but no other anomalies are known in this area (Pl. 4). Most of the land is used for ranching and gas exploration and production.

Areas F_1 through F_4

Areas F_1 through F_4 (Pl. 1a and 1e) contain an environment favorable for Texas roll-type uranium deposits of Subclass 242 in fluvial-channel-system facies in the upper and lower sands of the Frio Formation. These channel systems extend from the Corpus Christi Quadrangle on the east to the updip limits of the formation on the west. Although the Frio Formation is far more clayey than the Catahoula Formation, potential uranium host sands do exist. There are numerous faults and related oil and gas accumulations to provide reductants for uranium deposition as well as provide carbonaceous material within the formation. The Frio Formation itself does not contain source rock. The probable uranium source is the overlying Catahoula Formation. The Frio Formation is bounded above by the Catahoula Formation, bounded below by the Whitsett Formation, and both of these are considered sources of uranium.

Area F_1, the largest of the areas, is a more broad, interfingering fluvial-channel system than the other areas. In the western portion, there are two northeast-southwest trending up-to-the-coast faults. Other faults are scattered throughout the whole of Area F_1 (Pl. 25). Just updip from area F_1 is an aerial radiometric anomaly (Geodata International, 1975 and 1979) located on the eastern edge of the Moca salt dome. Uranium Occurrence 8 (Pl. 41; App. A), which has 19 ppm U_3O_8 (MJP 009; Pl. 13 and 46), is on the contact of the Jackson Group with the Frio Formation near the airborne anomaly. Four other anomalous gamma-ray well logs from around the Freer area (No. 3205, 3403, 3506, and 3507; Pl. 37; App. E) are mostly centered around fault zones. One other anomalous gamma-ray well log (No. 11505; Pl. 37, App. E) is in the south center of the area. Favorable sandstone-to-shale ratios (1:1 to 4:1) are present throughout much of the area (Quick and others, 1977).

Area F_2 is two fluvial channel trends that are joined in the center by a fluvial cross channel (Pl.15). Numerous faults are also cutting this area. Seven anomalous gamma-ray well logs (No. 17105, 17114, 17117, 17120, 17121, 17124, and 17126; Pl. 37; App. E) are present in the northeastern extension along the Jim Wells--Kleberg county line.

Areas F_3 and F_4 have no anomalies associated with them but show good fluvial-channel trends. These channel sands are near favorable uranium source formations, are cut by structures suitable to allow reductants to enter the system, and have abundant aquitards. Land to the east is mainly used for farming, with other areas used for ranching. Oil, gas, and some uranium exploration and production occur within the favorable areas.

MAJOR FAULT-CONTROLLED SAND DEPOSITS

Major fault trends with fluvial sand facies are favorable for Texas roll-type uranium deposits in the Soledad and Fant Members of the Catahoula Formation (Areas G_1 through G_5), the Oakville Formation (Areas H_1 through H_5), and the Whitsett Formation of the Jackson Group (Areas I and J). The dimensions of the favorable areas are presented in Table 2.

Areas G_1 through G_5

Areas G_1 through G_5 (Pl. 1a and 1c) are along faults in the Soledad and Fant Members of the Catahoula Formation. They contain fluvial-channel-system facies that are favorable for Texas roll-type uranium deposits of Subclass 242. The lithology is similar to that of Areas A_1 through B_{15}, and they are favorable for the same reasons; the exception to this similarity is that these areas are also fault related. These are only the major deep-

TABLE 2. AREA, THICKNESS, VOLUME, AND DEPTH OF FAVORABLE AREAS RELATED TO FAULT-CONTROLLED SAND DEPOSITS

Favorable Area	Description	Area (km^2)	Average Thickness	Volume	Depth from Surface
G_1	Soledad and Fant Members	733.08	121.92	89.38	183 to 600
G_2	Soledad and Fant Members	103.80	45.72	4.75	411 to 671
G_3	Soledad and Fant Members	53.83	30.48	1.64	442 to 902
G_4	Soledad and Fant Members	38.45	182.88	7.03	579 to 914
G_5	Soledad and Fant Members	13.67	243.84	3.33	777 to 1,112
H_1	Oakville Formation	246.07	60.96	15.00	228 to 427
H_2	Oakville Formation	126.88	121.92	15.47	549 to 1,045
H_3	Oakville Formation	105.09	30.48	3.20	244 to 344
H_4	Oakville Formation	217.44	60.96	13.26	411 to 579
H_5	Oakville Formation	13.24	30.48	0.40	314 to 418
I	Whitsett Formation	706.59	30.48	21.53	Shallow subsurface to 777
J	Whitsett Formation	171.31	91.44	15.66	671 to 914

seated faults represented on the structure map (Pl. 22); although, many more faults occur throughout the other favorable areas in the Catahoula Formation. These major fault zones could act as an aquitard in sandstones and allow H_2S gas from deep-seated oil and gas accumulations access to the formation to form an excellent environment for uranium deposition. Land use is mostly ranching and oil and gas exploration and production.

Areas H_1 through H_5

Areas H_1 through H_5 (Pl. 1a and 1b) have an environment favorable for Texas roll-type uranium deposits of Subclass 242 in major fault trends (Pl. 23) associated with fluvial-channel sands and flood-plain clays of the Oakville Formation (Pl. 17). These fluvial sands represent the same channel systems described in Area C. The faults have related oil and gas accumulations that could supply ample reductants in the form of H_2S gas to precipitate uranium. The uranium source is most likely the tuffaceous beds within the Oakville Formation or was brought in by upwelling uranium-rich ground water from the underlying Catahoula Formation. The major fault systems would seem to enhance uranium favorability of associated channel sands of the Oakville Formation by providing open channel ways for the movement of reductant and/or uranium-rich solutions. Oil and gas production and exploration and ranching dominate the land use of these favorable areas, with Area H_4 being used predominantly for farming with oil and gas production and exploration.

Area I

Area I (Pl. 1a and 1d) contains an environment favorable for Texas roll-type uranium deposits of Subclass 242 in the Whitsett Formation of the Jackson Group. These are margin sands of lagoonal strand plain--barrier bar facies and a fluvial-channel-system facies that extends into the area from the northwest. In the area are two large up-to-the-coast fault trends (Pl. 20 and 46). The favorable area delineates the two parallel, northeast-trending margins of the barrier bar and the two faults. These two northeast-trending zones are connected by the northwest-trending channel.

Sands of the area are generally fine to coarse grained, quartzitic, friable, commonly laminated and crossbedded, and fossiliferous. They are white, gray, greenish brown, and light brownish yellow in color (Barnes 1976). The tuffaceous beds in the Jackson Group are believed to be the source of uranium deposits found within this area because the Frio Formation separates the Jackson Group from the Catahoula Formation. If the Catahoula did, at one time, overlie the Jackson Group, any uranium leached from the Catahoula as it weathered could also have gone into the Jackson Group; this could make the Catahoula Formation a possible source area. Reductants could come up the faults in the form of H_2S gas from oil and gas accumulations below. There is also silicified wood and carbonaceous material near the margins of the lagoonal and fluvial channel facies. Clayey aquitards and faults, which could act as aquitards, are also present. Most of the land is used for ranching and for oil, gas, and uranium exploration and production.

Area J

Area J (Pl. 1a and 1d) contains an environment favorable for Texas roll-type uranium deposits of Subclass 242 in the Whitsett Formation of the Jackson Group. This is in a strand plain--barrier bar facies to the southeast of a fluvial-channel system. The area, bounded by two faults (Pl. 20 and 25) that form a graben structure, contains gas accumulations that could provide reductants in the form of H_2S gas migrating up the faults. Uranium could have been leached into this formation at outcrop and could have migrated downdip. The Catahoula Formation is the likely source using this mechanism. Two aerial radiometric anomalies (Geodata International, 1975 and 1979) occur updip (Pl. 46 and 3). Land is used almost solely for ranching, with some gas production and exploration.

DOMAL STRUCTURES

Domal structures are favorable for Texas roll-type uranium deposits in the Goliad Formation (Areas K and N_1 through N_5), the Soledad and Fant Members of the Catahoula Formation (Areas L_1 through L_5), the Oakville Formation (Areas M_1 through M_6), the Frio Formation (Areas P_1 through P_5), and the Whitsett Formation of the Jackson Group (Area O). The dimensions of the favorable areas are presented in Table 3.

Area K

Area K (Pl. 1a and 1d) contains an environment favorable for Texas roll-type uranium deposits of Subclass 242 in the fluvial-channel sandstones of the Goliad Formation. Fine- to medium-grained sands dominate the area, and clay aquitards are also present. This area represents the well-known Palangana area that is centered around two salt domes. The boundaries of Area K are defined by parallel fault trends updip and downdip from the domes by the presence of a fluvial sand trend (Pl. 18), one aerial radiometric anomaly (Quick and others, 1977), and anomalous amounts of trace elements (Weeks and Eargle, 1960).

The Palangana Operations leach mine is within the boundaries of Area K (Occurrence Y13, Pl. 2; App. A). Production is from about 100 m below the surface "in highly calcareous, clay-ball conglomerate interbedded with friable fine- to medium-grained sand locally impregnated with oil" (Weeks and Eargle, 1960). The chief ore mineral is pitchblende, and the ore zones are bound by clay aquicludes. To the south, the clayey aquicludes become sandier, and some uranium-bearing waters could have escaped to form deposits further downdip. Thus far, industry has been unable to find other economic deposits nearby.

Core samples taken over and near the dome show evidence of a reducing environment. Pyrite and greenish gray coloration were noted in, and 50 feet above and below, the ore zone. Samples taken updip from the dome are oxidized and pinkish to yellowish gray in color. Analysis of elements shows anomalous concentrations of iron, molybdenum, and vanadium. There is "about 75 times as much molybdenum and 5 times as much vanadium as in average sandstone" (Weeks and Eargle, 1960).

TABLE 3. AREA, THICKNESS, VOLUME, AND DEPTH OF FAVORABLE AREAS RELATED TO DOMAL STRUCTURES

Favorable Area	Description	Area (km^2)	Average Thickness	Volume	Depth from Surface
K	Goliad Formation	405.41	91.44	37.07	Shallow subsurface to 198
L_1	Soledad and Fant Members	49.56	243.84	12.08	671 to 960
L_2	Soledad and Fant Members	107.65	228.60	24.61	1,250 to 1,524
L_3	Soledad and Fant Members	18.37	335.28	6.16	670 to 1,097
L_4	Soledad and Fant Members	44.86	274.32	12.31	701 to 1,036
L_5	Soledad and Fant Members	16.23	274.32	4.45	701 to 1,036
M_1	Oakville Formation	49.56	91.44	4.53	335 to 518
M_2	Oakville Formation	35.03	60.96	2.14	238 to 518
M_3	Oakville Formation	107.65	121.92	13.12	783 to 1,459
M_4	Oakville Formation	44.86	91.44	4.10	421 to 646
M_5	Oakville Formation	16.23	91.44	1.48	579 to 936
M_6	Oakville Formation	18.37	60.96	1.12	366 to 609
N_1	Goliad Formation	49.56	91.44	4.53	Shallow subsurface to 180
N_2	Goliad Formation	18.37	60.96	1.12	Shallow subsurface to 244
N_3	Golaid Formation	44.86	76.20	3.42	Shallow subsurface to 210
N_4	Goliad Formation	16.23	45.72	.74	Shallow subsurface to 244
N_5	Goliad Formation	107.65	60.96	6.56	Shallow subsurface to 488
O	Whitsett Formation	86.51	30.48	2.63	Shallow subsurface to 640
P_1	Frio Formation	49.56	30.48	1.51	963 to 1,311
P_2	Frio Formation	107.65	30.48	3.28	137 to 1,524
P_3	Frio Formation	18.37	30.48	0.56	1,109 to 1,463
P_4	Frio Formation	44.86	30.48	1.37	1,082 to 1,463
P_5	Frio Formation	16.23	30.48	0.49	1,493 to 1,524

The deposit at the Palangana dome roughly fits the Subclass 242 criteria, but the ore formation is directly related to the salt dome and its structure. The source of the uranium is believed to be remobilized uranium or reworked tuffaceous sediments of older rocks such as the Catahoula Formation. After being leached by alkaline carbonate water, the uranium traveled downdip until it reached a reducing environment over the dome. Reductants, from both the sulfur-bearing caprock and oil and gas accumulations, traveled up by way of faults and/or the loosely compacted sediments to precipitate the uranium. This is thought to be a young deposit, and there is probably uranium mineralization continuing today because ground water in the area is high in radium and H_2S (Weeks and Eargle, 1960).

The Piedras Pintas dome is the other salt dome in favorable Area K. To the south of this dome, there is a uranium occurrence (No. Y14, Pl. 2; App. A). The PRR for this occurrence reports analyses of 0.14% U_3O_8 from selected samples. During followup sampling, scintillometer readings of up to 5 times background were noted, and higher readings were taken beneath the soil surface. Chemical analysis of a rock sample taken from an ashy carbonaceous clay and limestone shows 30 ppm U_3O_8 (MJQ 006, Pl. 42; App. B). HSSR sampling (ORGDP, 1980) did not include any water-well samples taken directly over the domes. Most of the land in Area K is used for ranching and uranium, oil, and gas production.

Areas L_1 through L_5

Areas L_1 through L_5 (Pl. 1a and 1d) contain an environment favorable for Texas roll-type uranium deposits of Subclass 242. These are located over domal structures in the fluvial-channel-system sands of the Soledad and Fant Members of the Catahoula Formation. Lithology is similar to that of the other favorable areas of the Catahoula Formation. These areas are all related to domal structures: Area L_1 to the Sejitas dome, Area L_2 to the Gyp Hill dome, Area L_3 to the Palo Blanco dome, Area L_4 to the Alta Verde dome, and Area L_5 to the Alta Mesa North dome. As explained previously, the proximity of faults and oil and gas accumulations to a domal structure, such as Palangana, is a favorable characteristic of uranium deposition, especially with a proven uranium source and host rock (i.e., the Catahoula Formation). Some of these domes have not been classified as salt domes, but the faulting and oil- and gas-related reductants are known to exist. Land is used for ranching and oil and gas exploration and production.

Areas M_1 through M_6

Areas M_1 through M_6 contain an environment favorable for Texas roll-type uranium deposits associated with domal structures in sands of the Oakville Formation. However, not enough data are available to verify that they are all salt domes. These sands represent the same fluvial systems described in Area C. Good shale breaks are present to act as aquitards. Oil and gas fields related to the domal structure are a likely source of H_2S gas reductants. The gas could travel up the faults over the domal structures into permeable sands. Uranium deposits formed would be similar to the Palangana deposit (Y13; Pl. 2) in Area K. The source of uranium is believed to be the tuffaceous beds of the Oakville Formation or uranium-rich ground water from the Catahoula Formation. The sandstone-to-shale ratios (1:1 to 4:1) of Quick and others (1977) are favorable for these areas.

Area M_1, associated with the Sejitas dome, has an anomalous gamma-ray well log (No. 18901; Pl. 37 and 46; App. E) updip and an aerial radiometric anomaly (Geodata International, 1975). Area M_2 is on the Palangana and Piedras Pintas domes. Area M_3 is associated with the Gyp Hill dome and is similar to the Palangana dome. Area M_4 is associated with the Alta Verde dome. Area M_5 is associated with the Alta Mesa North dome; and Area M_6 is associated with the Palo Blanco dome. Areas M_4 trough M_6 have aerial radiometric anomalies (Geodata International, 1975 and 1979) associated with them. Land is used mostly for oil and gas production and exploration and for ranching.

Areas N_1 through N_5

Areas N_1 through N_5 (Pl. 1a and 1d) contain an environment favorable for Texas roll-type deposits of Subclass 242 in the multistoried channel sands of the Goliad Formation. These areas are located on a series of north-south trending domal structures. They stretch from southern Duval County into Brooks County. These domes are: the Sejitas (Area N_1), Palo Blanco (Area N_2), Alta Verde (Area N_3), Alta Mesa North (Area N_4) and Gyp Hill (Area N_5). Gyp Hill is the only verified salt dome of the group. All of these domal structures exhibit a geologic environment similar to that of Area K.

The sands are mostly calcitic, medium to very coarse grained, and become conglomeratic in places. The Gyp Hill salt dome has a caprock that was, at one time, mined for gypsum. All of the domal structures have associated fault systems, with larger fault trends located updip and downdip (Pl. 24). There are oil and gas fields, which are related to the domal structures and fault trends, that would be excellent sources of reductants in the form of H_2S gas. Electric well-log studies show good sands with shale aquitards. These domes have aerial radiometric anomalies (Geodata International, 1975 and 1979) associated with them.

There are two HSSR well-water anomalies, with 28.17 and 22.41 ppb U_3O_8 (ORGDP, 1980), near Area N_5. Updip and south, outside the area, are four more anomalous HSSR well-water samples with 44.93, 42.41, 19.24, and 15.52 ppb U_3O_8 (Pl. 46). Most of the land is used for ranching or is leased for gas and oil production and exploration. There is some farming in Areas N_1 and N_5 and a large water reservoir present in Area N_5.

Area O

Area O contains an environment favorable for Texas roll-type uranium deposits of Subclass 242 in the Whitsett Formation of the Jackson Group. It has a lithology similar to that of Area I but is over the Moca salt dome, which makes it structurally controlled. The mechanics for any deposits here would be similar to those of Area K over the Palangana salt dome. There are gas fields associated with this dome, as well as an aerial radiometric anomaly (Pl. 46) and a uranium occurrence (No. 8; Pl. 41; App. A), which could be in either the Frio Formation or the Jackson Group. However, there are not enough data available to determine which stratigraphic unit the occurrence is in. A source of uranium here could be either from the Jackson Group or from the leaching of uranium from the Catahoula Tuffs, which at one time may have overlain this area. The land is used for ranching and gas production.

Areas P_1 through P_5

Areas P_1 through P_5 (Pl. 1a and 1e) are situated over domal structures and contain an environment favorable for Texas roll-type uranium deposits of Subclass 242 in the fluvial-channel-system facies of the Frio Formation. Area P_1 is associated with the Sejitas dome, Area P_2 with the Gyp Hill dome, Area P_3 with the Palo Blanco dome, Area P_4 with the Gyp Hill dome, and Area P_5 with the Alta Mesa North dome. The lithology is similar to that of Areas F_1-F_4. Oil and gas accumulations associated with the domal structures are present to supply reductants along with the carbonaceous material present in the formation. The overlying Catahoula Formation is the probable source rock. These areas are favorable for the same reasons stated in the description of Area K, the Palangana dome (Pl. 1a), except that there are no known anomalies present. This is possibly due to depth and a finer grained, more clayey, less thick sandstone. The land is mostly used for ranching and oil and gas production.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

SUMMARY

The Midway Group; the Reklaw, Weches, Cook Mountain, Caddell, Wellborn, Manning, Vicksburg, and Anahuac Formations; the Chusa Member of the Catahoula Formation; the Fleming, Uvalde, Lissie, and Beaumont Formations; the river terrace deposits, and deposits of Recent age are considered unfavorable for uranium occurrences. These units do not meet sufficiently the recognition criteria established by Mickle and Mathews (eds., 1978).

DOMAL STRUCTURES

Domal structures are favorable for Texas roll-type uranium deposits in the Goliad Formation (Area K and Areas N_1 through N_5), the Soledad and Fant Members of the Catahoula Formation (Areas L_1 through L_5), the Oakville Formation (Areas M_1 through M_6), the Frio Formation (Areas P_1 through terrace deposits. The deposits of Recent age, however, are considered unfavorable for uranium occurrences. These units do not sufficiently meet the recognition criteria established by Mickle and Mathews (eds., 1978).

MIDWAY GROUP

The Midway Group is predominantly marine clay. There are no uranium source rocks or radiometric anomalies nearby. Considering that it does not possess favorable uranium-host or uranium-source lithologies, it does not meet the favorability criteria set forth by Mickle and Mathews (eds., 1978). As a result, this unit is considered unfavorable for uranium deposits.

REKLAW FORMATION

The Reklaw Formation is predominantly clay. It contains no uranium source or host rocks. This unit does not fit favorability criteria defined by Mickle and Mathews (eds., 1978) and is therefore considered unfavorable for uranium deposits.

WECHES AND COOK MOUNTAIN FORMATIONS

The Weches and Cook Mountain Formations are both of the Claiborne Group. These formations have no potential uranium-source rocks nearby and no known anomalies. With the exception of a discontinuous middle sand unit in the Cook Mountain Formation, they are clay for the most part. For those reasons, these formations do not meet the favorability criteria set forth by Mickle and Mathews (eds., 1978) and are therefore considered unfavorable for uranium deposits.

CADDELL, WELLBORN, AND MANNING FORMATIONS

The Caddell, Wellborn, and Manning Formations of the Jackson Group have some uranium-related anomalies in the Karnes uranium district and surrounding area. However, no deposits of economic grade have been found. Lignite beds in the Manning Formation have been the most radioactive, and nearly favorable environments have been explored. There is also a fairly attractive series of sands in the lower Jackson Group, called the Hockley Sands (oil field terminology), which are present only in the subsurface. Cross sections (Pl. 26, 28, and 30) show the sands are developed in the subsurface in Duval County and are enclosed in clay, and no uranium-rich waters could have circulated into them. Most of the remainder of the Jackson Group is clayey with occasional enclosed sands. Therefore, these formations are considered unfavorable for uranium deposits described by Mickle and Mathews (eds., 1978).

VICKSBURG FORMATION

The Vicksburg Formation does not contain favorable uranium host or source rock lithologies required for the formation of uranium deposits approaching the 100-ton limit of this study. There are occasional very fine-grained sands, but these are not continuous nor is there any sizable uranium source rock nearby. It is entirely enclosed in clay, is mostly clay itself, and is only present in the subsurface (Pl. 26, 28, and 30).

ANAHUAC FORMATION

The Anahuac Formation is considered unfavorable for uranium deposits approaching the 100-ton limit of this study. There is a uranium source rock in the overlying Catahoula Formation, but sands in the Anahuac Formation are highly discontinous, fine to medium grained, and partially glauconitic. Most of the formation is clay or clayey sand and is an unsuitable uranium host rock.

CHUSA MEMBER OF THE CATAHOULA FORMATION

The Chusa Member of the Catahoula Formation has favorable uranium source rock above and below and contains tuffaceous material itself. It is an unstratified, noncalcareous-to-marly, poorly consolidated pisolitic or lumpy bentonitic clay (Sellards and others, 1932). It is not considered a favorable uranium host rock because there is no way for large amounts of uraniferous ground waters to flush through this system. This unit is, therefore, considered unfavorable for uranium deposits described by Mickle and Mathews (eds., 1978).

FLEMING FORMATION

The Fleming and Oakville Formations are undifferentiated on the geologic map (Pl. 7). They can, however, be separated on electric well logs throughout a large portion of the quadrangle. The Fleming Formation is separated in the cross sections. Based on studies of electric well logs in this report, as well as data by Quick and others (1977), this formation appears to lack a favorable uranium host facies and does not meet the favorability criteria set forth by Mickle and Mathews (eds., 1978). There is one anomalous gamma-ray well log (No. 1101; Pl. 37; App. E), but this could be associated with the Oakville Formation because the anomaly is located near the contact of the two formations. There are some potential host sands downdip on the eastern edge of the quadrangle, but these are not continuous updip; and, the formation is predominantly clay throughout the quadrangle. The Fleming Formation is not likely to contain uranium deposits approaching the 100-ton criterion and is, therefore, unfavorable for uranium deposits described by Mickle and Mathews (eds., 1978).

UVALDE FORMATION

The Uvalde Formation is marly-to-caliche gravel with flint cobbles. Some limestone, quartz, and flint pebbles are also present. These sediments are derived from Cretaceous and earlier rocks and usually occupy high topographic positions (Sellards and others, 1932). There is no uranium source rock, reductants, or supportive evidence to show this formation to be favorable for uranium deposits as described by Mickle and Mathews (eds., 1978).

LISSIE FORMATION

The Lissie Formation has highly permeable fluvial sands. Some HSSR anomalies occur in the Lissie Formation (ORGDP, 1980), but no highly uraniferous tuffs are present nearby. The Goliad Formation underlies and crops out updip from the Lissie Formation, but does not appear to be a likely uranium source rock. There is also the possibility that the HSSR anomalies are caused by contamination of oil-field brines as suggested by Droddy and

Hovorka (1981) in the Beeville Quadrangle. The writers agree with their conclusion that there is little evidence or chance for deposits of 100 tons of U_3O_8 being present in the Lissie Formation; it is, therefore, considered unfavorable for uranium deposits described by Mickle and Mathews (eds., 1978).

BEAUMONT FORMATION, RIVER-TERRACE DEPOSITS, AND DEPOSITS OF RECENT AGE

The Beaumont Formation, river terrace deposits, and deposits of Recent age have no potential uranium sources, are highly oxidized and leached, and have no characteristics suggesting uranium favorability. They are considered unfavorable for uranium deposits described by Mickle and Mathews (eds., 1978).

UNEVALUATED ENVIRONMENTS

SUMMARY

The Yegua and older formations (Fig. 3) are unevaluated for uranium potential. Exceptions are the Weches and Cook Mountain Formations of the Claiborne Group, the Midway Group, and the Reklaw Formation, which are considered unfavorable for uranium deposits. Not enough data were available to determine the favorability of the remaining formations, and further work is suggested.

YEGUA FORMATION

This formation was included as one of the favorable formations of the South Texas Uranium Belt by Quick and others (1977). They prepared structure, isolith, isopach, sandstone-to-shale ratio, optimum-sands, and facies maps. However, the structure map was the only one made that covered the entire quadrangle (Pl. 8, 13, and 19). Electric well-log data suggests that there are favorable sands in the Yegua Formation in the more easterly portions of the quadrangle that are associated with extensive faulting (Pl. 19 and 25). Oil and gas fields are associated with these faults, and these hydrocarbons could provide reductants for the precipitation of uranium. Minor lignites and carbonaceous trash are also present to act as reductants (Eargle and others, 1971). There are two salt domes with associated oil and gas fields in the Yegua Formation (Pl. 46), which could provide a favorable host environment for uranium deposits.

According to Quick and others (1977), a fluvial-channel system may trend in from the southwest, but additional subsurface mapping is needed to better determine this. There may also be another fluvial-channel system further north in Webb County. One aerial radiometric anomaly (Geodata International, 1979) is associated with the Yegua Formation (Pl. 3). HSSR sampling results (ORGDP, 1980) have shown no anomalies, but this may be due to the lack of wells in the area. More subsurface data are needed to delineate favorable sands and locate gamma anomalies in this unit.

There is also the question of an available uranium source. Galloway (pers. comm., 1980) of the University of Texas BEG suggests the Catahoula and possibly other uraniferous, tuffaceous formations have overlain the older formations at one time. Due to weathering, these air-fall tuffs were reworked and removed to areas downdip. During this process, it is possible that uranium was leached out and could have entered the outcropping sands of these aquifers. The uranium-rich waters would then travel downdip until they reached an environment favorable for deposition. Whether this happened, and how far these waters may have traveled is speculative at the present time. Further subsurface and geochemical studies are needed to resolve this question and properly evaluate the formation.

SPARTA AND LAREDO FORMATIONS

The Sparta Formation was considered unfavorable as part of a study of the Claiborne and Wilcox Groups by Wilbert and Templain (1978). This was a regional study only, and no detailed work was done. The Sparta Formation is characterized as a massive sand that becomes clayey above and below. These lithologies produce a distinctive bell curve on electric well logs. It is bounded by the clayey Cook Mountain Formation above, and the clayey Weches Formation below. It appears to be a good uranium host sand with aquitards above and below. The Sparta sand is quartzose and hematitic, and cross bedding is evident over the area. It is a fluvial-deltaic facies and seems to fit the favorability criteria of Austin and D'Andrea (1978).

The Laredo Formation, the updip equivalent of the Sparta Formation, is composed of very fine- to fine-grained sand with interbedded clays. More surface and subsurface data are needed for this formation for complete evaluation.

Again, the question is whether there is an available uranium source. As stated in the previous section, Galloway (pers. comm., 1980) of the University of Texas BEG suggests the Catahoula and possibly other uraniferous, tuffaceous formations have overlain the older formations at one time. Due to weathering, these wind-blown tuffs were reworked and removed to areas downdip. During this process, it is possible that uranium was leached out and could have entered the outcropping sand of these older aquifers. The uranium-rich waters would then travel downdip until they reached an environment favorable for deposition. Whether this happened, and how far these waters may have traveled, is speculative at the present time. Further subsurface and geochemical studies are needed to resolve this question and properly evaluate the formation.

QUEEN CITY FORMATION, EL PICO CLAY, AND BIGFORD FORMATION

The Queen City Formation has been studied and considered unfavorable by Wilbert and Templain (1978). This work covered the entire Wilcox and Claiborne Groups in Texas, and no detailed work was done. The available electric well logs indicate numerous favorable sands, good reductants, and, in general, a good host-rock environment for uranium deposition. There is no apparent uranium source, except for the possibility of the Catahoula Formation having overlain the surface outcrop in the past (Galloway, pers. comm., 1980). If this Catahoula overlap did in fact happen and the uranium was leached out, then uranium may have been transported into the underlying formations. The

Queen City Formation appears to have a large north-trending delta sequence that grades into delta front, meanderbelt, and stacked-barrier bar facies in the Laredo Quadrangle (Guevara and Garcia, 1972). It appears that any ground water above these sands would circulate into this aquifer.

Most work done along the Rio Grande River has usually omitted these older formations or has covered them only as part of a regional study. There are some HSSR anomalies (ORGDP, 1980) in the Queen City Formation; but due to the late release of the above report, no reliable interpretation could be made. Favorable areas were assigned to the Queen City Formation in the Crystal City Quadrangle (Greimel, 1979). Some water and rock samples were collected as part of this study, but too few were collected for evaluation. The water samples (MJP 527 533) had fairly high arsenic, selenium, and copper values; but the samples were low in U_3O_8, molybdenum, and vanadium (Pl. 43; App. B-2). Of the rock samples (MJP 010, 020), only MJP 010 showed any significant results: high boron, berylium, iron, niobium, and lead values, as well as higher uranium values than any other sample taken in the area north of Laredo (Pl. 43; App. B-1). This sample was of a sandy clay. Very little of the Queen City Formation crops out on the surface; more subsurface work is needed to evaluate the unit.

The El Pico Clay and Bigford Formation, a series of sands and clays with interbedded coal and lignite, are the updip equivalents of the Queen City Formation. More surface and subsurface work is needed to evaluate these formations.

CARRIZO FORMATION AND WILCOX GROUP

The Carrizo Formation and Wilcox Group (which are undifferentiated in the Laredo Quadrangle) is another group of potential uranium host sands with available reductants. As in the case of the Yegua and Queen City Formations, the only possible uranium source is Catahoula tuffs that blanketed the outcrops of these formations at one time. As described in the previous sections, the uranium-rich ground waters and runoff from the Catahoula Formation probably would have gone into these highly permeable sand units.

There are reports of possible saline, uraniferous, and/or H_2S-rich waters coming up along faults and into the younger uranium-bearing formations downdip (Galloway, 1979). If this is true, perhaps some uranium could be deposited in these formations further updip; here, the reductants could have created a suitable host environment. More subsurface data are needed to evaluate these units.

ESCONDIDO AND OLMOS FORMATIONS

The Escondido and Olmos Formations appear to be similar in lithology on electric well logs. Both seem to have potential uranium host sands. These formations occupy a small portion of the Laredo Quadrangle; therefore, a regional study is recommended. There was one anomalous gamma-ray well log observed in the Olmos Formation (No. 7201; Pl. 37; App. E). Other anomalous gamma-ray well logs were reported in the Crystal City Quadrangle (Greimel, 1979).

SAN MIGUEL FORMATION

The San Miguel Formation is the oldest formation above 1500 m and occurs only in the subsurface of the northwest portion of the quadrangle. This formation contains sandstones and shales, with the sandstone being gray to yellow, calcareous, and fossiliferous. As is the case with the Olmos and Escondido Formations above it, too little of this formation occurs within the quadrangle boundaries for evaluation in this study. However, the unit could be examined further in a regional study.

RECOMMENDATIONS TO IMPROVE EVALUATIONS

Improvement of the evaluation of uranium potential of the Laredo Quadrangle should include a detailed study of the formations mentioned in the unevaluated section of this report (Yegua Formation and older sand units). Additional electric and gamma-ray well logs should be acquired in order to prepare useful maps and define sand trends in these formations. Extensions of isoliths in the younger favorable formations should also be made in the eastern and southeastern section of the quadrangle.

A detailed, closely spaced ground-water sampling program for the entire quadrangle would be of help in locating oxidation-reduction boundaries throughout all favorable and unevaluated formations. A well-water elemental analysis program to accompany the Eh-pH readings collected with the water sample would be useful in determining the oxidation-reduction interface in places where reduction has taken place and masks the usually noticeable boundary.

In addition, there is a publication being prepared by the University of Texas BEG on the Oakville Formation, which should contain significant information. It covers an area much larger than that covered in this report and should be incorporated into the evaluation.

Boreholes should be drilled and logged along the Yegua-Jackson outcrop trend to supply subsurface data in the area where it is now lacking. Also recommended is the acquisition of electric and gamma-ray well logs for the upper portion of the Goliad Formation since most wells are cased off in this interval. An increase of gamma-ray well log coverage over the entire quadrangle would better indicate mineralization trends and alleviate the lack of information concerning uranium in all areas, especially in the Yegua and older formations. The continuous emergence of new information concerning South Texas uranium indicates the need for these additional studies.

The HSSR data (ORGDP, 1980) should also be properly analyzed in order to make more meaningful interpretations. These data came in too late to be throughly incorporated into this study.

A program is being completed presently by the Department of Energy which involves drilling and logging holes through the Oakville and Goliad Formations over domal structures in the north Brooks County area. The results should give a better idea of the uranium favorability over domal structures. A logging program and gamma-ray well-log search report are almost complete, which should provide better well-log coverage.

There are also two in-situ leach mines proposed for the future (Pl. 46; App. A). The locations are known from county court house records (Schuenemann, 1979). No other data are available, so it is not known in which formations they will be. The mines could be located in an area other than the Catahoula Formation, providing more supportive evidence for other formations in the quadrangle.

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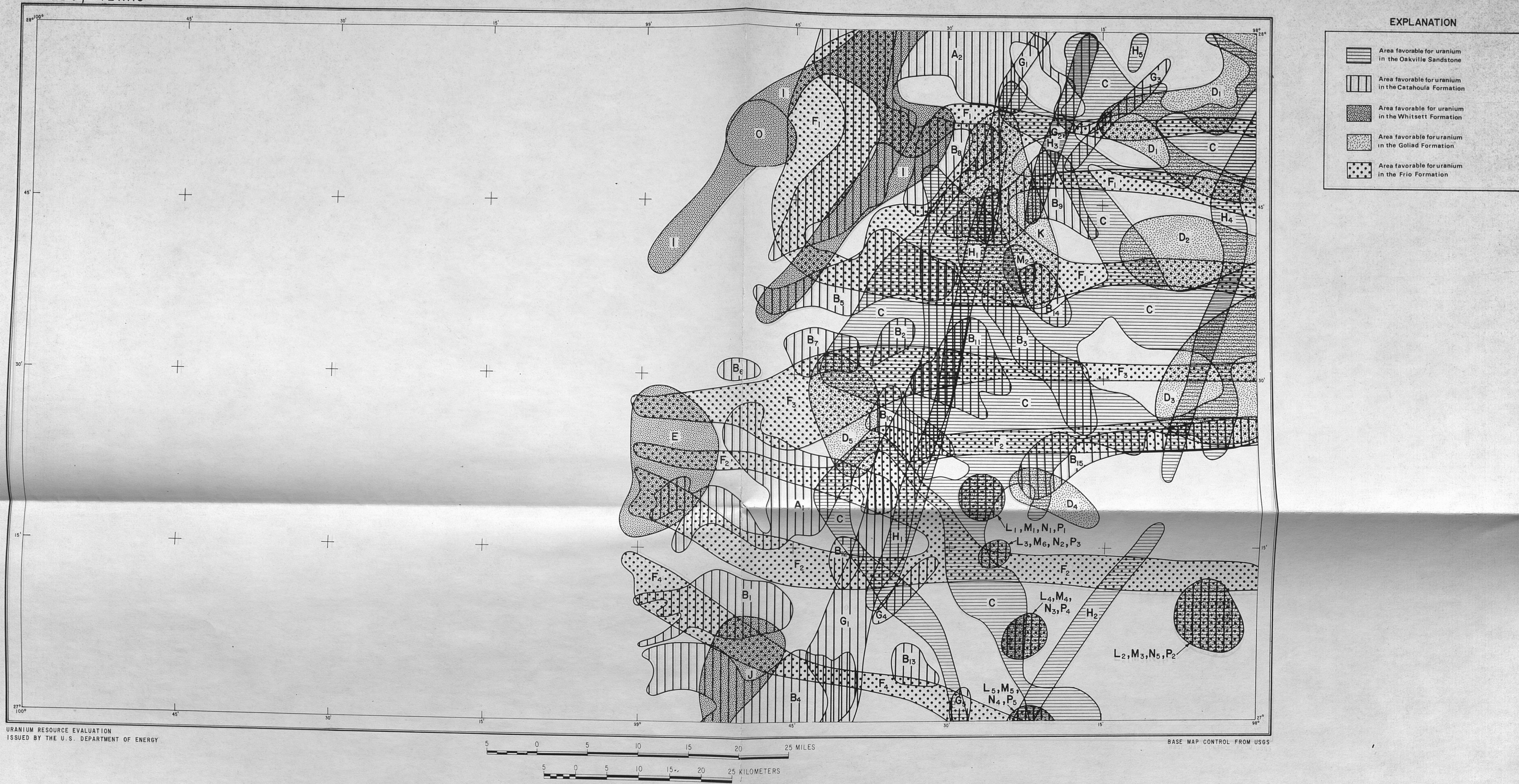
LAREDO, TEXAS



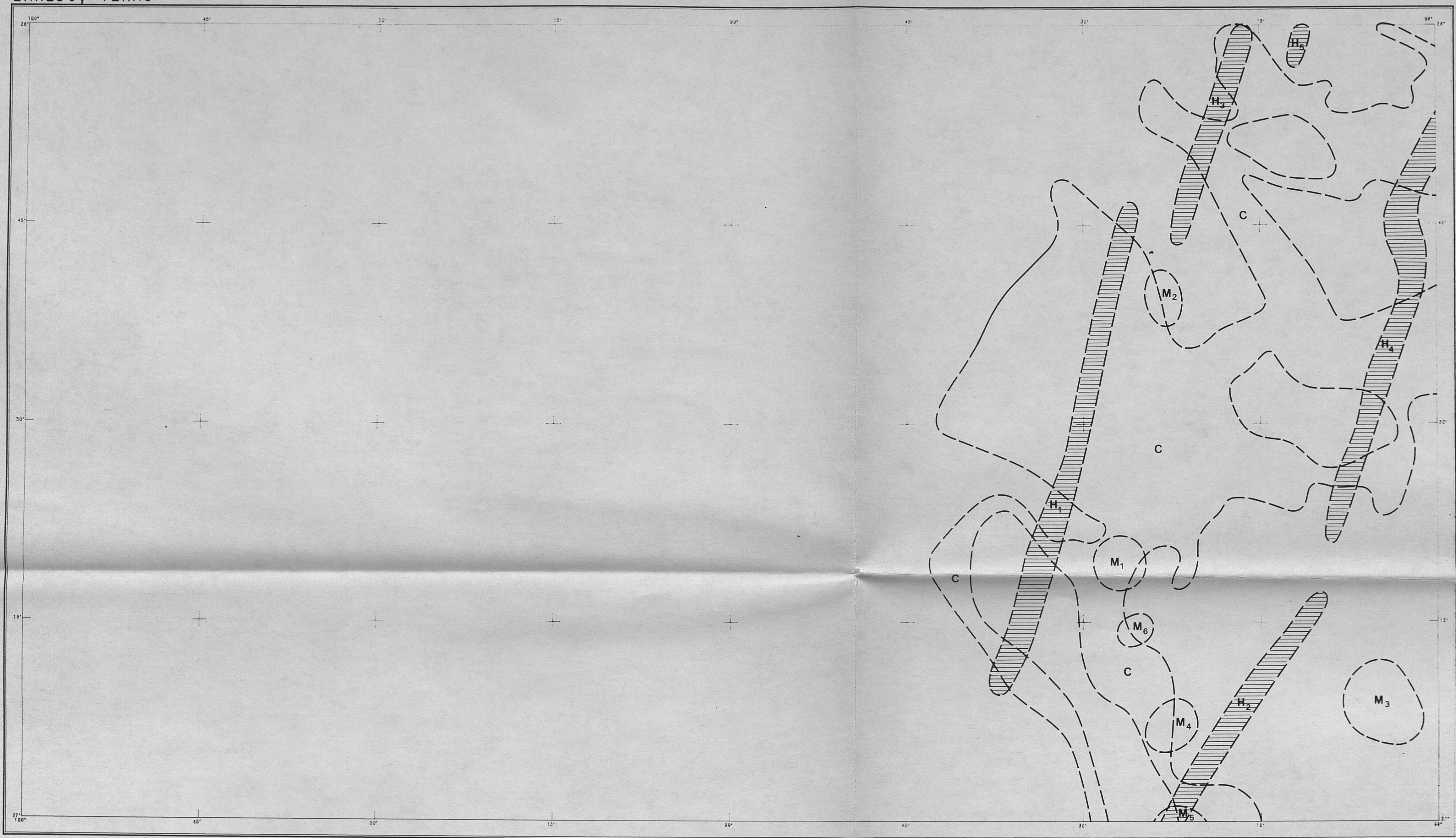
URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

Plate 1a. AREAS FAVORABLE FOR URANIUM DEPOSITS

May 1980
Plate 1a.

LAREDO, TEXAS



EXPLANATION

Fault areas overlain by other favorable units

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

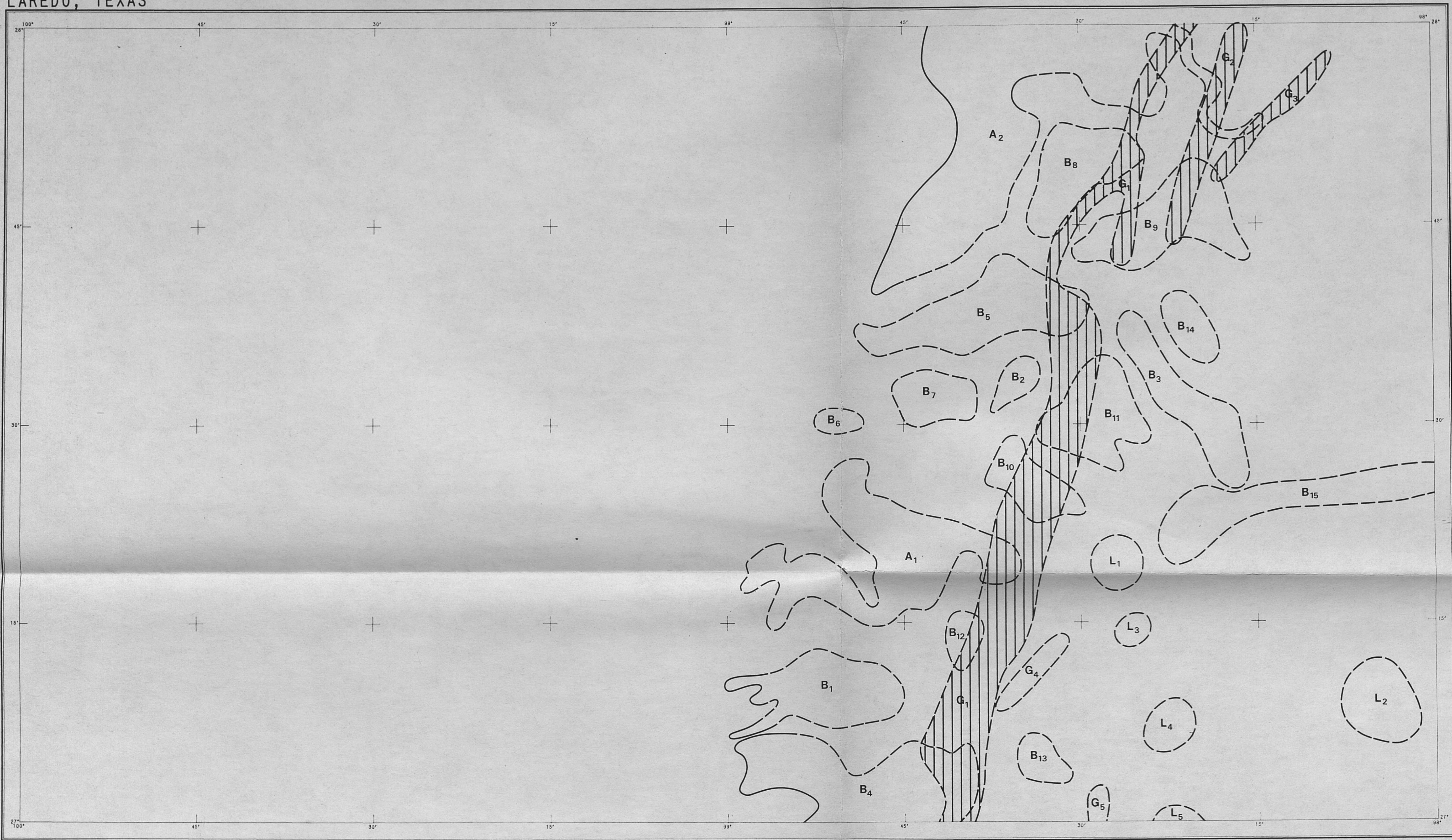
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 1b. AREAS FAVORABLE FOR URANIUM DEPOSITS IN THE OAKVILLE FORMATION

May 1980
Plate 1b.

LAREDO, TEXAS



EXPLANATION

Fault areas overlain by other favorable units

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

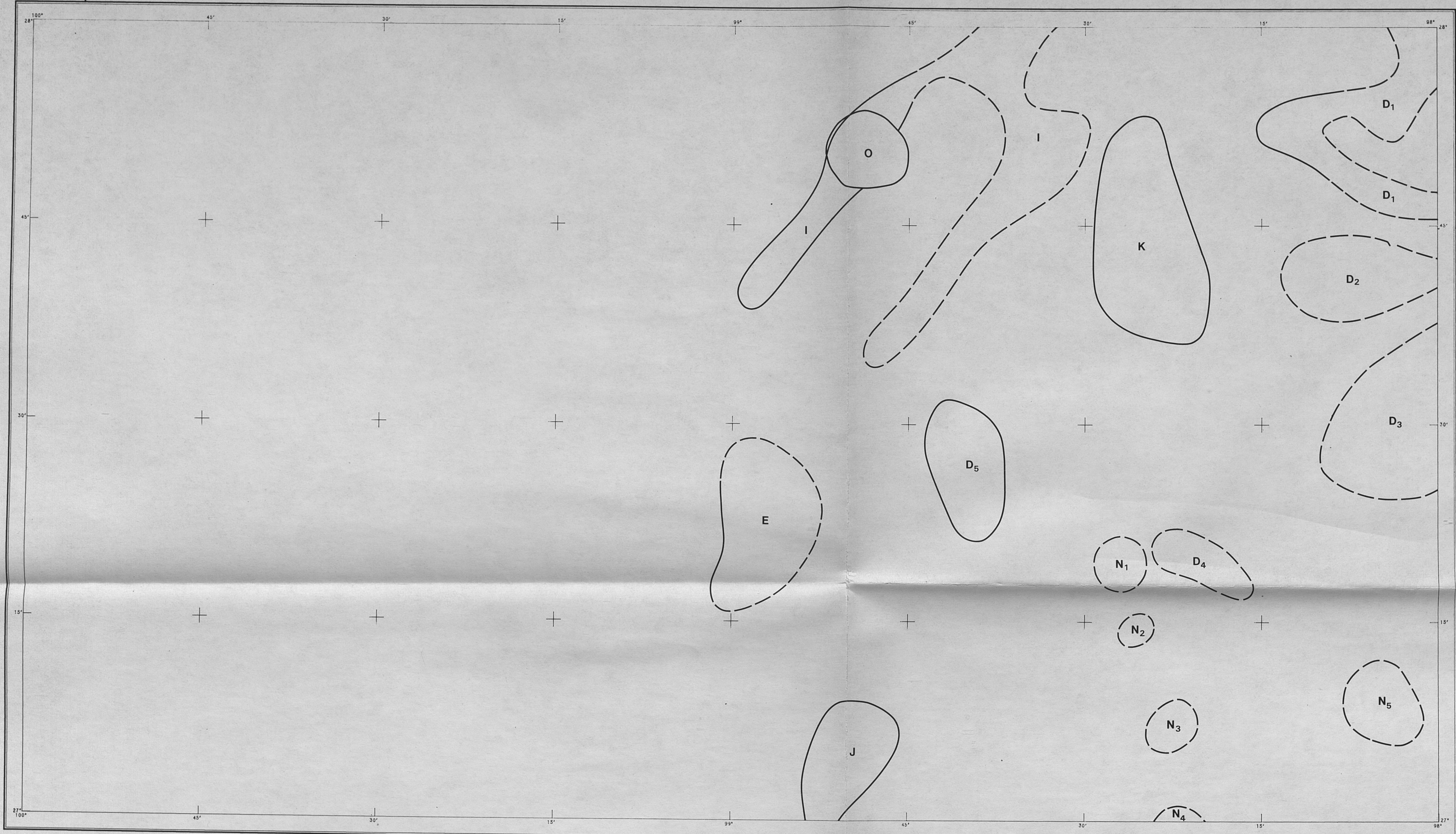
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 1c. AREAS FAVORABLE FOR URANIUM DEPOSITS IN THE CATAHOULA FORMATION

May 1980
Plate 1c.

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

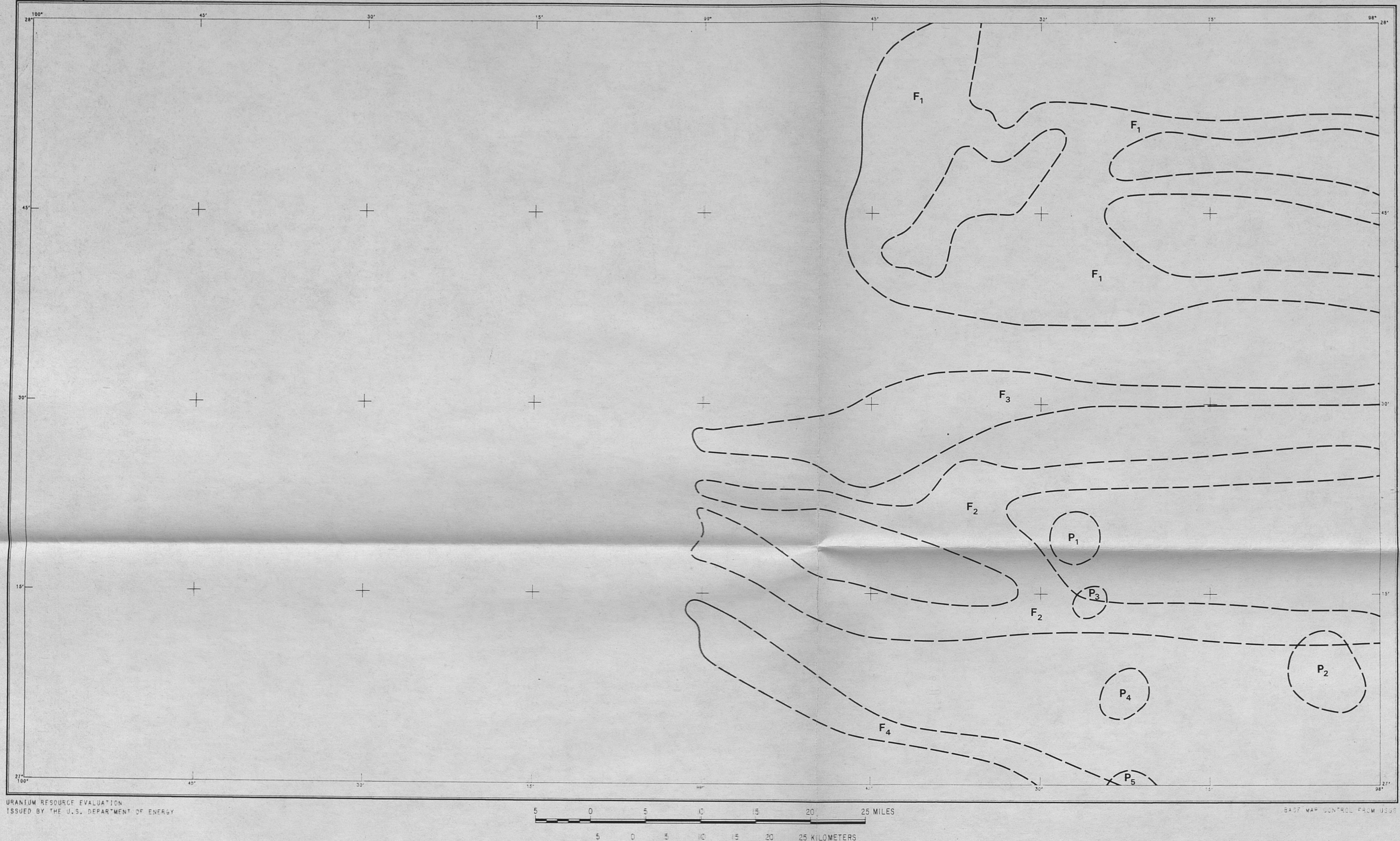
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 1d. AREAS FAVORABLE FOR URANIUM DEPOSITS IN THE WHITSETT AND GOLIAD FORMATION

May 1980
Plate 1d.

LAREDO, TEXAS



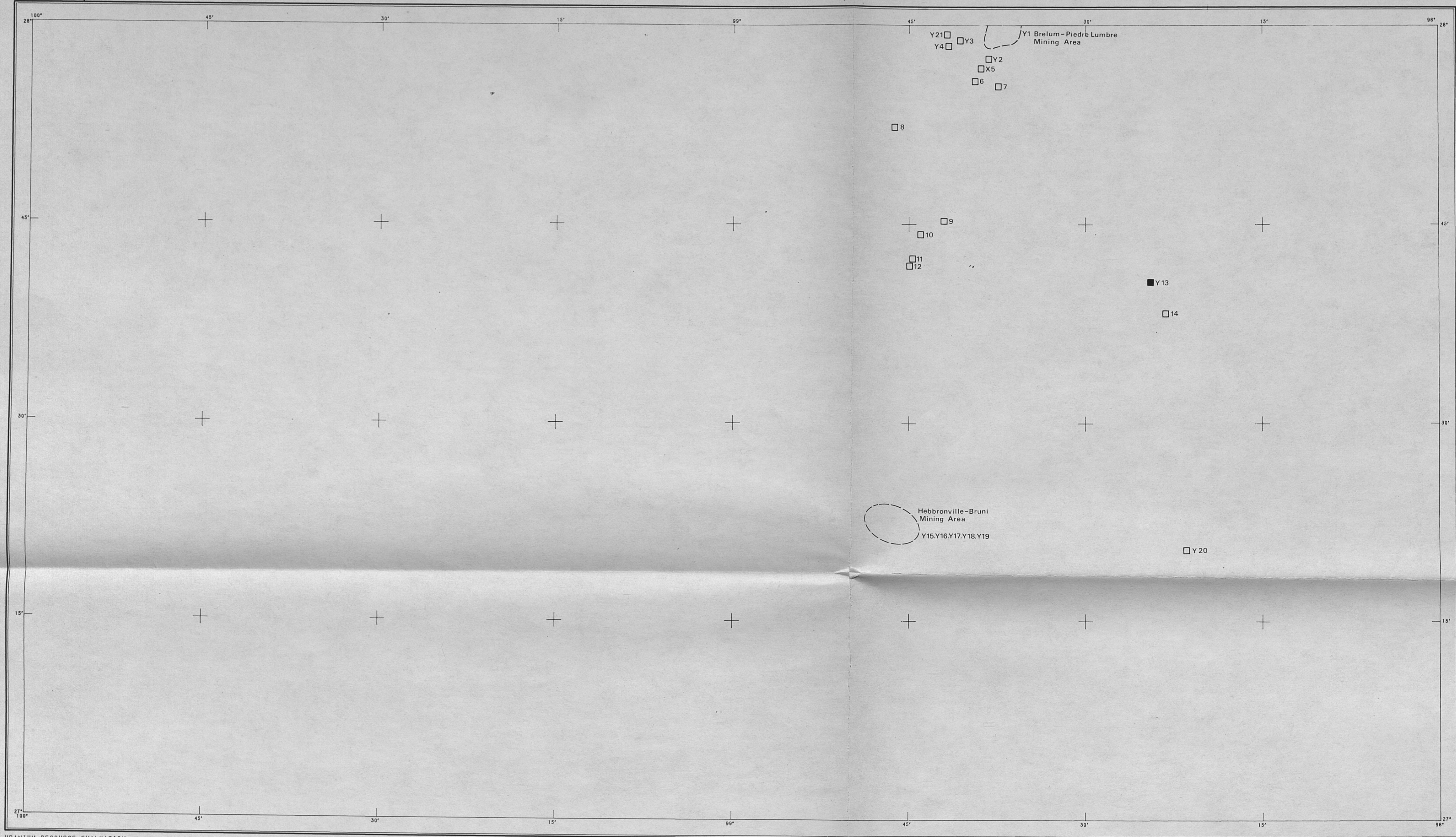
URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

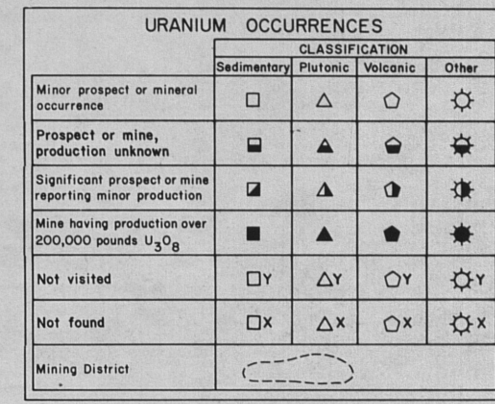
BASE MAP CONTROL FROM USGS

Plate 1e. AREAS FAVORABLE FOR URANIUM DEPOSITS IN THE FRIO FORMATION

May 1980
Plate 1e.

LAREDO, TEXAS





URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

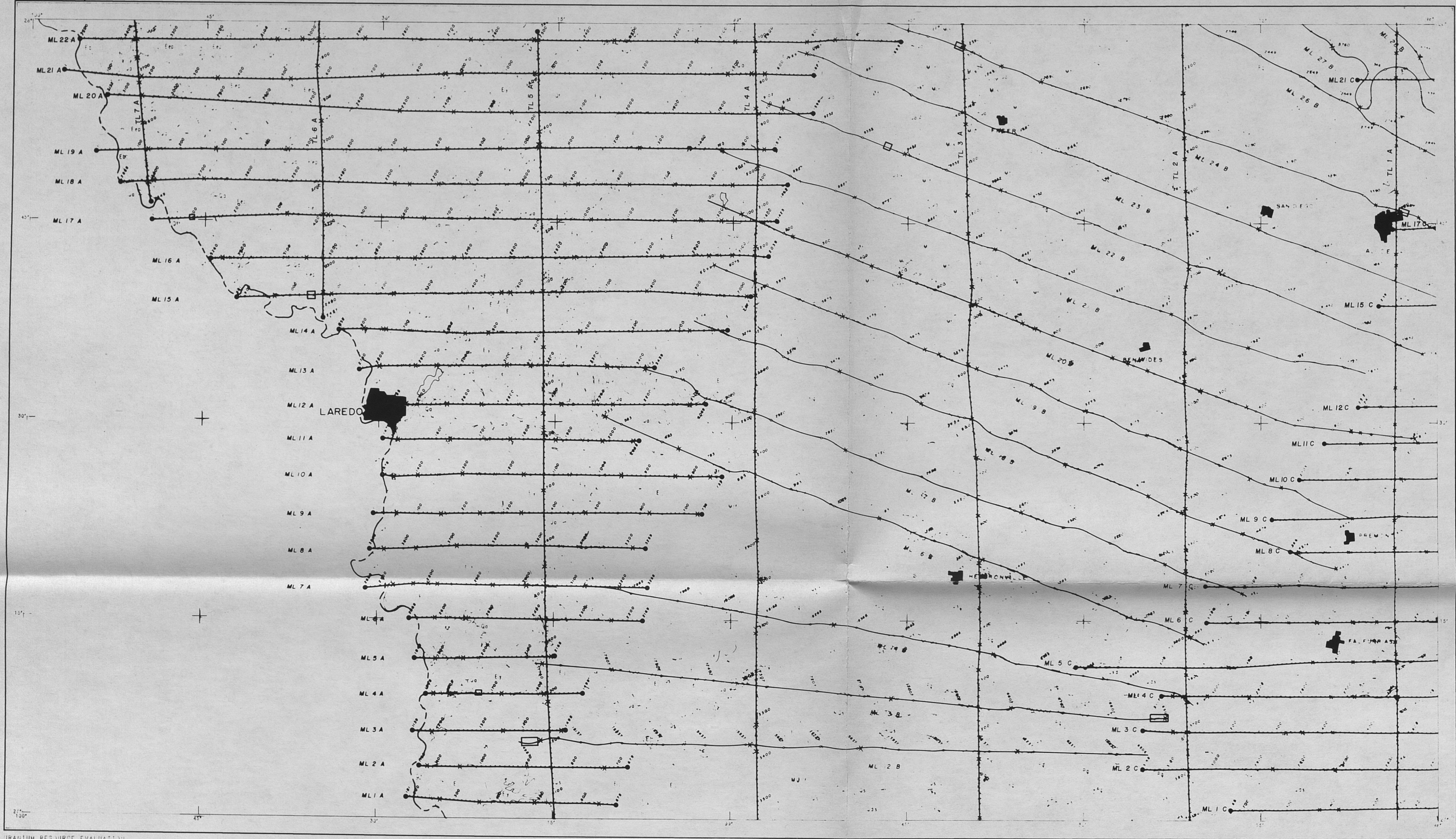
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 2. URANIUM OCCURRENCES

May 1980
Plate 2.

LAREDO, TEXAS



EXPLANATION

Area of Bi and Bi/Tl Radiometric Anomaly

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

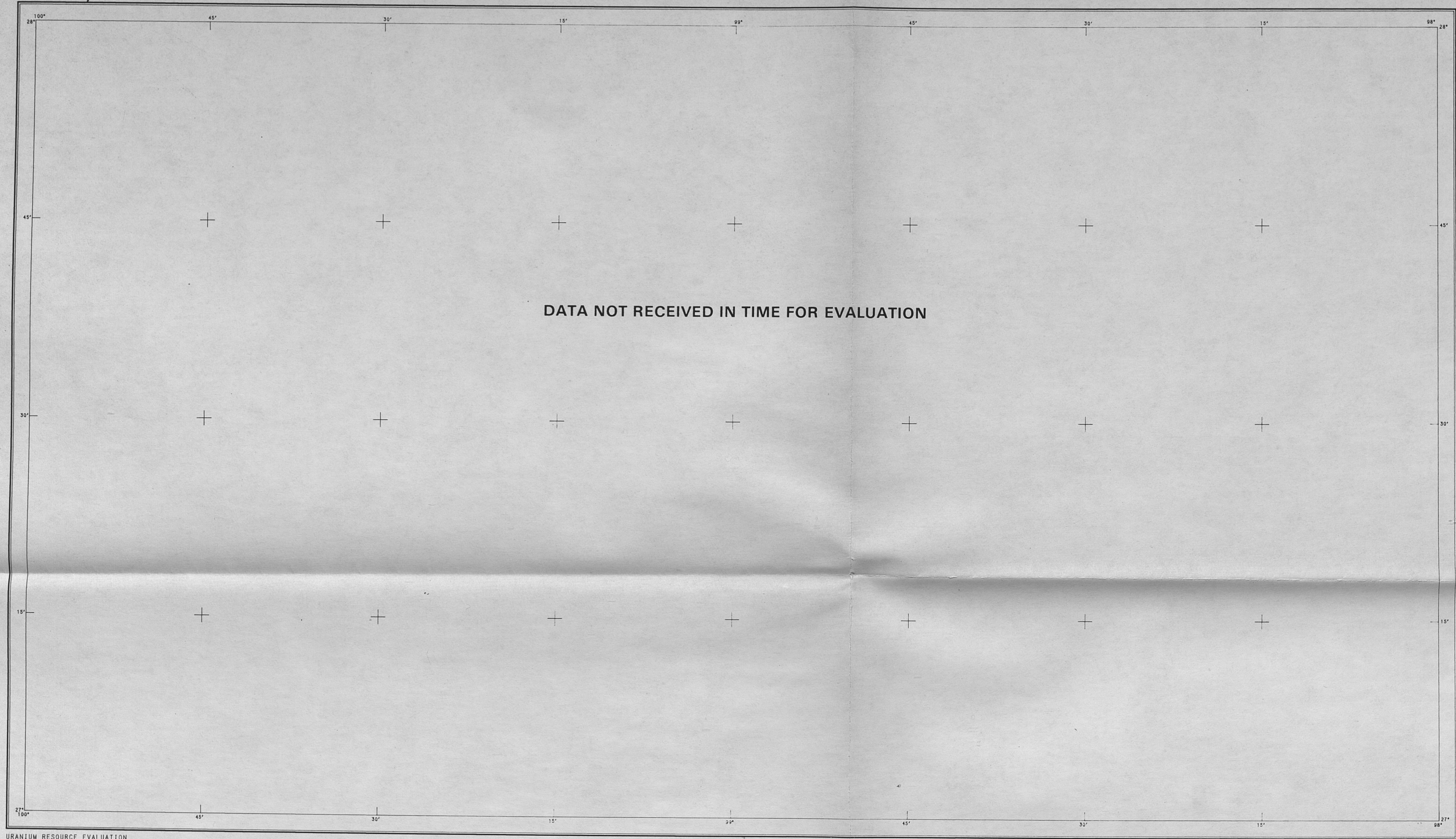
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 3. INTERPRETATION OF AERIAL RADIOMETRIC DATA

May 1980
Plate 3.

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

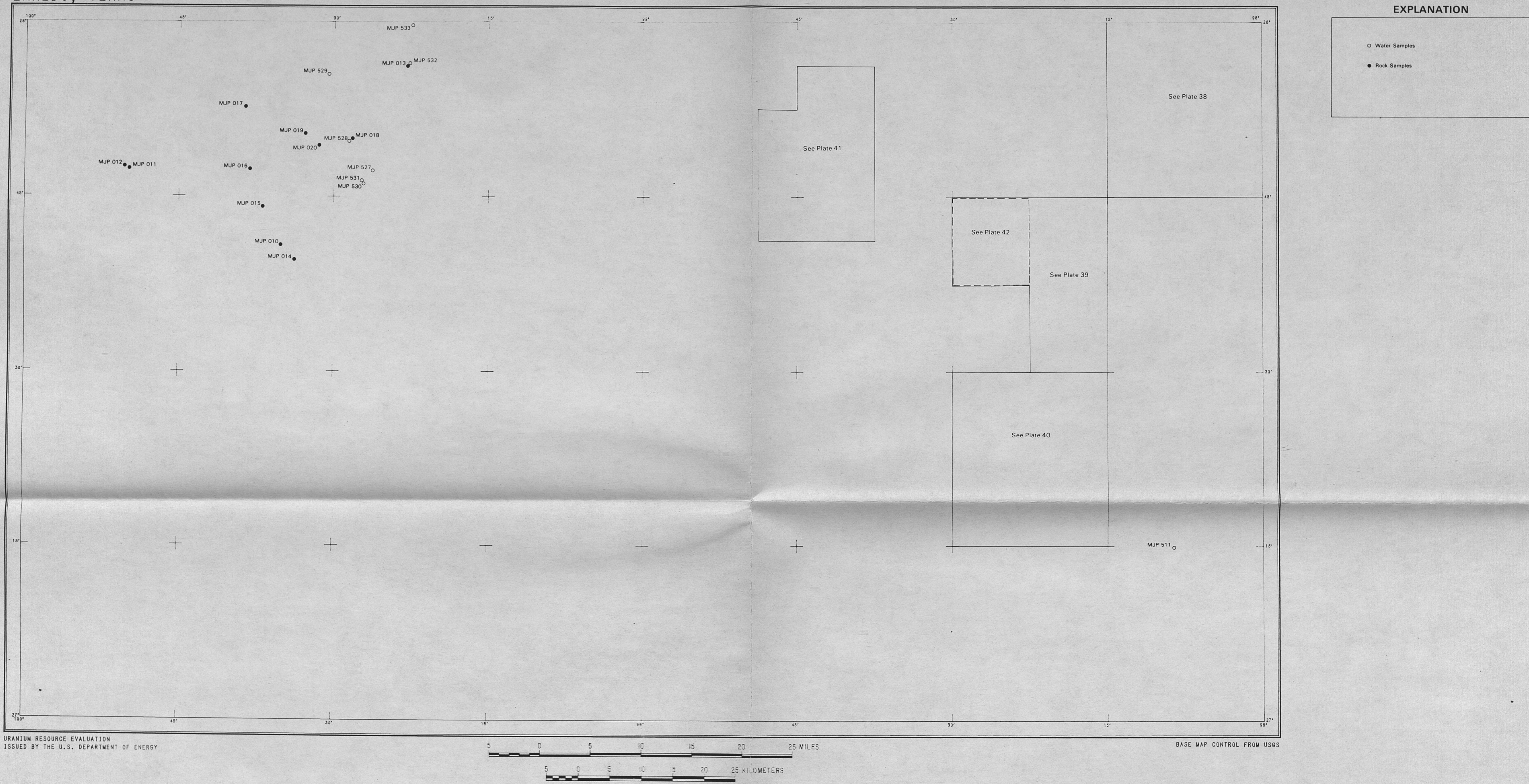
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS

Plate 4. INTERPRETATION OF DATA FROM HYDROGEOCHEMICAL AND STREAM-SEDIMENT RECONNAISSANCE

LAREDO, TEXAS



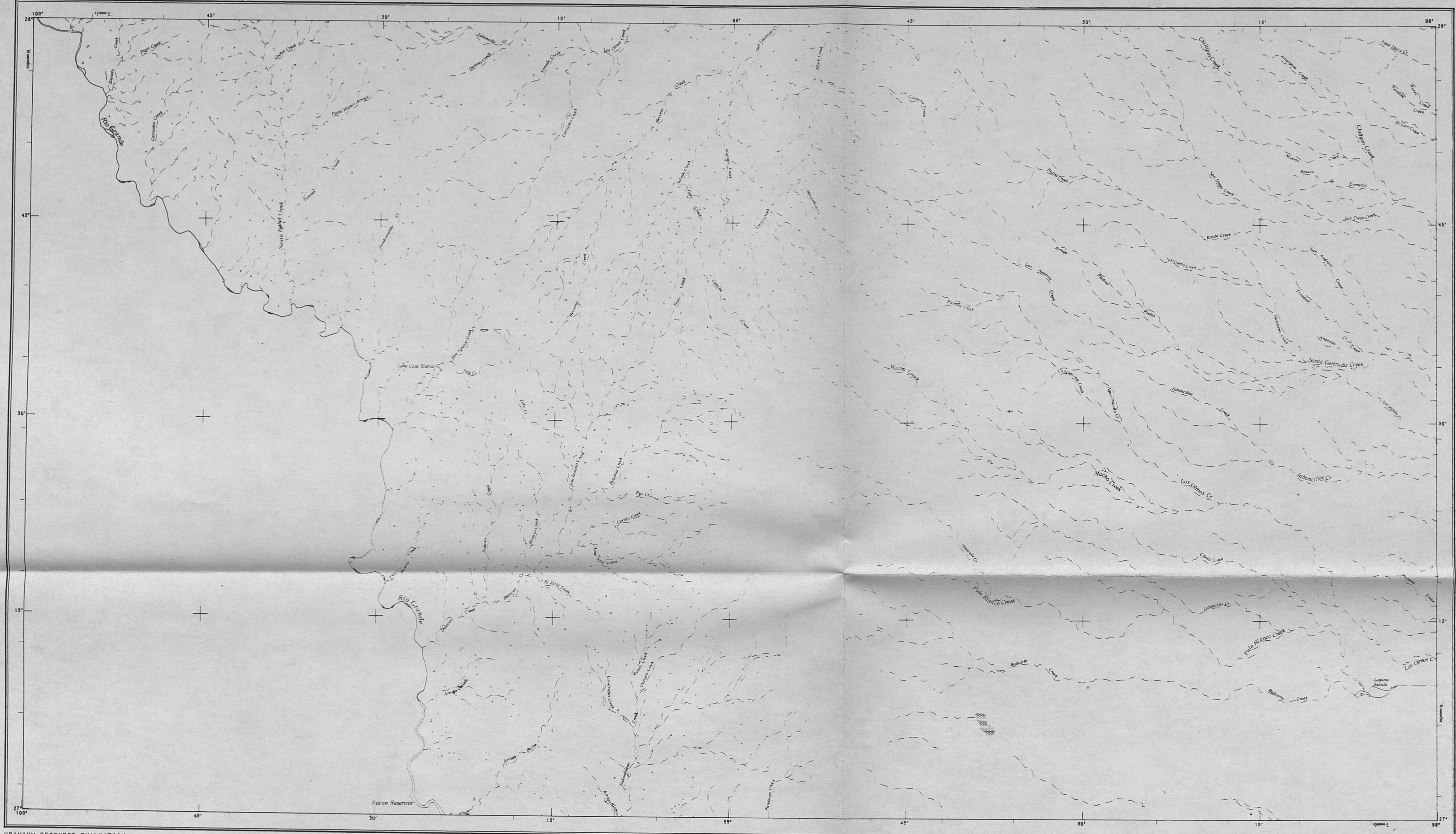
URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

Plate 5. LOCATION MAP OF GEOCHEMICAL SAMPLES

May 1980
Plate 5.

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 6. DRAINAGE

May 1980
Plate 6.

LAREDO, TEXAS

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

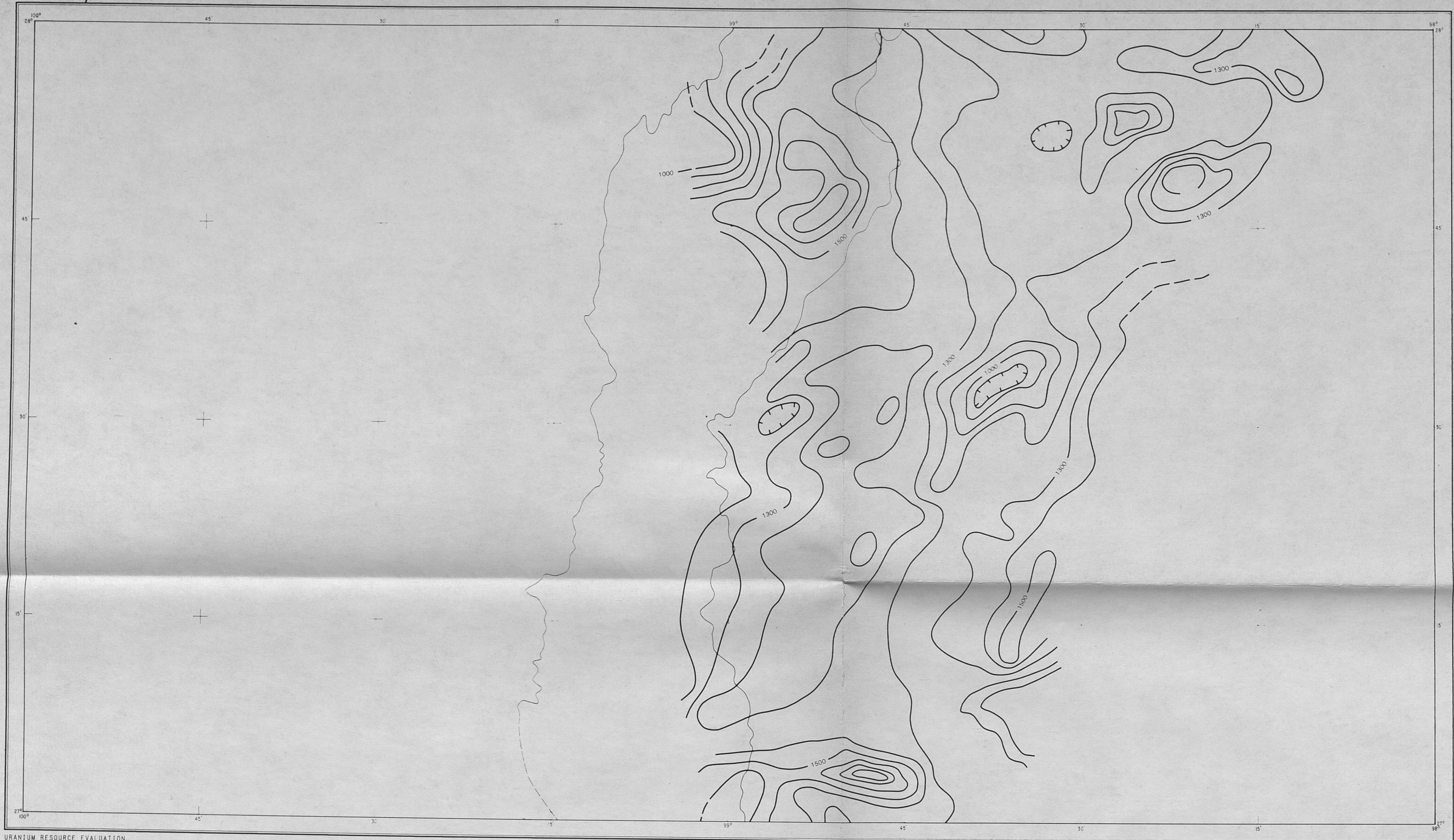
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

SOURCE OF DATA QUICK AND OTHERS, 1977.
CONTOUR INTERVAL IS 100 FT

Plate 8. THICKNESS OF THE YEGUA FORMATION (FEET)

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS
SOURCE OF DATA QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 100 FT

Plate 9. THICKNESS OF THE JACKSON GROUP (FEET)

LAREDO, TEXAS

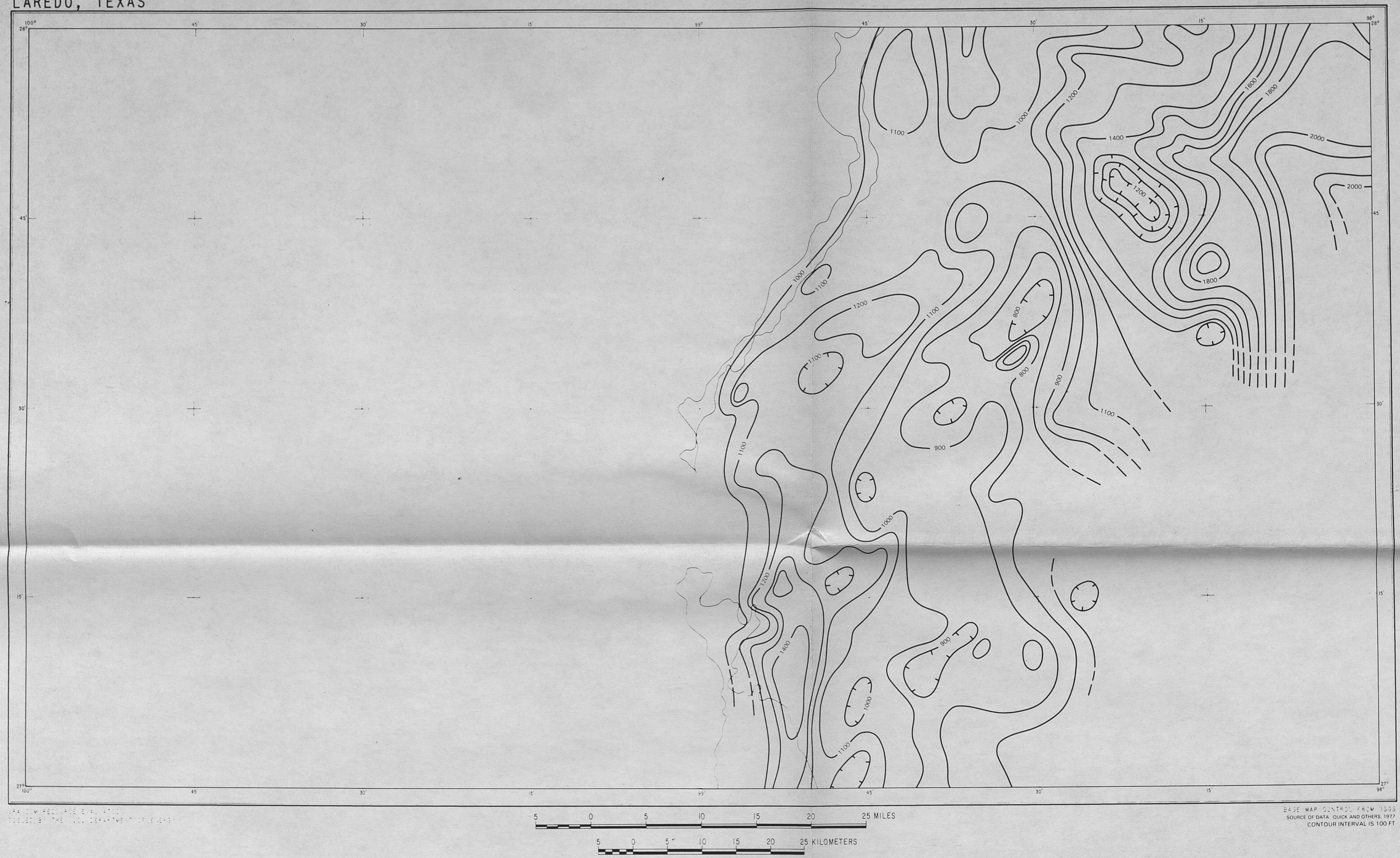
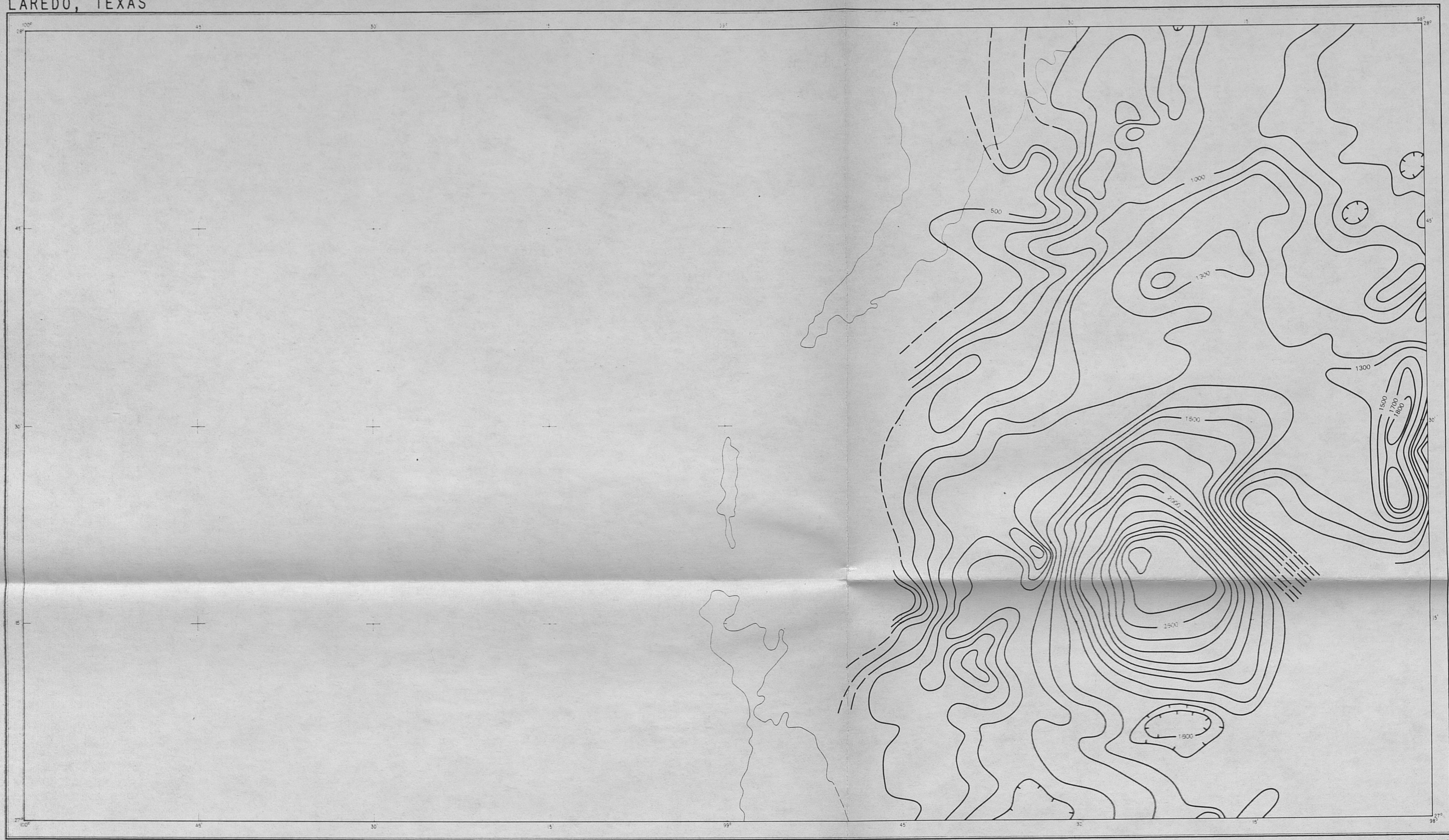


Plate 10. THICKNESS OF THE FRIO FORMATION (FEET)

May 1980
Plate 10.

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

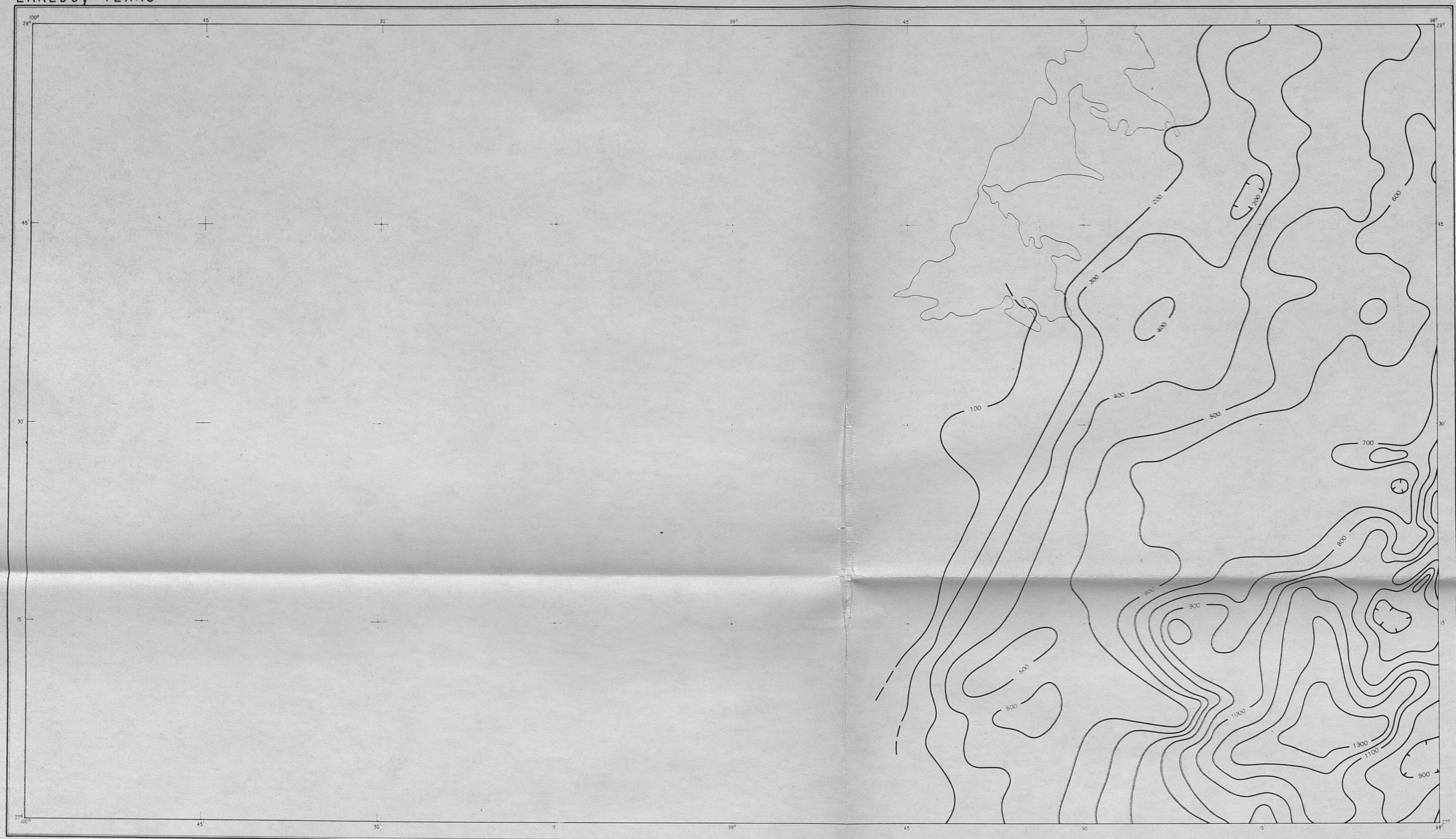
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS
SOURCE OF DATA: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 100 FT

Plate 11. THICKNESS OF THE CATAHOULA FORMATION (FEET)

LARREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS
SOURCE OF DATA QUICK AND OTHERS 1977
CONTOUR INTERVAL IS 100 FT

Plate 12. THICKNESS OF THE OAKVILLE FORMATION (FEET)

LAREDO, TEXAS

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

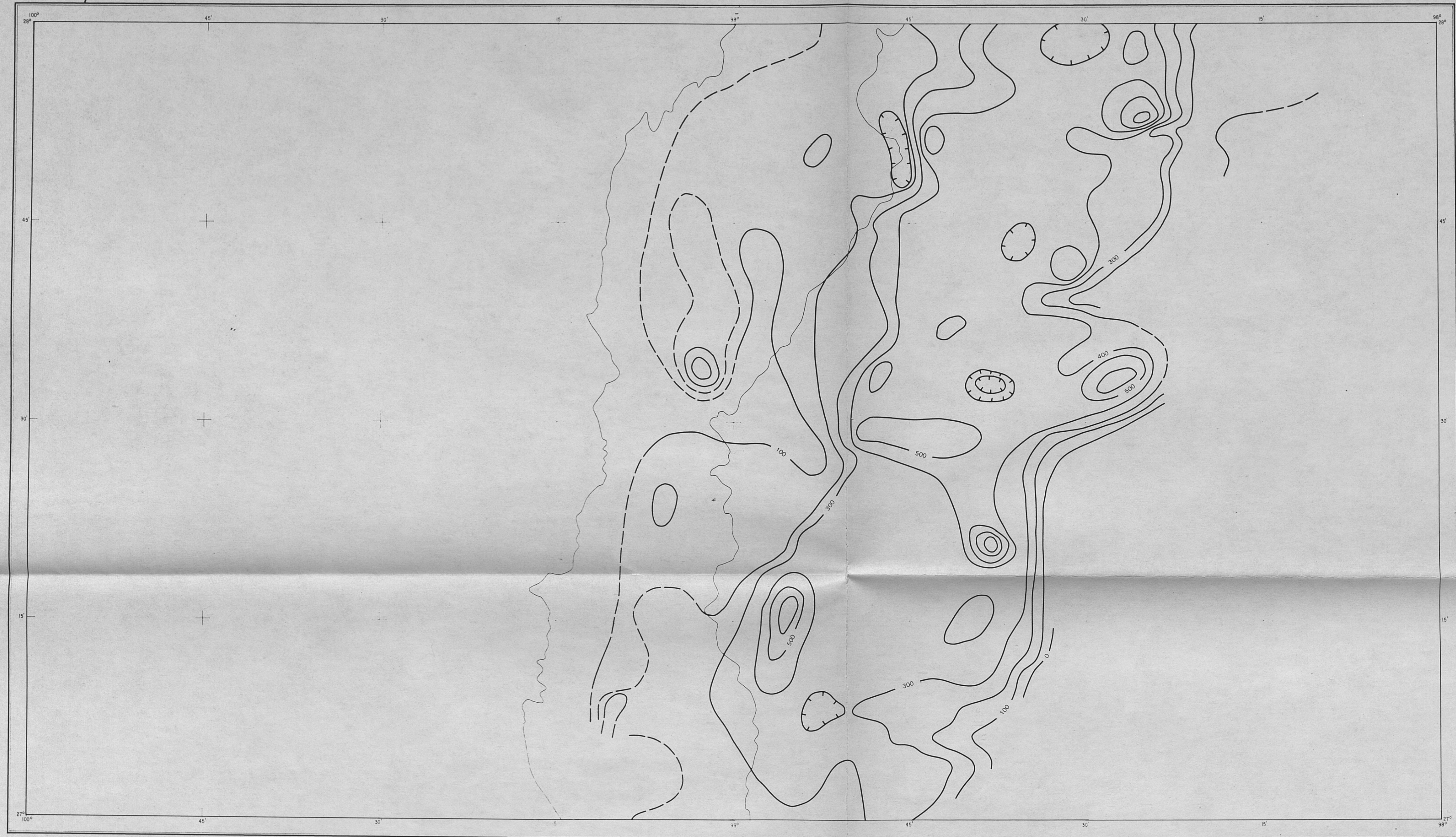
5 0 5 10 15 20 25 KILOMETERS

SOURCE OF DATA: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 100 FT

Plate 13. TOTAL SANDSTONE THICKNESS OF THE YEGUA FORMATION (FEET)

May 1980
Plate 13.

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

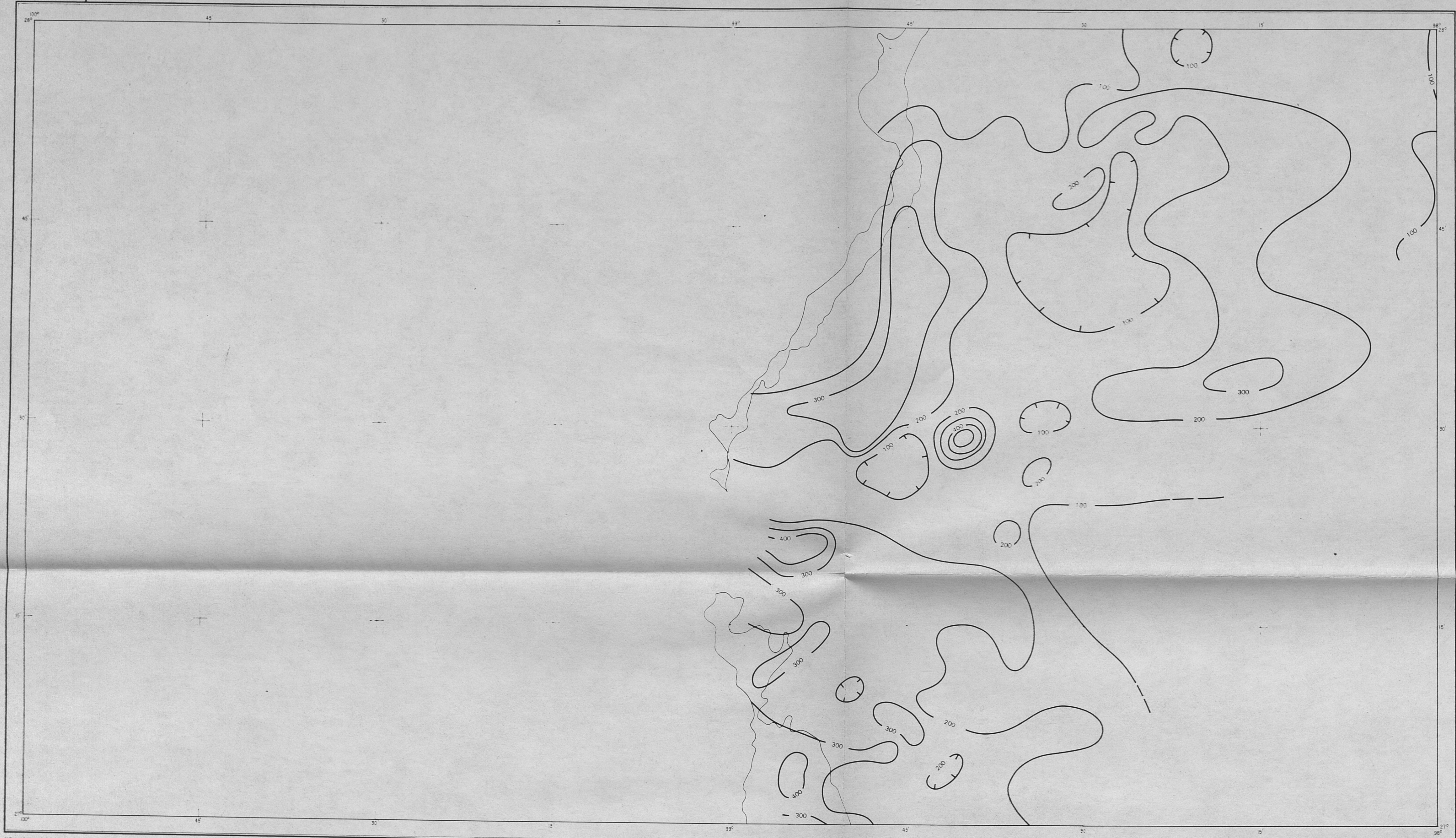
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

SOURCE OF DATA QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 100 FT

Plate 14. TOTAL SANDSTONE THICKNESS OF THE JACKSON GROUP (FEET)

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS
SOURCE OF DATA: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 100 FT

Plate 15. **TOTAL SANDSTONE THICKNESS OF THE FRIO FORMATION (FEET)**

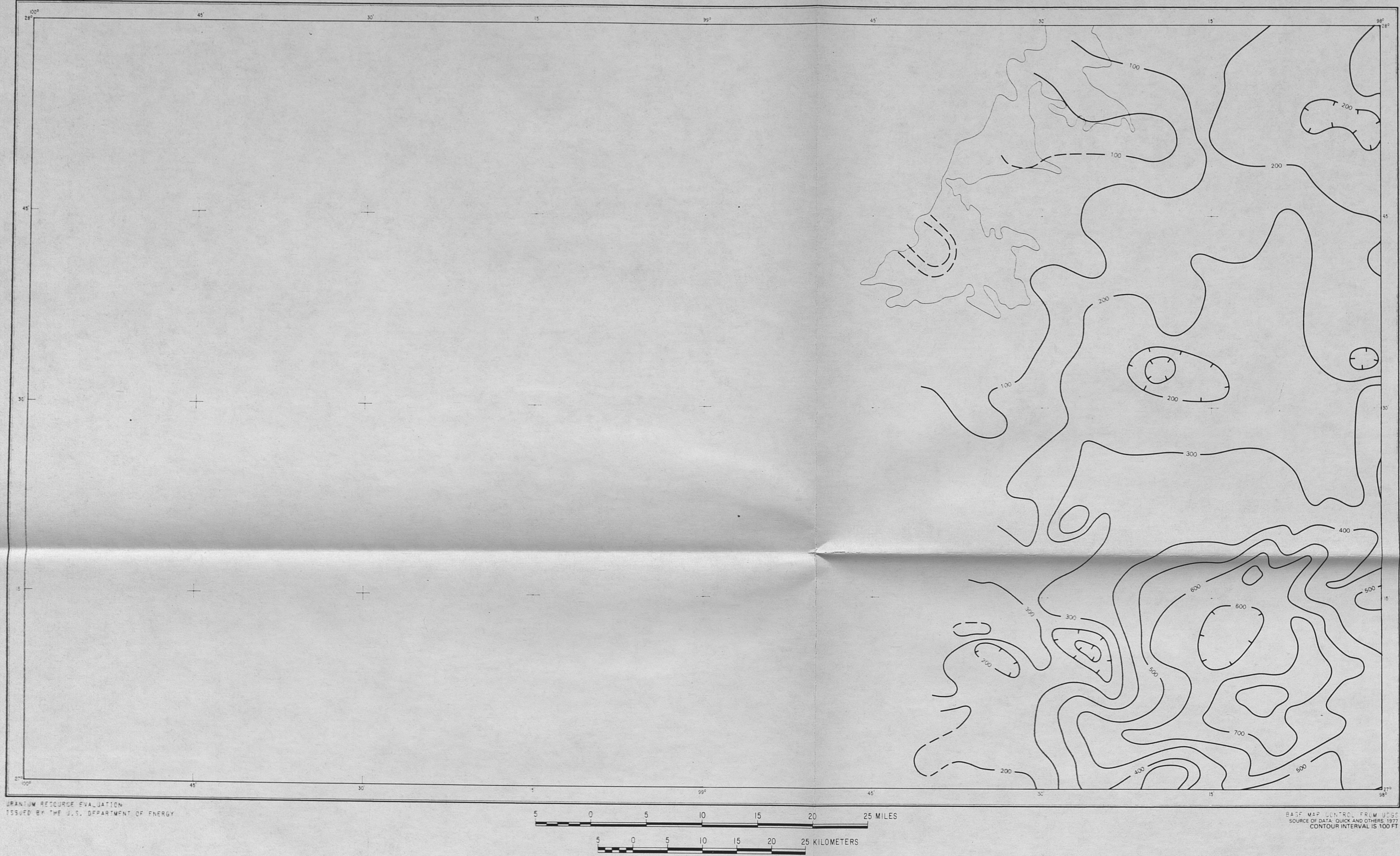
LAREDO, TEXAS

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

SOURCE OF DATA: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 100 FT

Plate 16. TOTAL SANDSTONE THICKNESS OF THE CATAHOULA FORMATION (FEET)

LAREDO, TEXAS

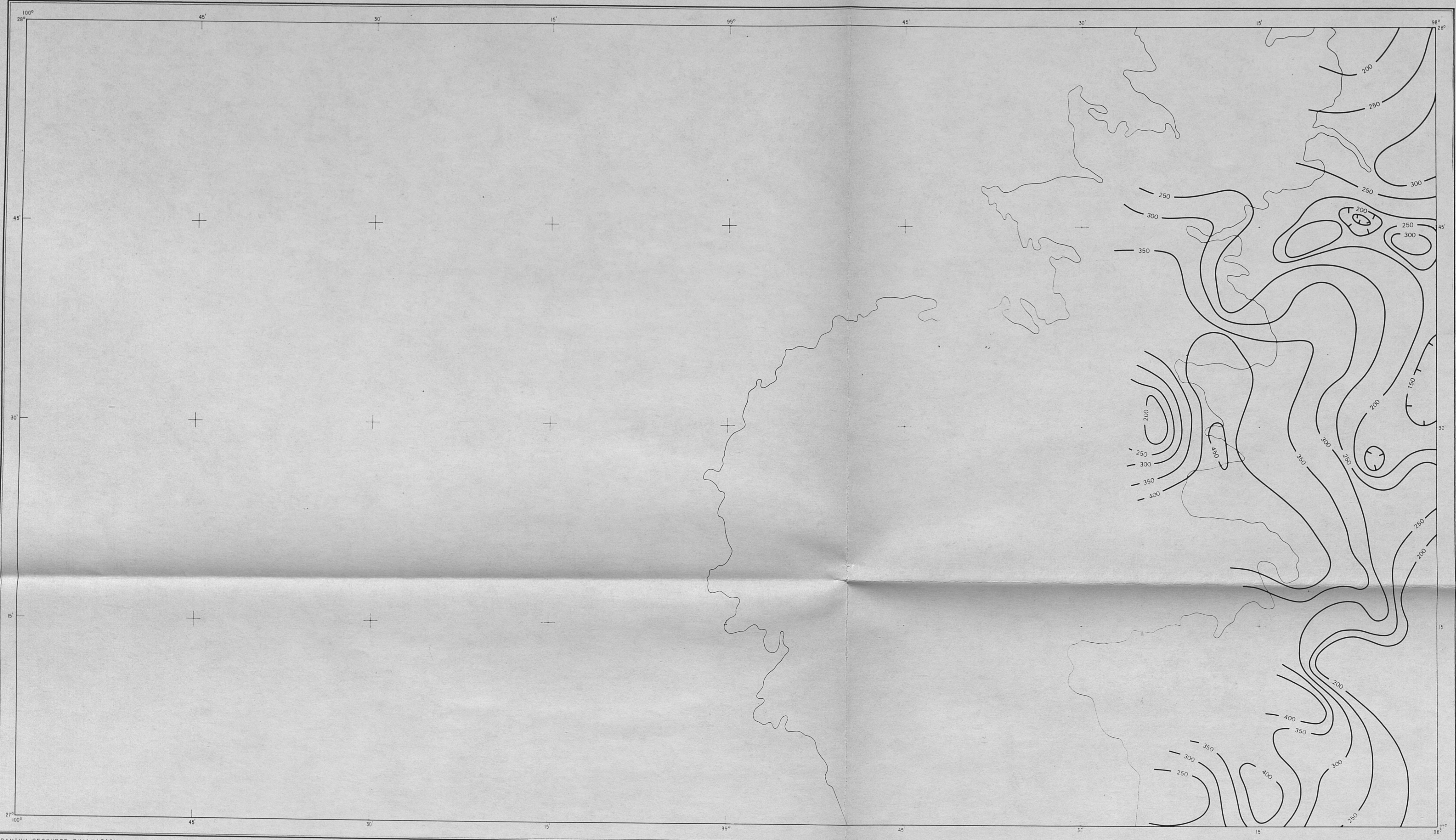


URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS
SOURCE OF DATA: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 100 FT

Plate 17. TOTAL SANDSTONE THICKNESS OF THE OAKVILLE FORMATION (FEET)

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

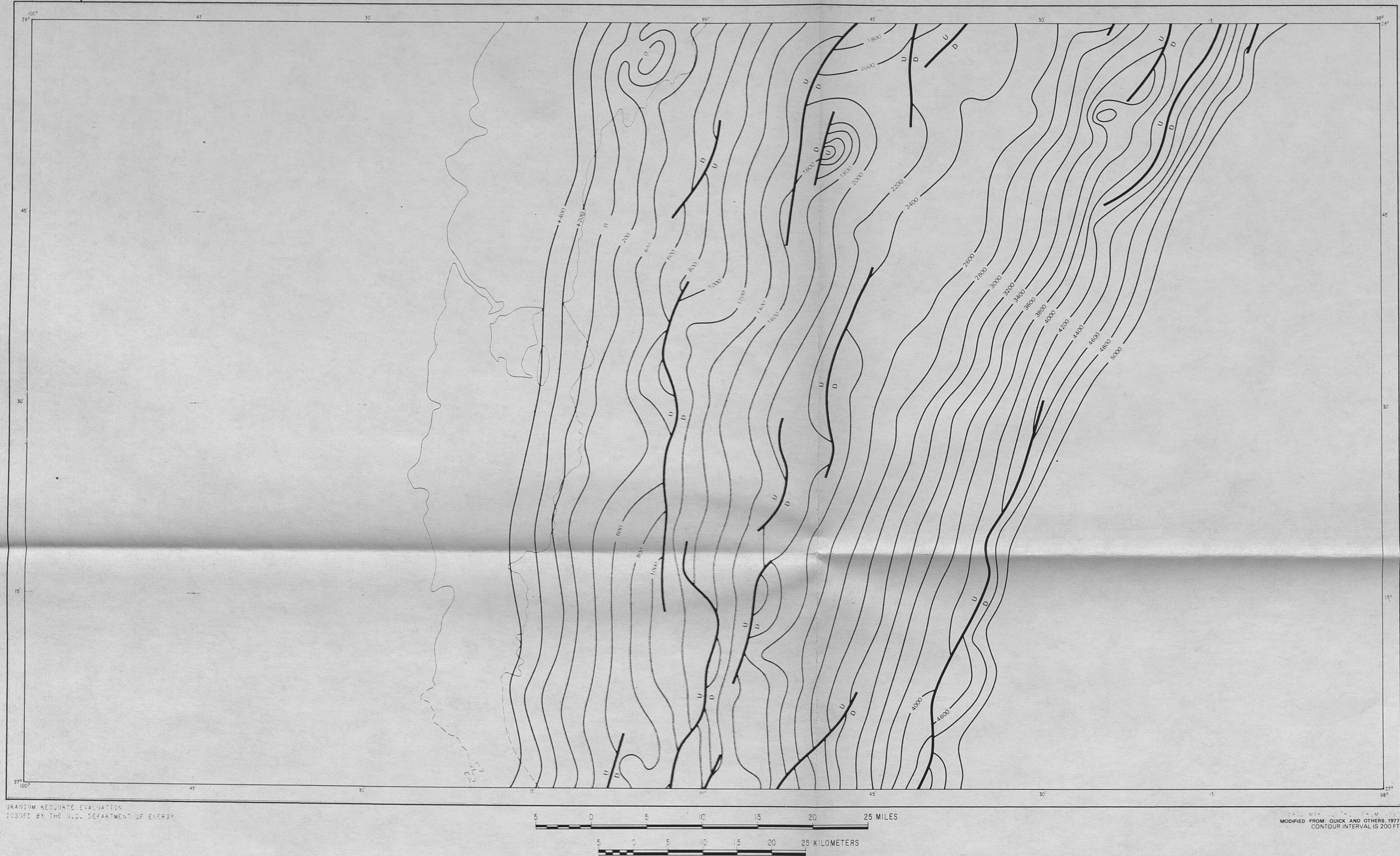
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM U.S.G.S.
SOURCE OF DATA: QUICK AND OTHERS 1977
CONTOUR INTERVAL IS 50 FT

Plate 18. TOTAL SANDSTONE THICKNESS OF THE LOWER 500 FT OF THE GOLIAD FORMATION (FEET)

LAREDO, TEXAS

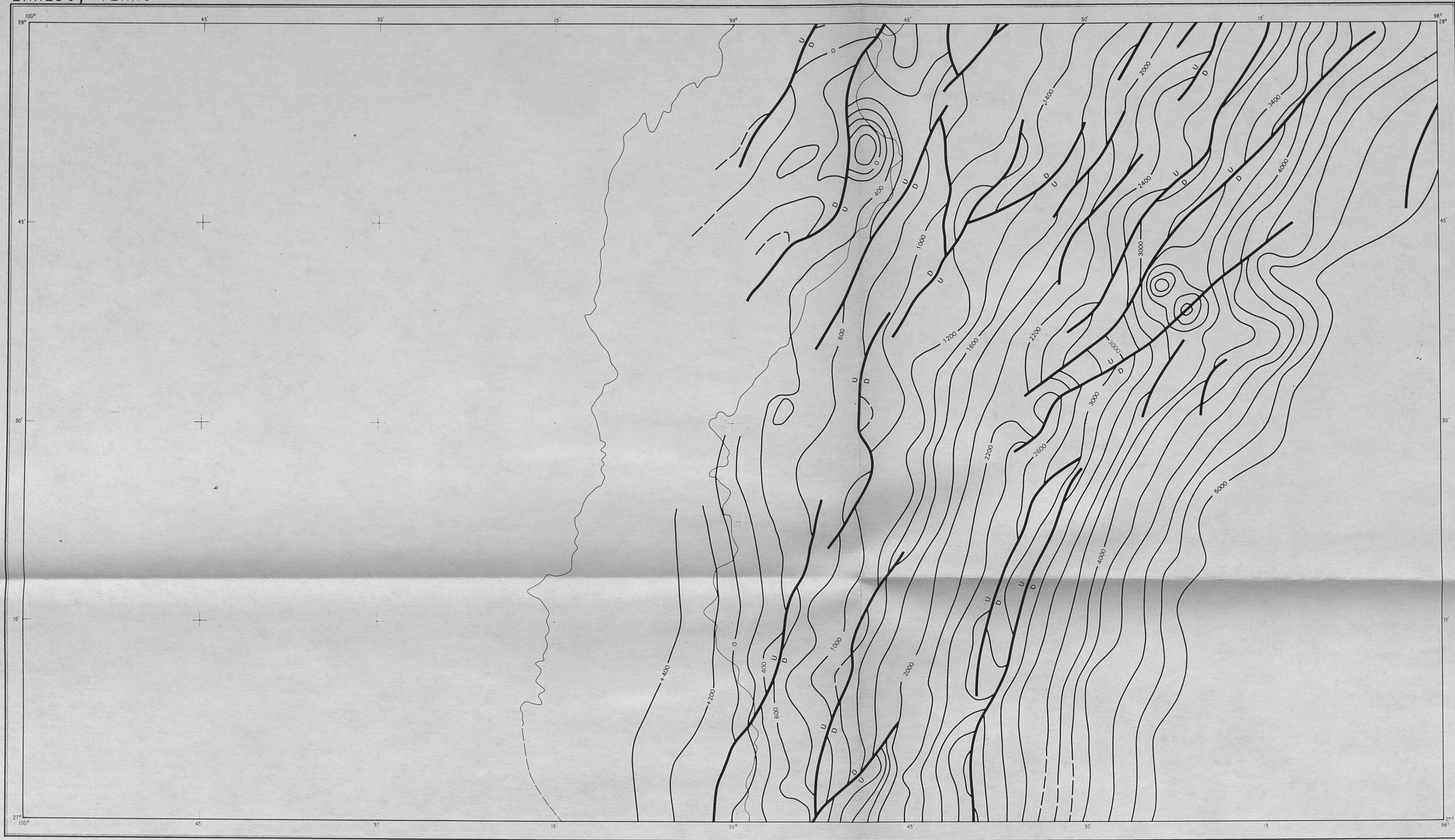


URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

MODIFIED FROM: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 200 FT

Plate 19. STRUCTURE ON TOP OF THE YEGUA FORMATION (FEET BELOW SEA LEVEL)

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

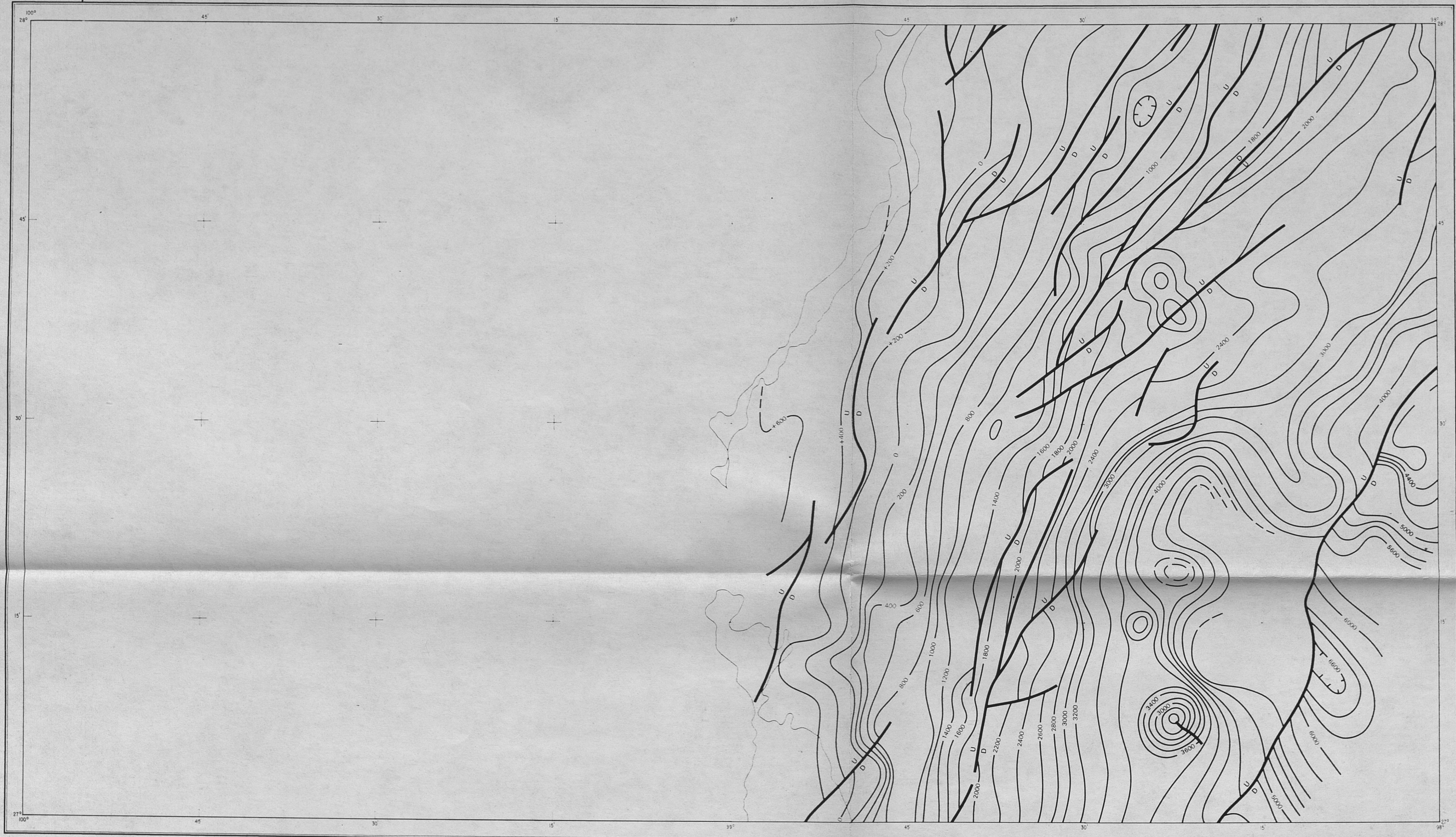
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

MODIFIED FROM QUICK AND OTHERS 1977
CONTOUR INTERVAL IS 200 FT

Plate 20. STRUCTURE ON TOP OF THE JACKSON GROUP (FEET BELOW SEA LEVEL)

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

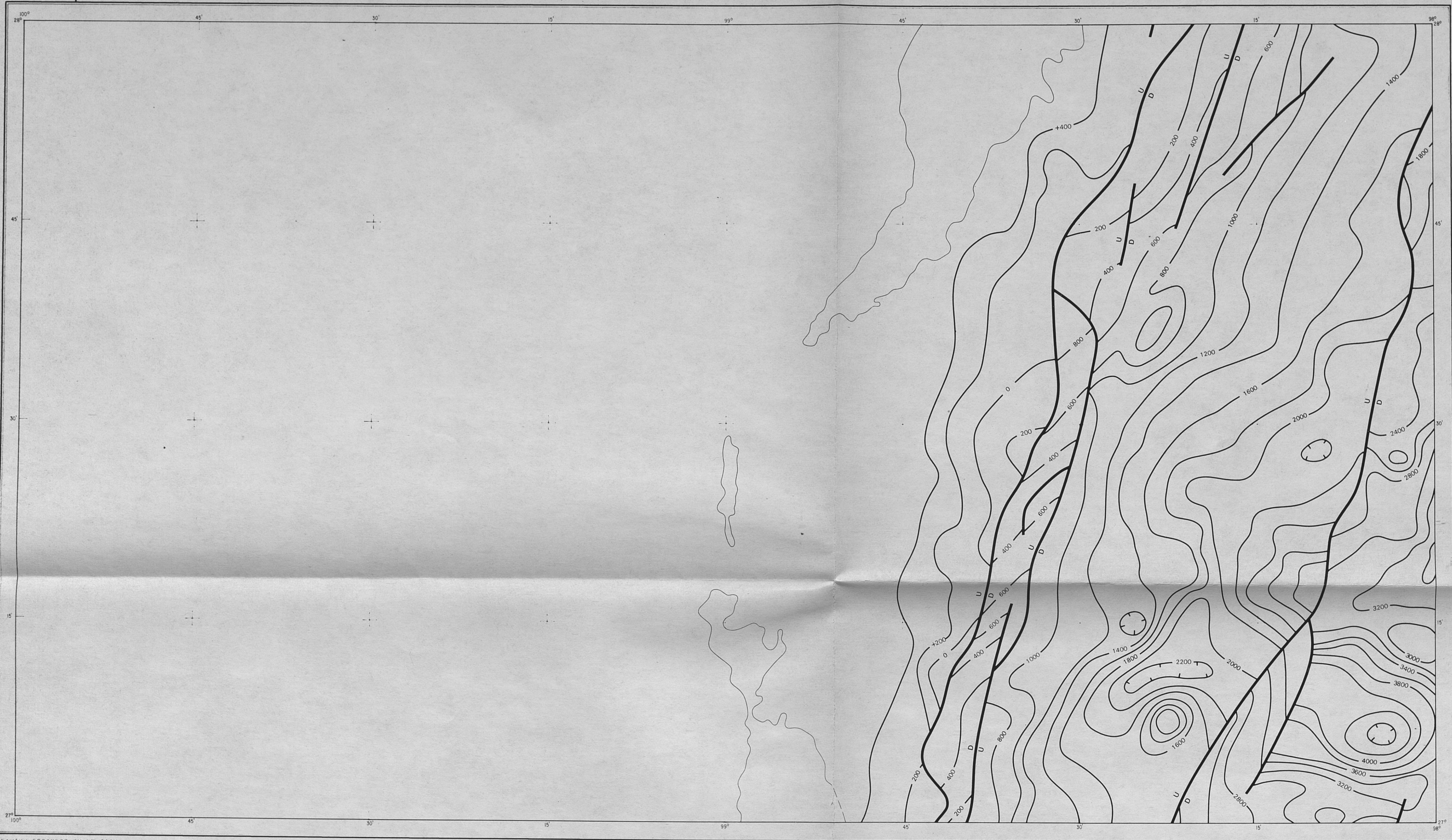
5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS
SOURCE OF DATA: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 200 FT

Plate 21. STRUCTURE ON TOP OF THE FRIO FORMATION (FEET BELOW SEA LEVEL)

May 1980
Plate 21.

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

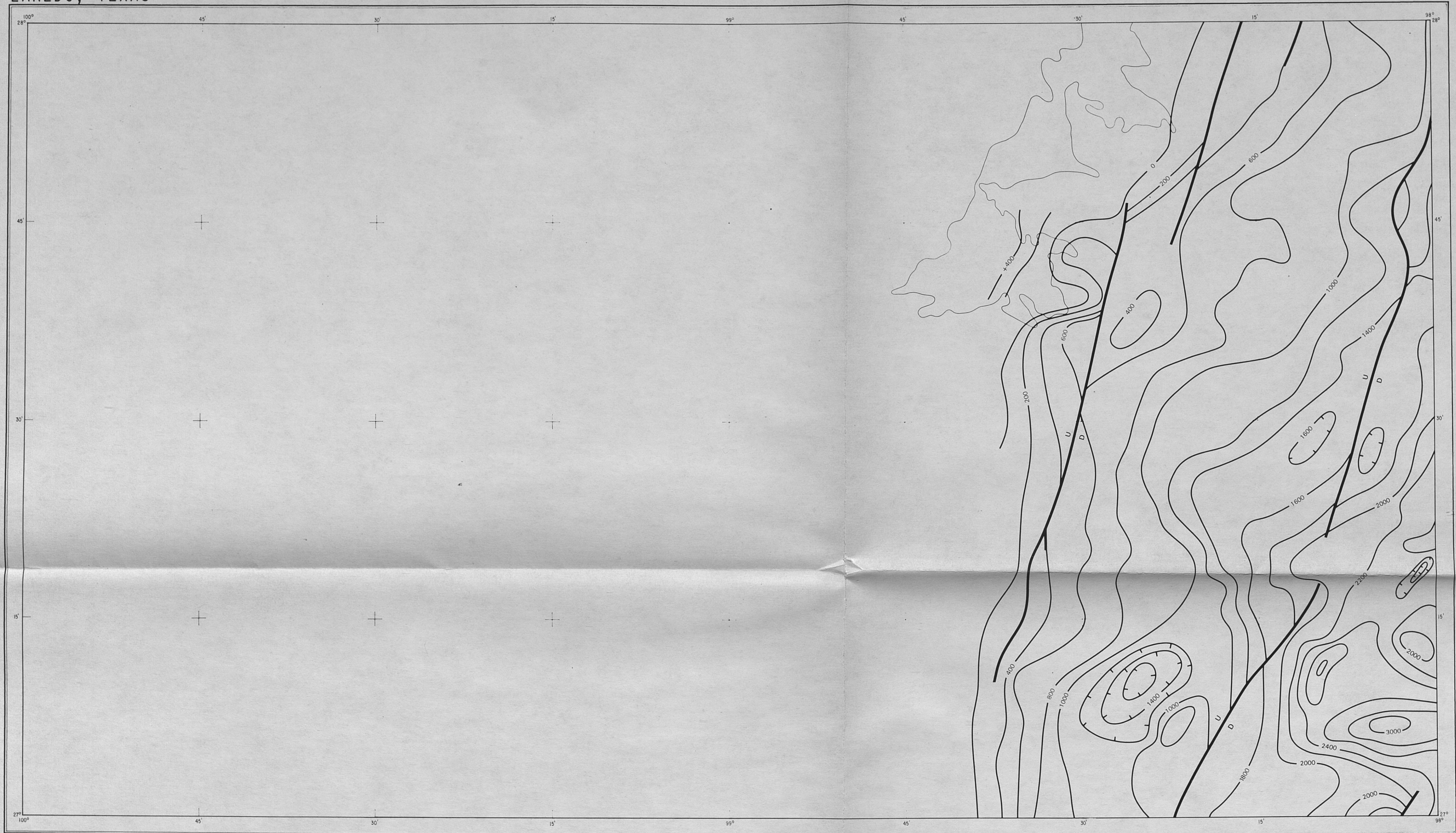
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

MODIFIED FROM: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 200 FT

Plate 22. STRUCTURE ON TOP OF THE CATAHOULA FORMATION (FEET BELOW SEA LEVEL)

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

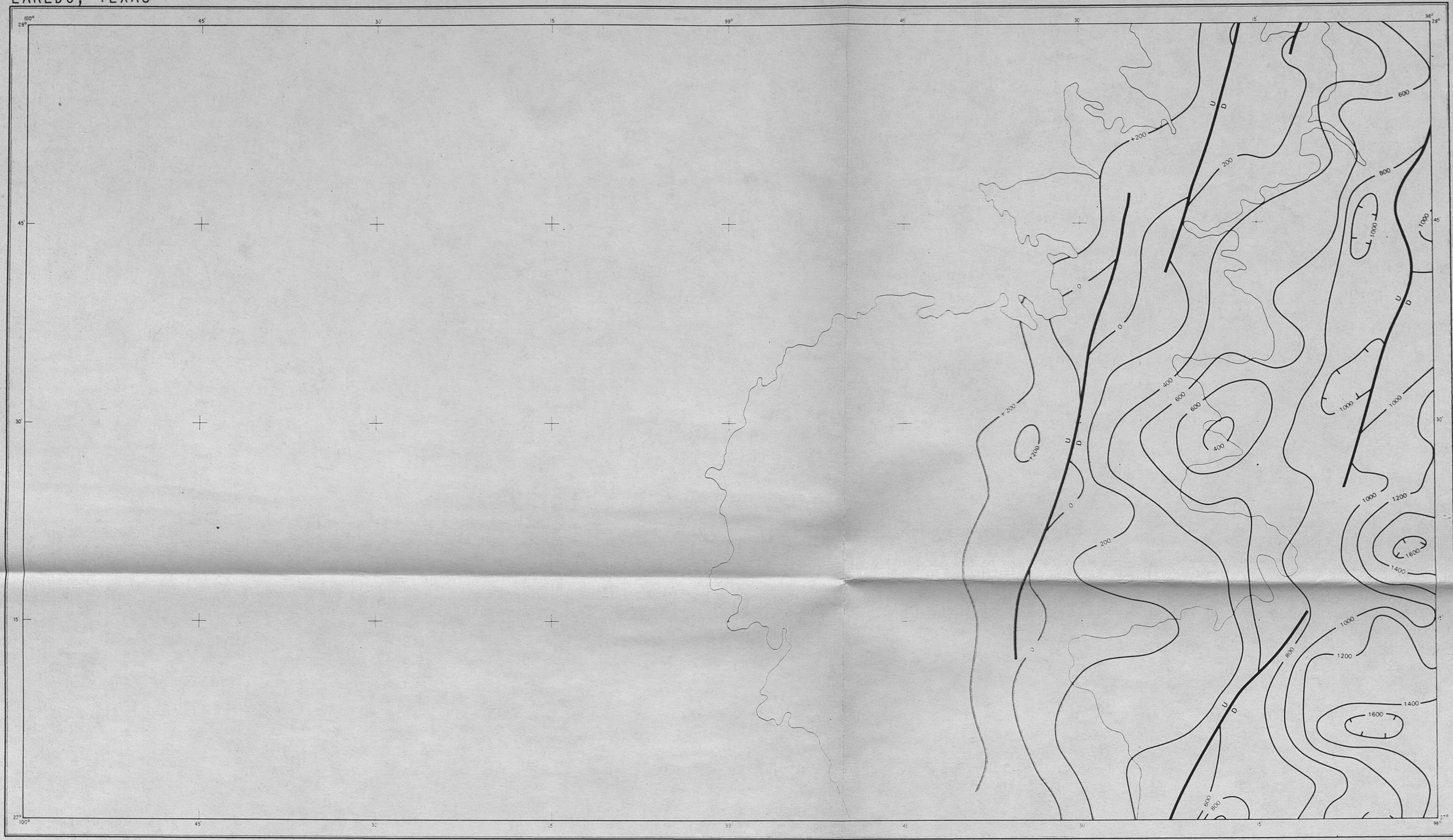
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

SOURCE OF DATA: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 200 FT

Plate 23. STRUCTURE ON TOP OF THE OAKVILLE FORMATION (FEET BELOW SEA LEVEL)

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

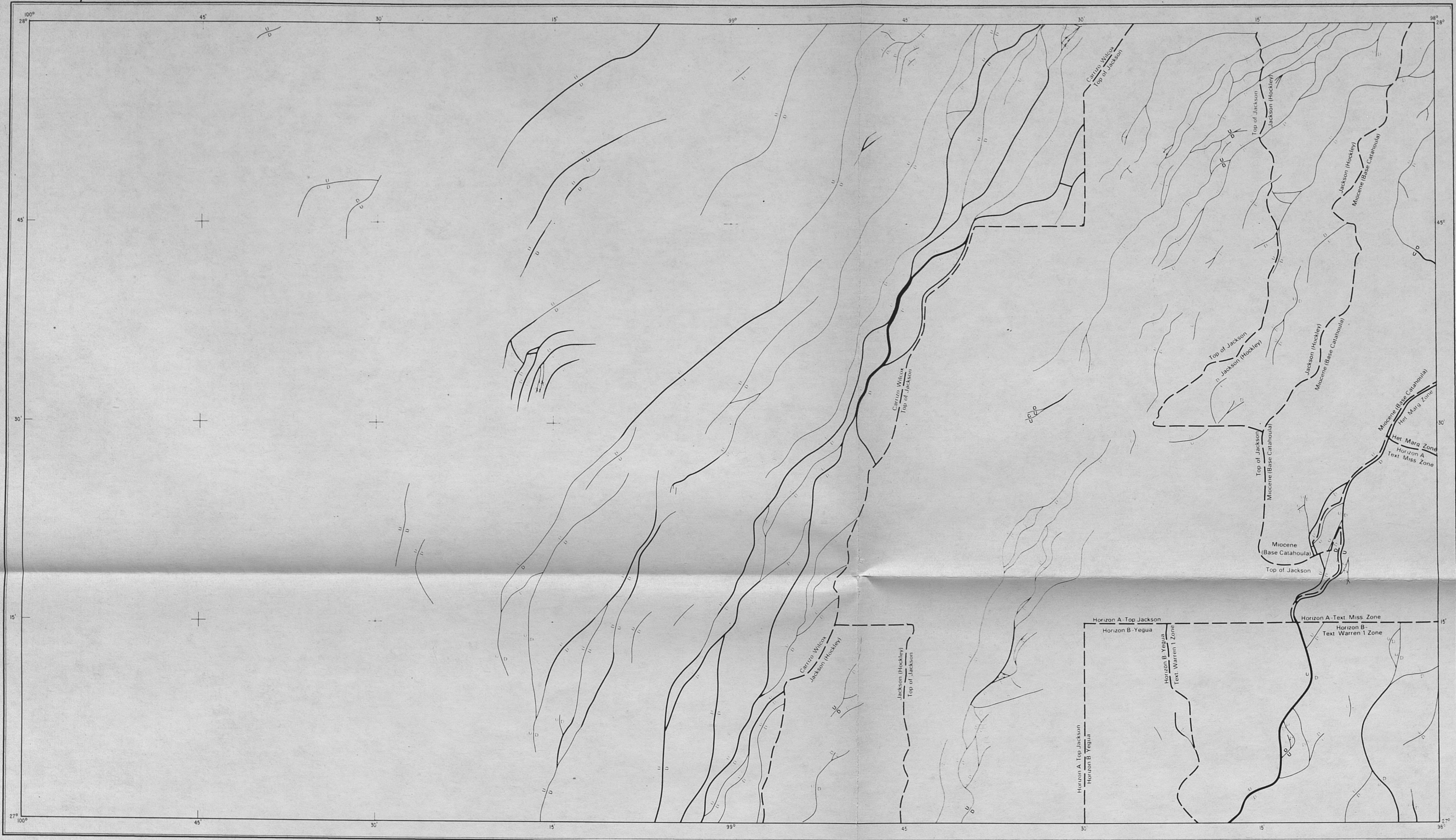
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS
MODIFIED FROM: QUICK AND OTHERS, 1977
CONTOUR INTERVAL IS 200 FT

Plate 24. STRUCTURE ON THE BASE OF THE GOLIAD FORMATION (FEET BELOW SEA LEVEL)

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS
Data courtesy of GeoMap

Plate 25. SUBSURFACE FAULTS

LAREDO, TEXAS

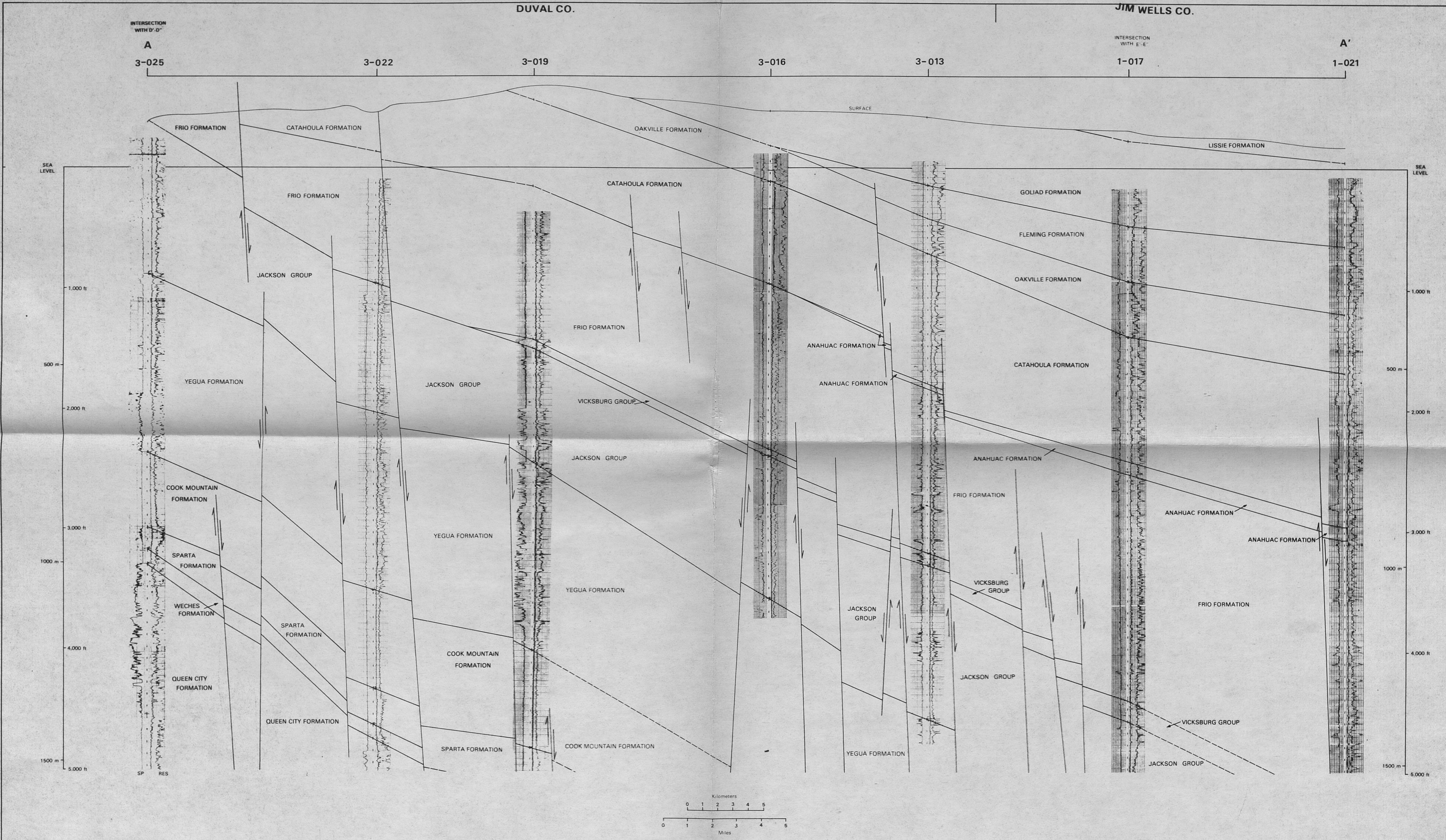


Plate 26. CROSS SECTION A-A'

SEE PLATE 43 FOR LOCATION OF SECTION

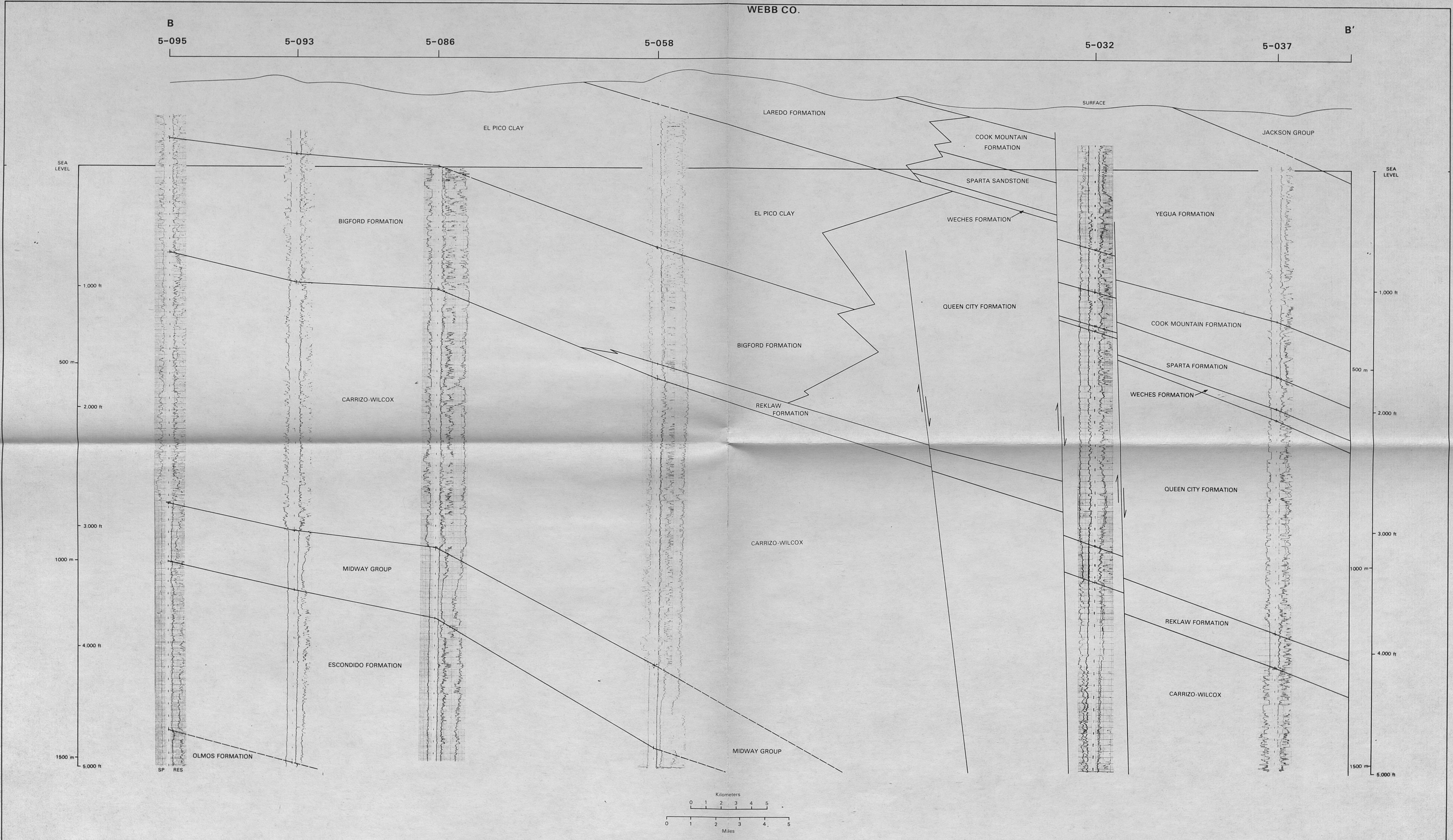


Plate 27. CROSS SECTION B-B'

SEE PLATE 43 FOR LOCATION OF SECTION

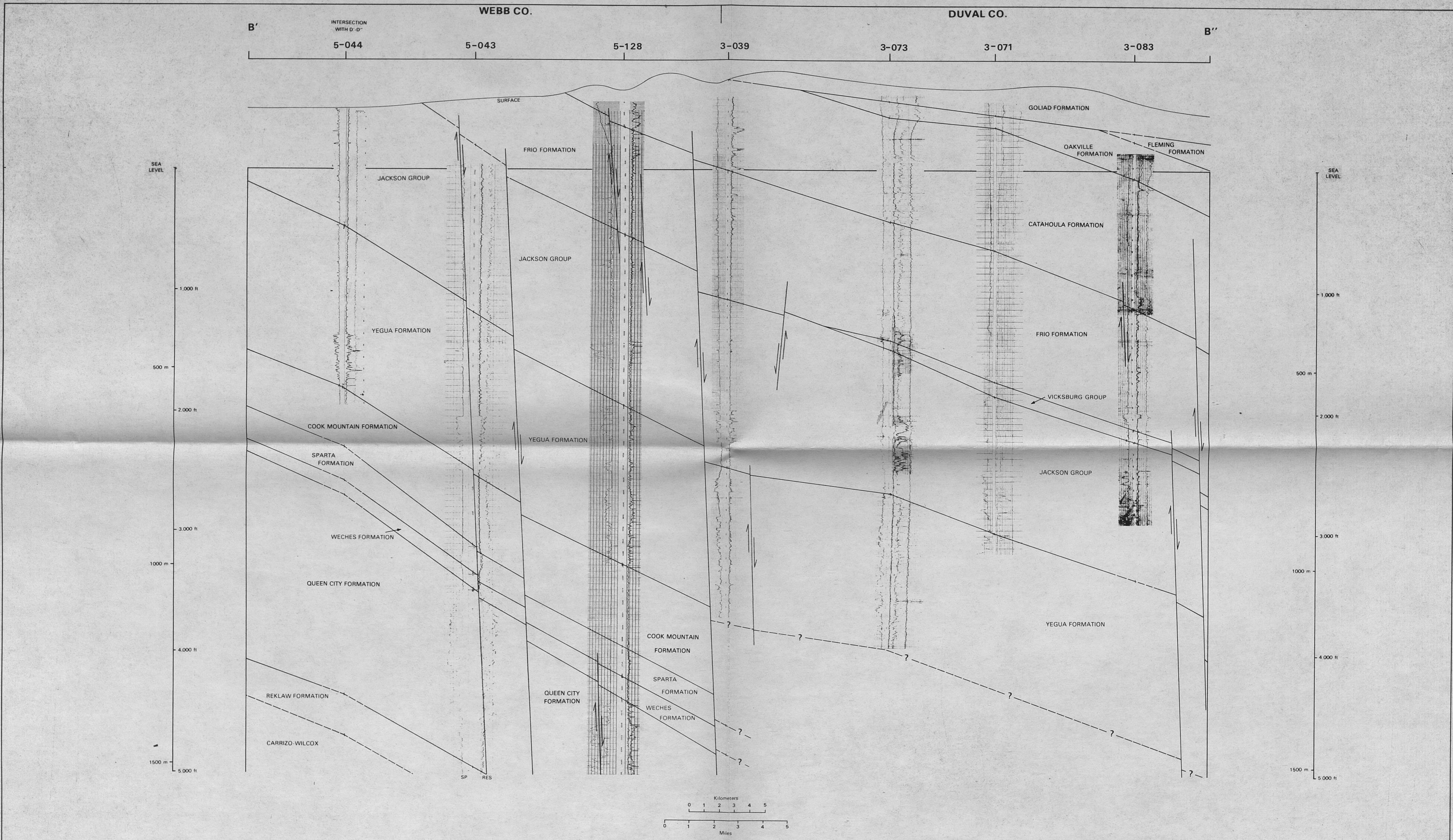


Plate 28. CROSS SECTION B'-B''

SEE PLATE 43 FOR LOCATION OF SECTION

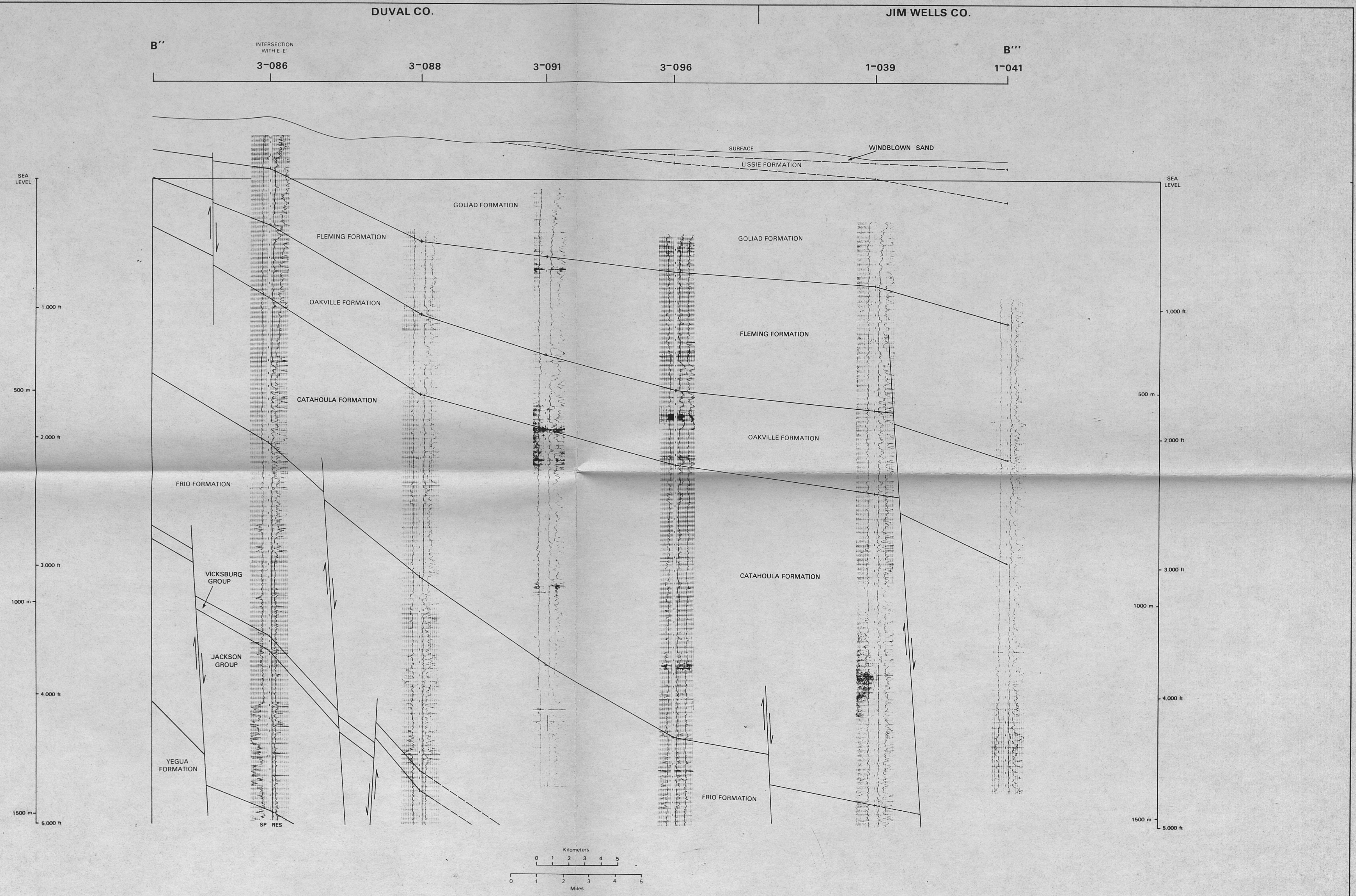


Plate 29. CROSS SECTION B''-B'''

SEE PLATE 43 FOR LOCATION OF SECTION

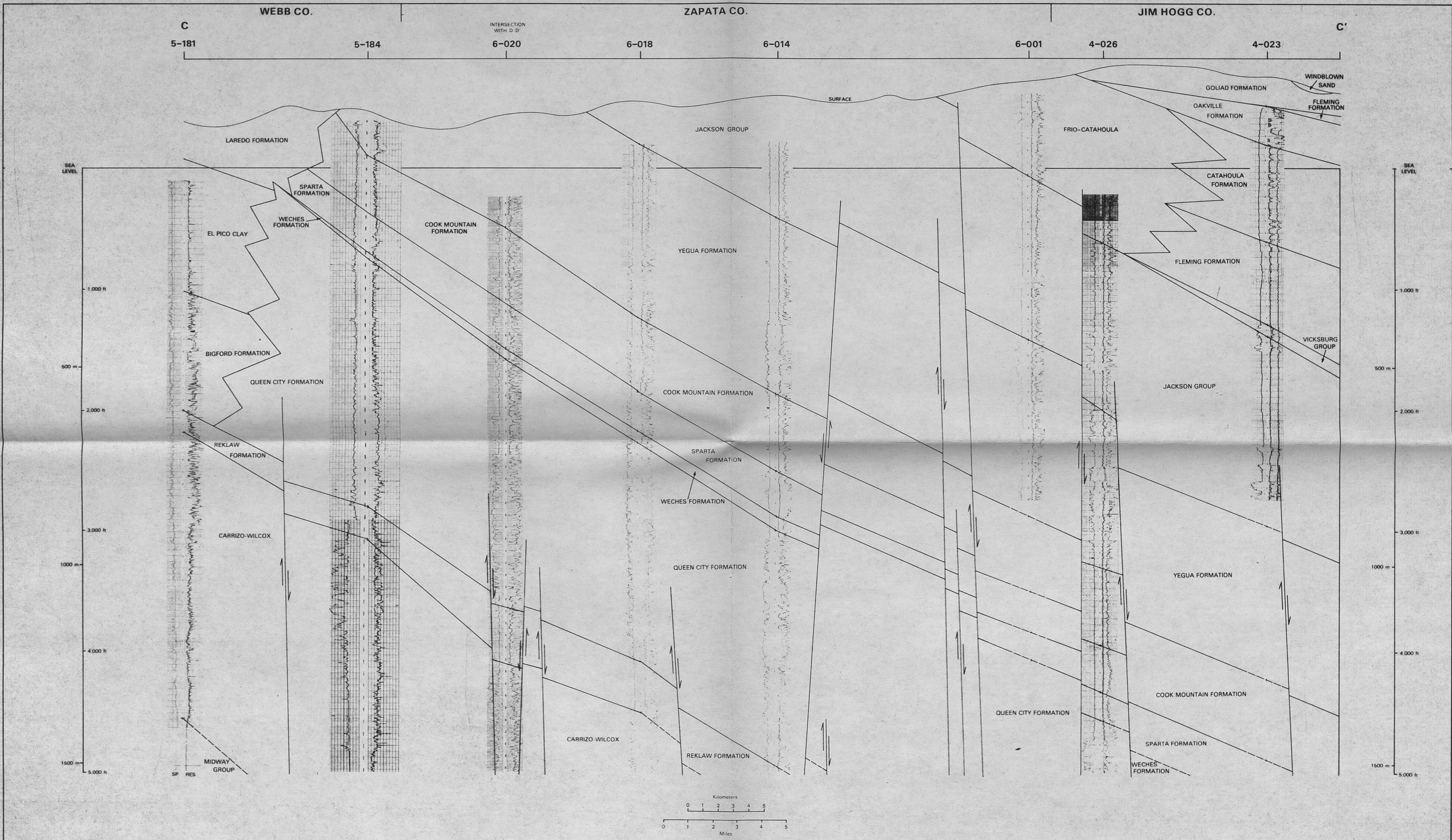


Plate 30. CROSS SECTION C-C′

SEE PLATE 43 FOR LOCATION OF SECTION

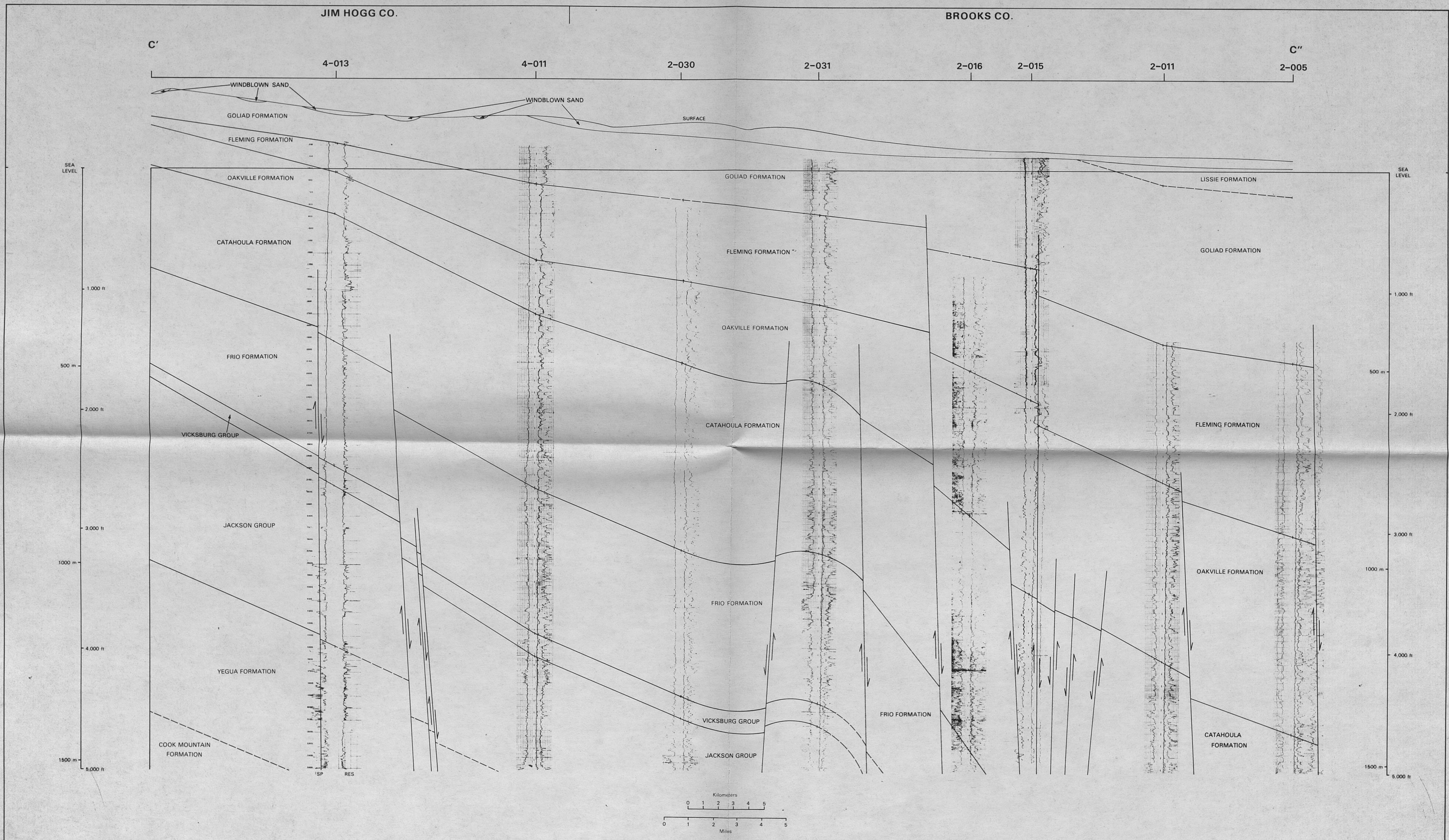


Plate 31. CROSS SECTION C'-C"

SEE PLATE 43 FOR LOCATION OF SECTION

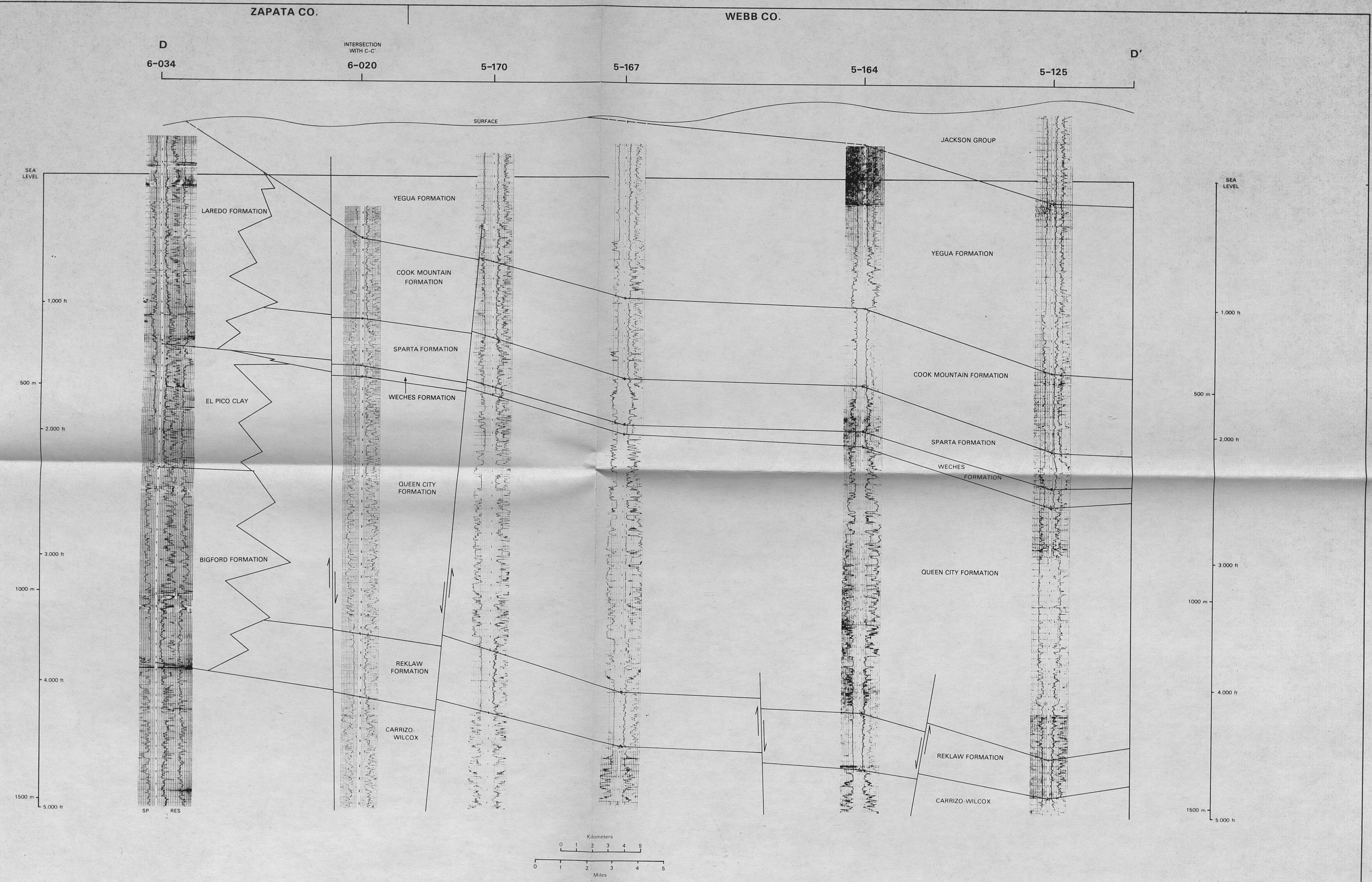


Plate 32. CROSS SECTION D-D'

SEE PLATE 43 FOR LOCATION OF SECTION

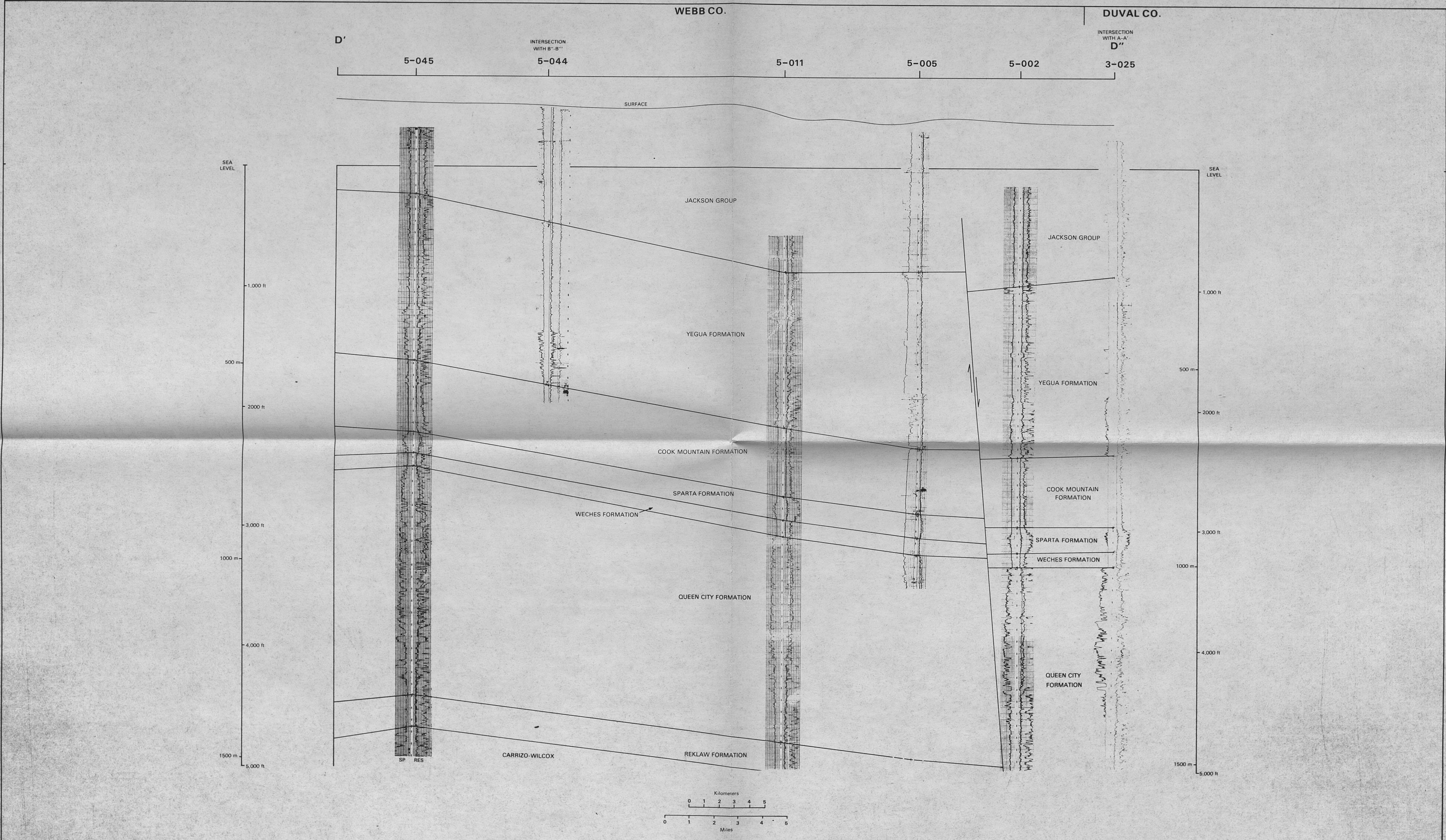


Plate 33. CROSS SECTION D'-D''

SEE PLATE 43 FOR LOCATION OF SECTION

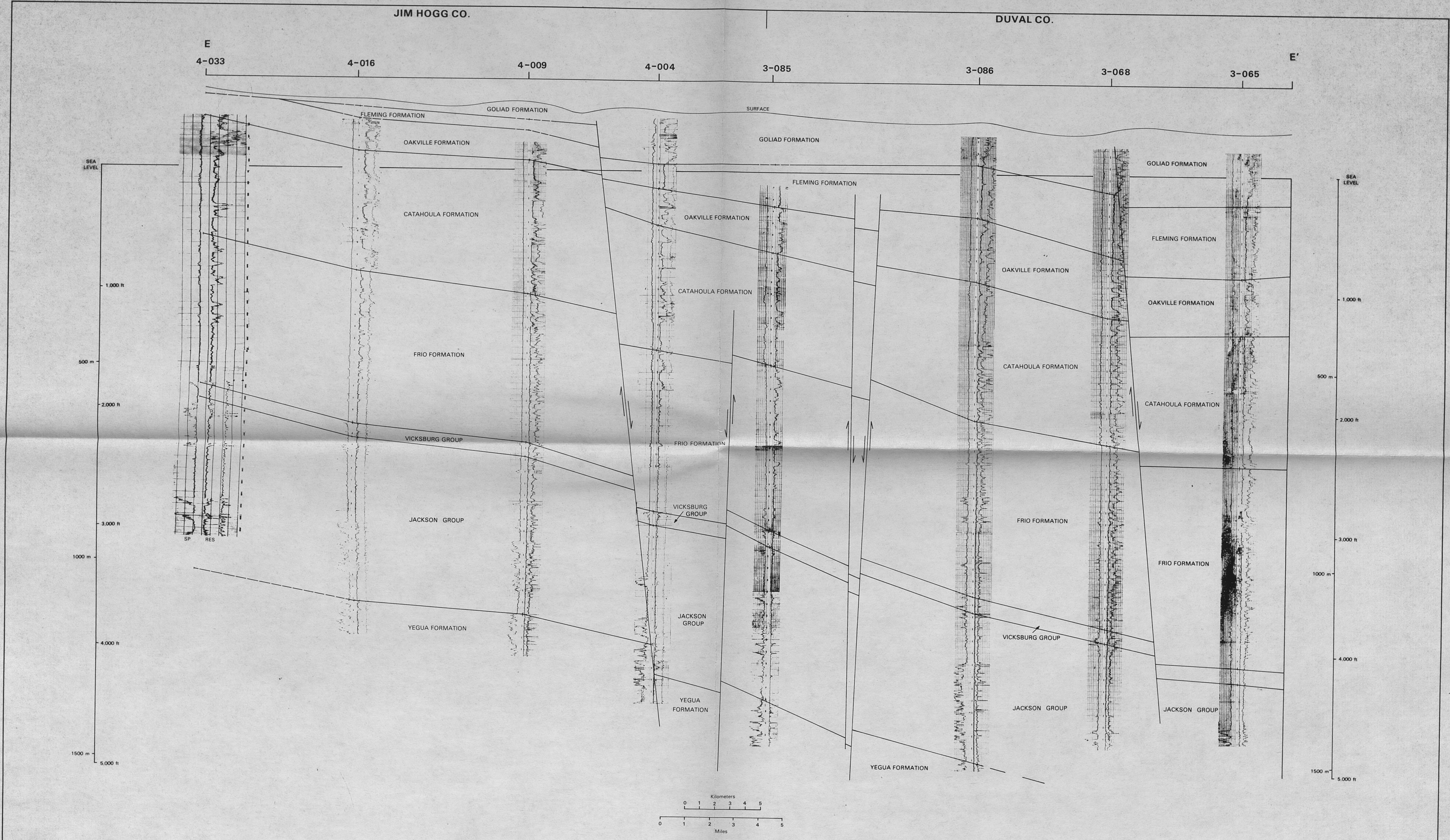


Plate 34. CROSS SECTION E-E′

SEE PLATE 43 FOR LOCATION OF SECTION

LAREDO, TEXAS

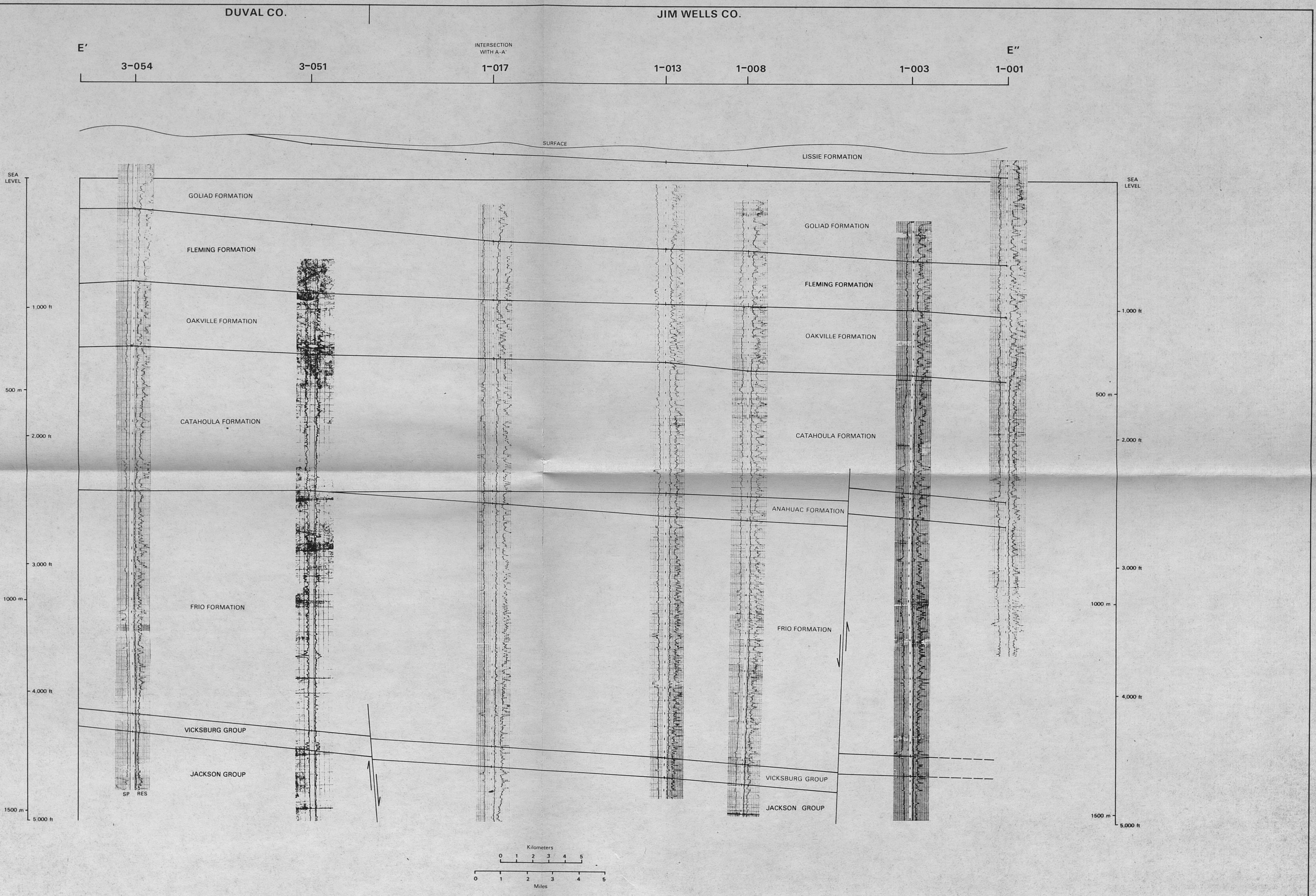
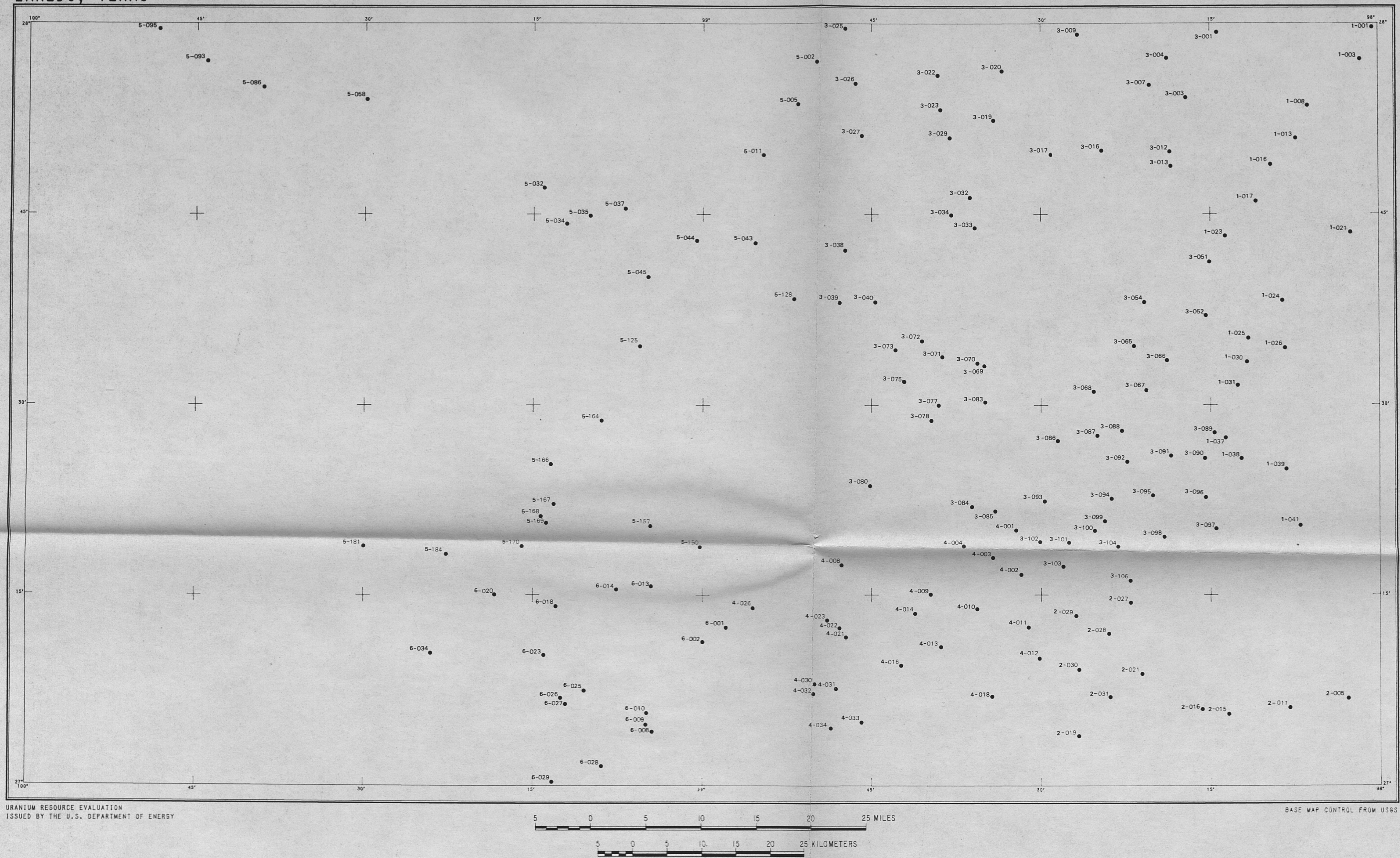


Plate 35. CROSS SECTION E'-E"

SEE PLATE 43 FOR LOCATION OF SECTION

May 1980
Plate 35.

LAREDO, TEXAS



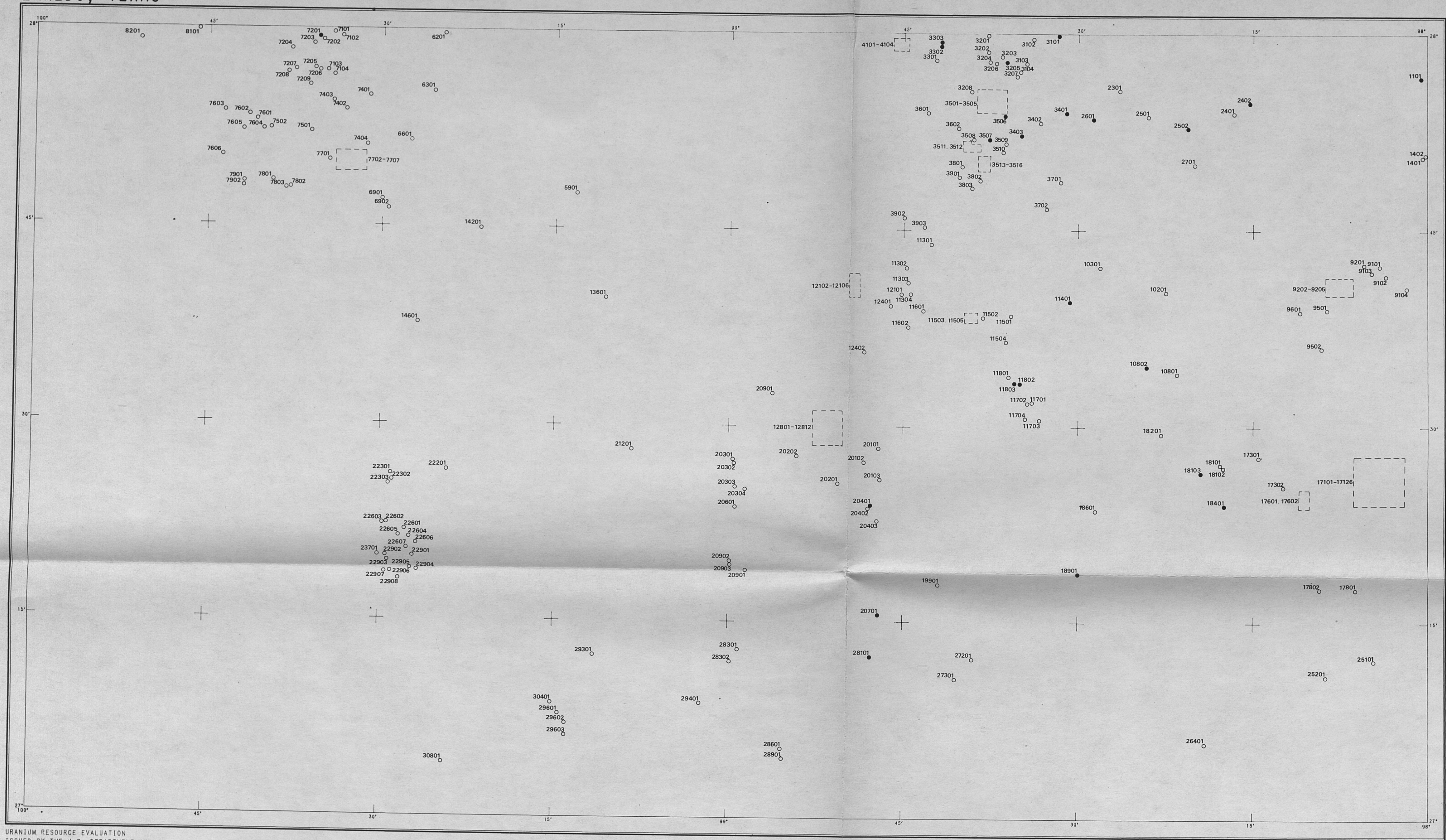
URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

Plate 36. LOCATION OF ELECTRIC WELL LOGS

May 1980
Plate 36.

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

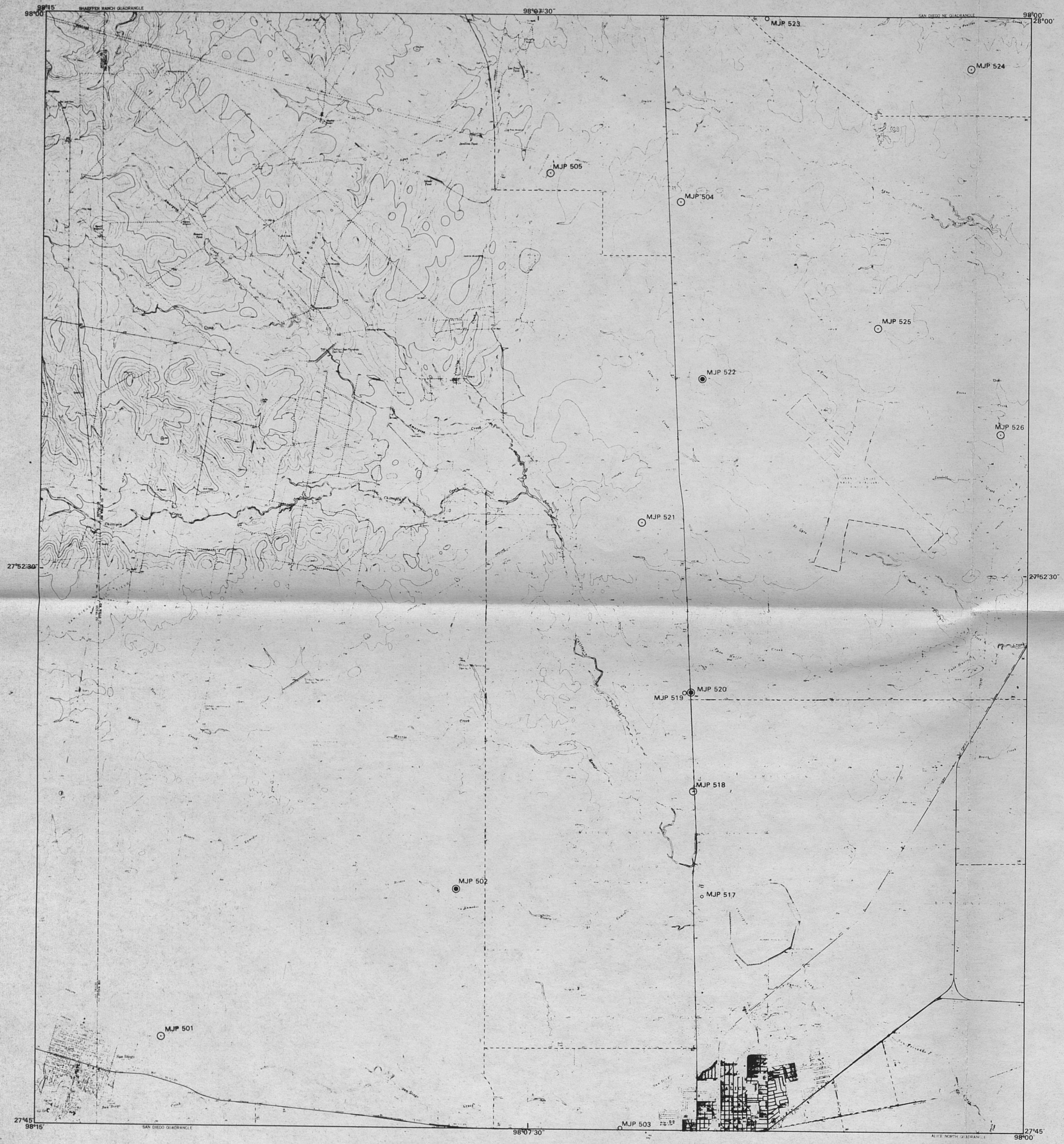
5 0 5 10 15 20 25 KILOMETERS

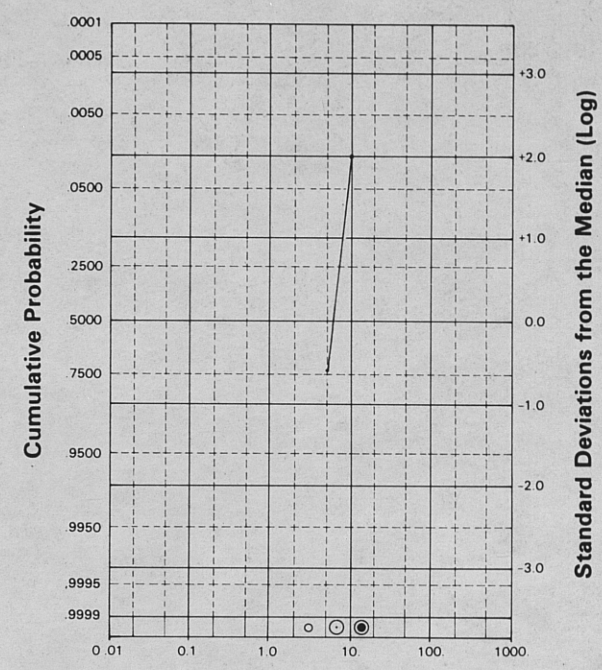
BASE MAP CONTROL FROM USGS

Plate 37. LOCATION OF GAMMA-RAY WELL LOGS

May 1980
Plate 37.

LAREDO, TEXAS





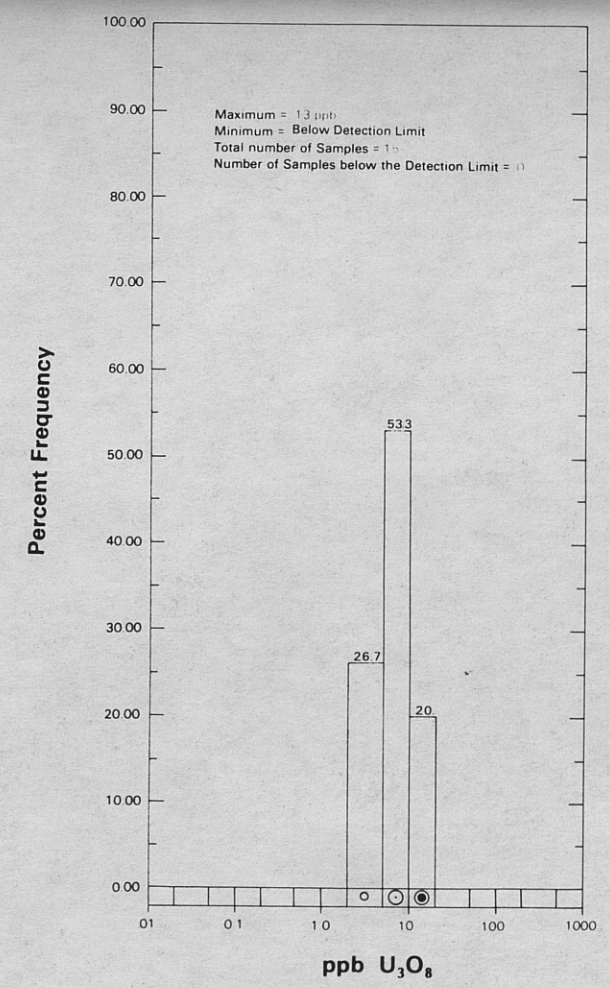
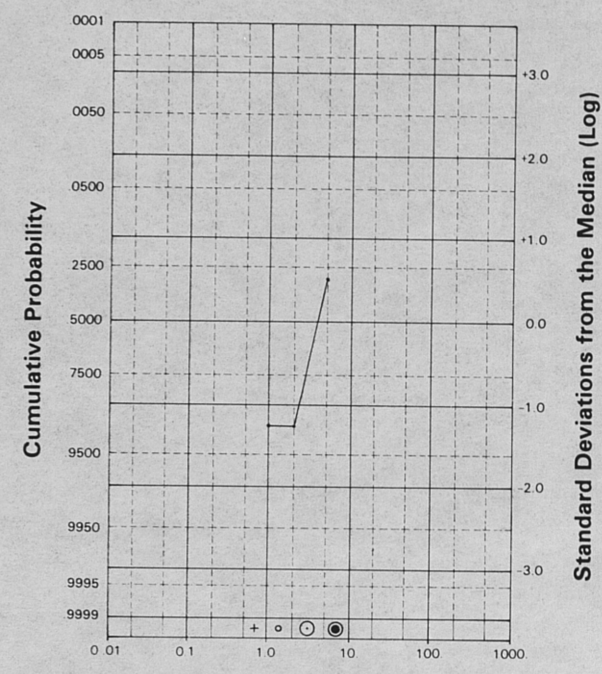


Plate 38. RESULTS OF DETAILED GEOCHEMICAL SAMPLING IN AREA 1-WELL-WATER SAMPLES

May 1980
Plate 38.

LAREDO, TEXAS



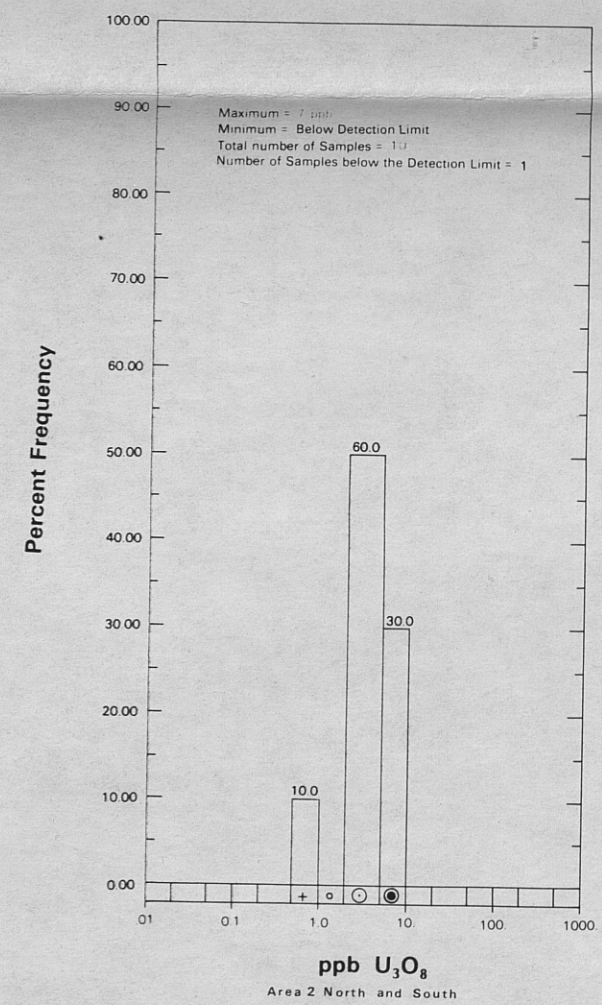
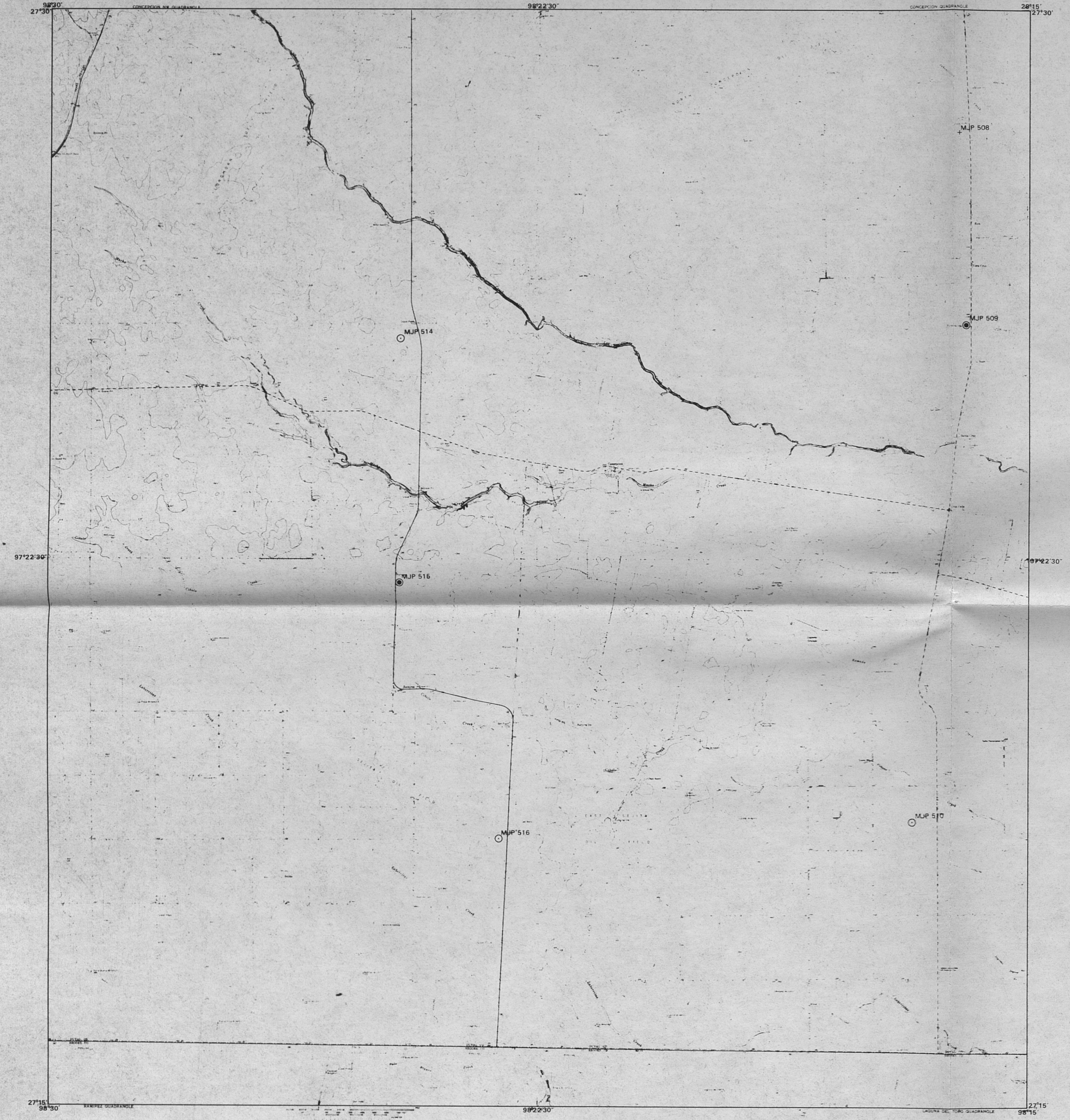


Plate 39. RESULTS OF DETAILED GEOCHEMICAL SAMPLING IN AREA 2 (NORTH)-WELL-WATER SAMPLES

LAREDO, TEXAS



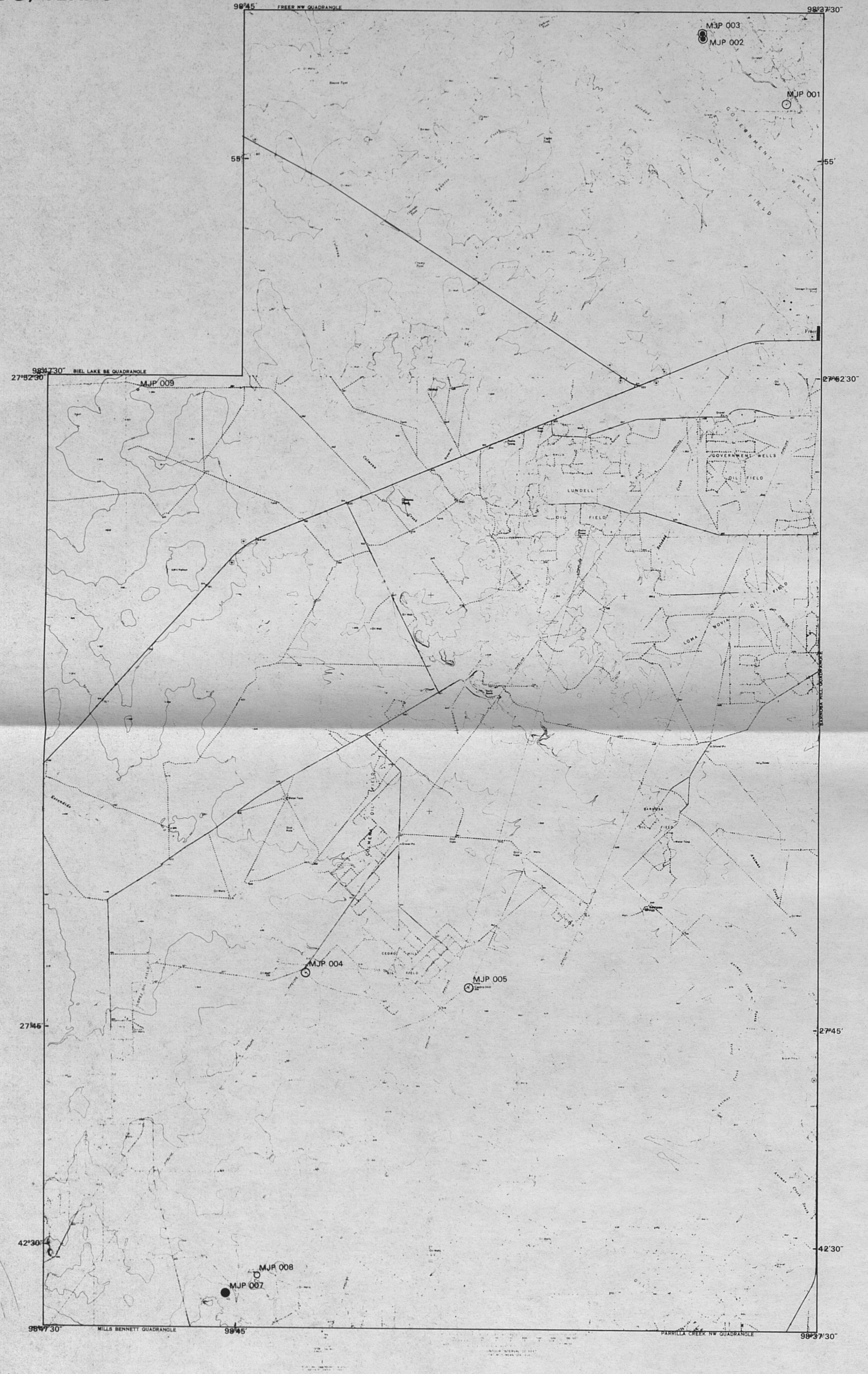
URANIUM

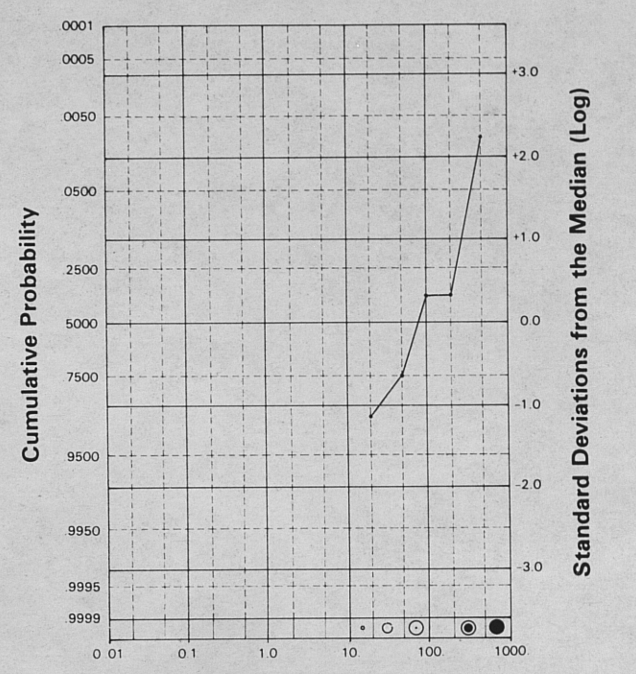
See Plate 39 for Statistical Results

Plate 40. RESULTS OF DETAILED GEOCHEMICAL SAMPLING IN AREA 2 (SOUTH)-WELL-WATER SAMPLES

May 1980
Plate 40.

LAREDO, TEXAS





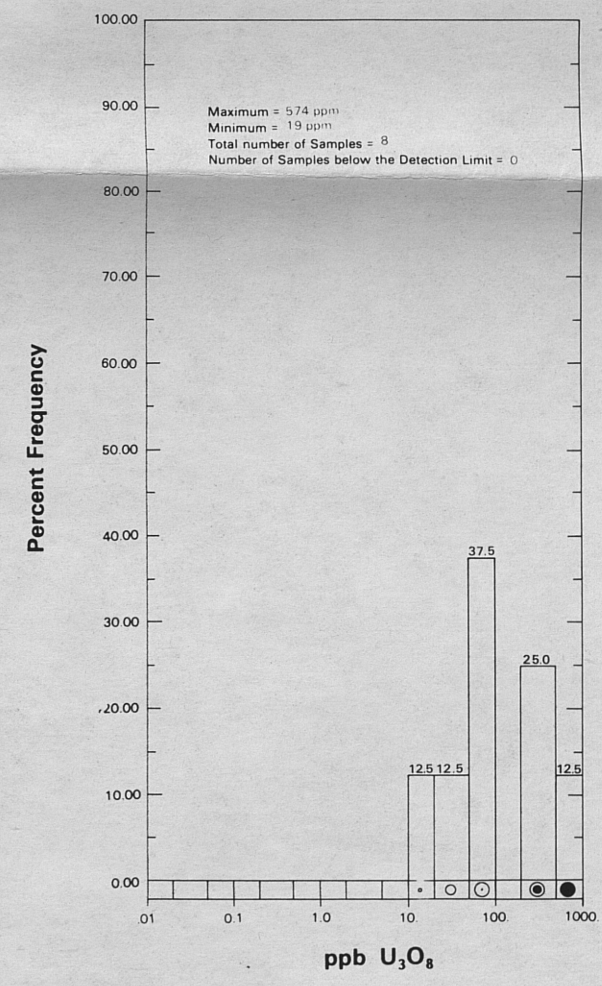
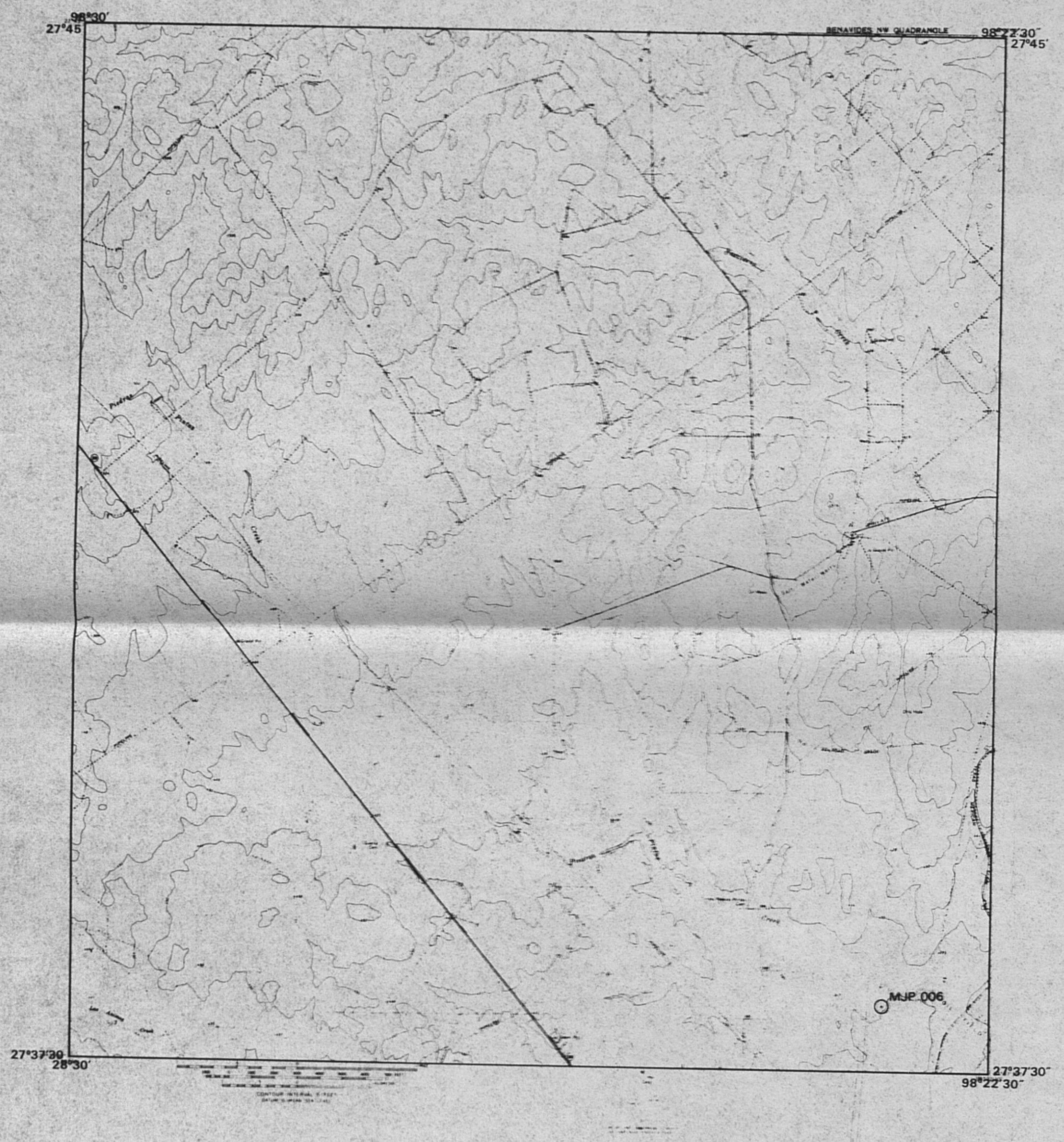
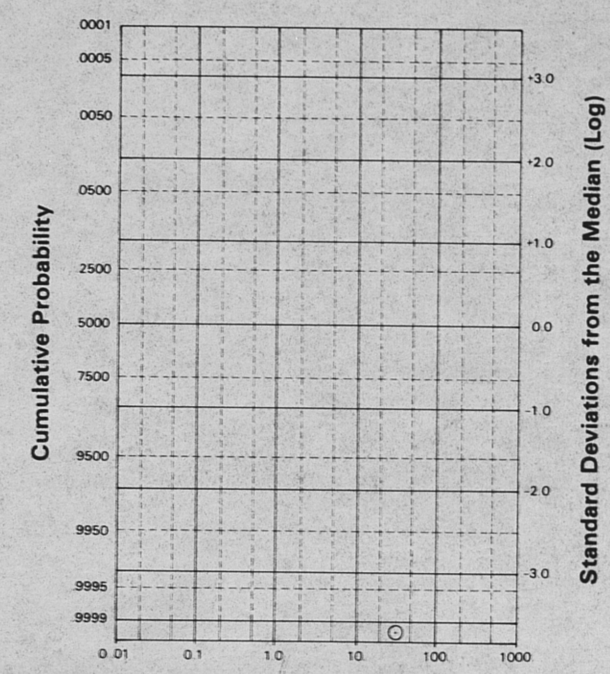


Plate 41. RESULTS OF DETAILED GEOCHEMICAL SAMPLING IN AREA 3-ROCK SAMPLES

May 1980
Plate 41.





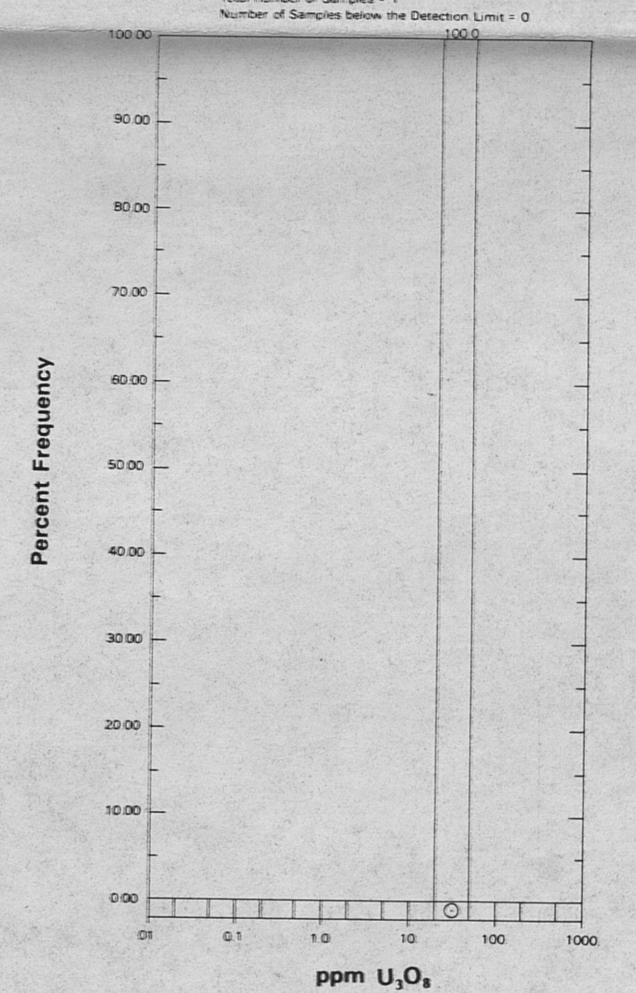
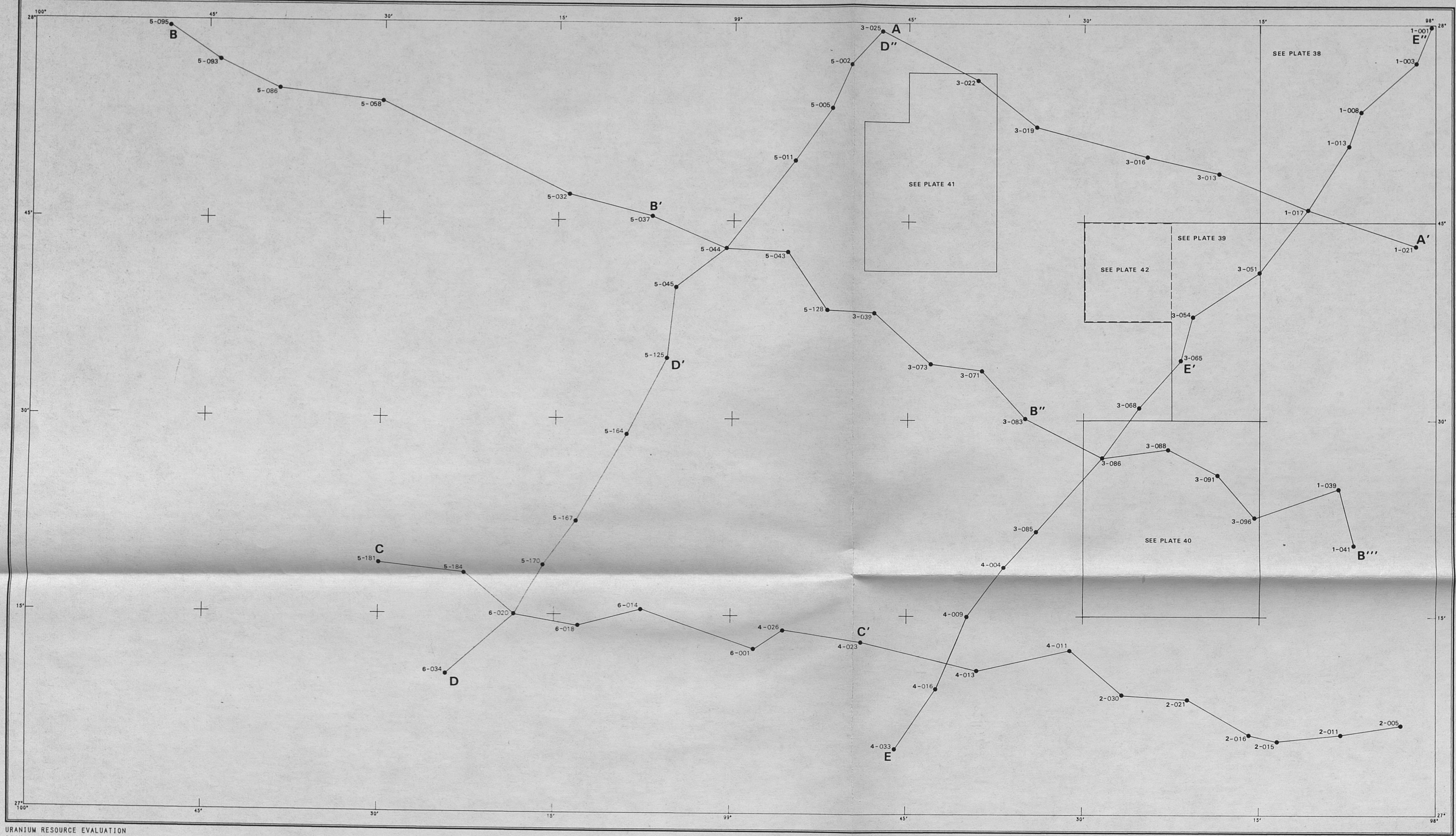


Plate 42. RESULTS OF DETAILED GEOCHEMICAL SAMPLING IN AREA 4-ROCK SAMPLES

LARADO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

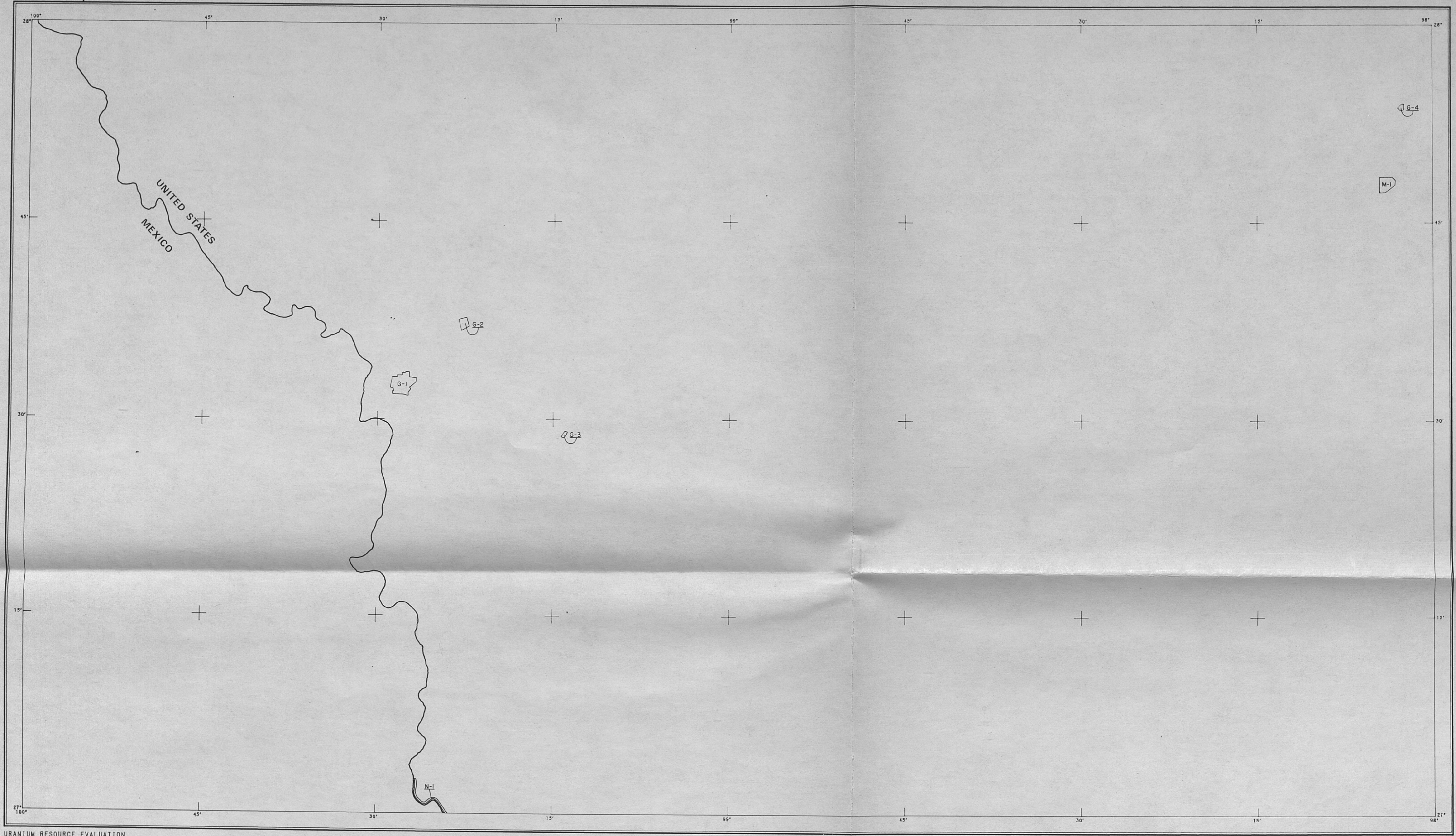
BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 43. INDEX TO LARGE-SCALE MAPS

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

EXPLANATION

G. Government Installations

- G-1 Laredo Air Force Base
- G-2 Laredo Air Force Base Test Site
- G-3 Laredo Air Force Base Auxiliary Field
- G-4 Orange Grove Naval Auxilliary Field

M. State Withdrawls

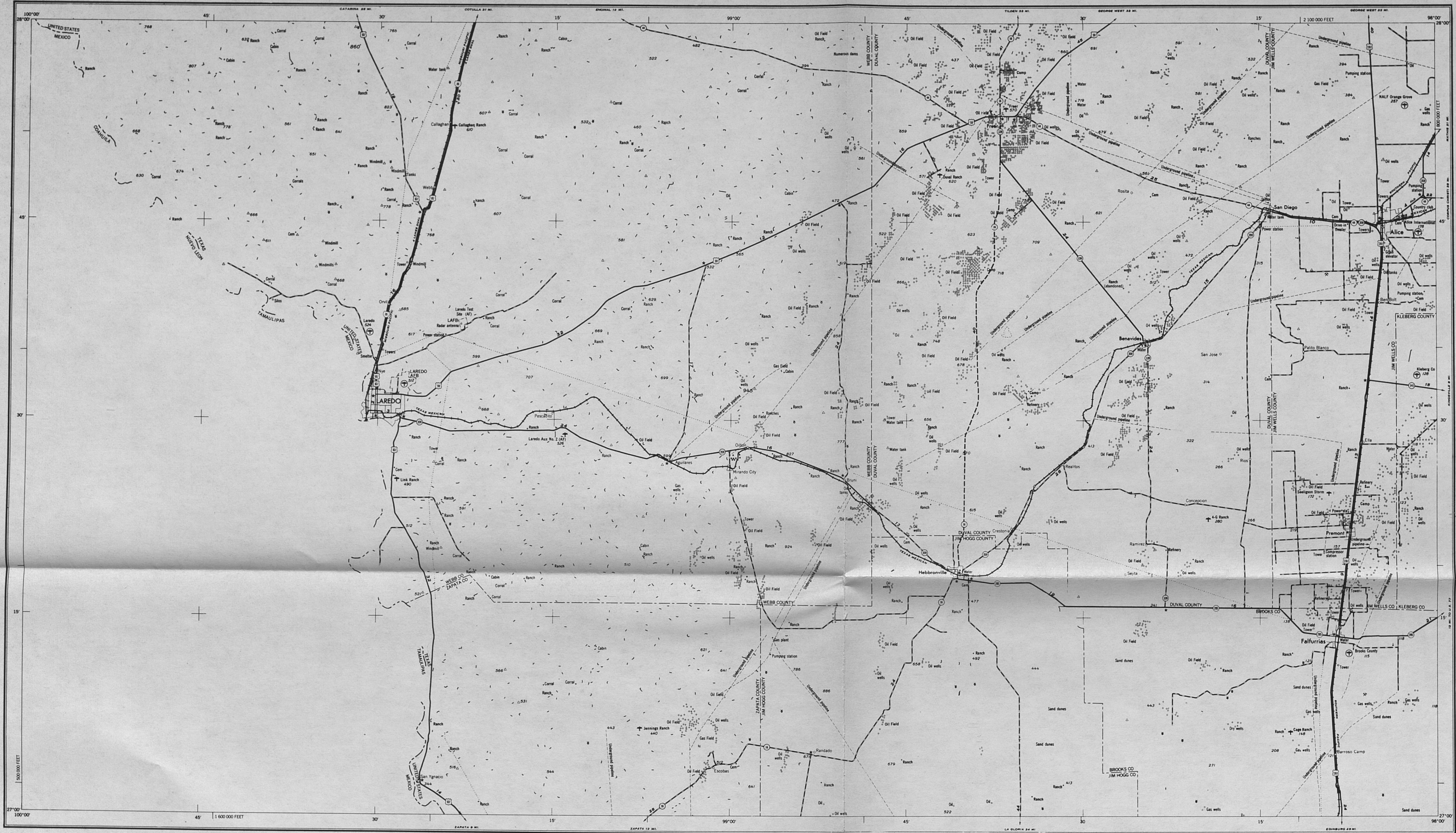
- M-1 Terminal Reservoir – Jim Wells County

N. Other Land Categories

- N-1 International Falcon Reservoir

Plate 44. GENERALIZED LAND-STATUS MAP

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

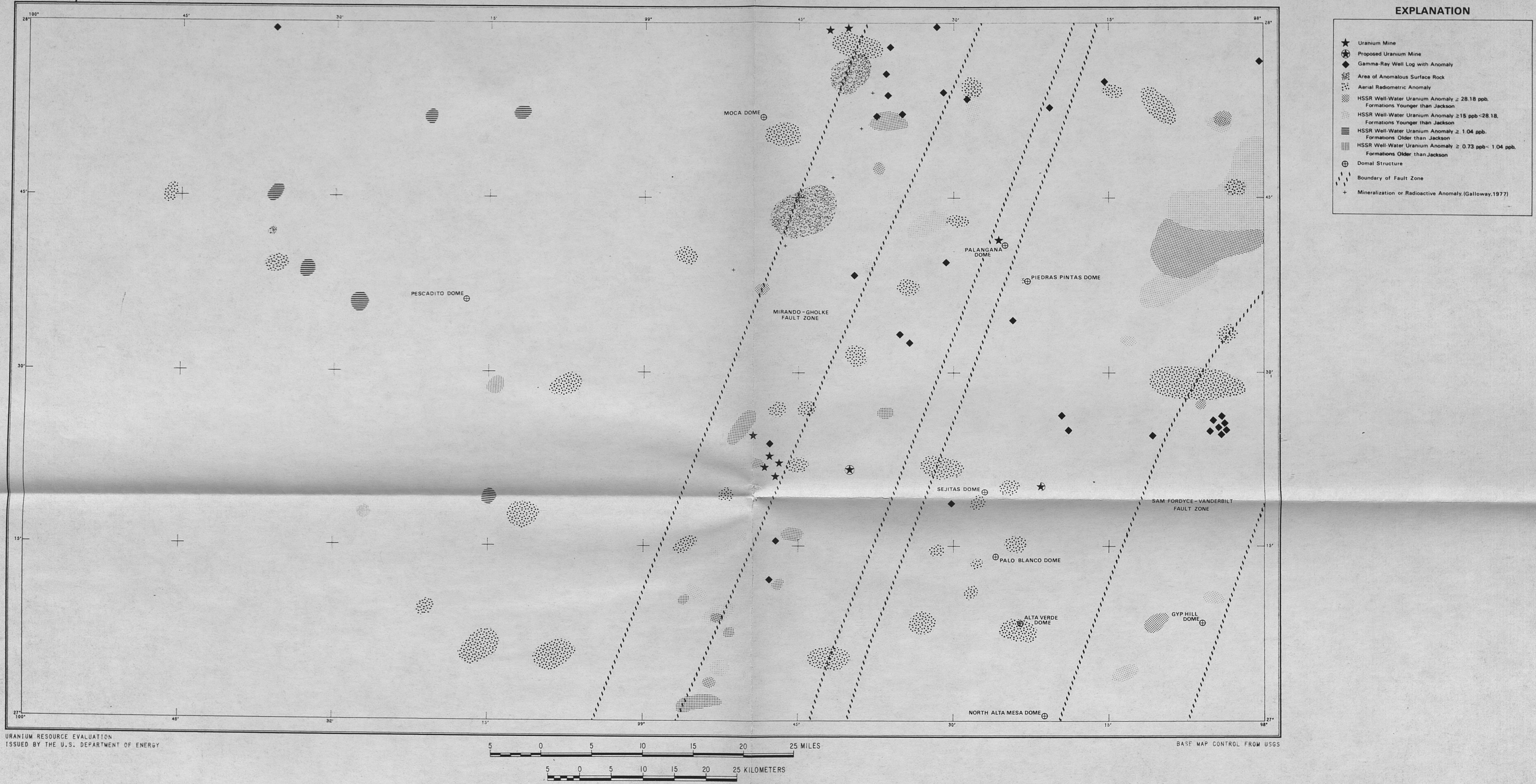
BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 45. CULTURE

LAREDO, TEXAS



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

Plate 46. COMPOSITE MAP OF SUPPORTIVE URANIUM FAVORABILITY CRITERIA

May 1980
Plate 46.