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National Uranium Resource Evaluation

MARFA QUADRANGLE TEXAS

Bureau of Economic Geology
The University of Texas at Austin
Austin, Texas

and

Bendix Field Engineering Corporation
Grand Junction, Colorado

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Assistant Secretary for Nuclear Energy
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NATIONAL URANIUM RESOURCE EVALUATION: MARFA QUADRANGLE, TEXAS

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GRAND JUNCTION AREA OFFICE
GRAND JUNCTION, COLORADO 81502

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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ABSTRACT

The uranium favorability of the Marfa 1° by 2° Quadrangle, Texas, was evaluated in accordance with criteria established for the National Uranium Resource Evaluation. Surface and subsurface studies, to a 1500 m (5,000 ft) depth, and chemical, petrologic, hydrogeochemical, and airborne radiometric data were employed. The entire quadrangle is in the Basin and Range Province and is characterized by Tertiary silicic volcanic rocks overlying mainly Cretaceous carbonate rocks and sandstones.

Strand-plain sandstones of the Upper Cretaceous San Carlos Formation and El Picacho Formation possess many favorable characteristics and are tentatively judged as favorable for sandstone-type deposits.

The Tertiary Buckshot Ignimbrite contains uranium mineralization at the Mammoth Mine. This deposit may be an example of the hydroauthigenic class; alternatively, it may have formed by reduction of uranium-bearing ground water produced during diagenesis of tuffaceous sediments of the Vieja Group. Although the presence of the deposit indicates favorability, the uncertainty in the process that formed the mineralization makes delineation of a favorable environment or area difficult. The Allen Intrusions are favorable for authigenic deposits. Basin fill in several bolsons possesses characteristics that suggest favorability but which are classified as unevaluated because of insufficient data. All Precambrian, Paleozoic, other Mesozoic, and other Cenozoic environments are unfavorable.

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INTRODUCTION

PURPOSE AND SCOPE

The Marfa Quadrangle, Texas, was evaluated to identify and delineate geologic units and areas exhibiting characteristics favorable for the occurrence of uranium deposits. Surface and subsurface data were used to evaluate all environments to a depth of 1500 m (1,500 ft). Because subsurface data in the area are sparse, evaluation of the subsurface was based primarily on extrapolation from surface data. All geologic environments within the quadrangle were classified as favorable, unfavorable, or unevaluated in accordance with the recognition criteria of Mickle and Mathews (eds., 1978). A favorable environment in this study is defined as one that could contain at least 100 tons U_3O_8 in rocks with an average grade of at least 100 ppm U_3O_8.

Evaluation of this quadrangle was a joint effort of Bendix Field Engineering Corporation (BFEC) and the University of Texas at Austin, Bureau of Economic Geology (BEG) for the National Uranium Resource Evaluation (NURE) program. NURE is managed by the Grand Junction, Colorado, office of the Department of Energy. BFEC was responsible for evaluation of pre-Tertiary rocks, which are predominantly sedimentary rocks, and BEG was responsible for evaluation of Tertiary rocks; which are predominantly igneous or igneous-derived sedimentary rocks.

ACKNOWLEDGMENTS

Discussions with other geologists, particularly A. W. Walton (University of Kansas), J. A. Wilson (The University of Texas at Austin), Pat Kenney of Marfa, Texas, W. E. Bourbon of Alpine, Texas, James A. Wolleben, formerly head of the Geology Department at Sul Ross State University, Alpine, Texas, students at Sul Ross State University, and students at the University of Texas at El Paso helped the authors clarify their ideas on regional geology.

The staff of the Bureau of Economic Geology, Austin, was very helpful and cooperative during all phases of the investigation. Of particular assistance were Drs. L. F. Brown, Jr., and V. E. Barnes.

Many landowners in the Marfa Quadrangle are thanked for allowing access to their property to examine geologic relationships, to examine uranium occurrences or radiometric anomalies, and to collect geochemical samples. Without their cooperation this study could not have been done.

PROCEDURES

During Phase I, previously published literature was reviewed, and a compilation was made of maps and information on uranium occurrences. During Phase II, literature research continued and field work was performed. Field work consisted of (1) examination known uranium occurrences and areas of anomalously high radioactivity, as reported in Preliminary Reconnaissance Reports (PRR's) of the U.S. Atomic Energy Commission (AEC); and, (2) identification and examination, on the basis of geologic inference and the literature, of other areas of potential mineralization. Rock samples (App. B) and scintillometer readings were taken at each accessible occurrence and also randomly throughout the quadrangle. A Scintrex GAD-6 gamma-ray spectrometer with a 3-inch sodium iodide crystal was used locally. After initial reconnaissance, scintillometer traverses were run and samples were collected for geochemical analysis.

Fluorometric determination of chemical U_3O_8 content and emission spectrography for 29 elements were obtained for all rock samples. Analyses were performed at three laboratories: Skyline Labs (Tucson, Arizona); Core Laboratories (Albuquerque, New Mexico); and the BFEC laboratory in Grand Junction performed emission spectrographic analysis and U_3O_8 determination. Eight samples were analyzed using the gamma spectroscopy method.

Subsurface data consisted almost entirely of electric logs from widely spaced hydrocarbon tests.

Integral parts of the evaluation consisted of incorporation of airborne radiometric data (LKB Resources, 1979), hydrogeochemical and stream-sediment reconnaissance (Union Carbide, 1978a and b; Butz and others, 1979), and detailed studies into a geologic framework.

Some of the samples collected were analyzed at Mineral Studies Laboratory under the supervision of Dr. Clara Ho. Uranium analysis was by a total-fusion fluorometric procedure. Multi-element analysis for 30 elements was by inductively coupled argon plasma spectrometer. In addition, some samples were sent to Uranium West Laboratory for analysis of uranium and thorium by neutron activation. Splits of all samples were sent to Grand Junction for analysis by gamma-ray spectroscopy.

GEOLOGIC SETTING

The Marfa Quadrangle, an area of 11,000 km^2 (4,200 mi^2), is located in the southern Basin and Range Province of Trans-Pecos Texas (Fig. 1). The area is bounded on the east by long 104°W. and on the north and south, respectively, by lat 31°N. and 30°N. The Rio Grande River, which forms the western boundary, roughly follows the boundary between the Basin and Range Province and the Chihuahua Tectonic Belt. This belt is a Mesozoic depocenter complexly deformed during Laramide time. Physiographically, the western half of the quadrangle consists of a series of mountain ranges separated by fault-bounded basins. The northeastern half is occupied by the Davis Mountains, which are largely unaffected by Basin and Range faulting. Rocks in the quadrangle range in age from Precambrian to Recent.

Precambrian Rocks

Precambrian rocks crop out only in the north-central part of the quadrangle. The largest exposures are in the Carrizo Mountains, which is one of the structurally highest parts of Trans-Pecos Texas. Smaller outcrop areas occur in the Wylie Mountains to the east, the Van Horn Mountains to the south, and the Eagle Mountains to the west of the Carrizo Mountains. Precambrian

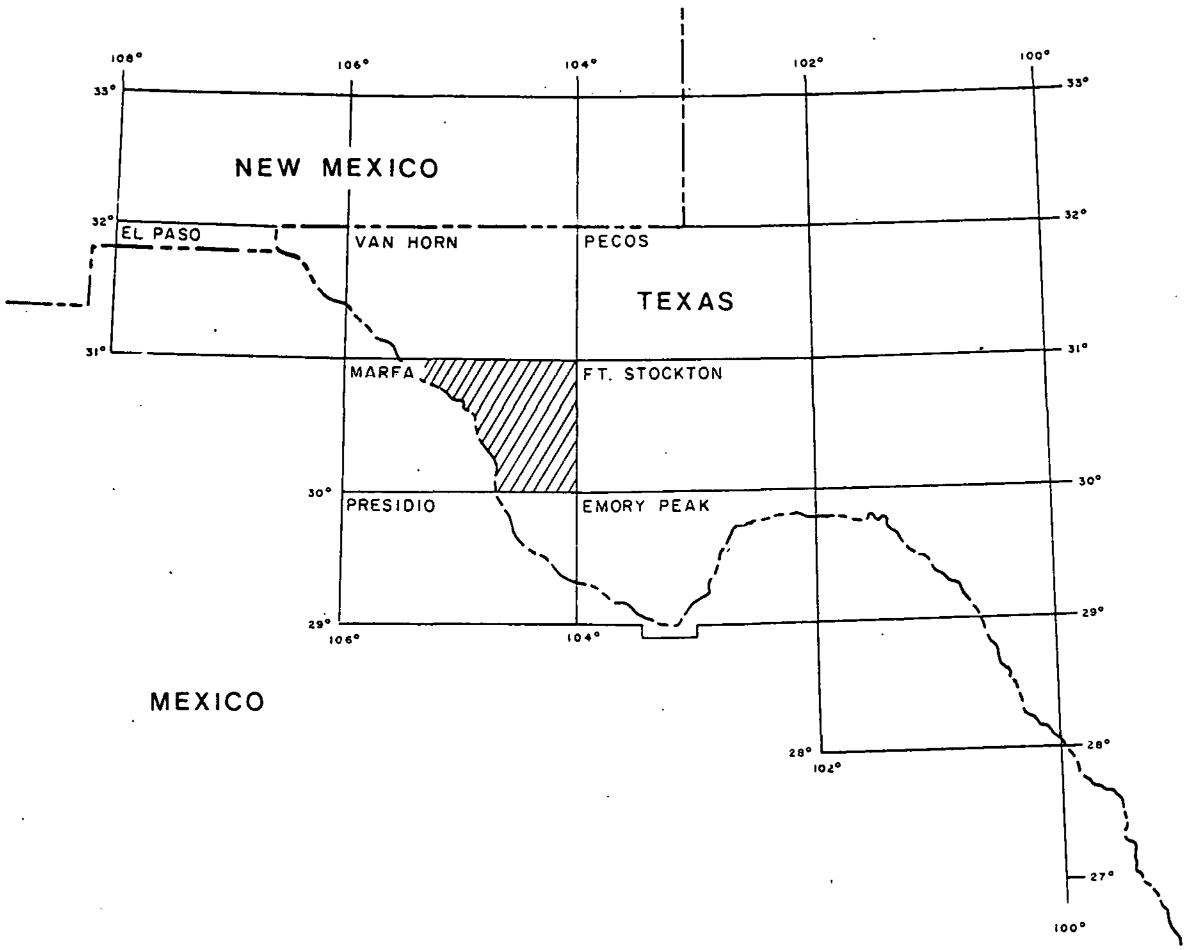

Figure 1. Marfa Quadrangle location map.

rocks consist of a thick sequence of metamorphosed sedimentary rocks (limestone, phyllites, schists, and quartzites), that are intruded by metamorphosed rhyolite and diorite. This sequence is thrust to the north over a thick sequence of limestone, volcanic rocks, and sandstone that has also undergone extreme deformation. The age of the rocks is late Precambrian; although, there is evidence of previous deformation. Alluvium, now designated Van Horn Sandstone (McGowen and Groat, 1971), was deposited after Carrizo Mountain deposition. Thickness of the formation in the Marfa Quadrangle is undetermined (Fig. 2). Precambrian rocks occur in the subsurface throughout much of the quadrangle. Details of Precambrian geology are summarized by King and Flawn (1953), Hay-Roe (1957), Twiss (1959), and Underwood (1963).

Paleozoic rocks

The Permian System is represented by two distinct facies. The first facies is composed chiefly of pure to slightly silty shelf carbonates; these crop out in the Delaware Basin, Guadalupe Mountains, and the extreme northwestern portion of the Marfa Quadrangle. This facies is represented by the Hueco and Victorio Peak Limestones and the Seven Rivers Formation. The second facies consists of the Cibolo, Pinto Canyon, Ross Mine, and Mina Grande Formation. The "dirty" (sandy, cherty, shaly, and, at places, conglomeratic carbonate) facies is present to the south of the "clean" facies and crops out chiefly in Pinto Canyon and in the Presidio Quadrangle to the south (Fig. 3). The "dirty" facies represents marine environments of varying subsea depth. The increased volume of terrigenous admixture, reflecting increased detrital influx to the south, may be associated with local uplifts of sedimentary rocks originally deposited in the early Paleozoic Ouachita Geosyncline.

Approximately 1800 m (6,000 ft) of Permian rocks are preserved in the quadrangle. About 1000 m (3,300 ft) of sandstone, shale, and conglomerate in the south part of Pinto Canyon are thought to be of Late Pennsylvanian age (Amsbury, 1958) and are designated the Cieneguita Formation (Jones and Reaser, 1970).

The "dirty" Permian facies is host for the silver and base-metal deposits at Shafter, Texas, in the Presidio Quadrangle. There are no known silver, base-metal, or uranium occurrences in Permian rocks of the Marfa Quadrangle.

Cretaceous Rocks

Cretaceous sedimentary rocks are divided into two megafacies: (1) an Early Cretaceous, Bahama-like, complex of carbonates; and, (2) a Late Cretaceous sequence of fluvial and strand-plain sandstone, prodelta clay, and minor, very shallow water carbonates. In contrast to the Permian, this division is temporal, not geographic. Cretaceous rocks of equivalent age are similar throughout the quadrangle. The lithology differs slightly but not significantly.

Early Cretaceous carbonate deposition was interrupted only occasionally by influx of sand, mud, and gravel. Clastics become finer grained and less abundant higher in the sequence. Early Cretaceous time tectonically was the

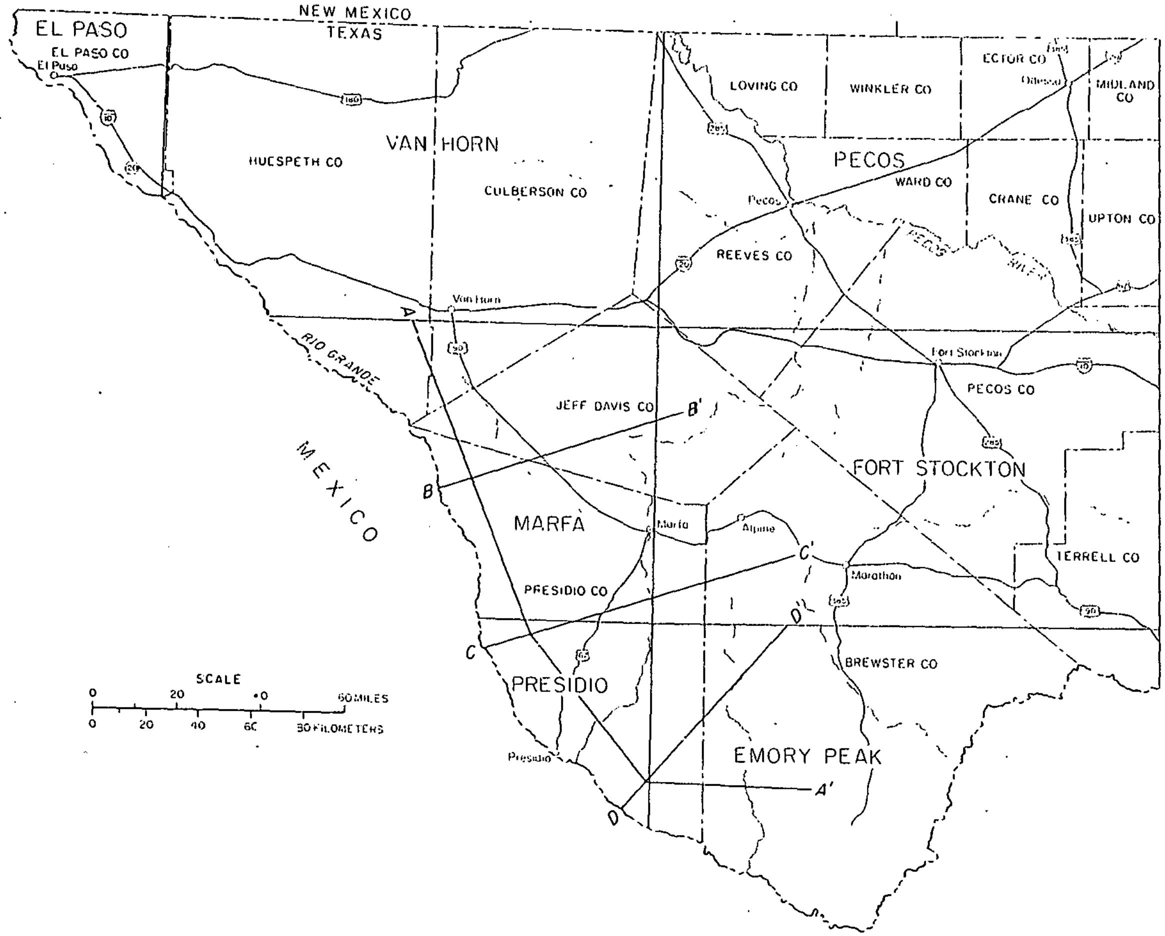

Figure 2. Cross section location map.

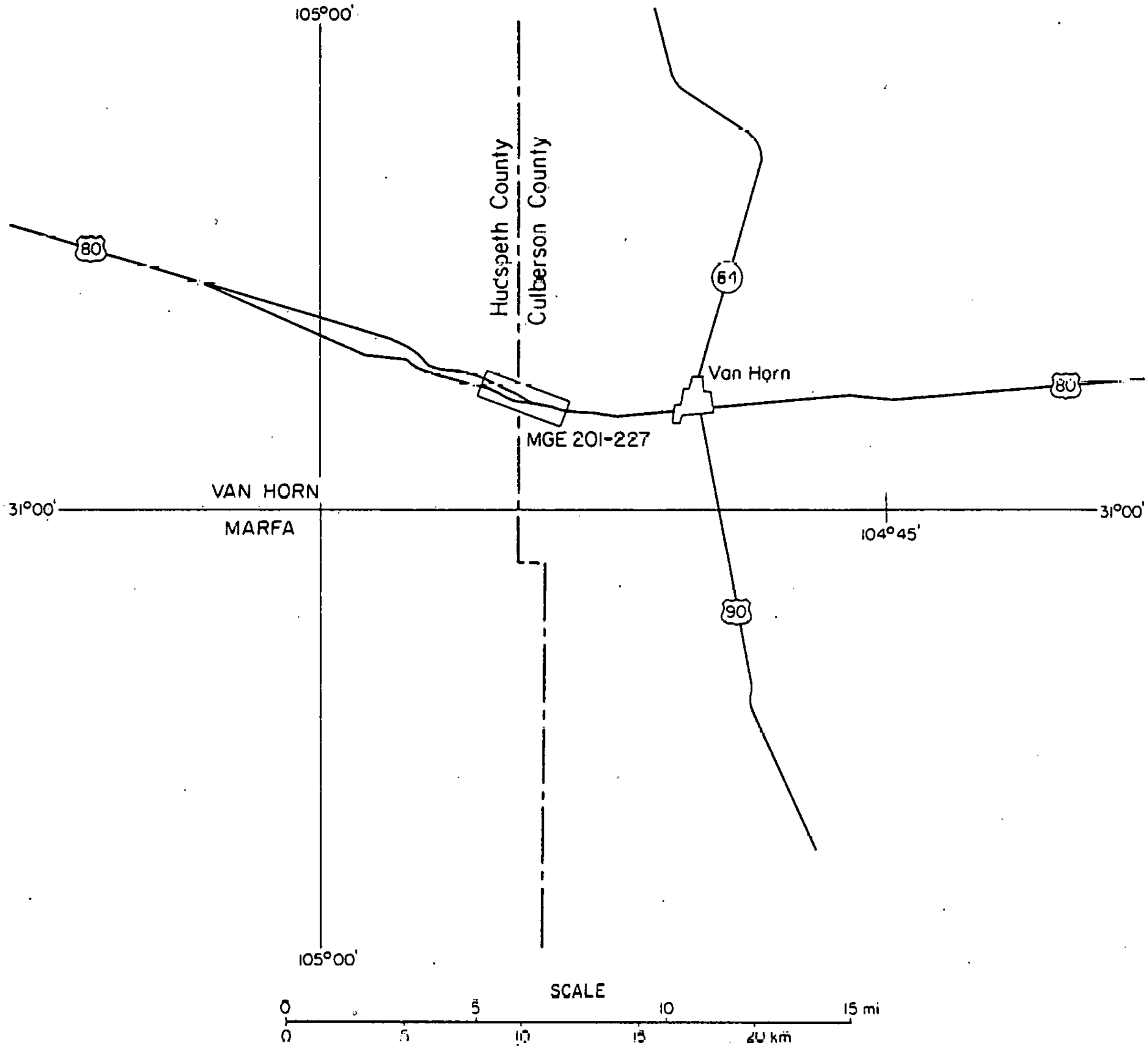

Figure 3. Geochemical (rock) sample locations in Van Horn Quadrangle.

most stable period and is represented by sedimentary rocks in the Marfa Quadrangle. Total thickness of the Early Cretaceous is several thousand meters.

Deposition of the Ojinaga Formation, which is a prodelta black shale, marked the beginning of the Late Cretaceous regression. Progradation, chiefly from the west (Weidie and others, 1972), culminated in the mainly continental El Picacho Formation. Continental depositional environments existed earlier in the Cretaceous, mainly at the time of deposition of the Cox Sandstone; but, these environments were relatively short-lived and were intertongued with thicker marine carbonates.

Total thickness of the progradational unit, from the base of the Ojinaga Formation to the base of the overlying Tertiary volcanic pile, is about 1000 m (3,300 ft; Fig. 4).

Tertiary Rocks

The Tertiary rocks are predominantly volcanic rocks or volcaniclastic sediments. Intrusive rocks occur almost exclusively in a few volcanic centers in the Davis, Wylie, and Eagle Mountains and near the southwest corner of the quadrangle. In general, several volcanic centers (both within and outside the quadrangle) produced thick sequences of lava flows and ash-flow tuffs. Thick sequences of water-laid and minor air-fall tuffs, separated by a few, thin ash-flow tuffs and lava flows, accumulated in basins between eruptive centers. The Davis Mountains are the major volcanic center in the area, but the Chinati Mountains in the Presidio Quadrangle immediately to the south probably provided much of the volcaniclastic sediment within the quadrangle. Smaller volcanic centers occur in the Eagle Mountains and the Wylie Mountains; another center, which provided some volcanic material to the quadrangle, occurs in the northern Quitman Mountains just off the northwest edge of the quadrangle.

The Davis Mountains consist of a series of alkalic, silicic flows and pyroclastic units with subordinate mafic flows (Fig. 5). Major activity was limited to a period between 38 m.y. and 35 m.y. ago (Parker and McDowell, 1979), but other volcanic units are of late Eocene to Oligocene age. The volcanic rocks were intruded by stocks, sills, and dikes of the same compositional range during the latter part of the eruptive period. No calderas have been positively identified in the Davis Mountains within the Marfa Quadrangle; however, the presence of numerous major ash-flow tuffs suggests that calderas must occur there.

The Chinati Mountains and an area around them, including parts within the Marfa Quadrangle, were volcanic centers through much of the Tertiary (Fig. 6). Documented volcanic activity in the Chinati is, for the most part, around 31 m.y. old (Cepeda, 1979); but reconnaissance by the authors showed the presence of an older resurgent caldera, partly truncated by the Chinati Caldera, along the south-central border of the quadrangle. Also several small rhyolite-porphyry intrusions occur along the south border of the quadrangle.

The Eagle Mountains appear to be a resurgent caldera, which have a thick sequence of caldera-filling ash-flow tuff. Volcanic rocks derived from this caldera have been largely eroded in the Eagle Mountains vicinity. The Wylie

SYSTEM	SERIES	FORMATION OR GROUP	MEMBER	LITHOLOGY	DESCRIPTION
CRETACEOUS	UPPER	El Picacho Formation			Claystone, sandstone, and lignite
		San Carlos Sandstone			Sandstone; some clay and coal
		Boquillas Limestone / Ojinaga Formation			Boquillas: Limestone, marl, and shale Ojinaga: Black shale
	LOWER	Buda Limestone			Limestone
		Del Rio Clay / Eagle Mountain Sandstone			Del Rio: Interbedded marl and limestone Eagle Mountain: Fine-grained, calcareous sandstone
		Espy Limestone / Loma Plata Limestone / Boracho Limestone			Espy: Flaggy to thick-bedded limestone Loma Plata: Thin- to thick-bedded limestone Boracho: Thick bedded limestone
		Benevides Formation			Shale; thin limestone beds
		Finlay Limestone			Thick-bedded to massive limestone
		Cox Sandstone			Sandstone; some shale
		Bluff Mesa Formation			Fine-grained, thin-bedded to massive limestone; some sandstone and shale
		Yucca Formation			Microgranular limestone; some sandstone and shale
PERMIAN	GUADALUPIAN	Mina Grande Formation			Massive, dolomitic limestone
		Ross Mine / Seven Rivers			Sandstone, limestone, shale, chert
		Pinto Canyon Formation			Siltstone, limestone, bituminous shale; some chert and pyrite
	LEONARDIAN	Cibolo Formation / Victorio Peak Formation			Limestone and dolomitic limestone
	WOLFCAMPIAN	Hueco Limestone			Thin-bedded limestone
			Powwow Conglomerate		Conglomerate, sandstone, siltstone, limestone
		Alta Formation			Mudstone and sandstone
PRECAMBRIAN		Van Horn Sandstone			Feldspathic sandstone and arkose
		Carrizo Mountain Group			Interbedded metaigneous and metasedimentary rocks

Figure 4. Generalized regional stratigraphic column.

SYSTEM	SERIES	FORMATION	MEMBER	LITHOLOGY	DESCRIPTION
TERTIARY	OLIGOCENE	Petan Basalt (Tpe)			Trachyandesite porphyry, up to 500 feet thick
		Brooks Mountain (Tbm)			Fine-grained to aphanitic porphyritic trachyte, up to 985 feet thick
		Goat Canyon (Tgc)			Porphyritic-aphanitic trachyte, up to 515 feet thick
		Wild Cherry (Twc)			Densely to poorly welded ash-flow tuff, porphyritic rhyolite, up to 355 feet thick
		Mount Locke (Tml)			Quartz trachyte and rhyolite porphyry, up to 580 feet thick
		Barrell Springs (Tbs)			Densely to poorly welded ash-flow tuff, porphyritic rhyolite, up to 250 feet thick
		Wild Cherry & Barrell Springs undivided			The Mount Lake Formation is absent and the remaining formations become similar in Locke appearance, up to 600 feet thick
		Merrill (Tmer)			Latite porphyry, up to 130 feet thick
		Sheep Pasture (Tsp)			Slightly porphyritic rhyolite, indurated to friable, up to 510 feet thick
		Adobe Canyon (Tac)			Rhyolite and trachyte lava flows, up to 1,000 feet thick
	?	Gomez Tuff (Tg)			Peralkaline, densely to poorly welded, ash-flow tuff, abundant xenoliths, up to 1,200 feet thick
	EOCENE	Huelstar (Th)			Densely to poorly welded ash-flow tuff, tuffaceous sandstone, siltstone and conglomerates, up to 490 feet thick

Figure 5. Stratigraphic column Tertiary rocks of the Davis Mountains area.

SYSTEM	SERIES	FORMATION	MEMBER	LITHOLOGY	DISCRIPTION
QUATERNARY	PLEISTOCENE PLIOCENE MIOCENE	Bolson Fill QTb			Conglomerate, sandstone, and mudstone, filling fault-bounded basins, up to 4,000 feet thick
TERTIARY	OLIGOCENE	Perdiz Conglomerate Tpc			Alternating conglomerate and tuffaceous sandstone, up to 500 feet thick
		Petan Basalt Tpe			Trachyandesite porphyry, possibly correlative with Tcm5, up to 300 feet thick
		CHINATI MOUNTAINS GROUP (Tcm)	Tcm 6		Upper rhyolite, peralkaline ash-flow tuff, greater than 500 feet thick
			Tcm 5		Upper trachyte, lava flows, up to 900 feet thick
			Tcm 4		Lower rhyolite, lava flows, up to 500 feet thick
			Tcm 3		Middle trachyte, lava flows, up to 1,000 feet thick
			Tcm 2		Lower trachyte, lava flows, up to 500 feet thick
			Tcm 1		Limestone conglomerate, up to 100 feet thick
		Mitchell Mesa (Tmm)			Densely to poorly welded ash-flow tuff, up to 300 feet thick
		SHELY GROUP (Tsh)	Tsh8		Rhyolitic ash-flow tuff, up to 250 feet thick
			Tsh6		Rhyolitic ash-flow tuff, up to 250 feet thick
			Tsh5		Tuffaceous sandstone, siltstone, and conglomerate rhyolitic lava flows; up to 300 feet thick
			Tsh 4		Mud-flow breccia, up to 50 feet thick
			Tsh 3		Rhyolite ash-flow tuff, up to 70 feet thick
			Tsh 2		Trachyte lava flows, up to 400 feet thick
			Tsh 1		Tuffaceous sandstone, siltstone, and conglomerate up to 1,500 feet thick, correlative with Capote Mountain Tuff (Tca)
	OLIGOCENE ? EOCENE	DIPPER * (Tdip)			Rhyolitic to intermediate lava flows, Rhyolitic ash-flow tuffs, mudflow breccias; thickness greater than 2,000 foot, fills Dipper Caldera * Age relations between Tdip and Tm are unknown; both directly overlie Cretaceous rocks but do not contact each other
	EOCENE	MORITA * RANCH (Tm)			Rhyolite and basalt lava flows and rhyolitic ash-flow tuffs, up to 800 feet thick

Figure 6. Stratigraphic column, Tertiary and Quaternary rocks of the Chinati Mountains area.

Mountains may also be a caldera; but, now they are so highly dissected that only a central intrusion, possibly a resurgent dome, remains. Volcanic rocks of the Garren Group, south of the Wylie Mountains, may have been erupted from this area.

Much of the volcanic material in the quadrangle consists of tuffaceous sediment of the Vieja Group in the Sierra Vieja and various equivalents in the south and southeast parts of the quadrangle. The Vieja Group is divided into three sedimentary formations that are separated by an ash-flow tuff and a major rhyolitic lava flow. Probably all of the volcanic centers discussed above contributed material to the sediments at various times. The major sources were in the Davis and Chinati Mountains; lesser amounts were added from the Eagle and Wylie Mountains.

The Mitchell Mesa Welded Tuff was erupted from the Chinati Caldera about 31 m.y. ago. It caps the Vieja Group throughout much of the Sierra Vieja and is the major ash-flow tuff of Trans-Pecos Texas. It also caps the undifferentiated Pruett-Duff Formations in the southeastern part of the quadrangle. The Pruett and Duff Formations are time-equivalent to the Vieja Group sediments; continuity of the two sequences beneath younger rocks in the south-central part of the area is uncertain.

The Tascotal Formation overlies the Mitchell Mesa in the southern part of the area. It was deposited as an alluvial fan of tuffaceous sediment derived from the Chinati Mountains during waning stages of pyroclastic activity (Walton, 1979).

Total thickness of the tuffaceous sedimentary sequence ranges up to 1000 m (3,300 ft) in the central part of the Sierra Vieja (Fig. 7). Open-hydrologic-system diagenesis has converted the initially glass-rich tuffaceous sediments to a zoned assemblage of montmorillonite, opal, calcite, and zeolites. Glass was preserved only in upper parts of the Vieja Group in the southern Sierra Vieja and in the upper part of the Tascotal Formation. Diagenesis probably occurred penecontemporaneously with deposition of the sediments.

The Petan Basalt caps the Mitchell Mesa or the Tascotal Formation in the southern part of the quadrangle. Several similar basalts, for instance those at the western edge of the Davis Mountains and north to the Wylie Mountains, have been correlated with the Petan.

The Perdiz conglomerate is a thick alluvial fan composed of volcanic debris shed from the Chinati Mountains following cessation of pyroclastic activity (Walton, 1978; Jordan, 1978). Perdiz caps the Tascotal Formation or Petan Basalt throughout much of the southern part of the quadrangle. It consists of a boulder conglomerate in proximal areas grading to finer sediment in distal areas. The Perdiz is diagenetically altered, has calcite in proximal areas, and a combination of opal clinoptilolite and montmorillonite in distal areas. Diagenesis occurred in a hydrologic system apparently unrelated to the system that affected the underlying tuffaceous sediments.

Basin and Range faulting began about 23 m.y. ago and followed the cessation of almost all igneous activity (Dasch and others, 1969; McDowell and Henry, unpublished data). Faulting divides the western two-thirds of the

SYSTEM	SERIES	FORMATION	MEMBER	LITHOLOGY	DESCRIPTION
QUATERNARY	PLEISTOCENE	Bolson Fill (Qtb)			Conglomerate, sandstone, and mudstone filling fault-bounded basins, up to 1,000 feet thick
TERTIARY	PLIOCENE				
	MIOCENE				
	OLIGOCENE	Perdiz Conglomerate (Tpc)			Alternating conglomerate and tuffaceous sandstone, up to 300 feet thick
		Petan Basalt (Tpb)			Tough, vesicular, porphyritic, fine-grained, plagioclase trachyte, up to 500 feet thick
		Mitchell Mesa Tuff (Tmm)			Densely to poorly welded ash-flow tuff, up to 100 feet thick
		Capote Mountain Tuff (Tco)			Noncalcareous, rhyolitic, glassy or zeolitic tuffaceous sandstone, siltstone, and conglomerate, up to 2,100 feet thick
		Bracks Rhyolite (Tbr)			Greenish rhyolitic lava flow, up to 300 feet thick
		Chambers Tuff (Tch)			Tuffaceous sandstone, siltstone, and conglomerate, zeolitic, up to 250 feet thick
		Buckshot (Tbu) Ignimbrite			Densely to moderately welded, peralkaline ash-flow tuff, up to 75 feet thick
	?	Colmena Tuff (Tca)			Tuffaceous sandstone, siltstone, and conglomerate, zeolitic, up to 450 feet thick
	EOCENE	Gill Breccia (Tgi)			Trachyandesitic to basaltic flow breccia
		Jeff (Tj) Conglomerate			Interbedded sandstone and conglomerate, up to 25 feet thick

Figure 7. Stratigraphic column, Tertiary and Quaternary rocks of the Sierra Vieja.

quadrangle into a series of north- or northwest-trending mountain ranges, which are separated by basins (bolsons) largely filled with debris shed from the ranges. Major basins are Lobo Valley--Ryan Flat, Eagle Flat, Red Light Bolson, Presidio Bolson, and Hueco Bolson. Most of the latter two areas occurs in the Presidio Quadrangle and Van Horn Quadrangle, respectively. Basin fill is as thick as 1250 m (4,000 ft) in Lobo Valley and in Presidio Bolson, but it generally is thinner in the other bolsons in the Marfa Quadrangle. Basin-fill deposits grade from boulder conglomerate to fine mud. Playa-lake and evaporite deposits occur in Presidio Bolson and probably in other basins, but the others are relatively undissected, so basin-center facies are not exposed. Integration of the Rio Grande drainage system has destroyed the closed-basin nature of the bolsons along the Rio Grande. Lobo Valley and Eagle Flat are still part of a closed basin that drains into Salt Basin to the north in the Van Horn Quadrangle. However, both surface and ground water drain out of Lobo Valley and Eagle Flat at present.

Igneous activity during basin filling was neglible. Numerous dikes along Basin and Range faults in the Sierra Vieja may have fed the basalt flows that interbed with basin-fill deposits. Rhyolitic volcanism and ash deposition were not active after about 26 m.y. ago.

Quaternary Rocks

The Quaternary Period was characterized by valley filling. Lithology of the fill consists of mud, sand, and gravel, which are mainly volcanic debris derived from the Tertiary volcanic piles. Degree of induration varies with caliche content.

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

SUMMARY

Three environments in the Marfa Quadrangle are favorable for uranium deposits. Area A (Pl. 1), 16 km (10 mi) north of Candelaria, meets some of the criteria for both non-channel-controlled peneconcordant sandstone-type deposits and roll fronts (Subclasses 244 and 242, respectively; Austin and D'Andrea, 1978). Potential host rocks are the El Picacho--San Carlos sequence and include strand-plain and fluvio-deltaic Upper Cretaceous sandstones.

Area B, the Buckshot Ignimbrite, contains significant uranium mineralization of uncertain origin (Class 730; Mathews, 1978b) at the Mammoth Mine. Although the area around the Mammoth Mine is considered favorable, the uncertain origin makes precise delineation of a favorable area difficult.

The Allen intrusions (Area C, Pl. 1) are favorble for authigenic deposits (Class 360; Mathews, 1978a).

AREA A

Porous and permeable sandstones of the Upper Cretaceous (Gulfian) El Picacho and San Carlos Formations are favorable for sandstone-type uranium deposits in an area that extends along the Rio Grande from 24 km (15 mi) north of the Candelaria, Texas, to about 56 km (35 mi) north of Candelaria (Area A, Pl. 1). The favorable area is entirely west of the Buckshot Rim. Because the boundary between the formations is paleontologic, no attempt was made in this study to differeniate between them; the entire section, from the top of the Ojinaga to the base of the overlying Tertiary volcanic pile, is referred to as the El Picacho--San Carlos sequence. Tuffaceous sediments and ash-flow and air-fall tuffs of the Tertiary Vieja Group are likely sources of uranium-bearing fluids.

The El Picacho--San Carlos sequence meets important criteria for roll-front uranium deposits. Host-rock lithology, uranium source, sandstone geometry, local structures, associated rocks, and inferred depositional environments are very similar to regions where roll-front deposits are found.

Sandstone beds in the sequence are 3-5 m (10-17 ft) thick. They consist of cross-bedded, fine- to medium-grained, fairly well sorted, quartzose to feldspathic arenites. The beds are generally blanket-like, but a few are lenticular. Marine and brackish-water fossils (mostly pelecypods) and Ophiomorpha burrows are common in the blanket sandstone beds, but they are found very infrequently in the slightly coarser grained channels. Mudstones, coal beds, and lignite interfinger with the sandstone. These interbeds are interpreted as lagoonal in the lower part of the sequence and as interdistributary or bay deposits in the upper part. A sequence of strand-plain barrier-bar depositional environments, which graded upward as progradation continued into fluvio-delta depositional environments, is inferred.

The sequence is broken into areally small fault blocks by both Basin and Range faulting and Rio Grande rifting. The faults that bound the blocks may have served as conduits for descending uranium-bearing waters and also as conduits for ascending sour gas from Lower Cretaceous limestones.

Faulting, both by producing clay gouge and by juxtaposing permeable and relatively impermeable beds, furnished aquacludes that may have helped localize deposits. Because coal beds and interbedded shales are present, disseminated organic trash is likely. Many sandstones that host large uranium deposits, such as the Westwater Member of the Morrison Formation in the Grants Mineral Belt, show no organic debris on weathered outcrops; although, it is abundant in the non-oxidized subsurface. Another likely reductant is sour gas ascending along faults. This mechanism has been used to explain the South Texas Tertiary deposits (Galloway, 1977; Goldhaber and others, 1978). The coal beds may serve as local reductants.

There are no known uranium occurrences in the El Pacacho--San Carlos sequence. However, near the Capote Mountain graben, Reeves and others (1979) reported "anomalously high" radioactivity, which they attributed to escaping radon. If this is so, a likely source of the radon might be uranium deposits in the Upper Cretaceous sequence.

HSSR ground-water data (Butz and others, 1979) are sparse, but they reveal slightly elevated molybdenum, arsenic, vanadium, and uranium in a well on the McCutcheon Ranch 15 mi north of Candelaria. This is the only ground-water data point in the favorable area. Stream sediments (Butz and others, 1979), as expected, show high uranium values. Uranium in the stream sediments is mostly derived from the overlying Vieja Group tuffs and tuffaceous sediments. Radiometric data (LKB Resources, 1979) reveal one major anomaly (anomaly 120) over the favorable area. This anomaly is "distinguished by strong equivalent uranium/equivalent thorium and equivalent uranium/potassium rations", which indicates a concentration of uranium relative to other radioactive elements. Scintillometer readings taken over the El Picacho--San Carlos sequence (250-300 counts per second) are uniformly 5-6 times those taken over the dense Lower Cretaceous limestones. Radioactivity in the favorable area is about twice that of the lithologically similar Aguja Formation 130 km (80 mi) southeast in the Emory Peak Quadrangle. The radioactivity is about the same as that of the Marfa Basin, which is an intermontane basin filled largely with volcanic detritus.

Favorable lithology, together with proximity to a possible source and favorable, although scant, HSSR and radioactivity data, lead us to conclude that the Upper Cretaceous continental and marginal marine sandstones in Area A are favorable.

There is little information regarding subsurface extent or thickness of the favorable sequence. Thicknesses of 1000 m (3,300 ft) were reported by Barnes (1979b); but because of erosion and a presumed irregular lower contact, an average thickness of 500-700 m (1,650-2,300 ft) is reasonable.

AREA B

The Mammoth Mine in the Buckshot Ignimbrite is one of the most significant uranium prospects in Trans-Pecos Texas. Selection of a favorable environment on the basis of the Mammoth Mine is entirely dependent upon its presumed mechanism of formation. For this reason, it is necessary to discuss the regional setting and possible mechanisms of mineralization in some detail.

Regional Setting

The Buckshot Ignimbrite is one formation of the Vieja Group, which consists of 1100 m (3,500 ft) of tuffaceous sediments, lava flows, and air-fall and ash-flow tuffs. The Vieja Group is discussed in more detail by Bilbrey (1957), DeFord (1958), Wilson and others (1968), Twiss (1970), Anderson (1975), and Walton (1975). The Vieja Group overlies Upper Cretaceous sedimentary rocks. Two basal units occur irregularly throughout the Sierra Vieja. A limestone conglomerate, the Jeff Conglomerate, fills channels cut into the Cretaceous rock. In the southern part of the Sierra Vieja, the Jeff or Cretaceous rocks are overlain by the Gill Breccia, which is a flow-breccia complex composed mainly of trachcybasalt porphyry (DeFord, 1958).

Most of the Vieja Group is composed of diagenetically altered tuffaceous sediments and air-fall tuff. Three sedimentary sequences are distinguished, primarily on the basis of interveining ash-flow tuffs or lava flows. From the oldest to the youngest, they are composed of the Colmena Tuff: 10-135 m (30 to 450 ft) thick; the Chambers Tuff: 30-250 m (100-800 ft) thick; and the Capote Mountain Tuff: 400-550 m (1,300-1,800 ft) thick. All include fluvially deposited tuffaceous siltstone, sandstone, and conglomerate, as well as subordinate air-fall tuff. The sediments are composed of glass shards, pumice, and rock fragments. Glass shards predominate in fine-grained sediment; whereas, rock fragments are predominant in coarser deposits. The Colmena Tuff is separated in most places from the Chambers Tuff by the Buckshot Ignimbrite; the Chambers is, in turn, separated from the Capote Mountain Tuff by the Bracks Rhyolite. The Capote Mountain Tuff is capped by the Mitchell Mesa Welded Tuff. The age of the Vieja Group ranges from Eocene (40 m.y. at the Gill Breccia) to Oligocene (31 m.y. at Mitchell Mesa) (McDowell, 1979; Wilson and others, 1968).

The tuffaceous sediments have been diagenetically altered in an open hydrologic system to a sub-horizontally zoned assemblage of zeolite, montmorillonite, and silica minerals (Walton, 1975). Diagenetic mineral zones described by Walton "from top to bottom, are (1) montmorillonite-opal-glass, (2A) montmorillonite-opal-clinoptilolite, (2B) montmorillonite-quartz." Diagenesis occurred during deposition after a sufficent thickness of sediment had accumulated. In addition to diagenesis, pedogenic alteration produced paleosoil horizons that exhibited calcite concretions and root mottling, particularly in the Chambers Tuff.

The entire Sierra Vieja is extensively cut by north- and northwest-trending normal faults with displacement up to (1000 m) 3,300 ft. Faulting, which was postdiagentic (Walton, 1975), began approximately 23 m.y. ago (Dasch and others, 1969) and has continued to the present (Muehlberger and others, 1978). The Vieja Group and underlying rocks are broken into numerous individual fault blocks that are tilted as much as 20°.

All of the volcanic and volcaniclastic rocks contain high background concentrations of uranium. For example, hydrated vitrophyres of the Buckshot Ignimbrite contain approximately 12 ppm U_3O_8. Concentrations in glassy and altered tuffaceous sediments range from approximately 3 ppm to 15 ppm. Fission-track mapping shows that the uranium occurs predominantly in glassy rocks and in various secondary minerals in devitrified or diagenetically altered rocks. Thus, all the rocks constitute potentially good sources of uranium.

The Buckshot Ignimbrite, a peralkaline ash-flow tuff emplaced as a single cooling unit, is densely to moderately welded throughout its occurrence. Its maximum thickness is about 30 m (100 ft), but average thickness is only about 20 m (70 ft). A basal vitrophyre is preserved in many places, but it is invariably hydrated. An upper, nonwelded air-fall tuff (Anderson, 1975) is believed by us to be mostly the result of laminar flowage of the ash flow after deposition and partial consolidation. The Buckshot shows abundant evidence of a high volatile content and extensive vapor-phase activity. Anderson (1975) cites laminar-flow features, tumuli (resulting from a form of fumarolic activity), and the presence of abundant cavities in devitrification spheres up to 15 cm in diameter.

Uranium Mineralization at the Mammoth Mine

The Buckshot is 11.5 m (35 ft) thick at the Mammoth Mine and crops out along the middle of a steep slope above Quinn Creek. Mineralization extends for a distance of about 50 m (170 ft) along the cliff face. Vitrophyre is not exposed right at the prospect, but it does occur at several locations around the prospect usually within 100-200 m (300-700 ft) of the mine. The rock is densely to partly welded and exhibits a well-developed lithophysal zone.

Uranium mineralization is predominantly found in the densely welded zone, but minor amounts occur throughout the entire thickness. The only uranium mineral positively identified is beta-uranophane. However, Nye (1957) and Anderson (1975) found another yellow uranium mineral, which Nye speculated could be a barium analog of uranophane. Uranophane occurs in cavities in devitrification spheres, in fractures in rock fragments, and fractures. Uranophane also occurs in minor amounts along fractures in the underlying Colmena Tuff. Uranium concentrations found in this study range up to 2750 ppm U_3O_8; Nye reported an average assay of 0.27% U_3O_8.

Associated minerals found in cavities include secondary silica (quartz, chalcedony, and opal), calcite, and iron oxides. Limonite pseudomorphs after pyrite are common. The host rock is devitrified ash-flow tuff composed of quartz and feldspar. The rock is strongly bleached when compared to typical red-brown Buckshot outcrops. The bleaching apparently has not significantly altered the host rock mineralogy. Minor amounts of a soft, white mineral, possibly kaolinite, occur in some cavities. The bleaching might have resulted from acidic leaching, which in turn is the result of oxidation of pyrite; in that case, greater alteration of feldspar and more development of kaolinite might be expected.

Bilbrey (1957) stated that no mineralization was observed at the McSpadden Prospect and that radiation levels were typical of the Buckshot.

Origin of Mineralization

Nye's theories are (1) concentration of uranium in vesicles by late-stage volatile components of the uranium-rich parent magma, (2) ground-water leaching from the Buckshot and overlying tuffaceous sediments and reconcentration in the Buckshot, and (3) introduction of uranium by a hydrothermal source.

Our postulated general mechanism for formation of the Mammoth Mine deposit involves (1) introduction of pyrite in the Buckshot by upward leakage of H_2S-bearing gas or water coming from underlying Cretaceous sedimentary rocks, (2) mobilization of uranium in glass in tuffaceous sediments by open-hydrologic-system diagenesis, and (3) precipitation of reduced uranium minerals (probably coffinite) by reaction with pyrite and subsequent recent oxidation to form uranophane. Both good evidence and several problems are involved in this proposed mechanism.

1) Leakage of H_2S-bearing fluids from underlying Cretaceous rocks has not been documented in Trans-Pecos Texas, and the area is not a producer of hydrocarbons. However, several deep wells have been drilled along buried

Cretaceous structures to explore for hydrocarbons in the Mammoth Mine area (Bilbrey, 1957). Several of the wells encountered minor amounts of oil or gas. Two of the wells now produce hot water (approximately 80°C) that contains H_2S and several hot springs in the area also produce H_2S (Henry, 1979a). A boulder of massive Lower Cretaceous limestone occurs in Quinn Creek near the mine; it is highly petroliferous. Its occurrence here is unusual because Cretaceous rocks that crop out in the area are all Upper Cretaceous. Nevertheless, the petroliferous boulder implies that underlying Lower Cretaceous rocks could be a source of H_2S. This mechanism of pyritification and entrapment of uranium in major deposits is well documented in the Texas Coastal Plain uranium district (Goldhaber and others, 1978; Galloway and Kaiser, in press).

2) During diagenesis, glass shards and pumice in the tuffaceous sediments were dissolved; and all constituents of the glass, including uranium, went into solution. Thus, diagenesis ought to be an ideal mechanism for releasing uranium and allowing it to migrate to form deposits.

3) Uranophane is reported from fractures withing the underlying Colmena Tuff at the Mammoth Mine (Nye, 1957), and one sample (MGE-523) collected from an adit in the Colmena contained 19 ppm U_3O_8. Molybdenum occurs in moderately high concentrations (20-70 ppm) at the Mammoth Mine and shows some correlation with uranium ($R = 0.44$). Molybdenum concentrations in unmineralized Buckshot samples from throughout its outcrop area show a similar range. The high concentrations in both mineralized and unmineralized samples are probably primary.

The Buckshot is highly fractured in all outcrops observed in this study; these fractures should provide sufficient permeability. That permeability existed following consolidation and welding of the Buckshot is deomonstrated by the presence of secondary silica and calcite in fractures and vesicles at the mine.

As a compromise, we have designated almost the entire area of outcrop of the Vieja Group is favorable (Area B, Pl. 1). Only intensely faulted areas, where the Vieja Group overlies Cretaceous rocks at shallow depths, are included. Unfaulted areas and the Vieja Group above the Bracks Rhyolite are not included. Also, those parts of the Vieja Group buried beneath bolson fill are not included even though the favorable environment may extend beneath fill. Clearly not all of this area is truly favorable; the map should be interpreted accordingly.

AREA C

Fracture zones in the Allen Intrusions, a group of rhyolite porphyry domes of probable Oligocene age, constitute a favorable environment for authigenic class deposits (Class 360 of Mathews, 1978). The Allen Intrusions occur along the southern border of the quadrangle and extend slightly into the Presidio Quadrangle. Additional discussions of uranium mineralization in the Allen Intrusions are given by Amsbury (1958), Henry and Tyner (1978), and Reeves and others (1979).

The area of outcrop of the Allen Intrusions is only a few square miles. As the favorable environment consists of fracture zones within the intrusions, only a fraction of the total outcrop area is favorable. The fracture zones are probably a result of cooling of the intrusion. They dip steeply but irregularly and have irregular thicknesses up to approximately 4 m (15 ft). Mineralization was originally discovered at the surface, and drilling by Wyoming Minerals and Meeker & Co. found mineralized fractures to depths of at least 200 ft (60 m).

The Allen Intrusions are a group of shallow rhyolite domes with associated flows and breccias. They are contemporaneous with rhyolite lava flows, ash-flow tuffs, and diagenetically altered tuffaceous sediments of the Shely Group. Both groups of rocks are older than the rocks of the Chinati Caldera cycle but may be related to it or to an older caldera immediately east of the intrusions. All the major domes are rhyolte porphyries with quartz and alkali feldspar phenocrysts; plagioclase phenocrysts occur in some of the domes. The rocks are weathered or altered so that all ferromagnesian minerals and most feldspars are converted to oxides or clays. Vitrophyres associated with the porphyritic intrusions are rare, but two were found in this study (MGE-810 and MGE-811).

A second group of rocks associated with the domes includes non-porphyritic or sparsely porphyritic vitrophyres and perlites. They are probably remnants of flows associated with the domes.

Both groups of rocks are chemically similar. They are alkali-rich, high silica rhyolites with low Ca, Mg, and Fe concentrations. Aluminum is also low, but the rocks are not peralkaline, as shown by both the chemical analyses and by the presence of biotite in the two vitrophyre samples from the porphyritic group.

Evidence of favorability includes (1) abundant areas of uranium mineralization in fractures, and (2) geologic characteristics similar to those of the authigneic class (Class 360; Mathews, 1978a). Mineralization occurs as uraniferous Fe-Mn oxyhydroxides and as secondary uranium minerals. Reeves and others (1979) reported autunite, metatorbernite, and tyuyamunite. Anomalous uranium concentrations occur in many fracture zones throughout the porphyritic domes. Amsbury (1958) reported that 200 tons of ore averaging 0.34% U_3O_8 were extracted in the 1950s. The highest grade found in this study was 1430 ppm U_3O_8 in a sample recovered from clay gouge (MGE-568). An Fe-Mn or Fe-Ti-Mn oxyhydroxide from the same area contained 825 ppm U_3O_8 (MGE-545). Slightly lower concentrations were found associated with oxyhydroxides from several other fracture zones at the surface and were encountered in drill cores. Other elements enriched in the hydroxides are Cd, Be, Co, Cr, Cu, Ni, and V.

The fracture zones are generally smaller and of lower uranium grade at depth. This suggests that the presence of pitchblende veins is unlikely.

Probable sources of the uranium are the rhyolite porphyries themselves or the associated glassy rocks of the Allen Intrusions. Diagenetically altered tuffaceous sediments of the Shely Group are a third possible source. Primary uranium concentrations of the rhyolite porphyries may be as high as 23 ppm U_3O_8, the concentration found in the two vitrophyres (MGE-810 and

MGE-811). All unmineralized surface samples contain lower concentrations, which range from approximately 5 ppm to 15 ppm. Relatively unweathered and unfractured samples from drill cores contain variable concentrations closer to those of the vitorphyres.

Glassy samples of the non-porphyritic rocks contain 7-9 ppm U_3O_8; this content is lower than the concentrations of the porphyritic vitrophyres, but it still makes them adequate source rocks.

Geologic setting, alteration, and type of deposit agree well with the authigenic class (Mathews, 1978a). The rhyolite porphyry intrusions occur in a mobile belt and are postorogenic and epizonal. They are greatly differentiated with high silica, alkali, and uranium concentrations and low calcium, magnesium, and iron concentrations. Mineralization occurs in fracture zones where uranium released by devitrification or weathering could be concentrated. Alteration is minor and consists primarily of the alteration of feldspar and mafic phenocrysts, argillic alteration along the fracture zones, and abundant limonitic staining and Fe-Mn hydroxides along the fractures.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

SUMMARY

Many environments in the Marfa Quadrangle are considered unfavorable for uranium deposits. They are (1) Precambrian rocks, (2) Paleozoic rocks, (3) most Mesozoic rocks, (4) mafic rocks, including lava flows and small intrusive bodies, (5) most silicic and intermediate lava flows, ash-flow tuffs, and intrusions, (6) plutonic rocks, (7) most tuffaceous sediments, and (8) fluorite deposits in the Eagle Mountains. Most of these environments are considered unfavorable because they contain no mechanisms to trap uranium. However, some could serve as source rocks for uranium deposits in other units where trapping mechanisms are present.

PRECAMBRIAN ROCKS

Although the Precambrian rocks in the Marfa Quadrangle include a wide variety of meta-igneous and meta-sedimentary rocks, they have uniformly low uranium concentrations (highest uranium content was 6.5 ppm in sample MGE-206, App. B). Furthermore, they lack the physical conditions for trapping or concentrating uranium and did not reveal any radiometric anomalies. Therefore, these rocks are considered unfavorable environments for uranium deposits.

PALEOZOIC ROCKS

Permian rocks (for nomenclature, see Fig. 3) directly overlie the Precambrian at the surface and in the shallow subsurface. Although there is some uranium mineralization associated with Tertiary instrusions near the Chinati Caldera (Dietrich, 1965), there is no uranium mineralization in

Paleozoic rocks in the area. Permian rocks are, however, age equivalent to argentiferous limestones at Shafter (Presidio Quadrangle). Several samples from Permian units in Pinto Canyon occurring in the Presidio Quadrangle (MGF-362 and MGF-363) yield low concentrations of U_3O_8 and exhibit few characteristics judged favorable for uranium deposits. There are no HSSR or radiometric anomalies over the Paleozoic outcrop. Subsurface Paleozoic rocks are either unfavorable by analogy to outcrops or are too deep to be evaluated here.

MESOZOIC ROCKS

No Triassic or Jurassic rocks crop out within the quadrangle. No Triassic rocks and only thin, possible Jurassic rocks were recognized on well logs. The Malone Mountains, where the only known Jurassic rocks in Texas crop out, are 30 miles north in the Van Horn Quadrangle. There is no reason to believe that the Jurassic rocks, even if present in the shallow subsurface of the Marfa Quadrangle, would be favorable for uranium. Mesozoic rocks that do crop out in the Malone Mountains are marine limestones; and, extensive studies of outcropping and subsurface Mesozoic rocks to the south in Chihuahua (Haenggi, 1966) have not revealed Triassic or Jurassic rocks, except for a thick sequence of evaporites, which is commonly considered Cretaceous. Triassic and Jurassic rocks, even if present in the shallow subsurface, would very likely be unfavorable.

The Cretaceous Yucca, Bluff Mesa, Finlay, Espy, Loma Plata, and Borracho and Buda Formations are unfavorable for uranium deposits; these units are chiefly dense marine limestones that do not contain a suitable reductant and which exhibit no radiometric (airborne or ground) or chemical anomalies.

The Cox, Bienvenides, and Del Rio Formations, chiefly siliciclastic units, are unfavorable because they lack reductants. Their radiometric signature (average 50-70 counts per second) hardly warrants further study.

Upper Cretaceous rocks have largely been eroded from the Marfa Quadrangle. They are preserved in two places: (1) Chispa Summit, the pass between the Sierra Vieja and the Van Horn Mountains; here, an extensive area of Boquillas Formation crops out, and (2) the area west of the Vieja Rim; here, Upper Cretaceous sandstones are favorable. The Boquillas in the first area has a radiometric signature (150 counts per second) that is about three times that of the dense Lower Cretaceous limestone. The elevated radiometrics are due to bentonite beds in the Boquillas that, while slightly uraniferous, do not approach favorability because they lack a concentrating mechanism.

TERTIARY ROCKS

Mafic Rocks

Mafic lava flows in the Marfa Quadrangle considered unfavorable for uranium deposits include: (1) the Petan Basalt (MGE-921, 0.5 ppm U_3O_8); (2) mafic units in the Garren Group (MGE-968, 2.5 ppm U_3O_8); (3) the Pantera Trachyite (MGE-997, 7.3 ppm U_3O_8); (4) the basalt lentil of the Hogeye Tuff (MGE-992, 1.3 ppm U_3O_8); and (5) mafic rocks in the Davis

Mountains. These units are judged unfavorable on the basis of surface rock sampling; they have generally low uranium concentrations and contain neither evidence of uranium enrichment nor known mechanisms for trapping uranium.

Silicic and Intermediate Rocks

Numerous rhyolitic to intermediate lava flows, ash-flow tuffs, and small intrusive bodies in the Marfa Quadrangle are judged to be unfavorable for uranium deposits. These units include lava flows and ash-flow tuffs in the Shely, Garren, and Vieja Groups, and most units in the Davis Mountains. Geochemical analyses and inspection of the radiometric data indicte that these units have low to moderate uranium and total-radioelement concentrations. Inspection of a known radiometric anomaly in the Davis Mountains (Mt. Livermore anomaly; Reeves and others, 1979) revealed low to moderate concentrations of uranium in the rocks sampled (highest uranium value was 21.0 ppm U_3O_8 in sample MGE-938; App. B). No process or mechanism capable of concentrating uranium was observed in these units. However, they are potentially favorable sources for uranium to form epigenetic deposits elsewhere.

Plutonic Rocks

Large intrusive masses of generally felsic composition are considered to be unfavorable environments because of low uranium content and a lack of any indication of primary magmatic deposition. These plutons are the Eagle Peak Syenite (highest uranium content was 5.5 ppm in sample MGE-812; App. B) in the Eagle Mountains, quartz microsyenite and quartz trachyte in the Davis Mountains (highest uranium content was 9.7 ppm, MGE-733; App. B), the quartz monzonite of Canning Ridge (uranium content 2.8 ppm, MGE-867; App. B), and the Ojo Bonito "Laccolith" north of the Chinati Mountains (uranium content 3.8 ppm, MGE-794; App. B). In addition, no radiometric or geochemical anomalies are associated with these rocks. As with to the silicic flow rocks, these plutons could be potential sources of uranium.

Tuffaceous Sediments

Most tuffaceous sediments of the Vieja Group, Garren Group, Shely Group, Buck Hill Group, and Davis Mountains are unfavorable for uranium deposits because they lack reductants or other trapping mechanisms. Channel sandstones containing organic debris, or lacustrine deposits containing lignites, are not known to occur in any of these rocks in the Marfa Quadrangle. Reducing environments, which occur in the basal Pruett Formation of the Emory Peak Quadrangle, may also occur in that part of the Pruett Foramtion in the subsurface in the Marfa Quadrangle. However, the formation is not exposed in the Marfa Quadrangle and cannot be evaluated. Epigenetic reductants, such as those postulated for the Mammoth Mine uranium occurrence, may exist in lower parts of the tuffaceous sedimentary sequence, especially in the Vieja Group. This environment is considered along with the Buckshot Ignimbrite. Nevertheless, no trapping mechanisms have been identified in tuffaceous sediments of the above formations. Therefore, these are considered unfavorable.

Although the tuffaceous sediments are considered unfavorable, since they lack environments suitable to concentrate uranium, they are potentially excellent uranium sources. All tuffaceous sediments examined in the Marfa Quadrangle have been diagenetically altered. Diagenesis may have released uranium to solution to be concentrated elsewhere.

Fluorite of the Eagle Mountains

Fluorite deposits associated with rhyolitic intrusive bodies in the Eagle Mountains have low uranium concentrations; the highest uranium content in fluorite from the Eagle Mountain fluorospar district is 4.5 ppm (MGE-850, App. B). This is in contrast to fluorite deposits in the Christmas Mountains (Emory Peak Quadrangle), which have anomalously high uranium (Daugherty and Fandrich, 1979). The variable uranium content of fluorite from these two areas can be attributed to a difference in composition of the associated rocks. The igneous rocks of the Eagle Mountains are less alkalic than those of the Christmas Mountains (Barker, 1977). The mechanism for concentrating uranium in fluorite deposits in the Eagle Mountains is adequate because of low uranium content and association with unfavorable rock types.

UNEVALUATED ENVIRONMENTS

BOLSON-FILL SEDIMENTS

Bolson-fill sediments within Presidio, Hueco, and Red Light Bolsons, Eagle Flat, and Lobo Valley--Ryan Flat are classifed as unevaluated. Although several lines of evidence suggest that the fill, especially in Presidio Bolson, could be favorable, other evidence suggests that it is unfavorable. Information to draw a final conclusion is not available.

Geologic Setting

The bolsons are filled with detritus that was shed from adjacent highlands and composed of either Tertiary volcanic and intrusive rocks or Cretaceous or older sedimentary rocks. Deposition began about 23 m.y. ago with initiation of faulting (Dasch and others, 1969). Deposition continued in closed basins until the Pleistocene; at that time, integration of the Rio Grande drainage system allowed through-going drainage of the several basins along the Rio Grande. Bolson fill there is now being dissected, and several different terrace levels are developing as the Rio Grande cuts downward. Lobo Valley and Eagle Flat are not part of this drainage system but drain into a closed system to the north in the Van Horn Quadrangle called Salt Basin.

On the basis of the dominant lithology, Groat (1972) divided basin fill in Presidio Bolson into conglomerate, sandstone, and mudstone lithosomes. Although his model is probably appropriate to the other basins, because most are not as dissected as is the Presidio Bolson, basin fill deposits are either poorly exposed or not exposed at all. The fill is zoned, and the coarsest material is adjacent to major basin-bounding faults along the mountain fronts. Fill adjacent to the mountain front was deposited in alluvial fans. The material fines basinward into the mudstone lithosome; although, conglomerate and sandstone lenses compose as much as 10% of the mudstone lithosome. During closed basin sedimentation, the center was occupied by a playa lake; evaporite beds containing gypsum occur within the mudstone lithosome in several locations. Groat considered the alluvial fan, gypsum, and playa deposits as being similar to deposits associated with playas in the Mojave Desert.

Thickness of the fill ranges from greater than 4,000 ft (1200 m), in several locations along the center of Presidio Bolson, down to areas of pinch-out along the margins of the basin. However, thickness changes abruptly at faulted margins where basin fill is displaced aganist older rocks. Thickness of fill in the other basins is comparable to that in Presidio Bolson.

Faulting has continued to the present; recent fault scarps cut several terraces developed since integration of the Rio Grande drainage. Recent fault scarps also occur along the west side of Lobo Valley (Muehlberger and others, 1978). Although the largest faults are along basin margins, numerous additional faults occur within the basins, especially in the northern part of the dissected Presidio Bolson. Faults within the other basins are also likely, but most are probably buried beneath recent sediments.

Uranium Favorability

Epigenetic uranium deposits, the most likely type to form in the bolsons, require the appropriate interaction of three factors: (1) a source rock that has released uranium, (2) a transporting medium, and (3) trapping and concentrating mechanisms and locations. All three factors may exist within the bolsons, but the actual existence or effectiveness of them has not been completely evaluated.

Source Rocks. Much of the detritus composing the basin fill and much of the adjacent highlands that drain into the basins are composed of Tertiary volcanic, volcaniclastic, or intrusive rocks that have relatively high primary uranium conentrations. In highland areas, where non-volcanic Cretaceous or older sediments are now exposed (for example the Quitman Mountains, and parts of the Eagle Mountains, Van Horn Mountains, and Wylie Mountains), volcanic rocks initially capped the sediments but have since been eroded. Thus, basin fill in these areas may be at least partly composed of igneous or igneous-derived rocks. Uranium concentrations in basin fill and in volcanic rocks of the highlands typically range from a few ppm to about 15 ppm, which makes them more than adequate sources of uranium. Analyses of stream sediments within Presidio Bolson show similar concentrations (Union Carbide, 1978b). Uranium mineralization within the Allen Intrusions could also be a potential source of uranium for basin fill in the northern Presidio Bolson.

Less certain is whether or not significant amounts of uranium have been released from any of these rocks. Release would have to be by weathering rather than by any process of devitrification or diagenesis. High-temperature devitrification would have occurred before basin formation; open-hydrologic-system diagenesis of tuffaceous sediments would also have occurred before basin formation because diagenesis occurred soon after initial deposition of the sediments (Walton, 1975). Also, tuffaceous sediments do not occur within basin fill because tuff-producing volcanism ceased before formation of the basins.

Nevertheless, weathering may be an effective mechanism of uranium mobilization from volcanic rocks. Results from this study, from evaluation of the Emory Peak and Presidio Quadrangles, and from previous work in the Chinati Mountains that border Presidio Bolson (Henry and Tyner, 1978), indicate that weathering can release 50% or more of the primary uranium content of some rocks. Probably sufficient amounts of uranium have been released from potential source rocks to form significant deposits if a concentrating mechanism exists.

Migration. Surface and ground-water flow, both during basin filling and since integration of the Rio Grande, was from high areas along basin margins towards the basin center. While the basin was closed, all water and any dissolved uranium was trapped within the basin. After integration, uranium-bearing waters could reach the Rio Grande and be removed from the system. Permeability of the basin fill varies from very high permeability in the basin-margin conglomerate lithosome to very low permeability in the basin-center mudstone lithosome (Groat, 1972). Sandstone lenses do occur even within the mudstone lithosomes; therefore, beds with sufficient permeability to enable transport of ground water to the basin center do exist.

Entrapment. A possible mechanism of entrapment is the most poorly evaluated of the three factors needed for uranium deposits. The most likely entrapment mechanism is reduction of either by organic material (or pyrite generated from the organic material) deposited in channels in conglomerate or sandstone lithosomes or as lignite beds in the basin center, or by pyrite generated by post-depositonal reduction by discharge of H_2S-bearing waters from underlying Cretaceous or Permian sedimentary rocks. The first mechanism is unlikely; evidence for or against the second is meager.

Neither lignitic beds nor organic material of any kind has been found in the basin fill. Although lignite is common in closed basins formed during early Tertiary time (for example, the Pruett Formation of the Emory Peak Quadrangle), the climate may have been considerably drier during deposition; therefore, any organic material that did form may have been oxidized immediately. Playa-lake deposits of the Mojave Desert are commonly highly oxidized (W. E. Galloway, pers. comm., 1979)

Post-depostional reduction by H_2S leaking along faults that cut basin fill is entirely theoretical. The general mechanism and evidence for such reduction are discussed above in the Buckshot Ignimbrite section. Faults cutting through basin fill provide conduits for the rise of thermal water from hot springs, particularly along the Rio Grande. A similar process conceivably could lead to reduction of sediments in basin fill adjacent to fault zones.

If neither reduction mechanism exists, other concentrating processes are still less likely. Formation of calcrete deposits by adsorption of uranium on secondary amorphous silica or hydroxides is a possible process. However, it is more likely that, without reduction, uranium in water entering the playa would simply be dispersed throughout playa sediments without being concentrated. Reeves and others (1979) reported uranium mineralization associated with the Quebec Siding anomaly. Radiometric data do show a radioactivity anomaly in that area (LKB Resources, 1979), but our investigation suggests that this results from the presence of detritus moderately rich in U, Th, and K, rather than from mineralization.

Information to Improve Evaluation of Bolson Fill

Factors 1 and 2, required for the formation of epigenetic uranium deposits, have probably been operative; therefore, the limiting factor (factor 3) is the existence of reducing environments to concentrate uranium. With this uncertainty, the environment is classified as unevaluated. Ground-water analyses of basin fill are sparse because wells are sparse in the relatively unpopulated bolsons. The few reported concentrations (Union Carbide, 1978b) are relatively low (less than 10 ppb). However, because there are so few analyses, characterization of present day ground-water concentrations is not possible. Also, no measurements of oxidation-reduction status were made; therefore, the existence of reducing environments within basin fill cannot be established. More complete sampling, which emphasizes oxidation-reduction status of existing wells or of wells drilled expressly for uranium exploration in basin fill could resolve this uncertainty.

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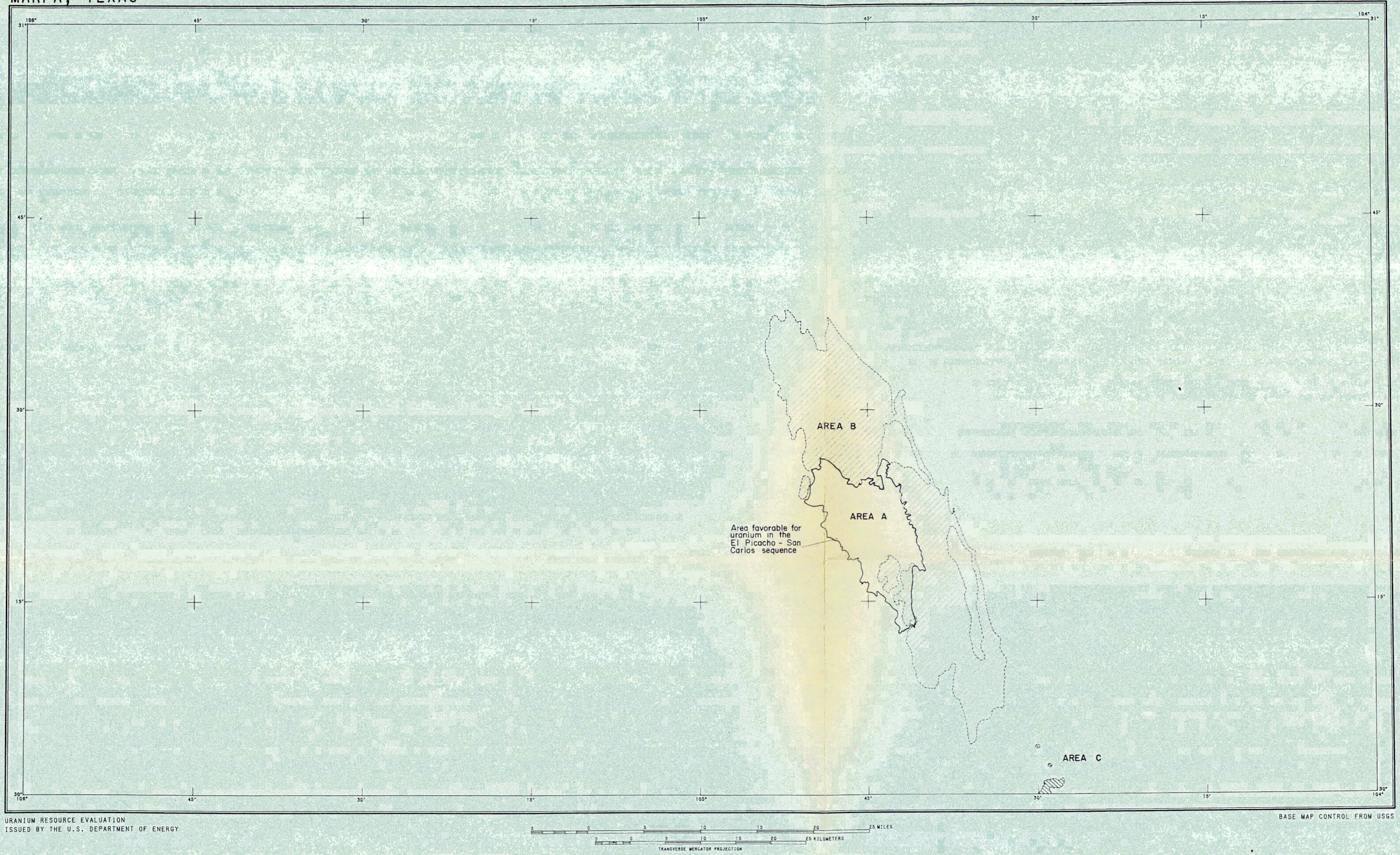
MARFA, TEXAS



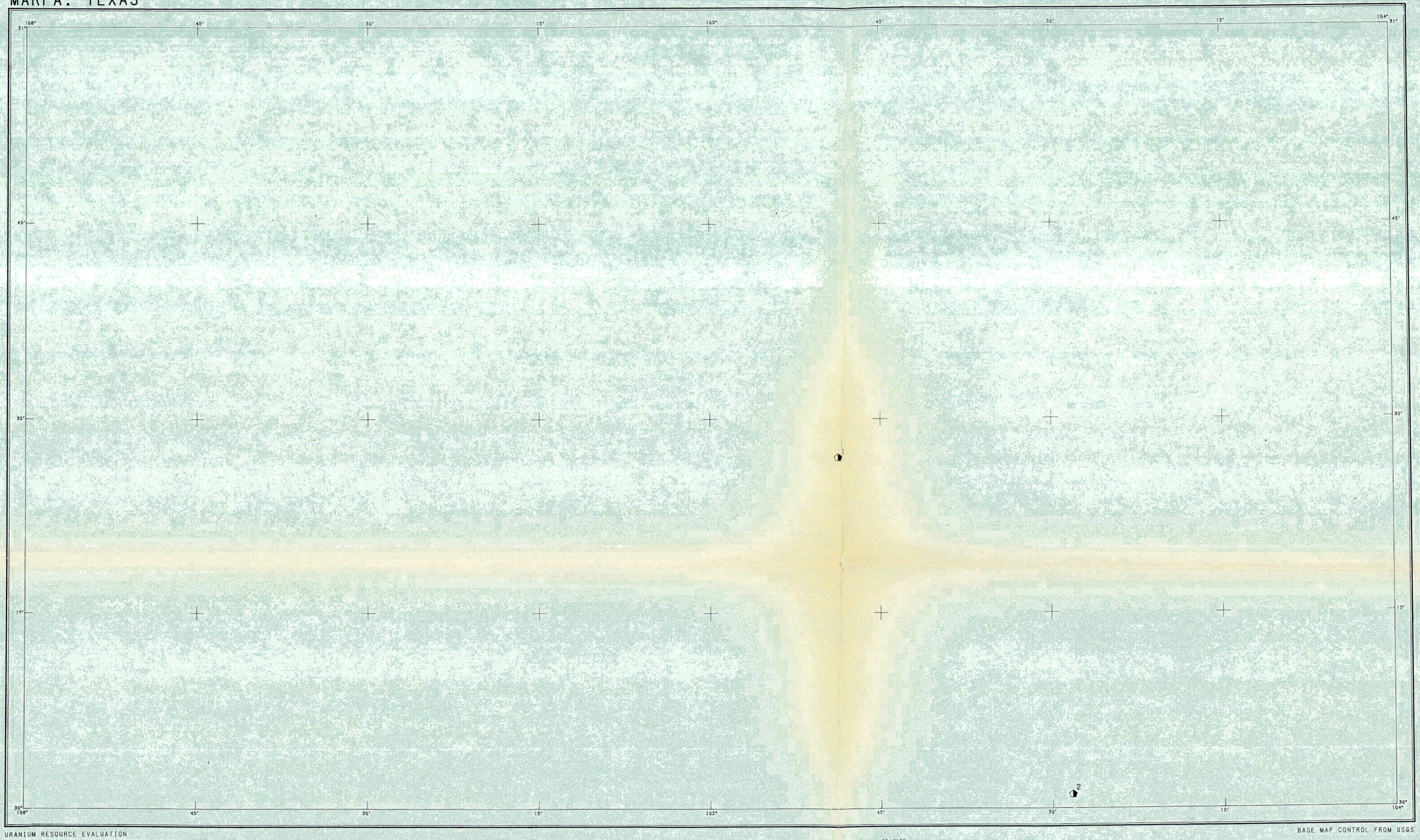
URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

Plate I. AREAS FAVORABLE FOR URANIUM DEPOSITS

Plate I.

MARFA, TEXAS



URANIUM RESOURCE EVALUATION
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BASE MAP CONTROL FROM USGS

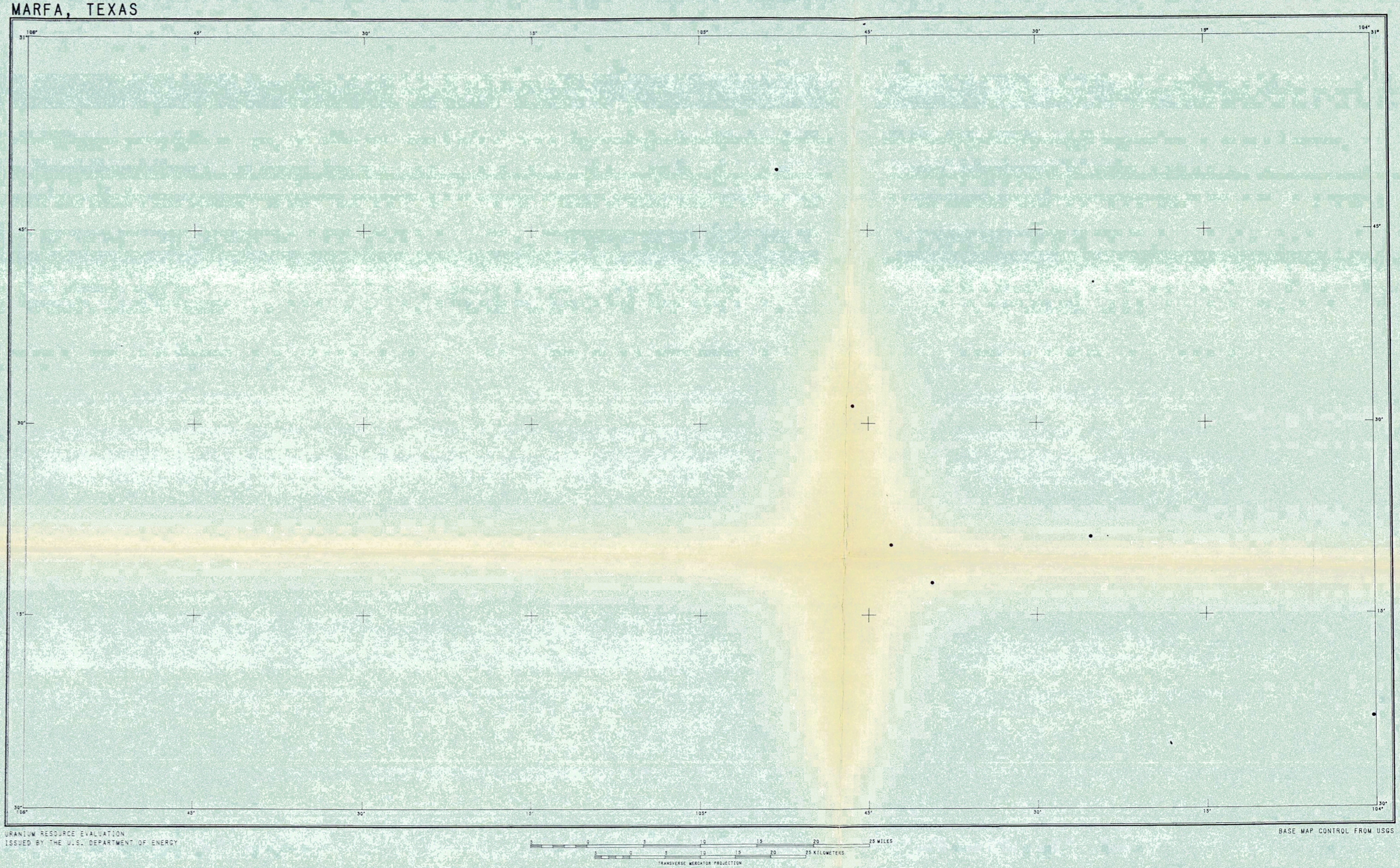
TRANSVERSE MERCATOR PROJECTION

EXPLANATION

URANIUM OCCURRENCES	CLASSIFICATION			
	Sedimentary	Plutonic	Volcanic	Other
Minor prospect or mineral occurrence	□	△	⬠	☼
Significant prospect or mine reporting minor production	◪	◭	⬠	☼
Mine having production over 200,000 pounds U_3O_8	■	▲	⬟	✸
Mining District				

Plate 2. URANIUM OCCURRENCES

MARFA, TEXAS



URANIUM RESOURCE EVALUATION
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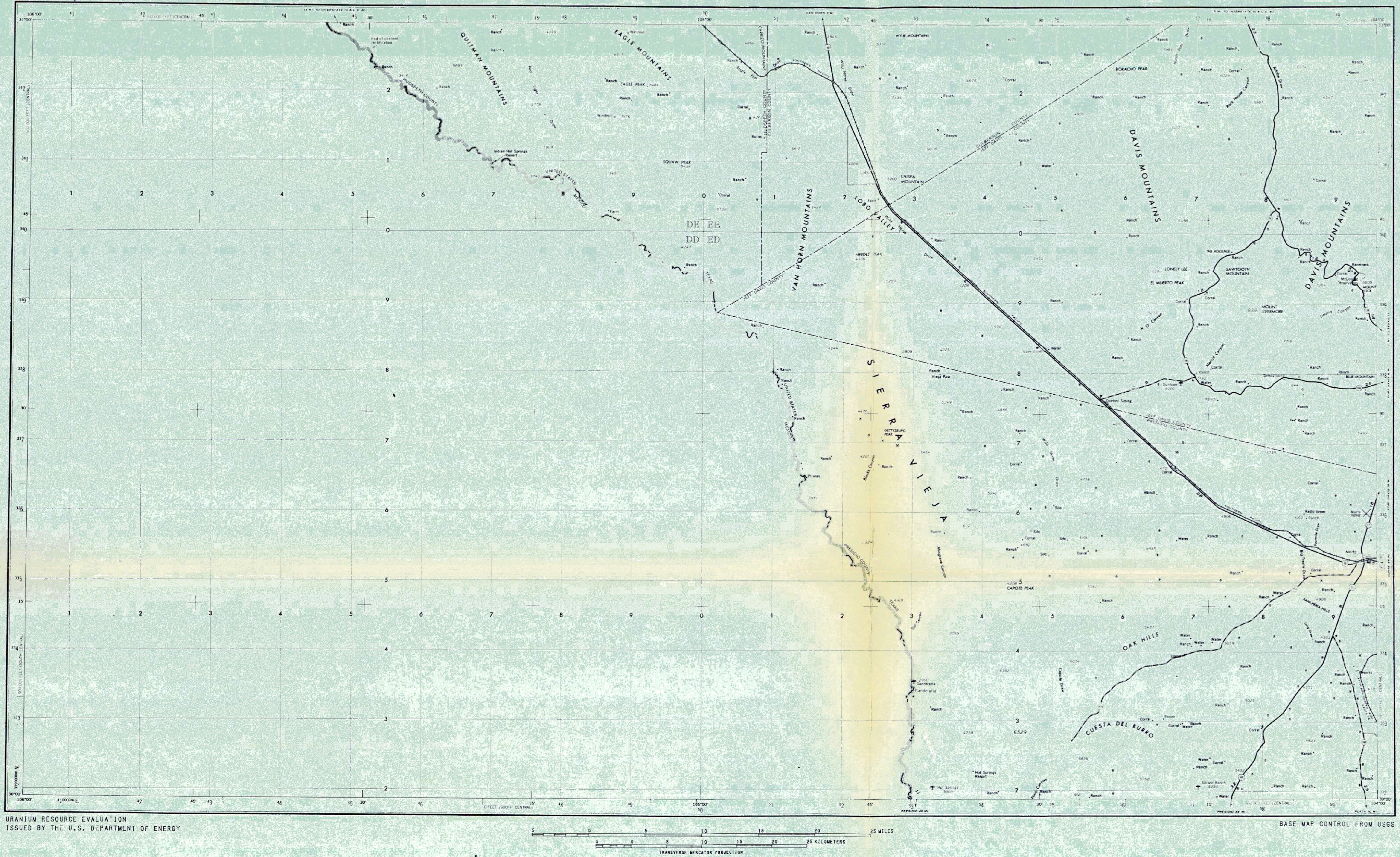
Plate 3. PREFERRED EQUIVALENT URANIUM ANOMALIES IDENTIFIED BY LKB RESOURCES, 1979

MARFA, TEXAS



URANIUM RESOURCE EVALUATION
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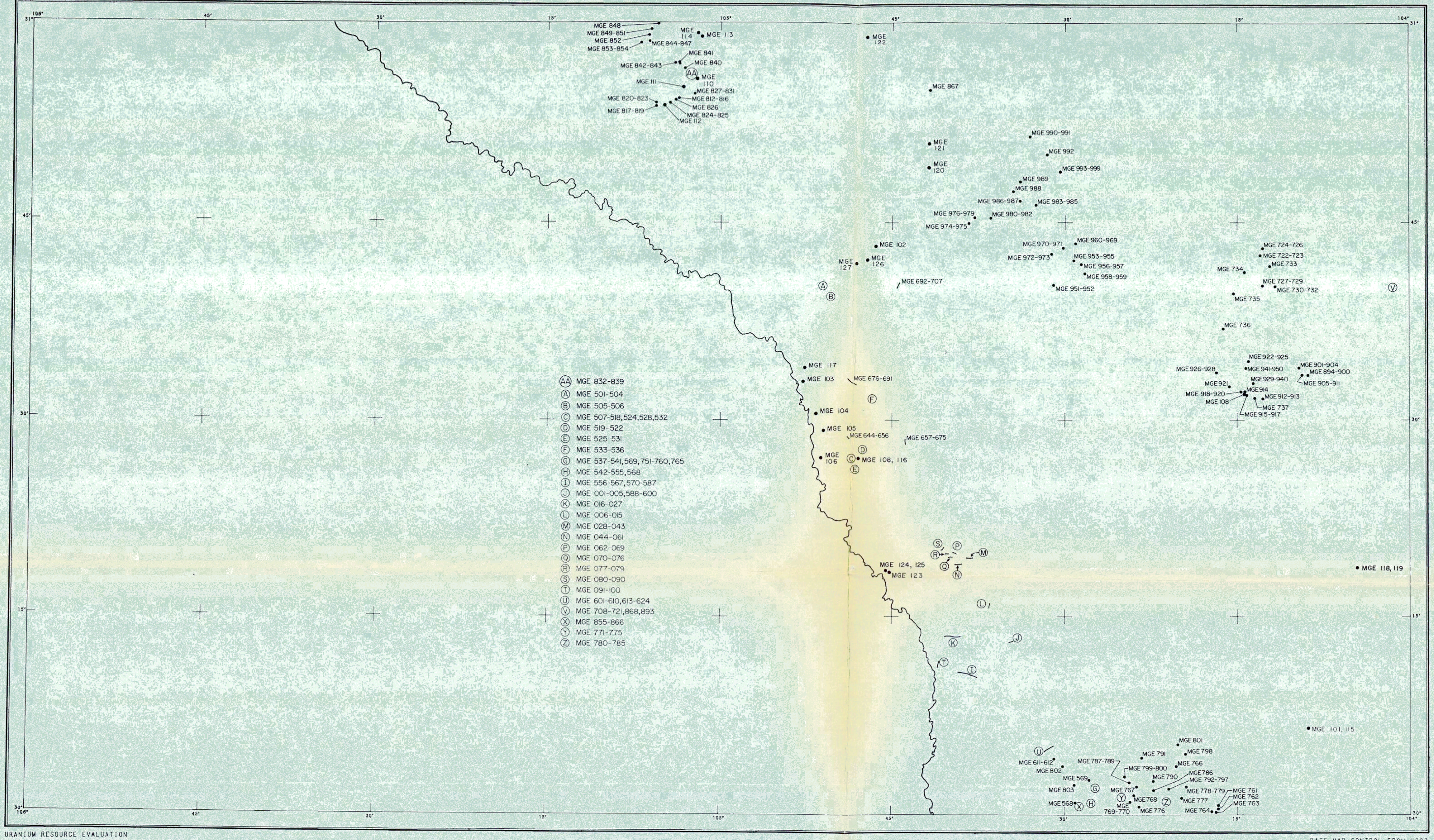
Plate 4. CULTURE

MARFA, TEXAS



URANIUM RESOURCE EVALUATION
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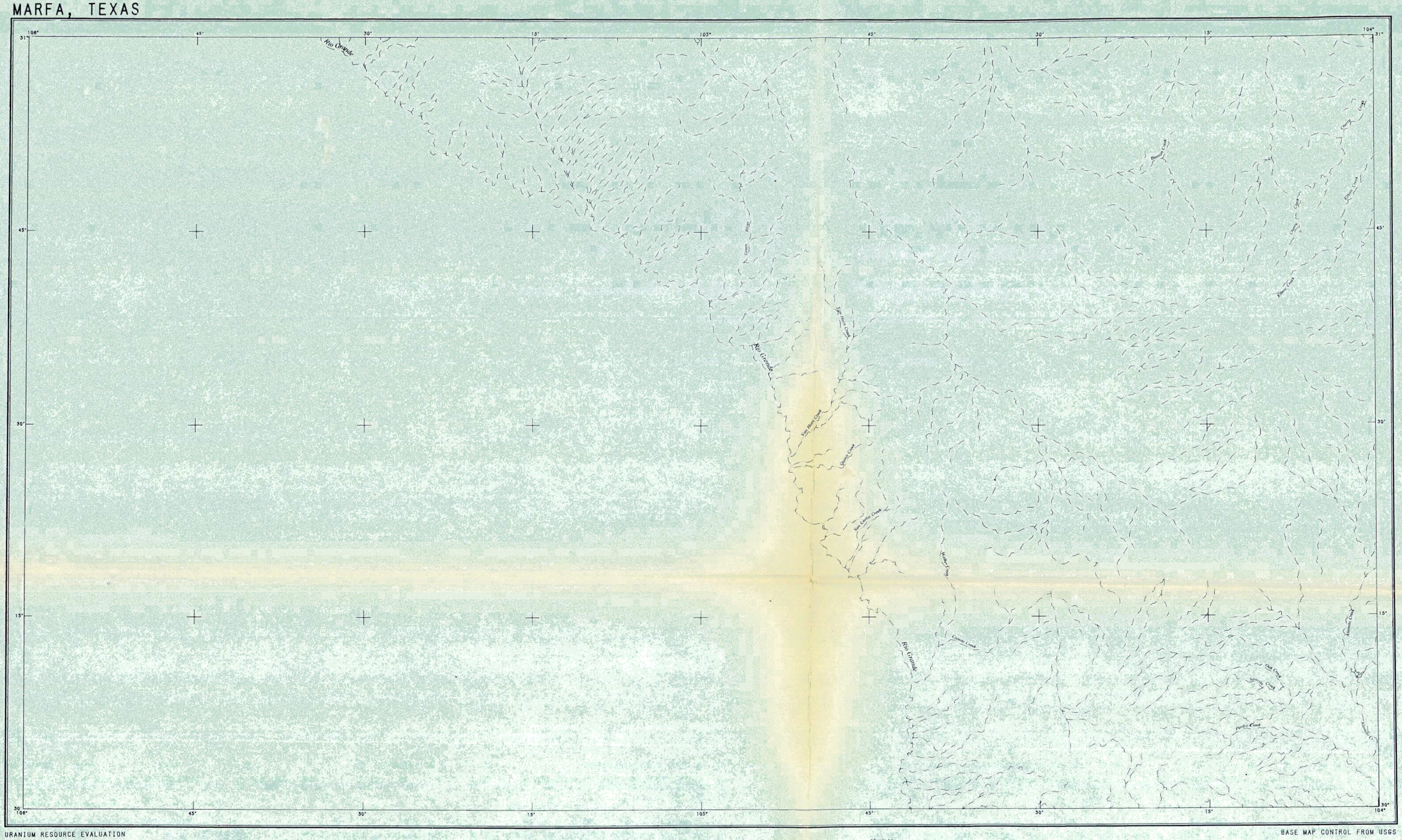
Plate 5. LOCATION MAP OF GEOCHEMICAL SAMPLES

MARFA, TEXAS



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

BASE MAP CONTROL FROM USGS

25 MILES

25 KILOMETERS

TRANSVERSE MERCATOR PROJECTION

Plate 6. DRAINAGE

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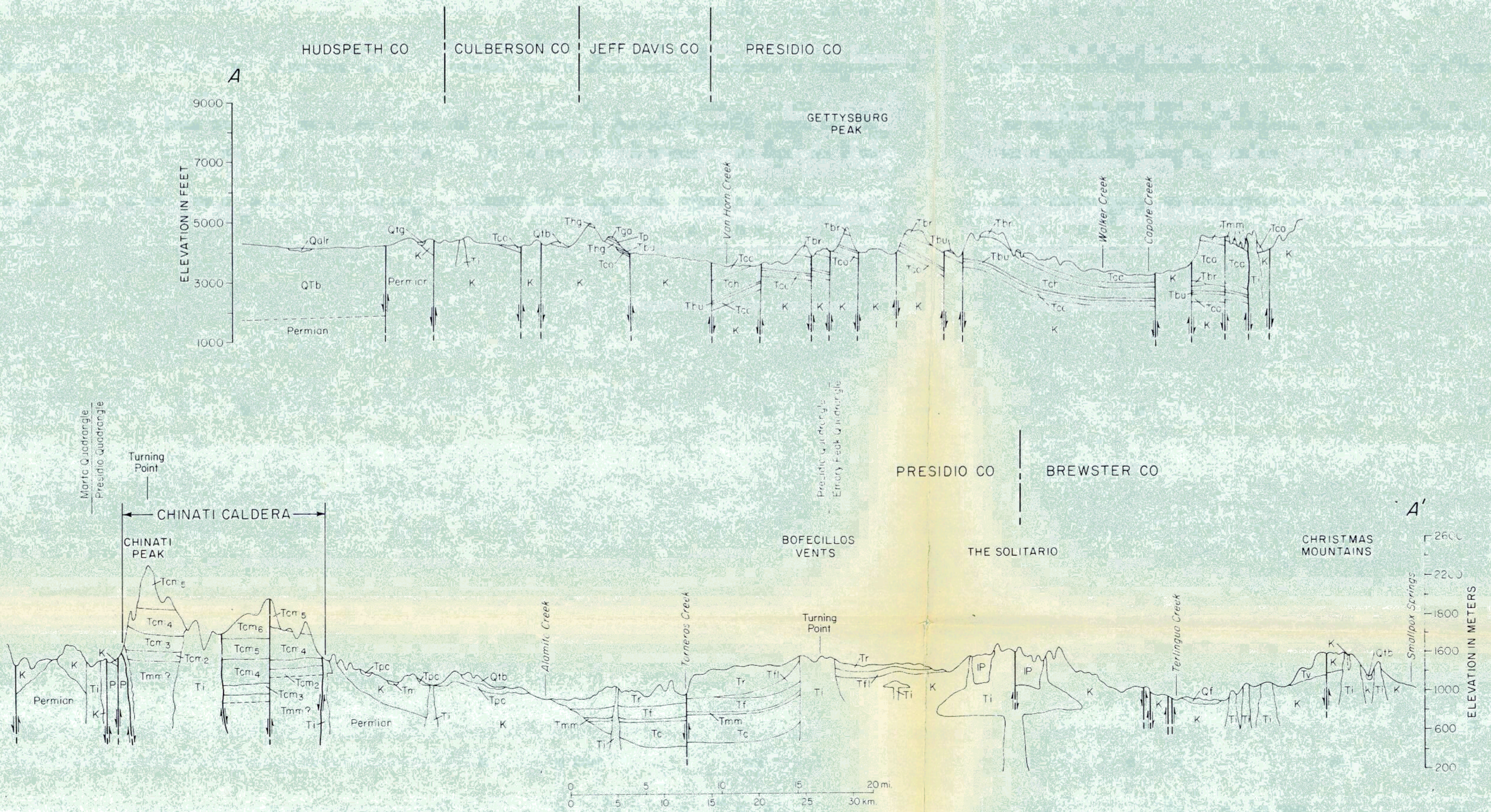
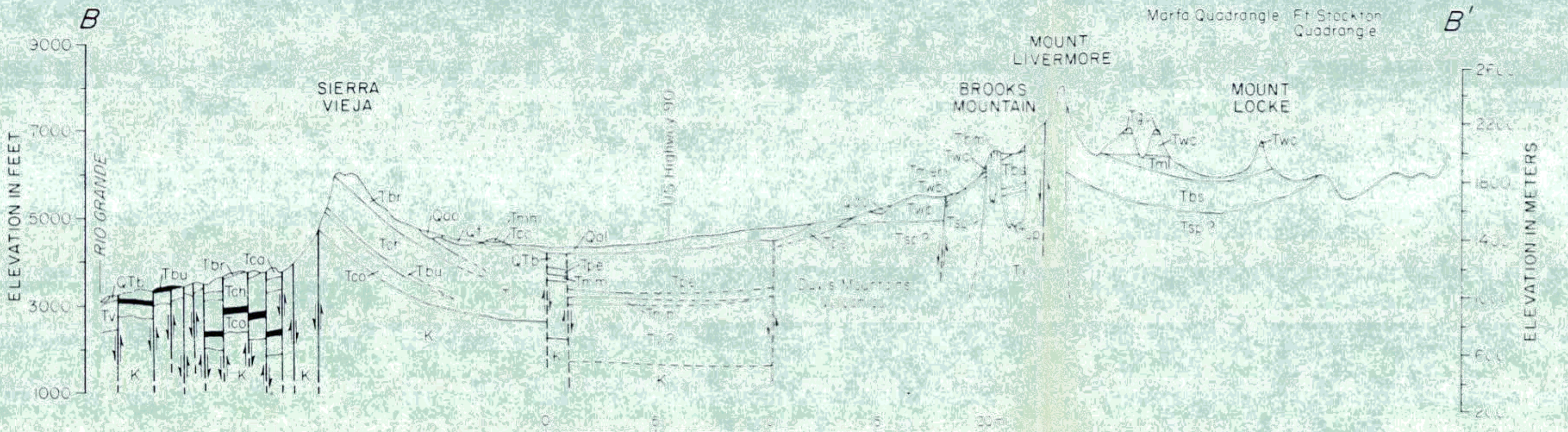
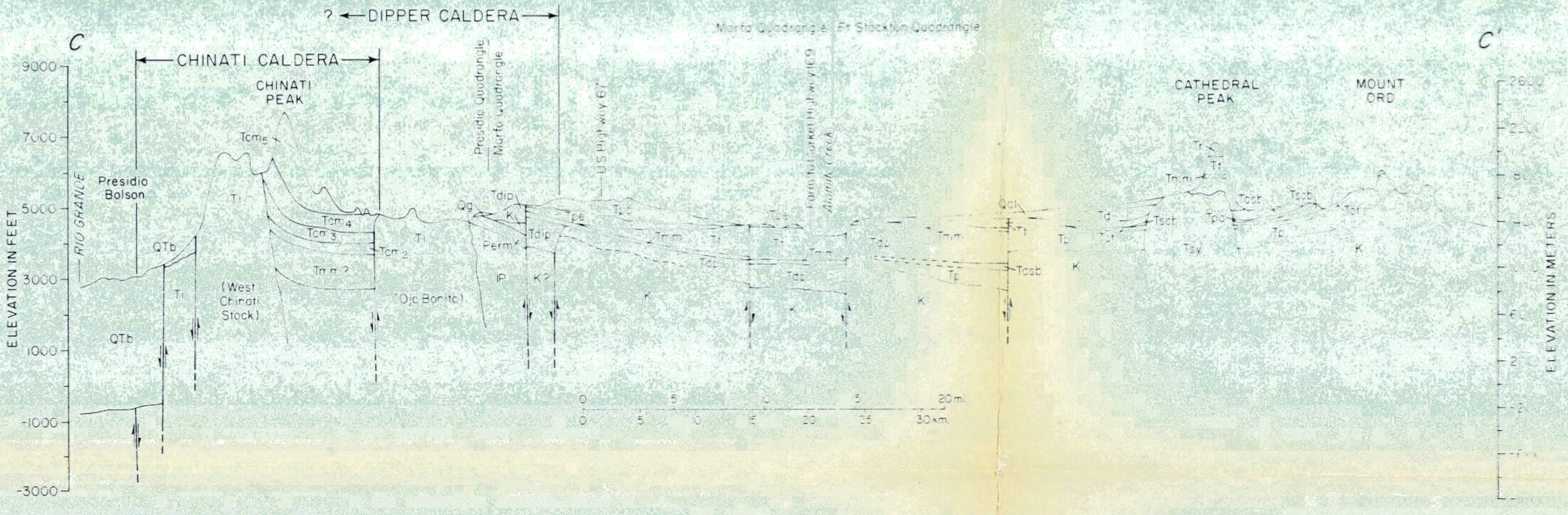


Plate 8. REGIONAL TERTIARY CROSS SECTION, TRANS-PECOS TEXAS

March, 1980
Plate 8

MARFA, TEXAS





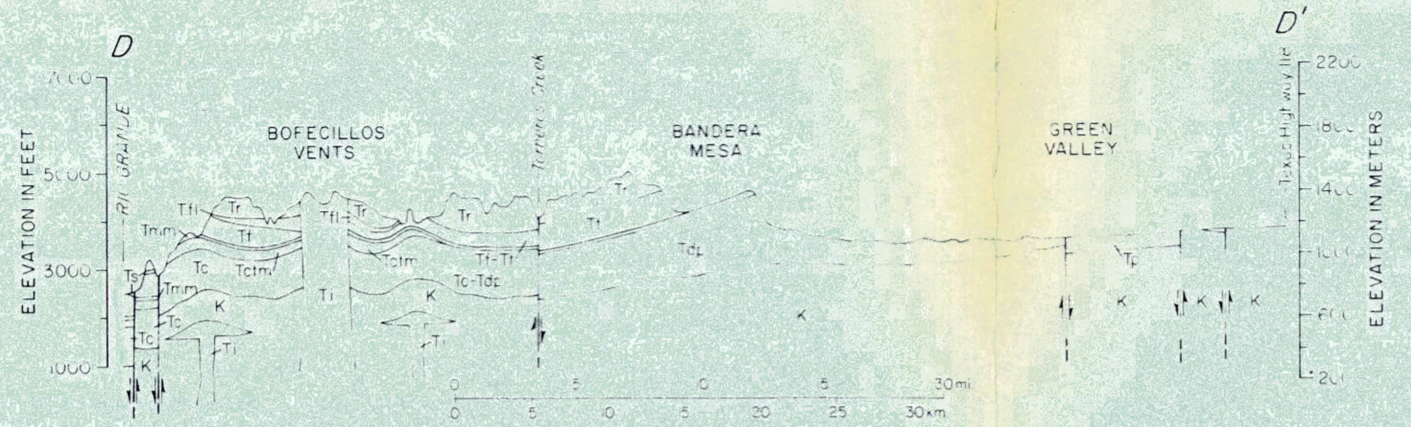
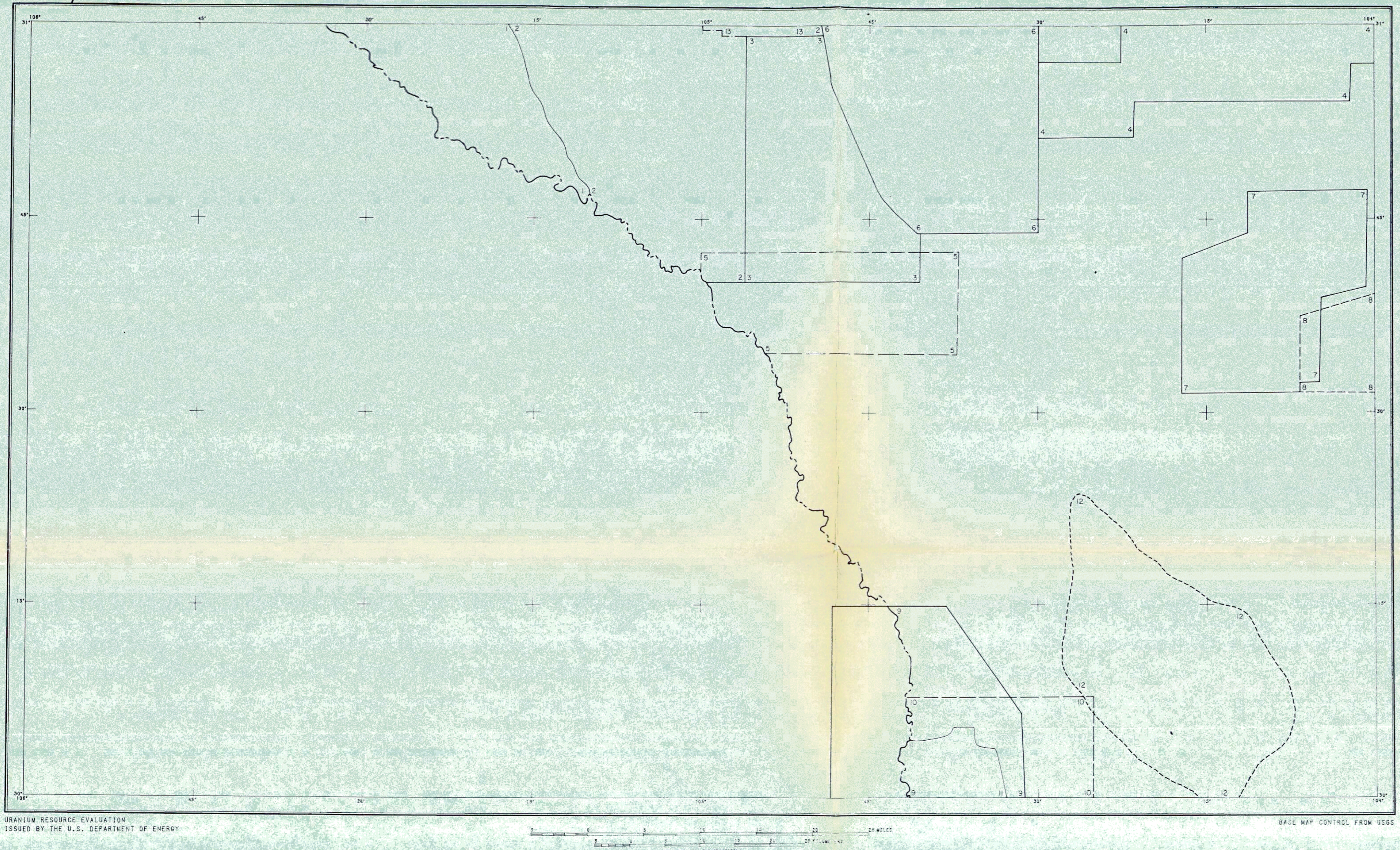


Plate 9. REGIONAL TERTIARY CROSS SECTIONS, TRANS-PECOS TEXAS

March, 1980

Plate 9

MARFA, TEXAS



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

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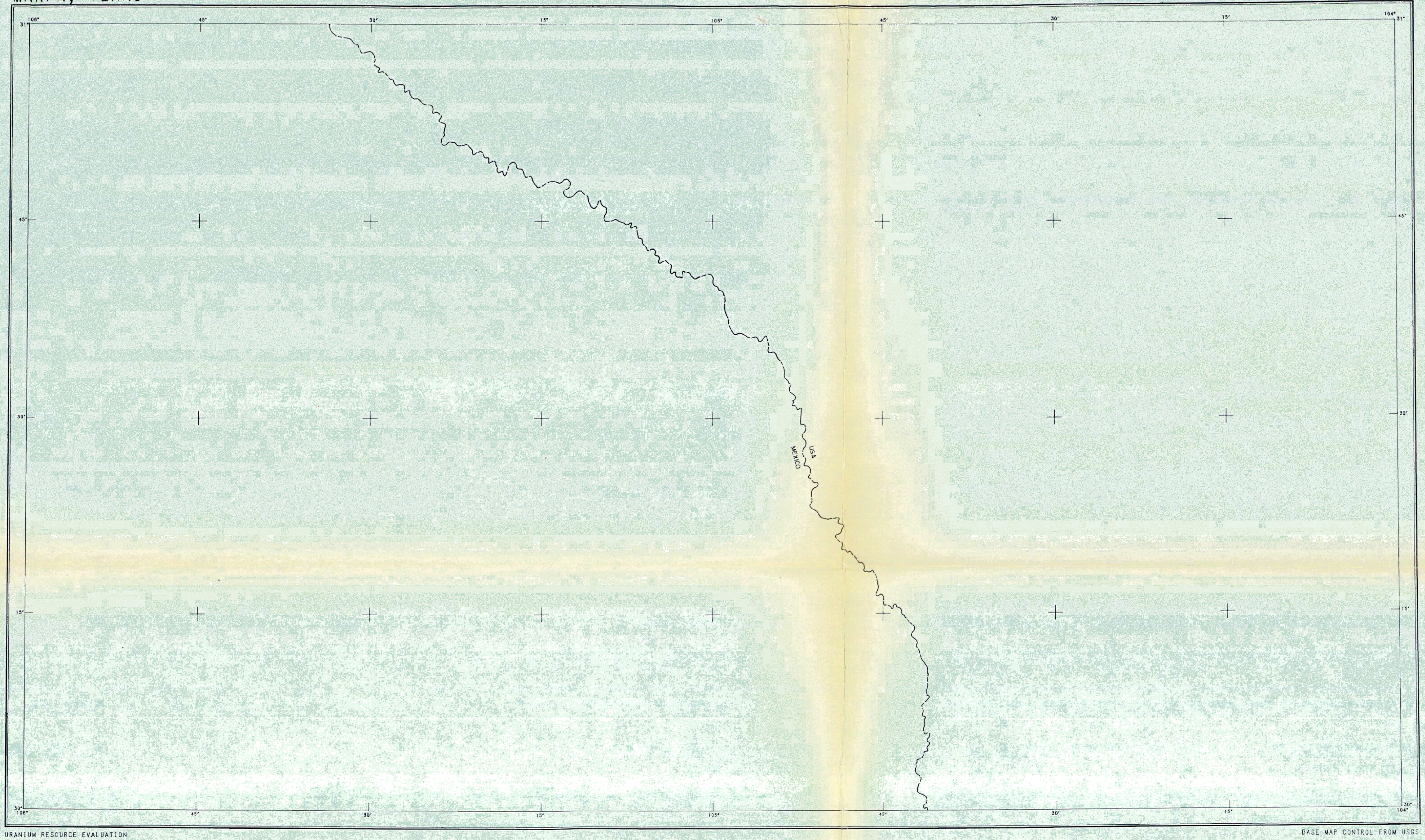
March, 1980
Plate 10

MARFA, 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

TRANSVERSE MERCATOR PROJECTION

Plate II. GENERALIZED LAND STATUS

July '80
Plate II.