URANIUM RESOURCE EVALUATION
EMORY PEAK QUADRANGLE
TEXAS

W. P. Wilbert,* T. W. Duex,† and C. D. Henry†

*Bendix Field Engineering Corporation
Grand Junction Operations
Grand Junction, Colorado 81502

†Bureau of Economic Geology
The University of Texas at Austin
University Station, Box X
Austin, Texas 78712

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ABSTRACT

The uranium potential of the 1° by 2° Emory Peak Quadrangle, Texas, was evaluated using criteria established for the National Uranium Resource Evaluation program. Only that portion in the United States was evaluated. Surface and subsurface studies (to a 5,000 ft; 1500 m depth) were employed, along with chemical, petrologic, hydrogeochemical, and airborne radiometric data. The western half of the quadrangle is in the Basin and Range Province and is characterized by Tertiary silicic volcanic and volcaniclastic rocks overlying Cretaceous carbonate rocks. Stocks and laccoliths of alkalic silicic to mafic rocks intrude both the Tertiary and Cretaceous rocks. The westernmost Great Plains Province (here composed of flat-lying Cretaceous carbonate rocks of the Stockton Plateau) forms the eastern half. Paleozoic leptogeosynclinal rocks of "Ouachita" facies in the Marathon Basin extend into the northern part of the quadrangle. Four environments favorable for uranium deposits have been identified: (1) basal conglomerates and (2) lacustrine-lignite deposits within the Pruett Formation, (3) fluorite deposits at the contacts between alkali rhyolite intrusions and Cretaceous carbonate rocks, and (4) alkaline rhyolitic to syenitic intrusions. Big Bend National Park is largely unevaluated because of access problems with the park service. A karst area near Dryden, which exhibits anomalous uranium, molybdenum, selenium, and arsenic concentrations in stream sediments and which exhibits radiometric anomalies, is also classed as unevaluated because little of it lies within the evaluated area. Another solution feature, the Stilwell Ranch prospect, is interesting academically, but is unfavorable.

INTRODUCTION

PURPOSE AND SCOPE

The Emory Peak 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 5,000 ft (1500 m). 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, using the recognition criteria of Mickle and Mathews (1978). A favorable environment in this study is defined as one that could contain at least 100 tons U_3O_8 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). 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 the Tertiary rocks, which are predominantly igneous or igneous-derived sedimentary rocks.

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Dr. F. W. Daugherty allowed access to the D & F Minerals Fluorspar Mine near Study Butte. His long experience in many aspects of Trans-Pecos geology aided the writers.

The staff of the Bureau of Economic Geology, Austin, were 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 Emory Peak Quadrangle generously allowed 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.

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PROCEDURES

Because the evaluation of this quadrangle was a cooperative effort, this section is divided into two parts, one applicable to the BFEC contribution, written by W. P. Wilbert, and the other, applicable to the BEG contribution, written by C. D. Henry and T. W. Duex.

Bendix Field Engineering Corporation

BFEC was responsible for the pre-Tertiary rocks and Quaternary sediments in the quadrangle. During Phase I of the evaluation, Wilbert, in cooperation with the

BEG, reviewed the literature and compiled maps and information on uranium occurrences. During Phase II (6/30/78-9/30/79), literature research continued and field work was performed. Field work consisted of examining known uranium occurrences and areas of anomalously high radioactivity, as reported in Preliminary Reconnaissance Reports (PRR's) of the U.S. Atomic Energy Commission, and identification and examination of other areas of potential mineralization on the basis of geologic inference and the literature. Rock samples (App. B) and scintillometer (Mt. Sopris model SC-132) readings were taken at each accessible occurrence and also randomly throughout the quadrangle. After initial reconnaissance, radiometric (scintillometer) traverses were run and samples were collected for geochemical analysis. In addition to areas of anomalously high radioactivity, samples were taken from areas where radiometric background was low, to establish a "normal" background for a particular rock unit in a certain area. This technique was also used to fill geographic gaps. No regular pattern for sampling was used.

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 laboratories at BFEC's Grand Junction (Colorado) facility. Gamma spectroscopy was also done at BFEC Grand Junction laboratory after emission spectrographic analysis and U_3O_8 determination. Except for four samples (MGD-976, MGD-980, MGD-984, and MGD-985), splits sent to Grand Junction were of insufficient volume to make gamma spectroscopy feasible. Thus, only these four samples have values in the eK, eU, and eTh columns in Appendix B.

Subsurface data consisted almost entirely of widely spaced (average approximately 15 mi; 24 km) electric logs from hydrocarbon tests. While too widely spaced to be of much value in regional evaluation of an environment, these tests can be of local value. Data from numerous mineral exploration holes were not available.

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), and detailed studies into a geologic framework.

Bureau of Economic Geology

Procedures used by the Bureau of Economic Geology are similar to those used by Bendix Field Engineering Corporation with a few minor differences and one major difference in concept of evaluation discussed below. Minor differences include (1) Phase II lasted from 8/15/78 to 11/15/79; and (2) a Geometrics model GR-101A scintillometer was used in place of the Mt. Sopris model used by Bendix, and a Scintrex GAD-6 gamma-ray spectrometer with a 3-inch sodium iodide crystal was used locally. The spectrometer is awkward to transport on foot in the rugged terrain of Trans-Pecos Texas and was used only where access allowed.

Samples collected were analyzed at the Bureau's Mineral Studies Laboratory under the supervision of Dr. Clara Ho, chemist-in-charge. Uranium analysis was by a total-fusion fluorometric procedure. Multielement 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 as required by the contract. However, no gamma-ray analyses were provided.

The major difference in methodology employed by the Bureau of Economic Geology is in an attempt to understand the processes that could lead to uranium ore formation in volcanic terrain, a relatively frontier field for uranium exploration. Although employed extensively, this approach can best be illustrated by using the extensive Tertiary tuffaceous sedimentary sequence as an example. Epigenetic uranium deposits require three factors acting together: (1) a uranium source that has released uranium, (2) migration of the uranium from the source to a site of entrapment, and (3) entrapment and enrichment of uranium in a deposit, commonly by reduction of U^{+6} to U^{+4}. All three factors can be identified in Trans-Pecos Texas.

The metaluminous to peralkaline igneous and igneous-derived sedimentary rocks contain high background concentrations of uranium (up to 20 ppm). In tuffaceous sediments, the uranium is predominantly tied up in volcanic glass shards and pumice fragments. The tuffaceous sediments are highly permeable. Potential trap rocks exist in both the Tertiary sediments, either in channel sandstones containing organic trash or in lacustrine deposits with thin but extensive lignite beds, and in underlying Cretaceous sedimentary rocks. The key to evaluating uranium favorability in relation to the tuffaceous sediments is understanding the release part of factor 1. The sediments have undergone open-hydrologic-system diagenesis (Hay and Sheppard, 1977; Walton, 1975; Botros, 1976; Hively, 1976) in which the glass shards are dissolved by through-flowing ground water. All chemical constituents of the shards, including uranium, are placed in solution in ground water, seemingly an ideal situation for long-distance migration of uranium and formation of major deposits. However, previous work (Walton, 1978; Walton and others, in progress) indicates that in some types of alteration of glass, although uranium enters into solution, it does not migrate sufficient distances to be concentrated. Other types of alteration do allow long-distance migration (Galloway and Kaiser, in press). Without long-distance migration of uranium, the tuffaceous sediments are only potential source rocks.

We have used extensive sampling of the tuffaceous sediments along with chemical analysis, particularly of uranium and thorium, petrographic analysis to identify types of alteration, and fission-track mapping to identify sites of uranium in unaltered (glassy) and altered sediments to evaluate whether or not diagenesis has released significant quantities or proportions of uranium from the potential source rocks. If significant quantities have been released from a given area, that area or potential trapping environments down hydrologic gradient must be considered highly favorable. If only small or unmeasurable quantities of uranium have been released, the area is much less favorable. Under the latter case the area is not necessarily totally unfavorable, however. Release of only 1 ppm of uranium from a large volume of source rock could create immense deposits, although such release would be difficult to ascertain by almost all analytical methods.

Uraniferous fluorite is a second example. High concentrations of uranium are irregularly distributed in fluorite, even within a single deposit. The process that leads to erratic enrichment is not understood other than that the fluorite is in general contact-metasomatic in origin. Understanding the controls of uranium distribution in fluorite would allow better evaluation of the possible existence of significant uraniferous fluorite deposits and could provide an effective exploration technique.

Investigation of the subsurface favorability of the Tertiary rocks has been done entirely from examination of surface exposures and extrapolation to depth. This approach is feasible, and excellent regional cross sections can be constructed (Pls. 8 and 9) because Trans-Pecos Texas is an area of high relief and is cut by numerous normal faults. However, logged wells are sparse, and none provide usable information about the Tertiary rocks other than total thickness. In some areas of extensive

Quaternary cover, subsurface relations of the volcanic and volcaniclastic rocks can only be surmised, especially where rocks derived from different source areas interfinger.

The currently available aeroradiometric data (LKB Resources, 1979) are considered of little value. Few of the known major uranium prospects were located, probably because the 5-mi (8-km) spacing is too wide and the area is geologically too complex. A total of 135 equivalent uranium aeroradiometric anomalies were identified by the survey; LKB Resources identified 28 of these as "preferred anomalies" (Pl. 3). However, field examination of several of these revealed no anomalous uranium. Additional aeroradiometric surveys at 0.25-mi (0.4-km) spacing have been done in some areas. However, the results of these surveys are not yet available.

GEOLOGIC SETTING

The 1° by 2° Emory Peak Quadrangle lies along the Rio Grande in Trans-Pecos Texas. Its eastern and western boundaries are long 102°W. and 104°W., respectively. The northern boundary is lat 30°N. The southern boundary is the Rio Grande, which follows an irregular course southeast from 104° to about 103° and then turns sharply northeast to about 103°30' where it flows irregularly eastward to the east boundary. Total area of the quadrangle is approximately 4,900 mi^2 (12,700 km^2). The quadrangle lies dominantly in the Basin and Range physiographic province but faulting dies out eastward. The eastern part of the quadrangle is part of the Edwards Plateau of the Great Plains physiographic province. The Paleozoic Marathon Fold Belt is exposed in the north-central part of the quadrangle and is buried beneath Cretaceous and Tertiary rock throughout the rest of the quadrangle except in the Solitario Uplift in the southwest corner. Rocks that crop out in the quadrangle range in age from Cambrian to Recent.

Marathon Basin

King (1937) wrote what is perhaps the definitive work on the highly deformed Paleozoic sedimentary rocks of the Marathon Basin. Later workers have discussed details of the petrology and stratigraphy.

Thick intensely deformed pre-Permian Paleozoic sedimentary rocks are exposed in two areas in the Emory Peak Quadrangle, the Marathon Basin and the Solitario Uplift (King, 1937). The Marathon Basin is chiefly in the Fort Stockton Quadrangle, but the extreme southern part is exposed in the Emory Peak Quadrangle. Rocks in these areas are chiefly marine (only the Cambrian Dagger Flat Sandstone has continental facies) and represent a wide range of sedimentary depositional environments, from shallow shelf (Marathon Limestone), to outer shelf turbidity current deposits (Dimple Limestone; Tesnus Formation) to probable abyssal plain radiolarian chert (Caballos Formation). Thomson and McBride (1964) interpret at least the Ordovician part of the basin as having been "starved."

The Solitario, a circular uplift of Paleozoic rocks resulting from laccolithic intrusion (Corry, 1976), differs from the Marathon Basin stratigraphy only in detail (Wilson, 1965). In the Solitario, however, the massive, prominent Caballos Formation does not crop out; only the lower part of the section is exposed, unconformably overlain by Cretaceous limestones.

Cretaceous Rocks

Cretaceous rocks occur in both the Edwards (Stockton) Plateau and the Basin and Range physiographic provinces. The Edwards Plateau is characterized structurally by virtually flat-lying strata and stratigraphically by Cretaceous carbonates. Massive rudistid-bearing limestones of the Comanche Series predominate east of U.S. Highway

385, which connects Marathon and Big Bend National Park. This province extends to the Balcones Fault Zone, which trends northeast to southwest through Austin and San Antonio, along the trend of the Paleozoic Ouachita Geosyncline. The Cretaceous rocks are relatively pure carbonate, deposited on the shelf of the extensive Mesozoic seaway. They are chiefly limestone, which are little dolomitized and are the lateral equivalents of rocks that are folded into the Sierra Madre Oriental in Mexico. Minor clastic units are present in the Lower Cretaceous. An erosional remnant of shaly Upper Cretaceous strata is present to the east.

The area between Highway 385 and the western edge of the quadrangle is believed by Henry (1979) and Muehlberger (1979) to belong to the Basin and Range Province, although it does not display the "typical" northwest-to-southeast-oriented structures of the Marfa Quadrangle. It is so considered here because it has a relatively high heat flow and the crust is thin (Henry, 1979). The NW-SE to N-S trending Santiago Mountains (parallel to Highway 385) form the eastern boundary with the Stockton Plateau. Numerous intrusions in, west of, and north of Big Bend National Park have obliterated any structural trends that may once have been present.

Two Cretaceous formations are extensively exposed in the Basin and Range Province: (1) the Boquillas Formation, which crops out extensively from Lajitas through the western side of the park and then northward generally along the route of Highway 118 to the southern Davis Mountains, and (2) the Aguja Formation in the western part of the park and near Study Butte and the Christmas Mountains. The Terlingua Fault forms the southern boundary of the Upper Cretaceous outcrop; the deep scenic canyons in the park and the cliffs along the Mexican side of the Rio Grande are chiefly Del Carmen and Santa Elena limestones.

Tertiary Rocks

Tertiary rocks include numerous small- to moderate-sized intrusions, extensive areas of volcanic and volcaniclastic rocks and minor basin-fill sediments. Volcanism and intrusion occurred contemporaneously from approximately 45 m.y. to less than 20 m.y. ago and were in part cogenetic. Two major volcanic centers occur within the quadrangle: the Chisos Mountains and the Bofecillos Mountains. In addition, ash-flow tuffs, lava flows, and tuffaceous sediments erupted from several volcanic centers outside the quadrangle crop out in the Emory Peak Quadrangle.

The Chisos Mountains contain only one documented caldera, the Pine Canyon Caldera (Ogley, 1979), but the presence of numerous intrusions and thick sequences of tuffaceous sediments suggests that several more calderas may occur there. The Pine Canyon Caldera and related rocks are about 30 m.y. old and are the youngest igneous activity in the Chisos Mountains. Stratigraphically older rocks exist but are poorly dated. Much of the tuffaceous sediments of the Chisos Formation may be derived from sources outside the Chisos Mountains.

The Bofecillos volcanic center is composed dominantly of mafic and alkalic lava flows erupted from a stratovolcano centered approximately on the Emory Peak - Presidio quadrangle boundary (McKnight, 1970). Volcanic rocks were erupted from several vents and include lava flows in the Fresno Formation and almost all of the Rawls Formation. The Bofecillos center was active from about 28 m.y. to at least 18 m.y. before present, although most activity may have ceased about 22 m.y. ago (McDowell, 1979).

The Santana Tuff, an ash-flow tuff up to 560 ft (170 m) thick along the Rio Grande, separates the underlying Fresno Formation from the Rawls Formation. The Santana Tuff was probably erupted from a major caldera to the south in Mexico.

Intrusive rocks unrelated to any known volcanic activity are abundant in the west-central part of the quadrangle, particularly in an area around the Christmas Mountains and in a belt running north along the Santiago Mountains. The rocks are alkalic, ranging in composition from analcime basalts and syenogabbros to rhyolites, peralkaline (riebeckite) rhyolites, and fayalite granites (Lonsdale, 1940; Barker, 1977). They are intruded into Cretaceous sediments as dikes, sills, stocks, and laccoliths. The stocks range up to about 10 mi (16 km) in diameter, but most are only about 1 to 2 mi (2 to 3 km) in diameter. The Solitario is a dome uplifted by a partly exposed laccolith of quartz monzonite (Corry, 1976). Ages of intrusion range from about 40 to 26 m.y. (McDowell, 1979; Daily, 1979).

Much of the volcanic section in the Emory Peak Quadrangle consists of tuffaceous sediments derived largely from volcanic centers outside the quadrangle. Some of the sediments may have come from the Chisos Mountains area, but most of the sediments probably came from centers to the west in the Chinati Mountains, to the north in the Davis Mountains, and possibly to the southwest in the Sierra Rica of Mexico. The oldest sediments are the Pruett and Duff Formations in the northwest and west-central part of the quadrangle and the time-equivalent Chisos Formation in the south-central part of the quadrangle. The Mitchell Mesa Welded Tuff caps both. The Tascotal Formation overlies the Mitchell Mesa Welded Tuff and Pruett and Duff Formations in the west-central part of the quadrangle, whereas the Fresno Formation, the time equivalent of the Tascotal Formation, overlies the Mitchell Mesa Welded Tuff and Chisos Formation in the southwestern part of the quadrangle. The Tascotal Formation forms an eastward-thickening wedge of sediment derived from the Chinati Mountains (Walton, 1978). Source areas of the other sediments are more problematical. Total thickness of the entire sequence exceeds 3,000 ft (900 m) along the western margin of the quadrangle. Open-hydrologic-system diagenesis has converted tuffaceous sediments to an assemblage of zeolites, including clinoptilolite and analcime, montmorillonite, opal, and calcite. Glass is preserved only in the upper part of the Tascotal Formation (Walton, 1978). Diagenesis probably occurred largely during deposition of the sediments.

Most of the sediments were deposited as alluvial fans shed off the major volcanic centers. However, in several places interbedded lava flows created locally closed basins in which lacustrine sediments accumulated. The most extensive areas of lacustrine sediments are in the Pruett Formation in the northwest part of the quadrangle extending into the Fort Stockton Quadrangle. In this area, lignite and fresh-water limestone are interbedded with more typical tuffaceous sediments (Goldich and Elms, 1949). Total area of the closed basin may be approximately 100 mi^2 (250 km^2), if a number of isolated outcrops are all parts of a former single basin. A much smaller area of lacustrine sediments (fresh-water limestone but no lignite) also occurs in the Duff Formation below Bandera Mesa.

Potassium-argon ages of the sediments and interbedded ash-flow tuffs and lava flows range from approximately 49 m.y. in the Pruett Formation directly overlying the Cretaceous rocks to 26 m.y. for the Santana Tuff (McDowell, 1979). Tuffaceous sediments are also interbedded locally within the Rawls Formation.

Basin and range faulting began about 23 m.y. ago following cessation of most igneous activity (Dasch and others, 1969; McDowell and Henry, unpublished data). Faults trend generally northwest and show normal displacement. The Chisos Mountains, although a topographic high, are structurally downdropped between major normal fault systems along the southwestern and northeastern edges of the mountains (Udden, 1907). Offsets of more than 3,000 ft (900 m) occur on some faults, but no major enclosed basins (bolsons) formed in the quadrangle. Thin remnants of basin fill are preserved in three localities: the southwest and northeast parts of Big Bend National Park near the bounding faults (Stevens, 1969), and in the small Santana bolson (Robinson, 1976) at the southwest edge of the quadrangle.

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

SUMMARY

Four favorable environments have been identified in the Emory Peak Quadrangle. Basal conglomerates of the Pruett Formation and the undifferentiated Pruett-Duff Formations (Area A, Pl. 1) contain uranium anomalies and exhibit characteristics of Subclass 243 of Austin and D'Andrea (1978). Lacustrine-lignite deposits in the Pruett Formation (Area B, Pl. 1) also contain uranium anomalies and exhibit characteristics of Class 210 of Jones (1978). Fluorite deposits associated with alkaline rhyolite intrusions in the Christmas Mountains (Area C, Pl. 1) contain both anomalous uranium and thorium concentrations. The deposits best fit the contact-metasomatic class (340) of Mathews (1978), although they do not fit this classification perfectly. Black Mountain and other alkaline rhyolite to syenitic intrusions (Areas C and D, Pl. 1) contain minor uranium anomalies and best fit the orthomagmatic class (310) of Mathews. They are probably subeconomic but may be potential source rocks for epigenetic deposits.

PRUETT FORMATION AND UNDIFFERENTIATED PRUETT-DUFF FORMATIONS

Geologic Setting

The Eocene Pruett Formation and the undifferentiated Pruett-Duff Formations are favorable for uranium deposits. Both are the basal Tertiary units overlying Cretaceous sedimentary rocks. The Pruett Formation is separated from the overlying Oligocene-age Duff Formation in the northwestern part of the quadrangle by the Cottonwood Springs Basalt. In the west-central part of the quadrangle the Cottonwood Springs Basalt is absent and the entire tuffaceous sedimentary sequence beneath the Mitchell Mesa Welded Tuff is called undifferentiated Pruett-Duff Formation (Barnes, 1979a). However, fossil assemblages identified by Wilson and others (1979) within this sequence are all late Eocene, equivalent to Pruett Formation in age. Wilson and others suggest renaming the undifferentiated Pruett-Duff Formation in the southwestern part of the quadrangle the Devil's Graveyard Formation. For convenience, we will refer to both the Pruett and undifferentiated Pruett-Duff Formations as Pruett Formation. Basal conglomerates and lacustrine deposits in the Pruett Formation are favorable for uranium deposits.

The Pruett Formation crops out over much of the northwestern part of the quadrangle. At one time it extended farther to the east and possibly to the south to join with the time-equivalent Chisos Formation. Its present distribution results from erosion that has exposed the Pruett-Cretaceous contact along the eastern edge of its outcrop. To the west the Pruett disappears beneath the overlying Duff Formation and Mitchell Mesa Welded Tuff along an irregular escarpment (relief approximately 300 to 1,200 ft; 90 to 350 m), which runs northward from Bandera Mesa to the north edge of the quadrangle. Both the Pruett and Duff Formations continue an uncertain distance beneath this escarpment. Subsurface control is not available due to the paucity of wells, but the formations are known to pinch out to the west at several places in the Presidio Quadrangle. Our interpretation, based on outcrop data and geologic inference, is shown in Plates 8 and 9.

The Pruett Formation is up to 1,000 ft (300 m) thick and is composed of tuffaceous sediment, including conglomerate, sandstone, mudstone, and minor fresh-water limestone. Descriptions of the formation are from Stevens (1979), McAnulty (1955), Goldich and Elms (1949), and our own observations.

Tuffaceous sandstone and mudstone composed of glass shards and rock and mineral fragments make up most of the formation. The sediment was deposited in a fluvial environment, probably reworked from air-fall and ash-flow tuffs. Preserved tuff beds are rare.

Conglomerates are most abundant at or near the base of the Pruett and, in general, the formation fines upward. Basal conglomerates contain dominantly sedimentary rock fragments derived from the underlying Cretaceous and Paleozoic rocks. Volcanic rock fragments are present but minor. Carbonaceous debris or petrified wood is common in basal conglomerates; unsilicified organic material may be more common in the southern part of the outcrop area. Conglomerates above the base are composed dominantly of volcanic rock fragments; we observed no organic material in any of these upper conglomerates.

Lacustrine deposits are found in two areas: at the northern edge of the quadrangle, where they continue into the Fort Stockton Quadrangle, and in the Fizzle Flat area. The northern deposits include calcareous tuff, fresh-water limestone, and lignite. These were apparently deposited in closed basins created by lava flows that were interbedded with the tuffaceous sediments of the Pruett Formation. Robinson (1978) recognized three depositional environments: (1) shallow, open nearshore; (2) protected nearshore (lagoonal); and (3) transitional. Organic material dominantly formed and was preferentially preserved in the lagoonal environment. Organic material observed includes lignite and organic-rich, petroliferous limestone. Fresh-water limestone is also found in the Fizzle Flat area, but although carbonaceous material is preserved in conglomerates there, no lignites or organic-rich limestones are noted in this area. Origin of the lacustrine deposits in the south is uncertain.

Stevens (1979) thought the Pruett Formation in the Fizzle Flat area was deposited by braided streams associated with lakes and swamps. The Pruett Formation elsewhere may also have been deposited by braided streams or alluvial fans, such as in the Tascotal Formation (Walton, 1978). Transport directions are dominantly from the north and west, probably from volcanic centers in the Davis Mountains and Chinati Mountains.

The Pruett Formation has been diagenetically altered in an open hydrologic system (Hay and Sheppard, 1977). All original glass has been dissolved by ground water; the dissolved constituents reprecipitated as various diagenetic minerals, including clays, zeolites, calcite, and silica minerals. The Pruett Formation in the south contains clinoptilolite, opal, and montmorillonite (Botros, 1976), a mineral assemblage characteristic of initial diagenesis. The Pruett Formation near the north edge of the quadrangle contains analcime, indicating more advanced diagenesis. The boundary between these zones has not been precisely delineated, but is probably sub-horizontal, dipping slightly to the south.

Favorable Environments

The two favorable environments for uranium deposits in the Pruett Formation are (1) basal conglomerates containing organic debris as a reductant (Subclass 243, Austin and D'Andrea, 1978) and (2) lacustrine-lignite deposits (Class 210, Jones, 1978, for lignite; no classification for lacustrine).

Basal Conglomerates. Basal conglomerates occur irregularly throughout the Pruett Formation. They range widely in size; width and thickness of individual channels varies up to a maximum of 300 ft (100 m) and 100 ft (30 m), respectively. According to Reeves and others (1979), the channels average 5 ft (1.5 m) in thickness. They commonly cannot be traced far in outcrop. Numerous channels are exposed along the contact between the Pruett Formation and Cretaceous sedimentary rocks. To the west the conglomerates disappear beneath upper parts of the Pruett Formation and eventually beneath the Duff Formation and Mitchell Mesa Welded Tuff near the west edge of the quadrangle. Thus depth of the favorable environment varies from 0 to greater than 2,000 ft (600 m). The favorable environment (Area A, Pl. 1) has been continued to the northern and western boundaries of the quadrangle and terminated along a somewhat arbitrary line on the southwest. The extent to which the Pruett Formation or basal conglomerates continue in these directions is not known. Regional subsurface data would greatly enhance evaluation.

Primary evidence of favorability consists of the presence of numerous mineralized channels in the Fizzle Flat - Green Valley area, including some observed by us, several reported in the literature (Reeves and others, 1979), and several reported, but not located, from proprietary information. Two samples (MGD-499 and MGD-500) collected by us contain 800 and 1,700 ppm U_3O_8, along with high concentrations of V, Mo, As, and Se. The trace element association suggests that uranium vanadates are the major ore minerals; Reeves and others reported carnotite and tyuyamunite along with schroeckingerite.

Other important evidences of favorability include (1) the abundance of potential source rocks, (2) inferred high permeability, not only in the channel deposits but also in the tuffaceous sediments in general, and (3) the presence of appropriate host rocks and reductants (channel deposits with carbonaceous debris).

(1) The tuffaceous sediments of the Pruett, Duff and Tascotal Formations constitute an immense reservoir of uranium. Uranium concentrations in these rocks range from a few ppm to about 12 ppm and average about 5 to 6 ppm. Diagenetic alteration of these rocks dissolved glass and could have released considerable uranium to solution. Release of even a fraction of this uranium could produce significant deposits as long as the concentrating mechanism is available. Analysis of uranium and thorium concentrations, thorium-uranium ratios, mineralogy of the sediments, and fission-track maps showing uranium distribution does not indicate release of a majority of the primary uranium content, but the significance of these results is uncertain (Henry and Duex, 1980).

(2) Immediately after deposition, the tuffaceous sediments consisted of poorly sorted, uncemented glass shards and rock and mineral fragments. Permeability of the sediments should have been extremely high; the fact that they were subsequently altered by open-hydrologic-system diagenesis attests to their high permeability. Even after diagenesis, the sediments are highly permeable. They are the major sources of ground water to ranchers in the area and, although no pump tests are available to document permeability, the tuffaceous sediments produce abundant ground water.

(3) The channel conglomerates should have the highest permeability of any of the tuffaceous sediments, and in most places they overlie relatively impermeable Cretaceous sedimentary rocks. Also the channels commonly contain abundant carbonaceous debris. Thus ground-water flow should have been concentrated in the channels where adsorption or reduction of oxidized uranium could occur.

Conglomerates in the southern area may have preferentially preserved organic debris, whereas organic material in conglomerates to the north may have been silicified during diagenesis. For this reason reductants may be more abundant in the southern area. However, with our paucity of knowledge we have denoted the entire Pruett Formation as favorable.

Hydrogeochemical data (Pl. 4; Union Carbide, 1978a) also indicate favorability, although the data can be interpreted in several ways. Ground water in most tuffaceous sediments in the Emory Peak Quadrangle contains generally high concentrations of uranium, arsenic, selenium and vanadium. However, present-day ground water was probably not responsible for mineralization. For example, the exposed mineralized channels are now, and have been for some time, isolated from ground water. Mineralization must have occurred much earlier, probably during diagenesis, at which time uranium and the other elements may have been most mobile. The present-day concentrations may simply reflect equilibrium of ground water with rocks that contain relatively high concentrations of uranium and the other elements compared with normal rocks.

As discussed in the section on procedures, aeroradiometric data are considered of little value because they failed to identify any of the major uranium prospects in the Emory Peak, Presidio or Marfa Quadrangles, probably because the 5-mi (8-km) spacing was too wide.

Lacustrine Deposits. Lacustrine deposits of calcareous tuff, fresh-water limestone, and minor lignite occur in a large area along the northern boundary of the quadrangle and extend into the Fort Stockton Quadrangle. At one location 10 mi (16 km) north of the quadrangle boundary, the deposits are 300 ft (90 m) thick. Deposits examined within the Emory Peak Quadrangle are much thinner, but the Pruett Formation is poorly exposed in this area so exact thickness and extent are uncertain. The lacustrine deposits generally occur near the top of the formation and crop out along steep escarpments capped by resistant flow rocks. Depth to the favorable environment varies from 0 to about 300 ft (90 m). Several different areas of lacustrine deposits are known, but it is not known if they represent individual small basins or a larger continuous basin. Also the western limit of the favorable environment (Area B, Pl. 1) is poorly known, because the Pruett Formation disappears beneath the Duff Formation. It is not known how far the lacustrine environment continues beneath the Duff Formation. Determination of the total extent of the lacustrine environment and whether it consists of a single large basin or several smaller basins would aid in evaluation.

Lignites and petroliferous limestone beds contain high concentrations of uranium and other trace elements in several locations near the northern edge of the Emory Peak Quadrangle. Reeves and others (1979) and the Atomic Energy Commission (1955) reported uranium concentrations as high as 0.062 percent U_3O_8 and stated that uranium minerals identified include carnotite, autunite, and uraninite. Samples collected by us (MGD-684 to MGD-697) from a location near the Emory Peak Quadrangle contained up to 80 ppm U_3O_8, but no uranium minerals could be identified. Associated trace elements include molybdenum, arsenic, and phosphorus, suggesting that at least some uranium is present as a phosphate. However, uranium probably also occurs as reduced uranium minerals and possibly adsorbed by the organic material.

Other evidences of favorability are similar to those for the basal conglomerate environments -- the presence of source rocks, permeability and reductants. Source rock considerations are identical. Lacustrine beds are less permeable than the conglomerates but probably most ground-water flow was through the tuffaceous sediments anyway. In addition, the lacustrine deposits accumulated in closed basins. Uranium in ground or surface water discharging into these basins would have been trapped even if reductants were not available. In fact, reductants were abundant so uranium could be concentrated.

The significance of the hydrogeochemical data is similar for both the conglomerate and lacustrine deposits. Similar to the conglomerate deposits, lacustrine deposits were not formed by present-day ground water as they crop out along high scarps well removed from the water table.

Lacustrine deposits in the Fizzle Flat area are considered unfavorable because there is no evidence that they contain organic material or other reductants.

FLUORITE DEPOSITS -- CHRISTMAS MOUNTAINS AREA

Fluorite deposits in the Christmas Mountains contain anomalous concentrations of uranium and thorium. Fluorite occurs as replacement deposits, mostly in Cretaceous limestones, along contacts and in brecciated zones near hypabyssal rhyolitic intrusions. These deposits are contact-metasomatic class (340) but they also display some features of magmatic-hydrothermal class (330) and hydroallogenic class (540). Although fluorite is spatially associated with rhyolitic intrusions, the source of mineralization is believed by Daugherty and Fandrich (1979) to be late-stage fluorinebearing solutions given off by "differentiation of an alkaline magma at depth." The hydrothermal solutions contained not only fluorine but a number of other trace elements including vanadium, arsenic, molybdenum, thorium, and uranium, which are incorporated in the fluorite deposits. However, the distribution of these elements is irregular even within a single deposit. For example, sample MGD-403 contains over 600 ppm U_3O_8 with less than 5 ppm Th, whereas sample MGD-404 contains 940 ppm Th with less than 20 ppm U_3O_8. Eighteen samples of fluorite from the Christmas Mountains average just over 100 ppm U_3O_8 and about 30 ppm Th. These values should not be considered representative of fluorite deposits in the area, however.

The color of fluorite seems to be a qualitative indicator of uranium concentration. Dark-purple, massive varieties contain the highest concentrations whereas lighter purple, green or colorless varieties contain progressively lower concentrations. Light-green and gray fluorite samples from the Eagle Mountains in the Marfa Quadrangle have uniformly low uranium concentrations (less than 5 ppm U_3O_8). The dark color may result from radiation damage to the fluorite crystal lattice. However, some coarsely crystalline, purple fluorite has low uranium concentrations. The color in these samples must result from substitution of some other element.

The site of uranium in fluorite is uncertain. Preliminary fission-track maps of some uraniferous fluorite samples show uranium to be uniformly distributed through the fluorite. This uranium may be incorporated in the actual fluorite crystal lattice. However, uranium may also occur as uniformly distributed, submicroscopic uranium minerals. Also at one location, bright yellow U^{+6} minerals occur in fractures and vugs in the fluorite and associated rhyolite. These may be secondary in origin, however.

Uraniferous fluorite seems to be restricted to deposits adjacent to highly alkaline rhyolites. Many of the rhyolites of the Christmas Mountains are peralkaline, based on both mineralogy and actual chemical analysis (Lonsdale, 1940; Barker, 1977). Other rhyolites there may also be peralkaline, but petrographic or chemical information is not available to confirm this supposition. In contrast, fluorite of the Eagle Mountains (Marfa Quadrangle) has consistently low uranium concentrations. The rhyolitic rocks of the Eagle Mountains fall within Barker's (1977) metaluminous belt. Although chemical analyses of these rocks are not available, they are definitely not peralkaline. Apparently, uranium enrichment in fluorite is related to the peralkaline nature of the rhyolites responsible for mineralization. However, the differences are not due solely to differences in primary uranium concentrations in the different types of rhyolites. Unmineralized peralkaline rhyolites do contain higher uranium concentrations than unmineralized nonperalkaline rhyolites (7.4 ppm U_3O_8 vs. 2.9 ppm U_3O_8), but fluorite deposits associated with peralkaline rocks are many more times enriched. Thus other factors besides primary uranium concentrations are responsible for the uranium enrichment.

Daugherty and Fandrich (1979) report that 60,000 tons of fluorspar were produced from the Christmas Mountains fluorite mine from 1971 through 1977, and total production through October 1979 exceeds 100,000 tons (Daugherty, 1979, personal communication). If the average grade is 100 ppm U_3O_8, over 20,000 lb of U_3O_8 have been removed from the mine along with the fluorite since operations began. Whether secondary recovery of uranium would be feasible is a critical question. Although uranium is enriched in many samples, it is unevenly distributed and determining average grade is difficult. The site of uranium in fluorite is not determined and it is not known if discrete uranium minerals exist within the mineral lattice. The position and mineralogy of uranium in fluorite is important because it would affect recovery techniques and criteria for exploration. Fluorite deposits are considered to be a favorable environment for uranium deposits based on geochemical (rock) sampling and association with peralkaline igneous rocks. Favorable areas for this type of deposit in and around the Christmas Mountains (Area C, Pl. 1) are identical to those of orthomagmatic class (310) environments because both are associated with similar rock types.

ALKALINE INTRUSIONS

Igneous rocks in the Emory Peak Quadrangle are highly alkaline, typical of intracontinental rifting and extensional tectonics. This area encompasses some of the most strongly peralkaline rocks in the United States. Alkaline rocks in the Emory Peak Quadrangle contain high background concentrations of uranium, thorium, and potassium, and local occurrences of uranium mineralization. Alkaline rocks like those found in this quadrangle are known to host many types of uranium mineralization in other parts of the world (Murphy and others, 1978). In this quadrangle, uranium is concentrated in the more peralkaline rocks such as alkali syenite and peralkaline (riebeckite) rhyolite and in contact zones around intrusions of that composition. These environments belong to the orthomagmatic class (310) or initial-magmatic class (510) and represent submarginal resources. They are favorable environments because they have anomalous uranium contents (greater than 10 ppm) and trace elements typically associated with uranium deposits, such as cadmium, cobalt, molybdenum, lead, tin, and vanadium. Thorium to uranium ratios in orthomagmatic occurrences generally vary from 3 to 5 and indicate that the uranium in these rocks is primary. A few examples of this class of deposits are given below.

Black Mountain

Black Mountain is located about 4 mi (6.5 km) north of Santiago peak and about 35 mi (56 km) south of Alpine, Texas. It is composed of alkali syenite and microsyenite and crops out as a flat-topped ridge about 3 mi (5 km) long (in an east-west direction) and 1 mi (1.6 km) wide. Although it is grouped with alkali rhyolites from the Christmas Mountains - Solitario area as a favorable environment, Black Mountain is considered as a separate favorable area (Area D, Pl. 1) because of the distance between the two occurrences. The rock is composed dominantly of plagioclase (60-90%) with subordinate orthoclase (25-40%) and accessory ilmenite, magnetite, apatite, riebeckite, aegirine, augite, and biotite (Eifler, 1943). Samples taken around the edge of the pluton average 15.3 ppm U_3O_8, with a maximum of 23.3 ppm (MGD-882, App. B). This area is associated with a radiometric anomaly (LKB Resources, 1979) and carnotite was reported in vugs in the syenite (Reeves and others, 1979). No uranium minerals were observed in this study. Fission-track maps of the syenite show that uranium is unevenly distributed among the minerals that comprise the rock. "Hot spots" are located preferentially but not exclusively in and along contacts of mafic and opaque minerals. Other mafic and opaque grains have a low fission-track density. Large early-formed feldspar phenocrysts are generally barren but may have some uranium along crystal boundaries and fractures. In summary, uranium is found throughout the rock but is concentrated preferentially in mafic and opaque minerals. These observations are consistent with an orthomagmatic origin for uranium in the Black Mountain intrusion.

Alkali Rhyolite in the Christmas Mountains - Solitario Area

Silicic hypabyssal intrusions in the Emory Peak Quadrangle in and around the Christmas Mountains are enriched in alkali metals and uranium. Rock types included in this category are rhyolite, soda rhyolite, riebeckite rhyolite, and soda trachyte of Lonsdale (1940). Peralkaline rhyolites with significant quantities of diagnostic soda-rich mafic minerals are more abundant in and near the Christmas Mountains than around the Solitario. The rocks are fine-grained aggregates of alkali feldspar and quartz with sparse feldspar phenocrysts. Distinctive soda-bearing mafic minerals such as riebeckite and aegerine are minor constituents but impart a light-blue to gray-green color to the rocks. The rocks have a variety of textures and minor mineral constituents.

The rocks are relatively enriched in uranium; 10 samples have an average content of 10.3 ppm U_3O_8. Trace elements typically associated with these rocks include cobalt, molybdenum, and tin. In addition, some breccia zones at the contact of rhyolite intrusions and Cretaceous limestone are highly enriched in uranium. At Packsaddle Mountain, about 7 mi (11 km) east of Agua Fria Mountain, the rhyolite intrusion produces scintillometer readings around 100 cps and has a uranium content of 4.5 ppm. A breccia zone at the contact of the intrusion and Cretaceous limestone reads about 300 cps and has 21.0 ppm uranium. Enrichment such as this could be caused by late-stage, uranium-rich fluids moving along the contact of the two rock masses. If this is the case, the situation is similar to fluorite deposits in the Christmas Mountains and could indicate significant uranium concentration in many areas where alkali-rich rocks intrude Cretaceous sediments. Consequently, Area C, Plate 1 is shown as a favorable area for both this class of deposits (orthomagmatic 310) and for uraniferous fluorite occurrences (contact-metasomatic 340).

Uranium Release

No ore-grade occurrences have been found in alkaline intrusions in the Emory Peak Quadrangle. However, many large bodies do contain anomalous uranium concentrations, which could be released from the host rocks and concentrated as an economic deposit in another environment. High-temperature processes are capable of releasing uranium. Devitrification occurs when hot glassy rocks cool and crystallize into distinct mineral phases. Devitrified peralkaline igneous rocks of this study have 30 to 50% less uranium than associated glassy rocks. The best example of this phenomenon in the Emory Peak Quadrangle is from a small intrusive body in the Solitario Uplift. A glassy rhyolitic rock (MGD-856, App. B) has 14.0 ppm uranium (with 24 ppm Th), whereas devitrified rock (MGD-857, App. B) just a few meters away has 6.8 ppm uranium (with 29 ppm Th). The relatively constant thorium concentration indicates that the samples had approximately similar radioelement concentrations when they were formed.

Low-temperature processes associated with weathering can cause uranium loss. Weathered samples show up to 50% uranium depletion compared with associated fresh rocks. Examples of this type of uranium release come from a syenite intrusion at Black Mountain where the fresh rock (MGD-879, App. B) has 11.3 ppm uranium and the weathered equivalent (MGD-878, App. B) has 8.3 ppm uranium. A fresh riebeckite rhyolite north of the Solitario Uplift (MGD-863, App. B) has 9.0 ppm uranium, whereas an extremely weathered sample nearby (MGD-865, App. B) has 4.5 ppm uranium.

In summary, alkali intrusions in the Emory Peak Quadrangle are considered favorable environments because they meet recognition criteria for orthomagmatic deposits. The possibility that late stage pegmatitic or hydrothermal activity could concentrate uranium needs to be explored further. Evaluation of the uranium potential of this quadrangle could be improved by more detailed investigation of the alkali intrusive bodies. Because uranium is shown to be enriched and concentrated in contacts and late-stage hydrothermal deposits, such as fluorite, further work detailing the site and mechanism of deposition of uranium would improve evaluation of the resource potential in this area. Even though no economic uranium deposits have been found in alkali igneous rocks, they are good exploration targets because they can release uranium which could be concentrated in nearby rocks.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

SUMMARY

All environments, whether volcanic, volcaniclastic, intrusive, or sedimentary, that are not mentioned in the Environments Favorable for Uranium Deposits fail to meet the recognition criteria specified for NURE.

These environments include (1) Paleozoic rocks, (2) Cretaceous rocks, and (3) the following Tertiary rocks: (a) mafic rocks including most lava flows, tuffs, and small intrusive bodies, (b) rhyolitic and intermediate flows, ash-flow tuffs, and small intrusive bodies, but excluding alkali syenite and riebeckite rhyolite, (c) plutonic rocks, (d) tuffaceous sediments other than those found favorable, and (e) bolson fill. Most of the Tertiary rocks, especially b, c, and d, although unfavorable for deposits because they lack trapping mechanisms, constitute important potential source rocks for deposits in other environments.

PALEOZOIC ROCKS

Complexly folded and faulted Paleozoic sedimentary rocks in both the Marathon Basin and the Solitario are unfavorable. They largely comprise distal turbidities and abyssal plain cherts. Neither environment is noted for hosting uranium deposits. They are, for the most part, very impermeable. There are also no tuffaceous beds or intrusions to have served as source rocks for epigenetic deposits. They also exhibit no aeroradiometric or hydrogeochemical anomalies.

There is one small area of uranium mineralization in the Solitario. This is considered of little consequence as the anomalous radioactivity is now slight and confined to a small (approximately 1 m^2) area along fractures.

CRETACEOUS ROCKS

Most Cretaceous rocks possess no favorable characteristics. They lack reductants, and though fractured, are separated from their only potential source, the Tertiary volcaniclastics, by hundreds of feet of dense to impermeable strata.

Several Cretaceous units are worthy of mention: (1) the Aguja Formation --This unit contains reductants (coal beds, but no carbonaceous trash) and lenticular sandstone beds, but is not considered favorable, unlike its lateral equivalent, the El Picacho - San Carlos sequence in the Marfa Quadrangle. During Tertiary diagenesis of the tuffaceous sediments (and presumed release of uranium) it was covered by more clayey beds of the Javelina Formation. Also, the Aguja itself is notably more clayey than the El Picacho - San Carlos sequence. It contains several limey beds which, during diagenesis, could have supplied lime to complex with the uranyl ion and prevent entrapment. Several samples of Aguja taken proximal to known slightly uraniferous (10-15 ppm U_3O_8) intrusions are markedly less uraniferous (average is about 5 ppm). Two samples (MGD-987 and MGD-988) taken within a foot of the humate-producing horizon in the Aguja near Study Butte also contain little uranium (average is about 4 ppm U_3O_8). (2) The Santa Elena and Buda Formations near the intrusions in the Christmas Mountains have been fluoritized by hydrothermal solutions (Daugherty and Fandrich, 1979) and one sample of fluorspar was assayed at 600 ppm U_3O_8 (MGD-980).

However, there is no known uranium mineralization in the actual Cretaceous rocks. (3) Boquillas Formation--There are two small areas of uranium mineralization in the Upper Cretaceous Boquillas Formation in the Basin and Range part of the quadrangle in Fizzle Flat and near Adobe Walls Mountain. These are epigenetic deposits along fractures in the limestone. Outcrops of shaley Boquillas in all areas of the quadrangle exhibit two to three times the radioactivity of other Cretaceous rocks (including the Del Rio Shale) and numerous samples (App. B) average 15-20 ppm U_3O_8. The collapse feature at Stilwell Ranch (where marl in the solution feature contains up to 59 ppm U_3O_8 [MGD-951]) is filled with Boquillas detritus. Sharp (1964) has mapped numerous "subsidence" features in the Dryden Crossing Quadrangle, where the predominant bedrock is Boquillas.

Shales in the Boquillas are potential host and source rocks, as they are presumed to be bentonitic. They are thin, 1- to 2-inch (2.5- to 5-cm) thick, whitish, and swell appreciably when wet, producing "wavy" outcrops. Anomalously high U_3O_8 in stream sediments and in bed rock in Terrell County may be due entirely to the shales in the Boquillas, as Union Carbide (1978a) suggests, but the shales are discontinuous and the radiometric anomalies are spotty.

Two areas, Dryden and Stilwell Ranch, while unfavorable, are worthy of mention as they provide a possible link between the extensive deposits in South Texas and their presumed source. The Stilwell Ranch prospect qualifies as an occurrence, the only one in the Stockton Plateau part of the quadrangle.

Dryden Area

A karst surface is developed atop outcropping Cretaceous carbonate sedimentary rocks in the extreme eastern portion of the Emory Peak Quadrangle, generally east of

102°15'W. The town of Dryden, Texas, is within the area discussed in this section. The surface is post-Boquillas and is interpreted to be pre-Holocene. Several sinkholes, averaging about 100 ft (30 m) in diameter, are filled with yellow marl that has an average radioactivity three times that of the surrounding carbonates.

The anomalies are documented in the HSSR report on the Emory Peak Quadrangle (Union Carbide, 1978a); chemical analyses by them revealed high Mo, Se, and As, as well as uranium. Anomalies were found only in stream sediments; ground water showed no anomalies. There is evidence from aerial radiometrics that the radiometric anomalies continue northward in the southeastern part of the Fort Stockton Quadrangle (LKB Resources, 1979).

Many authors, most recently Galloway (1977), consider the extensive uranium deposits in Catahoula Tuff and younger sediments of the Texas Coastal Plain to have been derived ultimately from the extensive volcanics of the western United States and/or northern Mexico. Paleowinds would carry the tuffaceous debris directly over the Dryden Area. Though Galloway's (1977) work did not extend west of Webb County, the westernmost Catahoula outcrop, he indicates that the Catahoula of South Texas is the product of well-developed streams that have reworked the volcanic debris and deposited it at its present position. Presence of carbonate rock fragments in the Catahoula shows that Cretaceous carbonate rocks were exposed during Catahoula deposition (Galloway, 1977).

It is herein speculated that air-fall tuff from the Trans-Pecos and northern Mexico volcanic centers formed a veneer between Trans-Pecos and South Texas during this time. This veneer was (1) eroded from the Edwards (Stockton) Plateau, probably during Miocene uplift along the Balcones Fault Zone or during Pleistocene isostatic adjustment, or (2) mistakenly included as "soil" or a Cretaceous shaly bed in numerous sections measured by Shell Development Corporation (Lozo and Smith, 1964), in the vicinity of Del Rio and San Angelo. Preservation of thick debris was limited to the sinkholes, thus the "spotty" and surficial nature of the anomalies.

An irregular gravel cap (Pleistocene ?) in the area is probably not responsible for the anomalies, as its radiometric signature is virtually nil and is comparable to background values in the surrounding limestone (30 to 80 counts per second). Several limestone samples from near Dryden show high radioactivity values; they are believed to result from intercalation with shaley horizons and/or an epigenetic contribution from the speculated tuffaceous veneer. Anomalous radioactivity does not extend below the Del Rio Shale.

Stilwell Ranch

The Stilwell Ranch uranium occurrence is a solution feature, possibly related to the Dryden Area karst. It is on the axis of a pronounced anticline in the Santa Elena Formation, is filled with yellowish debris and several jumbled blocks of flaggy carbonate, presumably the Boquillas Formation, which is normally several tens of feet stratigraphically higher. The Stilwell Ranch occurrence is virtually identical to occurrences in the Pryor Mountains succinctly described by Hart (1958) and to Sierra de Gomez, Chihuahua (Gabelman, 1955). Because the Dryden area carbonates are flat lying, there has been not nearly the fracturing (and hence solution and concentration) as at Stilwell Ranch.

TERTIARY ROCKS

Mafic Rocks

Mafic flows, tuffs, and small intrusive bodies are considered unfavorable for uranium deposits because of low uranium content in geochemical (rock) samples taken from these units and because no known site or mechanism exists for trapping uranium. Mafic flows included in this category are those in the Buck Hill and Big Bend Park Groups, the Rawls and Fresno Formations, and the Petan Basalt. Lacustrine deposits associated with mafic units in the Buck Hill Group are not considered part of this category and are evaluated elsewhere as a favorable environment. Small mafic dikes, sills, and stocks--present throughout the quadrangle but especially abundant in the Chisos and Christmas Mountains--are consistently low in uranium. Analyses of 36 basalts and syenogabbros from the Emory Park Quadrangle averaged 2.4 ppm U_3O_8 (App. B). Inspection of aeroradiometric anomalies associated with mafic rocks failed to find any uranium enrichment. Basalt from the Butcherknife Hill area, where two aeroradiometric anomalies exist, had 1.8 ppm U_3O_8 (MGD-677, App. B).

Rhyolitic and Intermediate Rocks

Small intrusive bodies, lava flows, and ash-flow tuffs of non-peralkaline rhyolitic to intermediate composition are abundant in the Emory Peak Quadrangle. They are considered to be unfavorable environments for uranium deposits because they have only moderate uranium concentrations, they lack trace elements typically associated with uranium prospects, and because they are not known to contain any mechanism for concentrating or trapping uranium. This category includes flows in the Buck Hill and Big Bend Park Groups, the Santana and Mitchell Mesa ash-flow tuffs, and numerous sills and stocks in the Christmas and Chisos Mountains, although the latter area is poorly evaluated because it is within Big Bend National Park.

Plutonic Rocks

Large bodies of coarse-grained intrusive rocks are environments unfavorable for uranium deposits. This category includes the granitic rocks in the Rosillos Mountains, where the highest uranium content of 11 samples is 5.8 ppm (MGD-617, App. B) and the average is 3.5 ppm. The main intrusive body in the Christmas Mountains is a syenogabbro having low uranium content (MGE-423, 2.8 ppm U_3O_8, App. B). The highest uranium value in syenite from Nine Point Mesa is 3.8 ppm (MGE-892, App. B).

Tuffaceous Sediments

Tuffaceous sediments of the Tascotal Formation, most of the Duff Formation, most of the Chisos Formation, and units within the Rawls Formation are unfavorable. All are potential sources for deposits elsewhere, but lack evidence of reductants, such as organic trash or lignites found in the Pruett Formation, to trap uranium. Clinoptilolite, a common constituent of all the above rocks, has been found to trap uranium in at least two other areas of tuffaceous sediments, the Tono Mine of Japan (Katayama and others, 1974) and in the Reese River Valley of Nevada (Basinski and Larson, 1979). However, fission-track mapping of uranium distribution in tuffaceous sediments of the Emory Peak Quadrangle shows that clinoptilolite and another zeolite, analcime, are depleted in uranium. Reasons for this difference are not known. Nevertheless, no mechanisms to trap uranium have been identified in the tuffaceous sediments other than organic material. For this reason the above formations are unfavorable.

One sample from the Chisos Formation (MGD-561) did smell of H_2S. However, we do not know the origin of the H_2S and the sample did not seem to come from lacustrine deposits, which might have accumulated organic debris. The occurrence is curious but not a sufficient indication of favorability. Nevertheless, the Chisos Formation may warrant further investigation.

Bolson Fill

Bolson fill, which was considered potentially favorable but insufficiently evaluated in the Marfa and Presidio Quadrangles, is considered unfavorable here. Bolson fill exists in only a few thin remnants in the Emory Peak Quadrangle. Potentially favorable source rocks occur around the areas of bolson fill and the fill is made up at least partly of these same rocks (Stevens, 1969; Robinson, 1976). However, no reductants or other materials to trap uranium have been found in the fill. Two of the three areas of fill are within Big Bend National Park and have not been studied. Thus it is possible that additional study would either enhance the favorability of bolson fill or further confirm its unfavorability.

UNEVALUATED ENVIRONMENTS

Most of Big Bend National Park remains unevaluated, because early in the study, access was restricted by heavy rains and flooding. Later, the National Park Service refused to allow any work associated with NURE. Therefore, the small number of samples do not contain enough information to evaluate adequately the large area of the park. Of 16 samples of igneous rocks collected, the highest uranium content is 13.8 ppm, and the average is 7.5 ppm. Several rock units (Hannold Hill, Black Peaks, and Canoe Formations) possess favorable characteristics (they are fluvial sandstones) but are unevaluated as they crop out only in Big Bend National Park and could not be sampled. Because mining is restricted within the park, evaluation of most of the above units is not essential. However, several more regional rock units, such as the Chisos Formation, extend well beyond the park. Study of them within the park could aid in regional evaluation.

RECOMMENDATIONS TO IMPROVE EVALUATION

Specific recommendations regarding individual favorable, unfavorable, or unevaluated environments are given above grouped under the appropriate environment. Recommendations given here are of a more general or generic nature. Of particular importance is understanding the processes that could lead to uranium ore formation either in Tertiary igneous rocks or in other rocks from uranium released from the Tertiary rocks. The tuffaceous sediments constitute an immense potential source of uranium. A preliminary attempt has been made in this study to understand the effect of diagenesis or other alteration processes on uranium mobility. However, this question is poorly understood and the conclusions of this report are tentative, at best. Further study of diagenesis, pedogenesis, or other types of alteration and their effects on uranium mobility would greatly enhance evaluation not only of the Emory Peak Quadrangle but also of all other areas where volcanic or volcaniclastic rocks are potential sources of uranium.

The genesis of many types of uranium deposits is extensively debated. Exploration methods are commonly dependent upon ideas about genesis. Methods applicable to one ore formation model would be useless for another model. Although information on genetic models would aid evaluation, such studies are beyond the scope of NURE.

Aeroradiometric data were of little use in evaluation. A followup study using closer spacing has been done but is not yet available. The results of this later study may aid evaluation. Likewise the hydrogeochemical study is of uncertain significance. High concentrations of uranium and several trace elements exist in ground water in almost all the tuffaceous units (Pl. 4; Union Carbide, 1978a and b). Whether these are indicative of mineralization or simply indicate a high regional trace element background is uncertain. Determination of the oxidation state of ground water would aid in interpreting the results and exploring for sandstone-type deposits.

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APPENDIX A. URANIUM OCCURRENCES IN THE EMORY PEAK QUADRANGLE

Occurrence no.	Name	County	Location: ¼ Sec.	Sec. (S)	Twp. (S)	Rng. (W)	Lat. (N)	Long. (W)	Host rock formation/member	Deposit class or subclass (no.)	Production#	Reference
1	Paisano	Brewster					29 27 45	103 28 00	Santa Elena Fm.	Contact Metasomatic(340)*	a	Daugherty and Fandrich, 1979
2	Adobe Walls	Brewster					29 29 10	103 30 20	Aguja Fm.	Contact Metasomatic(340)*	a	---
3	Fizzle Flat	Brewster					29 34 00	103 44 30	Pruett Fm.	Peneconcordant (243)**	a	Reeves and others, 1979
4	Black Mountain	Brewster					29 53 00	103 25 30	Tertiary Intrusive Syenite	Orthomagmatic (310)*	a	Reeves and others, 1979
5	Stilwell Ranch	Brewster					29 40 00	102 58 00	Santa Elena Fm.	Vein-type in sedimentary rocks (730)*	a	Reeves and others, 1979

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

*Mathews, 1978.

**Austin and D'Andrea, 1978.

URANIUM-OCCURRENCE

REPORT

Quad Name A90 < Emory Peak >

Quad Scale A100 < 2,5,0,0,0,0 >

Deposit No. B40 < 1 >

Deposit Name A10 < Paisano Mine (Mine is for Fluorite) >

Synonym Name(s) A11 < >

District or Area A30 < Christmas Mountains >

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

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

Position from Prominent Locality A82 < 65 miles south of Alpine on Hwy 118; 5 miles east of Hwy >

Field Checked G1 < 7 8 | 0 9 > (Yr, Mo) By G2 < Henry (Last name), Christopher (First) D. (Initial) >

Latitude A70 < 2 9 - 2 7 - 4 5 N > (Deg, Min, Sec) Longitude A80 < 1 0 3 - 2 8 - 0 0 W > (Deg, Min, Sec)

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

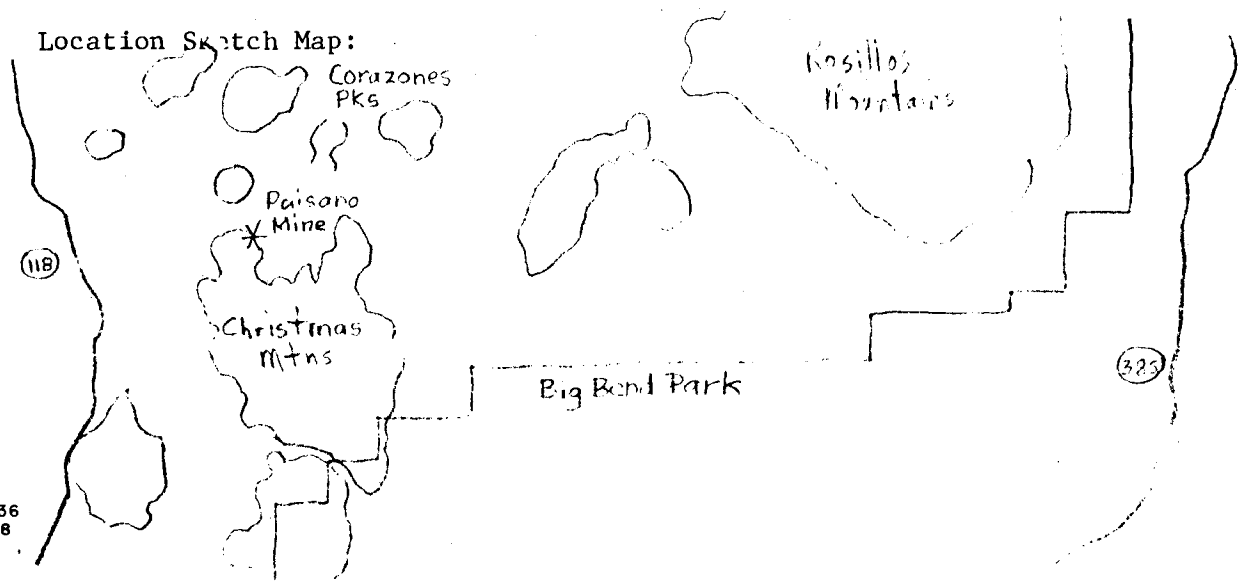
Meridian A81 < > Altitude A107 < > FT/M

Quad Scale A91 < > (7½' or 15' quad) Quad Name A92 < >

Physiographic Province A63 < 1 2 > (List K) | Basin and Range >

Location Comments A83 < On NW side of Christmas Mountains, on NE side of hill >

Location Sketch Map:



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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 1

Commodities Present:
C10 < F | U | T H | B E | | | | | >

Commodities Produced:
MAJOR < F | | | | > COPROD < | | | >

MINOR < | | | | > BYPROD < | | | >

Potential Commodities:
POTEN < U | T H | B E > OCCUR < | | | >

Commodity Comments C50 < Replacement fluorite deposit; uranium might be produced as byproduct or primary commodity from some parts of deposit >

Status of Exploration and Development A20 < 4 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < >

Property is A21 (Active) A22 (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< Extensive shallow open pits, tunnels, major adit recently completed (All for fluorite) >

Cumulative Uranium Production PROD YES NO SML MED LGE (circle)

DH2 accuracy thousands of lb. years grade
G7< U | > G7A< > G7B<LB> G7C< > G7D< % U308>

Source of Information D9 < >

Production Comments D10 < >

Reserves and Potential Resources

EH accuracy thousands of lb. year of est. grade
E1< U | > E1A< > E1B<LB> E1C< > E1D< % U308>

Source of Information E7 < >

Comments E8 < >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 1

Deposit Form/Shape M10 < Lenticular along contact, irregular >

FT/M

Length M40 < > M41< >

Width M50 < > M51< >

Thickness M60 < > M61< >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

A 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Mobile Belt >

Major Regional Structures N5 < Northern edge of Christmas Mountains >

Local Structures N70 < Contact between rhyolite intrusive and Cretaceous limestone >

Host-FM. Name U1 < Santa Elena > Member U2 < >

Host Rock K1 <|C|R|E|T| | | | | | |B| Limestone, massive, gray, fine-grained
(Age) (Rock type, texture, composition, color,

alteration, attitude, geometry, structure, etc.)

>

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

Comments on Associated Rocks U4 < Tertiary intrusive rhyolites >

Ore Minerals C30 < No uranium minerals observed >

Gangue Minerals K4 < Calcite, recrystallized host rock >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 1

Alteration N75 < None observed >

Reductants U5 < Minor pyrite on fractures in fluorite and rhyolite >

Analytical Data (General) C43 < U - up to 600 ppm in fluorite; some low-U has high Th (940 ppm); Commonly present are As, Co, Mo, Pb, Sn, V >

Radiometric Data (General) U6 < 5 to 20 times BG (1 x 20+ ft) >
(No. times background and dimensions)

Ore Controls K5 < Along rhyolite-Ls contacts, interaction of fluoride-rich solutions containing uranium with Ls caused formation of fluorite and a loss of a complexing agent for uranium which caused the deposition of uranium. Other controls must operate since not all fluorite has high uranium content. >

Deposit Class C40 < contact metasomatic > Class No. U7 <3 4 0>

Comments on Geology N85 < >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 1

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MGD402	Massive light purple fluorite	250 ppm U_3O_8
MGD403	Massive dark purple fluorite	600 ppm U_3O_8
MGD404	Massive dark purple fluorite - 940 ppm Th	12.0 ppm U_3O_8
MGD410	Fluorite, rhyolite, Mn-oxides - 44 ppm Th	143 ppm U_3O_8
MGD839	Very dark purple fluorite - 223 ppm Th	150 ppm U_3O_8
MGD469	Massive fluorite	15.0 ppm U_3O_8

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

References:

F1 <Daugherty, F.W. and Fandrich, J.W., 1979, Geology of the Christmas Mtns Fluorspar District in Cenozoic Geology of the Trans-Pecos>

F2 < >

F3 < >

F4 < >

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 1

Continuation from p. 1-5:

Label

F1 < Volcanic Field of Texas, A.W. Walton and C.D. Henry eds; Bur. Eco. Geol., The University of Texas at Austin, Guidebook 19

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URANIUM-OCCURRENCE

REPORT

Quad Name A90< Emory Peak >

Quad Scale A100< 2,5,0,0,0,0 >

Deposit No. B40< 2 >

Deposit Name A10 < Adobe Walls Prospect >

Synonym Name(s) A11 < >

District or Area A30 < Christmas Mountains >

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

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

Position from Prominent Locality A82 < 60 miles south of Alpine on Hwy 118, 2 miles east of Hwy >

Field Checked G1 < 7 9 | 0 8 > (Yr Mo) By G2< Henry, Christopher D. > (Last name, First Initial)

Latitude A70 < 2 9 | 2 9 | 1 0 N > (Deg Min Sec) Longitude A80 < 1 0 3 | 3 0 | 2 0 W > (Deg Min Sec)

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

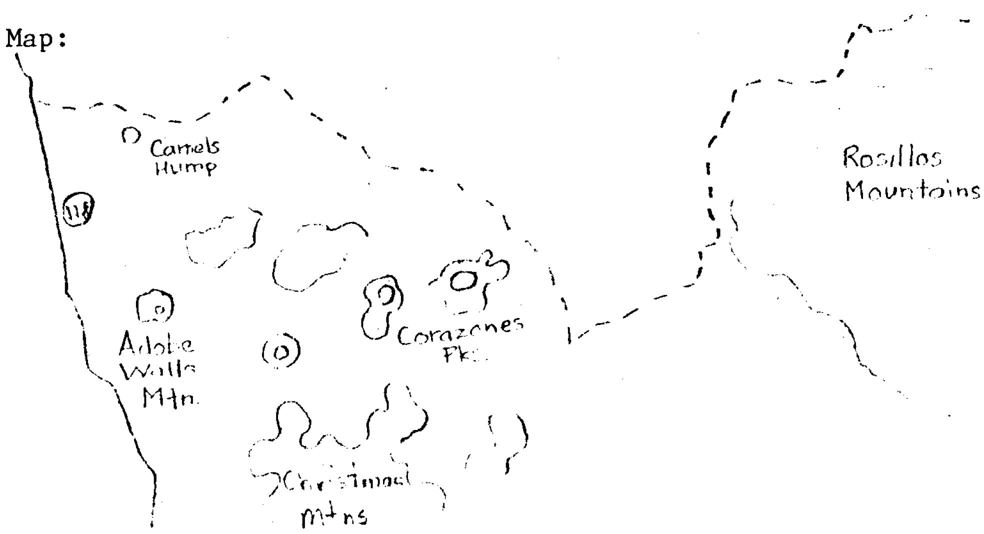
Meridian A81 < > Altitude A107 < > FT/M

Quad Scale A91 < > (7½' or 15' quad) Quad Name A92 < >

Physiographic Province A63 < 1 2 > (List K) | Basin and Range >

Location Comments A83 < On NW side of hill >

Location Sketch Map:



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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 2

Commodities Present:
C10 ◁F | U | | | | | | ▷

Commodities Produced:
MAJOR ◁ | | | | ▷ COPROD ◁ | | | ▷

MINOR ◁F | | | | ▷ BYPROD ◁ | | | ▷

Potential Commodities:
POTEN ◁U | | | ▷ OCCUR ◁ | | | ▷

Commodity Comments C50 < Replacement fluorite deposit; uranium might be produced as byproduct >

Status of Exploration and Development A20 < 3 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < >

Property is A21 (Active) A22 (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< 2 shallow trenches along fracture zone >

Cumulative Uranium Production PROD YES NO SML MED LGE (circle)

DH2 accuracy thousands of lb. years grade
G7◁ U | ▷ G7A◁ ▷ G7B<LB> G7C< > G7D< % U308>

Source of Information D9 < >

Production Comments D10 < >

Reserves and Potential Resources

EH accuracy thousands of lb. year of est. grade
E1◁ U | ▷ E1A◁ ▷ E1B<LB> E1C◁ ▷ E1D< % U308>

Source of Information E7 < >

Comments E8 < >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 2

Deposit Form/Shape M10 < Lenticular along contact, irregular >

Length	M40 < >	M41 < > (FT/M)	
Width	M50 < >	M51 < >	
Thickness	M60 < >	M61 < >	
Strike	M70 < >		
Dip	M80 < >		

Size M15 (circle letter):

lb U308

A 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Mobile Belt >

Major Regional Structures N5 < NW of Christmas Mountains >

Local Structures N70 < NW of Christmas Mountains, contact of rhyolite intrusive and Cretaceous limestone >

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

Host Rock K1 < CRET K shale, sandstone, limestone
(Age) (Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.) >

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

Comments on Associated Rocks U4 < Tertiary rhyolite intrusives >

Ore Minerals C30 < sparse yellow uranium minerals along fractures in rhyolite and fluorite >

Gangue Minerals K4 < secondary silica and inclusions of rhyolite >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 2

Alteration N75 < Rhyolite altered along contact, kaolinized, oxidized >

Reductants U5 < >

Analytical Data (General) C43 < U up to 850 ppm in fluorite and altered rhyolite; associated anomalous concentrations of Cd, As, Cu, Mo, Pb, Sb, Sn, V: >

Radiometric Data (General) U6 < 10 times BG (1x20 ft) >
(No. times background and dimensions)

Ore Controls K5 < Uraniferous flourite deposited along LS-Rhyolite contacts by interaction of fluoride-rich solutions containing uranium with LS; formation of fluorite caused a loss of complexing agent for uranium which was then deposited >

Deposit Class C40 < contact metasomatic > Class No. U7 <3 4 0>

Comments on Geology N85 < Narrow (1 ft wide) zone of uraniferous fluorite along rhyolite-Ls contact; variable U-content; green-yellow U minerals on fractures may be secondary >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 2

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MGD776	Altered rhyolite; yellow-green U-minerals	575 ppm U_3O_8
MGD777	Fluorite at contact	500 ppm U_3O_8
MGD778	Dark purple fluorite, U-minerals on fractures	630 ppm U_3O_8
MGD779	Altered rhyolite, U-minerals on fractures	850 ppm U_3O_8
MGD780	Altered rhyolite, U-minerals on fractures	525 ppm U_3O_8
MGD781	Altered rhyolite, No U-minerals; Fe-Ox	31.0 ppm U_3O_8

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

References:

F1 < >

F2 < >

F3 < >

F4 < >

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 2

Continuation from p. 1-5:

Label

<

URANIUM-OCCURRENCE

REPORT

Quad Name A90< Emory Peak >

Quad Scale A100< , 2, 5, 0, 0, 0, 0 >

Deposit No. B40< 3 >

Deposit Name A10 < Fizzle Flat >

Synonym Name(s) A11 < >

District or Area A30 < Fizzle Flat or Green Valley >

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

State Texas

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

County A60 < Brewster >

Position from Prominent Locality A82 < 60 miles south of Alpine, Texas on Hwy 118; approximately 8 miles west of hwy on poorly marked, private dirt roads. >

Field Checked G1 <7,8|1,2> (Yr Mo) By G2< Henry, Christopher D. > (Last name, First, Initial)

Latitude A70 <2,9|3,4|0,0, N> (Deg Min Sec)

Longitude A80 <1,0,3|4,4|3,0, W> (Deg Min Sec)

Township A77 < , , , | > N/S

Range A78 < , , , | > E/W

Section A79 < , >

Meridian A81 < >

Altitude A107 < > FT/M

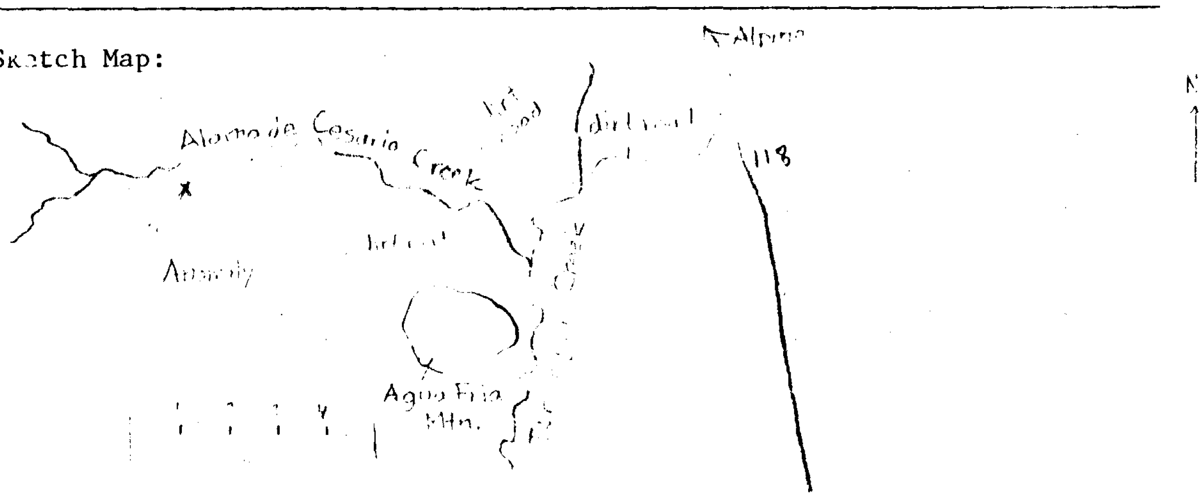
Quad Scale A91 < , , , , , , , >
(7½' or 15' quad)

Quad Name A92 < >

Physiographic Province A63 <1,2| | Basin and Range >
(List K)

Location Comments A83 < >

Location Sketch Map:



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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 3

Commodities Present:
C10 <U V MO>

Commodities Produced;
MAJOR < > COPROD < >

MINOR < > BYPROD < >

Potential Commodities:
POTEN < > OCCUR <U V MO>

Commodity Comments C50 < Sampled site is probably occurrence only but similar setting in area should be favorable environment >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < Extensive drilling in area in late 1970's but not at sampled location >

Property is A21 (Active) A22 (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< Surface investigation only; drilling in similar geologic setting nearby >

Cumulative Uranium Production PROD YES NO SML MED LGE (circle)

DH2 accuracy thousands of lb. years grade
G7< U > G7A< > G7B<LB> G7C< > G7D< % U308>

Source of Information D9 < >

Production Comments D10 < >

Reserves and Potential Resources

EH accuracy thousands of lb. year of est. grade
E1< U > E1A< > E1B<LB> E1C< > E1D< % U308>

Source of Information E7 < >

Comments E8 < >

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 3

Deposit Form/Shape M10 < elongate parallel to channel >

FT/M

Length M40 < 100 > M41 < ft >

Width M50 < 20 > M51 < ft >

Thickness M60 < 10 > M61 < ft >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

A 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Mobile Belt >

Major Regional Structures N5 < Southeastern part of Basin and Range, southern part of Trans-Pecos volcanic field >

Local Structures N70 < North of Torneros Creek fault zone and 8 miles north of The Solitario >

Host-FM. Name U1 < Pruett Formation > Member U2 < >

Host Rock K1 < E 0 | | | | | | | | | b conglomerate
(Age) (Rock type, texture, composition, color,

alteration, attitude, geometry, structure, etc.)

>

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

Comments on Associated Rocks U4 < Channel is in thick sequence of water-laid tuffaceous sediment with minor interbedded air-full tuff; channel is near base of Tertiary age tuff, which overlies Cretaceous * >

Ore Minerals C30 < Abundant yellow uranium minerals associated with organic debris, possibly carnotite or tyuyamunite >

Gangue Minerals K4 < >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 3

Alteration N75 < Conglomerate and related sandstone is heavily oxidized, red, with only local organic debris preserved >

Reductants U5 < organic matter, very little preserved >

Analytical Data (General) C43 < samples are enriched in U, V, Mo, Se, As >

Radiometric Data (General) U6 < >
(No. times background and dimensions)

Ore Controls K5 < Uranium was precipitated by reduction by organic matter in channel in tuffaceous sediments. Channel is mineralized preferentially to other sediments because 1) ground-water flow is concentrated in channel and 2) organic matter is restricted to channels: Deposit was subsequently exposed and oxidized with primary reduced minerals, if once present, oxidized probably to uranium vanadates. >

Deposit Class C40 < Epigenetic > Class No. U7 <2 4 1 0>

Comments on Geology N85 < Numerous similar channels occur in area at or near base of Tertiary section; several are reported to be mineralized. One such occurrence in subsurface was extensively drilled in late 1970's; no data are available >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 3

Continuation from p. 1-5:

Label

U4 < sedimentary rocks

F1 - Texas: The University of Texas at Austin Bureau of Economic Geology Guidebook 19, p. 127-136

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URANIUM-OCCURRENCE REPORT

Quad Name: Emory Peak

Deposit No. 3

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MGD499	carbonaceous debris from conglomerate	800 ppm U_3O_8
MGD500	grab sample of mineralized conglomerate	1700 ppm U_3O_8

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

References:

F1 < Reeves, C.C.; Kenney, P; Wright, E. (1979) Known radioactive anomalies and uranium potential of Cenozoic sediments, Trans-Pecos > *

F2 < >

F3 < >

F4 < >

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URANIUM-OCCURRENCE

REPORT

Quad Name A90< Emory Peak >

Quad Scale A100< 2 5 0 0 0 0 >

Deposit No. B40< 4 >

Deposit Name A10 < Black Mountain >

Synonym Name(s) A11 < Black Mesa >

District or Area A30 < >

Country A40 < U S > U S

State Texas

State Code A50 < 4 8 > 4 8
(Enter code twice from List D)

County A60 < Brewster >

Position from Prominent Locality A82 < 4 miles N of Santiago Pk >

Field Checked G1 < 7 9 (Yr) (Mo) > By G2< Duex (Last name), Timothy (First) W. (Initial) >

Latitude A70 < 2 9 (Deg) 5 3 (Min) 0 0 N (Sec) >

Longitude A80 < 1 0 3 (Deg) 2 5 (Min) 3 0 W (Sec) >

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

Meridian A81 < > Altitude A107 < > FT/M

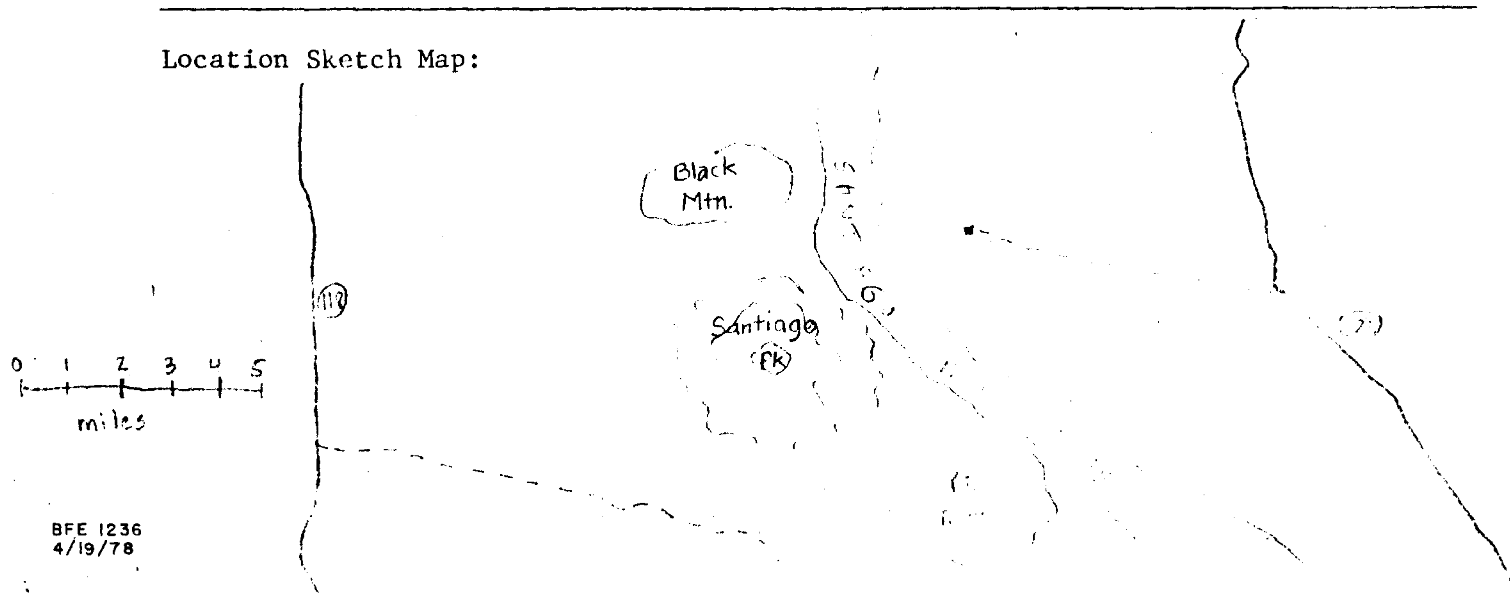
Quad Scale A91 < >
(7½' or 15' quad)

Quad Name A92 < >

Physiographic Province A63 < 1 2 > Basin and Range >
(List K)

Location Comments A83 < >

Location Sketch Map:



URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 4

Commodities Present:
C10 <   >

Commodities Produced:
MAJOR <   > COPROD <   >

MINOR <   > BYPROD <   >

Potential Commodities:
POTEN <   > OCCUR <   >

Commodity Comments C50 <   >

Status of Exploration and Development A20 < 1 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 <   >

Property is A21 (Active) A22 (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< Shallow drill holes and surface radiometric survey >

Cumulative Uranium Production PROD YES NO SML MED LGE (circle)

DH2 accuracy thousands of lb. years grade
G7< U ><   > G7A<   > G7B<LB> G7C<   > G7D<   % U308>

Source of Information D9 <   >

Production Comments D10 <   >

Reserves and Potential Resources

EH accuracy thousands of lb. year of est. grade
E1< U ><   > E1A<   > E1B<LB> E1C<   > E1D<   % U308>

Source of Information E7 <   >

Comments E8 <   >

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 4

Deposit Form/Shape M10 < Tabular sill >

FT/M

Length M40 < 5000 > M41 < M >

Width M50 < 1500 > M51 < M >

Thickness M60 < 200 > M61 < M >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U_3O_8

A 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Mobile Belt >

Major Regional Structures N5 < West of Santiago Mtns, North of Santiago Peak >

Local Structures N70 < Intrudes relatively flat-lying Cretaceous >

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

Host Rock K1 < T E R T | | | | | | B Syenite, fine to coarse grained phaneritic >
(Age) (Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.)

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

Comments on Associated Rocks U4 < Intrudes Cretaceous limestone and Tertiary sands >

Ore Minerals C30 < None observed but carnotite has been reported >

Gangue Minerals K4 < Syenite with plagioclase (60-90%) and orthoclase (25-40%) >

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 4

Alteration N75 < None >

Reductants U5 < None >

Analytical Data (General) C43 < up to 23 ppm U_3O_8 in whole-rock syenite analyses >

Radiometric Data (General) U6 < 5 times BKG (5000 x 1500 M) >
(No. times background and dimensions)

Ore Controls K5 < Uranium disseminated throughout rock but present as minute "hot spots", some associated with mafics, other U along grain boundaries >

Deposit Class C40 < orthomagmatic > Class No. U7 < 3110 >

Comments on Geology N85 < It has been suggested that Black Mtn is actually a flow - not an intrusive. >

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 4

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MGD878	Syenite Dike	8.3 ppm U_3O_8
MGD879	Syenite	11.3 ppm U_3O_8
MGD880	Syenite	22.0 ppm U_3O_8
MGD882	Coarse Syenite	23.3 ppm U_3O_8

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

References:

F1 < Reeves, C.C.Jr., Kenney, Pat Jr., Wright, E., 1979 Known radioactive anomalies and U potential of Cenozoic sediments, Trans-Pecos Texas:*

F2 < >

F3 < >

F4 < >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 4

Continuation from p. 1-5:

Label

F1 < in Cenozoic Geology of the Trans-Pecos Volcanic Field of Texas; A.W.Walton and C.D.Henry, eds.; Bureau of Economic Geology, The University of Texas at Austin, Guidebook 19, p. 127-136

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URANIUM-OCCURRENCE

REPORT

Quad Name A90< Emory Peak >

Quad Scale A100< 250000 >

Deposit No. B40< 5 >

Deposit Name A10 < Stilwell Ranch Prospect >

Synonym Name(s) A11 < >

District or Area A30 < Black Gap Area >

Country A40 < U S > U S

State Texas

State Code A50 < 48 > 48
(Enter code twice from List D)

County A60 < Brewster >

Position from Prominent Locality A82 < ~1/2 mile N 10 W from summit of Stillwell Mtn, 5 miles E of Stilwell Ranch house (which is on Maravillas Ck) >

Field Checked G1 < 78 | 12 > Yr Mo

By G2< Wilbert, William P. > Last name First Initial

Latitude A70 < 29 | 40 | N > Deg Min Sec

Longitude A80 < 102 | 58 | W > Deg Min Sec

Township A77 < > N/S

Range A78 < > E/W

Section A79 < >

Meridian A81 < >

Altitude A107 < 2850 ft > FT/M

Quad Scale A91 < >
(7½' or 15' quad)

Quad Name A92 < >

Physiographic Province A63 < 07 > Great Plains >
(List K)

Location Comments A83 < Take road NE from Stilwell Ranch along ridge to N., cross Maravillas Ck., occ in wind gap >

Location Sketch Map:

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 5

Commodities Present:
C10 ◁U C A R ▷

Commodities Produced:
MAJOR ◁ ▷ COPROD ◁ ▷

MINOR ◁ ▷ BYPROD ◁ ▷

Potential Commodities:
POTEN ◁U C A R ▷ OCCUR ◁ ▷

Commodity Comments C50 < ________ >

Status of Exploration and Development A20 < 2 >
(1 = occurrence, 2 = raw prospect, 3 = developed prospect, 4 = producer)

Comments on Exploration and Development L110 < some drilling by Wyoming Minerals (joint venture with Meeker and Co.) >

Property is A21 (Active) A22 (Inactive) (Circle appropriate labels)

Workings are M120 (Surface) M130 (Underground) M140 (Both)

Description of Workings M220< ________ >

Cumulative Uranium Production PROD YES NO SML MED LGE (circle)

DH2 accuracy thousands of lb. years grade
G7◁ U ▷ G7A◁ ▷ G7B<LB> G7C< ________ > G7D< ________ % U308>

Source of Information D9 < ________ >

Production Comments D10 < ________ >

Reserves and Potential Resources

EH accuracy thousands of lb. year of est. grade
E1◁ U ▷ E1A◁ ▷ E1B<LB> E1C◁ ▷ E1D< ________ % U308>

Source of Information E7 < ________ >

Comments E8 < ________ >

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 5

Deposit Form/Shape M10 < Elliptical area in plan view >

Length M40 < 30 > M41< ft > (FT/M)

Width M50 < 20 > M51< ft >

Thickness M60 < > M61< >

Strike M70 < >

Dip M80 < >

Size M15 (circle letter):

lb U308

A 0 - 20,000
B 20,000 - 200,000
C 200,000 - 2 million
D 2 million - 20 million
E More than 20 million

Tectonic Setting N15 < Platform >

Major Regional Structures N5 < near western margin of Edwards Plateau >

Local Structures N70 < Solution feature on axial plane of Stilwell anticline >

Host-FM. Name U1 < Santa Elena * > Member U2 < >

Host Rock K1 < CRETACEOUS (Age) limestone, grey, U occurs in yellow marl filling solution pits along crest of anticline >
(Rock type, texture, composition, color, alteration, attitude, geometry, structure, etc.)

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

Comments on Associated Rocks U4 < yellowish marl from overlying (now eroded) Boquillas Fm. fills "pipe". Some pieces of flaggy Boquillas Ls. also in pipe. Basalts nearby, but apparently unrelated >

Ore Minerals C30 < yellow uranium minerals >

Gangue Minerals K4 < fine-grained carbonate and clay >

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* see note, p. 4, comments

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 5

Alteration N75 < None observed other than solution and collapse >

Reductants U5 < Some carbonaceous matter, very minor pyrite >

Analytical Data (General) C43 < >

Radiometric Data (General) U6 < 10 x BG (2x2 ft) 3 x BG (30x20 ft)
(No. times background and dimensions) >

Ore Controls K5 < Uranium is localized in cylindrical (karst?) features. The solution has dissolved the Santa Elena limestone & bentonitic Boquillas has filled them. Possibly some Oligocene air-fall tuffaceous material is an admixture. Uranium is 1) assoc. with bentonite; 2) assoc. with tuff; 3) both. >

Deposit Class C40 < unclassified (most like 730) > Class No. U7 < >

Comments on Geology N85 < very similar to Pryor Mt. occurrences. (Wyo-Mont.) Occurrence is in material in collapse feature (formed by dissolution of) in Santa Elena Ls.; material filling collapse believed to be derived from Boquillas Fm. >

URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 5

Uranium Analyses:

Sample No.	Sample Description	Uranium Analysis
MGD997	clayey bed in pit	39 ppm U_3O_8
MGD951	grab sample from shallow pit	59 ppm U_3O_8
MGD995	dense limestone 30 ft from pit	4.7 ppm U_3O_8

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

References:

F1 < Reeves, C.C.Jr., Kenney, Pat Jr., and Wright, Elwood, 1979, Known radioactive anomalies and uranium potential of Cenozoic * >

F2 < >

F3 < >

F4 < >

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URANIUM-OCCURRENCE REPORT

Quad Name Emory Peak

Deposit No. 5

Continuation from p. 1-5:

Label

F1 < sediments, Trans-Pecos, Tx; in Cenozoic geology of the Trans-Pecos Volcanic Field of Texas; A.W.Walton and C.D.Henry, eds.; Bureau of Economic Geology, The University of Texas at Austin, Guidebook 19, p. 127-136

Spectrometer readings in pit to east of road very similar to chemical (59 ppm U_3O_8 vs. 58 ppm U_3O_8)