URANIUM RESOURCE EVALUATION
PRESIDIO QUADRANGLE
TEXAS

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ABSTRACT

The uranium potential of the 1° by 2° Presidio Quadrangle, Texas, was evaluated using criteria devised for the National Uranium Resource Evaluation program. Surface and subsurface studies (to a 5,000 ft; 1500 m depth) were employed, along with chemical, petrologic, hydrogeochemical, and airborne radiometric data (5-mi; 8-km spacing). The entire quadrangle is in the Basin and Range Province and is characterized by Tertiary silicic volcanic rocks (caldera and outflow facies) and tuffaceous sediments, which overlie chiefly Cretaceous carbonate rocks. Presidio Bolson, a large basin filled mostly with detritus from the Chinati Caldera Complex, occupies the southwestern third of the quadrangle bordering the Rio Grande. Favorable environments include the Allen Intrusions, a group of rhyolite domes that contain authigenic (Class 360) type deposits, and Cienega Mountain, a homogeneous riebeckite (peralkaline) rhyolite intrusion that could contain subeconomic orthomagmatic (Class 310) type deposits. Bolson fill exhibits several characteristics that suggest it could be favorable; however, insufficient information is available for complete evaluation, so it is classed as unevaluated. Well control is sparse; several subsurface environments are judged unfavorable chiefly by analogy with adjacent quadrangles and by projection of unfavorable outcropping rocks.

INTRODUCTION

PURPOSE AND SCOPE

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

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

Many landowners in the Presidio 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

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 reported in Preliminary Reconnaissance Reports (PRR's) of the U.S. Atomic Energy Commission and identification and examination of other areas of potential mineralization based on geologic inference and the literature. Rock samples (App. B-2) 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. Besides areas of anomalously high radioactivity, samples were taken from areas where radiometric background was low, in order 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 one sample (MGF-351), splits sent to Grand Junction were of insufficient volume to make gamma spectroscopy feasible. Thus, only this one sample has 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, 1978b), and subsequent followup 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. 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 dominantly 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 containing 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, uranium enters into solution but 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 asçertain by almost all analytical methods.

Uraniferous fluorite comprises a second example. High concentrations of uranium are irregularly distributed in fluorite, even in one 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 (Fig. 2; 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 giving 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 presently available aeroradiometric data (LKB Resources, 1979) are considered of little value. Almost none of the known major uranium prospects were located either in the Presidio Quadrangle or the adjacent Marfa and Emory Peak Quadrangles, probably because the 5-mi spacing is too wide, and the area is geologically too complex. A total of 42 equivalent uranium aeroradiometric anomalies were identified by the survey; LKB Resources identified three of these as "preferred anomalies" (Pl. 3). However, field examination of several of these revealed no anomalous uranium. Additional aeroradiometric surveys at one-quarter mile (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° Presidio Quadrangle is irregularly shaped, with an area of approximately 1,100 mi^2 (2900 km^2), and located in Trans-Pecos Texas. Latitude 30°N. forms the north boundary and longitude 104°W. forms the east boundary. The southwest boundary is the Rio Grande; most of the 1° by 2° quadrangle lies in Mexico and was not evaluated in this study. The entire quadrangle is in the southern part of the Basin and Range physiographic province. It is bordered on the west by the Chihuahua Tectonic Belt, a Mesozoic-age basin that received as much as 18,000 ft (5500 m) of Cretaceous sediments (DeFord and Haenggi, 1972) and was intensely folded in Laramide time. Presidio Bolson and a small extension, Redford Bolson, form topographically low (2,500 to 4,000 ft; 750 m to 1200 m) fault-bounded basins along the Rio Grande over most of the river's length, where it borders the quadrangle. The northern, northeastern, and eastern parts of the quadrangle are topographically higher, with elevations up to 7,700 ft (2350 m). They are dominantly composed of Tertiary igneous rocks, but Pennsylvanian, Permian, and Cretaceous sedimentary rocks also crop out (Fig. 3). Relief is extreme, especially along the border of Presidio Bolson, where elevations drop from greater than 7,000 ft (2100 m) to less than 3,000 ft (900 m) in about 5 mi (8 km).

Precambrian Rocks

Precambrian rocks are nowhere exposed at the surface in the Presidio Quadrangle. However, clasts of gneissic rock, possibly Precambrian in age, occur in a conglomerate in the Morita Ranch Formation (J. Hardesty, oral communication, September 1979). These clasts may indicate that Precambrian rocks are found, at least locally, at depths shallower than had been supposed. Schistose Precambrian rocks in the Van Horn Mobile Belt have been encountered in deep hydrocarbon tests (Flawn, 1956; Dietrich, 1965).

Paleozoic and Mesozoic Rocks

Three areas of Paleozoic and Mesozoic sedimentary rocks crop out in the quadrangle. These areas are discussed according to the age of the rocks.

Area North of Chinati Mountains. The Cieneguita Formation, a quartz-pebble conglomerate containing beds of black shale and limestone, crops out north of the Chinati Mountains. The formation is more than 2,000 ft (600 m) thick (Barnes, 1979a), is believed to be Pennsylvanian in age, and is the oldest rock exposed in the quadrangle (except for the probable Precambrian clasts in the conglomerate discussed above).

Pinto Canyon Area. Pinto Canyon extends from the Marfa Quadrangle into the Presidio Quadrangle. Outcropping sedimentary rocks are Permian and Lower Cretaceous. Although fault blocks contain some Cretaceous rocks, the main outcropping rock units are Permian Alta Formation and Pinto Canyon Formation.

The Alta Formation is gray thin-bedded mudstone and siltstone containing some fusulinids. The unit contains submarine slide features (Amsbury, 1958) and is interpreted as a slope deposit, fairly similar to deposits found in the Mississippi cone.

The Pinto Canyon Formation (Amsbury, 1958) includes microcrystalline limestone, chert, and cherty limestone and varying amounts of clay. Fossiliferous calcarenite lenses may represent carbonate turbidites. The formation was presumably deposited on the outer shelf and slope of the Permian sea.

Shafter Area. Outcropping rocks in the Shafter area -- Permian and Early Cretaceous in age -- all are marine, are partially equivalent to those exposed in Pinto Canyon, and are mostly shelf limestones. Before Tertiary volcanism and intrusion, these rocks undoubtedly were connected to those in Pinto Canyon. Rocks in the Cretaceous were deposited slightly higher on the shelf than Permian rocks. The extent of pre-Cretaceous erosion is not known, but no Triassic or Jurassic rocks are preserved. How much Permian was eroded is indeterminate.

Tertiary Rocks

Tertiary rocks are predominantly igneous (plutonic or volcanic) and igneous-derived sedimentary rocks. Two volcanic centers, the Chinati Mountains in the northwest and the Bofecillos Mountains in the southeast, were major source areas (Figs. 4 and 5). The Chinati Mountains are the remnant of a major caldera. Eruption of the Mitchell Mesa Welded Tuff about 31 m.y. ago produced a caldera, 30 mi (50 km) in diameter, that was subsequently filled by more than 3,300 ft (1000 m) of trachytic to rhyolitic lava flows and a rhyolitic ash-flow tuff of the Chinati Mountains Group (Cepeda, 1979). The caldera fill was cut by several small to moderate-sized plutons, including the west Chinati stock, a 5- by 3-mi (8- by 6-km) resurgent dome. Base-metal and precious-metal mineralization occur at Shafter, at the southern edge of the caldera, where the mineralization is probably related to late igneous activity along the caldera fracture zone. Mineralization in the west Chinati stock is probably related to resurgent doming. The Mitchell Mesa is the largest ash-flow tuff of Trans-Pecos Texas, extends off the quadrangle to the north, northeast, east, and southeast, and is a major marker bed throughout its extent.

Studies by Amsbury (1958) and Rix (1953) and recent reconnaissance by the authors show that the Chinati Mountains area was the site of earlier caldera-forming volcanism. One caldera lies to the northeast of the Chinati Mountains, is partly in the Marfa Quadrangle, and is partly cut off by the younger Chinati Caldera. The Ojo Bonito intrusion and the Shely Group volcanic rocks are probably related to this older caldera. The Morita Ranch Formation consists of mafic and alkalic lava flows, several rhyolite ash-flow tuffs, and several rhyolite flow domes. They are older than the Chinati Caldera and may be part of an earlier caldera cycle.

The Bofecillos volcanic center is composed dominantly of alkalic mafic to intermediate lava flows erupted from a stratovolcano centered approximately on the Presidio-Emory Peak Quadrangle boundary (McKnight, 1970). Volcanic rocks 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. before present 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.

Cienega Mountain, an apparently homogeneous riebeckite rhyolite intrusion, appears to be unrelated to either the Chinati or Bofecillos volcanic centers (Hardesty, personal communication, 1979).

Much of the volcanic section is dominated by tuffaceous sediments derived largely from the Chinati Mountains, but also probably from volcanic centers to the northeast in the Davis Mountains, to the east in the Chisos Mountains, and to the south in the Sierra Rica in Mexico. The oldest sediments are the undifferentiated Duff and Pruett Formations in the northeastern part of the quadrangle and the time-equivalent Chisos Formation in the southeastern part. These two sequences occur largely buried beneath younger volcanic and volcaniclastic units. The Mitchell Mesa caps both and is overlain by the Tascotal Formation in the northeast and its equivalent, the Fresno Formation, in the southeast. 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 eastern margin of the quadrangle. Open-hydrologic-system diagenesis has converted the 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. Diagenesis probably occurred largely during deposition of the sediments.

The Perdiz conglomerate is a thick alluvial fan of volcanic debris shed from the Chinati Mountains following cessation of major pyroclastic activity there (Walton, 1978; Jordan, 1978). It consists of coarse boulder conglomerate in proximal areas and finer sediment in distal areas. The Perdiz caps the Tascotal Formation and all the tuffaceous sedimentary sequences, but underlies part of the Rawls Formation to the south and southeast of Cienega Mountain. The Perdiz is also diagenetically altered to calcite in proximal areas and to clinoptilolite, montmorillonite, and opal in distal areas. Diagenesis was in an open hydrologic system, apparently unrelated to that which altered the underlying tuffaceous sedimentary sequence.

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).

Presidio Bolson is the major basin of the area, with as much as 1.2 mi (2 km) of normal displacement along boundary faults on both the east (United States) and western (Mexico) sides. Presidio Bolson is filled with up to 4,000 ft (1200 m) of clastic debris shed from igneous rocks of the Chinati Mountain area and Cretaceous and older sedimentary rocks in the southern part of the bolson. Near the basin margin, the bolson fill is coarse boulder conglomerate deposited in alluvial fans but grades to fine mud accumulated in playa lakes towards the middle of the basin (Groat, 1972). Presidio Bolson was a closed basin during much of its existence; a playa lake occupied at least part of the middle of the basin as indicated by the presence of thin deposits of bedded gypsum.

Redford Bolson is a much smaller basin (6- by 4-mi; 10- by 6-km), extending to the southeast of Presidio Bolson. It was filled dominantly by debris shed from the Rawls Formation. Santana Bolson is still smaller (1.2- by 0.3-mi; 2- by 0.5-km), is wholly within the United States, and extends into the Emory Peak Quadrangle. Basin and Range faulting other than that associated with these three bolsons is minor.

Igneous activity during basin filling was negligible. Minor basalt flows are interbedded with, and dikes cut, basin-filling sediments in Santana Bolson (Robinson, 1976). Ages of these rocks range from 22 to 18 m.y. (McDowell, 1979). However, tuffaceous activity ceased before basin filling.

In Pleistocene time, integration of the Rio Grande dissected the entire area, terminated closed basin conditions in the various bolsons, and provided hydrologic discharge to the Gulf of Mexico.

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

SUMMARY

Two environments are considered favorable in the Presidio Quadrangle. The Allen Intrusions (Area A - Pl. 1) are favorable for authigenic deposits (Class 360 of Mathews, 1978). The Allen Intrusions extend into the Marfa Quadrangle just north of the Chinati Mountains. Cienega Mountain (Area B - Pl. 1) is a large intrusive mass of riebeckite rhyolite located 10 mi (16 km) east-southeast of Shafter. It could contain orthomagmatic type deposits (Class 310 of Mathews, 1978).

ALLEN INTRUSIONS

Fracture zones in the Allen Intrusions, a group of rhyolite porphyry domes of probable Oligocene age, constitute a favorable environment for authigenic deposits (Class 360 of Mathews, 1978). The Allen Intrusions occur along the northern border of the quadrangle and are mainly in the neighboring Marfa Quadrangle. All samples from the Allen Intrusions were collected in the Marfa Quadrangle. That report should be consulted for analytical data. They are shown simply as undifferentiated Tertiary intrusions on the geologic map accompanying this report but are mapped separately by Amsbury (1958). Additional discussions of uranium mineralization in the Allen Intrusions are given by Amsbury (1958), Henry and Tyner (1978), and Reeves and others (1979).

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

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

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

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

Evidence of favorability includes: (1) the presence of abundant areas of uranium mineralization in fractures and (2) the similarity in overall geologic characteristics to those of the authigenic class (Class 360) of Mathews (1978). Mineralization occurs as uraniferous Fe-Mn oxyhydroxides and as secondary uranium minerals. Reeves and others (1979) reported autunite, metatorbernite, and tyuyamunite. Anomalous uranium concentrations occur in many fracture zones throughout the porphyritic domes. Amsbury (1958) reported that 200 tons of ore averaging 0.34% U_3O_8 were extracted in the 1950's from one trench and stockpiled nearby. The highest grade found in this study was 1,430 ppm U_3O_8 from clay gouge along the trench (MGE-568). An Fe-Mn or Fe-Ti-Mn oxyhydroxide from the same trench contained 825 ppm U_3O_8 (MGE-545). Slightly lower concentrations were found associated with oxyhydroxides from several other fracture zones at the surface and were encountered in drill cores. Other elements enriched in the hydroxides are Cd, Be, Co, Cr, Cu, Ni, and V.

Our interpretation of the origin of the mineralization involves adsorption from ground water of uranium and the other elements by amorphous Fe-Mn oxyhydroxides. Supergene weathering or crystallization of the amorphous hydroxides subsequently released the uranium, which then reprecipitated as secondary uranium minerals. Thus the highest grades should occur near the surface where secondary enrichment has produced an oxidized, supergene zone with both uraniferous hydroxides and secondary U^{+6} minerals. An alternative explanation is that pitchblende veins occur at depth and that both the oxyhydroxides and U^{+6} minerals are secondary. Drilling by Wyoming Minerals did not penetrate the water table, so this interpretation cannot be tested. However, the fracture zones are generally smaller and of lower uranium grade at depth. This suggests that the presence of pitchblende veins is unlikely.

Probable sources of the uranium are the rhyolite porphyries themselves or the associated glassy rocks of the Allen Intrusions. Tuffaceous sediments of the Shely Group are a third possible source. Primary uranium concentrations of the rhyolite porphyries may be as high as 23 ppm U_3O_8, the concentrations found in the two vitrophyres (MGE-810 and MGE-811). All unmineralized surface samples contain lower concentrations, ranging from approximately 5 to 15 ppm. Relatively unweathered and unfractured samples from drill cores contain variable concentrations closer to those of the vitrophyres. Thus surficial weathering rather than crystallization of the magma or subsequent devitrification is the most likely mechanism of uranium release.

Glassy samples of the nonporphyritic rocks contain 7 to 9 ppm U_3O_8, lower than the concentrations of the prophyritic vitrophyres, but still highly adequate source rocks. Diagenesis or weathering of these rocks could have released uranium to solution (Henry and Tyner, 1978).

An uncertainty is the timing of initial mineralization and temperature of the associated fluid. Mineralization may have occurred during initial cooling, involving moderately high temperature waters. Alternatively, mineralization may have occurred a sufficiently long time after cooling that only cold ground water was involved. By either mechanism, supergene enrichment is probably a continuous process related to present-day weathering and erosion.

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

There are no aeroradiometric anomalies associated with the Allen Intrusions. However, as discussed in the Procedures section, the aeroradiometric survey identified none of the known anomalies in the quadrangle. For that and several other reasons, the aeroradiometric survey is considered of no value. No hydrogeochemical anomalies are associated with the Allen Intrusions either, but the few wells sampled in the area all produce from Cretaceous rocks intruded by the rhyolites. It is unlikely that anomalies would show up in these rocks.

Prospects in the Allen Intrusions are abundant and several are of high enough grade to be economic. However, the total tonnage of currently known deposits is small and may be a limiting factor on development. Minor uranium concentrations also occur in secondary silica within parts of the nonporphyritic group of the Allen Intrusions. The uraniferous silica is both very low grade and low volume and is not of economic significance.

CIENEGA MOUNTAIN

Igneous rocks in the Presidio Quadrangle are alkaline rocks typical of intracontinental rifting and extensional tectonics. This area includes some of the most strongly peralkaline rocks in the United States. Alkaline rocks in the Presidio 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 more peralkaline rocks such as alkaline (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 and trace elements typically associated with uranium deposits, such as cadmium, 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.

The largest exposure of alkali (riebeckite) rhyolite in the Presidio Quadrangle is the intrusive mass of Cienega Mountain. Smaller intrusive bodies occur around the margins of the Chinati Caldera. Cienega Mountain occurs as a circular outcrop about 1 mi (1.6 km) in diameter and is located 10 mi (16 km) east-southeast of the town of Shafter. Uranium concentrations (average of 10 samples is 8.6 ppm U_3O_8) are higher than normal rhyolites but lower than other riebeckite rhyolite plutons in Trans-Pecos Texas. At best it is a submarginal resource. It is included as a favorable environment because it is similar to alkaline rocks in other areas that are known to host uranium deposits and because rocks like these can release uranium upon weathering, which could then be concentrated in nearby environments.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

SUMMARY

Several environments and formations in the Presidio Quadrangle are classified as unfavorable because they fail to meet recognition criteria of areas suitable for uranium deposits. They include all Paleozoic and Mesozoic rocks and the following Tertiary rocks: (1) mafic flows, tuffs, and intrusions, (2) rhyolitic lava flows and ash-flow tuffs, (3) plutonic rocks, and (4) tuffaceous sediments. Many of these units were also evaluated as part of related NURE work in adjacent quadrangles (Emory Peak and Marfa).

PALEOZOIC AND MESOZOIC ROCKS

No Paleozoic or Mesozoic sedimentary rocks in the Presidio Quadrangle are favorable for uranium deposits. There is no reductant and there is no known source of uranium for the sedimentary rocks. Additionally, there are no aeroradiometric anomalies over outcrops of pre-Tertiary sedimentary rocks, nor HSSR ground-water anomalies. Ground radiometries are uniformly low (<100 counts per second) except over the detritus in the Presidio Bolson. Mines in the Shafter silver-lead-zinc district are inaccessible; however, the mines were open during the 1950's, and AEC geologists reported slight, though insignificant, radioactivity. There was no reported uranium mineralization. These rocks are unfavorable based on analogy from nearby outcrops.

TERTIARY ROCKS

Mafic Rocks

Mafic flows, tuffs, and intrusions considered to be unfavorable for uranium deposits in the Presidio Quadrangle include units in the Fresno and Rawls Formations in the Bofecillos Mountains, mafic units in the Morita Ranch Formation, the Petan Basalt, and small plutons such as Black Hills. These units have low uranium concentrations and lack any indication of mechanisms for trapping uranium. Typical uranium values for some of these units are given below and listed with complete geochemical analyses in Appendix B: Fresno Formation, latite flow, 3.5 ppm U_3O_8 (MGF-031); basalt in the Morita Ranch Formation, 1.3 ppm U_3O_8 (MGF-011); and Rawls Formation, mafic flow, 2.0 ppm U_3O_8 (MGF-067), pumice tuff, 5.5 ppm U_3O_8 (MGF-068).

Rhyolitic Lava Flows and Ash-flow Tuffs

Felsic units that are considered unfavorable for uranium deposits in the Presidio Quadrangle include lava flows and ash-flow tuffs in the Chinati Mountains and Shely

Groups, the Santana and Mitchell Mesa ash-flow tuffs, and rhyolitic units in the Morita Ranch Formation. These units are not associated with any known aeroradiometric or geochemical anomalies and do not contain trace elements typically associated with any type of igneous uranium deposit. In addition these units have only moderate uranium concentrations and contain no mechanism for trapping uranium. Typical U_3O_8 values for various rhyolitic rocks are 6.3 ppm for the Lower Rhyolite of the Chinati Mountain Group (MGF-052); 1.3 ppm for a porphyritic rhyolite flow in the Morita Ranch Formation (MGF-018); 6.0 ppm U_3O_8 for a rhyolite ash-flow tuff of the Shely Group (MGF-023); and 7.3 ppm U_3O_8 for the Santana Tuff (MGF-036). These units are unfavorable environments because they lack characteristics of areas suitable for uranium deposits. However, geochemical (rock) sampling indicates that devitrification and weathering both release uranium, which could be concentrated in other environments, such as bolson fill. Thus the units listed above could serve as source rocks for epigenetic uranium deposits elsewhere.

Plutonic Rocks

Several large intrusive masses in and near the Chinati Mountains are unfavorable for uranium deposits. The main intrusive body in the Chinati Mountains is composed of quartz monzodiorite and granite (Cepeda, 1979). It is unevaluated because no geochemical (rock) samples were taken, but no aeroradiometric anomalies are associated with it. Just north of the Chinati Mountains, the Ojo Bonito "Laccolith" (Rix, 1953) is unfavorable because it has low uranium content (3.8 ppm U_3O_8, MGF-017, App. B), contains no environments for concentrating uranium, and is not associated with aeroradiometric or geochemical anomalies.

Tuffaceous Sediments

Tuffaceous sediments of the Presidio Quadrangle, including the Tascotal, Fresno, Chisos, Duff, and Pruett Formations, and tuffaceous sediments interbedded within the Rawls Formation, are considered unfavorable for uranium deposits because they lack effective trapping mechanisms. In particular the Tascotal and Fresno Formations appear to have been deposited by alluvial fans in an arid environment where little organic material formed or was preserved.

Much less is known about the Pruett, Duff, and Chisos Formations because they are largely restricted to the subsurface. Basal conglomerates in the Pruett Formation in the adjoining Emory Peak Quadrangle are shown as a favorable environment and the favorable environment is shown extending to the Presidio - Emory Peak boundary. However the Pruett in this area is covered by approximately 1,000 ft (300 m) of tuffaceous sediment and ash-flow tuff; no subsurface data are available to examine the Pruett in the Presidio Quadrangle but it is known that the formation pinches out within the quadrangle. For this reason the Pruett is considered unfavorable. By analogy and by comparison with the evaluation of the Emory Peak Quadrangle, the Duff and Chisos Formations are also considered unfavorable.

All the tuffaceous sediments could be significant source rocks for epigenetic deposits in other environments. Uranium and other trace element concentrations in present day ground water are high (Pl. 4; Union Carbide, 1978b), suggesting that uranium is presently mobile. However, Walton (1978) concluded that diagenesis of the Tascotal Formation did not mobilize measureable amounts of uranium. The dissolution of volcanic glass during diagenesis was probably the most favorable time for mobilizing large amounts of uranium. Thus its lack of mobility then suggests that the

Tascotal and other tuffaceous sediments did not act as effective source rocks. The high concentrations in present day ground water probably simply reflect equilibrium of the water with rocks having relatively high background concentrations of uranium.

UNEVALUATED ENVIRONMENTS

CHINATI MOUNTAINS AREA

A large part of the central and southern Chinati Mountains is unevaluated because local landowners refused access to the property. The areas and environments affected are the plutonic rocks in the central Chinati Mountains and associated fluorite and lead-zinc mineralization in and near San Antonio Canyon (Cepeda, 1979; McAnulty, 1972b). The fluorite is considered to be nonuraniferous like the fluorite in the Eagle Mountains of the Marfa Quadrangle because it is associated with similar igneous rocks.

BOLSON-FILL DEPOSITS

Bolson-fill deposits within Presidio and Redford Bolsons are classified as unevaluated. Although several lines of evidence suggest that the fill, especially in Presidio Bolson, could be favorable, other considerations suggest that it is unfavorable. Information to draw a final conclusion is not available.

Geologic Setting

The bolsons are filled with detritus shed off adjacent highlands composed of either Tertiary volcanic and intrusive rocks or Cretaceous or older sedimentary rocks. Deposition began with initiation of faulting, about 23 m.y. ago (Dasch and others, 1969). Deposition continued in a closed basin until the Pleistocene, when integration of the Rio Grande drainage system allowed through-going drainage. The bolson fill is presently being dissected and several different terrace levels are being developed as the Rio Grande cuts downward.

Groat (1972) divided basin fill in Presidio and Redford Bolsons into conglomerate, sandstone, and mudstone lithosomes, depending on the dominant lithology. The fill is zoned and the coarsest material is adjacent to major basin-bounding faults along the mountain fronts. Fill adjacent to the mountain front was deposited in alluvial fans. The material fines basinward into the mudstone lithosome, although conglomerates and sandstone lenses compose up to 10% of the mudstone lithosome. During closed basin sedimentation, the center was occupied by a playa lake; evaporite beds with gypsum occur within the mudstone lithosome in several locations. Groat considered the alluvial fan, gypsum, and playa deposits as being similar to deposits associated with playas of the Mojave Desert.

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

Faulting has continued to the present; recent fault scarps cut several terraces developed since integration of the Rio Grande drainage. Although the largest faults are along basin margins, numerous additional faults occur within the basins, especially in the northern part of Presidio Bolson.

Uranium Favorability

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

Source Rocks. Much of the detritus composing the basin fill and much of the adjacent highlands that drain into the basins are of Tertiary volcanic, volcaniclastic, or intrusive rocks having relatively high primary uranium concentrations. In highland areas where nonvolcanic Cretaceous or older sediments are now exposed, volcanic rocks initially capped the sediments but have since been eroded. Thus basin fill in these areas may be predominantly of igneous or igneous-derived rocks. Uranium concentrations in basin fill and in volcanic rocks of the highlands commonly range from a few ppm to about 15 ppm, making them more than adequate sources of uranium. Analyses of stream sediments within Presidio Bolson show similar concentrations (Union Carbide, 1978b). Uranium mineralization within the Allen Intrusions could also be a potential source of uranium. Concentrations up to 1,430 ppm U_3O_8 were found in prospects in the rhyolites of the Marfa Quadrangle. Less certain is whether or not significant amounts of uranium have been released from any of these rocks. Release would have to be by weathering rather than by any process of devitrification or diagenesis. High temperature devitrification would have occurred before basin formation; open-hydrologic-system diagenesis of tuffaceous sediments would also have occurred before basin formation, because diagenesis occurred soon after initial deposition of the sediments (Walton, 1975). Also, tuffaceous sediments do not occur within basin fill, because tuff-producing volcanism ceased before formation of the basins.

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

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

Entrapment. A possible mechanism of entrapment is the most poorly evaluated of the three factors needed for uranium deposits. The most likely entrapment mechanism is by reduction, either (1) by organic material (or pyrite generated from the organic material) deposited in channels in conglomerate or sandstone lithosomes or as lignite beds in the basin center, or (2) by pyrite generated by postdepositional reduction by discharge of H_2S-bearing waters from underlying Cretaceous or Permian sedimentary rocks. The first mechanism is unlikely; evidence for or against the second is meager.

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

Postdepositional reduction by H_2S leaking along faults that cut basin fill is entirely speculative. However, the mechanism is well documented for uranium deposits of the South Texas Coastal Plain, where oil and gas fields are common (Goldhaber and others, 1978). The Presidio area is not a producer of hydrocarbons. However, some lower Cretaceous limestones in the area are moderately petroliferous and many hot springs in Trans-Pecos Texas and adjacent Mexico smell of H_2S (Henry, 1979b). Several wells drilled into Cretaceous rocks in the Sierra Vieja immediately to the north in the Marfa Quadrangle encountered minor amounts of oil and gas (Bilbrey, 1957). Faults cutting the basin fill provide conduits for the rise of thermal water for the hot springs. A similar process conceivably could lead to reduction of sediments adjacent to fault zones in the basin fill.

If neither reduction mechanism exists, other concentrating processes are still less likely. Formation of calcrete deposits or adsorption of uranium by secondary amorphous silica or hydroxides are possible processes. However, it is more likely that, without reduction, uranium in water entering the playa would simply be dispersed throughout playa sediments without being concentrated.

Information to Improve Evaluation

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

RECOMMENDATIONS TO IMPROVE EVALUATION

Specific recommendations regarding individual favorable, unfavorable, or unevaluated environments are discussed above 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 the Tertiary igneous rocks or in other rocks containing uranium that has been 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, uranium mobility 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 Presidio Quadrangle but also of all other areas where volcanic or volcaniclastic rocks are potential uranium sources.

The genesis of many types of uranium deposits is extensively debated. Exploration methods are commonly dependent upon theories of 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 at a 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 background is uncertain. Determination of the oxidation state of ground water would aid in interpretation of results and exploration for sandstone-type deposits.

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REQUEST NO. 102356 BENDIX FIELD ENGINEERING CORPORATION PAGE 1
REQUESTER W. P. WILBERT GEOCHEMICAL ANALYSIS DEPARTMENT

DATE 80/01/14. EMISSION SPECTROSCOPY PROJECT 12787288
SEMI-QUATITATIVE ANALYSIS
JULIAN RUN DATE 480 CONCENTRATION IN PPM

	55557 MGE-0123	55558 MGE-0124	55559 MGE-0125	55560 MGE-0126	55561 MGE-0127	55562 MGE-0128	55563 MGE-0129	55564 MGE-0364	55565 MGE-0365	55566 MGE-0366
	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
	61700	94100	55300	8620	< 100	62600	68800	45400	57900	62100
	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
3	36	55	11	< 10	< 10	26	18	20	59	33
3A	242	258	199	390	< 100	371	795	315	222	379
3E	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
3I	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
:A	19300	25500	63300	> 100000	> 100000	53700	> 100000	59300	49300	35300
:D	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
:Ø	< 10	36	< 10	23	< 10	< 10	< 10	< 10	22	21
:R	71	166	40	16	14	11	11	54	28	51
	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
FE	36200	34100	19200	27500	28100	17400	22300	17200	25500	29900
L	21900	20400	13800	15300	16300	26900	26400	18600	16800	33400
A	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100
I	< 3000	< 3000	< 3000	< 3000	< 3000	< 3000	< 3000	< 3000	< 3000	< 3000
G	10500	11900	3900	3320	3300	4680	2870	5050	8180	4790
N	259	215	1160	677	134	371	1300	307	399	644
MO	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
A	24500	31200	20500	5320	< 100	26000	29100	17100	21400	34500
B	< 100	< 100	< 100	698	1030	< 100	184	< 100	< 100	< 100
I	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
	1400	2210	964	951	< 100	1050	877	770	1250	1580
PB	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
B	< 5000	< 5000	< 5000	< 5000	< 5000	< 5000	< 5000	< 5000	< 5000	< 5000
	< 3	6	< 3	31	26	< 3	9	< 3	< 3	< 3
	256000	355000	263000	52700	30800	296000	301000	334000	228000	315000
	< 10	< 10	< 10	20	17	< 10	< 10	< 10	< 10	< 10
	126	191	124	576	546	810	627	184	404	263
	3690	5790	3220	1180	731	2270	2110	2360	2600	3740
	274	269	179	296	341	199	245	214	294	286
	< 100	< 100	< 100	565	496	< 100	< 100	< 100	< 100	< 100
	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
N	< 100	129	< 100	580	900	< 100	238	< 100	< 100	< 100
R	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	51	85

>,< INDICATE CURRENT LIMITS OF ANALYSIS
***** INDICATES ELEMENT CANNOT BE DETERMINED AT PRESENT

REQUESTOR W. P. WILBERT GEOCHEMICAL ANALYSIS DEPARTMENT

DATE [illegible] EMISSION SPECTROSCOPY PROJECT 12737288

SEMI-QUANTITATIVE ANALYSIS

JULIAN RUN DATE 483 CONCENTRATION IN PPM

[illegible]	55568	55569	55570
[illegible]	MGF-0368	MGF-0369	MGF-0370
< 10	< 10	< 10	< 10
[illegible]	77700	< 100	23000
*****	*****	*****	*****
< 10	50	< 10	36
[illegible]	243	< 100	422
< 10	< 10	< 10	< 10
< 50	< 50	< 50	< 50
[illegible]	47600	> 100000	79600
< 10	< 10	< 10	< 10
< 10	< 10	< 10	< 10
[illegible]	13	< 10	562
< 10	< 10	< 10	< 10
[illegible]	19500	26300	24400
[illegible]	22300	14200	10000
< 100	< 100	< 100	< 100
< 3000	< 3000	< 3000	< 3000
[illegible]	3280	13000	170
[illegible]	537	217	226
< 10	< 10	< 10	20
[illegible]	32300	< 100	< 100
< 100	< 100	730	166
< 50	< 50	< 50	< 50
[illegible]	1130	< 100	713
< 40	< 40	< 40	< 40
< 5000	< 5000	< 5000	< 5000
< 3	< 3	27	< 3
[illegible]	311000	29500	369000
< 10	< 10	< 10	< 10
[illegible]	169	284	164
[illegible]	[illegible]	528	[illegible]
[illegible]	[illegible]	[illegible]	279
< 100	< 100	173	< 100
< 40	< 40	< 40	< 40
125	< 100	707	131
< 40	< 40	< 40	< 40

* INDICATE CURRENT LIMITS OF ANALYSIS

** INDICATES ELEMENT CANNOT BE DETERMINED AT PRESENT.

PRESIDIO GEOCHEMICAL SAMPLES (ppm except eK

Sample no.	Lithology	Code	eK(%)	eU	eTh	cU_3O_8	Ag	Al	As	B	Ba	Be	Ca	Co	Cr
MGF-351	rhyodacite	Tm	0.09±0.03	3±0.6	1.0±0.7	1	<10	100	<200	<10	20	<10	<200,000	<10	10
MGF-352	limestone	Prm				<1	<10	100	<200	<10	<20	<20	200,000	<10	10
MGF-353	sandstone	Kbm				<1	<10	5,000	<200	<10	<20	<10	5,000	<10	200
MGF-354	shale (black)	Pp				<1	<10	15,000	<200	70	<20	<10	2,000	<10	70
MGF-360	siltstone	Tf				3.0	<0.5	70,000	<200	10	1,000	20	50,000	5	10
MGF-361	siltstone	Tf				2.9	<0.5	70,000	<200	10	700	30	50,000	5	[illegible]
MGF-362	chert	Pf													
MGF-363	chert	Pp													
MGF-364	silt	Qtb				1									
MGF-365	silt	Qtb				3									
MGF-366	gravel	Qtb				2									
MGF-367	gravel	Qtg				6									
MGF-368	tuff	Tf				9									
MGF-369	limestone	Ksh				2									
MGF-370	limestone	Kdm				2									

PLES (ppm [illegible] [illegible]K)

Ca	Co	Cr	Ca	Fe	La	Li	Mn	Mo	Na	Nb	Ni	Pb	Sb	Sc	Sn	Sr	Ti	V	W	Y	Zn	Zr
[illegible],000	<10	10	<10	5,000	<20	<5	200	<10	300	<20	<10	<10	<100	<10	<10	<100	100	<10	<100	<10	<200	[illegible]
[illegible],000	<10	10	<10	500	<20	<5	100	<10	300	<20	<10	<10	<100	<10	<10	<100	100	<10	<100	<10	<200	[illegible]
5,000	<10	200	[illegible]0	3,000	<20	<5	200	<10	300	<20	<10	<10	<100	<10	<10	<100	150	<10	<100	<10	<200	[illegible]
2,000	<10	70	<10	30,000	<20	<5	300	<10	500	<20	20	<10	<100	<10	<10	<100	1,000	10	<100	<10	<200	300
[illegible],000	5	10	7	20,000	150	<100	300	<10	15,000	10	<10	50	<100	10	<10	700	2,000	10	<100	50	200	[illegible]
[illegible],000	5	10	7	15,000	100	<100	300	<10	15,000	10	<10	50	<100	5	<10	700	2,000	10	<100	20	<200	300