FRANKLIN MTNS.

MINERAL RESOURCE ASSESSMENT OF LANDS ADMINISTERED BY THE TEXAS GENERAL LAND OFFICE IN THE FRANKLIN MOUNTAINS, EL PASO COUNTY, TEXAS

by

Jay A. Raney
Edward W. Collins

for

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Noel Tyler
Director

Bureau of Economic Geology
The University of Texas at Austin

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Plates (in pocket)

GEOLOGIC SETTING

The Franklin Mountains, with relief as great as 2,700 ft, bound the west edge of the northwest Hueco Bolson. El Paso lies at the south margin of the mountains where they terminate at the Rio Grande. The mountain range, a west-dipping, tilted fault block that trends northerly, is composed of a relatively continuous stratigraphic section of Precambrian through Permian rocks that are locally intruded by Tertiary igneous rocks (Harbour, 1972; LeMone, 1982, 1988). Quaternary alluvial-fan deposits have built up off the edge of the mountains into the adjacent basins (Raney and Collins, 1994a, b). Tertiary to Quaternary basin-fill fluvial and older lacustrine deposits rarely crop out. We have compiled the geology of the El Paso and North Franklin Mountain quadrangles, which are enclosed in the pocket at the back of this report.

Precambrian Strata

Precambrian rocks consist of about 5,340 ft of metasediments and meta-igneous rocks that range in age from about 1.4 to 1.0 Ga (Muehlberger and others, 1966) and igneous basic and granitic intrusive rocks (Harbour, 1972; LeMone, 1982, 1988; Pittenger and others, 1994). The units that comprise the Precambrian section include the Castner Limestone, Mundy Breccia, Lanoria Quartzite, Thunderbird Group, and Red Bluff Granite complex. The Castner consists of slightly metamorphosed limestone, hornfels, conglomerate, dolomite, and diabase. Mundy Breccia is composed of randomly oriented, black basalt boulders. Quartzite dominates the lithology of the Lanoria. The Thunderbird Group includes the (1) upper Tom Mays Park Formation composed of rhyolitic ignimbrites and porphyritic rhyolite dikes, (2) middle Smugglers Pass Formation composed of porphyritic trachyte, tuffaceous sandstone and conglomerate, and ignimbrite, and (3) lower Coronado Hills Formation composed of rhyolite-cemented conglomerate of cobble- to pebble-sized quartzite, siltstone, shale, chert, ignimbrite, and trachyte. The Red Bluff Granite complex (Ray, 1982; LeMone, 1982, 1988) includes porphyritic granite, biotite granite, biotite-hornblende granite, riebeckite granite, and associated pegmatite, aplite, and basalt.

The Lanoria Quartzite has been evaluated as a source of silica at one locality. Local veins and pegmatite dikes within porphyritic granite have been mined and prospected for sources of tin. Local copper and iron prospects also occur within the Mundy Breccia, Castner Limestone, and Red Bluff Granite complex.

Paleozoic Strata

About 8,900 ft of Paleozoic rocks crop out in the Franklin Mountains (Harbour, 1972; LeMone, 1982, 1988). The upper Cambrian (?)–lower Ordovician Bliss Sandstone consists of quartz-rich sandstone, quartzite, and siltstone. The overlying lower Ordovician El Paso Group is composed of limestone, dolostone, sandy dolostone, and some dolomitic sandstone. Upper and middle Ordovician Montoya Group dolostone, limestone, marl and shale overlie the El Paso Group. The Montoya Group is overlain by the Silurian Fusselman Dolomite, which commonly forms massive cliffs within the mountains. The Devonian Canutillo Formation and Percha Shale comprise limestone, shale marl, and some siltstone that are above the Fusselman Dolomite. Mississippian Las Cruces Formation limestone, Rancheria Formation limestone with some siltstone and shale, and Helms Formation shale with some limestone overlie the Devonian rocks. Limestone, shale, argillaceous limestone and some gypsum beds comprise the Pennsylvanian Magdalena Group that overlies the Mississippian strata. Above the Magdalena strata are Permian Hueco Group limestone, dolomitic limestone to dolostone, siltstone, and shale. The Paleozoic strata are the chief source of limestone that has been quarried in the Franklin Mountains.

Mesozoic Strata

Some Cretaceous limestone, conglomeratic sandstone, and shale crop out locally along the west margin of the mountains (Harbour, 1972; Lovejoy, 1976; LeMone and Simpson, 1982). These rocks are on the downthrown block of the West Boundary fault (Lovejoy, 1976) that bounds the west edge of the mountains. They comprise only a minor part of the sedimentary strata at the Franklin Mountains.

Cenozoic Strata

Tertiary intrusive rocks include andesite, commonly located along the west margins of the mountains, and felsite dikes and sills that occur within the Franklin Mountains. Pliocene–Pleistocene basin-fill gravel, sand, silt, and clay crop out locally in arroyos along the margins of the mountains. These deposits include fluvial and associated deposits of the Camp Rice Formation and younger piedmont, basin floor, valley border, and alluvial plain deposits of alluvial fans, incised alluvial fans, bajadas, and terraces. Holocene alluvium and colluvium also occur along the margins of the mountains and as minor deposits within the mountains.

STRUCTURE

Strata within the range are cut by faults that strike north, northeast, and northwest (Richardson, 1909; Lovejoy, 1975; Dyer, 1989; Stacy and others, 1992). Many of these faults may predate the generally north-trending range-bounding faults that represent the latest episode of range uplift and tilting. Age relations and tectonic control on earlier faulting episodes are poorly understood (Dyer, 1989). Because some of the early, originally west dipping normal faults have been rotated by later tilting of the range, some faults have the appearance of westward, east-dipping reverse faults (Dyer, 1989). Demonstrable compressive deformation associated with the Laramide Orogeny has not been documented in the Franklins (Dyer, 1989;

Stacy and others, 1992). The most recent episode of faulting and tilting in the mountains probably began in the late Pliocene and continues to the present (Dyer, 1989; Machette, 1987). The range is bounded on the east by a distinct, north-striking Quaternary fault, the East Franklin Mountains fault, which crosses the El Paso and North Franklin Mountain quadrangles (Raney and Collins, 1994a, b). The fault cuts middle Pleistocene and upper Pleistocene deposits and may displace Holocene deposits.

Some of the structural history of the Franklin Mountains is not well understood. Lovejoy (1975) interpreted possible Pliocene-age, large-scale downslope movement of rock masses as gravity glides or large landslides on the west and east sides of the mountains. The Crazy Cat Mountain landslide is a primary example. In the northeast part of the mountains, Figuers (1987) mapped a complex of low-angle normal faults that are cut by younger, higher angle normal faults. And in a review of the structure of the Franklin Mountains, Dyer (1989) reported that identification of detachment faults in the Rio Grande rift near Albuquerque led Rhoades and Callender (1983) to propose that some of the low-angle faults mapped in the Franklins by earlier researchers are detachment faults associated with extension earlier than that of the high-angle normal faults that bound the range. The detailed fieldwork required to resolve the origin of many of the low- to moderately dipping faults of the Franklin Mountains has not yet been done.

The structural geology of the Franklin Mountains must be understood before assessing the mineral potential because either some of the metallic mineral prospects are structurally controlled or they may be hidden beneath unmineralized strata in subjacent fault blocks. In places where faults and fractures have been mineralized or altered, the age of the faulting may constrain the age of the mineralization. No significant mineral production has occurred from any known fault- or fracture-controlled mineralization in the Franklin Mountains, however, other than the vein-associated tin mineralization.

INDUSTRIAL AND METALLIC MINERAL POTENTIAL

Introduction

The objective of this study, the ranking of mineral potential on tracts of land in the Franklin Mountains (fig. 1) administered by the Texas General Land Office (GLO), is to evaluate the known mineral prospects and assess the favorability of the geologic setting to host additional undiscovered mineral deposits. Many known metallic mineral prospects are described in Mineral Resource Circular No. 73 (Price and others, 1983). These descriptions are, with modifications based on observations made as part of this investigation, reproduced here. Additional areas of potential interest were examined as part of this study and are described in the same format. Evaluation of these areas has benefited from discussions with Mr. Bill Farr of the GLO and from access to records maintained by the GLO.

Industrial Minerals—Description of Mines and Prospects

The major nonmetallic industrial minerals present in the Franklin Mountains are sand and gravel, limestone, and silica. Sand and gravel deposits are ubiquitous throughout the flanks of the Franklin Mountains. Because the deposits are so common, their value is based more on nongeologic attributes (access, land ownership, and ease of excavation and transportation) than on quality of resource. The presence or absence of sand and gravel resources is thus not considered a contributing factor in the exploration potential of these lands.

Limestone is a common mineral commodity in the Franklin Mountains. The Jobe Quarry on the east flank of the Franklins is the major active quarry. Several lower Paleozoic limestones have been quarried in the southern and eastern Franklin Mountains, and small production from the upper Paleozoic (Permian) Hueco Limestone has occurred in the northwestern Franklin Mountains near Vinton Canyon. Small quantities of limestone have also been quarried here and there as construction material or as building stone. Limestone is present in many tracts of GLO

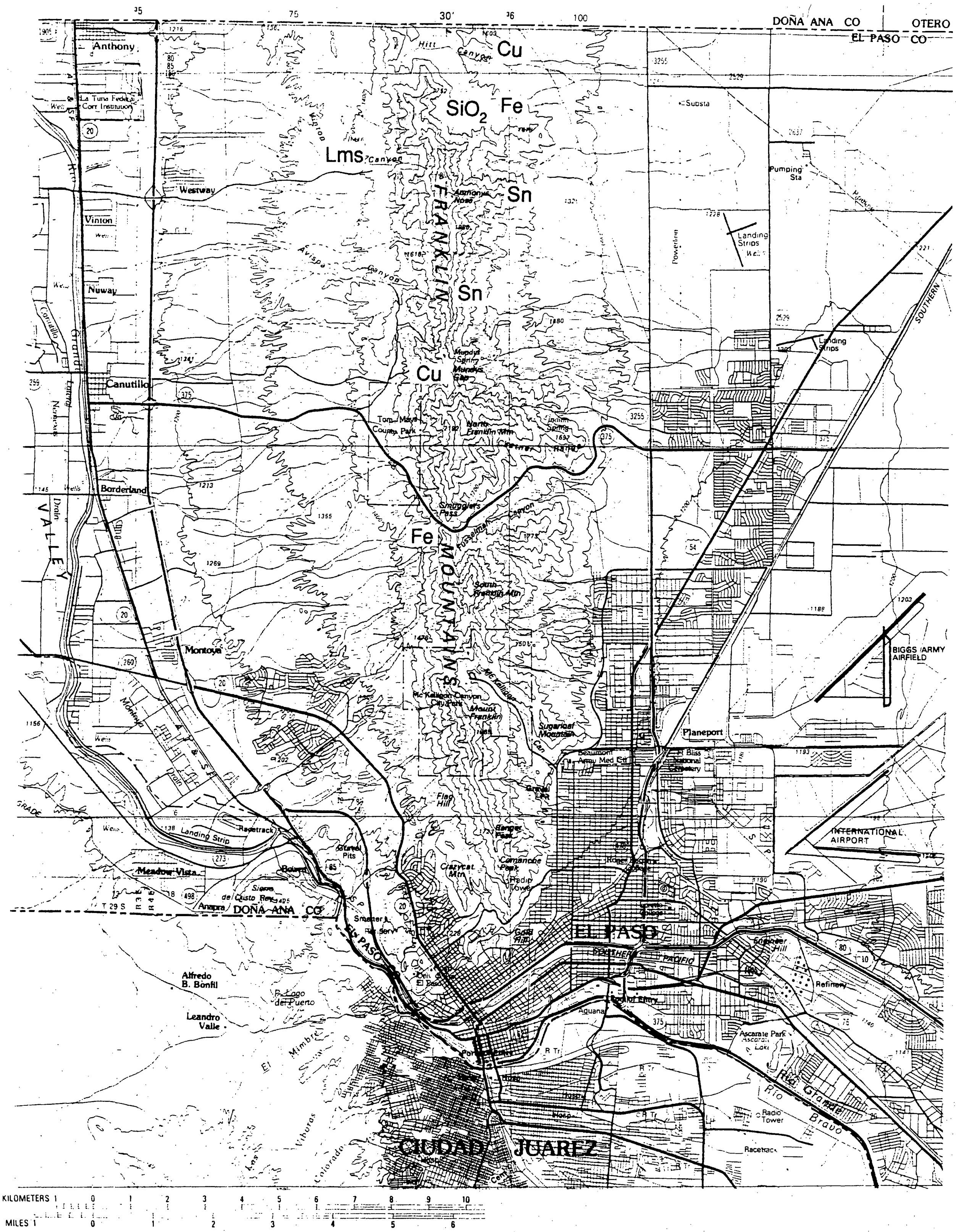

Figure 1. Location of Franklin Mountains, West Texas, and some of the mineral prospects evaluated in this report. Cu = copper; Fe = iron; Sn = tin; Lms = limestone; SiO_2 = silica.

lands. Those tracts that contain known limestone prospects or evidence of past limestone production are thought to have somewhat higher exploration potential than those that do not (table 1). Because these and other private and State lands are excluded from mining activities, the value of limestone resources on lands still open to mining, even though they lie farther from the consumer, will increase.

Several sections contain more or less extensive outcrops of Precambrian Lanoria Quartzite. These are noted by Q in the comments column in table 1. The Ples Schnitz silica prospect is described next (format modified from Price and others [1983]). Because the prospect is reported to contain (1) silica of a purity appropriate for use by the ASARCO smelter, (2) probably significant tonnages, and (3) a geometry favorable for open-pit mining, the tract containing the Ples Schnitz silica prospect is thought to have the highest exploration potential of GLO lands in the Franklin Mountains.

Ples Schnitz Silica Prospect

Location:	~14 mi (~22 km) north of downtown El Paso, south side of Hitt Canyon 7.5-minute quadrangle: North Franklin Mountain Latitude: 31° 58′ 50″ Longitude: 106° 29′ 30″ GLO control number: 7043683
Commodity:	Silica
Status:	Prospect, open cut on side of ridge
Geology:	
Host rock:	Quartzite
Formation age and name:	Lower Lanoria Quartzite
Deposit type:	Bedded
Other data:	Quartzite is highly fractured and stained by iron oxides; mostly limonite with minor hematite. Consultant estimated >7,000,000 tons of quartzite "above ground." Analyses reported to indicate SiO_2 content of 94 percent.
References:	Harbour (1972); GLO files (unpublished data and reports); personal communication, Ples Schnitz and Bill Farr (1994).

Table 1. State ownership—Franklin Mountain State Park.

Section	Part	Block	TSP	Grantee	Acres	File no.	Control no.	Comments	Ranking
297	All			A. G. McMath	594.50	SF10722	4006337	1,7,P,F,A,S	3
298	SE PT			A. G. McMath	96.03	SF10723	4006346	2,3,5	4
299	All			A. G. McMath	640.00	SF10724	4006355	1,2,3,4,5	5
300	All			A. G. McMath	640.00	SF10724	4006364	2,4,5	4
252	All			Clara Mundy	259.60	123730	4006373	1	4
253	All			Clara Mundy	261.00	112123	4006382	1,Plms,A	3
277	All			W. P. Paschal	160.00	132593	4006550	3,P,A	3
400	All			J. A. Rogers	639.00	SF11422	4006783	3,P,A	3
2	All	82	1	T & P	671.50	123489	4006916	1	5
4	All	82	1	T & P	640.00	123490	4006925	1	5
8	All	82	1	T & P	640.00	123491	4006943	1	5
260	E PT			H. G. Foster	636.21	90130	7041863	2,4,5,6	5
261	E PT			H. G. Foster	495.84	90131	7041872	2,4,5,6	5
301	PT			A. G. McMath	313.00	SF10987	7041916	2,F,5	4
306	PT			A. G. McMath	219.40	SF10988	7041925	2	5
217	E PT			A. F Miller	273.05	117825	7042041	2,F	4
221	N PT			Lee Moor	223.60	117824	7042069	2	4
221	W PT			Lee Moor	80.00	122874	7042078	2	5
222	PT			Lee Moor	120.76	117823	7042087	2	5
271	PT			Eli Nations	451.65	SF07266	7042210	2	5
272	PT			Eli Nations	609.70	SF07267	7042229	2,Q	4
8	All	81	1	T & P	656.90	126912	7043683	3,P,Q,F,A	1
6	All	81	2	T & P	640.00	93845	7043923	2,Q	4
14	W PT	81	2	T & P		88978	7043978	2,Q	4
259	PT			H. G. Foster	23.88	129622	7041845	4	5
270	All			S. J. Larkin	640.00	SF7264	15000000	1,F, A	4
4	All	81	1	T & P	379.71	152951	15002060	3,A	4
6	All	81	1	T & P	661.20	152952	15002079	1,3	5
16	All	81	1	T & P	349.06	152953	15002088	3,P,A	3
24	All	81	1	T & P	334.78	152956	15002113	3,Q	4
269	E PT			S. J. Larkin	320.00	152965	15002202	1	5
251	All			Clara Mundy	259.50	152969	15002248	1	5
296	All			A. G. McMath	640.00	SF10721	15006921	1	4
268	E/2			S. J. Larkin	320.00	152964	15002195	1	5
				Total acres:	13,889.87				

Ownership breakdown

Fee	5,241.63
Mineral classified	4,743.99 +/–
Land trade	3,904.25 +/–

Comments

1. Canutillo 1:24,000 quadrangle
2. El Paso 1:24,000 quadrangle
3. North Franklin Mountain 1:24,000 quadrangle
4. Smeltertown 1:24,000 quadrangle
5. Location on map interpreted from data provided by GLO; perimeter uncertain
6. Reported acreage may be inconsistent with perimeter shown on map
7. Assumes south boundary of section 297 is Canutillo–Smeltertown quadrangle boundary

P = Prospect or other evidence of exploration present
Plms = Excavation in limestone; possible minor production
F = Fault present that may have local mineralization or alteration
Q = Precambrian Lanoria Quartzite present in outcrop
A = See description in appendix; areas described by quadrangle and by control number

Unnamed Limestone Deposit

Location:	~4.5 mi (~7.2 km) east of Vinton; Vinton Canyon area 7.5-minute quadrangle: Canutillo Latitude: 31° 58′ Longitude: 106° 31′ 45″ GLO control number: 400637
Commodity:	Limestone
Status:	Inactive; open cut
Geology:	
Host rock:	Limestone and marl, fossiliferous (corals, brachiopods, fusilinids, etc.)
Formation age and name:	Permian Hueco Limestone
Deposit type:	Bedded
Other data:	Small quarries; probably inactive for 15 to 20 yr. Small production (few tens to couple hundred tons). Favorable topographic setting for mining.
References:	Harbour (1972); GLO files (unpublished data and reports); personal communication, Bill Farr (1994).

Metallic Minerals—Description of Mines and Prospects

The proximity of the Franklin Mountains to El Paso, the presence of the ASARCO smelter, and the generally excellent exposures of geology all have encouraged prospecting. Numerous prospect pits and shafts, many excavated on very limited evidence of mineralization, are testimony to both the optimism and the hard labor of prospectors over many decades. With the exception of the El Paso Tin Deposit (description follows), prospects for other metallic mineral commodities (Cu, Fe) have produced no more than a few tons of hand-sorted ore, and none has been an economically viable producer. Although trace quantities of precious metals may be associated with some of the base metals, these are not known to be economically significant. In the field, mineralization is commonly fault or fracture controlled, of limited tonnage over narrow widths, and erratic in distribution. No large centers of hydrothermal alteration suggest major mineralized porphyry systems. Exposed skarn-associated mineralization is of low grade and of only local extent. The areas previously mined and explored for tin appear to have the most intriguing exploration potential; however, veins of previously mined ore are narrow, and similar deposits may not be economic under today's economic conditions. Given the small production at El Paso Tin Deposit and the lack of exploration success, it appears unlikely that a major tin deposit is present.

The descriptions following are based on those in Mineral Resource Circular No. 73 (Price and others, 1983) and on fieldwork associated with this project:

El Paso Tin Deposit

Identification no.:	EL-EL-A3-1
Location:	Not on GLO lands 9 mi (15 km) North of El Paso 7.5-minute quadrangle: North Franklin Mountain Latitude: N31° 56′ 09″ Longitude: W106° 29′ 14″
Commodities:	Tin and tungsten
Status:	Abandoned mine
Dates of activity:	1896 (discovery); 1909 to 1910's (production); intermittent exploration since then
Production:	8 tons of high-grade ore
Geology:	
Host rock:	Granite
Formation age and name:	Precambrian Red Bluff Granite
Ore mineralogy:	Cassiterite (SnO_2) and minor amounts of wolframite
Gangue mineralogy:	Quartz, plagioclase, microcline, topaz, tourmaline, sphene, fluorite, pyrite, limonite, minor hornblende
Alteration:	Scattered silicification, chloritization, tourmalinization
Age of mineralization:	Precambrian
Deposit type:	Pegmatite (Pyron, 1980) veins striking N70° to 90°W, dipping nearly vertically

Other data:	The host rock contains microcline, plagioclase, quartz, biotite, hornblende, and accessory fluorite, topaz, tourmaline, and zircon and has an average tin content of 0.0005 percent (Pyron, 1980). Harbour (1960, 1972) recognized the Red Bluff Granite to be one of the youngest Precambrian intrusions in the Franklin Mountains. It is late Proterozoic, approximately 950 m.y. old (Denison and Hetherington, 1969). Pyron (1980) reported romarchite (SnO) in microcline pegmatite, but his data do not support a definite identification. The Bureau of Economic Geology's X-ray diffraction of heavy-mineral separates of samples from the same locality indicates the presence of cassiterite, fluorite, pyrite, and topaz, but no romarchite.
References:	Weed (1901, 1903), Richardson (1906, 1909), Dinsmore (1909), Chauvenet (1910), Lakes (1910), Evans (1958), Killeen and Neuman (1965), Goodell (1976), Deen (1976, 1977), Pyron (1980) - deposits; Harbour (1960, 1972), McAnulty (1967), Denison and Hetherington (1969), Dye (1970), Hoffer (1972, 1976), Thomann (1980, 1981) - regional geology; also unpublished field and laboratory notes at the Bureau of Economic Geology.

Franklin Mountains Tin Prospect

Location:	~2.5 mi (~4 km) south of the Texas–New Mexico state line 7.5-minute quadrangle: North Franklin Mountain Latitude: 31° 57′ 30″ Longitude: 106° 28′ GLO control numbers 4006783; 4006550; 15002088
Commodity:	Tin
Status:	Prospect, no past production; exploration drilling, surface sampling, geophysical surveys
Geology:	
Host rock:	Granite and aplite dikes
Formation age and name:	Precambrian Red Bluff Granite
Ore mineralogy:	Assumed to be cassiterite
Gangue mineralogy:	Quartz veins, aplite dikes, and local pegmatites in granite; minor accessory sulfides
Alteration:	Limonite after sulfides; specular hematite; deuteric alteration of mafics (biotite, hornblende)
Age of mineralization:	Probably Precambrian
Deposit type:	Tin mineralization associated with late-stage pegmatites and aplites. Mineralized fragments seen in float suggest similarity to known tin mineralization at El Paso Tin Deposit (see last description), but quartz-vein

development appears to be less common. Northeast- and northwest-trending fractures appear to control quartz veins.

Other data: Tin anomaly in soil identified by analysis of panned concentrates. A 1985 geophysical survey (resistivity and magnetics) within the main area reported to contain anomalous tin mineralization did not apparently cross any lateral changes (alteration boundaries or major faults) and did not identify any targets for exploration drilling.

References: Harbour (1972); GLO files (unpublished data and reports); personal communication, Bill Farr (1994).

Hitt Canyon Skarn Deposits

Identification no.: EL-EL-A3-2

Location: Not on GLO lands
14 mi (22 km) north of El Paso
7.5-minute quadrangle: North Franklin Mountain
Latitude: N31° 59′ 29″
Longitude: W106° 28′ 51″

Commodities: Copper and iron

Status: Prospect

Geology:

Host rock: Marble

Formation age and name: Precambrian Castner Marble

Ore mineralogy: Magnetite, bornite, chalcopyrite, covellite, secondary malachite

Gangue mineralogy: Pyrite, marcasite, minor amounts of pyrrhotite

Age of mineralization: Precambrian (Deen, 1977) or possibly post-Silurian Fusselman Dolomite (Goodell, 1976)

Deposit type: Skarn

Other data: Goodell (1976) and Deen (1977) reported an intrusive breccia, which is unlike the Precambrian intrusion in this area. Goodell (1976) suggested that the breccia (and related mineralization) is post-Silurian in age because the Fusselman Dolomite of the area is altered. Deen (1977) mapped the breccia as Precambrian and indicated a fault between the Fusselman Dolomite and the Precambrian rocks.

References: Deen (1976, 1977), Goodell (1976) - deposits; Richardson (1909), Harbour (1960, 1972), Denison and Hetherington (1969), Lovejoy (1975), Hoffer (1976) - regional geology.

Tom Mays Park Copper Deposit

Identification no.:	EL-EL-A2-1
Location:	Not on GLO lands 9 mi (15 km) north-northwest of El Paso 7.5-minute quadrangle: Canutillo Latitude: N31° 54′ 51″ approximate Longitude: W106° 30′ 18″ approximate
Commodities:	Copper and arsenic
Status:	Prospect
Geology:	
Host rock:	Granite
Formation age and name:	Precambrian Red Bluff Granite
Ore mineralogy:	Primary: chalcopyrite and bornite; secondary: malachite, chalcanthite, azurite, chrysocolla
Gangue mineralogy:	Quartz, pyrite, limonite, hematite, siderite, fluorite, halotrichite
Alteration:	Pyritization of diabase dike; feldspar destruction in granite wall rock
Age of mineralization:	Tertiary (Goodell, 1976) or possibly Precambrian
Deposit type:	Vein along fault–mafic dike zone striking N60°E and dipping 35°NW
Other data:	Evans (1943) reported that a deposit of arsenopyrite was prospected at the west base of the Franklin Mountains, east of Canutillo.
References:	Evans (1943), Deen (1976, 1977), Goodell (1976) - deposits; Richardson (1909), Harbour (1960, 1972), Denison and Hetherington (1969), Lovejoy (1975) - regional geology.

Unnamed Prospect

Location:	~7.5 mi (~12 km) north of El Paso 7.5-minute quadrangle: Canutillo Latitude: 31° 52′ 45″ Longitude: 106° 34′ 30″
Commodity:	Copper or precious metals
Status:	Shaft (~15 to 20 m deep), adits, exploration pits
Geology:	
Host rock:	Fault contact between Paleozoic limestone and Precambrian rhyolite and quartzite
Formation age and name:	Lower Paleozoic limestone; Precambrian Thunderbird rhyolite and quartzite
Ore mineralogy:	Azurite on fracture surfaces in rhyolite; gossan (no known analyses) in fault zone
Gangue mineralogy:	Quartz, locally with euhedral crystals in gossan; calcite; limonite
Alteration:	Limonite after pyrite common in rhyolite; brecciation and minor limonite and remobilized carbonates restricted to fault zone and appear to narrow with depth
Age of mineralization:	Association with West Boundary fault suggests probable Tertiary age
Deposit type:	Fracture controlled, weak hydrothermal system
Other data:	Series of small workings are associated with the West Boundary fault of the Franklin Mountains. Whereas the sheared and brecciated rock of the fault zone has been a pathway for fluids, no significant mineralization has been found.
References:	No recorded description found.

Ranking of Exploration Potential

The relative mineral potential of tracts of land administered by the Texas General Land Office that lie within the Franklin Mountains was evaluated on the basis of an assessment of available data and field observations (table 1). The section, part, block, township, grantee, acres, file number, and control number were provided by the General Land Office, as were topographic maps showing the probable location of each section. These are listed numerically by control number in table 1. Total acreage and a summary of ownership tabulated by fee, mineral classified, or land trade were also provided by the General Land Office.

Exploration potential of the Franklin Mountains for major deposits of metallic minerals is assessed as generally low. The most significant past production, which was small, was of tin. Indications of other metallic minerals are locally present, but no significant production has occurred and no evidence of large tonnages or high grades over minable widths are known. Nonmetallic mineral production, chiefly limestone, occurs locally in the Franklin Mountains, and limestone and dolomite are common in outcrop. Because these rock types are so widespread, they are not considered part of the ranking of exploration potential unless evidence exists of previous exploration or production, either nearby or within the section being ranked. Similarly sand and gravel deposits, caliche, or rock suitable for construction (such as facing materials) are not factored into the rating. The Lanoria Quartzite has been evaluated as a source of silica at one locality. Given a more favorable location, this and other outcrops of the Lanoria would potentially be economic as small-scale operations. Sections containing Lanoria quartzite are thus denoted by Q in the comments column in table 1.

The scheme for rating exploration potential has five levels, 1 being most prospective and 5 being least prospective:

Level 5. No obvious mineral potential: no known prospects or reported evidence of mineralization. These tracts commonly do not (a) lie within 1 mi of known prospects,

(b) include a geological setting similar to that of known mineralization, or (c) lie on trends of known mineralized structures. Any alteration known to be present is thought to be unrelated to economic mineralization.

Level 4. Speculative mineral potential: tracts are not known to contain evidence of significant mineralization, but may have altered rocks present. Tracts lie less than 1 mi from prospects or reported mineralization in a similar geologic setting, or they lie on a projection of a possibly mineralized structure or host horizon. In the Franklin Mountains, sections containing outcrops of the Lanoria Quartzite were given this ranking, although quality of resource has not been evaluated.

Level 3. Low mineral potential: tracts contain evidence of mineralization or include attractive alteration. If prospects are present, the presence of economic metals or minerals may be indicated, but economic potential may be small because of either the quantity or quality of the possible resource.

Level 2. Possible mineral potential: using reasonable exploration models of ore deposits, tracts are found to contain evidence suggesting that significant mineralization could be present. Mineralization of probable economic grade over minable widths may have been reported, or area is attractive because of size and intensity of alteration. Significant exploration may have occurred.

Level 1. Moderate mineral potential: tracts contain extensive evidence of alteration or mineralization, or geology is clearly analogous to known deposits. Rocks of near-economic grade may have been reported, or ore may have been produced. Significant exploration (excavations or drilling) may have occurred.

ACKNOWLEDGMENTS

We very much appreciate the assistance and pleasant company of Mr. Bill Farr of the General Land Office, who provided us with access to GLO data and files, accompanied us during part of the field examination, and shared with us his knowledge of the mineral prospects of the

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APPENDIX A: EXPLANATION OF GEOLOGIC UNITS

El Paso, Campo Grande Mountain, Cavett Lake, Diablo Canyon West,
Fort Hancock, and North Franklin Mountain Quadrangles,
El Paso region, West Texas

QUATERNARY

Holocene–Late Pleistocene

Qws—Windblown sand. Coppice dunes 0.5 to 2.0 m (1.6 to 6.5 ft) high common; includes undifferentiated local drainageway alluvium.

Qac—Slope-wash alluvium and/or colluvium. Commonly covers Santa Fe Group basin-fill deposits along arroyos and Rio Grande valley border; covers bedrock and basin-fill deposits along the margins of mountains and Diablo Plateau.

Qarg—Alluvium of Rio Grande floodplain. Sand, silt, clay, and gravel; commonly cultivated; urbanized in and near El Paso; locally covered by undifferentiated windblown sand (Qws).

Qa—Undifferentiated alluvium of drainageways, young fans (Qf4), and young arroyo terraces (Qt4). Sand, silt, gravel, and clay; gravel locally derived. Includes undifferentiated young deposits in relatively active settings and deposits in more stable settings that contain stage I to II BK horizons. Possibly includes local undifferentiated older alluvium and windblown sand. May overlie or be inset against older deposits.

Qavb—Undifferentiated alluvium of drainageways, young fans, and young arroyo terraces located along the Rio Grande valley border. Sand, gravel, silt, and clay; includes locally derived and exotic gravel. Includes undifferentiated young deposits in relatively active settings and deposits in more stable settings that contain I to II BK horizons. May include local undifferentiated older alluvium and windblown sand. May overlie or be inset against older deposits.

Qf4—Alluvium of young fans. Sand, gravel, silt, and clay; gravel locally derived. Includes deposits that have stage I to II BK horizons. Possibly includes local, undifferentiated drainageway alluvium, older alluvium, and windblown sand. May overlie or be inset against older deposits.

Qt4—Alluvium of young terraces along large arroyos. Sand, gravel, silt, and clay; gravel locally derived. Includes deposits that have stage I to II BK horizons. May include local undifferentiated drainageway alluvium and windblown sand. Inset against older deposits.

Qt4rg—Alluvium of young terraces and fans along the Rio Grande valley border. Sand, gravel, silt, and clay; includes locally derived and exotic gravel. Includes deposits that have stage I to II BK horizons. May overlie or be inset against older deposits.

Qf3-4—Undifferentiated Qf3 and Qf4 alluvium.

Qt3-4—Undifferentiated Qt3 and Qt4 alluvium.

Late Pleistocene Deposits

Qf3—Piedmont alluvium of alluvial fans, incised alluvial fans, and bajadas. Sand, gravel, silt, and clay; gravel locally derived. Commonly contains stage III BK horizon, <0.5 m (<1.6 ft) thick. May overlie or be inset against older deposits. Locally covered by younger drainageway alluvium and windblown sand.

Qt3—Alluvium of terraces within large arroyos. Sand, gravel, silt, and clay; gravel locally derived. Commonly contains stage III BK horizon, <0.5 m (<1.6 ft) thick. Inset against older deposits. Locally covered by younger drainageway alluvium and windblown sand.

Qt3rg—Alluvium of terraces and alluvial fans located along Rio Grande valley border. Sand, gravel, silt, and clay; includes locally derived and exotic gravel. Commonly contains stage III BK horizon, <0.5 m (<1.6 ft) thick. May overlie or be inset against older deposits. Locally covered by undifferentiated younger drainageway alluvium and windblown sand.

Late Pleistocene to Middle Pleistocene

Qf2—Piedmont gravel and sand alluvium of alluvial fans, incised fans, and bajadas. Sand, gravel, silt, and clay; includes locally derived gravel. Commonly contains stage IV K horizon calcrete, 0.2 to 1.0 m (0.6 to 3.0 ft) thick. May overlie or be inset against older deposits. Locally covered by undifferentiated younger alluvium and windblown sand.

Qt2—Alluvium of terraces along large arroyos. Sand, gravel, silt, and clay; gravel locally derived. Commonly contains stage IV K horizon calcrete, 0.2 to 1.0 m (0.6 to 3.0 ft) thick. Inset against older deposits. Locally covered by undifferentiated younger alluvium and windblown sand.

Qtrg2—Alluvium of terraces and alluvial fans along Rio Grande valley border. Sand, gravel, silt, and clay. Includes locally derived gravel and exotic gravel. Commonly contains stage IV K horizon calcrete, 0.2 to 1.0 m (0.6 to 3.0 ft) thick. May overlie or be inset against older deposits. Locally covered by undifferentiated younger alluvium and windblown sand.

Qf1-2—Undifferentiated Qf1 and Qf2 alluvium.

Qf2-3—Undifferentiated Qf2 and Qf3 alluvium.

Middle Pleistocene

Qf1—Alluvium of alluvial fans, bajadas, and alluvial plains. Sand, gravel, silt, and clay; gravel generally locally derived, local exotic gravel along Rio Grande valley border. Commonly contains stage IV to V K horizon calcrete, 0.7 to 1.5 m (2.3 to 5.0 ft) thick. Locally may be covered by younger alluvium and windblown sand. Surface of Qf1 is approximately equivalent to Jornada I surface of Mesilla basin, southern New Mexico; locally may be equivalent to La Mesa surface if some Qf1 alluvial deposits are time-equivalent facies of Camp Rice fluvial deposits.

Late Pleistocene to Pliocene

QTbf—Undivided Santa Fe Group basin-fill deposits. Includes gravel, sand, silt, and clay of the Fort Hancock Formation (Tfh) and Camp Rice Formation (QTcr), and younger piedmont, basin floor, valley border, and alluvial plain deposits of alluvial fans, incised alluvial fans, bajadas, and terraces.

Middle Pleistocene to Pliocene

QTcr—Camp Rice Formation. Sand and gravel; lesser amounts of silt and clay. Represents fluvial, alluvial fan, floodplain, and minor lacustrine deposition. Constructive depositional surface commonly contains stage V K horizon calcrete, 1.0 to 1.5 m (3.0 to 5.0 ft) thick. Ash at top of unit assigned as 0.6-m.y.-old Lava Creek B ash (Izett, 1981; Izett and Wilcox, 1982; location in El Paso, Texas). Ash in lower part of unit assigned as 2.1-m.y.-old Huckleberry Ridge ash (Izett, 1981; Izett and Wilcox, 1982; locations in Arroyo Diablo and Madden Arroyo, Campo Grande Mountain, Texas Quadrangle). Locally covered by younger alluvium and windblown sand. Depositional surface of QTcr equivalent to La Mesa surface of Mesilla basin, southern New Mexico.

Pliocene

Tfh—Fort Hancock Formation. Lacustrine clay, bedded gypsum (southeastern Hueco Bolson), and silt; alluvial fan gravel, sand, silt, and clay; minor fluvial deposits. Blancan vertebrate fossils. Locally covered by younger alluvium and windblown sand.

FINLAY MOUNTAINS AND DIABLO PLATEAU

TERTIARY

Ti—Undifferentiated intrusive igneous rocks. Dikes and sills of andesite porphyry, hornblende andesite porphyry, and latite porphyry in Finlay Mountains. Many small dikes and sills not shown. K-Ar ages of some Finlay Mountain intrusions range between about 46 and 50 m.y. (Matthews and Adams, 1986).

LOWER CRETACEOUS

Kf—Finlay Formation. Limestone, marl, shale, and sandstone. Gray; abundant marine microfossils and macrofossils. In Finlay Mountains, mostly medium and thin beds and nodular; some thick and massive beds; thin sandstone beds near base; about 61 m (200 ft) thick. In Diablo Plateau area, mostly limestone along rimrock of plateau; sandstone beds near base; about 53 to 61 m (175 to 200 ft) thick.

Kcx—Cox Sandstone. Quartz sandstone, conglomerate, limestone, and shale. Mostly quartz sandstone; fine- to medium-grained, thin- to thick-bedded, crossbedded, and rippled. Contains silicified wood; some silicified branches and logs several feet long. Fossiliferous limestone common in upper half of unit. Various shades of brown, gray, orange, and pink. About 152 m (~500 ft) thick at Diablo Plateau; about 165 to 206 m (~540 to 675 ft) thick in Finlay Mountains; about 213 to 226 m (~700 to 740 ft) thick at Campo Grande Mountain.

Kb—Bluff Mesa Formation. Limestone and sandstone; some limestone conglomerate and sandy shale. Locally crops out in hills northwest of Campo Grande Mountain on upper

Laramide thrust plate of area; basinward facies approximately equivalent to Campagrande Formation (Kca).

Kca—Campagrande Formation. Limestone, marl, conglomerate, sandstone, siltstone, and shale. Interbedded limestone and marl in upper 61 to 76 m (200 to 250 ft); thin to thick beds; gray. Lower part is interbedded sandstone, fossiliferous limestone, siltstone, sandy shale, and limestone and chert conglomerate. About 114 m (~375 ft) thick in northwest Finlay Mountains; about 244 m (~800 ft) thick in southwest Finlay Mountains.

FRANKLIN MOUNTAINS

TERTIARY

Ti—Undivided intrusive rocks. Includes Campus Andesite west of Crazy Cat Mountain; felsite dikes and sills unmapped.

CRETACEOUS

K—Undivided Cretaceous strata.

PERMIAN

Ph—Hueco Group. Limestone, dolomitic limestone to dolostone, siltstone, shale; thin- to thick-bedded; generally light gray; about 670 m (~2,200 ft) thick.

PENNSYLVANIAN

Magdalena Group

IPmps—Panther Seep Formation. Argillaceous limestone, gypsum beds, silty shale, chert-pebble conglomerate. Conglomerate marks base of unit; gypsum beds 2 to 12 m (6.5 to 39 ft) thick; generally forms gentle slopes; about 360 m (~1,180 ft) thick.

IPmbc—Bishop Cap Formation. Shale, limestone. Composed primarily of poorly exposed shale with some thin, resistant beds of limestone. About 194 m (~636 ft) thick.

IPmb—Berino Formation. Limestone, shale. Composed primarily of alternating limestone and shale units about 0.6 to 6 m (~2 to 20 ft) thick; shale dominates base of unit; about 21 m (~70 ft) of massive, resistant limestone at top of unit. Common fossils include mollusks, brachiopods, corals, bryozoans, and fusulinids. Total thickness about 137 m (~448 ft).

IPml—La Tuna Formation. Limestone. Cherty; massive limestone beds at base; shale interbeds increase upward and unit more thinly bedded upward. Resistant to weathering; forms cliffs. Common fossils include silicified corals, brachiopods, crinoids, mollusks, bryozoans; some petrified wood. About 85 m (~280 ft) thick.

MISSISSIPPIAN

Mh—Helms Formation. Shale, some limestone. Shale is calcareous and gray. Limestone locally oolitic; contains traces of quartz sand; commonly <0.3 m (<1 ft) thick. Limestone interbeds as thick as 1 m (3 ft) more common in upper part of unit. Fossils include brachiopods, gastropods, ostracodes, crinoids, and bryozoans. About 46 to 70 m (~150 to 230 ft) thick; thins northward.

Mr—Rancheria Formation. Limestone, some siltstone and shale. Lower part is mostly cherty limestone with some siltstone and shale interbeds; about 40 m (130 ft) thick; limestone beds as thick as 0.6 m (2 ft); siltstone and shale beds as thick as 2 m (7 ft). Middle part is black limestone; 8.5 to 12.8 m (28 to 42 ft) thick; forms a light-gray band in weathered hillsides. Upper part is limestone with siltstone and shale near the top; limestone is black, cherty, and sandy; about 61 to 70 m (~200 to 230 ft) thick.

Mlc—Las Cruces Formation. Limestone. Evenly bedded; beds about 0.3 to 0.6 m (~1 to 2 ft) thick; mostly chert free; weathers white to light gray and commonly forms distinct band at the base of ledgy cliffs. About 15 to 27.5 m (~50 ft to 90 ft) thick.

DEVONIAN

Dpc—Undivided Canutillo Formation and Percha Shale. Limestone, shale, marl, and some siltstone. Canutillo limestone, shale, marl, and siltstone, about 41 m (135 ft) thick, is overlain by 12-m (40-ft) thick Percha black shale. Lower part of Canutillo is shale, limestone, and dolomite breccia (derived from Fusselman Dolomite) overlain by interlensed chert and marl. Chert lenses 0.15 to 0.6 m (0.5 to 2 ft) thick. Upper part of Canutillo is calcareous dark-gray shale interbedded with thinner (<0.3-m- [<1-ft-] thick) beds of dark-gray marl and limestone. Local evidence that some lower Canutillo strata were deposited in sinkholes or channels in the underlying Fusselman Dolomite.

SILURIAN

Sf—Fusselman Dolomite. Dolostone, some limestone. Mostly light-gray to tan dolostone; some gray limestone patches surrounded by dolomite/dolostone in upper part of unit; minor chert; karst breccia. Resistant to weathering; forms massive cliffs. Fossils include brachiopods, corals, and gastropods. About 152 to 183 m (~500 to 600 ft) thick.

UPPER AND MIDDLE ORDOVICIAN

Om—Montoya Group. Dolostone, some limestone, marl, and shale. Includes undivided lower, 30.5-m- (100-ft-) thick Upham Dolomite, middle, 46-m- (150-ft-) thick Aleman Formation, and upper, 39.5- to 50-m- (130- to 165-ft-) thick Cutter Formation. Upham is massive, gray dolostone. Aleman is dark-gray dolostone commonly interlayered with chert lenses and nodules. Cutter is about 9 m (~30 ft) of nodular marl, dolostone, limestone, and shale overlain by cliff-forming, 0.6 to 1.8 m (2 to 6 ft) thick, evenly bedded, light-gray dolostone. Karst breccia common. Fossils include brachiopods, corals, and gastropods, and abundant, dolomitized fossil debris.

LOWER ORDOVICIAN

Oe—El Paso Group. Limestone, dolostone, sandy dolostone, and some dolomitic sandstone. Massive to thin bedded; some crossbeds and cross-laminations; some chert; karst breccia. Several published subdivisions of these cyclic, shelfal carbonate strata exist. Seven formations (LeMone, 1968, 1988) include, from base to top: (1) 26 to 49 m (85 to 160 ft) of Sierrite sandy dolostone, (2) about 33 m (~110 ft) of Cooks dolomite,

(3) about 88 m (~290 ft) of Victorio Hills limestone and dolostone, (4) 21 to 27.5 m (70 to 90 ft) of José sandy, crossbedded dolostone, massive dolostone, and dolomitic sandstone, (5) 173 to 210 m (570 to 690 ft) of McKelligon Canyon limestone and dolostone (upper 7.6 m [25 ft]), (6) about 88 m (~290 ft) of Scenic Drive dolomitic sandstone (base), sandy dolostone and dolostone (lower 18 to 30.5 m [60 to 100 ft]), and limestone (upper part), and (7) about 12 m (~40 ft) of Florida Mountains limestone. Common fossils include snails, brachiopods, trilobites, and conodonts.

LOWER ORDOVICIAN – UPPER CAMBRIAN (?)

OCb—Bliss Sandstone. Quartz-rich sandstone, quartzite, and siltstone. Fine- to medium-grained; medium- to thick-bedded; laminated and cross-laminated; glauconitic in upper half; weathers dark reddish brown. Sparse fossils include brachiopods, gastropods, rare trilobites; some trace fossils. As thick as 76 m (250 ft); locally absent.

PRECAMBRIAN

P€g—Undivided porphyritic granite, biotite granite, biotite-hornblende granite, riebeckite granite, and associated pegmatite, aplite, and basalt dikes. Includes granites of Red Bluff Granite complex. Granite is commonly medium to coarse grained, massive, and pink to red. Intrudes all other Precambrian rocks. May include local, undifferentiated rhyolite (pCr).

p€r—Undivided Thunderbird Group: (1) rhyolitic ignimbrites and porphyritic rhyolite dikes (upper Tom Mays Park Formation; as thick as 168 m [550 ft]);
(2) porphyritic trachyte, tuffaceous sandstone and conglomerate, and ignimbrite (middle Smugglers Pass Formation; as thick as 140 m [460 ft]); and (3) rhyolite-cemented conglomerate of cobble- to pebble-sized quartzite, siltstone, shale, chert, ignimbrite, and trachyte (lower Coronado Hills Formation; 11 to 27 m [35 to 90 ft] thick).

p€l—Lanoria Quartzite. Quartzite, sandstone, siltstone, and shale. Three members include (1) **lower Lanoria (pCll)**; 320 m (1,050 ft) thick; fine-grained quartzite, sandstone, siltstone, and shale; commonly forms slopes; (2) **middle Lanoria (pClm)**; 183 to 243 m (600 to 800 ft) thick; medium-grained quartzite, crossbedded; commonly forms cliffs; (3) **upper Lanoria (pClu)**; 168 to 213 m (550 to 700 ft) thick; fine-grained quartzite, sandstone, siltstone, shale; thin bedded; commonly forms slopes.

p€mc—Undivided Mundy Breccia and Castner Limestone. Mundy Breccia: randomly oriented, black basalt boulders, angular to slightly rounded, in matrix of dark-gray mudstone; as thick as 76 m (250 ft). Castner Limestone: limestone, hornfels, conglomerate, dolomite, and diabase; mostly limestone, slightly metamorphosed, some chert lenses, thin-bedded, containing metamorphic minerals that include serpentine, tremolite, and garnet; numerous thin beds of hornfels in upper third of unit, very fine grained, laminated; some conglomerate in upper third of unit; dolostone in basal part of unit; local algal structures; diabase sills near base and middle, dark greenish gray, thin to thick, constituting about one-third of unit; thickness of formation about 335 m (~1,100 ft); base not exposed.

Normal fault. U = upthrown, D = downthrown.

Known lower angle normal fault. Bar on footwall block.

Probable normal fault scarp covered by windblown sand. U = upthrown, D = downthrown.

Strike and dip of beds.

Monocline.

Covered thrust fault. T indicates upper plate. Marks approximate edge of Laramide thrusting.

Ash; assigned as 2.1-m.y.-old Huckleberry Ridge ash by Izett (1981) and Izett and Wilcox (1982).