

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

MINERAL RESOURCE POTENTIAL OF THE
SHEEP HOLE-CADIZ WILDERNESS STUDY AREA (CDCA-305),
SAN BERNARDINO COUNTY, CALIFORNIA

SUMMARY REPORT

by

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FOREWORD

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report summarizes the results of a mineral survey of the Sheep Hole-Cadiz Wilderness Study Area (CDCA-305), California Desert Conservation Area, San Bernardino County, California.

SUMMARY

The Sheep Hole-Cadiz Wilderness Study Area (CDCA-305) has potential for several mineral resources, classified here using the McKelvey diagram. These include (1) large inferred to hypothetical resources of sodium and calcium brines in porous sediments at depth on the northwest, east, and west sides of the study area, possibly associated with lithium and (or) strontium; (2) small indicated subeconomic to speculative resources of base- and precious-metal vein-type deposits in the Sheep Hole and Calumet Mountains, with a speculative resource of porphyry molybdenum; (3) a small measured resource of decorative building stone in the east-central Sheep Hole Mountains; (4) large quantities of sand and gravel, not considered a resource because of distance from possible consumers; (5) a speculative resource of unknown value for geothermal resources, reflected by industry exploration in the area; (6) three areas of speculative to hypothetical vein-type uranium resources; and (7) minor resources of low potential for undiscovered contact metamorphic tungsten, placer deposits of gold, and oil and gas. None of the identified resources are presently economic. There is no documented production history. There is no current production in the wilderness study area.

INTRODUCTION

This report summarizes the results of a mineral survey conducted by the U.S. Bureau of Mines and U.S. Geological Survey of the Sheep Hole-Cadiz Wilderness Study Area (CDCA-305), about 200,000 acres (80,000 ha), including enclosed private lands, in south-central San Bernardino County, California (fig. 1). The U.S. Bureau of Mines studied the mineral resources of mines and prospects and the U.S. Geological Survey conducted geological, geochemical, and geophysical investigations to define the extent of mineralization associated with mines and prospects and to determine if previously unknown resources exist in the area. The areas of mineral resource potential, shown on Figure 4 and defined in this report, were classified using the McKelvey diagram (fig. 5).

The study area is located in the Mojave Desert 13 mi (21 km) southeast of Amboy, California, 20 mi (32 km) east of Twentynine Palms, California, and 90 mi (145 km) east of San Bernardino, and encompasses parts of the Dale Lake, Bristol Lake, Cadiz Valley, and Cadiz Lake 15-minute quadrangles. Its borders are defined by the Amboy Road and a gas pipeline service road on the northwest, the northern border of sections 25-30 in T.4N. on the north, the unimproved Cadiz Valley access road on the east, State Route 62 along the south, and the Iron Age Road and an unimproved powerline service road on the west. Major access from the east and west is provided by State Route 62 and from the north by the Amboy Road.

Local topography is dominated by two elongate, northwest-trending mountain ranges, the Sheep Hole Mountains on the west and the Calumet Mountains and south Calumet Mountains on the east, separated by a 5 to 8 mi (8 to 13 km) wide basin (Dry Lake valley). Elevations above mean sea level range from 560 ft (171 m) at Cadiz Lake playa to 4,613 ft (1,406 m) in the Sheep Hole Mountains. The mountainous terrain is commonly rugged and steep, while the valleys are characterized by gently sloping, dissected flanks and relatively flat bottoms. Dunes cover large areas southeast of Dale Lake playa and on both flanks of the northern Calumet Mountains. The area lacks perennial streams or springs.

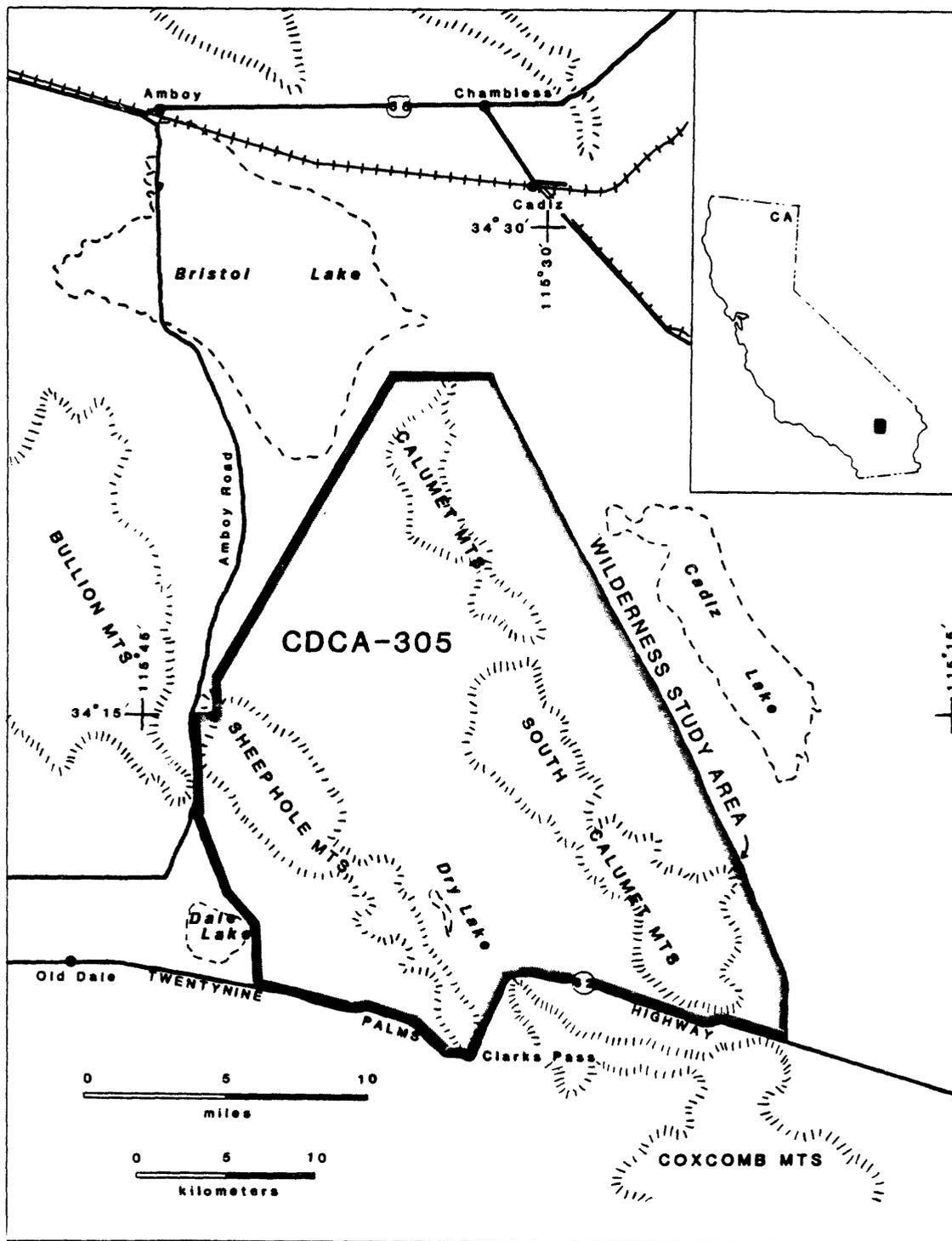


Figure 1. Location map

The earliest published geologic reports of the area resulted from a reconnaissance of the Mojave Desert region by Thompson (1929). Investigations and mapping emphasizing Cenozoic geology in the southeastern Mojave Desert are reported in Kupfer and Bassett (1962) and Bassett and Kupfer (1964). The Southern Pacific Company studied the geology and mineral resources of the northern half of the study area (Anctil and Schafer, 1958; Cunningham and others, 1958; Danehy, 1959; Danehy and Collier, 1959; and Spurck, 1959a, b, and c). More recently, John (1981) discussed the character of Mesozoic plutonic rocks in and near the study area, Howard and others (1982) discussed their deformation, Calzia (1982) described plutonic rocks in the adjacent Coxcomb Mountains, and D. Miller and others (1982) summarized the geologic framework of the area. Mohorich (1980), Fuis (1981), Lachenbruch and others (1978) and Lachenbruch and Sass (1981) discussed regional geophysical features that are pertinent to the evaluation of geothermal potential.

Considerable literature has addressed the geology and mineral resources of evaporites and brines in dry lakes contiguous to the study area (Hess, 1910, 1920; Gale and Hicks, 1920; Foshag, 1926; King, 1948; Ver Planck, 1950, 1952, 1957, 1958; Gale, 1951; Durrell, 1953; Bassett and others, 1959; Moyle, 1961; Withington, 1966; Calzia, 1979a and b; Calzia and others, 1979; and Calzia and Moore, 1980). Reports on mines and mineral occurrences within the study area and in nearby mining districts are found in Cloudman and others (1919), Tucker (1921), Newman (1923), Tucker and Sampson (1930, 1931, 1940, 1943), Hewett and others (1936), Wright and others (1953), Calzia and Luken (1981), and Vredenburg (1981). Land classifications for leaseable mineral resources are published by the U.S. Geological Survey (1980, 1981a and b). Historical perspectives of mining in the Mojave Desert are provided by Miller (1965) and Vredenburg and others (1981).

Results from the present investigation of the Sheep Hole-Cadiz Wilderness Study Area are detailed in companion reports that describe the geology (Howard and John, 1982), gravity and magnetics (Simpson and others, 1982), geoelectrical surveys (Hoover, 1982), geochemical surveys (Marsh and Raines, 1982), hydrothermal alteration studies (Raines, 1982), and mines and prospects (Moyle and Rumsey, 1982, and unpublished property reports, U.S. Bureau of Mines, Spokane, Washington). Peter S. Galanis, James K. Otton, Arthur H. Lachenbruch, George I. Smith, James P. Calzia, and Barbara E. John of the U.S. Geological Survey each provided unpublished data, interpretations, and perspective that were used in the evaluation of resources reported here.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

The Sheep Hole-Cadiz Wilderness Study Area lies in a part of the Mojave Desert in which mountain ranges of pre-Tertiary rocks and Tertiary volcanic rocks alternate with broad alluviated basins. Three major tectonic provinces adjoin each other near the area: the east-west-trending Transverse Ranges on the southwest, the Sonoran block of irregularly trending mountains to the east, and the Mojave block of dominantly northwest trending ranges in the west. The Sheep Hole and Calumet Mountains are examples of these northwest-trending ranges.

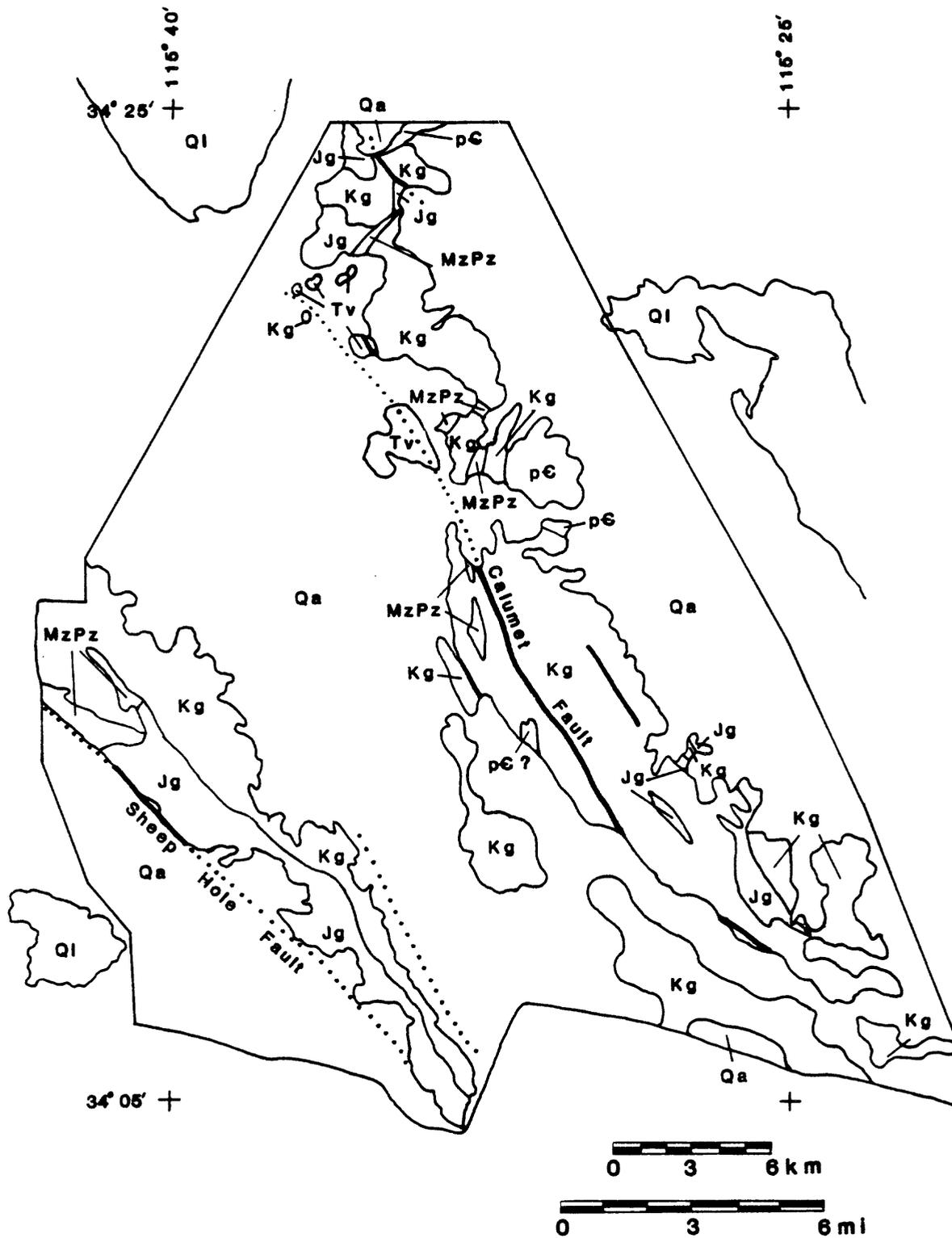


Figure 2. Generalized geologic map of the Sheep Hole-Cadiz Wilderness Study Area

EXPLANATION

- Qa** ALLUVIUM AND WINDBLOWN SAND (QUATERNARY)
- Q1** PLAYA DEPOSITS (QUATERNARY)
- Tv** VOLCANIC ROCKS (MIOCENE)
- Kg** GRANITE AND GRANODIORITE OF THE CADIZ VALLEY
BATHOLITH (CRETACEOUS)
- Jg** GRANITE, GRANODIORITE, QUARTZ DIORITE AND
DIORITE (JURASSIC)
- MzPz** METASEDIMENTARY ROCKS (MESOZOIC? AND PALEOZOIC)
- pE** GNEISS (PRECAMBRIAN -- PROTEROZOIC)
-
- CONTACT
- ... FAULT--Dotted where concealed
- APPROXIMATE BOUNDARY OF WILDERNESS STUDY AREA

The Sheep Hole and Calumet Mountains are largely bare rock with scant soil or vegetation. The NNW trend of both ranges is controlled both by lithologic belts and by younger faults (fig. 2). Granite, granodiorite, and other plutonic rocks of Mesozoic age predominate, and are part of an extensive batholithic terrane involving much of the Mojave Desert. The plutonic rocks intrude older metamorphic rocks in the Sheep Hole and Calumet Mountains, and are locally intruded by Tertiary dikes. Tertiary volcanic and sedimentary rocks occur locally. Lowlands around the ranges are underlain by sand and gravel washed out of the ranges, windblown sand, and playa (dry-lake) deposits.

Prebatholithic rocks include several gneiss units of probable Proterozoic age, exposed in the Calumet Mountains. Proterozoic rocks such as these are hosts for mineral deposits elsewhere in the Mojave Desert, but are not known to be mineralized here. Metamorphosed Mesozoic(?) and Paleozoic strata occur in both ranges, and include small amounts of contact-metamorphosed marble and calc-silicate rocks. Minor foliated quartzite, which weathers to flagstone, is also present.

Mesozoic plutonic rocks are represented by two suites, one assigned a Jurassic age and one assigned a Cretaceous age. The older Jurassic suite ranges in composition from diorite to granite. It crops out in both ranges, most extensively in the western Sheep Hole Mountains. This Jurassic suite is metamorphosed and intruded by a younger, more voluminous Late Cretaceous suite consisting of granite, two-mica granite, and granodiorite in several plutons collectively grouped as the Cadiz Valley batholith. Pluton walls, pendants, and rare layering in the Cadiz Valley batholith are concordant, generally dip steeply, and suggest the batholith was forcefully intruded in a mesozonal environment. The Cadiz Valley batholith is broken by northwest-striking joints coated by white mica, hematite, and rare pyrite, and locally occupied by vein quartz or aplite.

The Cadiz Valley batholith underlies most of the study area, and its late Mesozoic age is pertinent to evaluation of oil and gas potential. The study area lies along the extrapolated trend of a belt, commonly called the overthrust belt, of Mesozoic thrust faults which elsewhere in the Cordillera are known to trap oil and gas in Paleozoic and Mesozoic strata. Although most strata of this age are metamorphosed in this region (Stone and others, 1981), nonmetamorphosed Paleozoic strata crop out in the Marble and Ship Mountains, 10-15 miles (15-25 km) north of the study area, and a thrust inferred to be part of the Cordilleran frontal thrust belt involves Paleozoic strata just east of the study area in the Old Woman Mountains and Kilbeck Hills (Howard and others, 1980; C. Miller and others, 1982). Jurassic plutons cut thrust-faulted Paleozoic rocks in the Marble and Bristol Mountains north of the study area (Burchfiel and Davis, 1981; Brown, 1981), and Cretaceous granodiorite older than the Cadiz Valley batholith cuts the thrust that is in the Old Woman Mountains and Kilbeck Hills. These rocks and thrusts predate the Cadiz Valley batholith, which underlies most of the study area. From these intrusive relations it can be concluded that any pre-Tertiary strata that may be concealed by overthrusts beneath the study area are likely to be engulfed and metamorphosed by the Cadiz Valley batholith, and, therefore, unlikely to contain oil or gas.

Dacite and felsite dikes of Tertiary age cut the batholith rocks in the northern Calumet Mountains. A major swarm of similar dikes occurs in the western Bullion Mountains, and may be associated there with gold mineralization at the America Mine, 10 miles (15 km) west of the northern Calumet Mountains. Steeply tilted Miocene volcanic rock in the Calumet Mountains may be the extrusive equivalent of some of the dikes. Similar volcanic rocks are mineralized 1/2 mile (1 km) north of the northern boundary of the study area.

Faults in the area commonly are marked by red oxidized rocks, and are in places mineralized. Three northwest-trending faults cut Lower Pleistocene alluvium along the flank of the Sheep Hole Mountains and in the southern Calumet Mountains. The northwest orientation of ranges and basins reflects such faults, but also reflects northwest-trending metamorphic and plutonic rock units.

Alluvial fans of poorly sorted sand and gravel derived from the adjacent mountains form much of the basinal material in the study area. Downstream from mineralized areas, the alluvium may include low-grade placer deposits. Sheets and dunes of well-sorted windblown quartz sand cover about 25 square miles (40 square kilometers) of the study area.

Basinal deposits of saline minerals and brines occur in Bristol, Dale, and Cadiz Lake playas adjacent to the study area. Brines from Bristol and Cadiz Lakes are currently being mined.

The Cadiz and Bristol Lake basins are part of the larger Barstow-Bristol-Danby structural trough, which transects this part of the Mojave Desert on a west-northwest trend (Bassett and Kupfer, 1964; Gardner, 1980; Glazner, 1981; D. Miller and others, 1982). High heat flow in the study area possibly relates to the presence of this structure and also may relate to regional boundaries in neotectonics and seismicity (Carr and Dickey, 1976), crustal thickness (Fuis, 1981), upper mantle seismic velocity (Hadley and Kanamori, 1977), and heat flow (Lachenbruch and others, 1978; Lachenbruch and Sass, 1981).

Geochemistry and Remote Sensing

A reconnaissance geochemical study of the Sheep Hole-Cadiz Wilderness Study Area used three sample media to best represent this area in the arid desert environment of southeastern California: stream sediments, panned concentrates from stream sediments, and rocks. Sediments and concentrates were collected from 91 drainages in the Sheep Hole and Calumet mountain ranges, each drainage representing a 1-2 sq mile (2.5-5 sq km) area (Marsh and others, 1982). Selected rock samples were taken from outcrop areas of observed alteration and from existing mining areas to determine mineral suites related to mineralization and to determine trace element-signatures of mineralized systems.

The -80 mesh (-177 micron) fraction of sediments and the nonmagnetic heavy (2.6 sp gr) fraction of concentrates were analyzed for 31 elements by a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). Rock samples were pulverized, and also analyzed by the semiquantitative emission spectrographic method. To investigate limonitic alteration, the intermediate magnetic fractions of selected panned concentrates from stream sediments were analyzed (Marsh and Raines, 1982). This sample media

was used because it contains the absorbed iron and manganese oxides on sediments from the representative drainage basins. The iron and manganese oxides were dissolved from the samples using hot aqua-regia and were analyzed using the induction coupled plasma spectrograph (ICP) (Chruch, 1981, 1982) to see if they contained anomalous concentrations of metals.

As a part of this study limonitic materials were identified in LANDSAT images of the Sheephole and Calumet Mountains using a color-ratio-composite method (Rowan and others 1974). This technique was used to map areas of hydrothermal alteration associated with limonitic materials (Raines, 1982) and to help define potential mineralized systems. The term limonite is used (Blanchard, 1968; Hunt, 1980) for hydrous iron oxides and ferric oxide minerals such as hematite and goethite that have similar reflectance properties within the spectral range of the LANDSAT multispectral scanner. Pyrite and other sulfide minerals are almost universally associated with hydrothermal alteration that is potentially related to mineralization; these minerals weather to produce limonite, which is detected by this technique. All areas defined as limonitic from the satellite analysis were visited and sampled selectively to determine if the limonite was associated with hydrothermal alteration, and if so, what type of alteration and (or) mineralization. The selected rock samples were analyzed by a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968) to determine trace-element assemblages associated with mineralization, in order to help define the type and extent of any mineralizing process that could have produced the observed hydrothermal alteration. From these hydrothermal-alteration studies, several mineralized areas were identified and the extent, distribution, and type of alteration were mapped.

The regional geochemical survey in the Sheep Hole-Cadiz study area (Marsh and Raines, 1982) delineated regions of known mineralization, helped identify and define an area of potential stockwork or porphyry molybdenum mineralization in the northern Calumet Mountains (Area M-3, fig. 4), and identified an area of previously unknown alteration in the south Calumet Mountains (Area M-5, fig. 4). In addition, the survey identified geochemical suites of elements related to, and characterizing the granitic rocks in the Sheep Hole and Calumet Mountains.

Geophysics

Aeroradiometric data produced for the NURE (National Uranium Resource Evaluation) program of the U.S. Department of Energy (Geodata International Inc., 1979) were analyzed (J. K. Otton, written commun., 1981) and found to show two anomalous areas of uranium in the Sheep Hole Mountains and one in the south Calumet Mountains.

Geophysical investigations conducted by the U.S. Geological Survey of the Sheep Hole-Cadiz Wilderness Study Area include gravity and aeromagnetics (Simpson and others, 1982) and vertical electrical soundings and audio-magnetotelluric studies (Hoover, 1982).

A Bouguer gravity map of the Sheep Hole-Cadiz Wilderness Study Area shows gravity lows associated with sediment-filled basins marginal to the wilderness study area. The basins at Dale Lake, southern Cadiz Lake, and between the northern Sheep Hole Mountains and the Calumet Mountains are estimated to contain 2000 to 4000 ft (600 - 1200 m) of sediment fill. Dale Lake and Cadiz

Lake both contain surface exposures of brine deposits near the study area. A smaller basin under Dry Lake between the two ranges contains as much as 1500 ft (450 m) of sediments, although the potential for existence of brine in this lake appears to be small. Broad aeromagnetic lows confirm the presence of these sediment-filled basins, and depth-to-basement estimates from aeromagnetic anomalies are in fair agreement with sediment thickness estimates made from gravity data.

Gravity and magnetic highs coincident with the Calumet and south Calumet Mountains cannot be explained in terms of the physical properties of the granitic rocks exposed at the surface, and suggest that this range is underlain at shallow depth by a Precambrian basement terrane similar to that exposed to the north and east of the study area (Chapman and Rietman, 1978). Broad gravity and magnetic highs also exist over exposed Precambrian rocks. The absence of similar highs over the Sheep Hole Mountains indicates a different basement for this range and suggests that the southwestern edge of the Precambrian basement terrane may lie between the Sheep Hole Mountains and the Calumet and south Calumet Mountains.

Small elongate magnetic highs in the south Calumet Mountains correlate with exposures of more mafic rock enclaves in the granitic Cretaceous batholith. Other small magnetic highs within the wilderness study area are probably caused by similar materials at greater depths; however, the shapes of certain of these highs could be explained alternatively by small stocks at depth, perhaps related to Tertiary volcanic and intrusive rocks that are exposed in the Calumet Mountains.

Magnetically "quiet" areas within the ranges are caused by relatively nonmagnetic bedrock--either because of a scarcity of primary magnetic minerals, or because of the destruction of magnetic minerals by alteration. For example, a magnetically quiet area in the south Calumet Mountains which is marked by limonite alteration (fig. 4, Area M-5) may be underlain at depth by altered rocks, although the low magnetic susceptibilities measured from exposed bedrock indicate that scarcity of primary magnetic minerals cannot be ruled out.

Linear gravity and magnetic gradients result from contrasts in physical properties such as could occur across geologic contacts and structures. Within the study area linear gradients with NW-SE trends are most common and best defined, although E-W trends occur immediately north and south of Dale Lake. A broad, poorly defined zone of disrupted and truncated gravity anomalies seems to trend NE-SW across the area. This zone appears to separate a shallower, structurally complex basement under the northern end of Cadiz Lake from a deeper basement under the south end of the lake.

Two electrical methods were used to investigate the area: audio-magnetotelluric (AMT) and Schlumberger vertical electrical sounding (VES). Both of these techniques give a measure of changes in earth resistivity from the surface to a maximum depth of exploration, dependent on the earth's resistivity and electrode separation for Schlumberger soundings, or frequency for audio-magnetotelluric soundings. Schlumberger methods were most effective in sounding the playas at Dale, Bristol, and Cadiz lakes because of the very low resistivities encountered. Seventeen vertical electric soundings (VES) were obtained on the lake margins principally to investigate the potential for

saline deposits. Fourteen AMT soundings were obtained on the margins and within the study area.

On the edges of the playas adjacent to the study area the generalized resistivity section consists of four layers. The upper layer has very low resistivities, about 1 ohm-meter, on the playas proper and intermediate resistivities, 10 to 100 ohm-meters, on the pediment surface. The second layer has intermediate resistivities below which a low-resistivity layer is again found. Resistivities in this third layer are from 1 to 100 ohm-meters, and the top is generally about 300 ft (100 m) deep. The bottom of the third layer was identified on most soundings by an increase in resistivity. Interpreted resistivities of the fourth layer are, however, poorly constrained by the data.

On the playas proper the first layer of low resistivity is the zone from which past and present production of saline solutions has occurred. This is consistent with the very low observed resistivities. The third layer whose top is at a depth near 300 ft (100 m) is inferred to be similar to the first layer and contains very saline solutions. The third layer, however, extends beyond the present borders of the playas and well into the study area. The thickness of this third layer is generally greater than 300 (100 m) on the margins of the study area and appears to be greatest adjacent to Cadiz Lake.

AMT soundings adjacent to the saline playas showed low resistivities in agreement with the VES data but were limited in depth of exploration because of the very low resistivities observed. Soundings adjacent to Dry Lake valley within both the Sheep Hole and Calumet Mountains were on Mesozoic plutonic rocks and generally showed monotonically increasing resistivities with depth to values of about 1000 ohm-meters at 3,000 ft (1000 m). This behavior is typical of normal plutonic rocks and is believed to reflect the closure of fractures with depth. Two AMT soundings of plutonic rocks were anomalous, one at the Calumet Mine, and another on the west edge of the south Calumet Mountains. These two soundings showed an essentially uniform resistivity of about 100 ohm-meters to depths near 3000 ft (100 m). This resistivity is very low for fresh unaltered plutonic rock and suggests that fracturing and(or) alteration is present to considerable depth at these two sites.

MINERAL DEPOSITS

Mining History

Gold was discovered in the vicinity of Twentynine Palms, California, in 1873, and in northern Pinto Basin and on the shore of Dale Lake in 1883 (Miller, 1965, p. 9-13). The Dale Mining District and the town and mill of Virginia Dale, southwest of the study area, were established with the discovery of lode gold in the Pinto Mountains (Vredenburg and others, 1981, p. 140). A small rush was subsiding by 1898, but numerous mines in the Dale Mining District operated intermittently until World War II, and small scale activity continues to the present. Vredenburg and others (1981, p. 140) estimate that the eleven most productive lode deposits in the Dale Mining District produced 184,000 oz (5,723,000 g) of gold. The Sheep Hole Mountains have been included in the Dale Mining District in recent years. The Iron Age and Snowflake Mines, southwest of the study area, are past producers of skarn-type iron ore.

Mining in the study area has been largely confined to relatively small hydrothermal gold deposits. The earliest known claim locations or developments occurred at the Sheep Hole Mine (fig. 3 and table 1, no. 37) in 1917 and at the Aljac (Calmont, Calumet) Mine (fig. 3 and table 1, no. 1) in 1926 (Barstow Printer, August 26, 1926). The Alpha and Sunshine claims (fig. 3 and table 1, no. 7) were located in 1932 and 1943, respectively. The size and conditions of workings indicate several periods of development and probable production at the Aljac, Big Horn, and Sheep Hole Mines (fig. 3 and table 1, nos. 1, 35 and 37), but there are no substantive records. Hundreds of placer claims have been located in the Dale Lake basin and Dry Lake valley since 1923, with most prospecting activity occurring in the 1960's.

Twenty-eight unpatented placer and thirty-seven unpatented lode claims are actively held by claimants within and contiguous to the study area; however, there is no current production. Current activity includes minor improvements in access and minor exploration/development on two properties. Recent activity by private industry also includes uranium exploration, oil and gas lease applications, and shallow drilling to evaluate geothermal gradients.

Three areas of past or present brine production lie adjacent to the Sheep Hole-Cadiz Wilderness Study Area. Brine minerals are naturally soluble salts normally found dissolved in seawater or brine. Commercially important brines in California include borates, bromides, calcium chloride, calcium sulfate (gypsum), iodine, potassium salts, sodium chloride (salt), sodium carbonate (soda ash or trona), sodium sulfate (salt cake), and may include tungsten, lithium, strontium, and magnesium compounds (Ver Planck, 1950, p. 208). Recovery methods include mining of surface or shallow sub-surface precipitates or by treatment of brines pumped to the surface. Gypsum, calcium chloride, and sodium chloride production began on Bristol Lake (fig. 1) in 1906, 1910, and 1918, respectively. Dale Lake produced sodium sulfate and salt from 1940 to 1948, and production of calcium chloride brines from Cadiz Lake began in the early 1970's. Salt (NaCl) and calcium chloride are produced from Bristol and Cadiz Lakes near the study area.

Resource Evaluation

During the joint U.S. Geological Survey and U.S. Bureau of Mines study of the Sheep Hole-Cadiz Wilderness Study Area, all areas of brine, geothermal and oil and gas potential were evaluated, and all of the known mines, prospects and limonitic altered zones were visited. Potential resources of brines, base and precious metals, uranium, rock products, and geothermal resources in the wilderness study area are outlined on Figure 4. The mineral resources are classified using the terminology of the McKelvey diagram (fig. 5--U.S. Bureau of Mines and U.S. Geological Survey, 1980).

Brines and Saline Deposits

Five playas occur in or near the study area (fig. 1). The largest three, Cadiz Lake, Dale Lake, and Bristol Lake, are adjacent to the study area and have brine resources that are interpreted to extend into the study area. The other two, upper and lower Dry Lakes, within the study area in secs. 14, 24, 25, and 36, T. 1 N., R. 13 E., are narrow playas that are apparently dry and barren of salts; four seismic surveys indicate, and two test auger holes confirm, the absence of a moisture horizon at shallow depths and only scattered gypsum nodules in the sediments.

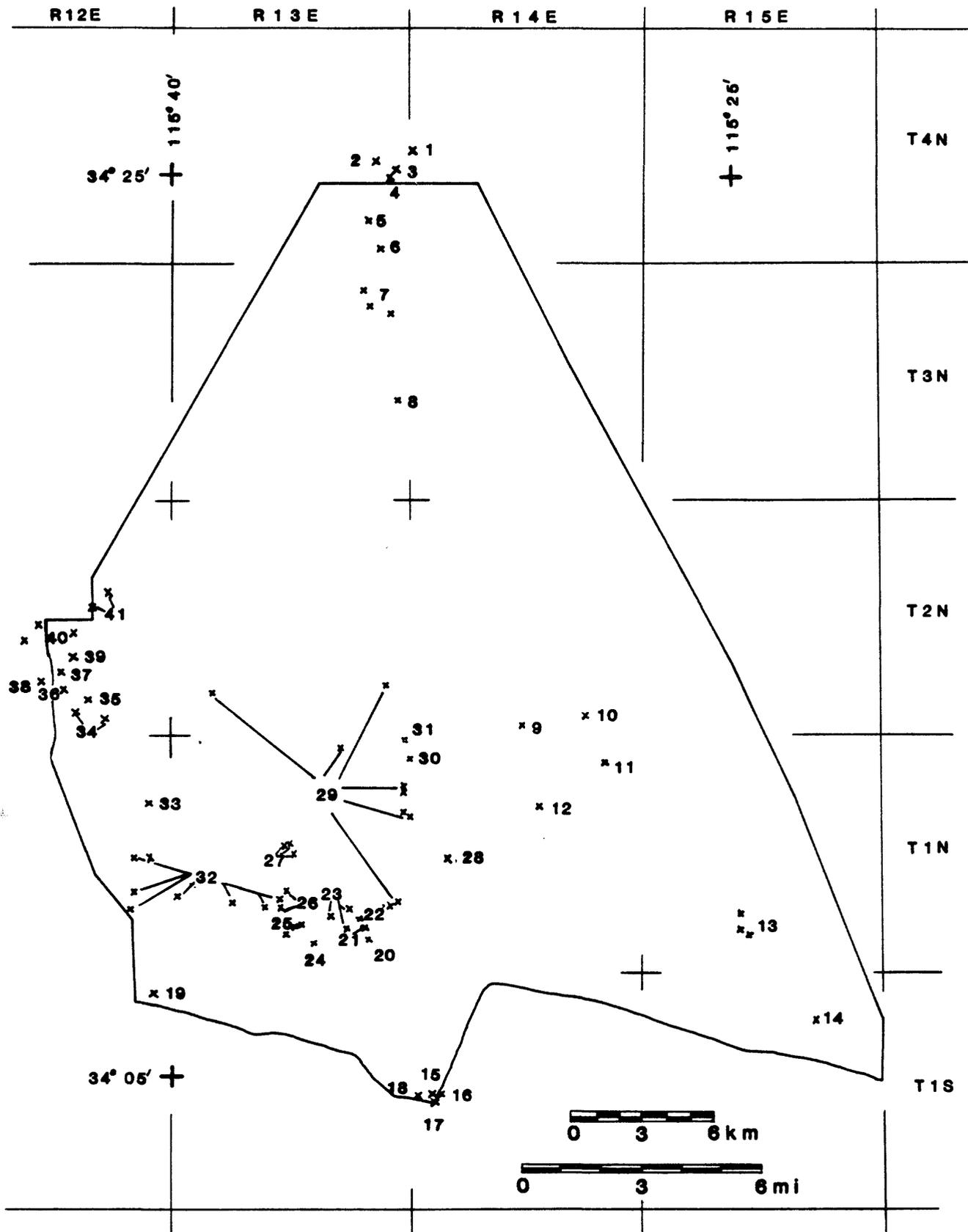


Figure 3. Mines, prospects, and mineral occurrences in the Sheep Hole-Cadiz Wilderness Study Area

Table 1.--Mines, prospects and mineral occurrences located in figure 3.

Map No.	Name	Workings	Resource Data
1.*	<u>Aljac Mine</u>	Inclined shaft with drifts, four sand filled shafts; three pits, arrastra, headframe and miscellaneous foundations	Quartz vein N 55°-70°E, 45°-50° SW, 680 ft long, in sericitically altered granitic rock; miscellaneous mineralized zones. Twenty-four samples: twenty contained a trace to 0.182 oz gold/ton; ten contained 0.2 to 0.4 oz silver/ton, one contained 0.66 oz silver/ton; copper ranged from 0.01 to 0.02 percent in ten samples. Subeconomic, identified resource - 65,000 tons containing 0.02 - 0.03 oz gold/ton.
2.	Prospect	One shaft and miscellaneous foundations	Shaft through overburden into rhyolite, metarhyolite and porphyroblastic metamorphic rocks. Three samples across dump: two contained 0.006 to 0.007 oz gold/ton; one contained 0.2 oz silver/ton.
3.	Mineral occurrences	Claim cairns in vicinity	Fault zone, N 85° E, 76° SE, with brecciated quartz and thin limonite-clay zone. One sample 0.2 oz silver/ton.
4.	Prospect	One pit	Seven ft mineralized shear, N 75° E, 72° SE, with quartz, specularite and limonite in porphyroblastic metamorphic rocks. Three samples: one contained 0.008 oz gold/ton.
5	Lucky Vein	Mineral location	Intersecting shears, N 3° E, 37° SE, and N 10° E, 74° SE, with quartz and chlorite in granitic gneiss. One sample contained 0.01 percent copper.
6.	Morgan Property	Three pits	Hornblende quartz diorite pendant intruded by quartz veins, N 40° E, 58° SE.
7.	<u>Sunshine-Alpha Area</u>	Six pits	Two sets of quartz veins - N 10° W, SW dip and N 45°-65° SW dip in granites of granodiorites. Nine samples: four contained a trace to 0.056 oz gold/ton; two contained 0.3 to 0.5 oz silver/ton; three contained 0.01 to 0.06 percent copper; four contained 0.01 to 0.08 percent lead; three contained from 0.02 to 0.15 percent zinc.
8.	Prospect	Two pits	Quartz vein and altered zone N 35° W, 72° NE. Four samples: one contained 0.006 oz gold/ton; one contained 0.2 oz silver/ton.
9.	Lost Weekend	Minor excavations	Alteration zone N 80° W, 61° NE.
10.	Mineral occurrence	None	Gossan zone in muscovite granite.
11.	Prospect	Minor excavations	Quartz vein N 30° W, 76° NE intruding amphibolite pod in granodiorite.
12.	Prospect	One pit	Irregular gossans in granitic terrain.
13.*	<u>Queens Gold (Black Granite)</u>	Six pits and one adit	Quartz vein N40°-60°E, 25°-43°SE in altered granite with granodiorite gneiss enclaves. Seventeen samples: ten contained a trace to 0.034 oz gold/ton; six contained 0.2 to 0.4 oz silver/ton; five of sixteen contained 0.003 to 0.011 percent uranium.
14.	Disclaim #1	Minor excavations	Broad, limonite-stained alteration zone N 40° W, 55° NE, with quartz and specularite veinlets. One sample: 0.4 oz silver/ton.
15.	Highee	Shallow shaft	On NE-trending gneiss to metaplutonic contact with secondary E-W and N 45° W shears. Two samples: one contained 0.008 oz gold/ton and 0.2 oz silver/ton; 0.01 and 0.06 percent copper and 0.01 percent zinc in both samples.
16.	M. Placer	One trench and a shallow shaft	Fine to coarse pebbly sand and silt with caliche layer. Two trench samples: one contained 0.000028 oz cu yd gold.
17.	Placer prospect	One large pit	Reddish, unconsolidated, fine sand with 0.5 ft caliche layer.
18.	Desert Rat Placer	Mineral location	Alternating aeolian sand and caliche layers.
19.*	Tuborg #8 Placer	Mineral location	Fine dune sand and silt. One reconnaissance placer sample: 0.000046 oz/cu yd gold.
20.*	Good Grief	Two pits	N 20° E, near vertical, friable, iron oxide stained zone at contact between granodiorite and foliated gneiss. One sample: 0.9 oz silver/ton and 5 ppm uranium.
21.	<u>Rainbow Rock Quarry</u>	Quarry	Micaeous, hematite stained quartzite; fractures into 1 to 4 in. thick slabs, 0.5 to 2 ft in diameter; suitable for use as decorative stone. Estimated 2,100 tons usable decorative stone and approximately 2,400 tons of decorative aggregate. Subeconomic.
22.*	Sheep Hole #1 and 2	Mineral location and minor excavations	Claimant has declined to answer inquiries for permission to examine the claims and publish the data.
23.	Quartz prospects	Minor excavations	N 20°-40° W, 45° NE to vertical, quartz veins to lenticular pods in granite, and granitic gneiss to metasediment contact zone. One E-W vertical pegmatite dike. Six samples: one contained 0.007 oz gold/ton; three contained 0.2-0.5 oz silver/ton; one contained 0.24 percent copper.
24.	Dunite	Miscellaneous excavations	N 20° W, 45° SW, lenticular quartz veins in chloritically altered gneiss.
25.	Wild Joker Iron	Two pits	Hornblende-epidote stringers and pods along N 10° E, vertical limestone-wollastonite beds in schistose to gneissic metasedimentary rock assemblage.
26.	Mineral occurrence	Minor excavations at two locations	Bedded schistose to gneissic metasediments with high epidote content. Two samples: 0.7 and 1.4 ppm silver; 16 and 150 ppm copper; 11 and 17 ppm lead; 26 and 34 ppm zinc; 11 ppm tungsten in one sample.

Table 1.--Mines, prospects and mineral occurrences located in figure 3 (continued).

Map No.	Name	Workings	Resource Data
27.	Stearman	Minor excavations at three	1) N 5° E, 60° NW, iron oxide stained shear in metasediments. 2) Limonite stained bedding shear N 74° W, 52° SW, in quartzite pendant. One sample: 0.35 percent copper. 3) Contact zone: medium-grained, hypabyssal intrusive and metasediments.
28.	Mineral occurrence	None	Limonite stained sericitic alteration zone 15 ft wide, N 65° E, 65° NW; quartz veinlets, hematite, limonite, pyrite in N 50° W, 49° SW joints.
29.	Dry Lake Placer Area	Six or more placer prospect pits	Granitic to gneissic cobbles, pebbles, sand, and silt in pediment, basin fill, and playa terrain. Sediments are coarse and poorly sorted on pediments; playas commonly consist of finely laminated silt. Five of thirteen samples contained wet recoverable gold in the range of 0.000012 to a 0.001142 oz/cu yd.
30.	"Pediment" prospect	Two pits	N 30° W, vertical, 0.5 ft limonite stained quartz pods in 3.0 ft sericite gouge approximately sericite gouge approximately 40 ft long. One sample: 0.3 oz silver/ton.
31.	"Pediment" Mine	One vertical shaft, one caved inclined shaft, one pit, miscellaneous bulldozed strips	Limonite-stained, brecciated shear zone in granitic country rock with calcite and manganese oxide coatings. Three samples: One sample contained 0.1 percent lead and 0.1 percent zinc.
32.*	Dale Lake Placer Area-JRM Placers	In excess of 65 backhoe and bulldozer pits	Granitic, schistose and gneissic floodwash sediments in pediment to basin fill environments. Materials become finer to the west. Southern portion of this basin covered by sand dunes. Four of fourteen samples contained gold ranging from 0.000005 to 0.000228 oz/cu yd.
33.	Prospect	Possible pit	Wide, bleached to iron-oxide stained, possibly displaced gouge zone N 40° W, 60° SW; possible exposure to Sheep Hole Fault. Two samples: trace gold and 0.001 percent mercury.
34.	<u>Sheep Watsnew-Withers</u>	Two pits, one drill hole	Hydrothermally-altered metasedimentary rock assemblage N 40°-70°W, 30°-70° SW, intruded by intermediate plutonic rocks. Uranium probably from late-stage magmatic solutions. Twenty samples: U ₃ O ₈ content ranged from 4 to 86 ppm and averaged 18 ppm.
35.	<u>Big Horn Mine</u>	Three adits, five inclined shafts, and several pits and trenches	N 45-65° W, 34-74° NE, hydrothermally altered and mineralized fault zone 2,500 ft long in schistose to gneissic metasedimentary assemblage intruded by granite, aplite, alaskite and pegmatite dikes. Thirty-six samples: four contained 0.012 to 0.162 oz gold/ton; twenty-two contained 0.2 to 0.8 oz silver/ton and one contained 1.4 oz silver/ton; copper, lead, and zinc ranged from 0.01 to 0.03 percent in six samples analyzed.
36.*	<u>Wagner Mine</u>	Three adits, one inclined shaft and five pits	N 20°-70° W, NE dipping quartz-pegmatite veins in moderately to severely sericitically altered granite; limonite after pyrite common. Thirty-four samples: one contained 0.19 oz gold/ton; twenty-three contained from 0.2 to 0.7 oz silver/ton. In fifteen samples analyzed for lead and zinc, eight contained 0.01 to 0.02 percent lead and fifteen contained 0.01 to 0.04 percent zinc.
37.	<u>Sheep Hole Mine</u>	Five inclined shafts, nine adits, one tunnel drift, five trenches, and 14 pits	N 45° W, 40°-75° NE, mineralized quartz veins along faults in quartz monzonite to granodiorite. Eighty samples: sixty-eight contained trace to 0.351 oz/ton gold; forty-one contained 0.2 to 1.6 oz/ton silver; several contained minor copper, lead, zinc and arsenic. Subeconomic identified gold resource estimated to be 165,000 tons containing 0.01 oz/ton.
38.	Meadow	One declined adit and one prospect pit	N 45° W, 23-47° NE, hydrothermally altered gouge zone; approximately 780 ft outcrop. Four samples: three contained 0.011 to 0.050 oz gold/ton; two contained 0.2 to 0.27 oz silver/ton; one sample contained 0.08 percent zinc and 0.03 percent arsenic.
39.	Boney	One pit	N 84° W, 67-74° SW, iron-oxide stained alteration zone 140 ft long in porphyritic quartz monzonite. Two samples: one contained 0.8 ppm silver and 6 ppm copper.
40.*	Green Scorpion Group	Five lode pits and one shallow inclined shaft; several small placer pits	Several quartz veins and pegmatite dikes with northwest strike and northeast dip in granodiorite-granite terrane. Twelve lode and ten placer samples: one contained 0.03 ppm gold; nine ranged from 0.0001 to 0.7 oz/ton silver; several contained small amounts of copper, lead, zinc, manganese, tungsten. Those samples analyzed for U ₃ O ₈ ranged from 3 to 71 ppm.
41.	Lost Sheep Gold	One shallow shaft, four pits and minor excavations	Quartz veins, N 26°-83° W, 25-70° NE, in porphyritic granite, commonly with large limonite after pyrite and intense sericitic alteration; some comb quartz and large, brown calcite crystals along walls. Fourteen samples: one sample contained trace gold; four contained 0.2 to 0.6 oz silver/ton; three ranged from 0.01 to 0.02 percent zinc and 0.01 to 0.05 percent arsenic. Specimen collecting area.

* actively held claims or leases
 underlined properties are considered to have resource potential.

Calcium, sodium, lithium, and strontium occur in the large playas adjacent to the study area. Brines rich in calcium and sodium chlorides are currently being produced from shallow wells drilled into the playas of Bristol and Cadiz Lakes, and sodium sulfate brines (and surface layers of thenardite-- Na_2SO_4) formerly were produced from the playa of Dale Lake. Milling operations for current production are located in Amboy and Saltus, California.

The Conservation Division of the U.S. Geological Survey (1981b) considered lands contiguous to these lakes, including portions of the study area, to be prospectively valuable for sodium. Vertical Electrical Sounding resistivity surveys (Hoover, 1982) suggest the presence of high-conductance layers at depth within the study area along the boundaries of all three saline lakes. The extent to which these may represent clay layers or deep crystalline salt horizons is unknown. However, the survey results suggest that substantial quantities of brines similar in character to those of the adjacent saline lakes are present at depth in basinal areas within the wilderness study area (fig. 4, B-1, B-2, B-3). The easiest production of such brines is likely to be by pumping from the playas outside the study area. Most of the wilderness study area is elevated with respect to the dry lakes and is less favorable for pumping and development of evaporating ponds. Therefore, while the brine resources discussed here probably exist within the wilderness study area, any production of these brines most probably would occur from locations outside the area. Layers of crystalline salt and layers containing strontium or lithium could exist in any of the areas identified to have potential for saline brines.

Area B-1--The companies operating on Cadiz Lake pump calcium chloride from a production zone at a depth averaging 200 ft (60 m) from at least 10 wells, and concentrate the brines at five evaporation pond complexes. One operator produces 1,000 to 1,250 tons (900 to 1,130 t) per month of calcium chloride brine with a specific gravity of 1.6 (Calzia, and others, 1979). Based on drill hole data, Calzia and others (1979) determined that a near-surface, 3 ft to 12 ft (0.9 to 3.7 m) thick, massive, crystalline salt bed exists at Cadiz Lake. The resource is calculated as ranging from 31,000,000 to 112,500,000 tons (28,000,000 to 102,000,000 t) of salt, assuming the composition of the bed is 100 percent NaCl with a density of 134.7 lbs/cu ft (2.2 g/cu cm). Water quality data from several wells on Cadiz Lake (Calzia and Moore, 1980) indicate high calcium and sodium values and anomalous concentrations of lithium and strontium in the brines. Uranium concentrations are too low to be of economic interest at this time (Calzia and Luken, 1981, p. 12).

The wilderness study area includes a small, nonproducing portion of Cadiz Lake. Commercial brines are not likely to occur near the surface in this portion or elsewhere within the eastern side of the study area, as indicated by two factors: (1) a fresh-water well 300 ft (91 m) deep in sec. 20, T.3N, R.15E. on Cadiz Lake, and (2) decreasing values of calcium, sodium, and potassium in Cadiz Lake brines away from the near-surface salt beds, which lie outside the wilderness study area. However brines are inferred at depth within the wilderness study area based on the geophysical data.

In estimating the areal extent of this resource in the Sheep Hole-Cadiz Wilderness Study Area, criteria were established and using these criteria, area B-1 (fig. 4) was derived. The criteria were based on gravity, magnetic, and geoelectrical (vertical electrical sounding, and audio-magnetotelluric)

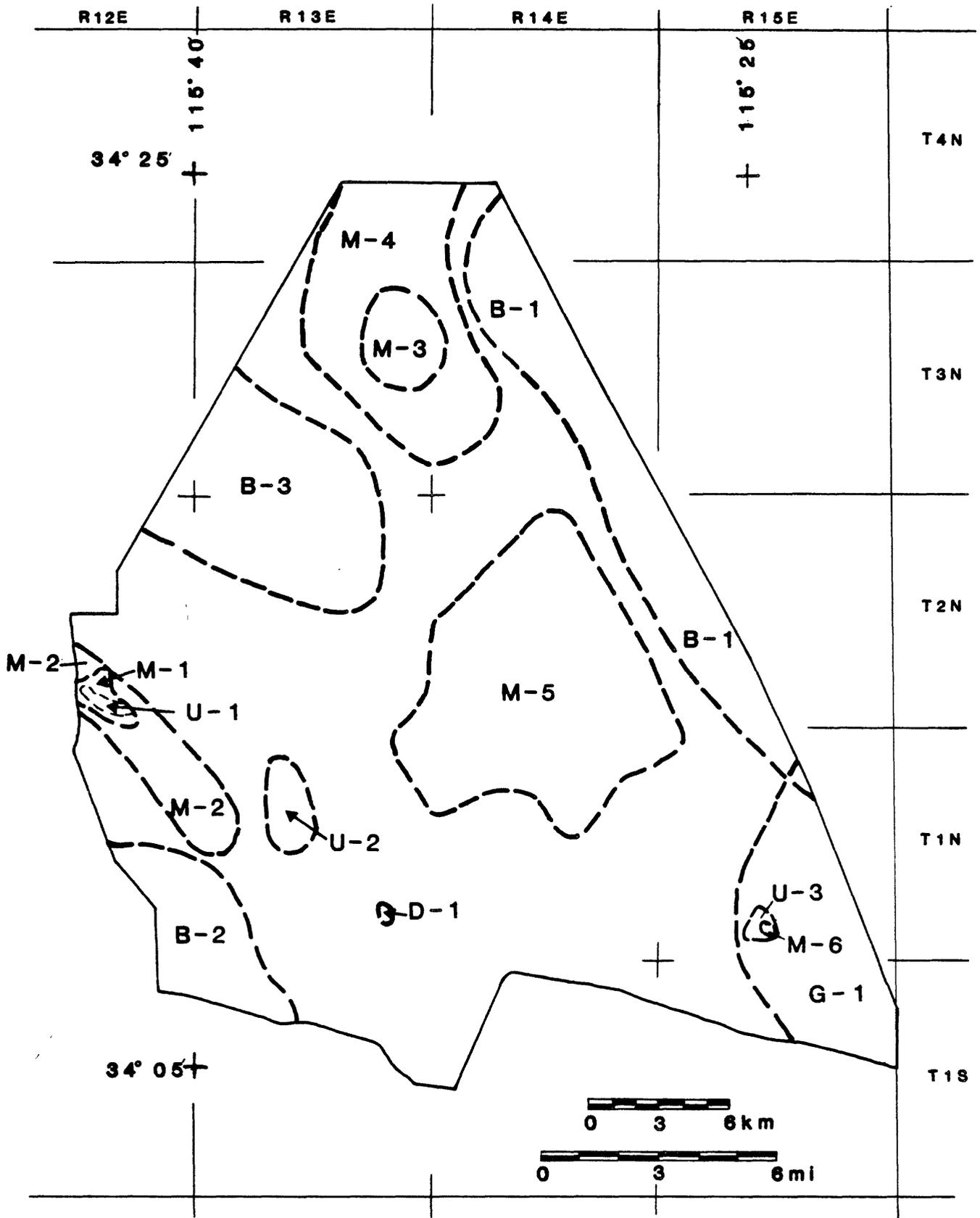


Figure 4. Mineral-resource potential map of the Sheep Hole-Cadiz Wilderness Study Area

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Hypothetical	Speculative
	Measured	Indicated		Resources more likely to be present.	Resources less likely to be present.
	Size, shape, depth and mineral content of the resource are well established.	Size & grade of resource is established with less assurance than for "measured".	Assumed continuity beyond reserve base for which there is geologic evidence.	Geologic conditions similar to producing mineral bodies in the same district or region.	Geologic setting is favorable for deposits.
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Figure 5. Classification of resources (after U.S. Bureau of Mines and U.S. Geological Survey, 1980)

studies. The results of these studies show that sedimentary fill exceeds 1000 ft (300 m) thick and contains thick zone(s) of extremely low electrical resistivity (1/2 to 1 ohm-meter). The zones are estimated to be 590 ft (180 m) deep in the north to 2950 ft (900 m) deep on the south. The low resistivity extends throughout area B-1 and continues eastward into the Cadiz Lake playa. The resistivity values and their spatial distribution are interpreted to result from the presence of porous sediments saturated by highly saline (on the order of 250,000 ppm total dissolved solids) brines. The composition of such brines is presumed to be similar to those currently produced from Cadiz Lake playa and, therefore, they probably contain resources of calcium and sodium chlorides as well as lithium and strontium. Crystalline salt layers may also persist from beneath the playa into area B-1. Area B-1 is considered to be an inferred resource as defined by the U.S. Bureau of Mines and U.S. Geological Survey (fig. 4).

Area B-2--Wright and others (1953, p. 220) cite the average composition of the deposits in Dale Lake as 60 percent Na_2SO_4 , 30 percent NaCl , and 10 percent insoluble constituents, and the brines as 7.5 to 8.0 percent Na_2SO_4 and 20.0 to 22.0 percent NaCl . Besides a surface thenardite deposit, borings have disclosed two buried zones, a 30 ft (9 m) zone beginning at depths of 20 to 40 ft (6 to 12 m), and a 100 ft (30 m) zone beginning at about 120 ft (37 m) deep. Lithium analyses at five-foot intervals in a test well (J. P. Calzia, personal communication, 1981) ranged from 5 to 178 ppm. The southeast corner of the playa is included in a tract classified as "lands valuable (known) for sodium" by the Conservation Division of the U.S. Geological Survey (1981b). Based on an estimated density of 136 lbs per cu ft (2.2 g/cu cm) and the given thickness of deposits, Calzia and others (1979, p. 146) calculated the indicated sodium resources of the known valuable area as 21,300,000 tons (19,300,000 t) and 71,700,000 tons (65,000,000 t) within the upper and lower zones, respectively. Seismic evidence (Simpson and others, 1982) indicates the basin is 5,000 to 6,000 ft (1,500 to 1,800 m) deep and elongated in an east-west direction; the deepest point is below the east end of the playa. The inferred areal extent of the Dale Lake brine deposits in the southwestern part of the Sheep Hole-Cadiz Wilderness Study Area is shown as area B-2 (fig. 4).

The criteria for establishing area B-2 are gravity, magnetic, and geo-electrical studies which show that sedimentary fill exceeds 1000 ft (300 m) in thickness and contains thick zones (250 to 450 ft) (76 to 120 m) having extremely low electrical resistivity (1/2 to 1 ohm-meter), which continue westward and southward into Dale Lake playa. These data are interpreted to result from the presence of porous sediment saturated by highly saline brines. Such brines are presumed compositionally similar to the thenardite- plus halite-bearing brines previously produced from Dale Lake playa. Lithium may also be present in the sediments within B-2. Area B-2 is considered to be an inferred resource.

Area B-3--Bristol Lake brines are rich in calcium and sodium and, as Durrell (1953, p. 9) noted, contain sufficient strontium on the west side to precipitate celestite (SrSO_4) concretions. Various salt beds have been reported at depth in even the deepest test wells (1,007 ft--307 m--Bassett and others, 1959). Calzia and others (1979, p. 124) have estimated the indicated surface and near-surface salt resources as 26,100,000 tons (23,700,000 t) at 75 percent NaCl .

In estimating the areal extent of the Bristol Lake brines in the northwestern part of the Sheep Hole-Cadiz Wilderness Study Area area B-3 (fig. 4) was derived. The criteria for establishing area B-3 are gravity, magnetic, and geoelectrical (vertical electrical sounding and audio-magnetotelluric) data that reveal a basin in which sedimentary fill is at least 1000 ft (300 m) thick and contains a thick zone (up to 1100 ft) (335 m) having low electrical resistivity (10 ohm-meter) along its northern margin. The presence of saline brines is strongly suspected. Near-surface sediments in this basin are probably continuous with sediments in the Bristol Lake basin; however, deeper sediments may be separated from the Bristol Lake basin by a buried basement ridge. Chemistry of the suspected brines is presumed similar to the sodium and calcium chloride and strontium-bearing brines of Bristol Lake playa. Area B-3 is considered to be a hypothetical resource.

Base and Precious Metals

Many of the mines, prospects, and areas of mineralized rock in the study area are associated with contact zones of the Cadiz Valley batholith of Cretaceous age where it intrudes Proterozoic, Paleozoic, and Jurassic meta-igneous and metasedimentary rocks. The mineralized zones are characterized as fissure-filling quartz veins containing pyrite, calcite, barite, manganese minerals, minor gold and silver, and traces of chalcopyrite, chrysocolla, malachite, galena, sphalerite, and molybdenite, although not all are present at all localities. Alteration nearest the vein is predominantly phyllic with subordinate argillic zones; pyrite is commonly weathered to limonite. Mineralized zones are structurally controlled by joints, shears, and faults along the boundaries of plutonic rocks, and by local shears and bedding planes intruded by dikes within older basement rocks; the predominant trend of these structures is northwesterly.

Six areas (fig. 3, M-1, M-2, M-3, M-4, M-5, M-6) in the Sheep Hole-Cadiz Wilderness Study Area are considered to have potential for base and precious metals. Five of these areas are associated with or are proposed extensions of known mining or prospected areas. A sixth area in the south Calumet Mountains (fig. 4, M-5) is a previously unknown mineralized area that may have potential.

Area M-1--The Sheep Hole Mine and Big Horn-Wagner properties lie in a resource area designated M-1 (fig. 4).

The Sheep Hole Mine (fig. 3 and table 1, no. 37) has been intermittently claimed and operated since 1917 but is not known to be actively held at this time. Thirty-four workings, an old arrastra, millsite foundations, and several other abandoned facilities are on the property. Workings consist of nine adits totaling 270 ft (82 m), five shafts, a 47 ft (14 m) tunnel, five trenches totaling 413 ft (126 m), and fourteen pits. Most of the workings are along two prominent, northwest-striking, northeast-dipping mineralized fault zones. The mineralization consists of massive to sheared, milky white quartz veins with limonite after pyrite, limonite and hematite staining, minor sphalerite and chalcopyrite, and occasional galena and magnetite. Thin-section and polished section observations indicate that chalcopyrite and galena crystallized first followed by pyrite and finally sphalerite. Sericitic alteration is present throughout the mineralized zones, in country rock proximal to the faults, and along some joints. Chloritic and minor argillic alteration and interfingering earthy limonite layers are also found in gouge zones along the

main faults. Several small quartz veins, similar to those found in the main fault zone, occur along joints and minor shear zones. No widespread limonitic alteration was detected in this area but samples of the chloritic and argillic (propylitic?) alteration indicate a base metal suite of copper, lead, zinc, and silver mineralization.

Of 80 samples taken on the property, gold ranged from trace to 0.351 oz/ton (12.03 g/t) in 68 samples, silver ranged from 0.2 to 1.6 oz/ton (6.9 to 54.9 g/t) in 41 samples, and several contained low levels of copper, lead, zinc, and arsenic. Exposures of the mineralized zones can be traced for 2,100 ft (640 m) along strike with 330 ft (100 m) of relief. Subeconomic indicated and inferred resources of approximately 165,000 tons (150,000 t) are calculated, at an average grade of 0.01 oz gold per ton (0.34 g/t). This property is considered to have potential for relatively small, high-grade gold and silver deposits.

The history of development of the Big Horn-Wagner properties (fig. 3, and table 1, nos. 35 and 36) is not known. The Big Horn Mine was not actively held at the time it was examined, but the Wagner Nos. 1-3 claims were held by Mr. and Mrs. Coddling. Workings on the Big Horn consist of three adits totaling 441 ft (134 m), four shafts totaling 82 ft (25 m), two trenches, and five pits. Three adits totaling 100 ft (30 m), one 18 ft (5 m) inclined shaft, and five pits are developed on the Wagner Nos. 1-3. Both mines are on a mineralized fault zone which strikes N 45°-65° W, and dips 34°-74° NE. The fault zone consists of friable to silicified limonite-stained clay and sericite gouge associated with veinlets and brecciated veins of quartz up to 5 ft (1.5 m) thick. The zone can be traced for approximately 3,800 ft (1,160 m) along strike. At the Big Horn property, the same structure occurs in a transitional contact zone between schistose to gneissic metasedimentary rocks and intrusive granodiorite associated with ptgymatically folded aplite, alaskite, and pegmatite dikes. On the Wagner Nos. 1-3, to the northwest, the fault cuts only porphyritic granodiorite and appears to feather or horsetail and die out. Slickensides at this locality indicate the latest movement was vertical.

Of 70 lode samples taken from the properties, five contained 0.012 to 0.19 oz gold/ton (0.41 to 6.5 g/t) and 46 contained 0.2 to 1.4 oz silver/ton (6.9 to 48.0 g/t). Low levels of lead and zinc were also detected. Semi-quantitative spectrographic analyses of the lode samples reveal pervasive, low levels of copper and persistent, anomalous molybdenum values, both of which decrease northwesterly. The Big Horn and Wagner properties are currently classified as subeconomic; however, there is potential for discovery of small gold and silver vein deposits. There is also speculative potential for porphyry molybdenum.

The Big Horn and Wagner mines occur in a limonitic zone, characterized by argillic alteration interpreted as resulting from hydrothermal alteration and mineralization along the mineralized fault. Many of the concentrate samples are weakly anomalous in bismuth, molybdenum, beryllium, tin, and tungsten suggesting a magmatic mineral suite commonly associated with porphyry molybdenum type deposits. A large limonitic zone is identified in this area from LANDSAT images, and rock samples indicate a suite of molybdenum, copper, and silver with minor bismuth. Limonitic coatings obtained from concentrate samples from the along the front of the range downstream from Sheep-Watsnew-Withers group of claims area are also anomalous in molybdenum, copper, and

silver. The trace element suites from these areas suggest two mineralizing events, one associated with the magmatic suite of molybdenum, bismuth, beryllium, tin, and tungsten, and a later one associated with base metals, copper, lead, zinc, and silver.

Minor gold and silver along the contact between the Cadiz Valley batholith and older basement rocks at the Big Horn and Wagner Mines (fig. 3 and table 1, nos. 35 and 36) contrast with a varying amount or absence of such elements at mines progressively farther away from the contact (Sheep Hole, Boney, Green Scorpion, and Lost Sheep Gold properties--fig. 3 and table 1, nos. 37, 39, 40, and 41). Molybdenum and bismuth are present in highly anomalous amounts in rock samples collected from the Big Horn-Wagner area with lesser amounts of beryllium and trace amounts of tungsten. Although these concentrations may represent contact phenomena, this elemental suite is present, with tin, in concentrate samples throughout the Sheep Hole Mountains (Marsh and Raines, 1982) and may be the result of a mineralizing feature of the Cadiz Valley batholith and (or) Jurassic porphyritic granite. This geochemical suite is suggestive of porphyry molybdenum mineralization although no definitive indications of this type of mineralization were seen in this study.

Several criteria were used to define the areal extent of area M-1 (fig. 4). The criteria were (1) several old mines including The Big Horn-Wagner properties and the Sheep Hole Mine having probable past production and known to contain values in gold, silver, lead and zinc; (2) argillic and sericitic alteration occurring in the vicinity of mineralized structures; (3) anomalous values of silver and copper detected in the nonmagnetic fraction of panned concentrates from stream sediments; and (4) geologic terrane favorable for base and precious metal mineralization along faults cutting metasedimentary rocks intruded by the Cadiz Valley batholith. Area M-1 is classified as a subeconomic indicated and inferred resource for precious metals and is considered to have potential as a speculative resource of molybdenum.

Area M-2--This area (fig. 4) is an extension of area M-1 and although no mines exist within the area and no known mineral deposits are present, several criteria define M-2. The criteria used were a continuation of the same favorable geologic environment (Sheep Hole fault system, contact of granodiorite with country rock) and the presence of slightly anomalous values of barium, silver and copper detected in the nonmagnetic fraction of panned concentrates from stream sediments. Minor mineralization in older Quaternary alluvium exposed at an unnamed prospect (fig. 3, no. 33) is evidence of recent hydrothermal activity. Area M-2 is considered as a hypothetical resource of base and precious metals.

Area M-3--Area M-3 (fig. 4) contains the Sunshine-Alpha prospects (fig. 3 and table 1, no. 7), which consist of six pits within a one sq mi (2.6 sq km) area. Country rock is characterized as a gray to buff colored, moderately weathered, two-mica granite to granodiorite of the Cadiz Valley batholith. The pits expose two sets of mineralized quartz-pegmatite veins and lenticular quartz pods, oriented N 10° W, 47°-60° SW and N 40°-60° W, 45°-88° SW, found in the area. The latter set crosscuts a N 10° W, 85° SW set of aplite dikes. Several dacite dikes of Tertiary age intrude the country rock. Quartz vein mineralization consists of pyrite, limonite after pyrite, and minor chalcopyrite altering to red limonite, chrysocolla and malachite. Intense sericite-muscovite wallrock alteration, as well as moderate limonite, is commonly

associated with the quartz veins. Many of the quartz veins are brecciated and recemented. Based on strike directions and cross-cutting relationships, there is evidence in the Sunshine-Alpha area of at least two episodes of mineralization; the presence of Tertiary dacite dikes in the area suggest the possibility that the latest may be associated with them.

Four of nine chip or grab samples of quartz veins ranged from trace to 0.056 oz gold/ton (1.92 g/t) and two contained 0.3 and 0.5 oz silver/ton (10.3 and 17.1 g/t), while some samples contained minor amounts of copper, lead, and zinc. The nine rock samples of quartz veins were analyzed by a semiquantitative spectrographic technique (Grimes and Marranzino, 1968) and highly anomalous amounts of silver, beryllium, bismuth, copper, and molybdenum were found with minor amounts of lead, zinc, and tungsten. This assemblage of elements apparently represents two suites: (1) a base metal suite of copper, lead, zinc, and silver, and (2) a magmatic suite of beryllium, bismuth, molybdenum, and tungsten which is commonly associated with porphyry molybdenum systems. Semiquantitative spectrographic analysis of non-magnetic heavy mineral fractions of panned concentrates of stream sediments indicate above background values for molybdenum, barium (as barite), and strontium.

In defining the areal extent of M-3 several criteria were used: (1) the presence of peraluminous granite to granodiorite of the Cadiz Valley batholith injected by quartz and pegmatite veins associated with intense sericite-muscovite alteration and local limonitic staining, (2) intrusion by dacite dikes possibly associated with quartz veins, (3) stockwork veins that contain gold, silver, copper, lead and zinc as well as highly anomalous concentrations of molybdenum (10 to 1500 ppm) and bismuth (50 to 5000 ppm), and (4) the nonmagnetic fractions of panned concentrates from stream sediments contain high molybdenum and barium and selected rock samples are highly anomalous in silver, bismuth, beryllium, copper and molybdenum. Area M-3 is considered to have potential for small-tonnage gold deposits, and is classed as a hypothetical resource of gold. Although conclusive data are lacking, the rock type, mineralization, and alteration characteristics in area M-3 resemble those described by Westra and Keith (1981) for molybdenum stockwork deposits associated with calc-alkaline magma systems. Area M-3 is considered to have potential as a speculative resource for molybdenum.

Area M-4--Area M-4 surrounds area M-3 and represents a less well defined extension of the mineralization found in M-3. The Aljac Mine (previously known as the Calmont or Calumet Mine, fig. 3 and table 1, No. 1) lies on an extension of area M-4 and lies approximately one mile (1.7 km) north of the boundary of the wilderness study area. The mine is currently held by John Cooley and Al Mendel, Jr., who are improving access and evaluating mineralized zones. The main working consists of a 150 ft (46 m) inclined shaft with 140 ft (43 m) of drift on a prominent, 1 to 1.3 ft (0.3 to 0.4 m)-wide, 680 ft (207 m)-long mineralized quartz vein oriented N 55°-80° W, dipping 45°-50° SW. Other developments on the property include three sand-filled shafts, four pits, several foundations, and the remains of a 48 in. (122 cm) diameter arrastra. The vein is milky white quartz and contains gold, pyrite, and sphalerite; limonite banding and sparse chrysocolla and manganese oxide encrustations are found in the alteration zone. Wide bands of intensely sericitized and slightly chloritized country rock border the quartz vein.

Twenty of twenty-four samples contained trace to 0.182 oz gold/ton (6.24 g/t). Based on an average width of 3.3 ft (1.0 m) for seventeen samples and a minimum depth of 160 ft (49 m), it is estimated that the main structure contains an indicated plus inferred subeconomic resource of 65,000 tons (59,000 t) containing 0.02 to 0.03 oz gold/ton (0.69 to 1.03 g/t). Sampling of other structures (fig. 3 and table 1, Nos. 2-4) exposed on the property indicates potential for hypothetical resources of vein gold deposits.

The areal extent of M-4 was determined using the following criteria; (1) country rocks and geologic environment similar to that of area M-3 and (2) anomalous barium and molybdenum in the nonmagnetic fraction of panned concentrates from stream sediments. Area M-4 is considered a speculative resource for potential base- and precious-metal vein deposits.

Area M-5--A large (approximately 35 sq miles--90 sq km) area of iron-metasomatic hydrothermal alteration was identified in the south Calumet Mountains (M-5, fig. 4). The term iron metasomatism is used in the context of Goldschmidt (1922), Mason (1966), and Gary and others (1972) and is defined as incipient alteration that is indicative of the past presence of interstitial, chemically active pore liquids or gases contained within the rock body or introduced from external sources. Critical minerals are limonite and(or) local pyrite coatings with anomalous trace elements. In area M-5 the term iron metasomatism is used to describe rocks with limonitic and occasional pyritic coatings along horizontal joints in a two-mica granite. Sediment sampling suggests these coatings contain anomalous trace elements, and may represent fluids residual from the formation of the granite; the coatings are considered indicative of potential mineralization in the area.

Stream sediment and concentrate sampling in the area show an increase in rare earth content (lanthanum, yttrium, and thorium) and a decrease in the molybdenum, bismuth, tin, tungsten, beryllium suite going from the granitic rocks of the Sheep Hole Mountains to the granitic rocks of Calumet Mountains. This is consistent with the increasingly silicic character of the granitic rocks going eastward from the Sheep Hole Mountains to the granitic rocks of the Calumet Mountains.

Granite in area M-5 is stained with iron oxides. Field reconnaissance and geochemical results indicate that the iron oxides were not generated from the weathering of mafic minerals, that they seem to be related to only one of the three joint systems in the area (strike N 50°-70° W, dipping 18° S), and that rocks containing them are weakly anomalous in silver, lead, and barium. To further investigate and define this area iron and manganese oxides were analyzed to see if they contained anomalous concentrations of metals adsorbed by these compounds. The intermediate magnetic fraction of the concentrate samples was used for this investigation as this fraction contained adsorbed iron and manganese oxides on sediment from the representative drainage basins. The iron and manganese oxides were dissolved from the samples using hot aqua regia and were analyzed using the induction coupled plasma spectrograph (Church, 1981, Church and others, 1982). The results from this investigation revealed anomalously high amounts of arsenic, bismuth, cerium, lanthanum and molybdenum with minor amounts of copper, lead, zinc, and silver. It appears that although the suite of molybdenum, bismuth, tin, tungsten, and beryllium is not evident as discrete minerals in the non-magnetic fraction of the concentrates from this limonitic zone, it is in places present with base

metals and rare earths in the iron and manganese oxide fraction and may represent leakage of mineralization from depth. Several major NNW-trending faults that cut the area possibly provided a conduit system for the observed mineralization. The suite of elements seen in the samples is a common one found in most two-mica granites. The suite is, however, enhanced in concentration here and may represent concentrations of metals related to a mineralizing system. Some of the possible systems are base-metal veins, porphyry molybdenum, skarn, or tin granite.

The area roughly coincides with an aeromagnetic low and quiet area part of which is coincident with a gravity low over exposed granitic basement. This configuration possibly could be caused by hydrothermal alteration of a substantial thickness of material. An audio-magnetotelluric (AMT) sounding on the west side of the area revealed low resistivity (100 ohm-meter), which may indicate alteration, to depths near 3000 ft (1 km). An aeroradiometric anomaly in uranium is observed in the north-central part of area M-5 (J. K. Otton, written commun., 1981).

The principle criterion used in delineating area M-5 (fig. 4) is the large limonitic area identified on the LANDSAT imagery. Other criteria are the interpretation as alteration by iron metasomatism, a roughly coincident aeromagnetic low, a single sounding indicating low resistivities, and geochemical data from stream sediments and panned concentrates from stream sediments. The existence or type of deposit represented cannot be determined from the available evidence, and the area is classified tentatively as a speculative resource. The confidence that mineral deposits occur is low.

Area M-6--An area of prospects in the southern portion of the south Calumet Mountains (fig. 3 and table 1, no. 13) contains the Black Granite Claims located in 1955, the Golden Cross Group located in 1973, and the Queens Gold Group, located in 1980 (Area M-6, fig. 4). The terrane is low hills and pediment exposing weathered granite and numerous contained enclaves of dark granodiorite gneiss, in or near a suspected fault zone. The granite is in places slightly to intensely sericitized to argillized, with or without associated quartz veins. The workings include a 20-ft (6-m) adit developed on a northeast-trending quartz vein system, and small pits in altered granite and granodiorite gneiss. Of seventeen samples taken from the workings, 10 contained a trace to 0.034 oz gold/ton and 6 contained 0.2 to 0.4 oz silver/ton. No copper was detected in 11 samples analyzed. The main northeast-trending quartz vein is 185 ft long and averages 2.4 ft thick at less than 0.01 oz gold/ton--too small for a resource calculation. The presence of gold in altered granite, and in limonite-altered gneiss enclaves near the quartz vein system, suggests the possibility that the gold is part of a disseminated system. There is no apparent potential for silver or copper. The area is considered to have low to moderate potential as a hypothetical vein gold and speculative disseminated gold resource (fig. 4, area M-6).

Placer gold--Sixty-eight reconnaissance and trench placer samples were taken from the Sheep Hole-Cadiz Wilderness Study Area. Gold in amounts as high as 0.001 oz/cu yd (0.0002 to 0.0464 g/cu m) was recovered from eighteen of the samples. Fourteen of these sites are in deposits derived from the Sheep Hole Mountains, two are in deposits probably originating in the Pinto Mountains, and two are in deposits derived from the west-central Calumet Mountains. Factors which tend to inhibit recovery of placer gold in the study area in-

clude its small particle size, spotty occurrence, low grade, and the presence of moisture (which precludes the use of dry placer recovery methods). Based on this limited study, placer gold has very low or else no apparent potential as a resource.

Skarn tungsten--The local presence of carbonate-bearing metasedimentary rocks intruded by silicic granitoid bodies of the Cadiz Valley batholith in the central and northern Sheep Hole Mountains and the presence of anomalous tungsten in the nonmagnetic fraction of panned concentrates from stream sediments suggests a potential for skarns with small or poorly exposed concentrations of tungsten. Of the 30 concentrate samples collected from this area, 17 contained from 10-300 ppm tungsten. Tungsten was also detected in several of the workings in the northern Sheep Hole Mountains. Although no skarns were mapped in this study, evidence suggests that skarns may exist in the central and northern Sheep Hole Mountains. The potential does not warrant classification as a tungsten resource.

Portions of the alluvial area surrounding and within the Sheep Hole Mountains are considered to have very low potential for economic concentrations of placer scheelite (tungsten). Placer accumulations of tungsten have not been demonstrated to exist in the area; however, sediments occurring down from any contact metamorphic tungsten deposits have some slight chance of containing deposits of tungsten.

Rock Products

Voluminous deposits of common borrow, sand and gravel including quartz dune sand are present in the study area. Because of the low bulk value of the commodity and the high transportation costs involved in shipping to distant market areas, there is no apparent potential for development of these deposits in the foreseeable future other than for small local uses.

Area D-1--A small source of decorative stone, named the Rainbow Rock Quarry, was developed in the 1950's or early 1960's on the east slope of the central Sheep Hole Mountains (sec. 26, T. 1 N., R. 13 E.), (fig. 3 and table 1, no. 21; fig. 4). Developments consist of a loading ramp, a structure foundation, a staging and turn-around area, and two mine haulage roads cut across the west facing dip-slope of the deposit. The source of the stone is a roughly rectangular body 100 ft (30 m) long with a wedge shaped cross-section 8 ft (2.4 m) thick at its thickest point. It is composed of a foliated, meta-quartzite enclave or roof pendant with foliation oriented N 45° W, 40° SW. Well defined, subparallel, micaceous partings at one to three inch (2.5 to 7.6 cm) intervals, allow the rock to be ripped or split into tabular, polygonal plates suitable for use as decorative veneer. Based on field surveys, a specific gravity of 2.55, and an estimated useability factor of 60 percent, the net measured decorative stone resource is calculated to be 2,100 tons (1,900 t) with a coverage factor of 72 sq ft/ton (7.4 sq m/t) for 2 in. (5 cm) thick stone. An additional 2,400 tons (2,200 t) have potential as crushed decorative aggregate. The deposit is small and is far from any known market, rendering the product subeconomic. However, the resource may be suitable for a single large project such as a commercial or public building, and is therefore considered to have potential. It is classed as a subeconomic measured resource.

Geothermal Resources

The Sheep Hole-Cadiz Wilderness Study Area is located astride the boundary between the Mojave and Sonoran tectonic blocks (Fuis, 1981). The origin of the tectonic boundary is unknown, but its existence is indicated by a north-northwest trending asymmetric ridge on the mantle (Fuis, 1981), an eastward decrease in seismicity (Allen and others, 1965), and an eastward increase of crustal heat-flow (Lachenbruch and others, 1978).

Preliminary interpretation of U.S.G.S. heat-flow data obtained in 1977 and 1979 over the Mojave Desert region indicates a north-northwest trending region of moderate to high heat-flow (about 100 mw/m^2) that includes Cadiz Valley and the eastern portion of the study area (P. S. Galanis, written commun., 1982). No surface manifestations of geothermal activity are known in the study area except in older Quarternary alluvium at an un-named prospect (fig. 3 and table 1, no. 33) on the Sheep Hole fault where hydrothermal activity is indicated by minor mineralization in Quaternary alluvium. Further, the U.S.G.S. data do not allow a detailed evaluation of the geothermal resource, both because the data points are widely spaced (about 30 km), and because of the effects of complex hydrology. These hydrologic effects are reflected by differences of heat flux as great as 100 mw/m^2 in sites 25 km apart. Geothermal potential throughout the region of the wilderness study area is supported by regional heat flow values.

Area G-1--In 1981, several shallow geothermal gradient holes were drilled in and near the study area by the Geothermal Division of Phillips Petroleum. According to Phillips-Geothermal, this exploration was followed by a second phase of confirmation drilling in two areas pertinent to the Sheep Hole-Cadiz Wilderness Study Area: 1) between Dale Lake and the Sheep Hole Mountains, and 2) along the southwest side of Cadiz Valley. Lease applications were filed by Phillips-Geothermal in June 1981, for lands along the southwest side of Cadiz Valley; evidence motivating the second phase of drilling and data from completed holes is held in confidence. As of September, 1982, industry activity in the area has ceased. Criteria used for establishing area G-1 (fig. 4) were the fact that the area is being evaluated by and is under lease application by a major geothermal exploration company and that the area is within a large north-south trending zone of high but variable heat flow, as determined by the U.S.G.S. during ongoing regional studies of heat flow. Based on the above criteria the area within the Sheep Hole-Cadiz Wilderness Study Area along the southwest side of Cadiz Valley is considered as a speculative resource for geothermal resources of undetermined potential. A low-temperature hydrothermal convection system, if present, might be suited for direct applications in space heating, agriculture and industry (Mohorich, 1980).

Uranium

Hypothetical or speculative resources of vein-type uranium are identified in three areas: U-1, U-3, and U-3. Alluvial fans downstream from these areas are possible locations for uranium placers.

Area U-1--Recent uranium exploration by private industry is documented by claim locations in unsurveyed sections 27, 34, and 35, T. 2 N., R. 12 E., S.B.M. The Sheep-Watsnew-Withers Group of at least 24 claims occur in area U-1 (fig. 4) in the northwest end of the Sheep Hole Mountains (fig. 3 and table

1, no. 34). The Watsnew Claims were located in 1972, and the American Copper and Nickel Company located the Sheep Claims in the area in 1978. The Wither Claim(s) was probably located subsequent to the Sheep Claims. No active holdings are known in the area and there is no evidence nor record of production. Two prospect pits were excavated on the discoveries in 1972. American Copper and Nickel Company conducted limited geophysical and geochemical surveys, and drilled one exploratory hole in 1979. Aeroradiometric data obtained under the National Uranium Resource Evaluation (NURE) program (Geodata International Inc., 1979) indicate uranium twice background values, potassium twice background, and thorium 1.5 times background for a flight line across area U-1 (J. K. Otton, written commun., 1981).

Rock units in the vicinity of the claims are biotite schist, gneiss, and quartzitic metamorphic rocks injected with ptymatically folded aplite dikes and bounded by granite and granitic gneiss. Sparsely mineralized deposits are restricted to propylitically altered, red to purple, boudin-like outcrops of the metamorphic assemblage. The outcrop pattern is elongate in a N 50° W direction in two, subparallel, discontinuous lensoid bodies 4,000 to 5,000 ft (1,200 to 1,500 m) long. Foliation, shears and alteration zones strike N 40°-70° W and dip 30°-70° SW. The more intensely propylitically altered zones occur in association with aplite dikes, are gossan-like in appearance, and contain limonite after pyrite, although pyrite and arsenopyrite are commonly visible.

These prospects occur in part of the limonitic zone identified from LANDSAT images in the vicinity of the Big Horn and Wagner Mines. Samples of limonitic altered rocks indicate that this area is related geochemically to the fault zone and propylitic alteration at Big Horn and Wagner mines, because the geochemical suite of molybdenum, copper, and silver with minor bismuth typical of these deposits was present in most samples taken. Five scintillometer traverses registered counts 2 to 2.5 times above background over interfingered metamorphic and plutonic rocks. The association of aplite dikes with altered, mineralized zones and anomalous uranium suggests late-stage plutonic origin and the uranium and thorium probably were derived from late-stage magmatic fluids which evolved from the Cadiz Valley batholith. Later hydrologic and (or) thermal events may have resulted in a redistribution of the uranium. Twenty samples were taken on the properties. Uranium content in 18 samples ranged from 4 to 86 ppm and averaged 18 ppm U₃O₈. Excluding three anomalously high samples (33, 73, and 86 ppm), the remaining analyses ranged from 3 to 15 ppm and averaged 8-9 ppm U₃O₈. These are little more than background uranium contents in altered granitoid rocks of the Cretaceous suite (1-6 ppm) and the Jurassic suite (0-6 ppm) from throughout the study area.

The criteria used in delineating area U-1 (fig. 4) are: (1) Spotty, low-grade uranium mineralization along faults in and near the batholithic contact with older metasedimentary units, (2) eighteen of twenty rock samples having an average of 18 ppm uranium, (3) mineralization and alteration that is spatially associated with the uranium mineralization includes gossan-like zones of limonite after pyrite with pyrite and arsenopyrite commonly present, and (4) data from ground and airborne radiometric surveys that indicate the presence of anomalous uranium. The relatively low grade, irregular distribution, and discontinuous nature of mineralized zones make a resource estimate impractical. This property is considered to have low potential as a hypothetical resource of uranium.

Area U-2--A 2 sq mile (5 sq km) area in the west-central Sheep Hole Mountains (fig. 3) contains potential as a speculative resource for uranium and thorium. Delineation of this area was based on a NURE aeroradiometric anomaly in uranium (J. K. Otton, written commun. 1981) and anomalous thorium in the nonmagnetic fraction of panned concentrates from stream sediments. A north-west-trending fault system favorable for development of vein and replacement deposits is present, as are igneous rocks potentially suitable as source rocks. These rocks are propylitically altered over a substantial area, and limonitic coatings occurring on the intermediate fraction of panned concentrates from sediments contain anomalous cerium and bismuth suggesting an origin related to fluids of magmatic origin.

Area U-3--A one-square mile (2.5 km²) area in the south part of the southern Calumet Mountains (Area U-3, fig. 4) contains the Queens Gold Group of claims (fig. 3 and table 1, no. 13). Uranium commonly occurs with intense limonite alteration associated with pegmatite dike swarms in enclaves of granodiorite gneiss in the granite. The nature of the uranium occurrence resembles that of the Sheep-Watsnew-Withers deposit (Area U-1, fig. 4). Five of 16 samples analyzed for uranium ranged from 0.003 to 0.011 percent uranium (plus 1 value of 5 ppm U₃O₈) and 3 of 15 samples contained 0.003 to 0.004 percent thorium. Observed deposits containing uranium and thorium are too small and spotty to be economic; however, the area has low potential for discovery of larger deposits of a similar nature. Area U-3 is considered a hypothetical resource of uranium.

Oil and Gas

No known geologic structures in the Sheep Hole-Cadiz Wilderness Study Area are considered favorable for oil and gas. Approximately 21 sq mi (54 sq km) of land within the eastern boundary of the wilderness study area are under lease application by Buckhorn Petroleum Company and St. Marie Parish Land Co. These lands form the western perimeter of a larger block of lease applications, filed in November 1980, which blanket Cadiz Valley. From 1956 through 1967, periodic oil and gas leases were held on lands around the perimeter of Dale Lake; however, there are no active leases at this time.

Two types of targets may have been considered by these companies: basins of Cenozoic sedimentary fill, and older host environments beneath possible overthrusts. The possibility that overthrusts conceal oil- or gas-bearing strata below the crystalline rocks exposed in the study area is considered remote. The Cadiz Valley batholith has intruded and metamorphosed Mesozoic and older strata, thereby expelling any oil or gas. Younger (Cenozoic) overthrusts that might conceal sedimentary host rocks for oil or gas are considered unlikely.

Basin fill deposits of Cenozoic age are indicated, by geophysical data, to be about 1000-2000 ft (300-600 m) thick in parts of the study area that adjoin Cadiz and Bristol Lakes, and on the order of 4000 ft (1200 m) thick near Dale Lake. The basins are too shallow to suggest much potential for oil or gas and are not considered to warrant classification as a resource.

ASSESSMENT OF MINERAL-RESOURCE POTENTIAL

The mineral resource potential of the Sheep Hole-Cadiz Wilderness Study Area as assessed in this joint study by the U.S. Geological Survey and the U.S. Bureau of Mines is based on geologic environment, geophysical and geochemical data, mine and prospect evaluations and hydrothermal alteration studies. Figure 4 outlines the areas classified as potential mineral resources, discussed in the preceding pages. Resource potential in the wilderness study area is classified using the McKelvey diagram, according to definitions established by the U.S. Bureau of Mines and U.S. Geological Survey (1980).

The study identified fourteen areas of potential mineralization (fig. 4), three of which contain inactive mines (M-1, U-1 and D-1). Many of the other areas contain prospects, but five areas (B-1, B-2, B-3, M-5 and U-2) identified in this study had little or no previous indications of mineralization. Most resources are hypothetical or speculative. Identified resources in the wilderness study area are large estimated tonnages (on the order of millions of tons) of brines (areas B-1 and B-1), a small tonnage (165,000 tons) of gold resource at 0.01oz/ton gold--M-1 and a small amount (2100 tons) of decorative stone (area D-1). There is no documented production history in the wilderness study area. There is no current production.

Brine resources occupy sedimentary basins around three large playas that flank the wilderness study area. Large inferred to hypothetical resources of highly saline brines (areas B-1 through B-3) are thought to occur in porous sediments at depth on the northwest, east, and west sides of the wilderness study area. These brines are suspected to be rich in sodium and(or) calcium salts similar to the brines currently being produced commercially at adjacent Bristol and Cadiz Lakes and formerly produced at Dale Lake. The brines and(or) associated sediments may contain lithium and(or) strontium in two of the three areas.

Small subeconomic base- and precious- metal vein-type deposits are found in the Sheep Hole and Calumet Mountains and there is potential for similar deposits as hypothetical and(or) speculative resources (areas M-1 through M-6). Area M-3 is considered a speculative resource as an exploration target for stockwork or porphyry molybdenum. Porphyry molybdenum deposits are generally large and low-grade, and are mined in bulk on a large scale. Speculative resource area M-5 also possibly has potential for some type of large low-grade deposit, but the confidence that a deposit exists is low. Small vein-type uranium deposits may occur in areas U-1 through U-3.

Most of the known metallic mineralization occurs within the Cadiz Valley batholith or within relatively short distances outward from the batholithic contacts with older rock. Geochemical evidence suggests that certain phases of the batholith were originally somewhat enriched in several metals, especially tungsten, molybdenum and bismuth. This suggests the possibility that the metals now observed in fault and vein systems within the wilderness study area originated, or were originally concentrated by, the batholith. Subsequent modification of the original distribution of metals has resulted in the vein mineralization presently observed.

The wilderness study area contains a speculative geothermal resource (Area G-1) of unknown value. Rock products identified in the area include a small, currently subeconomic measured resource of decorative stone in the Sheep Hole Mountains (area D-1).

Large quantities of sand and gravel present are not considered a resource because of their distance from possible consumers. The potential in the Sheep Hole-Cadiz Wilderness Study Area for skarn tungsten, placer gold, placer tungsten, placer uranium, and oil and gas were also evaluated and no potential areas of resources were defined.

The mineral potential of large portions of the study area is not well defined, owing to overburden and other data gaps. Improved interpretations will be possible in the future as new techniques for and concepts of mineral resource evaluation are developed and applied to the area. Therefore, this report and these interpretations are considered to be interim evaluations of mineral potential, which should be updated periodically in the Sheep Hole-Cadiz Wilderness Study Area.

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