Mineral Resources of the Palen-McCoy Wilderness Study Area, Riverside County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1710-A

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DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE : 1985

For sale by the
Distribution Branch, Text Products Section
U.S. Geological Survey
604 South Pickett St.
Alexandria, VA 22304

Library of Congress Cataloging-in-Publication Data

Main entry under title:

Mineral resources of the Palen-McCoy Wilderness
Study Area, Riverside County, California.

(U.S. Geological Survey Bulletin 1710-A)
Bibliography
Supt. of Docs. no.: I 19.3:1710-A
1. Mines and mineral resources--California--
Palen-McCoy Wilderness. 2. Palen-McCoy Wilderness
(Calif.). I. Stone, Paul. II. Series: United
States Geological Survey Bulletin 1710-A.
QE75.B9 557.3 s[553'.09794'97] 85-600499
(TN24.C2)

STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Palen-McCoy Wilderness Study Area (CDCA-325), California Desert Conservation Area, Riverside County, California.

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By Paul Stone, Thomas D. Light, V.J.S. Grauch, and Warren E. Yeend
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SUMMARY

Abstract

The Palen-McCoy Wilderness Study Area (CDCA-325) is an area of about 81,000 acres located 20 mi west-northwest of Blythe and 15 mi east of Desert Center in the Mojave Desert of southeastern California. Geologic, geochemical, geophysical, and mineral surveys of the wilderness study area were conducted by the U.S. Geological Survey and the U.S. Bureau of Mines between 1981 and 1984 in order to appraise the identified mineral resources and to assess the mineral resource potential of the area. These surveys indicate that the Palen-McCoy Wilderness Study Area has identified resources of iron and pyrophyllite, that a small part of the area has high resource potential for iron, and that a small part of the area has moderate resource potential for pyrophyllite. The entire wilderness study area has low potential for copper, uranium, manganese, and clay, and unknown potential for oil, gas, and geothermal energy.

Character and Setting

The Palen-McCoy Wilderness Study Area includes the southern part of the Palen Mountains and the broad valley that lies between that range and the McCoy Mountains to the east (fig. 1). The southern Palen Mountains are composed of Jurassic(?) and Cretaceous metasedimentary and minor metavolcanic rocks (McCoy Mountains Formation of Miller, 1944) and a structurally overlying andesite-diorite complex. The remainder of the study area is covered by Quaternary alluvium that is underlain locally by Tertiary sedimentary rocks.

Resources

Mining and mineral exploration have occurred intermittently in and near the Palen-McCoy Wilderness Study Area since the late 1800's. Mines in the Palen Mountains north of the study area and in the McCoy Mountains east of it have produced small tonnages of copper, manganese, and uranium. Clay, iron, and pyrophyllite, an industrial mineral, were discovered in the southwestern Palen Mountains before 1945 but the prospects were never fully developed. Claims for copper, uranium, pyrophyllite, iron, oil and gas, and geothermal energy are located in and adjacent to the wilderness study area.

The andesite-diorite complex at the southwestern end of the Palen Mountains hosts a magnetite iron deposit at the Iron King and Iron Queen prospect (fig. 2). This deposit contains a minimum inferred resource of 672,000 short tons at an average grade of 47 percent iron. This magnetite deposit and a smaller magnetite body to the west lie within a well defined, southeast-trending aeromagnetic high that can be traced for a distance of about 3 mi. The area of this magnetic anomaly has high resource potential for undiscovered magnetite deposits similar to the deposit at the Iron King and Iron Queen prospect.

Pyrophyllite hosted by metavolcanic rocks at the top of the McCoy Mountains Formation occurs at the White Magic prospect in the southwestern Palen Mountains (fig. 2). The deposit lies adjacent to a fault that separates the McCoy Mountains Formation from the overlying andesite-diorite complex. The deposit contains a minimum inferred resource of 140,000 short tons at an average grade of 75 percent pyrophyllite. The metavolcanic rocks that host this pyrophyllite deposit crop out discontinuously for a distance of between 2 and 3 mi near and adjacent to the fault separating the McCoy Mountains Formation and the andesite-diorite complex. These rocks locally contain pyrophyllite. This narrow band of metavolcanic rocks has moderate resource potential for undiscovered pyrophyllite deposits similar to the deposit at the White Magic prospect.

Small amounts of copper have been mined from areas adjacent to the Palen-McCoy Wilderness Study Area, and copper minerals occur locally in quartz-carbonate veins and as disseminations within the wilderness study area. Despite these local

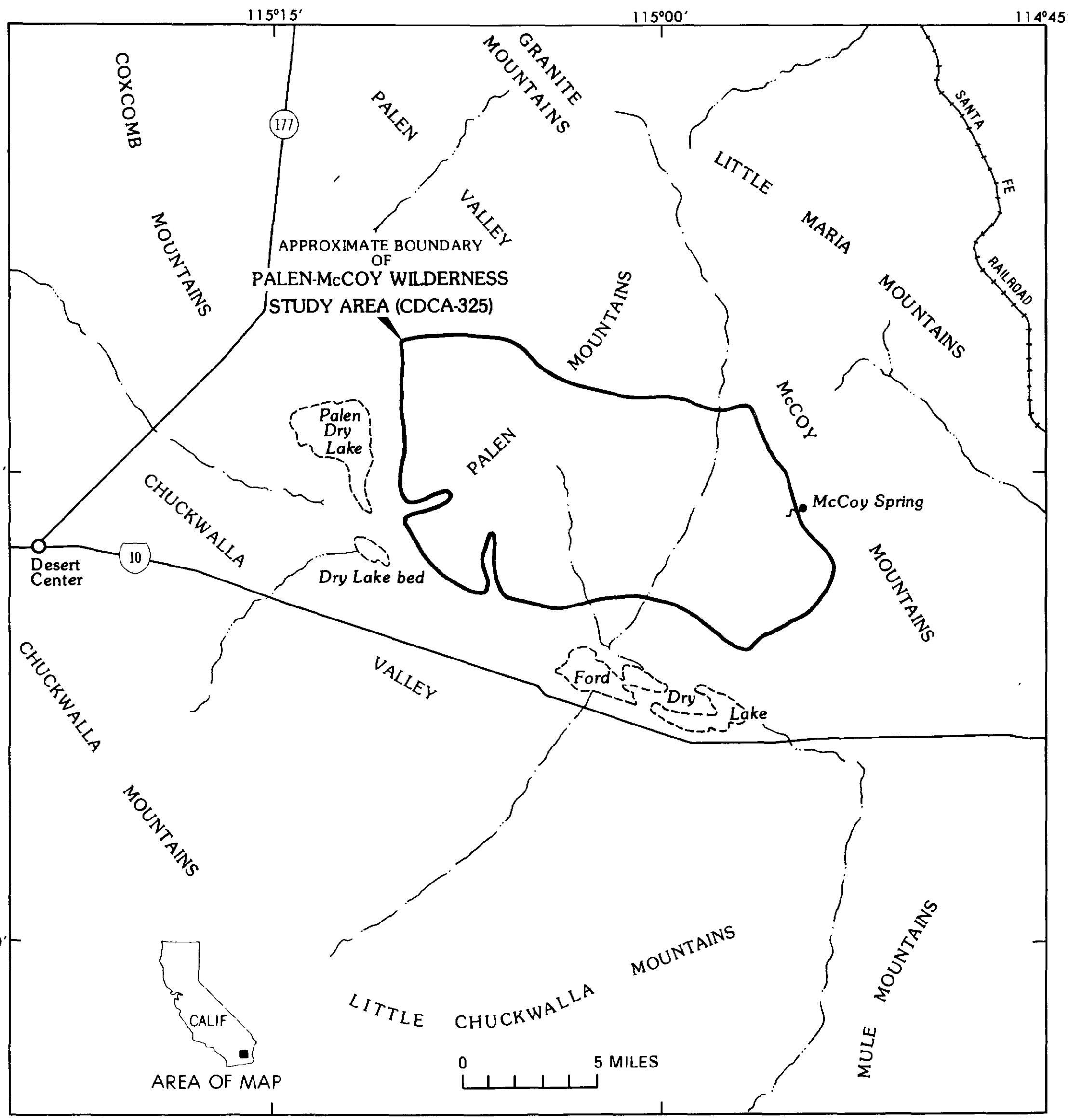

Figure 1. Index map showing location of the Palen-McCoy Wilderness Study Area, Riverside County, California.

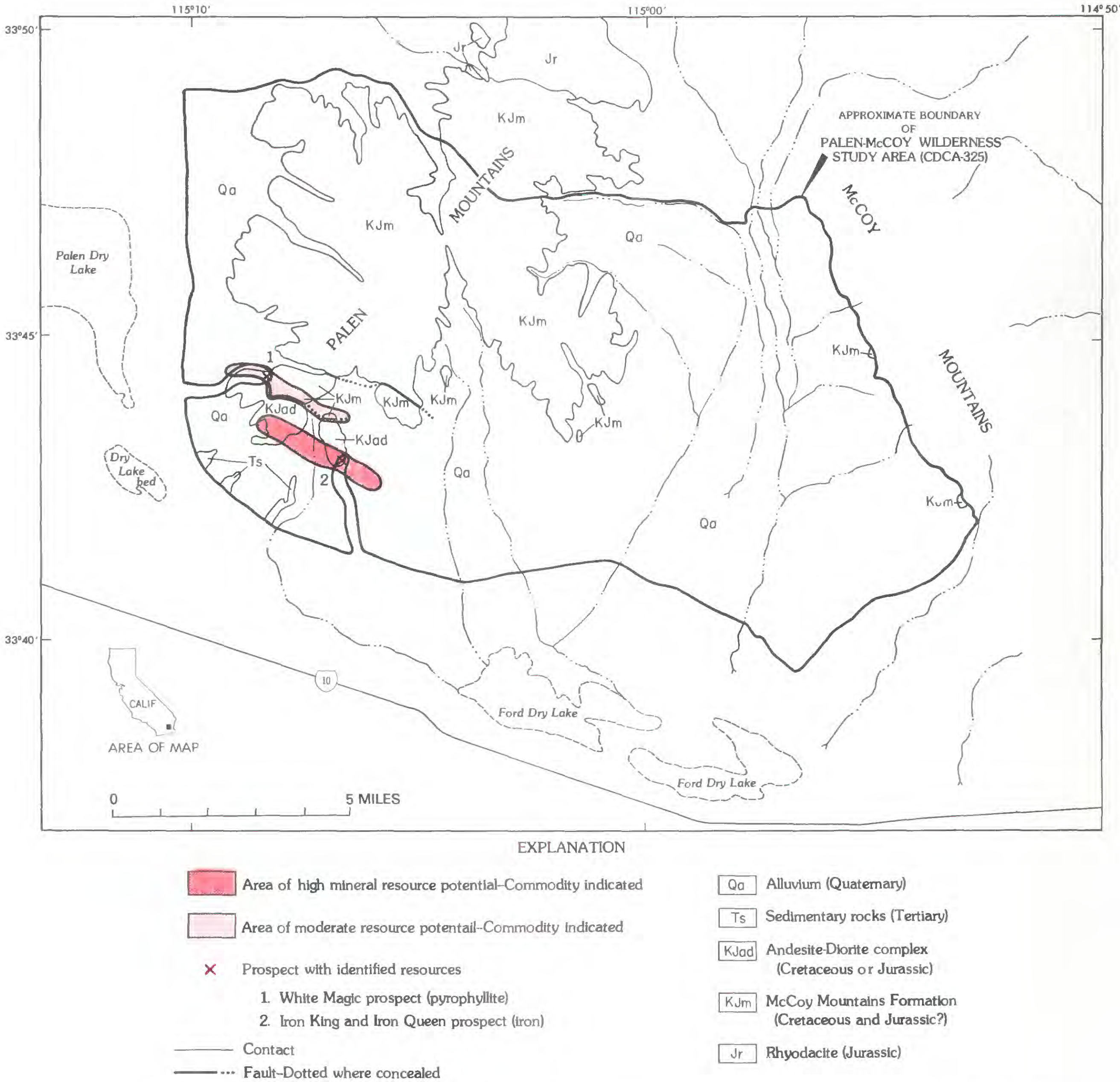

Figure 2. Map showing identified mineral resources and mineral resource potential of the Palen–McCoy Wilderness Study Area, Riverside County, California.

occurrences, the area has a low resource potential for copper.

Geophysical and geochemical studies indicate that the wilderness study area has moderate background levels of uranium. Although some uranium has been mined in the adjacent McCoy Mountains, there is no evidence for significant uranium concentrations in the wilderness study area. The resource potential of the area for uranium is therefore low.

Manganese has been mined from several deposits in the McCoy Mountains east of the wilderness study area, but manganese deposits are not known or suspected to exist within the area. The resource potential of the area for manganese is low.

A thin layer of silty montmorillonite claystone is present in Tertiary sedimentary rocks in the southwestern part of the wilderness study area, but this clay is too impure to be of economic value. The resource potential of the area for high-grade clay deposits is low.

Alluviated areas within the wilderness study area are under lease for oil and gas, but there are no subsurface data by which the oil and gas potential can be evaluated. The oil and gas resource potential of the wilderness study area is unknown.

Although the wilderness study area lies in a region of possible geothermal activity, data for accurately evaluating the geothermal resource potential of the area are not available. The resource potential of the area for geothermal energy is unknown.

INTRODUCTION

The Palen-McCoy Wilderness Study Area (CDCA-325) is in the Mojave Desert of southeastern California about 20 mi west-northwest of Blythe and 15 mi east of Desert Center (fig. 1). The area, which covers approximately 81,000 acres, encompasses the southern part of the Palen Mountains and the alluviated valley that lies between the Palen Mountains and the McCoy Mountains to the east. The area lies in the north-central part of the Salton Sea 1° by 2° quadrangle and includes parts of the Palen Mountains, Sidewinder Well, Midland, and McCoy Spring 15-minute quadrangles. Elevations within this topographically rugged area range from about 400 ft along the southern boundary to 3,623 ft on the crest of the Palen Mountains. The area is accessible by unpaved roads branching north from U.S. Interstate Freeway 10 and east from California State Highway 177.

The U.S. Bureau of Mines studied prospects and mineralized areas within the wilderness study area, investigated the history of mining and production within and near the area, and assessed the identified mineral resources. This study involved a literature search, field examination of workings and mineralized areas, and laboratory analysis of samples collected in the field (Schreiner, 1984). Reports containing information on mining and production within and near the area include those by Aubury (1902, 1908), Merrill (1917), Bradley and others (1918), Tucker and Sampson (1929, 1945), Trask and others (1943), Eric (1948), Trask (1950), Wright (1957), Walker and Butler (1966), Saul and others (1968, 1971), and Vredenburgh and others (1981). Additional data were furnished by M.W. Shumaker, U.S. Bureau of Land Management, Indio Resource Area Office (oral commun., 1982).

The U.S. Geological Survey assessed the mineral resource potential of the wilderness study area by integrating and interpreting geologic, geochemical, and geophysical data from existing sources and new investigations. Field mapping done in 1983 and 1984 provided most of the geologic information; the unpublished Ph.D. theses of Pelka (1973) and Harding (1982) provided supplementary geologic data. A reconnaissance sampling survey conducted in 1982 provided geochemical data (Detra and others, 1984). Existing gravity and aeromagnetic data (LKB Resources, Inc., 1979; Biehler and Rotstein, 1982; U.S. Geological Survey, 1983, 1985) provided a basis for geophysical interpretations. Aerial gamma-ray and geochemical data in reports on the Salton Sea 1° by 2° quadrangle prepared under the National Uranium Resource Evaluation (NURE) program (Heffner, 1980a, 1980b; LKB Resources, Inc., 1979; Chew and Antrim, 1982) provided the basis for evaluating the uranium resource potential of the area.

The Palen-McCoy Wilderness Study Area is in the southwesternmost part of the Great Basin physiographic province, a region characterized by low, narrow, north- to northwest-trending mountain ranges and comparatively broad intermontane valleys. The area lies within the western part of a narrow, west-northwest-trending outcrop belt of the Jurassic(?) and Cretaceous McCoy Mountains Formation of Miller (1944), a sequence of well indurated, weakly metamorphosed sandstone, conglomerate, and shale in excess of 20,000 ft thick (Pelka, 1973; Harding, 1982). These rocks occur in the Palen, McCoy, and Coxcomb Mountains in California and in at least two ranges in westernmost Arizona. The formation generally forms gently south- to southeast-dipping, homoclinal sections that are overlain stratigraphically or structurally by volcanic and metavolcanic rocks of presumed Jurassic or Cretaceous age (Pelka, 1973; Tosdal, 1982). In the Coxcomb Mountains, the McCoy Mountains Formation is intruded by Late Cretaceous plutonic rocks (Greene, 1968; Calzia, 1982; Calzia and others, 1983). The outcrop belt of the McCoy Mountains Formation is paralleled on the north by a belt of intensely deformed and metamorphosed rocks that include Precambrian granite and gneiss, Cambrian to Jurassic metasedimentary rocks (mainly marble, quartzite, and schist), and Jurassic metavolcanic and metaplutonic rocks (Hamilton, 1982). The McCoy Mountains Formation nonconformably overlies Jurassic metaigneous rocks of this belt (Pelka, 1973). The outcrop belt of the McCoy Mountains Formation is paralleled on the south by a belt of Precambrian gneiss and Mesozoic plutonic rocks. The poorly understood Mule Mountains thrust fault places those rocks structurally above the McCoy Mountains Formation and the associated metavolcanic rocks (Crowell, 1981; Tosdal, 1982).

APPRAISAL OF IDENTIFIED RESOURCES

By Russell A. Schreiner, U.S. Bureau of Mines

Methods and Scope of Investigation

Information from various sources was compiled and examined, and field work was conducted, to evaluate the mineral resources of the area. Published and unpublished literature relating to the area was searched to obtain information concerning past mineral and mining activity. Workings and mineralized areas within and up to 1 mi outside of the boundary were located, mapped, and sampled. Mapping was by photographs, plane table, and Brunton compass and tape. Petrographic thin sections were cut and studied to aid in identification of rock types and alteration. A total of 89 samples was taken for analysis from workings and mineralized areas in and around the study area. Samples were taken to obtain an indication of the representative element content by various analytical methods. Select samples were taken either to determine the maximum values present or to verify mineralization of rock. All samples were analyzed for gold and silver by fire assay. Inductively coupled plasma-atomic emission spectroscopy, fluorometry, and gravimetric methods were used on selected samples. At least one sample from each locality studied was analyzed for 42 elements (Al, Sb, As, Ba, Be, Bi, B, Ca, Cd, Cr, Co, Cb, Cu, Ga, Fe, La, Pb, Li, Mn, Mg, Mo, Ni, P, Ag, Si, Na, Sl, Ta, Sn, Ti, V, Y, Zn, Zr, Au, Hf, In, Pt, Re, Te, Tl, Sc) by semiquantitative optical emission spectrography to determine if anomalous amounts of unsuspected elements were present. Analytical data and unpublished maps pertinent to this report are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Denver Federal Center, Denver, Colorado 80225.

The major prospects in and near the area were described and compiled for the California Division of Mines and Geology by Saul and others (1968, 1971). A historical review of the mining in this area was presented by Vredenburgh and others (1981). The prospects studied for this report, along with sample localities, are shown on plate 1.

History of Mining and Mineral Exploration

The Palen-McCoy Wilderness Study Area lies within the Ironwood mining district. Intermittent mining activity has occurred here since the 1870's. Deposits of iron, pyrophyllite, clay, and occurrences of copper, with minor associated gold and silver, are found within the area and near the boundary. The most intense mining activity has generally been 1-4 mi outside of the area on deposits and occurrences of manganese, uranium, and copper. These deposits and occurrences are not known to extend into the wilderness study area. Their approximate locations are indicated by the Jackson and Independence claim group, the Plata Oro claim group, the Arlington claim group, the Eagles Nest and Son Bar claim group, and uranium claims held by numerous companies and independents (pl. 1).

As of July 1982, there were Federal oil and gas leases within and near the wilderness boundary (areas of leases shown in fig. 2 of Schreiner, 1984). No drilling had been conducted, but in 1982 seismic work was done in the valley between the Palen and McCoy Mountains (M.W. Shumaker, U.S. Bureau of Land Management, Indio Resource Area Office, oral commun., 1982).

No Federal sodium or potassium leases or lease applications are currently on file with the U.S. Bureau of Land Management, but the Ford and Palen Dry Lakes are considered to be prospectively valuable for sodium and potassium by the U.S. Geological Survey (Calzia and others, 1979) (prospectively valuable areas shown in fig. 3 of Schreiner, 1984). Three shallow holes, less than 550 ft deep, were drilled by the U.S. Geological Survey but a resource was not identified.

The Palen and Ford Dry Lake areas are considered by the U.S. Geological Survey (Calzia and others, 1979) to be prospectively valuable geothermal resource areas (prospectively valuable areas shown in fig. 3 of Schreiner, 1984). Federal geothermal lease applications are located a few miles outside of the wilderness study area (areas of leases shown in fig. 2 of Schreiner, 1984). The Ford Dry Lake area was considered a KGRA (known geothermal resource area) due to overlapping geothermal leases. The area was dropped from this classification as of June 4, 1982 (Stanley Sun, Minerals Management Service, oral commun., 1982) and the leases have expired. McCoy Spring, located just outside the wilderness study area boundary (fig. 1, pl. 1), is considered a thermal spring with a surface temperature of 28°C (82.4°F) (Higgins and Martin, 1980). No drilling had been conducted as of 1982 to verify the geothermal potential (M. W. Shumaker, U.S. Bureau of Land Management, Indio Resource Area Office, oral commun., 1982).

Identified Resources and Mineral Economics

All workings or mineralized areas within or along the boundary of the wilderness study area are located near the southwestern edge of the Palen Mountains with the exception of two uranium prospects in the McCoy Mountains, which are outside but within a mile of the wilderness study area boundary.

In the southwestern Palen Mountains, occurrences of copper and deposits of iron and pyrophyllite appear to be spatially related to faulting and igneous rocks (pl. 1). A clay deposit is present on the plain just southwest of the Palen Mountains (pl. 1).

Copper

Copper occurs in veins and as disseminations in metasedimentary and igneous rocks within and near the boundary of the wilderness study area. These occurrences have been explored by small pits and trenches (pl. 1, localities 1-13, 17-23, 27, 63-64, 66-70, 72-76). Most are located near three major parallel N. 70° W. striking faults in the southwestern Palen Mountains.

Veins in metasedimentary rocks in unit 3 of the McCoy Mountains Formation (pl. 1, localities 1-9) are generally thin (less than 1 ft), irregular, and discontinuous. The veins consist predominantly of quartz, subordinate brown carbonate, and widely scattered blebs of hematite-limonite with chrysocolla. Specular hematite occurs in a few places associated with lenses of sericite and chlorite.

Veins in rocks of the andesite-diorite complex in the vicinity of the Iron Cap and Iron King prospect (pl. 1, localities 10-13) are discontinuous, tend to pinch and swell, and in some places form large pods. The mineralogy of these veins is similar to that of the veins in the metasedimentary rocks, except for the presence of galena.

Disseminated copper occurs in two areas in unit 3 of the McCoy Mountains Formation. In one prospect pit (pl. 1, locality 27), a small area of gray phyllite, in contact with a dark-green metasandstone, exhibits fracture-controlled distribution of chrysocolla and specular hematite. A second occurrence (pl. 1, localities 22 and 23) contains blebs of chrysocolla and hematite-limonite in a small area of highly sheared and silicified, light-green metasandstone.

Disseminated copper occurs in rocks of the andesite-diorite complex at localities 17 and 18 (pl. 1). Hematite-limonite with chrysocolla is present both as disseminations and as fracture-fillings in rock from the dumps of two small caved pits.

Copper values as high as 1.9 percent occur at these prospects. In addition, four samples of vein material from scattered localities (pl. 1) contained significant gold and silver values (sample 2 contained 1.250 oz gold per ton and 6.3 oz silver per ton; sample 8 contained 0.118 oz gold per ton and 0.9 oz silver per ton; sample 9 contained 0.110 oz gold per ton; and sample 72 contained 0.9 oz silver per ton). All other samples contained less than 0.005 oz gold per ton and less than 0.2 oz silver per ton. In addition to the copper values, veins in the igneous rocks contained as much as 1.6 percent lead. The limited size of the occurrences studied suggests no developable resources are present at these prospects. Assay results and sample descriptions for localites 1-13, 17-23, 63, 64, 66-70, and 72-76 (pl. 1) are given by Schreiner (1984, p. 27-35).

Iron

Two magnetite lenses are partly exposed in the andesite-diorite complex where it is cut by the southernmost fault zone (pl. 1). The eastern lens on the southern boundary of the wilderness study area (pl. 1, localities 33-59) has been called the Iron King and Iron Queen prospect by Saul and others (1968, 1971). The western lens (pl. 1, localities 60-76) lies approximately 1.5 mi from the eastern lens and is called the Iron Cap and Iron King prospect by Saul and others (1968, 1971). These prospects are held under the Iron King and Iron Queen group of claims. The magnetite lenses at both localities contain coarse-grained magnetite in a gangue of calcite, quartz, epidote, actinolite, sphene, chlorite, and some blocks and/or lenses of country rock. The bodies also contain apatite crystals occurring in bands generally aligned parallel to the long axis of the lens.

The Iron King and Iron Queen prospect consists of four open cuts on the side of a ridge across a lens-shaped magnetite body emplaced in a fault zone. The magnetite lens is 60 ft wide near the base of the ridge where it is then concealed by alluvium in a wash; it pinches out laterally just below the ridge top. The lens averages about 50 ft wide and the total exposed length is approximately 450 ft. The magnetite lens has a sharp contact with the host rock on the north side and a gradational contact on the south side with a light-green, partially uralitized pyroxene diorite.

Open cuts provide good continuity of outcrop, and samples were taken in two of the cuts across the magnetite lens starting at the sharp contact between the diorite and magnetite on the north side of the lens. A continuous chip sample (localities 33-46) taken across the lens in one of these cuts had a weighted average of 49.8 percent total soluble Fe, with appreciable amounts of P_2O_5 (2.5 percent) and V_2O_5 (0.500 percent) (Schreiner, 1984, p. 36). Samples 47-59 from the other cut had a weighted average of 45.0 percent total soluble Fe, with appreciable amounts of P_2O_5 (5.0 percent) and V_2O_5 (0.457 percent) (Schreiner, 1984, p. 37). Inferred resources were calculated using only the exposed area of the lens. Calculations were based on a 450-ft exposed length and a 50-ft average width. Depth of the lens was assumed to be one-half the exposed length. Using these parameters, a minimum of 672,000 short tons of ore averaging about 47 percent iron is estimated.

The apparent small size of the Iron King and Iron Queen deposit limits its potential for development. In general, iron deposits require many millions of tons of ore to be economically significant. Because of foreign competition, declining markets, and high mining and transportation costs, even large iron mines (such as the Eagle Mountain mine a few miles west of the study area) have been forced to shut down within recent years.

The Iron Cap and Iron King prospect consists of several shallow pits and trenches on a small magnetite lens and a few magnetite veins within a fault zone. The veins are thin (about 1 ft), irregular, and discontinuous. The magnetite lens exposed in outcrop on a small ridge is 13 ft wide and 10 ft long. The east end of the lens is covered by alluvium and the west end is cut by a trench at the edge of a wash. Contacts with the host rocks are sharp. The host rock in this area is a uralitized gray-green porphyritic andesite body within diorite. The andesite contains higher, though variable, concentrations of quartz, apatite, and magnetite compared with the diorite. Magnetite occurs both as disseminations and in small globules and streaks. The porphyritic andesite is enriched in magnetite and some magnetite segregation appears to have taken place.

At the Iron Cap and Iron King prospect, two samples taken across the small lens had a weighted average of 53.8 percent total soluble Fe, and appreciable amounts of P_2O_5 (1.36 percent) and V_2O_5 (0.396 percent) (Schreiner, 1984, p. 38). Due to the limited exposure the resources present could not be delimited.

Pyrophyllite

Pyrophyllite, a soft aluminum silicate that resembles talc, and is used in ceramics, insecticide carriers, and in minor amounts in asphalt fillers and joint cements, is present in unit 3 of the McCoy Mountains Formation (pl. 1). It occurs near a fault contact between the McCoy Mountains Formation and the overlying andesite-diorite complex. The deposit is held under the White Magic group of claims along the boundary of the wilderness study area. A small amount of pyrophyllite, estimated at less than 50 tons, was reportedly shipped by the current owner (M.W. Shumaker, U.S. Bureau of Land Management, Indio Resource Area Office, oral commun., 1982). The White Magic prospect is denoted by localities 77-80 on plate 1; other pyrophyllite prospects are at localities 25, 26, and 28-32.

The exposed deposit at the White Magic prospect, which lies on a small ridge in weakly metamorphosed sedimentary and volcanic rocks about 100 ft north of a fault contact with andesite, is developed by a trench, an adit, and several prospect pits. The trench and adit cut 52 ft of mottled buff to black-gray, fine-grained pyrophyllite. Work was stopped after intersecting a siliceous bed. The pyrophyllite extends southward, on the other side of this siliceous bed, for approximately 25 ft before intersecting another siliceous bed and a light-green siliceous phyllite. The pyrophyllite also extends a few feet northward from the end of the trench, where it has a gradational contact with gray phyllite. From surface indications, the overall width of the deposit appears to be about 80 ft; however, bulldozing has scattered pyrophyllite rubble over a wide area making it difficult to determine the true width. The deposit extends at least 200 ft along the small ridge on which the trench and adit are located; both ends are buried by alluvium and the total length could not be determined.

The dump of a caved pit at locality 31 (pl. 1), approximately 1,500 ft to the west of the trench and adit, contains a grade of pyrophyllite similar to that found at the main occurrence (Schreiner, 1984, p. 39). Whether the pyrophyllite in the pit is continuous from the trench and adit or is an isolated occurrence could not be determined due to alluvial cover. Other pits are located along the fault up to a half-mile to the west, but contain only weakly mineralized rock.

A weighted average of chemical analyses from three samples of pyrophyllite taken in the trench and adit (pl. 1, localities 77-79) are compared with theoretically pure pyrophyllite in table 1. The difference between the weighted average values and the theoretical values appear to be due to the presence of impurities such as quartz, feldspar, and specular hematite in our samples, as noted in field observations.

From the weighted average of chemical analyses and from the minerals observed in the field, rough calculations were made for normative minerals using procedures defined by Cross and others (1903) and Niggli (1954). Results of these calculations indicate an approximate pyrophyllite content of 75 percent. The rest of the rock consists of 11 percent feldspar, 8 percent quartz, 3 percent hematite, and 3 percent accessory minerals. X-ray diffraction studies of this material indicated a pyrophyllite content of greater than 73 percent and an iron content of greater than 6 percent (Gerald Stock, Cyprus Industrial Minerals, Denver, Colorado, oral commun., 1982).

Inferred resources of 140,000 short tons of 75 percent pyrophyllite were calculated for the exposed part of the deposit. The calculations were based on a length of 200 ft and a width of 80 ft; depth of the deposit was assumed to be one-half the exposed length.

The White Magic deposit contains 75 percent pyrophyllite, a grade comparable to other producing deposits. The major drawback to developing the deposit appears to be the high iron content, which may make the pyrophyllite unsuitable for ceramic uses. The distance of the deposit from major markets and its location on the west coast, away from major producing areas on the east coast, are also limiting factors in its development.

Clay

A clay deposit, partially within the wilderness study area, lies in the small rounded hills southwest of the Palen Mountains. In 1945, six 160-acre placer claims, the Eureka group, were located here. The deposit was reported to be impure high-lime bentonite (Tucker and Sampson, 1945, p. 162). No claims are currently held in this locality and a few small caved pits were the only evidence of past exploration. The deposit was sampled at three sites by hand trenching through the clay horizon into the weathered outcrop (pl. 1, localities 81-86).

The deposit consists of a 4- to 5-ft-thick bed of compact waxy brown clay containing a large amount of quartz sand with minor calcite and gypsum. The deposit, overlain by alluvium and underlain by unconsolidated sand, covers an area of about 4 mi^2, as determined by ground reconnaissance and from aerial photographs. The geographic setting and mineralogy present in these unconsolidated sediments indicate that this is a local playa lake accumulation.

Samples from localities 81 and 82 contained the largest percentage of clay as indicated in the analyses by the higher aluminum, magnesium, and alkali contents. X-ray diffraction indicated that sample 81 contained mainly quartz and montmorillonite, minor calcite and gypsum, and traces of mica and chlorite (Schreiner, 1984, p. 41).

Compositions of clays can vary greatly and more importance is attached to their physical properties; specific physical testing is required for each specific use. The material present within the wilderness study area is a very impure montmorillonite containing a large amount of quartz sand and silt. The quartz would detract from the physical properties which make clays valuable, and make it unsuitable for common uses.

Uranium

In the McCoy Mountains a prospect pit and trench are located within 1 mi of the study area boundary in weakly metamorphosed sedimentary rocks (pl. 1, localities 87-89). In the southern pit (locality 87) radiation was twice background but no visible evidence of uranium mineralization was found in outcrops, or indicated by chemical analyses (Schreiner, 1984, p. 26). Several closely spaced drill holes (approximately 200-250 ft spacings) occur in the immediate vicinity. Data from these holes was not located.

Recommendations for further work

Additional exploration along structures containing known resources of iron and pyrophyllite is recommended. A detailed ground magnetic survey along the fault in the dioritic rocks that host the known magnetite bodies could indicate the presence and size of additional subsurface iron resources. Gravity surveys may be useful in evaluating excess mass due to the magnetite. From these values tonnage estimates of the amount of magnetite present could be made. A drilling program for pyrophyllite in the metasediments along the fault contact with andesite could determine the presence and size of resources.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Paul Stone, Thomas D. Light, V.J.S. Grauch, and Warren E. Yeend, U.S. Geological Survey

Geology

Rock Units

The southern part of the Palen Mountains is underlain primarily by weakly metamorphosed, pervasively cleaved sandstone, conglomerate, and shale of the Jurassic(?) and Cretaceous McCoy Mountains Formation (pl. 1). This formation is exposed in a faulted, homoclinal sequence about 21,000 ft thick and dipping gently to the south and southeast. About 2 mi north of the wilderness study area, the McCoy Mountains Formation rests nonconformably on Jurassic rhyodacite of volcanic or hypabyssal intrusive origin; similar igneous rocks underlie the formation in the McCoy Mountains (Pelka, 1973). At the southwest end of the Palen Mountains, the McCoy Mountains Formation is structurally overlain by massive, porphyritic andesite and diorite of probable Jurassic or Cretaceous age. The remainder of the wilderness study area is largely covered by Quaternary alluvium. A thin sequence of Tertiary arkosic sandstone and claystone underlies the Quaternary deposits along the southwest boundary of the area (pl. 1).

The rhyodacite beneath the McCoy Mountains Formation is a lithologically complex unit that may include both extrusive and intrusive components as well as large inclusions of older rock (Pelka, 1973). The rhyodacite hosts many of the small copper deposits and most of the known manganese deposits in the McCoy and Palen Mountains. This unit does not crop out inside the Palen-McCoy Wilderness Study Area, and we did not study it in detail.

The most extensive bedrock unit in the wilderness study area is the McCoy Mountains Formation, which we have divided into three informal stratigraphic units (pl. 1). The lower unit (unit 1) is about 6,500 ft thick and consists of dark-gray volcaniclastic sandstone, dark-gray mudstone, conglomerate, light-gray orthoquartzite, and tan marble. Conglomerate clasts in this unit are mainly quartzite and volcanic rock. Quartz-calcite veins in unit 1 host the small copper deposits of the Jackson and Independence claim group and the Oro Plata claim group. The overlying unit 2 is between 13,000 and 15,000 ft thick and consists of light-gray arkosic sandstone, conglomerate, and light-gray to greenish-gray shale and phyllite. Fossil wood fragments are present locally in the sandstone and conglomerate. Conglomerate clasts in this unit are mainly quartzite and plutonic rock; clasts of marble, foliated metasedimentary rock, and volcanic rock are less common. Unit 2, although extensively exposed, contains no known mineral occurrences. The upper unit (unit 3), which is in fault contact with unit 2, is about 2,500 ft thick and consists of gray sericitic phyllite, schist, sandstone, conglomerate, marble, and rare metavolcanic rocks. These rocks are more highly metamorphosed and deformed than rocks of units 1 and 2. Silicified metavolcanic rocks at the top of unit 3 host the pyrophyllite deposit at the White Magic prospect, and metasedimentary rocks in the unit host a few small copper-bearing quartz veins and disseminated copper minerals. The high ratio of sandstone to shale and the abundance of conglomerate in the McCoy Mountains Formation suggest a braided-stream or alluvial-fan depositional environment (Pelka, 1973; Harding, 1982).

The andesite-diorite complex at the southwest end of the Palen Mountains overlies unit 3 of the McCoy Mountains Formation along a south-dipping fault (pl. 1). This complex consists mainly of dark-colored andesitic volcanic or hypabyssal intrusive rocks composed of altered plagioclase phenocrysts in a fine-grained, chlorite- and epidote-rich groundmass. To the south, the unit contains increasing amounts of equigranular diorite that we tentatively interpret as intruding the andesite. Iron deposits of the Iron King and Iron Queen claim group are located along a fault near the south end of the complex.

Tertiary rocks exposed in the southwest corner of the wilderness study area comprise arkosic sandstone with a thin layer of silty montmorillonite claystone at the top. These rocks host the clay deposit described by the U.S. Bureau of Mines in a preceding section of this report. The thickness and subsurface extent of these Tertiary rocks are unknown.

We have divided Quaternary alluvium in the wilderness study area into two units (pl. 1). The older unit comprises highly dissected, extensively weathered alluvium exposed along the rangefronts of the Palen and McCoy Mountains. This alluvium has a well developed calcrete horizon about 6 ft thick, which distinguishes it from all the younger alluvium in the area. The younger unit consists of modern wash deposits and of finely dissected fan deposits with inactive surfaces.

Structural Geology

Major structural features in the Palen-McCoy Wilderness Study area are folds and pervasive cleavage in the McCoy Mountains Formation, and faults that cut the bedrock units.

The McCoy Mountains Formation, although generally homoclinal, is locally deformed by southeast-plunging folds with amplitudes ranging from less than a foot to several hundred feet. The largest fold is an anticline in unit 2 in the southwestern part of the Palen Mountains (pl. 1). Small-scale folds are common in unit 3. Many of the folds are asymmetric with a consistent southwesterly vergence. A pervasive north-dipping cleavage in the McCoy Mountains Formation may be axial-planar to the fold set.

At least three sets of faults cut the southern part of the Palen Mountains. Probably the oldest are two south-dipping faults near the southwestern end of the range, one between units 2 and 3 of the McCoy Mountains Formation and the other between unit 3 and the overlying andesite-diorite complex where the White Magic pyrophyllite prospect is located (pl. 1). These faults are subparallel to bedding and foliation in the McCoy Mountains Formation. A parallel fault to the south, along which the magnetite deposits in the andesite-diorite complex are located, may be related to these two faults. Two prominent sets of high-angle faults also are present: a northeast-trending set that is best developed in the western part of the range; and a younger, northwest-trending set that is best developed in the eastern part of the range (pl. 1). Quartz veins occur locally along these faults. The northwest-trending faults show right-lateral separations of several hundred to a few thousand feet, although their actual sense of displacement is unknown. A steeply dipping, east-west-trending, arcuate fault with an estimated 5,000 ft of dip-slip displacement cuts the McCoy Mountains Formation near the northwestern boundary of the wilderness study area. No recognized faults cut the Tertiary rocks or the Quaternary alluvium.

Geochemistry

In 1982 the U.S. Geological Survey collected stream-sediment samples, heavy-mineral-concentrates from stream sediments, and rock samples to provide a reconnaissance geochemical survey of the Palen-McCoy Wilderness Study Area (Detra and others, 1984). The samples were analyzed by a semiquantitative, direct-current arc emission spectrographic method (Grimes and Marranzino, 1968).

No significant geochemical anomalies were noted for samples collected within the wilderness study area. Slightly elevated concentrations of barium and boron throughout the area may reflect the presence of barite and tourmaline in the clastic rocks of the McCoy Mountains Formation. A concentration of 700 parts per million copper in a rock sample collected near the Iron King and Iron Queen prospect probably represents localized supergene enrichment rather than a major mineralizing system; copper values generally are low. Two heavy-mineral-concentrate samples contain 100 parts per million tungsten, and another contains 1,000 parts per million zinc. These and other isolated occurrences probably do not indicate extensive near-surface mineralization.

Stream-sediment samples collected within the Palen-McCoy Wilderness Study Area under the NURE program contain relatively high amounts of uranium and thorium (Heffner, 1980a, 1980b), and heavy-mineral concentrates from the east flank of the Palen Mountains show elevated thorium concentrations (Detra and others, 1984). These geochemical data support the aerial gamma-ray data discussed below.

Geophysics

Gravity

The Bouguer anomaly map of the Salton Sea 1° by 2° quadrangle (Biehler and Rotstein, 1982) shows regional gravity highs coinciding with the Palen and McCoy Mountains and lows coinciding with the adjacent valleys, a pattern typical of the Great Basin province where the low-density valley alluvium contrasts with the relatively high-density bedrock in the ranges. No detailed gravity data are available for the Palen-McCoy Wilderness Study Area.

Aeromagnetic Data

A survey flown in 1955 by Hycon Aerial Surveys, Inc., for a division of U.S. Steel Corporation (U.S. Geological Survey, 1985) supplied the principal aeromagnetic data for the Palen-McCoy Wilderness Study Area. The parts of this survey covering the wilderness study area were flown at barometric altitudes of 1,200 and 3,200 ft with an average spacing of 0.25 mi. A survey flown for the NURE program (LKB Resources, Inc., 1979) and a survey flown in 1981 by High Life-QEB (U.S. Geological Survey, 1983) supplied supplementary aeromagnetic data.

The only significant magnetic feature in the wilderness study area, as revealed by the 1,200-ft U.S. Steel survey, is a narrow, 3-mi-long, southeast-trending zone of sharp positive anomalies in the southwesternmost Palen Mountains. These anomalies, which have amplitudes between 100 and 200 gammas, coincide with the southern part of the andesite-diorite complex that overlies the McCoy Mountains Formation; they clearly are associated with the magnetite deposits of the Iron King and Iron Queen claim group. The anomalies extend about 0.5 mi into the alluvium southeast of the Iron King and Iron Queen prospect, suggesting that more magnetite exists in the shallow subsurface there. The data do not clearly define the northwestward extent of the anomalies, which appear to end abruptly just northwest of the Iron Cap and Iron King prospect. However, that prospect lies at the boundary between the 1,200-ft survey and the 3,200-ft survey, which was flown too high above ground to resolve such local anomalies.

The rest of the wilderness study area is associated with a relatively featureless pattern of magnetic contours, which is consistent with the predominance of weakly magnetic sedimentary rocks and alluvium in the area.

Aerial Gamma-ray Data

A regional aerial gamma-ray survey by LKB Resources, Inc. (1979) indicated moderately high background uranium and thorium radioactivity both in the bedrock of the Palen and McCoy Mountains and in the adjacent alluvium. However, the only significant gamma-ray anomaly in the vicinity of the wilderness study area is a uranium and uranium/thorium anomaly near known uranium deposits in the southern McCoy Mountains. In general, uranium/thorium gamma-ray counts in the wilderness study area are low to moderate; uranium/potassium and thorium/potassium are high.

Mineral and Energy Resources

Geologic, geochemical, and geophysical data indicate that the Palen-McCoy Wilderness Study Area has high resource potential (certainty level D) for iron in the vicinity of the Iron King and Iron Queen claim group and moderate resource potential (certainty level C) for pyrophyllite in the vicinity of the White Magic prospect (pl. 1). The resource potential for copper, uranium, manganese, and clay is low (certainty level C), and the potential for oil, gas, and geothermal energy is unknown. See Appendix 1 for definition of mineral resource potential and certainty of assessment (fig. 3).

Iron

Iron deposits are common in volcanic and plutonic terranes throughout the circum-Pacific region (Park, 1972; Hutchison, 1983). Most of these are lenticular magnetite bodies that occur at or near intrusive contacts. The intrusive rocks are dominantly intermediate types such as diorite, granodiorite, and tonalite. The country rocks commonly are either limestone or andesitic to dacitic volcanic rock. Most of these iron deposits have been ascribed to contact metamorphism, contact metasomatism, or replacement (Park, 1972). However, some of the deposits may have originated by magmatic segregation and injection, much like the lithologically similar Kiruna-type iron orebodies of Proterozoic age in Sweden (Hutchison, 1983).

The lenticular magnetite bodies in the southwestern Palen Mountains are hosted by the andesite-diorite complex that structurally overlies the McCoy Mountains Formation. These magnetite bodies, which occur along a fault within diorite, probably originated by magmatic injection.

As previously noted, the magnetite bodies in the southwestern Palen Mountains are associated with a linear, southeast-trending aeromagnetic high that extends for a distance of about 3 mi. The area of this magnetic anomaly has high resource potential for subsurface iron deposits similar in size and grade to the deposit at the Iron King and Iron Queen prospect (pl. 1). This assessment, which is supported by both geologic and aeromagnetic data, has a D certainty rating. Additional subsurface iron deposits could be present to the northwest where detailed aeromagnetic data are unavailable.

Pyrophyllite

Most of the world's economic pyrophyllite deposits occur in altered silicic volcanic and metavolcanic rocks (Cornish, 1983), where pyrophyllite evidently forms through hydrothermal alteration of feldspar (Deer and others, 1966). Deposits commonly are localized along faults or shear zones that presumably served as conduits for the hydrothermal solutions responsible for pyrophyllite mineralization.

The host rock for the pyrophyllite deposit at the White Magic prospect is light-gray to greenish-gray, fine-grained, silicic metavolcanic rock that forms a thin stratigraphic horizon at the top of unit 3 of the McCoy Mountains Formation. The deposit lies adjacent to the fault separating unit 3 and the overlying andesite-diorite complex. This fault probably served as a pathway for the solutions that formed both the pyrophyllite and abundant epidote and chlorite in the overlying andesite.

The fault between unit 3 of the McCoy Mountains Formation and the andesite-diorite complex is exposed in two segments separated by alluvium (pl. 1). Metavolcanic rocks like those that host the pyrophyllite deposit at the White Magic prospect crop out discontinuously along this fault and locally contain pyrophyllite. These rocks have moderate potential for undiscovered subsurface pyrophyllite deposits similar in size and grade to the deposit at the White Magic prospect. Pyrophyllite mineralization may have occurred in this area of moderate resource potential but is not clearly indicated by the available data. This assessment carries a C certainty rating; subsurface data would be required to support a higher certainty rating.

Copper

Despite the small showings of copper minerals described by the U.S. Bureau of Mines in the southwestern Palen Mountains, copper concentrations in geochemical samples within the wilderness study area are consistently low, and there is no geologic evidence to indicate that a large copper deposit such as a porphyry copper or skarn exists in the subsurface. The copper resource potential of the wilderness study area is therefore low with a C certainty rating.

Uranium

The uranium resource potential of the Palen-McCoy Wilderness Study Area is low with a C certainty rating. Despite the moderately high background levels of uranium indicated by geochemical and gamma-ray surveys, no significant uranium anomalies are known. Uranium/thorium ratios within the area are moderate to low, suggesting that no important uranium concentrations are present.

The McCoy Mountains Formation, although similar in general lithology to uranium-bearing sedimentary rock units of the Colorado Plateau and other uranium provinces, apparently contains little or no organic matter, which seems to be necessary to fix uranium in the sedimentary environment (Nash and others, 1981). If any organic matter originally existed, it probably was broken down during metamorphism and deformation.

In the southern McCoy Mountains, the McCoy Mountains Formation hosts at least three uranium deposits which consist of carnotite secondarily concentrated in faults and shear zones (Chew and Antrim, 1982). Similar secondary uranium deposits could be present in the Palen Mountains, but none were found during the present study. According to Pelka (1973), the stratigraphic subunits that host the uranium deposits in the McCoy Mountains are absent in the Palen Mountains.

The moderate background levels of uranium in alluvium within the wilderness study area probably reflect a moderately uranium-rich provenance (mainly the McCoy Mountains Formation) rather than the existence of significant uranium concentrations in the alluvium itself; unconsolidated alluvium generally is not a favorable uranium host. However, it is conceivable that the thick calcrete layer in the older alluvium contains minor concentrations of uranium; similar calcretes elsewhere in the Mojave Desert region are known to host subeconomic uranium deposits (Carlisle, 1978). In support of this possibility, a prominent uranium gamma-ray high along the western margin of the McCoy Mountains just outside the wilderness study area (near the prospect at locality 87, pl. 1) coincides with a large area of older alluvium, and a less prominent high coincides with older alluvium in the main wash south of the Palen Mountains (LKB Resources, Inc., 1979).

Manganese

Manganese deposits, most of which occur along faults and fractures within the Jurassic rhyodacite unit that underlies the McCoy Mountains Formation, are present a short distance north and northeast of the Palen-McCoy Wilderness Study Area. However, there is no obvious sign of manganese mineralization within the wilderness study area. The manganese resource potential of the area is therefore low with a C certainty rating.

Clay

The clay deposit in the southwestern corner of the wilderness study area is thin, silty, and not easily accessible. For these reasons the resource potential of the area for clay is low with a C certainty rating.

Oil and Gas

Pre-Tertiary rocks throughout southeastern California, including those in the wilderness study area, have generally low resource potential for oil and gas because of regional Mesozoic tectonism and metamorphism (Scott, 1982). Tertiary rocks such as those exposed in the southwest corner of the wilderness study area may have limited potential for oil and gas. However, because the subsurface extent of the Tertiary rocks within the wilderness study area cannot be determined from available data, the resource potential of the area for oil and gas is unknown.

Geothermal Energy

Warm water emanating from McCoy Spring provides an indication of geothermal activity in the Palen-McCoy Wilderness Study Area, but a lack of data prevents an adequate evaluation of the geothermal resource potential, which is therefore unknown.

Recommendations for Further Work

Further exploration in the southwestern Palen Mountains might reveal additional deposits of iron and pyrophyllite. Drilling could reveal the subsurface extent of known and undiscovered deposits, and further detailed aeromagnetic surveys could detect additional subsurface magnetite bodies. A detailed gamma-ray survey of the McCoy Mountains Formation in the Palen Mountains would provide the basis for a more certain resource potential assessment for uranium in this formation than can be made at present. Exploration in alluviated parts of the wilderness study area is needed to reveal the subsurface extent of the Tertiary rocks and help determine the resource potential of the area for oil, gas, and geothermal energy.

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APPENDIX 1. Definition of levels of mineral resource potential and certainty of assessment

Mineral resource potential is defined as the likelihood of the presence of mineral resources in a defined area; it is not a measure of the amount of resources or their profitability.

Mineral resources are concentrations of naturally occurring solid, liquid, or gaseous materials in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Low mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment where the existence of resources is unlikely. This level of potential embraces areas of dispersed mineralized rock as well as areas having few or no indications of mineralization. Assignment of low potential requires specific positive knowledge; it is not to be used as a catchall for areas where adequate data are lacking.

Moderate mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable chance for resource accumulation, and where an application of genetic and (or) occurrence models indicates favorable ground.

High mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resources, where interpretations of data indicate a high likelihood for resource accumulation, where data support occurrence and (or) genetic models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential requires positive knowledge that resource-forming processes have been active in at least part of the area; it does not require that occurrences or deposits be identified.

Unknown mineral resource potential is assigned to areas where the level of knowledge is so inadequate that classification of the area as high, moderate, or low would be misleading. The phrase "no mineral resource potential" applies only to a specific resource type in a well-defined area. This phrase should not be used if there is the slightest possibility of resource occurrence; it is not appropriate as the summary rating for any area.

Expressions of the certainty of the mineral resource assessment incorporate a consideration of (1) the adequacy of the geologic, geochemical, geophysical, and resource data base available at the time of the assessment, (2) the adequacy of the occurrence or genetic model used as the basis for a specific evaluation, and (3) an evaluation of the likelihood that the expected mineral endowment of the area is, or could be, economically extractable.

Levels of certainty of assessments are denoted by letters, A–D (fig. 3).

A. The available data are not adequate to determine the level of mineral resource potential. Level A is used with an assignment of unknown mineral resource potential.

B. The available data are adequate to suggest the geologic environment and the level of mineral resource potential, but either evidence is insufficient to establish precisely the likelihood of resource occurrence, or occurrence and (or) genetic models are not known well enough for predictive resource assessment.

C. The available data give a good indication of the geologic environment and the level of mineral resource potential, but additional evidence is needed to establish precisely the likelihood of resource occurrence, the activity of resource-forming processes, or available occurrence and (or) genetic models are minimal for predictive applications.

D. The available data clearly define the geologic environment and the level of mineral resource potential, and indicate the activity of resource-forming processes. Key evidence to interpret the presence or absence of specified types of resources is available, and occurrence and (or) genetic models are adequate for predictive resource assessment.

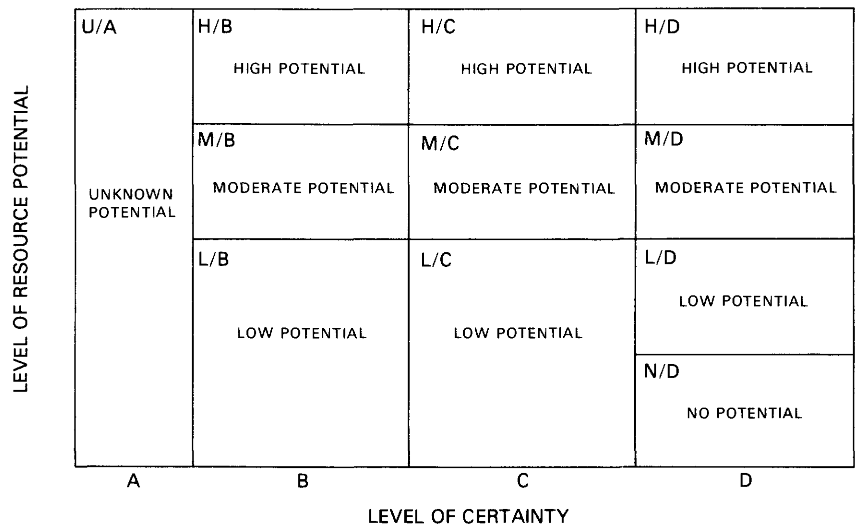

Figure 3. Major elements of mineral resource potential/certainty classification.

Table 1. Composition of pyrophyllite from the White Magic prospect compared to that of theoretically pure pyrophyllite. LOI, loss on ignition; < , less than; —, not present.

Oxide	Weighted average of three samples from trench and adit (percent)	Theoretically pure pyrophyllite (percent)
SiO_2	62.8	66.7
Al_2O_3	22.1	28.3
Fe_2O_3	2.6	---
Na_2O_3	1.08	---
TiO_2	.81	---
SO_3	.34	---
CaO	.23	---
K_2O	.08	---
MgO	.03	---
P_2O_5	<.23	---
H_2O^+	.05	5.0
LOI	5.6	---