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MINERAL RESOURCE POTENTIAL OF THE CHEMEHUEVI MOUNTAINS WILDERNESS STUDY AREA (CDCA-310), SAN BERNARDINO COUNTY, CALIFORNIA

SUMMARY REPORT

By

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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 their mineral resource potential. 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 Chemehuevi Mountains Wilderness Study Area (CDCA-310), California Desert Conservation Area, San Bernardino County, California.

SUMMARY

Geologic, geochemical, and geophysical evidence, together with a review of historical and modern mining and prospecting activities, suggests that all of the Chemehuevi Mountains Wilderness Study Area has a low potential for the occurrence of mineral and energy resources. Possible resources considered include base and precious metals, building stone and aggregate, fossil fuels, radioactive-mineral resources, geothermal resources, and chemical sources for fertilizer. Sparsely distributed mineralized areas of low mineral resource potential consist of small copper-barite-silver vein systems carrying minor lead, gold, and zinc. The veins are associated with Tertiary fault breccia and quartz veins in Proterozoic(?) gneiss.

INTRODUCTION

The Chemehuevi Mountains Wilderness Study Area is in San Bernardino County, southeastern California, in the Chemehuevi Mountains and adjacent lowlands of the Chemehuevi Wash (fig. 1). The study area lies about 11 mi south of the town of Needles and encompasses an area of approximately 86,500 acres that adjoins, along its east border, both the Havasu National Wildlife Refuge and the Chemehuevi Indian Reservation. The study area was examined in a cooperative survey to evaluate the potential for mineralization. The U.S. Bureau of Mines (USBM) studied the mineral resources of mines and prospects and the U.S. Geological Survey (USGS) conducted geologic, geochemical, and geophysical surveys to determine the extent of mineralization associated with the mines and prospects and to determine whether previously unknown resources occur in the study area.

The study area occupies rocky, mountainous terrain covered by desert vegetation and is traversed by Trampas Wash, which flows eastward into the Colorado River. Elevations range from approximately 500 ft near the Colorado River to 3,697 ft on Chemehuevi Peak. Access into the study area is gained by an unimproved dirt road that leads southeastward from Lobecks Pass on State Highway 95, and by a graded dirt road leading to a well westward from the town of Havasu Lake (fig. 1). Roads parallel the north, west, and south boundary of the study area, but access from the east is limited to entry from the Colorado River or the Chemehuevi Indian Reservation.

Geologic setting

The Chemehuevi Mountains Wilderness Study Area is underlain mainly by Proterozoic(?) and Mesozoic crystalline basement rocks. These rocks are grouped into an older, Proterozoic(?) suite of layered gneiss, schist, and migmatite, an intermediate-age deformed plutonic suite of Mesozoic intrusive rocks, and a younger suite of undeformed Mesozoic plutonic rocks. Tertiary volcanic and sedimentary rocks lie above low-angle normal faults cutting crystalline basement, and flank the range. Quaternary sedimentary deposits fringe the mountains along the margin of the study area. The structure of the range is dominated by multiple low-angle faults separating crystalline and stratified rocks above the faults from crystalline rocks below. Alteration and mineralization are confined to the Proterozoic(?) rocks and to the vicinity of breccia zones cutting these rocks, except for a fossil geothermal system that contains siliceous deposits.

Mining activity

At the time of the field investigation (1982), there was no evidence of current mining activity within the study area; however, several blocks of claims within a few miles of the study-area boundary were on file with the U.S. Bureau of Land Management (BLM) as of July 1982 (fig. 2). One of these blocks, the Desert claims, located southwest of the study area along Chemehuevi Wash in T. 4 N., R. 22 E., is reported to contain substantial placer gold (Mining Record, 1982).

Early prospectors probably first visited the area in the latter part of the 19th century, although there is no definite evidence of their presence there. It is not known when the major activity that resulted in the one inactive mine and the few scattered prospects occurred. No production is known from these workings.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geology

Lithologic units

Gneiss and granite

A suite of felsic gneiss and granite (unit gn) occurring only in the upper plate of the Chemehuevi fault, contains porphyritic granite, quartz monzonite, and monzodiorite, and fine-grained leucocratic orthogneiss and paragneiss; lesser amphibolite and coarse-grained augen gneiss occur locally. The porphyritic granite and related rocks are part of a distinctive suite with compositional, textural, and mineralogic affinities to intrusive rocks 1.4 to 1.5 b.y. old in the region (see Davis and others, 1980). The entire suite is intruded by coarse-grained pegmatite dikes and quartz veins.

Layered gneiss

Layered locally migmatitic quartzofeldspathic gneiss (unit MzPlg) of amphibolite facies is exposed in the northern, east-central, and southeastern parts of the study area. This Proterozoic(?) assemblage consists of biotite-bearing quartzofeldspathic gneiss and subordinate coarse pegmatite, interlayered augen gneiss, amphibolite, gabbro or diorite, and quartz veins. The assemblage is lithologically similar to Proterozoic rocks in the Whipple Mountains (Davis and others, 1980). Discordant sheetlike intrusions of muscovite-garnet monzogranite, biotite granodiorite, and hornblende-biotite monzodiorite that crop out in Bat Cave Wash, though probably Mesozoic on the basis of lithologic correlation, are here included in the layered-gneiss assemblage.

Rocks within the layered-gneiss assemblage have undergone a complex history of metamorphism, intrusion, and deformation. The assemblage as a whole is characterized by a varyingly dipping north- to northeast-striking foliation and, locally, by a penetrative subhorizontal northeast-trending mylonitic lineation and associated mylonitic foliation. The layered gneiss forms the country rock for the large Mesozoic intrusions that underlie the central and western parts of the study area.

Deformed plutonic suite

Foliated lithologically heterogeneous mafic plutonic rocks (unit Mzd), including gabbro or diorite, monzodiorite, quartz monzodiorite, and granodiorite, intrude the layered gneiss in the northern, eastern, and southern parts of the study area. Rocks of this assemblage are varyingly foliated and commonly bear a penetrative northeast-trending mylonitic lineation. Although no geochronologic data are available, these rocks are believed to be Mesozoic on the basis of crosscutting relations with the layered gneiss and of similarities with intrusive rocks known to be Mesozoic in the Whipple Mountains (Davis and others, 1980).

Undeformed plutonic suite

The undeformed plutonic suite (units Kpg and Kg) crops out in the western half of the Chemehuevi Mountains and underlies more than two-thirds of the study area. Porphyritic biotite granodiorite to monzogranite is the older and more voluminous of the two phases in the undeformed plutonic suite. Younger, crosscutting two-mica monzogranite occurs in a discrete body and as dikes of garnet-bearing muscovite-biotite monzogranite. These dikes, with associated quartz veins, are interpreted as representing late-stage magmatic fluids derived from the youngest, two-mica monzogranite phase. Limited geochronologic data and a lithologic similarity to dated plutonic suites in the Whipple Mountains suggest a Cretaceous age for the undeformed plutonic suite (John, 1982).

Tertiary volcanic and sedimentary rocks

In the western part of the study area, the undeformed plutonic suite is cut by hypabyssal and volcanic dikes of varying composition that parallel joint sets in the Mesozoic plutonic rocks. In the absence of geochronologic data, dikes of this swarm are presumed to be predominantly Tertiary, although some dikes could be as old as Late Cretaceous (John, 1982).

Tertiary volcanic and nonmarine sedimentary strata, generally tilted southwest along northeast-dipping normal faults, crop out along the periphery of the study area. These strata are predominantly Miocene on the basis of the K-Ar ages of equivalent strata in the vicinity, although some older strata may be Oligocene (Davis and others, 1980). Along the south and west margins of the study area, basalt, latite, andesite, dacite, and rhyolite flows, overlain by olivine-bearing basalt and rhyolitic welded tuff, crop out. Deposits of chalcedony and calcified material, possibly hot-spring deposits, that crop out locally above this tilted Tertiary volcanic sequence may be Tertiary or Quaternary. The Tertiary stratigraphic section in the eastern Chemehuevi Mountains resembles that in the western and southern parts of the study area but includes more monolithologic breccia, conglomerate, sandstone, and siltstone. This entire volcanic sequence pre-dates at least some of the detachment faulting.

Flat-lying (postdetachment faulting) marl, clay, silt, and sand assigned to the Pliocene Bouse Formation unconformably overlie the tilted Tertiary section at the mouth of Trampas Wash along the east margin of the study area (Metzger, 1968). These deposits are of shallow marine origin.

Quaternary deposits

Fluvial deposits of sand, silt, clay, and Colorado River cobbles of the Pleistocene Chemehuevi Formation (Longwell, 1963) occur in the southeast corner of the study area. Unconsolidated to consolidated alluvium and colluvium, and dissected deposits of older alluvium consisting of sand and gravel, crop out in valleys throughout the study area.

Structure

The most conspicuous structural feature in the study area is the Tertiary low-angle detachment fault (the Chemehuevi Mountains detachment fault) that flanks the range and separates allochthonous Proterozoic(?) to Miocene rocks cropping out along the exterior parts of the range from autochthonous Proterozoic(?) to Mesozoic crystalline rocks in the interior. Although separation along the Chemehuevi Mountains detachment fault is poorly constrained in the Chemehuevi Mountains, the probably equivalent structure to the south, the Whipple Mountains fault, is inferred to represent tens of miles of northeastward relative movement of the upper plate (Davis and others, 1980; Carr, 1981). Structurally below the Chemehuevi Mountains detachment fault lies another low-angle fault, the Mohave Wash fault, which has approximately 2 mi of strike separation with northeastward relative movement of upper-plate rocks (John, 1982). Conspicuous steeply northeast dipping normal faults cut this structurally deeper fault and the crystalline rocks below it, in the interior of the study area. Gouge and (or) breccia of varying thickness (max 330 ft), associated with both of the Tertiary detachment faults, apparently acted as a locus for mineralization.

Potential sources for mineralization

Several geologic settings commonly favorable elsewhere for the occurrence of significant mineral deposits also occur in the Chemehuevi Mountains Wilderness Study Area. Nonetheless, large deposits of precious or base metals and energy minerals have not been found. Sites favorable for mineralization might be expected in the following geologic environments: (1) The layered gneiss and the deformed plutonic suite, which contain quartz veins and pegmatitic segregations; (2) late Mesozoic intrusive rocks of the undeformed plutonic suite; (3) altered Tertiary volcanic rocks; (4) zones of faulting and intense fracturing, where the rocks may have been altered by hydrothermal fluids; (5) fossil-hot-spring deposits; and (6) placer deposits in gravel adjacent to the range.

1. The layered gneiss and the deformed plutonic suites show no evidence of significant mineralization. In these rocks, zones of alteration, pegmatite, and quartz veins are rare. Geochemical analyses of rock and sediment samples taken from areas underlain by these rocks show no anomalous concentrations of metals.
2. Granitic rocks of the undeformed plutonic suite are not mineralized significantly within the study area. However, rare quartz veins carrying white mica±hematite occur along some joints cutting porphyritic granodiorite in the west half of the study area, north of Chemehuevi Peak. Sparse coarse-grained muscovite-garnet pegmatite dikes associated with the youngest intrusions might be expected to be enriched in rare-earth elements; however, no elevated concentrations were recognized in geochemical analyses of stream sediment collected from drainages underlain by these bodies.
3. Alteration and mineralization of Tertiary volcanic rocks is common in areas surrounding the wilderness study area. Rocks of this type within the study area are locally intensely fractured and altered to argillic rocks. However, the alteration is not spatially systematic, no associated mineralization has been recognized, and geochemical analyses of stream sediment derived from altered volcanic rocks show no anomalous concentrations.
4. Copper and manganese mineralization occurs locally along sheared zones and faults cutting all types of crystalline rocks, both above and below the major low-angle faults. Copper stain, rare copper hydroxide minerals, and reniform pyrolusite are typical of this local mineralization. Intense limonitic alteration is common just above the Chemehuevi Mountains detachment fault, where the fault surface is defined by brecciated copper- and manganese-bearing oxides cementing the main fault surface, and extends into a zone upward about 15 ft. Similar copper and manganese associations are developed rarely along northeast-dipping normal faults within the layered gneiss and the deformed plutonic suite in the vicinity of Whale Mountain.
5. Localized exposures of chalcedony, selenite, and associated calcareous material crop out unconformably above the Tertiary sequence in the southern part of the study area. These deposits may be remnants of deposits left by a now-inactive thermal-spring system and thus could be a source of gold and mercury mineralization. However, no associated mineralization or elevated concentrations of metals have been found to date; in fact, no data specifically indicate that the deposits are thermal in origin.
6. Gravel and sand adjacent to the Chemehuevi Mountains are locally being prospected for gold. The absence of any known gold source in the Chemehuevi Mountains and evidence that the fans surrounding the range are locally derived indicate that the likelihood of placer deposits in the study area is poor.

Geochemistry

In April 1981 and March 1982, 160 geochemical samples were collected in and near the Chemehuevi Mountains Wilderness Study Area in a reconnaissance study by J. C. Antweiler to assess the mineral resource potential. These samples consisted of 65 fine-grained (minus 80 mesh) stream-sediment samples, 31 panned concentrates of stream-sediment samples, 53 rock samples, 7 mineralized-rock samples, and 4 water samples. In addition, 50 samples were collected and analyzed in 1978 by the USGS, and the data stored on magnetic tape in the Rock Analysis Storage System (RASS); the samples consisted of stream sediment sieved to pass a 200-mesh sieve, 15 panned concentrates collected at the same sites, and 20 rock samples. During the geologic-mapping studies, one of us (B. E. John) collected about 25 additional rock samples to assist in studying the geochemical aspects of the mineral resource potential of the area.

Fine-grained stream sediment and panned concentrates of stream sediment were collected from most of the main drainages; only the minus-80-mesh fraction of the stream sediment was analyzed. Rock samples were collected from outcrops and in mineralized or hydrothermally altered areas. Mineralized rocks were collected from six prospects within the study area and from the Needles district outside the study area to determine mineral suites and trace-element signatures of mineralized systems. All the rock samples, stream-sediment samples, and panned-concentrate samples were analyzed for 31 elements by the semiquantitative emission spectrographic technique of Myers and others (1961). The panned concentrates and mineralized-rock samples were analyzed for gold, and the rock and stream-sediment samples for Cu, Pb, Zn, Ag, Sb, Cd, and Bi by the methods of Ward and others (1969) and Viets and others (1979). The analytical data were stored on magnetic tape in RASS (J. C. Antweiler, unpub. data, 1982). Water samples were analyzed for Cu, Pb, Zn, U, Cl^-, F^-, and SO_4^{2-}, using the methods of Miller and others (1982).

Analyses of stream sediment and concentrates of stream sediment from the principal drainages resulted in the identification of several source areas (fig. 3; table 1) with apparently anomalous concentrations of Ba, Pb, Mo, Sn, Zn, and rare-earth elements, and a few with geochemically anomalous concentrations of Ag, W, and Th. The thresholds for geochemically anomalous abundance levels for Ba, Cu, Pb, Sr, Hg, and V were based on breaks in slope in plots of element concentrations versus cumulative frequency. The abundance levels for Ag, Au, Mo, Sn, W, and Zn were considered anomalous if the analytical values reported were at or above the detection limit. Nearly all these anomalies were in samples of the heavy fraction of panned concentrates—all of them rather rich in barite. Water from springs near the Chemehuevi detachment fault in Mohave Wash and near the northeast corner of the study area was geochemically anomalous in U (35-45 ppb), but delayed-neutron-activation analysis of other samples failed to disclose anomalous uranium concentrations except along the east boundary of the study area in sec. 16, T. 4 N., R. 24 E. Bedrock samples from the major geologic units throughout the study area were found by chemical analysis to contain the typical geochemical abundances for the rock types represented except in the vicinity of the detachment faults or in the vicinity of mineralized areas. Minerals identified in the panned concentrates include abundant barite and lesser monazite, wulfenite, powellite, sphene, scheelite, and (in the southeastern part of the study area) thorite. All these minerals are relatable to heavy minerals in the felsic rocks, particularly the granite and granite gneiss, and are easily concentrated by panning. Overall, their abundance in the panned concentrates is too small and sporadic to suggest mineralization of possible importance. Samples collected near intrusive contacts are generally not mineralized, nor are the abundant dikes.

The only geochemical anomalies that appear to be related to mineralization are those in samples collected in the immediate vicinity of prospects. The prospects (table 1) are characterized by veins that are generally narrow (less than 1 in. wide), and at many prospects, copper and silver are the metals of greatest enrichment. Barite is common in veins, and quartz is present in some veins; metallic minerals were generally not observed. Generally the veins may be described as Ba-Cu-Ag veins that may also include Pb, Zn, Au, and minor amounts of Bi and Mo. Ag is associated with nearly all the base-metal mineralization and in samples from one prospect averaged 70 ppm. Gold was detected in mineralized samples from one prospect in amounts as high as 50 ppm and in small amounts in some other prospects. Higher than background concentrations of Ba occur at most of the prospects, in both upper- and lower-plate rocks, as would be expected for Ba-Cu-Ag veins. Additionally, anomalous concentrations of Hg were present within all areas containing prospects and (or) anomalous concentrations of other elements.

Rock samples from possible thermal-spring deposits in the southeast corner of the study area yield no anomalous concentrations of Au, Ag, As, or Sb, which typically are associated with hot-spring gold deposits. Ba is in the normal range, and one sample contained slightly elevated concentrations of B and Mo. Elevated abundances of Hg in these samples are suggestive of mineralization in the area.

Remote sensing

As a part of the geochemical study of the Chemehuevi Mountains Wilderness Study Area, limonitic materials were identified in Landsat images by G. L. Raines (unpub. data, 1982), using a color-ratio-composite method (Rowan and others, 1974). This method was used to map areas of hydrothermal alteration associated with limonitic materials and to help define potential mineralized areas. The term "limonite," defined by Blanchard (1968 p. 7), is here used as a general term for hydrous iron oxide, but is modified to include any material with the unique spectral-reflectance properties of the ferric oxide minerals, such as hematite and goethite, as defined by Hunt (1980). The minerals pyrite and (or) hematite are commonly associated with hydrothermal alteration or zones of intensely oxidized rock that are potentially related to mineralization; these minerals weather to limonite, which is detected by this technique. Areas of hydrothermal alteration that lack limonitic materials are not detectable by this technique; however, such areas without limonite are believed to be insignificant.

All the areas defined as limonitic from the satellite analysis were visited and sampled selectively to determine whether the limonite is associated with hydrothermal alteration and, if so, with what type of alteration and (or) mineralization. The selected rock samples from limonitic areas were analyzed by a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968) to determine trace-element assemblages associated with mineralization, so as to help define the type and extent of any mineralizing process that could have caused the observed hydrothermal alteration. From these hydrothermal-alteration studies, several mineralized areas were identified, and the extent, distribution, and type of alteration were mapped.

On the basis of the methods described above, five areas of limonitic alteration were identified in the Chemehuevi Mountains Wilderness Study Area. Of these areas, four (M-4, M-5, M-8, M-9, fig. 3) are in the upper plate of the Chemehuevi Mountains detachment fault, associated with propylitic and argillic alteration that is widespread in that allochthon. Two areas (M-4, M-5) include the prospects described above; mineralization is believed to be of low concentration in these two areas on the basis of the geochemical studies described above. The third and fourth areas (M-8, M-9, fig. 3) include about 1 mi^2 of autochthonous rocks that are limonitically altered. Propylitic alteration is locally present, and a silver anomaly in altered-rock samples, slightly higher than background, was identified for area M-8; however, geochemical stream samples from the vicinity of this altered area yielded no anomalous values. Samples from area M-9 were rich in barium, probably owing to abundant barite in veins. In the fifth area (HS-2, fig. 3) identified by limonitic alteration, late solfataric alteration is present; here, abundant chalcedony suggests the former presence of possible fossil hot springs described previously.

Geophysical surveys

As a contribution to the mineral-resource evaluation, aeromagnetic and gravity maps of the Chemehuevi Mountains Wilderness Study Area were prepared by R. Simpson (unpub. data, 1982), and geoelectric studies were conducted by D. Hoover (unpub. data, 1982).

Gravity data

The Chemehuevi Mountains coincide with an area of high Bouguer gravity values relative to the surrounding valley areas. Within the mountain range, these values are lowest (less than -50 mGal) along the southwest and south sides in an area generally underlain by Cretaceous granitic rocks, higher (-50 to -45 mGal) to the east and northeast in an area underlain by Proterozoic(?) layered gneiss, and highest (greater than -45 mGal) in the northwest corner, where mafic igneous rocks of Mesozoic(?) age are exposed. Gradients in gravity values along the west, south, and east sides of the range separate the gravity high over the Chemehuevi Mountains from gravity lows over neighboring basins filled with low-density sedimentary and volcanic rocks of Tertiary and Quaternary age. The gravity data show no consistent relation to mineralized areas.

Aeromagnetic data

High magnetic-anomaly values (max 5,244 γ) in the northwest corner of the study area overlap the highest Bouguer gravity values. Dense and moderately magnetic Mesozoic(?) mafic igneous rocks exposed in this area could cause both anomalies, although magnetic Proterozoic(?) gneiss may also contribute to the magnetic high. A nearly identical pair of magnetic and gravity highs in the Whipple Mountains 25 mi to the southeast occur over small exposures of similar mafic rocks intruding magnetic Proterozoic gneiss (Marsh and others, 1982).

Aeromagnetic anomalies in the central part of the study area are, with a few exceptions, broad and subdued, features indicating that most of the Mesozoic granitic rocks and Proterozoic(?) gneiss exposed in this area are not particularly magnetic. A 5-mi-wide belt of low magnetic values (4,600-4,700γ) that trends N. 60° E. through the south-central part of the range approximately coincides with an anticline defined by the traces of subhorizontal detachment faults. Extension of this aeromagnetically low belt about 8 mi to the southwest into part of the Chemehuevi Valley suggests the presence of similar rocks under the valley.

The aeromagnetically low belt is bounded on its southeast side by a gradient with aeromagnetic values that are higher by about 100 to 150γ. This N. 60° E.-trending southeast boundary of the anomaly forms part of one of the longest and most conspicuous linear features on the aeromagnetic map of the Needles 1° x 2° quadrangle (U.S. Geological Survey, 1981). In the southern Chemehuevi Mountains, the gradient lies 0.5 to 1.0 mi southeast of the trace of the Mohave Wash detachment fault, which at that locality dips southeast. (In the Mohave Mountains, about 30 mi to the east, a detachment fault along the trend of the steep gradient dips northwest.) This aeromagnetic gradient and other parallel linear features on the aeromagnetic map of the east half of the Needles 1° x 2° quadrangle and in northern Arizona may delineate major structures in the Proterozoic basement.

Conspicuous northwest-trending aeromagnetic gradients immediately west of the study area parallel normal faults that cut the Tertiary volcanic rocks lying in an upper plate above the Chemehuevi detachment fault. Gradients with parallel trends inside the study area may mark similar normal faults cutting lower-plate rocks.

In the southeast corner of the study area, a sharp narrow north-south-trending aeromagnetic low (4,500 γ) overlaps an area of hydrothermal alteration. The alteration has probably destroyed the magnetic minerals and thus made the rocks nonmagnetic. The aeromagnetic low extends to the north and south of the most obvious surface manifestations of hydrothermal alteration, suggesting that altered rocks may extend to the north and south in the subsurface.

Electrical data

Electrical studies within and adjacent to the study area consisted of nine audiomagnetotelluric (AMT) soundings and an E-field-ratio telluric traverse. The AMT soundings were made over a frequency range of 4.5 to 27,000 Hz which in the study area gave information on earth resistivity from the surface to a depth of 3,000 to 15,000 ft. Because the depth of exploration is a function of both the earth resistivity and the frequency of the sounding, the maximum depth of exploration is not fixed. Details of the method and equipment were given by Hoover and others (1978). The telluric traverse was made at a single frequency centered at 0.033 Hz; thus, the measured electric fields were responsive to resistivity changes throughout most of the earth's crust. The best description of the method and equipment was given by Beyer (1977).

The AMT soundings were made on an approximately east-west-trending line across the central part of the study area, from Snaggletooth (fig. 1) on the west side, along Trampas Wash, to an area of limonitic alteration identified by G. L. Raines (area M-9, fig. 3). The lowest resistivity section seen was at Snaggletooth, west of the study-area boundary, where near-surface resistivities of 30 Ωm increase to more than 300 Ωm at a depth of 3,000 ft. This sounding is on a Tertiary intrusive body, and so the measured resistivities are lower than expected. The absence of significant mineralization, alteration, and geochemical anomalies associated with this intrusive body suggests that the low resistivities may be due to extensive fracturing. The increase in resistivity with depth is explainable as a normal consequence of fracture closure with increasing overburden pressure.

Igneous and metamorphic rocks structurally above the Chemehuevi Mountains detachment fault on the west edge of the study area were sampled by two soundings. On these soundings, the resistivity of several hundred ohm-meters in the near-surface increased to several thousand ohm-meters at depths of 6,000 to 9,000 ft. This behavior can be considered normal for such rocks, and the changes in resistivity would be due to fracture closure.

All other soundings were in rocks below the Chemehuevi Mountains detachment fault and, except for the very near surface resistivities, showed values generally higher than 1,000 m. A region of lower resistivity, with values slightly less than 1,000 m, was interpreted to lie at depths of 3,000 to 6,000 ft. This lower resistivity region could represent lithologic changes, or possibly increased permeability or porosity related to detachment faulting at depth. The easternmost sounding, which sampled the area of surficial limonitic alteration, showed no evidence of pervasive alteration at depth.

The AMT soundings did not reveal much detail about small structures because soundings, by their nature, sample relatively large volumes of rock. Thus, the soundings neither confirm nor deny the presence of small vein systems.

The telluric traverse used 1,640-ft dipole spacings and extended from lower-plate rocks south of Chemehuevi Peak within the study area, southward across Chemehuevi Wash, to the Whipple Mountains core complex, a distance of 14.3 mi (fig. 1). The traverse complements magnetic and gravity data from along the same line. Within the study area, resistivity lows correlate with known detachment faults, and the telluric data clearly identify the contact between upper-plate Tertiary sedimentary and volcanic rocks and lower-plate crystalline rocks. A narrow low-resistivity zone was identified in the lower-plate rocks that does not correspond well to mapped faults, although it does correlate with the south edge of a gravity high. These data appear to define a resistive and dense body within the lower-plate rocks that is not identified on the surface. There is no known evidence to connect this structure with mineralization.

MINING DISTRICTS AND MINERALIZATION

In February 1982, the USBM conducted a mineral investigation of the Chemehuevi Mountains Wilderness Study Area. Prior to field work, literature related to mining activity in the area and mining-claim records at the county courthouse in San Bernardino were searched to provide a historical overview of areas that have been prospected or mined. Mines, prospects, mineralized areas, and claims filed with the BLM that occur in, or within 1 mi of, the study-area boundary were examined, mapped, and sampled during the field investigation.

There are no organized mining districts within, or in the immediate vicinity of, the study area. The only known mine, the Blue Boy, is located in the central Chemehuevi Mountains, in an unsurveyed area. Four other prospects scattered throughout the study area were located and examined (fig. 2). Additional workings located east of Lobecks Pass were described above in the subsection entitled "Geochemistry" (area M-6, fig. 3).

The Blue Boy mine (area M-2, fig. 3) consists of a shaft, 40 ft deep, sunk along a vein in a brecciated zone in faulted gneissic granite. The breccia zone is heavily copper stained, with minor silicification of the hanging wall. Assays of samples 4 and 5 (table 2), chips taken across the vein and from the dump, respectively, indicate minor near-surface secondary enrichment in copper and gold. The fault on which the shaft was sunk is traceable on the surface for approximately 2 mi; local copper mineralization occurs south of the mine along this fault. No historical records of the Blue Boy mine have been found; therefore, production, if any, is unknown.

Approximately 1 mi south of the study area, a group of prospects are located in a cluster of low-lying hills of Tertiary volcanic rocks (fig. 2). These hills consist of a sequence of silicic ash-flow tuff and the prospects occur in a zone that consists almost entirely of silica. X-ray diffraction study of samples (8-10, fig. 2) shows the material to be primarily cristobalite and tridymite, with minor quartz and traces of kaolinite (table 3). The average SiO_2 content of the samples is 86 weight percent. A similar geologic environment occurs in the extreme southeast corner of the study area, but silica deposits have not been identified.

An open cut, 40 ft long, with two short crosscuts is located adjacent to the study area in sec. 36, T. 7 N., R. 22 E. (fig. 2). The open cut follows the trace of a vein striking N. 30° E. and dipping 50° SW. The vein consists primarily of quartz, with malachite, azurite, and chrysocolla as coatings on fracture surfaces and as vug fillings. Samples of the vein (1-3, table 2), contain minor amounts of copper. This vein could not be traced into the study area; however, similar mineralization occurs at the site of sample 6 (area M-1, fig. 3) within the study area.

The remaining prospect pit studied (fig. 2), in Trampas Wash, exposes mildly altered rock with secondary copper staining. The assay of sample 7 (table 2), from this prospect, shows a minor amount of copper.

In recent years, interest in the desert region of the Southwest as a uranium exploration target has grown considerably. Uranium has been mined from the Tertiary Artillery Formation approximately 50 mi east of the study area in Mohave County, Ariz., and from Cretaceous sedimentary rocks in the McCoy Mountains, 60 mi to the southwest in Riverside County, Calif. All the samples from the Chemehuevi Mountains were analyzed for uranium; however, none contained more than is considered typical for these rock types.

Oil and gas

Most of T. 5 N., R. 23 E. is covered by oil and gas lease applications (fig. 2). The basis for these lease applications is unknown; no oil or gas has been discovered in the region.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

On the basis of geologic examination of mines and prospects and assays of samples collected by the USBM, and of geochemical, geologic, and geophysical studies of the study area, particularly of the geologic environments surrounding the prospects and mines, by the USGS, the Chemehuevi Mountains Wilderness Study Area is determined to have a low potential for both base- and precious-metal deposits. The area does not have potential for other possible resources, which are not present in large enough quantities to be significant.

The potential for occurrence of mineral resources is here classified as high, moderate, or low. High mineral resource potential exists where all the conditions of a genetic model have been satisfied, and the necessary geologic processes and mineral concentration took place. Moderate mineral resource potential exists where the conditions of a genetic model have been satisfied but mineral concentrations are ambiguous or have not yet been found. Low mineral resource potential exists where evidence is absent to support a genetic model, an unfavorable combination of geologic factors exists, or mineral concentrations do not occur.

Favorability of geologic formations and structures, direct evidence for mineralization, and such indirect evidence as geochemical and geophysical anomalies were discussed above. In the following subsections we integrate these data to arrive at the mineral resource potential assessment. Figure 3 shows the study area, all of which is judged to have a low potential for occurrence of mineral resources. Outlined on figure 3 are areas in which prospects occur and where geochemical analyses indicate anomalous concentrations of elements; these areas are also described below.

Base and precious metals

Two broad areas of base- and precious-metal potential may be present in the Chemehuevi Mountains Wilderness Study Area. The first area, occurring in crystalline rocks at scattered localities (areas M-1 to M-9, fig. 3), is best described by a model for minor mineralization caused by a low- to moderate-temperature hydrothermal system spatially related to detachment faults and, less commonly, high-angle faults. Conceptually, such a mineralizing system, where present, might generate low-grade copper, silver, gold, lead, and zinc mineralization. Overall, the mineralization is not extensive, as shown by the areas containing geochemical anomalies in figure 3. The low-grade gold, silver, and copper mineralization exposed at the Blue Boy mine and at other prospects in the study area appears to be the result of near-surface secondary enrichment; even lower values should be expected at depth. The rocks in the Chemehuevi Mountains generally are remarkably free of any alteration associated with hydrothermal veins. Furthermore, there is no evidence of larger, high-tonnage, low-grade porphyry deposits.

The second possible mineralizing system is a hypothetical thermal-spring deposit in the southeast corner of the study area (area HS-1, fig. 3). Low silver and moderate mercury concentrations, solfataric alteration, and hot—springs-type chalcedony and calcareous deposits support such a model, but geochemical analyses in the area show no anomalous concentrations of other metals. Aeromagnetic anomalies partly coinciding with surface deposits suggest that alteration may extend to the north and south of the observed occurrences. This magnetically anomalous area is here designated "area HS-3," and the areas of limonitic alteration that were identified by remote sensing as area "HS-2" (fig. 3). All three of these areas have no geochemical anomalies sufficient to warrant an assessment other than a low potential. Silicification, represented solely by caps of siliceous rock, suggests that pervasive silicification does not extend to depth, and so any hypothetical mineralization is also unlikely to extend to depth.

The gold placer claims located southwest of the study area along Chemehuevi Wash (figs. 1, 2) are unlikely to mark a resource extending into the study area. Present claims extend from Chemehuevi Wash southwestward to an apparent source in the Turtle Mountains, where vein gold has been mined. Chemehuevi Wash has been stable as a low physiographic feature since the Pliocene, as indicated by outcrops of the Bouse Formation extending up the present Chemehuevi Wash. Therefore, it is improbable that gravel and sand derived from the Turtle Mountains once extended across the wash to the study area. No visible gold was detected in panned concentrates along the south and west margins of the study area, and Au analyses were negative. Therefore, there is no apparent potential for gold placer resources in the study area.

Radioactive-mineral resources

One uranium geochemical anomaly occurs in the southeast corner of the study area. Thorium shows slightly elevated concentrations in this area; thorite is common in panned concentrates. This geochemical anomaly is not large enough to indicate the possible occurrence of a resource.

Oil and gas

No known geologic structures in the Chemehuevi Mountains Wilderness Study Area are considered favorable for oil and gas. The Chemehuevi Mountains lie along the extrapolated trend of the western overthrust belt, which elsewhere in the Cordillera contains oil and gas in Paleozoic and Mesozoic strata. The possibility that similar overthrusts in the study area exist and conceal oil- or gas-bearing rocks is considered remote on the basis of geologic and geophysical data. Even if such rocks were present, they most probably would be metamorphosed and barren of oil and gas. Therefore, the potential for the occurrence of oil and gas is low.

Geothermal resources

The eastern Mojave Desert region is characterized by heat-flow values typical of the Basin and Range geologic province, which are higher than average crustal heat-flow values. Possible fossil thermal deposits in the southeastern part of the Chemehuevi Mountains Wilderness Study Area appear to be youthful because these deposits lie in present topographic depressions and apparently formed at the present surface. However, no direct constraints on the age of the deposits are available other than that they postdate the 18-m.y.-old-tuff on which they rest and that they are not presently active. Because it is possible that these deposits are youthful, a low potential for the occurrence of a geothermal resource (area G-1, fig. 3) is indicated for the southeastern part of the study area.

Rock products

Small deposits of common borrow, sand, and gravel are present along the south and east margins of the study area. Similar resources are far more extensive adjacent to the study area, where they also are more accessible. Therefore, a low resource potential is indicated.

Unconfirmed reports of mining of the Bouse Formation for nitrates indicate a possible resource where the formation crops out. A small exposure of the Bouse occurs in the southeastern part of the study area, but more extensive nitrate resources occur outside the study area.

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Table 1.--Selected analyses of mineralized samples from prospects in and near Chemehuevi Mountains Wilderness Study Area

[All values in parts per million; N, not detected]

Area (fig. 3)----- Prospect----------	M-1 Lobecks Pass	M-2 Blue Boy	M-3 Trampas Wash	M-4 Mohave Rock South	M-5 Quartz Queen	M-6 Northwestern Corner	M-7 BJ 74
Ag----------------	10	10	5	7	70	5	15
Au----------------	N	50	N	1.5	.1	N	N
Bi----------------	70	N	N	10	50	N	70
Ba----------------	700	>5,000	1,500	500	>5,000	200	20
Cu----------------	15,000	20,000	7,000	>20,000	5,000	10,000	5,000
Mo----------------	50	N	N	50	10	N	30
Pb----------------	100	200	50	100	20,000	150	20
Zn----------------	200	800	1,150	200	3,000	N	N
Co----------------	---	---	---	---	---	700	---

Table 2.--Analyses of samples from the Chemehuevi Mountains Wilderness Study Area
[Au and Ag determined by fire assay, Cu and Mn by atomic absorption, and U_3O_8 by fluorimetric analysis
See figure 2 for localities]

Sample			Assay data					
No.	Type	Width (ft)	Au (troy oz/ton)	Ag (troy oz/ton)	Cu (wt pct)	Mn (wt pct)	U_3O_8 (ppm)	Remarks
1	Chip	5.0	<.005	<.2	.07	.05	12	Quartz vein with malachite, azurite, and possbily, chrysocolla, in altered granodiorite in open cut.
2	Chip	5.1	<.005	<.2	.02	.05	22	Quartz vein in inclined shaft.
3	Select	--	<.005	<.2	.14	.02	8	Heavily iron stained quartz with copper and manganese staining from stockpile.
4	Chip	2.8	<.005	<.2	.10	.08	9	Blue Boy mine. Across vein, highly weathered gneissic granite with iron and copper staining, from shaft.
5	Grab	--	.028	<.2	.26	.05	28	Blue Boy mine. Random dump sample on 20-ft grid.
6	Chip	5.3	<.005	<.2	.01	.01	21	Granite with abundant quartz stringers, heavily iron stained, from prospect pit.
7	Chip	5.0	<.005	<.2	.46	<.01	33	Aplite dike in granodiorite containing abundant malachite and azurite, heavily iron stained, from prospect pit.

Table 3.--Analyses of samples from a silica prospect 1 mi south of the study area
[P determined by colorimetric analysis; all other elements by atomic absorption.
All values in weight percent. See figure 2 for localities]

Sample			Assay data							
No.	Type	Width (ft)	Si	Al	K	Na	Ca	Mg	P	Remarks
8	Chip	3.3	76	8.60	.15	.45	1.65	.6	.13	White siliceous material in volcanic rocks from open cut.
9	Chip	2.9	84	11.50	.03	.70	.10	.01	.05	Do.
10	Chip	5.6	97	.73	.01	.20	.10	.1	.01	Do.

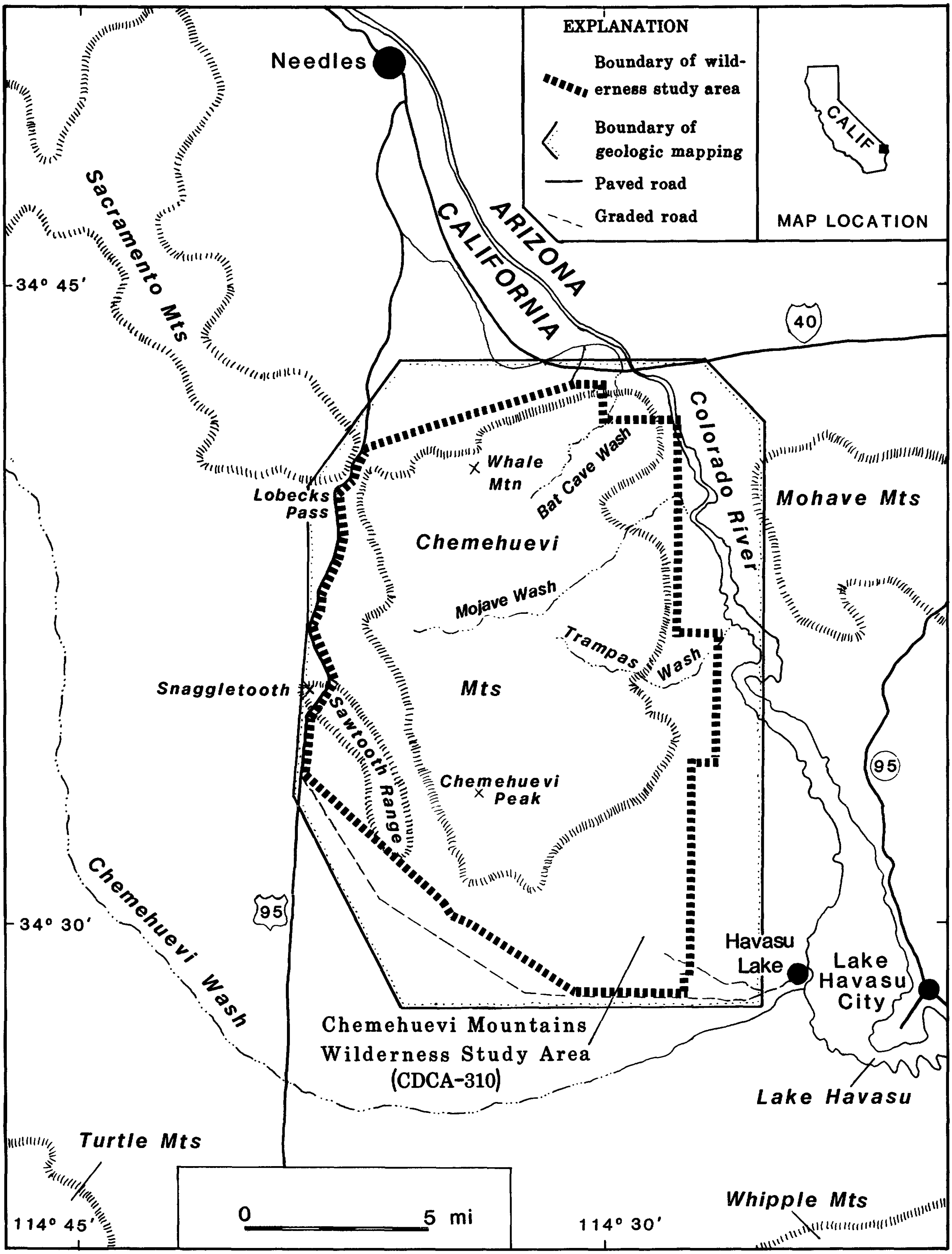

Figure 1. Index map of the Chemehuevi Mountains Wilderness Study Area (CDCA-310), showing study-area boundary and area of geologic map.

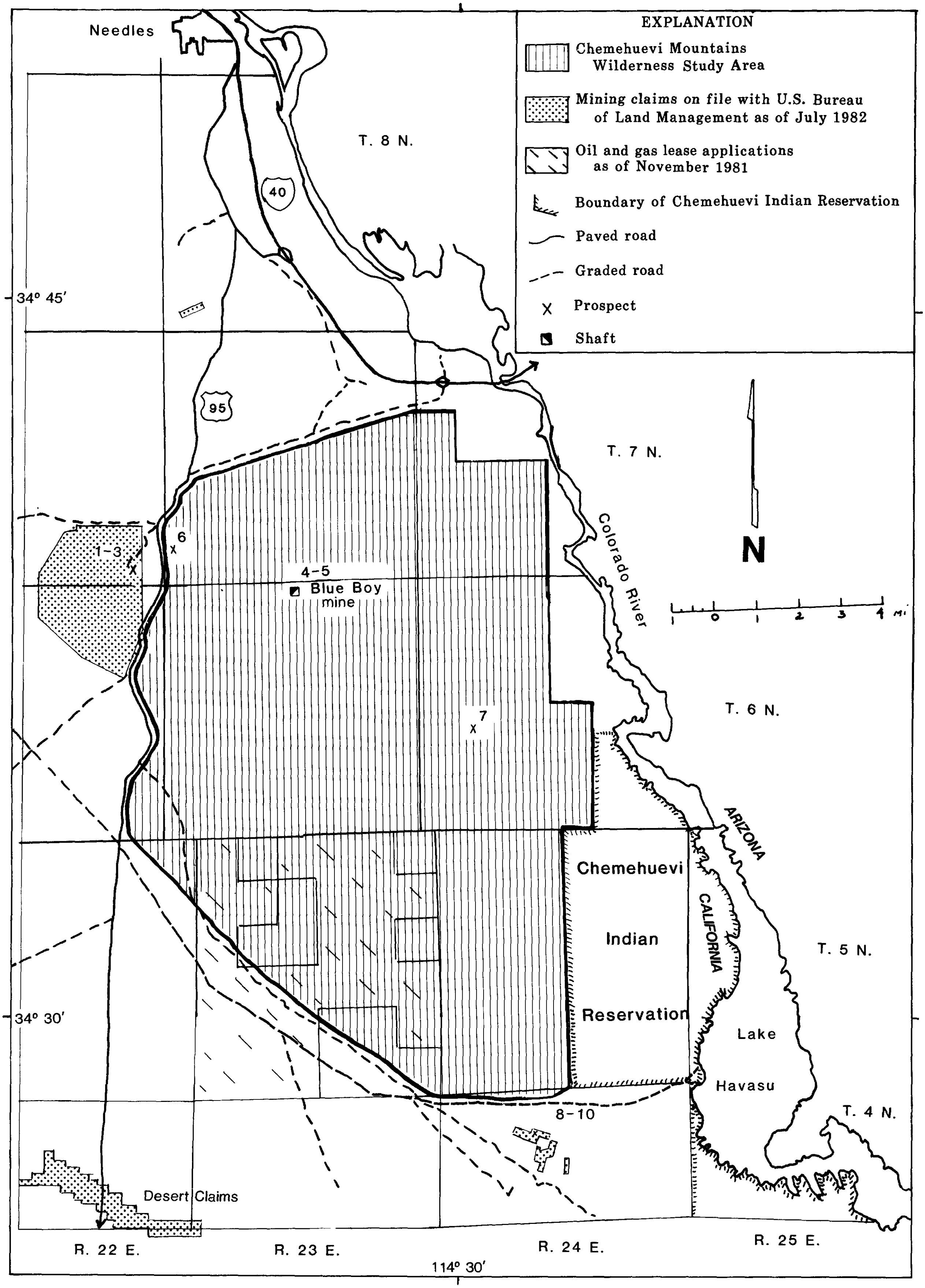

Figure 2. Chemehuevi Mountains Wilderness Study Area, showing mining claims, oil and gas leases, and localities of samples (nos. 1-10) listed in tables 2 and 3.

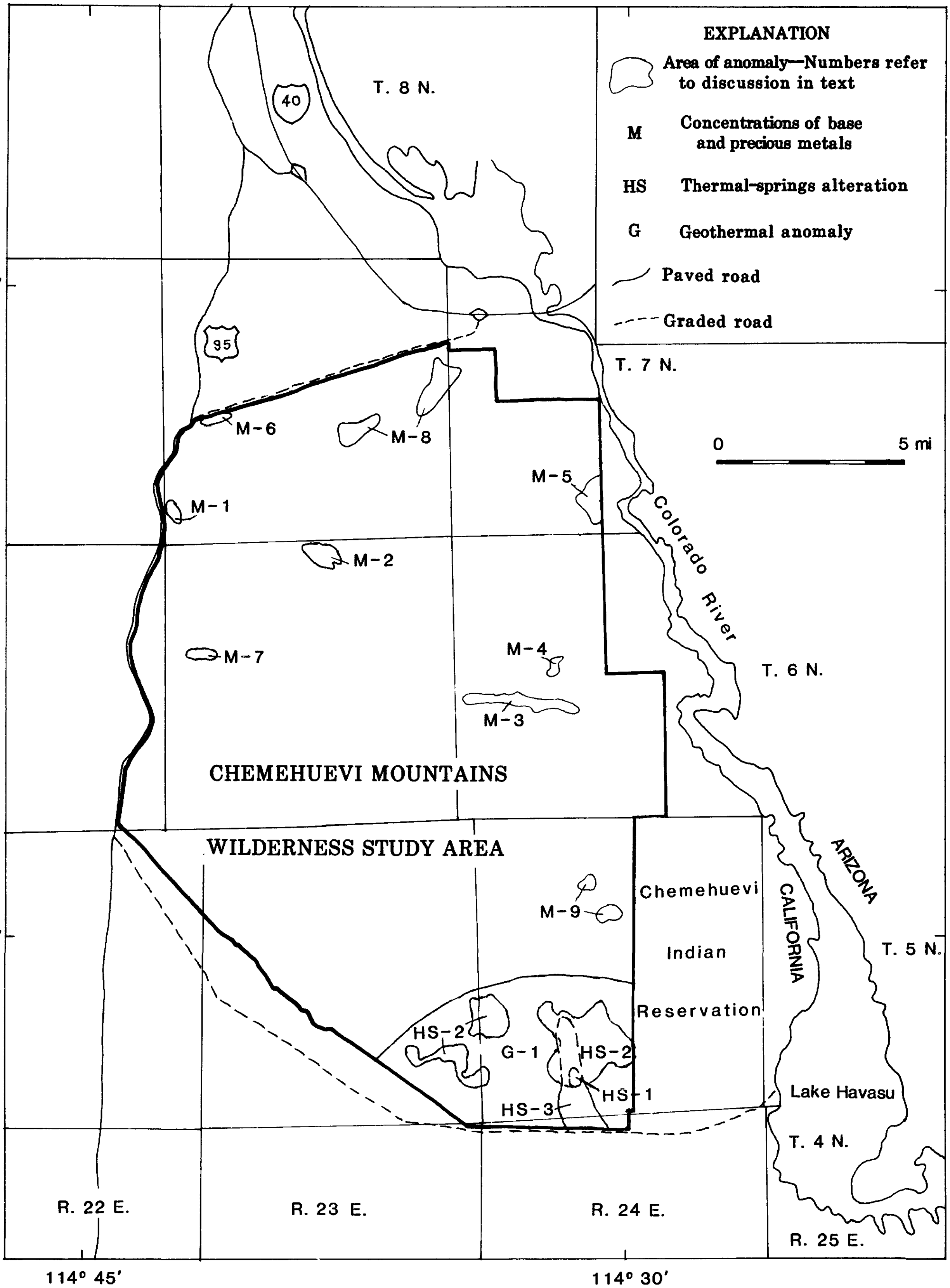

Figure 3. Mineral resource potential of the Chemehuevi Mountains Wilderness Study Area.