Mineral Resources of the Nopah Range Wilderness Study Area, Inyo County, California

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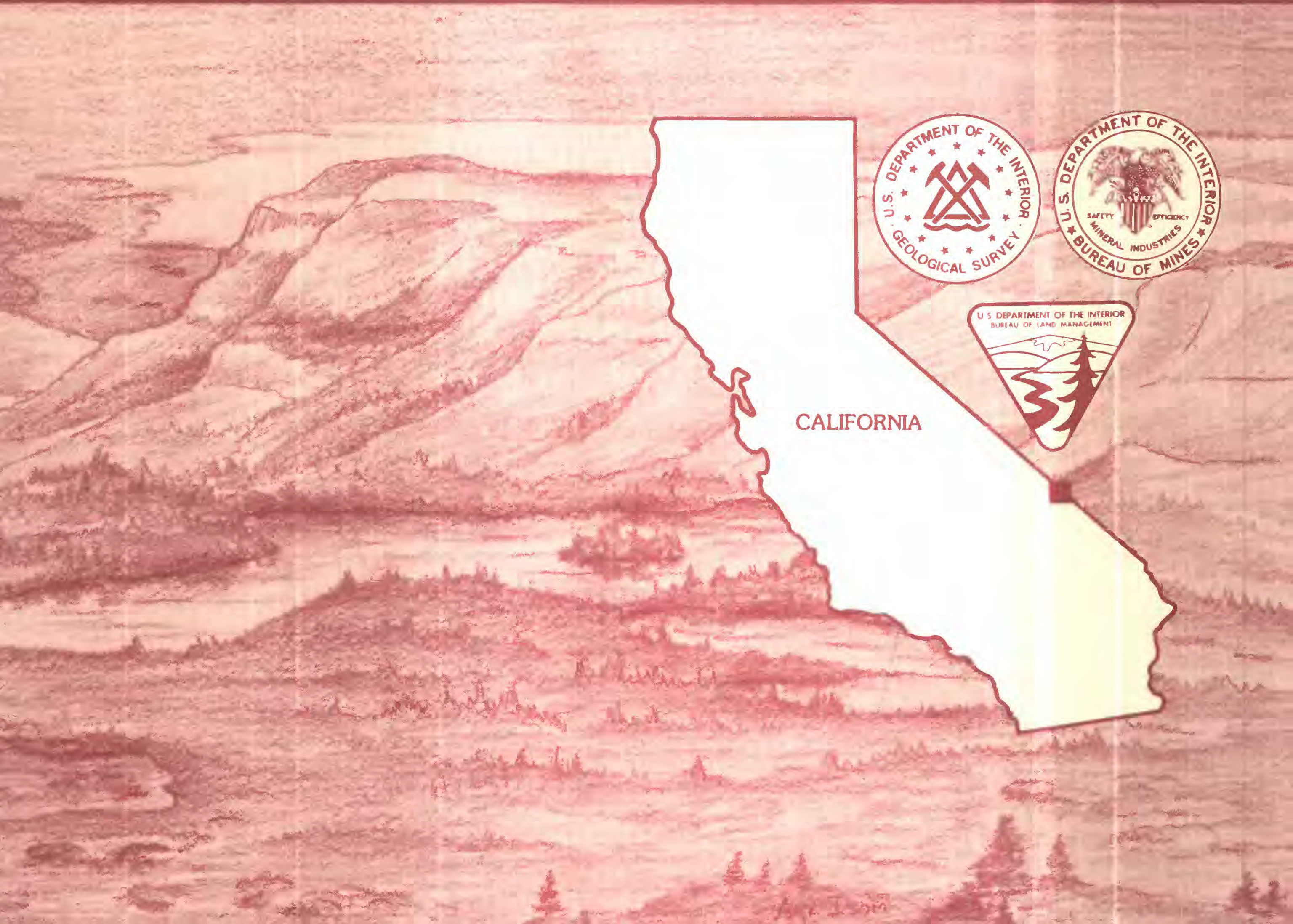

Chapter C

Mineral Resources of the Nopah Range Wilderness Study Area, Inyo County, California

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
NORTHEASTERN CALIFORNIA DESERT CONSERVATION AREA, CALIFORNIA

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Area

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 Nopah Range Wilderness Study Area (CDCA-150), California Desert Conservation Area, Inyo County, California.

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Mineral Resources of the Nopah Range Wilderness Study Area, Inyo County, California

By Augustus K. Armstrong, Cole L. Smith *and* George L. Kennedy

U.S. Geological Survey

Charles Sabine *and* Ronald T. Mayerle

U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the Bureau of Land Management, 109,061 acres of the Nopah Range Wilderness Study Area (CDCA-150) were originally designated for study by the U.S. Geological Survey and the U.S. Bureau of Mines. Subsequently, in 1983, the study area was decreased to the current 97,151 acres. This report presents the results of a mineral survey of part of the Nopah Wilderness Study Area. In this report, the area studied is referred to as "the wilderness study area," or simply "the study area."

There has been little mining activity in the region. Workings within and near the wilderness study area consist of one mine, three prospects, and one zeolite occurrence, none of which has identified resources. Four localities within the revised study area have mineral resource potential: (1) a 3-mi-long area on the northwest side of the Nopah Range with moderate resource potential for undiscovered silver, lead, and zinc resources; (2 and 3) two areas on the southeastern side of the study area have low resource potential for undiscovered silver and lead resources, and (4) an area on the east-central side of the range has low resource potential for gold, molybdenum, and lead resources. In the southern part of the Resting Spring Range west of the study area, one area has low potential for copper and 2 areas have low potential for zeolite (clinoptilolite). The resource potential for copper is unknown within the study area. The resource potential for borates and (or) zeolites in the Chicago Valley is unknown. There are numerous limestone, quartzite, and sand and gravel deposits in the study area. However, the resource potential of these commodities is low. The mineral resource potential for oil and gas and geothermal energy is low in the study area.

Character and Setting

The Nopah Range Wilderness Study Area is located in southeastern Inyo County, California, approximately 15 mi east of the south end of Death Valley National Monument and 2 mi southwest of the California-Nevada border (fig. 1). The study area lies within the Basin and Range geomorphic province and encompasses most of the Nopah Range, the southernmost part of the Resting Spring Range, and the intervening part of Chicago Valley. The Nopah Range, underlain predominantly by carbonate rocks of Cambrian through Pennsylvanian (see geologic time chart in appendix) age, 570 to 290 million years before the present (Ma), is characterized by deep canyons, ridges, and rugged topography; precipices of 1,000 ft or more are common. By contrast, the southern part of the Resting Spring Range, which is underlain predominantly by Late Proterozoic fine-grained terrigenous sedimentary rocks, is more subdued topographically. Minor amounts of volcanic rocks are present in both ranges. The flanks of the ranges are marked by coalescing alluvial fans that merge with lacustrine deposits in the surrounding valleys. Elevations in the area range from 1,800 ft at the south end of Chicago Valley to 6,394 ft on Nopah Peak.

Mining activity in the study area has been very limited, and only the Nancy Ann mine (fig. 2) has a history of production.

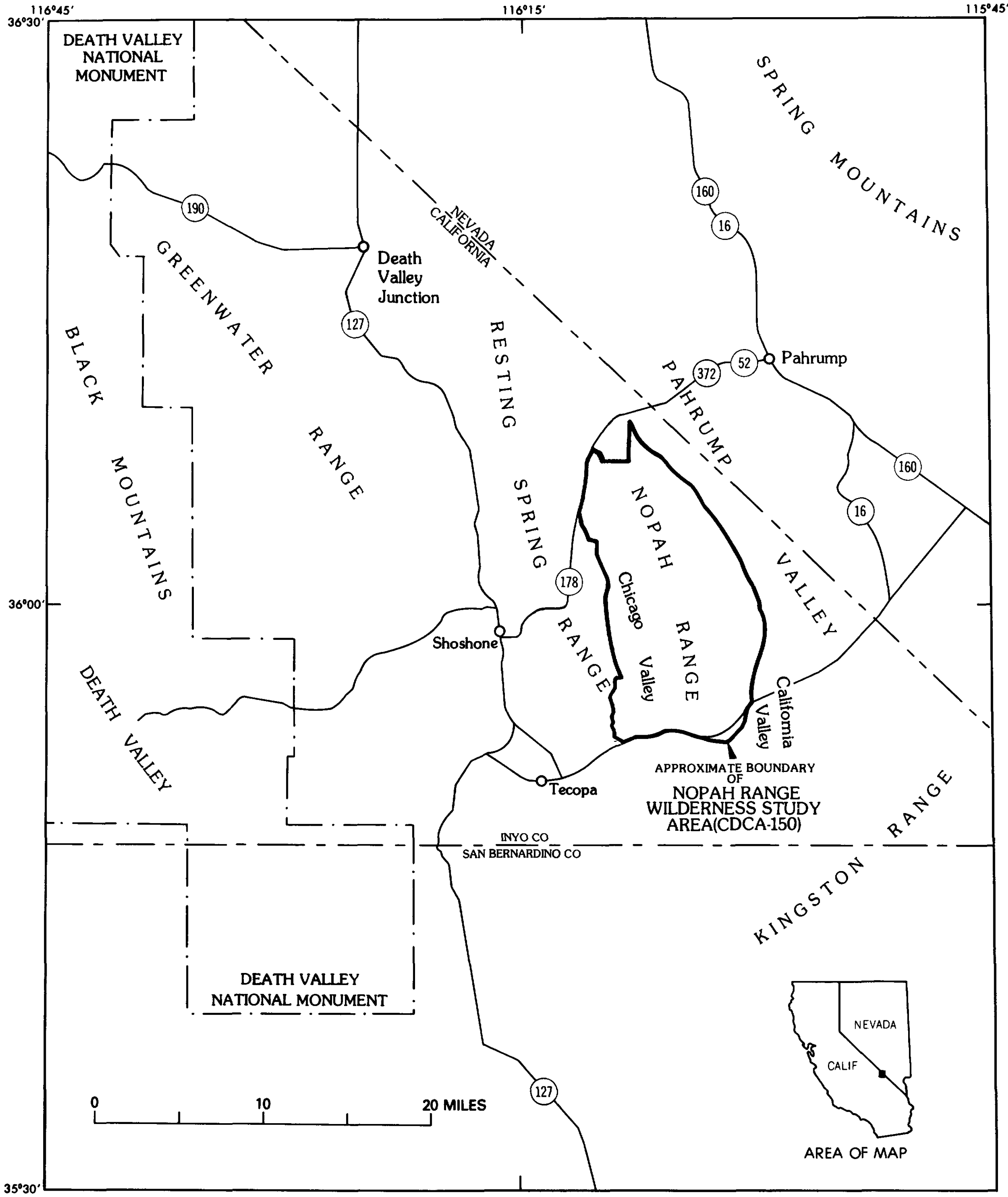

Figure 1. Index map showing location of the Nopah Range Wilderness Study Area, Inyo County, California.

Identified Resources

None of the mines or prospects in the study area have identified mineral resources. At the Nancy Ann mine (fig. 2), approximately 490 tons of mineralized rock are left in the old workings and an additional 290 tons are still on the dump. This material contains an estimated 650 oz of silver, 20,000 lb of lead, and 63,000 lb of zinc; at current (1986) market values, this is insufficient to warrant mining and does not constitute an economic resource.

Miocene tuff in the Resting Spring Range contains less than 100,000 tons of zeolitized material that averages 63 percent (±20 percent) zeolite clinoptilolite (fig. 2). The deposit is currently too small to be an economic resource.

Carbonate rocks underlie most of the Nopah Range; a major deposit (greater than 20 million tons) of limestone on the northwest side of the Nopah Range was identified by Bowen (1973, pl. 1). This deposit is far from large markets and is not likely to be developed in the foreseeable future. Existing quarries in the Spring Mountains, east of the study area, will most likely continue to meet limestone requirements for local markets.

Sand and gravel are plentiful in the study area, but alternate sources are readily available closer to local markets.

Mineral Resource Potential

Mineral resource potential in the study area was evaluated on the basis of investigations conducted by the U.S. Geological Survey from 1981 to 1983 and by the U.S. Bureau of Mines in 1983. Mineral resource potential was determined for lead, silver, copper, zinc, gold, molybdenum, and the zeolite clinoptilolite (fig. 2). There are numerous limestone, quartzite, and sand and gravel deposits in the study area that are suitable for construction use.

The study area lies within an extensive mineral province that is characterized by hydrothermal deposits containing lead, zinc, silver, and gold. Most silver, gold, copper, lead, and zinc in the study area is of hydrothermal origin and was deposited along faults and fracture systems in Paleozoic carbonate rocks of the Nopah Range. A three-mile-long area on the northwest side of the Nopah Range has a moderate resource potential for silver, lead, and zinc (fig. 2). Two areas on the southeast side of the range have low resource potential for silver and lead. One area on the east-central side of the range has low resource potential for gold, molybdenum, and lead. There are 2 acres of low resource potential for the zeolite mineral clinoptilolite in the south-central part of the Resting Spring Range west of the study area. The southern part of the Resting Spring Range has an area of low potential for copper; resource potential for copper is unknown within the study area. The resource potential for borates and (or) zeolites in Chicago Valley is unknown.

An area of low resource potential for quartzite, limestone, and sand and gravel is present along the northwest side of the Nopah Range.

The resource potential for oil and gas and geothermal energy in the study area is low.

INTRODUCTION

Area Description

At the request of the Bureau of Land Management, 109,061 acres of the Nopah Range Wilderness Study Area (CDCA-150) in the southeast corner of Inyo County, California (fig. 1) were originally designated for study. Subsequently, in 1983, the study area was decreased to the current 97,151 acres. The areas excluded were the north tip of the Nopah Range, the southern part of the Resting Spring Range, and the adjacent part of Chicago Valley. This report covers the original area established in 1980.

The Nopah Range is rugged and cut by deep canyons; sharp ridges and precipices of more than 1,000 ft are common. The topography of the Resting Spring Range is more subdued. Elevations in the area range from about 1,800 ft in Chicago Valley to 6,394 ft on Nopah Peak. The climate is arid and vegetation is sparse.

Primary access to the study area is provided by California State Highway 178 to the north and west and by a paved county road that leads eastward from Tecopa along the south margin of the study area. Jeep trails in Chicago Valley and along the east margin of the study area from California Valley northward along Pahrump Valley to Highway 178 provide secondary access.

Previous and Present Studies

A detailed stratigraphy of the Nopah and Resting Spring Ranges is given by Hazzard (1937) and his stratigraphic sections remain the standard for the area. Complete descriptions of stratigraphic units are given also by Stewart (1970) and Burchfiel and others (1982). Lithostratigraphic and biostratigraphic aspects of many of these units are discussed in a series of short papers by Cooper and others (1982). The geology of the area south of lat 36° N. was mapped by Mason (1948), but was remapped by Armstrong for this study. Wilhelms (1963) and Burchfiel and others (1982) provide geologic cross sections throughout the Nopah and Resting Spring Ranges. The structural geology of the region is discussed by Burchfiel and others (1983), and their comments are applicable even to those areas of the Nopah and Resting Spring Ranges not mapped by them. The following geologic summary is taken almost entirely from Burchfiel and others (1983).

Studies of Inyo County mines and mineral resources include those of Tucker and Sampson (1938), Norman and Stewart (1951), and Goodwin (1957).

The U.S. Geological Survey conducted geologic investigations in the study area from 1981 to 1983. Previous geologic mapping by Burchfiel and others (1982, 1983) north of lat 36° N. was field checked by Armstrong, and in 1982 he mapped areas south of lat 36° N. A reconnaissance geochemical survey of the study area was conducted by Cole L. Smith in 1982. Analytical data for rock, stream-sediment, and heavy-mineral-concentrate samples, and a sample-location map are given in Erickson and others (1984).

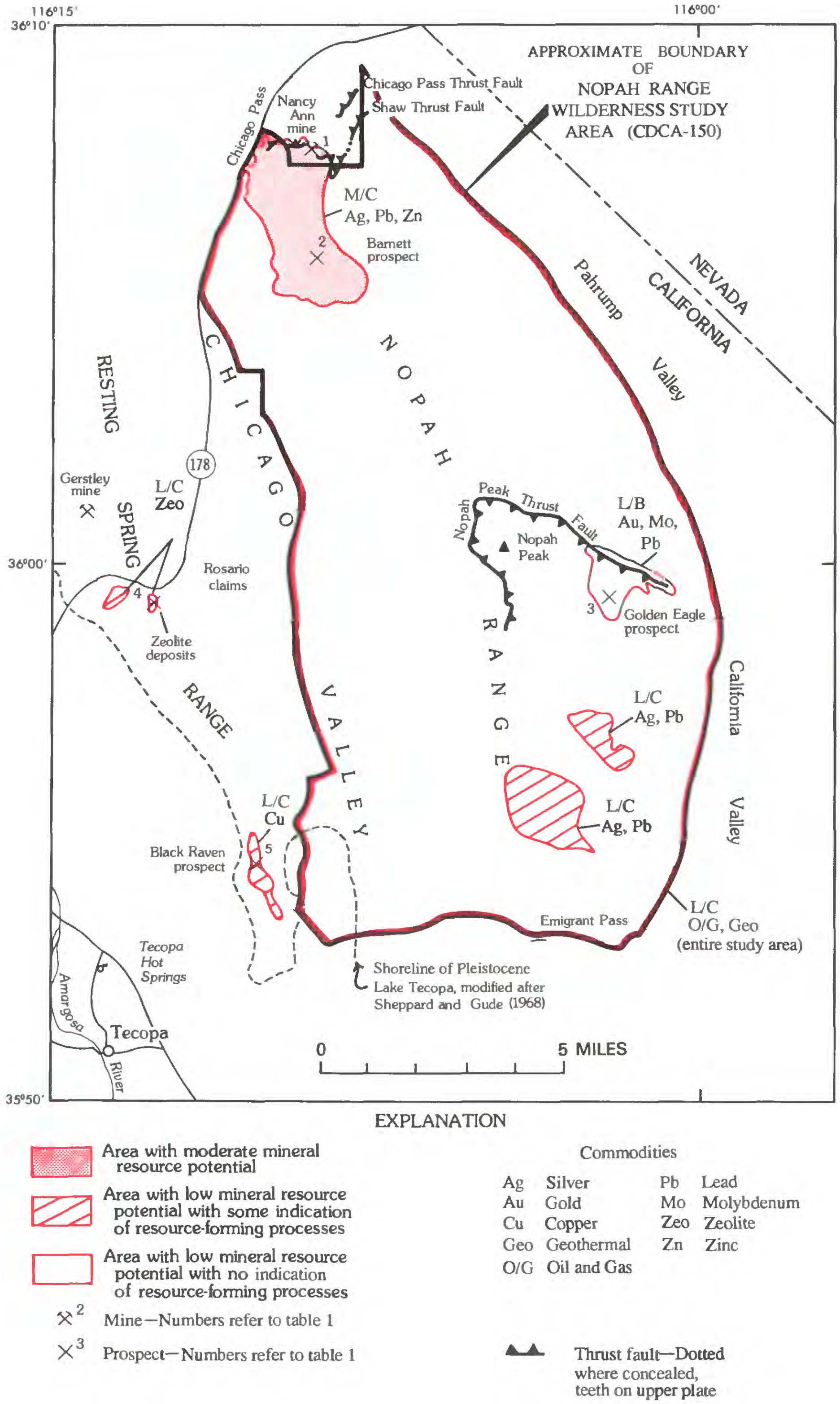

Figure 2. Mineral resource potential of the Nopah Range Wilderness Study Area, Inyo County, California.

Geophysical investigations were not done for this study.

The U.S. Bureau of Mines conducted a library search for information on mines and prospects within the study area. These data were supplemented by information from claim owners and Inyo County and U.S. Bureau of Land Management claim records. U.S. Bureau of Mines personnel conducted field studies in the spring of 1983. They collected 181 rock samples from the mines and prospects in the study area and analyzed them by fire-assay, atomic-absorption, and inductively coupled argon-plasma spectrophotometric methods. Results of the U.S. Bureau of Mines study are summarized in Sabine and Mayerle (1985). Complete analytical data and detailed property maps are on file at the U.S. Bureau of Mines, Western Field Operations Center, Spokane, WA 99202.

Acknowledgments

The authors wish to thank the owners of the Nancy Ann mine and the Barnett and Black Raven prospects for help and information concerning their properties. Advice by Brian P. Wernicke of Harvard University on structural problems of the Nopah Range is greatly appreciated. Frederic C. Johnson of Tecopa shared his knowledge of mines, prospects, and possible mineralized zones in the area. H.D. Curry of Salt Lake City, Utah provided information of the areal extent of zeolitized tuff in the sediments of Lake Tecopa.

APPRAISAL OF IDENTIFIED RESOURCES

By Charles Sabine and Ronald T. Mayerle
U.S. Bureau of Mines

Mining and Mineral Exploration History

Silver-lead ores were mined in the southern part of Inyo County by Mormon settlers prior to 1859 (Tucker and Sampson, 1938, p. 426). Since then, mines in Inyo County have been the principal source of lead in California, and have also produced considerable amounts of silver and zinc (Norman and Stewart, 1951, p. 55).

The Tecopa mining district, located immediately south of the study area, produced more than $3,000,000 in ore before 1928 (Tucker and Sampson, 1938, p. 426), and by 1950 had a probable total production of $7,000,000 of silver and lead, making it the second most important lead-producing district in the state (Norman and Stewart, 1951, p. 55).

Borates (colemanite, ulexite, and probertite) were produced from the Ryan district near Death Valley Junction, between 1874 and 1926. These deposits were the largest and most productive in California until the development of extensive kernite deposits in Kern County (Tucker and Sampson, 1938, p. 496). In 1971, the American Borate Company began mining new borate deposits at the Billie mine, east of Death Valley Junction. The Billie mine was put on standby in early 1986. Similar borate deposits were discovered in 1920 in the vicinity of the Gerstley mine, 2 mi northwest of Resting Spring Pass. The Gerstley mine produced borates more or less continuously until about 1980.

Prior to 1982, volcanic ash (for the manufacture of soap) was mined from an 8- to 10-ft-thick tuff bed located one-quarter mile west of Shoshone (fig. 1) (Tucker and Sampson, 1938, p. 486). Bentonite has been produced from the dry beds of Lake Tecopa, and zeolites in the dry lake beds have been prospected since the 1960's.

Despite the considerable production from the Tecopa mining district, the Nopah Range north of Emigrant Pass has seen very limited mining activity. Only the Nancy Ann mine, located at the north end of the Nopah Range, has had any production. From 1925 to 1928, the mine yielded 153 tons of ore averaging 18.4 percent lead, 12.6 percent zinc, and 7.8 oz silver per ton. In 1943, five rail cars of ore were shipped to a defense stockpile at Jean, Nevada; three of the cars contained ore that averaged 30 percent zinc (U.S. Bureau of Mines production records; Norman and Stewart, 1951, p. 77). The mine has been idle since 1943. The present block of 13 lode claims was located in 1973.

Mines and Prospects

Nancy Ann Mine

The Nancy Ann mine (table 1, No. 1), formerly known as the Collina, Nopah, or Shaw mine, is located at the north end of the Nopah Range outside the study area (fig. 2). It is situated in gently rolling terrane that is accessible by a jeep road from Chicago Pass.

The main deposit is developed by a 30-ft shaft that is inclined 80° to the southeast. The shaft connects drifts at three levels, the lowest of which was not accessible. Other mineralized structures are explored by four adits, two shafts, and six pits. Underground workings exceed 300 ft in total length. Five drill sites are located on the claim group, but drill-hole data were not available for inspection.

Mineralized zones are restricted to the upper plate of the Shaw thrust (pl. 1), which strikes N. 80° W. and dips 8-10° N. Shale, siltstone, and sandstone below the thrust are unmineralized. The thrust might intersect the lowest level of the main workings.

The main workings developed a 2- to 3-in.-thick vein of oxidized silver, lead, and zinc minerals. Some partially oxidized galena was observed at the intermediate level. A consulting geologist's report provided by the owner indicates that galena and other sulfides are abundant at the lowest level. The vein follows an arcuate, steeply dipping fault that separates limestone and dolomite from a breccia that consists of 1/4-in. fragments of dark-gray dolomite in a light-gray to pale-green argillic matrix. The breccia has been weakly mineralized near the vein; the limestone and dolomite are unmineralized. Other mineralized structures include some minor northeast-trending fractures and a northwest-trending fault trace that averages about 0.5 ft in thickness and extends 280 ft through the main workings.

Sixty-four samples were collected from the mine area and analyzed. On the basis of the sample data, it is estimated that about 490 tons of mineralized rock remain in the main workings. The average grade is 0.98 oz/ton silver, 1.37 percent lead, and 3.44 percent zinc. An additional 290 tons of rock on the dump averages 0.6 oz/ton silver, 1.2 percent lead, and 5.1 percent zinc. Total metal content is approximately 650 oz silver, 20,000 lb lead, and 63,000 lb zinc, and is valued at approximately $33,000, based on average July 1986 prices (Engineering and Mining Journal, 1986). Four samples from the 0.5-ft thick, northwest-trending fault average 1.5 oz/ton silver (range 0.64 to 2.1 oz/ton), 7.3 percent lead (range 4.2 to 15 percent), and 13.8 percent zinc (range 0.28 to 22.5 percent).

Identified mineral occurrences in the Nancy Ann mine are too thin and lack the necessary lateral and vertical continuity to be considered resources. Additional occurrences might be found along the northwest-trending fault and possibly along other fractures.

Barnett Prospect

The Barnett prospect is located on top of a precipitous ridge in the northern part of the study area approximately 2.5 mi south of the Nancy Ann mine (fig. 2). The prospect is accessible by a foot trail from Chicago Valley.

A trench was dug in a 2-ft-thick gossan zone of dark-red to brown limonite, geothite, and remnant galena in massive Ely Springs Dolomite. A grab sample collected from a 1-ton-stockpile of galena-bearing gossan material contained 31 percent lead and 19.75 oz/ton silver. However, chip samples collected across the gossan zone contained only 0.05 to 2.6 percent lead and 0.02 to 0.22 oz/ton silver.

Two pits and a 29-ft crosscut adit were found in a dark-red clay bed sandwiched between massive dolomite beds. The clay bed is as much as 6 in. thick and was traced for 80 ft along strike. Samples of the clay contained 0.15 to 7.8 percent lead and 0.02 to 0.44 oz/ton silver. Because high concentrations of silver and lead in a clay bed are unusual, it deserves further study. The bed displays no shearing or discordance to indicate that it is a fault gouge, and does not show any evidence of hydrothermal alteration.

The identified silver and lead occurrences are too small to constitute a resource.

Black Raven Prospect

The Black Raven prospect is an occurrence of stratabound copper minerals in quartzite and siltstone located in five zones. The mineralized zones are covered by a block of 28 lode claims and are explored by five shafts 4 to 10 ft deep, and 18 pits and cuts 2 to 11 ft long and 1 to 7 ft deep. The property is located near the southern end of the Resting Spring Range and is accessible by foot from a jeep road in Chicago Valley.

In the principal mineralized zone, chrysocolla, malachite, azurite, and turquoise are disseminated in maroon siltstone and cross-bedded quartzite in the late Precambrian Wood Canyon Formation. The zone strikes north to northwest, dips 40° to 78° east, and extends along strike for more than 9,000 ft. It averages about 2.5 ft thick. The zone is covered by alluvium and lake sediments at each end and is probably terminated by range-bounding faults.

Copper-bearing minerals occur in three adjacent layers. The uppermost, herein called the "A" layer, is a 0.1- to 10-in.-thick green siltstone that locally may contain a core of dark-green to reddish brown siltstone 0.1- to 1.2 in. thick. The boundaries of this core are in places delineated by dark-green to black chlorite cyrstals and rarely by specks of malachite. The "B" layer consists of gray to maroon siltstone and is about 0.5 to 1.0 ft thick. The "A" and "B" layers may be missing locally in the southern half of the zone. The lowest or "C" layer is an olive green to black, granular, cross-bedded quartzite 0.7 to 2.5 ft thick. The upper part locally displays worm borings and ripple marks. Copper minerals are most abundant in the "A" layer and upper half of the "C" layer; they are sparse in the "B" layer and lower half of the "C" layer.

The stratabound nature of this occurrence and its great lateral extent point to a syngenetic origin. Its association with cross-bedded sandstones and stromatolites (fossil algae) suggests deposition in a sabkha (supratidal) environment, although data are not sufficient to rule out an epigenetic origin whereby metals are precipitated from solution in a geochemically unique bed.

Eighty-two chip samples were collected from the copper-bearing strata. Copper content ranged from .003 to 1.22 percent, averaging 0.41 percent; silver was detected in 77 samples, ranging from 0.002 to 0.133 oz/ton and averaging 0.038 oz/ton.

Five other zones that have been prospected include quartz veins along faults, a highly fractured siltstone unit, an a pyrite-bearing quartzite bed. Nine samples collected from these zones had no significant metal content.

The metal content of the copper-bearing strata at the surface is too low and the zone is too thin to be considered a resource.

Golden Eagle Prospect

The Golden Eagle placer prospect, on the east side of the Nopah Range, is located in a broad wash underlain by coarse, angular limestone and dolomite gravel. A road was built in 1982. There has been no recorded production from this claim. Three channel samples from one trench and a stream-cut bank contained only traces of gold. The prospect has no identified gold resources.

Zeolite Minerals

Zeolitized tuff occurs on both flanks of the Resting Spring Range and is accessible by a jeep road that branches off from Highway 178 east of Resting Spring Pass. Exposures of Resting Spring Pass Tuff of Miocene age are explored by two short adits and a bulldozer cut. Seven chip samples were analyzed semiquantitatively by X-ray diffraction. They are estimated to contain 20 to 100 percent clinoptilolite, averaging 63 percent (±20 percent). Ammonium-cation-exchange values range from 0.38 to 1.4 mol equivalents/gram, averaging 0.87, which might indicate that the tuff would be suitable as absorbent material or soil conditioner. The deposit was not mapped and sampling was not sufficient to calculate a grade and tonnage. However, the deposit probably contains less than 100,000 tons of material, which is far too small to be considered a resource.

Borate Minerals

The Rosario Exploration Company located a block of lode claims on the projected extension of the Gerstley Lake Beds of Barker and Wilson (1975) in Chicago Valley. The company planned exploratory drilling for borates in 1982, but abandoned the claims without drilling.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Augustus K. Armstrong, Cole L. Smith, and George L. Kennedy, U.S. Geological Survey

Geology

The Nopah Range Wilderness Study Area consists of typical basin-and-range topography that reflects the tilted fault blocks of the Nopah and Resting Spring Ranges. The mountain ranges are composed of a thick sequence of marine sedimentary rocks of Late Proterozoic through Pennsylvanian age (refer to geologic time chart in appendix). These rocks have been deformed by several episodes of folding, normal faulting, and thrust faulting, which presumably occurred in the Mesozoic; they were further disrupted by Cenozoic basin-and-range-style faulting and tilting. Tertiary volcanic and volcaniclastic rocks are present locally, along with younger unconsolidated sediments that fill the down-dropped basins between the ranges.

A nearly complete sequence of Late Proterozoic crystalline basement rocks and Late Proterozoic through Middle Pennsylvanian sedimentary rocks is present in the Nopah Range (Hazzard, 1937; Mason, 1948; Burchfiel and others, 1982, 1983). In the southern part of the Resting Spring Range, however, only Late Proterozoic through Upper Cambrian rocks are present. Sedimentary rocks in the study area range in age from Late Proterozoic to Middle Pennsylvanian and represent a typical Cordilleran miogeosynclinal sequence that is about 25,000 ft thick. The lower half of the sedimentary sequence consists of quartz-rich and terrigenous rocks (shale, siltstone, and quartzite) and minor amounts of dolomite. The upper half of the sequence is dominated by limestone and dolomite containing only minor amounts of terrigenous sediments. In the Nopah Range, the only major unconformity within the stratigraphic section is at the base of the Devonian Lost Burro Formation where it rests on the Silurian Hidden Valley Dolomite east of Chicago Pass and on the Upper Ordovician Ely Springs Dolomite farther southeast.

Following a long period of general subsidence and concurrent deposition from the Late Proterozoic through Pennsylvanian (and probably Permian) time, the first deformational events occurred after the Paleozoic. Dating of these events is tenuous in the study area and can be bracketed only between the Middle Pennsylvanian and the middle(?) Tertiary. Regional evidence suggests that most of the faulting occurred in the Mesozoic. Complex Cenozoic folding and high-angle faulting have greatly disrupted the Mesozoic structures, and some ambiguity exists in their correlation from one range to another.

During the first phase of Mesozoic deformation, the rocks were folded and cut by numerous high-angle faults. These high-angle faults predate thrusting. East-directed Mesozoic thrust faults, the exact number of which is not certain, formed the major structural features in the region. This Mesozoic thrusting cut the rock sequence into four major structural units. In the Nopah Range, these are, from top to bottom, (1) the Chicago Pass thrust plate, (2) the Shaw thrust plate, (3) the Nopah Range unit between the Shaw thrust and the Nopah Peak thrust faults, and (4) the Nopah Peak unit south of the Nopah Peak thrust. Structural units in the Nopah Range cannot be unequivocally correlated with those in the Resting Spring Range to the west.

Complex Cenozoic folds and high-angle faults are related to progressive westward or northwestward crustal extension. Continued extension along the basin-and-range-style faults caused rotation of earlier high-angle dip-slip faults so that some of them are now subhorizontal. Some of the low-angle faults, however, may be gravity slides. Rotation and tilting of the mountain blocks is also indicated by the steep dips of Tertiary beds that were originally nearly flat lying. Welded tuffs of Miocene age, some 800 ft thick, are found lying unconformably on Lower Paleozoic rocks of the Resting Springs Range.

Lacustrine sedimentary rocks of Pleistocene Lake Tecopa contain interbeds of tuff altered to zeolite and bentonite (Sheppard and Gude, 1968). The southwest boundary of the study area parallels the ancient shoreline, but an arm of the lake extended up Chicago Valley for several miles. Tuff beds rich in the zeolite minerals phillipsite and erionite toward the center of the basin are also present in Chicago Valley; the tuffs do not appear to be zeolitized in Chicago Valley (H.D. Curry in Sabine and Mayerle, 1985). Mineralogical changes, whereby unaltered glass shards near the edge of the former lake grade into rock replaced by zeolites, can be correlated with changes in the lake from relatively fresh water near the margins to alkaline and saline water near the center (Sheppard and Gude, 1968; Papke and Schilling, 1975, p. 14; Sheppard, 1985). On the basis of this occurrence model, the possibility of zeolitization occurring in distal extensions of the lake, such as in Chicago Valley, is slim (Hillhouse, 1987).

In 1920, borate minerals were discovered near the Gerstley mine (fig. 2; pl. 1) in the Resting Spring Range 2 mi northwest of Resting Spring Pass (Barker and Wilson, 1975). Lake beds at the Gerstley mine consist of more than 1,000 ft of lacustrine sedimentary rocks that include three zones of colemanite, ulexite, and probertite totaling 150 ft in thickness (Wilhelms, 1963; Barker and Wilson, 1975). The Gerstley lake beds have been traced southeastward from the Gerstley mine for an unspecified distance into Chicago Valley (Barker and Wilson, 1975, p. 25). A block of claims (Rosario claims) located on this projected extension was abandoned in 1982 without drilling (Sabine and Mayerle, 1985).

Geochemistry

Analytical Methods

The reconnaissance geochemical survey of the study area is based on analyses of 103 stream-sediment and 103 panned heavy-mineral concentrate samples collected from the margins of the Nopah and southern Resting Spring Ranges. Nine rock samples were also collected from areas of known mining activity. Samples were analyzed for 29 elements by semiquantitative emission spectrography (Grimes and Marranzino, 1968). All rock samples were analyzed for antimony, arsenic, and gold by a wet chemical method, and some rock samples were also analyzed for bismuth, cadmium, and zinc by atomic-absorption spectrometry.

Stream-sediment samples and heavy-mineral concentrates provide information on major rock types and surficial material present within a drainage system. Heavy-mineral-concentrate samples are useful in obtaining information about sulfide minerals, their oxidation products, and other minerals that contain most of the elements related to ore deposits.

Analyses of such samples normally reveal drainages that contain anomalous concentrations of ore-related elements. These anomalies usually reflect mineralized areas. Geochemically anomalous areas are ones in which the concentration of ore-related elements in the samples are above their threshold concentrations. Threshold concentrations of ore-related elements in the study area were determined by inspecting the concentrations of indicator elements in samples collected from drainages known to contain mineralized areas, both in the study area and in nearby mining areas. In the study area, stream-sediment samples seived to minus-80 mesh did not reliably identify even those drainages containing areas with known mining activity. Consequently, the geochemical anomalies are based entirely on analytical data from panned heavy-mineral-concentrate samples.

Rock samples collected from mine dumps were used to detect those elements characteristic of the types of mineralization that are known to be present in the study area. Anomalous concentrations of arsenic, copper, lead, molybdenum, silver, zinc, and, to a lesser extent, antimony characterize the known mineralized areas. Anomalous concentrations of these elements were used as the basis for identifying other areas that might have had a similar history of mineralization.

Most of the variation in the concentrations of other analyzed elements can be explained by variations in bedrock composition. None of the heavy-mineral-concentrate samples from the southern Resting Spring Range contained anomalous concentrations of any metallic elements. Some commodities of potential economic interest, such as borates and zeolites, would probably not be detected by this geochemical survey.

Results of Survey

The area with the most significant geochemical anomalies in the study area is on the northwest side of the Nopah Range extending southward from the Nancy Ann mine for approximately 3 mi to include the Barnett prospect. The element of primary economic interest at the Nancy Ann mine is probably silver, which was present in concentrations as high as 100 parts per million (ppm). Anomalous concentrations of arsenic (1,000 ppm), copper (1,000 ppm), lead (more than 2 percent), molybdenum (200 ppm), antimony (150 ppm), and zinc (more than 1 percent) were also present in rock samples collected from the mine dump. Cadmium, however, was not detected in either the stream-sediment or the heavy-mineral-concentrate samples in the vicinity of the Nancy Ann mine. Rock samples collected from the Barnett prospect contained 500 ppm silver and anomalous concentrations of those elements (except cadmium) that were anomalously high at the Nancy Ann mine. Panned heavy-mineral concentrates from the drainages containing the Nancy Ann mine and the Barnett prospect contain detectable amounts of silver, lead, and zinc.

Rock samples collected from a brecciated zone in the Nopah Peak fault, on the east side of the Nopah Range near the Golden Eagle placer prospect (fig. 2; pl. 1), contained relatively low concentrations of gold (0.10-0.15 ppm), but were anomalous in arsenic (55 to 1,100 ppm), antimony (2-160 ppm), and molybdenum (20-70 ppm). There were molybdenum, lead, and arsenic anomalies in panned heavy-mineral-concentrate samples collected in the drainages associated with the brecciated zone.

Samples collected between Emigrant Pass and Nopah Peak had anomalously high concentrations of silver, arsenic, copper, lead, molybdenum, zinc, and, to a lesser extent, antimony. Although individual samples contain anomalous concentrations of only one or two of these elements, they indicate that mineralization occurred in the area. However, drainages that do not contain unusual metal concentrations are usually separate from those that do. Copper minerals present at the Black Raven prospect, at the south end of the Resting Range, did not show up in anomalous concentrations in panned heavy-mineral concentrates collected from this area.

Mineral and Energy Resource Potential

The mineral resource potential of the study area was based on geological investigations conducted by the U.S. Geological Survey and on mining surveys and assay work done by the U.S. Bureau of Mines. These studies revealed one area with moderate potential for silver-lead-zinc resources on the northwest side of the Nopah Range, one area with low potential for gold-molydbenum-lead resources on the east-central side of the Nopah Range, and two areas with low resource potential for silver-lead resources on the southeast side of the wilderness study area. Resource potential for copper and the zeolite clinoptilolite west of the study area in the Resting Spring Range is low; potential for copper within the study area is unknown. In Chicago Valley, resource potential for borates and (or) zeolites is unknown. While limestone, quartzite, and sand and gravel are plentiful in most parts of the study area, the resource potential of these commoditeis is low. No evidence of oil and gas or geothermal energy sources was found. The potential for these resources is low in the entire study area.

Classification of mineral resource potential was done according to the guidelines in Goudarzi (1984). See appendix for definitions of mineral resource potential and certainty of assessment.

Silver, Lead, and Zinc

The study area lies within an areally extensive mineral province characterized by silver, lead, and zinc ores that have been mined extensively since the late 1800's (Goodwin, 1957). The metal-rich deposits throughout this province typically are found as veins, stockworks, or bedded replacement bodies along faults and (or) fracture systems in Paleozoic carbonate rocks. The source of the mineralizing fluids and the age of the mineralization event are unknown.

An area with moderate resource potential for lead, silver, and zinc on the northwest side of the Nopah Range (fig. 2; pl. 1) is delineated by the distribution of geochemically anomalous metals along a 3-mi segment of range front. Geochemically anomalous silver, lead, and zinc, as well as copper, molybdenum, and arsenic, were found in rock and panned heavy-mineral-concentrate samples collected from this area. The area encompasses the Nancy Ann mine, which has a history of minor silver, lead, and zinc production (table 1; Sabine and Mayerle, 1985), and the Barnett prospect. Two major thrust faults, the Chicago Pass thrust and the Shaw thrust, intersect the northeast corner of the study area and may have acted as conduits for mineralizing fluids. Although the area is well defined geochemically and has had some metal production, mineral occurrences are thin and lack lateral and vertical continuity (Sabine and Mayerle, 1985). The mineralized upper plate of the Shaw thrust may contain additional mineralized veins, but the plate is probably no more than 40 ft thick in the vicinity of the Nancy Ann mine, limiting the size of possible deposits (Sabine and Mayerle, 1985). The resource potential is moderate (certainty level C) for additional silver-lead-zinc resources on the northwest side of the Nopah Range.

Two areas (fig. 2; pl. 1) on the southeast side of the study area have a low resource potential (certainty level C) for silver and lead. Normal faults are the dominant structural feature and major thrust faults are absent from the south end of the study area. The sporadic mineralization that occurred here represents weak regional mineralization. The source and age of the mineralizing fluids have not been determined.

Gold, Molybdenum, and Lead

An area on the east-central side of the Nopah Range (fig. 2; pl. 1) has a low resource potential (certainty level B) for gold, molybdenum, and lead. Rock samples collected from an oxidized breccia zone associated with the Nopah Peak thrust fault contained relatively low concentrations of gold, but were high in arsenic, bismuth, and molybdenum. Molybdenum, lead, and arsenic were present in panned heavy-mineral-concentrate samples collected in the drainage associated with the brecciated zone. Mineralization appears to have been controlled by the zone of weakness along this thrust fault.

Copper

The Wood Canyon Formation quartzites at the south end of the Resting Spring Range contain narrow bands of stratabound copper minerals. The resource potential for copper is unkown within the study area. The resource potential for copper is low with a certainty level of C at the southern end of the Resting Springs Range.

Limestone, Quartzite, and Sand and Gravel

There are numerous limestone, quartzite, and sand and gravel deposits in the study area that contain materials suitable for construction use. Much of the carbonate rock in the study area is dolomite or dolomitic limestone and is unsuitable for making cement. Areas underlain by the Nopah Formation, the Bonanza King Formation, and the Carrara Formation (pl. 1) have low potential, certainty level D, for limestone. Areas underlain by the Eureka Quartzite (pl.1) have low potential for quartzite, certainty level D. Areas of Quaternary alluvium have low resource potential for sand and gravel, certainty level D.

Zeolites and Borates

Small deposits of the zeolite mineral clinoptilolite are known to be present in the Miocene tuffs on the east and west sides of the Resting Spring Range. The resource potential for clinoptilolite is low with a certainty level of C.

Lacustrine sedimentary rocks of Pleistocene Lake Tecopa contain interbeds of tuff altered to zeolites and bentonite (Hillhouse, 1987). These rocks are believed not to exist in the study area; drilling would be necessary to prove their presence. The Gerstley lake beds containing three rich zones of borate minerals have been traced southeastward from the Gerstley mine into Chicago Valley. Only exploration drilling can prove the existence of borates in the study area. The resource potential for borates and (or) zeolite minerals in Chicago Valley is unknown.

Oil and Gas

Although many of the rocks in the Paleozoic section of the study area have good porosity, petroleum source beds are rare in these rocks (Scott, 1983). The structurally complex geology, extensive faulting that would have disrupted any structural or stratigraphic traps, and the lack of good source beds preclude the accumulation of oil or gas resources in the study area. Therefore, the mineral resource potential for oil and gas is low throughout the study area with a C level of certainty.

Geothermal Energy

The study area lies 4 mi east of Tecopa Hot Springs (fig. 2; pl. 1) where water temperatures in pools range from 80° to 110° F (Sammel, 1979, p. 106; Troxel, 1982), although it may be discharged at temperatures as high as 118° F (Brook and others, 1979, p. 65). The hot springs are probably fed by the waters of the Amargosa River that are brought to the surface along the nearby rangefront faults. Geothermal potential should decrease rapidly as the distance from these features increases. However, there is no evidence of geothermal energy resources in the study area, and so the resource potential for geothermal energy is low throughout the study area with a C level of certainty.

Recommendations for Further Study

The assessment of resource potential in the Nopah Range Wilderness Study Area is based almost entirely on surface information from geological studies and a few near-surface observations made in widely scattered mine workings. Any thorough study of the area should include drill-hole data, especially for identifying deposits containing zeolites or borates in the lacustrine sediments between the Nopah and Resting Spring Ranges.

This study indicates that there is a need for more geologic, geochemical, and geophysical studies in areas containing geochemical anomalies.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LOW mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is permissive. This broad category embraces areas with dispersed but insignificantly mineralized rock as well as areas with few or no indications of having been mineralized.

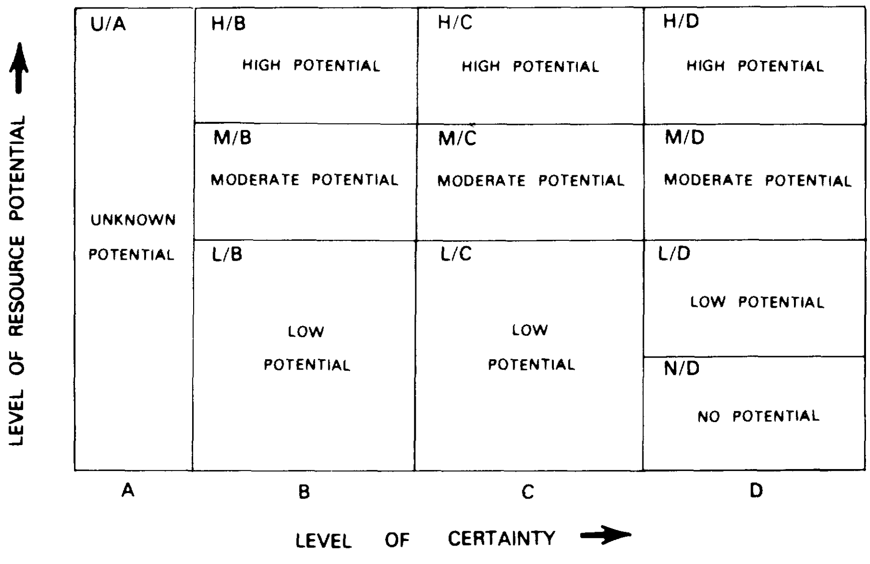
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate reasonable likelihood of resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

HIGH mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data supports mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

NO mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

Levels of Certainty



A. Available information is not adequate for determination of the level of mineral resource potential.
B. Available information suggests the level of mineral resource potential.
C. Available information gives a good indication of the level of mineral resource potential.
D. Available information clearly defines the level of mineral resource potential.

Abstracted with minor modifications from:

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RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		**Inferred**	**Probability Range**	
	Measured	**Indicated**		**Hypothetical**	**Speculative**
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U.S. Geological Survey in this report

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES (in Ma)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				(3800?)
pre-Archean[2]					4550

[1]Rocks older than 570 Ma also called Precambrian, a time term without specific rank.

[2]Informal time term without specific rank.

TABLE 1. *Mines, prospects, and mineral occurrences in and adjacent to the Nopah Range Wilderness Study Area*
[*, outside study area boundary]

Map No. (fig. 2)	Name (commodity)	Summary	Workings and production	Sample and resource data
1	Nancy Ann mine* (lead, silver, zinc)	Vein of oxidized zinc, silver, and lead minerals follows a fault that separates dolomitic breccia from unmineralized limestone and dolomite. A NNW-trending fault, 280 ft long, and some smaller NE-trending fractures also are mineralized. Mineralization restricted to upper plate of the Shaw thrust.	Inclined shaft with drifts at three levels produced 153 tons of ore and yielded 1,193 oz silver, 56,300 lb lead, 38,600 lb zinc in the 1920's. In 1943, three carloads of ore contained 30 percent lead and 17 oz/ton silver; two others contained 30 percent zinc (Norman and Stewart, 1951).	About 780 tons remaining in the workings and dump average 4.0 percent zinc, 0.8 oz silver/ton and 1.3 percent lead. Total in-place value is about $33,000 at average July 1986, prices. Four samples from the NNW-trending fault contained 0.3 percent to 22.5 percent zinc, 0.6 to 2.1 oz/ton silver, and 4.2 percent lead.
2	Barnett prospect (lead, silver)	Workings explore a 2-ft-thick gossan zone with remnant galena in Ely Springs Dolomite and in a 6-in.-thick dark-red clay bed.	One trench, two pits, and a 29-ft cross-cut adit.	A grab sample from a 1-ton stockpile of the gossan contained 31 percent lead and 19.75 oz/ton silver. Chip samples from the gossan zone contained 0.02 to 0.22 oz/ton silver and 0.05 percent to 2.6 percent lead. Samples from the clay bed contained 0.15 percent to 7.8 percent lead and 0.02 to 0.44 oz/ton silver.
3	Golden Eagle placer prospect (gold)	Very coarse gravel and sand composed mostly of limestone.	One trench.	One channel sample from the trench and two from stream banks contained only traces of gold.
4	Zeolite occurrence* (clinoptilolite)	Zeolitized Miocene tuff of Resting Spring Pass.	Two adits, one cut.	Semiquantitative X-ray diffraction analysis of 7 chip samples indicates that the tuff is rich in clinoptilolite. Ammonium cation exchange values range from 0.38 mol to 1.4 mol equivalents/gram.
5	Black Raven prospect* (copper, silver)	Copper minerals are disseminated in a zone of maroon siltstone and adjacent quartzite beds in the Wood Canyon Formation. Zone is about 2.5 ft thick, extends for 9,000 ft, is covered by alluvium and lake sediments at each end, and is probably terminated by range-front faults. Quartz veins, fractured siltstone, and pyrite-bearing quartzite also explored by prospects.	Five shafts, 4 to 10 ft deep, and 18 pits and cuts.	Eighty-two samples from the principal mineralized zones averaged 0.41 percent copper (range .003 to 1.22 percent). Silver was detected in 78 samples and ranged from 0.002 to 0.13 oz/ton.

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