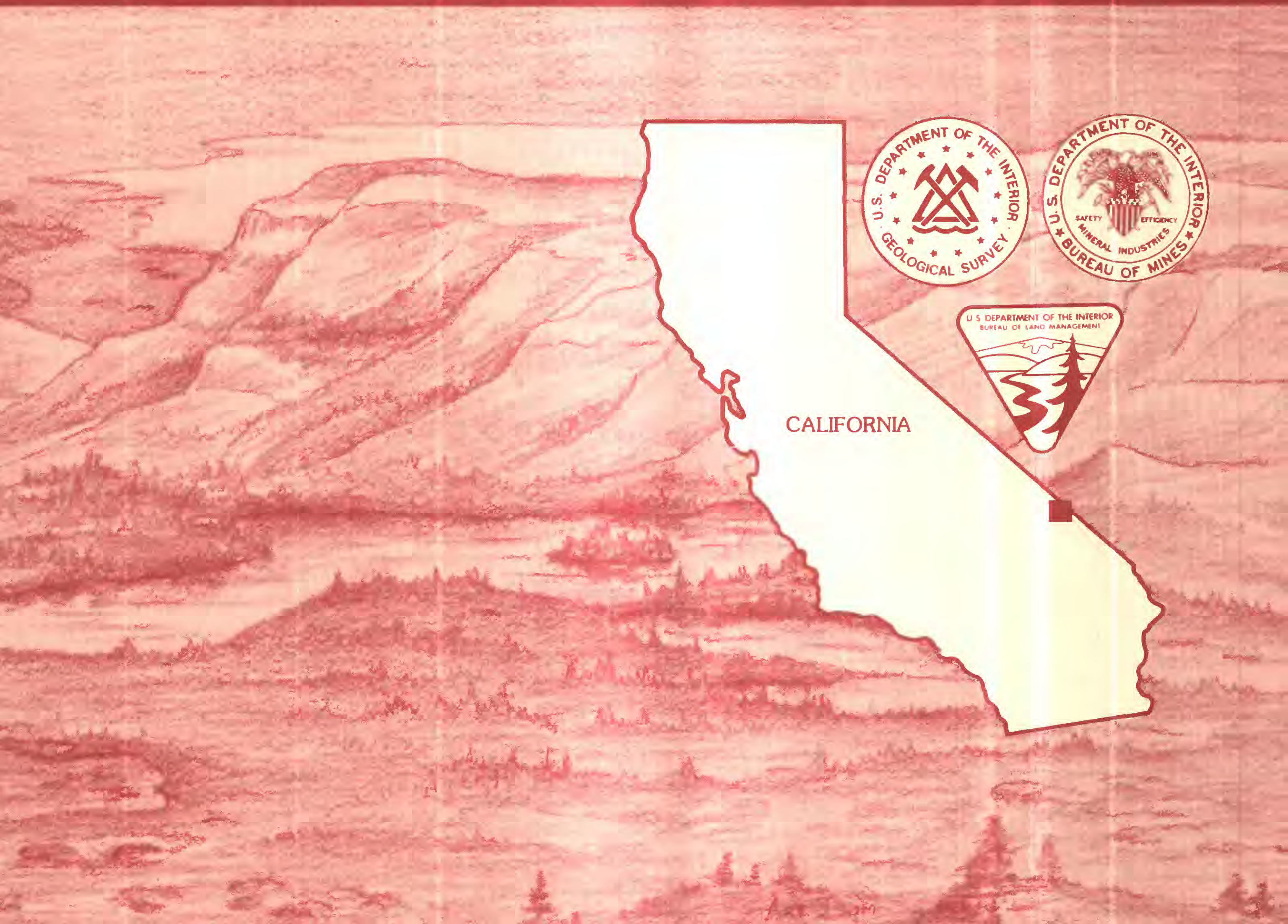
Mineral Resources of the Funeral Mountains Wilderness Study Area, Inyo County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1709–A



ERRATA FOR U.S. GEOLOGICAL SURVEY BULLETIN 1709-A

- In the Abstract, on page A1, line 20 should read "the potential for borate resources is moderate."

- In the Abstract, line 25 should read "There is high mineral resource potential for limestone, quartzite, and sand and gravel in the study area; however, there is little likelihood that these deposits will ever be exploited due to their distance from current markets."

- In the "Mineral Resource Potential Section" of the Summary, on page A3, the second paragraph should read "Those parts of the study area (fig. 2) composed of Quaternary alluvium (Qa) and Tertiary conglomerate (Tc) have a high resource potential for sand and gravel. Those parts of the study area composed of Devonian to Cambrian age limestone (Pzl) have a high resource potential for limestone and quartzite."

- In the "Mineral Resource Potential" section of the Summary, on page A3, the last sentence should have the word "coal" deleted from it.

- In the "Mineral and Energy Resources" section, the last line on page A8 and the first line on page A9 should read "Although limestone, quartzite, and sand and gravel are abundant in the study area, there is little likelihood that these deposits will be exploited as they are too far from current markets."

- In the "Conclusions" section, the second to the last paragraph on page A10 should read "Limestone, quartzite, and sand and gravel are abundant in the study area, and there is high potential for undiscovered resources of these commodities, certainty level D; however, there are economic factors that could affect their development, and these are treated elsewhere in this report."

Chapter A

Mineral Resources of the Funeral Mountains Wilderness Study Area, Inyo County, California

By AUGUSTUS K. ARMSTRONG, JAMES G. FRISKEN, and ROBERT C. JACHENS
U.S. Geological Survey

TERRY R. NEUMANN
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1709
MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
NORTHEASTERN CALIFORNIA DESERT CONSERVATION AREA, CALIFORNIA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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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 Funeral Mountains Wilderness Study Area (CDCA-143), California Desert Conservation Area, Inyo County, California.

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Mineral Resources of the Funeral Mountains Wilderness Study Area, Inyo County, California

By Augustus K. Armstrong, James G. Frisken, *and* Robert C. Jachens
U.S. Geological Survey

Terry R. Neumann
U.S. Bureau of Mines

SUMMARY

Abstract

At the request of the Bureau of Land Management, 13,709 acres of the Funeral Mountains Wilderness Study Area (CDCA-143) were studied by the U.S. Geological Survey and the U.S. Bureau of Mines. The study area is located in the southeastern part of the Funeral Mountains in the Death Valley region of eastern California. Geologic, geophysical, and geochemical studies were conducted in the study area during 1983-1984.

Four lapsed mining claims are present within the study area. There are no active mines in the study area, and there is no evidence of past production from any claim. The study area contains no identified mineral resources. Three drainage basins in the central, eastern, and western parts of the study area contain anomalous concentrations of lead and zinc, and have a low potential for lead and zinc resources. Borate deposits may be present in the subsurface of the southwestern part of the study area; the potential for borate resources is low. Parts of the study area were determined to have low potential for resources of bentonite, zeolite minerals, and strontianite (a strontium mineral). Concentrations of these commodities are such that any production from them is likely to be small. Limestone, quartzite, and sand and gravel are found within the study area and have a low economic potential due to the distance from current markets. Oil, gas, and geothermal resources were not found in the study area and so the potential is considered low. There is no potential for uranium or thorium resources.

Character and Setting

The Funeral Mountains Wilderness Study Area is located in southeastern Inyo County, California between the eastern boundary of Death Valley National Monument and the California-Nevada border (fig. 1). Death Valley Junction, the nearest community to the study area, is located 7 mi to the southeast.

The Funeral Mountains are a repetitious series of fault blocks underlain predominantly by carbonate rock of Cambrian through Mississippian age (570-330 million years before present (Ma); see Geologic time chart, last page of report).

The northeast-trending range of fault-controlled mountains encloses small, narrow interior valleys and is bounded by broad, coalescing alluvial fans. The study area is characterized by rugged peaks, steep, sloping ridges, and narrow drainages.

Relief within the study area is over 4,300 ft. Pyramid Peak, a dominant feature near the center of the study area, is the highest point at 6,703 ft. The surface elevation drops sharply to 2,400 ft at the southwest corner of the study area.

In this report, the area studied is referred to as "the wilderness study area", or simply "the study area".

Identified Resources

None of the prospects within the study area have identified resources of industrial commodities. However, the American Borate Company operates the Billie mine 4 mi southwest of the study area (fig. 2). Small-scale mining at the Sidehill mine, 2 mi east of the eastern boundary of the study area, produces clay for cosmetic and pharmaceutical products. The I.M. Vanderbilt mine (fig. 2, No. 14), operated by Industroa; Mineral Ventures, produces hectorite and sepiolite 3.5 mi northeast of the study area near Franklin Wells.

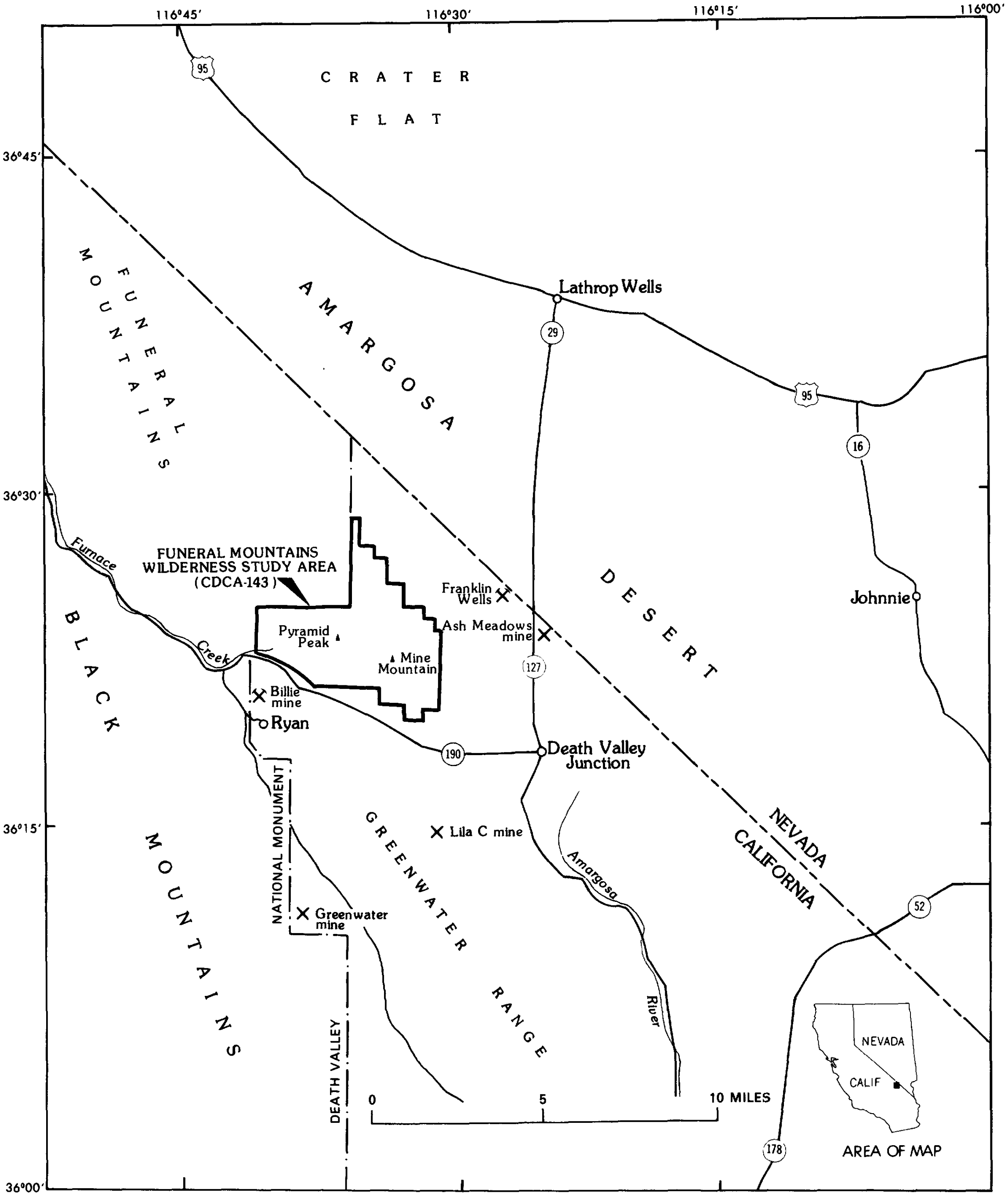

Figure 1.--Index map showing location of the Funeral Mountains Wilderness Study Area, Inyo County, California.

Carbonate rocks underlie much of the Funeral Mountains, and major deposits of limestone and dolomite could be developed. A number of possible quarry sites, all located near Highway 190, would each have more than 20 million tons of resources. However, these deposits are too far from large markets and are not likely to be developed in the near future. Existing quarries in the Spring Mountains, Nevada, about 45 mi southeast of the study area, will 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

Geochemical studies indicate that a low resource potential for lead and zinc exists in three areas. In the eastern, central, and western parts of the study area. Three additional areas are recognized in the study area. A moderate resource potential for large borate deposits in lake-bed sediments in the southwestern part of the study area. Bentonite and zeolite deposits are found in altered volcanic rocks in the southeast corner of the study area. Their resource potential is low. Strontium concentrations are found in small deposits in the western part of the study area. The resource potential for strontium is low.

Limestone, quartzite, and sand and gravel are abundant in the study area, and their resource potential is high, but the economic potential is low beause of the distance to potential markets.

No indication of the presence of coal, oil, gas, and geothermal resources were found and their potential is low.

INTRODUCTION

Area Description

The Funeral Mountains Wilderness Study Area (CDCA-143) is located in the southeastern part of the Funeral Mountains in the Death Valley region of eastern California (fig. 1). The study area contains 13,709 acres and is located between the eastern boundary of Death Valley National Monument and the California-Nevada border. Death Valley Junction, approximately 7 mi to the southeast, is the nearest community. Access to the eastern boundary of the study area is by California State Highway 127 and a graded gravel road through Franklin Wells; access to the western boundary is by State Highway 190 and a jeep trail to Red Amphitheater. Interior access is poor, with only one known trail leading to a small valley between Pyramid Peak and Mine Mountain.

The terrain of the Funeral Mountains is typical of the Basin and Range physiographic province. The northwest-trending, fault-controlled mountains enclose small, narrow interior valleys and are bounded by broad, coalescing alluvial fans. The mountains are characterized by rugged peaks, steep, sloping ridges, and narrow drainages. Maximum relief within the study area is more than 4,300 ft. The highest point is Pyramid Peak (6,703 ft), near the center of the study area. The surface elevation is 2,400 ft at the southwest corner of the study area. The region is sparsely vegetated, reflecting low annual precipitation, intense summer heat, and mild winters.

Previous and Present Investigations

Little information related to mineral resource potential is available for the area of the southern Funeral Mountains. The most detailed sources of geological information are reports by Hunt and Mobey (1966), McAllister (1970, 1971a, 1971b, 1973, 1976), Cemen and others (1982), Troxel (1968), and Denny and Drewes (1965). U.S. Bureau of Land Management unpublished mineral potential reports by Marcus (1980) and Schulte (1982) contain additional data. The U.S. Department of Energy conducted a uranium-potential survey of all land encompassed by the Death Valley 1° x 2° quadrangle, which includes the study area (Cook, 1980).

The U.S. Bureau of Mines conducted a mineral survey of the study area during 1983(Neumann, 1984). Prior to the field work for this report, a search of pertinent Federal and Inyo County mining-claim records was conducted to determine claim locations and mining activities. U.S. Bureau of Mines personnel collected 50 chip, grab, and select samples during a field investigation; the majority of the samples were sedimentary rocks. Grab and select samples were collected from mine and prospect dumps, stockpiles, and mineralized zones. Complete data for all samples are available for public inspection at the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Avenue, Spokane, Washington, 99202.

Armstrong conducted studies in the Funeral Mountains in 1980, 1983, and 1984. In 1984, Frisken conducted field and laboratory studies of the geochemistry of the wilderness study area. Mineral resources and mineral resource potential were classified according to Goudarzi (1984).

Frederic C. Johnson, a geologist with the American Borate Company, provided valuable information about the access, local geology, and mineral resource potential of the region.

APPRAISAL OF IDENTIFIED RESOURCES

By Terry R. Neumann, U.S. Bureau of Mines

Mining History

At the present time, there is no active mining within the study area and there is no evidence of past production from any claim within the study area. However, areas adjacent to the study area have had a rich and colorful mining history.

Greenwater Valley, located 12 mi south of the study area, was the site of the most spectacular boom in the history of mining in Death Valley. According to Latschar's (1981) meticulous account, copper was discovered in 1905 in the Greenwater district, 12 mi

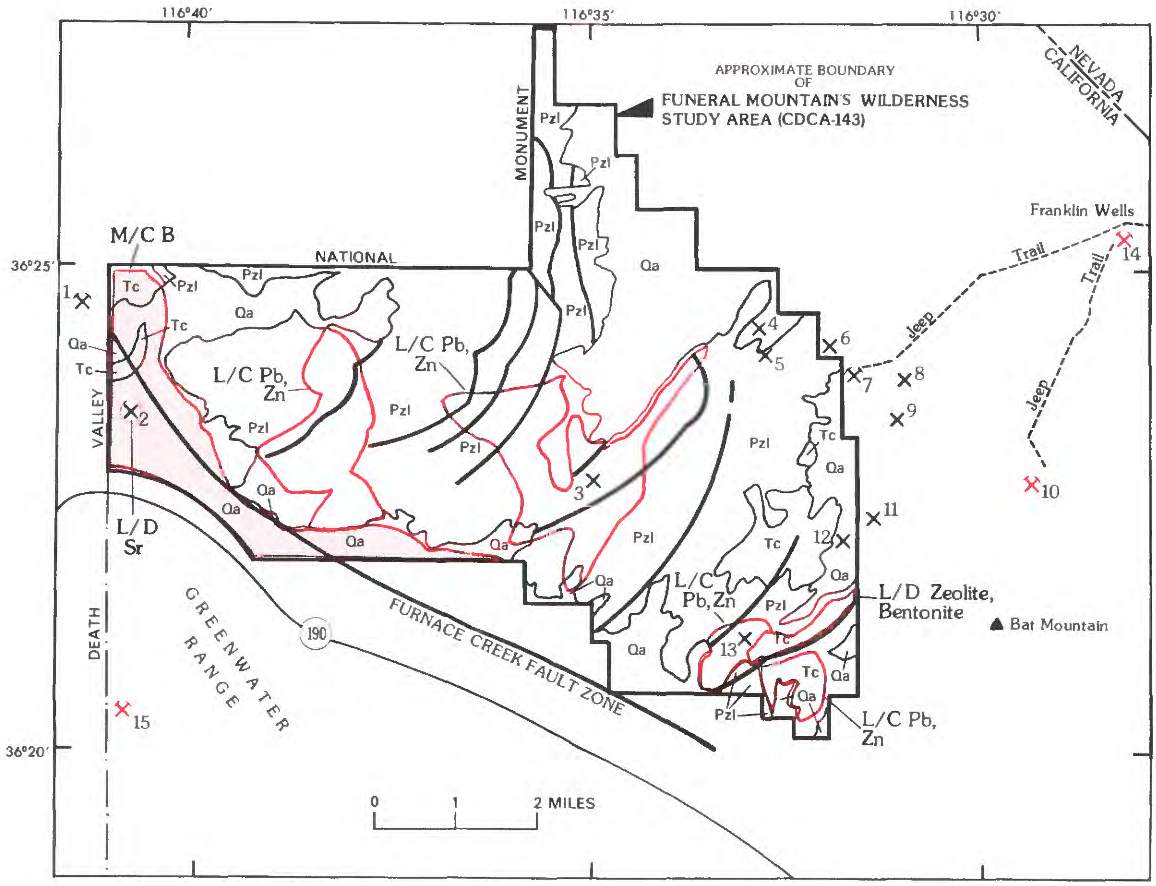

Figure 2.--Mineral resource potential map of the Funeral Mountains Wilderness Study Area, Inyo County, California.

EXPLANATION

Area with moderate mineral or geothermal energy resource potential, certainty level C (M/C)

Area with low mineral or geothermal energy resource potential

See Appendix 1 for definition of levels of mineral resource potential and certainty of assessment

×15 Mine with identified mineral resource

Commodities

B	Boron
Bentonite	Bentonite
Pb	Lead
Sr	Strontium
Zn	Zinc
Zeolite	Zeolite

Geologic map units

Qa	Alluvium (Quaternary)
Tc	Conglomerate (Tertiary)
Pzl	Limestone (Devonian to Cambrian)

Contact

Fault--Dashed where inferred

⚒1 Mine--Number refers to list of workings

×5 Prospect, claim, or mineralized area--Number refers to list of workings

Mines, prospects, claims, and mineralized areas

1	Red Amphitheater mine
2	Red Amphitheater mineralized zone
3	Bentonite Placer prospect
4	Yellow Heart prospect
5	Deborah prospect
6	Kaolin Extension prospect
7	Kaolin mine
8	Kingfish No. 1 prospect
9	Kingfish No. 2 prospect
10	Sidehill mine
11	Blanco prospect
12	Unnamed prospect
13	Southeast corner mineralized zone
14	I.M. Vanderbilt mine
15	Billie mine

Figure 2. Continued

south of the study area. By 1907, the district included 4 towns, with a total of 2,000 inhabitants and 73 incorporated mining companies with $140 million in mining capital. The boom collapsed when shafts more than 1,400 ft deep failed to produce sufficient amounts of ore. Within 3 years, the district was virtually abandoned, with only small amounts of copper having been produced. In Gold Valley, 12-16 mi southwest of the study area, small-scale mining of gold, silver, copper, and lead accompanied the Greenwater boom; activity in the area ceased by 1910.

Between 1905 and 1907, a gold-prospecting boom reached its peak in an area 6 to 18 mi north of the study area. In the northern Funeral Mountains, the Keane Wonder and Chloride Cliff mines, and the Eho-Lee mining district straddle the lower Funeral Mountains from Schwab Camp on the west to the Lee mines on the east. The production potential of the mines and prospects was greatly exaggerated and over-publicized. The Funeral Mountains were then left much as they had been found, except that numerous shafts, tunnels, and prospect holes now dot the countryside (Latschar, 1981).

Underground borate mining began in 1907 at the Lila C mine 7 mi southeast of the study area. In 1914, development shafts were sunk into the large borate ore bodies at Ryan, 3 mi southwest of the study area. By 1928, the Ryan mines were closed. In 1976, Tenneco started shafts for the Billie mine adjacent to the Ryan property.

Three mining operations have recently produced industrial minerals within 3.5 mi of the study area. The American Borate Company operates the Billie mine 4 mi southwest of the study area (fig. 2). As of February 1982, the Billie mine produced 210,552 tons of ore-grade colemanite and ulexite-probertite from a boron-bearing spring-lacustrine deposit (F.C. Johnson, American Borate Company geologist, oral commun., 1983). The borates are used principally in glass products. After 10 years of production, the Billie mine was put on standby in early 1986.

Clay for cosmetic and pharmaceutical products (Lease, J.R.T. Vanderbilt Co., oral commun., 1983) is produced at the Sidehill mine (fig. 2, No. 10) 2 mi east of the study area. The J.R.T. Vanderbilt Company intermittently mines bentonitic clay from an early Miocene tuffaceous red sandstone unit. Hectorite, a lithium-rich clay, and sepiolite (meershaum) are mined from Quaternary lakebed sediments near Franklin Wells (fig. 2) by Industrial Mineral Ventures, Inc. The hectorite and sepiolite were formed by alteration of volcaniclastic sediments. Hectorite is used in drilling mud and as a component of construction materials; sepiolite is sold as a soil conditioner.

Until 1983, the Anaconda Copper Company operated the Ash Meadow open-pit zeolite mine 10 mi east of the study area. Since 1979, Anaconda has been mining clinoptilolite, a zeolite mineral used mainly for agricultural fertilizers and waste-water ammonia absorption. The company sold the property in 1983, and it is now idle.

Mines, Prospects, and Mineralized Zones

Eleven mines and prospects and two mineralized zones were examined by the Bureau of Mines during this study. Of these, four prospects and two mineralized zones are located within the study area; the remaining prospects are adjacent to it. The four prospects within the study area, Bentonite Placer, Yellow Heart, Deborah, and an unnamed prospect in the southeast corner of the area (fig. 2, Nos. 3, 4, 5, and 12), are all inactive. No patented claims or existing leases are located within the study area; the nearest patented property is the Sidehill mine, 2 mi east of the study area (fig. 2, No. 10).

Outcrops of mineralized rock traced from existing claims are located in the southeast corner of one mineralized zone (fig. 2, No. 13) and in the Red Amphitheater mineralized zone (fig. 2, No. 2). Table 1 includes descriptions of mines, prospects, and mineralized zones examined for this report.

Conclusions

The study area contains no identified mineral resources. However, three prospects, the Bentonite Placer, the Deborah, and an unnamed prospect (fig. 2, Nos. 3, 5, 12), contain occurrences of zeolite minerals and bentoitic clay. A mineralized zone in the southeast corner of the study area (fig. 2, No. 13) containing bentonite and zeolite minerals, and the Red Amphitheater mineralized zone (fig. 2, No. 2) containing strontium are also classified as mineral occurrences. Seven mines and prospects containing resources of bentonitic clay, pumice, and dimension stone are located adjacent to the wilderness study area.

Bentonitic clay and zeolite in the study area are present in altered zones in Tertiary waterlain tuffaceous sediments. Local concentrations are relatively low grade, thin, and discontinuous; only bentonite at the Deborah prospect (fig. 2, No. 5) and Kaolin mine (fig. 2, No. 7) meet industry standards as pelletizing agents (such as taconite) and as bonding media. Because the beds are steeply dipping, substantial amounts of overburden would need to be removed for surface mining.

High concentrations of strontium (fig. 2, No. 2) in Tertiary mudstones in the Red Amphitheater mineralized zone approach commercial grades (more than 1 percent strontium), but small tonnage and low average grade preclude classifying the zone as a resource.

Limestone, quartzite, and sand and gravel in the study area are suitable for many types of construction uses. However, similar materials are available closer to existing markets, making exploitation of the deposits in the study area economically unfeasible.

No energy resources have been identified within the study area.

ASSESSMENT OF UNDISCOVERED RESOURCES

By Augustus K. Armstrong, James G. Frisken, and Robert C. Jachens U.S. Geological Survey

Geologic Setting

The Funeral Mountains trend northwest, are fault controlled, and have rugged relief. They rise

4,300 ft above the adjoining pediments that are largely coalesced alluvial fans. The mountains possess typical basin-and-range topography and are comprised of Paleozoic stratified rocks. These rocks are unconformably overlain by 3,000-5,000 ft of fluvial and lacustrine deposits of Tertiary age. The rocks in the foothills are overlapped by Quaternary alluvium; at some distance from the highlands, the fan deposits intertongue with playa deposits.

Structural Geology

Structural features within the study area consist of strike-slip faults, high-angle faults, folds, and tilted and warped strata. High-angle faulting was accompanied by tilting, as illustrated by Cenozoic sedimentary rocks that now dip as steeply as 60°. Many of the high-angle faults are northeast-trending normal faults that have arcuate traces and whose planes may flatten at depth. These planes are present throughout the area. Some of the earlier normal faults were rotated to subhorizontal positions during progressive high-angle faulting and tilting. Other low-angle faults underlie gravity-slide blocks. The basin-and-range structures present in the area are the result of block faulting due to east-west or southeast-northwest extension that developed over a considerable span of time during the Cenozoic era (Burchfiel and others, 1983).

The Funeral Mountains are bounded on the southwest by the Furnace Creek strike-slip fault zone. Denny and Drewes (1965) believed that the oldest movements along this fault zone took place during the Oligocene. It was probably during this time that movement took place along subsidiary faults in the older rocks. By Miocene or Pliocene time, the Funeral Mountains were elevated in relation to the area southwest of the Furnace Creek faults.

Stratigraphy

A complexly faulted stratigraphic sequence of Cambrian to Mississippian age marine sedimentary rocks is exposed in the southeastern part of the Funeral Mountains. This exposure is 18 miles long and about 9,000 ft thick. McAllister (1971b) correlated the sequence in the Funeral Mountains with the formations that have been described in the Nopah Range (Hazzard, 1937; Burchfiel and others, 1982). Mesozoic strata are absent.

The older Cenozoic deposits are confined to the eastern side of the wilderness study area, where they form a 1,000-8,000-ft thick sequence of stream and lake sediments and basalt. Younger Cenozoic deposits are composed of lake, stream, and fan sediments interbedded with volcanic rocks. These are found along the flanks of the Funeral Mountains.

The Cambrian through Mississippian strata in the study area are predominantly carbonate rocks that were deposited in shallow marine environments.

The Bonanza King and Nopah Formations are composed of Cambrian-age gray to light-brown, subtidal limestone and dolomite. They are about 3,600 ft thick. The Lower and Middle Ordovician Pogonip Group dolomites are 2,200 ft thick. The Middle Ordovician Eureka Quartzite is 160 ft thick and contains white quartzite. The Middle and Upper Ordovician Ely Springs Dolomite is more than 400 ft thick and is composed of fossiliferous dark-gray dolomite and limestone. The Silurian and Lower Devonian Hidden Valley Dolomite, 1,400 ft thick, is a massive gray dolomite. The dolomite of the Middle and Upper Devonian Lost Burro Formation is 2,500 ft thick. Mississippian rocks crop out a few hundred yards east of the study area. The Mississippian Tin Mountain Limestone and Perdido Formation together are composed of 820 ft of limestone, chert, and shale. Younger Paleozoic rocks were eroded prior to the deposition of Tertiary fanglomerates.

Between the Spring Mountains, Nevada, and Death Valley, California, the Mesozoic sedimentary and volcanic units have been eroded away. These units are absent in the study area.

The oldest Tertiary unit in the study area is an unnamed conglomerate that is 60 ft thick and consists of pebble-to-boulder size clasts bound by a sandy matrix. The clasts are derived from Proterozoic and Paleozoic rocks. The overlying Oligocene and Miocene Horse Spring Formation of Cemen and others (1982) is 500 ft thick and consists of a succession of interbedded limestone, siltstone, and tuff. Above the Horse Spring Formation is the Red Sandstone; it is 1,000 ft thick and is composed of a variety of rocks ranging from mudstone to conglomerate. The clasts were derived from Paleozoic bedrock similar to the rocks within the study area that were described above and Tertiary volcanic rocks not found within the study area. Above the Red Sandstone unit are 300 ft of pinkish-gray to white fresh-water micritic algal limestones.

Overlying the algal limestone is the Miocene Bat Mountain Formation of Cemen and others (1982) that is correlative with the upper fanglomerate of Denny and Drewes (1965). The Bat Mountain Formation is 1,500 ft thick and consists of clasts of Proterozoic and Paleozoic sedimentary rocks in a sand and clay matrix.

The Miocene and Pliocene (?) Furnace Creek Formation is 7,000 ft thick and crops out in the southwestern part of the study area. The borate-bearing rocks of the Furnace Creek Formation are light-colored, fine-grained rocks originally deposited as lakebed sediments. The formation also contains basalt, thin limestone layers, and gypsum beds.

The Pliocene and Pleistocene age Funeral Formation is 700 ft thick and consists of poorly sorted conglomerate composed of Paleozoic limestone, Cenozoic volcanic clasts, and thick basaltic sequences.

The Quaternary deposits of the study area are composed of Pleistocene and Holocene alluvium. The surface of the older alluvium has been smoothed by the breakdown of coarse material and the development of desert pavement. The younger alluvium consists of gravel deposited along recent stream channels. The gravel is fresh gray in the youngest channels and is coated brown (desert varnish) along abandoned stream courses.

Geophysics

An aeromagnetic survey of the study area was flown by High Light Helicopters (Puyallup, Wash.) and compiled by Geodata International (Dallas, Tex.) under contract to the U.S. Department of Energy as part of the National Uranium Resource Evaluation Program (NURE). In 1977 and 1978, total-field magnetic data were obtained along north-south flight lines spaced approximately 1 mi apart and flown at an average elevation of 400 ft. Because of the ruggedness of the Funeral Mountains, actual terrain clearance varied from about 300 to 1,400 ft. Corrections were applied to the data to compensate for diurnal variations of the Earth's magnetic field and the International Geomagnetic Reference Field (updated to the months that the data were collected) and were subtracted to yield a residual magnetic field.

The residual magnetic field over the study area is characterized by long-wavelength (4 mi), low-amplitude anomalies generally measured at less than 50 nanoteslas. The long wavelengths of these anomalies and their broad, gently sloping flanks indicate that the magnetic sources may lie at depths of a mile or more below the survey altitude. These anomalies are probably caused by magnetic variations within the Proterozoic crystalline basement, or by relief of the basement surface that is concealed beneath the thick section of carbonate rock exposed at the surface. The lack of correlation between the topography and the residual magnetic field indicates that the exposed carbonate rocks are not magnetic. The data show no anomalies within the study area that would indicate large, shallow magnetic bodies, such as the magnetic plutons exposed in the Kingston Range to the southeast and the Black Mountains to the southwest.

Geochemistry

The reconnaissance geochemical survey was based on analyses and evaluations of heavy-mineral concentrates of 34 samples collected from dry washes in the study area. The survey was conducted in order to identify patterns of stream-sediment chemistry that might reflect mineralizing processes in the major rock units of drainage basins within the study area.

All samples were analyzed for 29 elements by a 6-step, semiquantitative emission-spectrographic method (Grimes and Marranzino, 1968). These analyses helped identify drainages containing anomalous concentrations of metallic elements. Anomalous values were determined by enrichment of the rocks relative to crustal abundance.

Three of the drainage basins in the study area contain highly anomalous concentrations of barium, lead, and zinc. The drainage basin occupying the eastern part of the study area contains anomalous concentrations of barium (10,000 parts per million (ppm)), lead (300 ppm), and zinc (1,000 ppm). Samples collected from the drainage basin occupying the central part of the study area contain anomalous concentrations of barium (10,000 ppm), lead (2,000 ppm), and zinc (20,000 ppm). A watering station is located at the head of the central drainage, and so galvanized pipe used in the construction of the station may account for some anomalous concentrations of lead and zinc. There is no way to distinguish contamination from naturally occurring lead and zinc. The westernmost drainage basin in the study area with pronounced geochemical anomalies contains concentrations of barium (10,000 ppm), zinc (2,000 ppm), and lower concentrations of lead (100 ppm). Low concentrations of copper (300 ppm) were found in the southern part of the westernmost anomalous drainage area. Silver was not detected. However, a flake of gold was found in a dry-pan sample collected from a drainage basin in the eastern part of the study area.

The combination of highly anomalous concentrations of barium, lead, and zinc indicates that these metals may be derived from hydrothermal vein deposits, or that they may occur as low-temperature, strata-bound lead and zinc deposits in the Paleozoic carbonate rocks exposed in the study area.

The Bureau of Mines collected six chip samples from the Red Amphitheater mineralized zone that contained strontium (0.062-1.7 percent), lithium (0.024-0.08 percent), and boron (0.0041-0.042 percent). This occurrence is believed to be the result of hot water from thermal springs altering sedimentary clastic rocks (Neumann, 1984).

Mineral and Energy Resources

Bentonite and Zeolite

Bentonite and zeolite deposits in the study area generally occur in altered silicic volcanic rocks of the Miocene Horse Springs Formation. These are fresh water lakebed sediments and ash-fall deposits. Just outside the study area, the only active mine is the Sidehill mine, which produces bentonite for the cosmetic and pharmaceutical industries. Although a large number of tuff beds are present in the Horse Spring Formation, only one bed is mineralogically suitable or thick enough for mining.

Bentonitic clay and zeolite minerals found in the study area occur in alteration zones in Tertiary tuffaceous lakebed deposits. The bentonite deposits in the study area are erosional remnants of the Miocene lake beds and are thin and discontinuous.

Sheppard (1985) described the Pliocene-Miocene Ash Meadows zeolite deposit (10 mi east of the study area) as clinoptilolite-rich tuffs that were formed by reaction with alkaline ground water. Similar deposits are unknown within the study area.

The resource potential for bentonitic clay and zeolite minerals in the study area is low with a D level of certainty. See fig. 3 and appendix 1 for definitions of mineral resource potential and levels of certainty.

Limestone, Quartzite and Sand and Gravel

There are numerous limestone, quartzite, and sand and gravel deposits in the study area that are suitable for use as construction materials. However, much of the carbonate rock in the study area is dolomite or dolomitic limestone and is unsuitable for making cement. The potential for limestone, quartzite, and sand and gravel is high with a D level of certainty. Although limestone, quartzite, and sand and gravel is abundant in the study area, the economic potential is low.

Base and Precious Metals

Geochemical investigations in the study area indicate a low potential for lead and zinc resources. Only a few scattered drainage basins in the study area contain metallic anomalies. Lead and zinc concentrations are low; typical concentrations of lead and zinc in the pan concentrates of stream-sediment samples are 100-1,000 ppm and 500-20,000 ppm, respectively. The only copper values (100-200) may be the result of contamination. Barium concentration is as high as 10,000 ppm. Although a single flake of gold was found in the southeast part of the study area, gold was not detected elsewhere. Arsenic, mercury, molybdenum, and silver were not detected.

Model for Strata-bound Lead-Zinc Deposits

Two possible mineralization models may explain the occurrence of lead and zinc in the study area. The lead-zinc geochemical signature in the samples collected within the study area may be derived from strata-bound deposits of sphalerite and minor galena from primary and secondary voids of favorable beds in the lower Paleozoic carbonate rocks. The lower Paleozoic carbonate rocks of the Funeral Mountains are very smiliar in lithology, texture, and facies to the lower Paleozoic rocks of Missouri, Kentucky, and Tennessee that contain ore bodies of low-temperature, strata-bound lead and zinc (Pratt, 1982). Strata-bound ore deposits similar to those of the central United States have not been found in the western states. This is probably due to distinctly different late Paleozoic tectonic histories of the two regions.

Model for Mesothermal-epithermal Gold, Copper, and Lead- Zinc Vein Mineralization

Lead and zinc are found in veins, stockworks, and bedded replacement bodies in carbonate rock associated with a quartz-calcite gangue in the Death Valley region; the ore minerals are galena and sphalerite (Goodwin, 1957). On the basis of trace elements present in the mineral suites in heavy-mineral concentrate samples, the conceptual model for mineralization appears to be related to low- to moderate-temperature hydrothermal events. The geologic environment in a Paleozoic carbonate-rock terrane is conducive to this type of mineralizing phenomenon. The plutonic rocks may have provided the mineralizing fluids that formed veins in the surrounding reactive carbonate rocks. The Cerro Gordo mine in the Inyo Mountains is an example of this type of mineralization (Merriam, 1963).

The study area contains little evidence of local igneous activity in the form of exposed plutons or intrusive bodies, and only indirect evidence (in the form of recrystallized carbonates) that would indicate the presence of buried plutons that could form Cerro Gordo-type ore bodies.

Geologic and geochemical investigations in the study area indicate that three drainage basins (the eastern, central, and western) contain anomalous concentrations of lead and zinc; however, based on the proceeding analysis, the resource potential of the study area for lead and zinc is low with a C level of certainty.

Boron

Evans and others (1976) calculated that 6,675,400 short tons of boron reserves were contained in the Ryan-Death Valley Junction area adjacent to the south side of the Funeral Mountains Wilderness Study Area. The Furnace Creek Formation is the host rock for the major boron deposits that are known to exist west and south of the study area. Undiscovered deposits of considerable size may be present in the southwestern part of the study area in the Furnace Creek Formation. Exploration drilling would be needed to locate these deposits. The resource potential for boron is moderate with a C certainty level.

Other Commodities

Strontium concentrations in Tertiary mudstones in the Red Amphitheater mineralized zone are locally higher than 1 percent. The strontium concentrations are found in small deposits. The resource potential for strontium is low with a D level of certainty.

In a study of the uranium resources of the Death Valley region, Cook (1980) showed that there was no indication of the presence of uranium or thorium within the study area. There is no resource potential for uranium or thorium within the study area.

Stratified sedimentary rocks in southeastern California, including those in the study area, have low potential for oil and gas because of the Mesozoic and Tertiary igneous activity and Cenozoic extensional tectonism of the region. Because of the area's igneous activity, complex tectonics, and high-temperature history, the resource potential for oil and gas is low with a C certainty level (Scott, 1983).

The Amargosa Desert, adjacent to the northeast side of the Funeral Mountains, is a large area favorable to the development of local sources of low-temperature (less than 90°C) geothermal water (Sammel, 1979). The Shoshone area has similar geology and tectonic style to the Funeral Mountains. The presence of warm water from the Shoshone Springs, 20 mi southeast of the study area, indicates possible geothermal activity in the wilderness study area. The geothermal resource potential is low with a D level of certainty.

Conclusions

Geochemical evidence indicates that lead-zinc-barium mineralization occurred within three drainage basins in the study area. These basins contain anomalous concentrations of barium, lead, and zinc. The combination of pronounced anomalies of barium, lead, and zinc indicates that these base metals may be derived from hydrothermal vein deposits, or that they may occur as low-temprature, strata-bound lead-zinc deposits in the Paleozoic carbonate rocks of the study area. The resource potential for lead and zinc is low with a C level of certainty.

Strontium deposits may be present in the southwestern part of the study area in the Furnace Creek Formation. The resource potential for strontium in this area is lowwitha D level of certainty.

Bentonite and zeolite-mineral deposits present in altered silicic volcanic rocks were formed by the hydrothermal alteration of feldspar. An altered zone in the southeast corner of the study area contains disconnected erosional remnants of bentonite beds. The resource potential for bentonitic clay and zeolite minerals is low with a D level of certainty.

Exploration in the wilderness study area may reveal small deposits of bentonite clay and zeolite minerals, and the Cenozoic lakebed deposits in the southwestern part of the study area may contain large deposits of borate minerals. An exploratory program that would drill through the Funeral Formation and penetrate to the Furnace Creek Formation may reveal an extension of the borate deposits that are present in the American Borate Company's Billie mine adjacent to the study area. These borate deposits are believed to have formed as the result of hot brines moving up along extensional fractures and faults during the deposition of the Furnace Creek Formation. The major fault system in the southwestern part of the study area is the Furnace Creek fault zone. The areas where north- and northeast-trending faults join the Furnace Creek fault zone prime locations for exploratory drilling to reach the lower part of the Furnace Creek Formation. Elsewhere in the region, along the Furnace Creek fault system, the junctures of these two sets of faults were determined to be the loci of ancient hot springs and major borate deposits. The resource potential for boron in the western part of the study area is moderate, with a C level of certainty.

Limestone, quartzite, and sand and gravel are abundant in the area and there is a high potential for undiscovered resources of these commodities; however, there are economic factors which could affect development, and these are treated elsewhere in this report.

No indication of oil or gas was found in the study area; the resource potential for oil and gas is low with a certainty level of C. The potential for geothermal resources is considered to be low with a D level of certainty.

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TABLE 1. - Mines, prospects, and mineralized zones in and adjacent to the Funeral Mountains Wilderness Study Area (BLM No. CDCA-143)
[asterisk (*) indicates outside study area]

Map No.	Name	Geology	Workings and production	Sample and resource data
1	*Red Amphitheater mine(flagstone)	A flat-lying sequence of Tertiary lacustrine mudstone is exposed at the entrance to Red Amphitheater. The mudstone has local shale partings and breaks into slabs which average 4 to 6 in. thick. The rock is limey in places, grading into marlstone.	Several small pits where no more than 10,000 tons of flagstone were removed for local construction.	Appears suitable for flagstone and other dimension stone uses.
2	Red Amphitheater mineralized zone	A small segment of Furnace Creek Formation mudstone and shale lap up on Paleozoic marine sedimentary rocks at the west entrance to Red Amphitheater on the WSA's western boundary. The mudstone is tuffaceous, limey, and contains fibrous gypsum. The sediments are lacustrine in origin.	None	Six chip samples contained strontium (0.062-1.7 percent), lithium (0.024-0.08 percent), and boron (0.0041-0.042 percent).
3	Bentonite Placer prospect	A bentonitic shale-mudstone bed as thick as 4.2 ft strikes N. 10° E. and dips 45° SE. Abundant popcorn texture occurs on a 40 ft exposure.	One prospect pit is 5 x 5 x 2 ft.	Six chip samples of clay were taken: all six composed predominantly of montmorillonite with cristobalite impurities. Two samples contained 10 to 13 percent clinoptilolite.
4	Yellow Heart prospect	Thin, gray-green zeolitic shale lies above tuff and below alluvial fan gravels. Beds strike N. 15° E., dip 27° NW., average 1.5 ft thick, and are intermittently exposed for 100 ft.	One small cut	Three chip samples averaged 35 percent clinoptilolite and mordenite.
5	Deborah prospect	Gray-green bentonitic bed averages 2.0 ft thick and is exposed in workings in a 3.6 acre area. Best exposures are along a 280-ft-long bentonitic mudstone-limestone contact.	Five trenches (two 30 x 12 x 3 ft; the others less than 20 ft long) and three small prospect pits.	Three chip and two grab samples contained montmorillonite and cristobalite with minor gypsum. Four samples averaged 10 percent clinoptilolite. Three samples meet industry standards for use as a foundry sand bonding medium.
6	*Kaolin Extension prospect	Four lenses of montmorillonite clay are discontinously exposed for 260 ft between limestone beds. The clay lenses are as much as 8.2 ft thick (average 2.0 ft) and parallel north to northwest striking limestone units. Dips range from 45° to 70° E.	Two trenches, each 18 x 6 x 3 ft deep.	Four chip samples were taken: two contained anomalous amounts of lithium (>0.1 percent).

7	*Kaolin mine prospect	Bentonitic clay, seen only on dump, displays popcorn texture on the surface. It appears to be altered from tuff in the red sandstone unit exposed nearby.	One collapsed shaft. Production records are unavailable.	Three select samples were taken of apparently high-grade material. The calcium-rich clay contains montmorillonite suitable for use as a pelletizing agent (taconite) and as a bonding medium.
8	*Kingfish No. 1 prospect	Sandy, tuffaceous bentonite bed as thick as 6.5 ft is enclosed in a red sandstone unit. Bentonite displays popcorn texture on the surface. A distinctive cream-colored algal limestone overlies the red sandstone.	One collapsed adit	One chip sample contained montmorillonite and cristobalite with 3 percent clinoptilolite.
9	*Kingfish No.2 prospect	A gritty bentonite layer 5.5 ft thick is enclosed in a tuffaceous red sandstone unit and overlain by arenaceous lacustrine limestone.	One collapsed adit	Two chip samples of bentonitic clay: one contained 4.0 percent clinoptilolite and one contained 63 percent clinoptilolite and mordenite.
10	*Sidehill mine (bentonite)	Two bentonite beds as much as 20 ft thick strike approximately N. 10°-30° E. and dip 40° SE. The bentonite is overlain by beds of cemented volcanic ash.	One adit, two shafts, and a surface trench on four patented claims. Production records are unavailable.	No samples taken
11	Blanco prospect	A white-gray pumice bed is friable, gritty, and underlies a red sandstone unit.	One small prospect pit	Optical petrographic examination of one sample verified pumice.
12	Unknown name prospect	White to light-green interbedded tuffs and shales ranging from 1.0 to 7.5 ft thick. Trough and laminar cross-bedding seen in tuffs indicate fluvial origins.	Three pits, the largest is 20 x 10 x 10 ft deep.	Six chip samples: five contained major montmorillonite. One sample had 60 percent clinoptilolite and mordenite.
13	Southeast corner mineralized zone	A succession of thin-bedded sandstones, siltstones, tuffs, and bentonitic clays are in thin (thickness to 2.3 ft) and discontinuous beds. The layers are correlated with the Horse Spring Formation (Cemen, Drake, and Wright, 1982). A sandstone unit overlies the Horse Spring sequence and is exposed for about 1.5 miles.	None	Six chip samples taken from tuff unit of Horse Spring Formation contained from 39 percent to 70 percent clinoptilolite and mordenite. Two chipsamples from a bentonitic layer within the red sandstone outcrops, contained major montmorillonite. One sample contained major quantities of sepiolite.

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

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

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

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

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

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

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

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

Levels of certainty of assessment are denoted by letters, A-D (fig. 3).

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

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

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

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

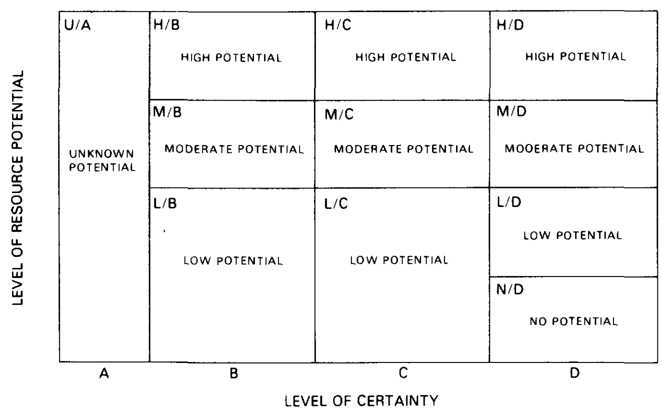

Figure 3.--Major elements of mineral resource potential/certainty classification.

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