Mineral Resources of the Castle Peaks Wilderness Study Area, San Bernardino County, California

U.S. GEOLOGICAL SURVEY BULLETIN 1713–A

Chapter A

Mineral Resources of the Castle Peaks Wilderness Study Area, San Bernardino County, California

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS: EASTERN CALIFORNIA
DESERT CONSERVATION AREA

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 Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine their mineral 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 a part of the Castle Peaks (CDCA-266) Wilderness Study Area, California Desert Conservation Area, San Bernardino County, California.

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Mineral Resources of the Castle Peaks Wilderness Study Area, San Bernardino County, California

By David A. Miller, James G. Frisken, *and* Robert C. Jachens
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SUMMARY

Abstract

The Castle Peaks Wilderness Study Area (CDCA-266) comprises approximately 45,000 acres in the northern New York Mountains, San Bernardino County, California. At the request of the Bureau of Land Management, 39,303 acres of the wilderness study area were studied. The area was investigated during 1982-1985 using combined geologic, geochemical, and geophysical methods. are considered preliminarily suitable for wilderness deignation. There are no mineral reserves or identified resources in the study area. Fluorspar, occurring in sparse veins, has moderate resource potential, as do silver and lead in fault zones, and gold and silver in sparse, high-grade veins and fault breccia. Each area of moderate resource potential encompasses less than one square mile. These same commodities have low resource potential in similar occurrences throughout much of the study area. In addition, there is low resource potential for gold in placer deposits, uranium in altered breccia and gouge, and rare-earth elements in pegmatite dikes. There is no resource potential for oil and gas resources over most of the study area, but the potential is unknown along its western margin. In this report, the area studied is referred to"the wilderness study area", or simply "the study area."

Character and Setting

The Castle Peaks Wilderness Study Area comprises part of the northern New York Mountains (fig. 1). It includes most of the area northeast of Ivanpah Road, northwest of Hart Mine Road, southwest of the Nevada state border, and east of the Union Pacific railroad line in Ivanpah Valley. Elevations in the study area range from more than 5,000 ft in high, sparsely forested mountains to about 3,200 ft in Ivanpah Valley to the west. Much of the bedrock in the study area is coarsely crystalline Early Proterozoic (570 to 2,550 million years before present, or Ma; See Geologic Time Chart, last page of report) gneiss and granite. Miocene (3 to 23 Ma) volcanic rocks overlie the gneiss and granite on the east, and are in turn overlain by late Cenozoic (0 to 23 Ma) alluvial deposits. Normal faults that cut volcanic strata and underlying rocks generally strike north and dip west.

Past mining activity in the study area included exploration for gold, silver, copper, lead, zinc, fluorspar, and uranium. As of May 1982, ongoing mining activity in the study area consisted of exploration for gold and silver and assessment work on numerous lode and placer claims. Oil and gas leases and lease applications have been filed for parts of the study area.

Mineral Resource Potential

No mineral reserves or identified resources occur in the study area. Resource potential for several commodities is assessed below.

Allanite in pegmatite dikes that intrude granite and gneiss appears to carry thorium and rare-earth elements, such as lanthanum. These elements, as well as yttrium, occurred in anomalous concentrations in stream-sediment samples from the study area. Consequently, that part of the study area underlain by Proterozoic rocks has a low potential for rare-earth and related-element resources.

Fluorspar in vein or disseminated occurrences has a moderate resource potential in the northern part of the study area (fig. 2) and low resource potential in remaining exposures of Proterozoic rocks in the study area. In the northern part of the study area, veins are sparse and not systematically oriented, but concentrations of fluorite in stream sediments are high; fluorite was noted in three concentrate samples, and rich fluorspar veins have been worked intermittently.

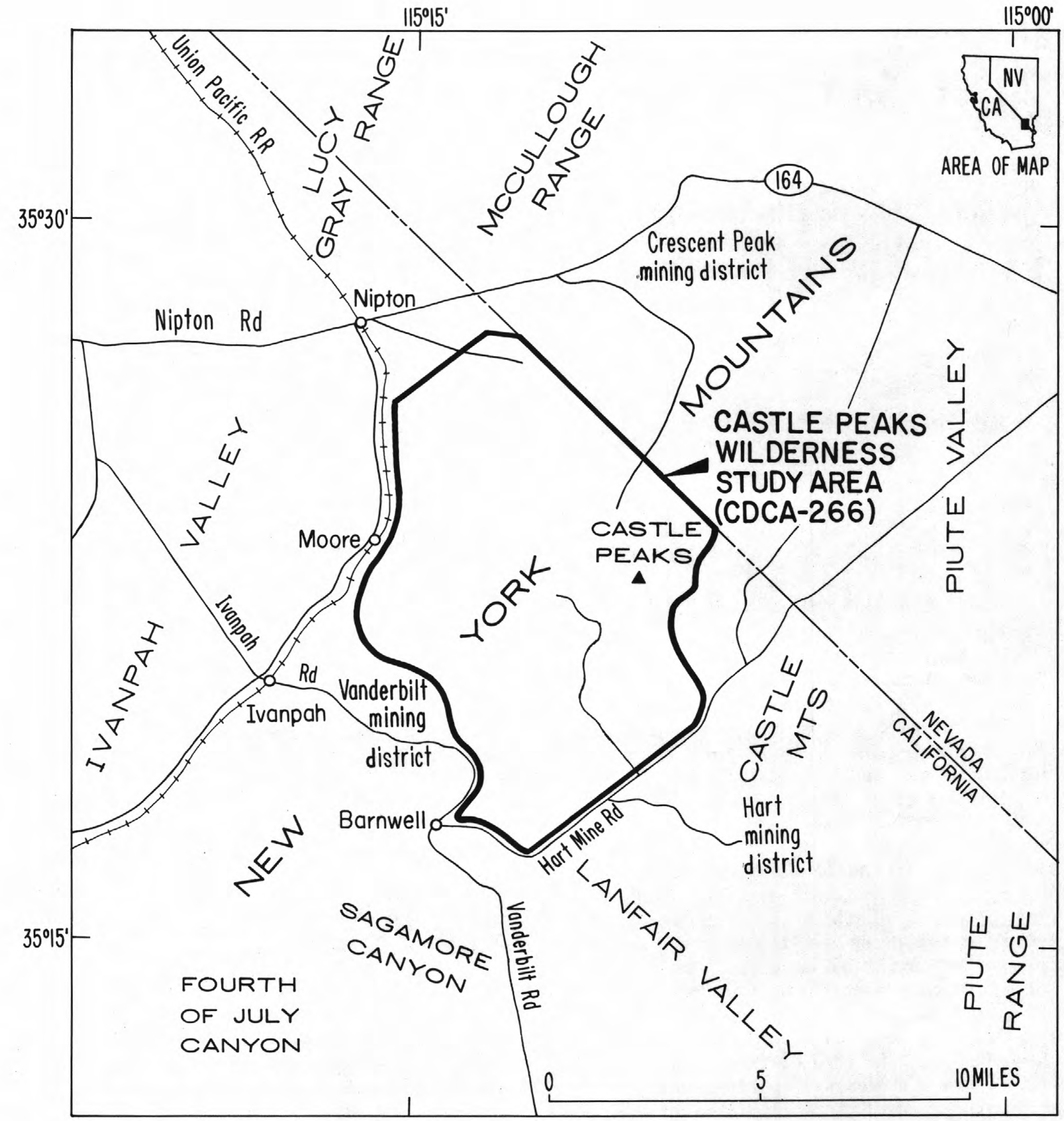

Figure 1. Index map showing location of the Castle Peaks Wilderness Study Area.

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Sporadically mineralized quartz veins and fault breccia in much of the study area contain hydrothermal gold, silver, lead, copper, and zinc. Silver and lead production from the Albermarle mine (fig. 2), coupled with strongly anomalous geochemical values, indicates a moderate resource potential for silver and lead in and near the mine (fig. 2). The remainder of the study area that is underlain by Proterozoic rocks has a low resource potential for silver and lead. Near the Vanderbilt mines, quartz veins and fault breccia contain gold, silver, lead, and copper. On the basis of its mining history and favorable geochemical values, that part of the study area near the Vanderbilt mines is assigned a moderate resource potential for gold and silver (fig. 2). The area adjacent to Vanderbilt mines north of Willow Wash (fig. 2) has lower geochemical values and less favorable geologic structure, and is assigned a low resource potential for gold and silver.

No gold was detected in stream-sediment-concentrate samples from the study area. Gravel derived from nearby regions, including mining districts whose rocks contain gold-bearing veins, was deposited in the study area. The gravel is assigned a low resource potential for gold in placer deposits.

Fault zones near Juniper Spring (fig. 2) contain highly altered breccia and gouge that have been prospected for uranium. Geochemical analysis of stream-sediment concentrates indicated no anomalous concentrations of thorium, and only 4 of 18 chip samples in this zone were composed of greater than 0.002 percent uranium (U_3O_8). Aeroradiometric surveys did not detect favorable terrane for uranium resources. On the basis of geochemical and airborne geophysical surveys and the prospecting history, rocks in the fault zones are assigned a low potential for uranium resources.

Oil and gas resources may have accumulated in Tertiary (about 2 to 66 million years before present) sediments possibly underlying the extreme northwest part of the study area, but their resource potential is unknown. There is no resource potential for oil and gas in the remainder of the study area.

INTRODUCTION

The Castle Peaks Wilderness Study Area (CDCA-266) is comprised of 44,998 acres in the northern New York Mountains and at the southern terminus of the McCullough Range in northeastern San Bernardino County, California. At the request of the U.S. Bureau of Land Management, 39,303 acres of the wilderness study area were studied. The study-area boundaries are defined on the northwest by a powerline road, on the northeast by the Nevada-California state border, on the southwest by Ivanpah Road, on the southeast by Hart Mine Road, and on the west by the Union Pacific railroad right-of-way. Paved and improved dirt roads provide access to the boundaries of the study area and several unimproved dirt roads and jeep and foot trails provide access within it. Elevations within the study area range from 3,200 ft on the west in Ivanpah Valley to 5,829 ft at the top of the Castle Peaks in the New York Mountains. Mountainous parts of the area are rugged, commonly with elevation changes of 500 to 600 ft over a horizontal distance of 1/4 mi. Of the approximately 45,000 acres included in this report, 39,303 acres are considered to be preliminarily suitable for wilderness designation.

Prior to field investigations, published and unpublished literature relating to the study area was reviewed the authors. Files at the San Bernardino County Courthouse in San Bernardino, California, and the Bureau of Land Management State Office in Sacramento, California were reviewed by one of the authors of this report (DDG) for patented and unpatented mining claim locations and oil and gas and geothermal leases.

Field studies conducted by the U.S. Bureau of Mines included mapping and collecting samples from known mines, prospects, and mineralized areas in and within 2 mi of the study area. Companion studies conducted by the U.S. Geological Survey included geologic mapping, geochemical sampling of stream sediments, limited rock-chip geochemical sampling, and geophysical surveys.

The U.S. Geological Survey wishes to acknowledge the assistance of L.L. Glick, S.L. Garwin, and S.L. Gusa for geologic mapping; A.D. McCollum, M.A. Mast, K.R. Greene, and J.C. Grey for stream-sediment sampling; and R.L. Morin for acquiring geophysical data. J.L. Wooden lent valuable help in understanding geologic relations in much of the study area. Discussions with J.E. Nielsen were helpful for interpreting Tertiary strata. J.K. Nakata and Ed DeWitt provided unpublished geochronologic data. Chemical analyses were performed by G.W. Day, J.A. Domenico, and R.T. Hopkins. R.M. Tosdal, R.E. Powell, and Andrew Griscom gave thorough reviews of this document.

APPRAISAL OF IDENTIFIED RESOURCES

By Diann D. Gese, U.S. Bureau of Mines

Mining Activity

Past mineral exploration within the study area was for gold, silver, copper, lead, zinc, fluorspar, and uranium. As of May 1982, ongoing activity consisted of exploration for gold and silver and assessment work on numerous lode and placer claims. Most mining claims at that time were located in the northern part of the study area and in the Vanderbilt mines area (fig. 2). Heavy Metals Development Corporation, a wholly owned subsidary of the Vanderbilt Gold Corporation, and B and B Mining Company were engaged in an exploration and evaluation program, including geologic study, geochemical sampling, and drilling in and near the southwest part of the study area.

Oil and natural gas leases and lease applications that were filed by various companies and individuals cover parts of the study area (Gese, 1984). Three wells have been drilled for oil and gas between 2 and 4.5 mi west of the area; however, only minor shows of oil and gas were reported.

In May 1982, Crescent Mining Ltd. had a small cyanide heap-leach operation in Nevada approximately

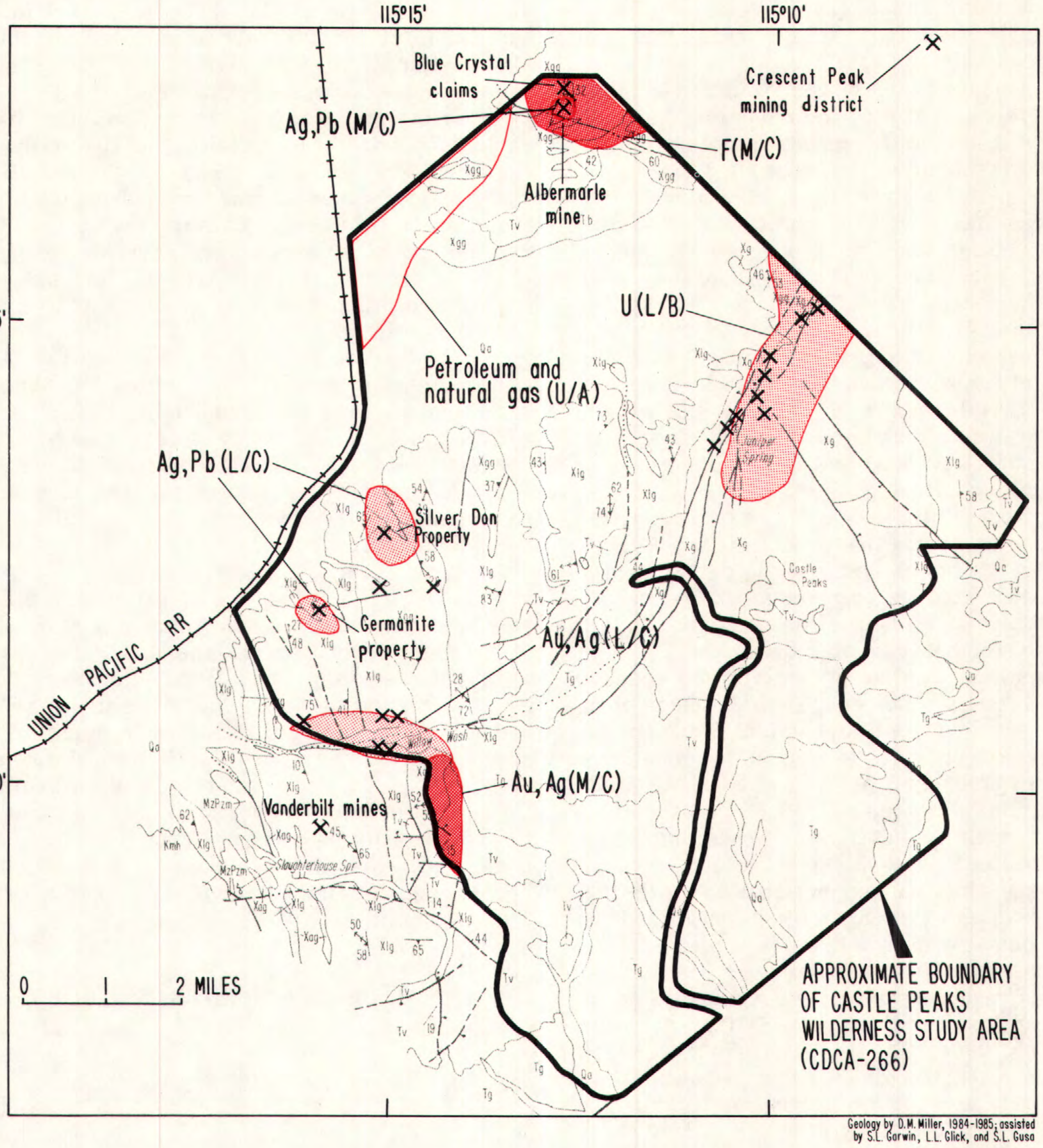


Figure 2. Map showing geology, mineral resource potential, and locations of mines and prospects in the Castle Peaks Wilderness Study Area

EXPLANATION

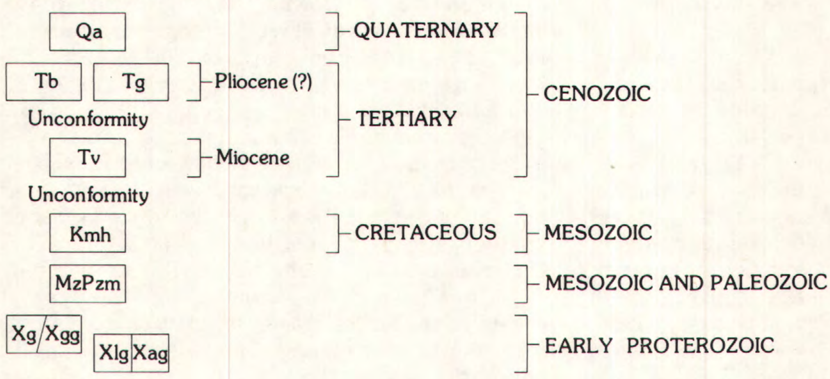
AREA WITH MODERATE MINERAL RESOURCE POTENTIAL--Commodities as shown. See appendix 1 and figure 5 for definition of levels of mineral resource potential and certainty of assessment

AREA WITH LOW MINERAL RESOURCE POTENTIAL--Commodities as shown

COMMODITIES

Au	Gold
Ag	Silver
F	Fluorspar
	Petroleum and natural gas
Pb	Lead
U	Uranium

CORRELATION OF MAP UNITS



GEOLOGIC MAP UNITS

Qa	ALLUVIUM (QUATERNARY)
Tb	BRECCIA (PLIOCENE ?)--Monolithologic breccia of granitoid gneiss
Tg	GRAVEL DEPOSITS (PLIOCENE?)
Tv	VOLCANIC ROCKS (MIOCENE)--Interfingering flows of volcanic rocks: welded rhyolite ash flow, dacite lahars and mudflows, andesite breccia and lahars, and basalt lava flows and lahars
Kmh	MID HILLS ADAMELLITE OF BECKERMAN AND OTHERS (1982) (CRETACEOUS)--Medium to coarse grained and sparsely porphyritic. Light-gray biotite monzogranite. Contains dikes of varied composition
MzPzm	STRATIFIED METAMORPHIC ROCKS (MESOZOIC AND PALEOZOIC)--Metamorphosed fine-grained felsic volcanic rocks, conglomerate, cherty dolomite, and clean limestone
Xg	GRANITE (EARLY PROTEROZOIC)--Medium to coarse grained and subequigranular leucocratic biotite garnet monzogranite
Xgg	GRANITOID GNEISS (EARLY PROTEROZOIC)--Gneiss derived from granitoid rocks
Xlg	LAYERED GNEISS (EARLY PROTEROZOIC)--Compositionally heterogeneous gneiss showing well-developed compositional layering
Xag	AMPHIBOLE-RICH GNEISS (EARLY PROTEROZOIC)--Black mafic rocks including hornblende amphibolite, biotite-garnet-pyroxene-hornblende gneiss

MAP SYMBOLS

- × PROSPECT, ADIT, OR SHAFT
- ⚒ MINE
- CONTACT--Dotted where concealed
- HIGH-ANGLE FAULT--Dashed where uncertain; dotted where concealed; ball and bar on downthrown side
- STRIKE AND DIP OF BEDDING
- STRIKE AND DIP OF FOLIATION
- MINERAL LINEATION
- MYLONITIC LINEATION

Figure 2. Continued.

3,000 ft northeast of the study area. From 1969 to 1970, and during 1974 and 1975, Vanderbilt Gold Corporation operated a 500 ton per day capacity mill on their Heavy Metal mill site, less than 1 mi south of the study area (Vredenburgh and others, 1981, p. 119). In May 1982, Vanderbilt Gold Corporation was in the process of converting their bulk-flotation mill to an agitated-leach operation (John Jordan Jr., Heavy Metals Development Corporation, oral commun., May 1982).

Description of Properties

The study area is near three mining districts: the Crescent Peak mining district to the northeast, the Hart mining district to the southeast, and the Vanderbilt mining district to the south (fig. 1). All three mining districts have had intermittent production since mineral deposits were discovered in the late 1800's.

A total of 179 chip, grab, and panned concentrate samples were taken from prospects and mines within and less than one mile outside the study area. All samples were fire assayed for gold and silver, and 84 samples were analyzed by semiquantitative optical emission-spectrographic methods for 42 elements. Additional analyses were made by atomic absorption when spectrographic results or the visible (or suspected) presence of certain minerals in samples required the quantitative determination of some elements. Properties described below are located on figure 2.

Sixty-seven placer and lode claims in Nevada and California held by the Blue Crystal Mining Company Inc. comprise the Blue Crystal property (fig. 2). The Albermarle mine is within the Blue Crystal property, and is discussed separately. This property has had several periods of mining activity; recently, the Blue Crystal Mining Company Inc. has been involved in an exploration program to evaluate the property for gold, silver, copper, lead, and fluorspar. In the 1920's, fluorspar was mined from several deposits in the area, and in the 1930's and 1940's gold, silver, and lead were produced from the Albermarle mine and smaller deposits. Tucker and Sampson (1930) described 1- to 3-ft-wide fluorspar veins in this area, then known as the McDermott fluorspar deposit. Assays of samples from the veins ran from 50 to 60 percent calcium fluoride (CaF_2). At that time, development consisted of two shafts, 50 and 60 ft deep, and a tunnel 20 ft long (Tucker and Sampson, 1930, p. 302). In 1925, several tons of fluorspar were shipped from the McDermott deposit, according to a report by A.M. Smith (in Burchard, 1934, p. 395).

During 1973 and 1974, several bulldozer trenches, approximately 300 ft north of the study area, were cut by the Blue Crystal Mining Company Inc. to determine the extent of the fluorspar mineralization. Their assays of samples taken from these trenches indicated gold and silver in the fluorspar veins, as well as in the Proterozoic granitoid gneiss country rock (N. K. Barker, Blue Crystal Mining Co., unpublished report, 1976).

In May 1982, there was no evidence of any recent mining on the claims held by the Blue Crystal Mining Co. Only a few of the prospected east-west-trending fluorspar veins that cut the gneiss were located within the northern part of the study area. At these, copper-carbonate minerals and calcite occur as secondary minerals that coat the fluorspar veins and line the contact between the veins and the wallrock. These veins were generally less than 1 in wide and did not appear to be extensive. Samples collected on the Blue Crystal lode claims by the Bureau of Mines contained as much as 59.1 percent CaF_2, 0.042 oz gold per ton, and 0.3 oz silver per ton. The largest fluorspar vein cropped out for 16 ft along a north trend and ranged in thickness from less than 1 in to 7 in.

The Albermarle mine, a 129-ft-long, 96-ft-deep inclined shaft, was sunk along a mineralized N. 55° E.-trending fault zone containing silver, lead, and minor gold. Three levels with more than 350 ft of workings were driven from the shaft at depths of 35, 54, and 96 ft. The 35-ft level follows the mineralized fault zone in which the shaft was sunk; however, the 54-ft and 96-ft levels were driven along parallel mineralized fault zones that strike approximately perpendicular to the fault exposed at the 35-ft level. The fault zones exposed in the mine are generally 3 to 5 ft wide, although one mineralized fault zone on the 96-ft level is 8 ft wide. Ore minerals that were identified in hand specimens include galena, cerussite(?), wulfenite, malachite, azurite, and chrysocolla. Tetrahedrite and chalcopyrite also have been reported (C. W. Lynch III, Geologist, C. L. Ranch, Inc., written commun., 1981).

Analyses of 31 samples collected at the 54-ft level in the Albermarle mine yielded values ranging from 0.4 to 17.1 oz silver per ton and from 0.08 to 6.85 percent lead. Although the 96-ft level appears to contain only minor amounts of silver or lead minerals, the two west drifts may not have been driven far enough to intersect the mineralized zone that was stoped on the 54-ft level. More mineralized rock could exist in this fault zone along the strike or at a greater depth.

U.S. Bureau of Mines records in Spokane, Washington, show that silver, lead, and minor gold and copper were produced from the Albermarle mine intermittently from 1942 to 1948. The 112 tons of ore that was taken from the mine during this period yielded 7 oz gold, 950 oz silver, 7,671 lbs lead, and 650 lbs copper. There has been no reported production from the Albermarle mine since 1948.

Three-thousand feet east of the Albermarle mine, along the Nevada-California border, and about 1 mi northeast of the study area, several prospect pits, shafts, adits, and trenches were driven to explore the contacts between Proterozoic gneiss and Tertiary basalt dikes (Hewett, 1956; Gese, 1984). Twelve of 42 samples taken across basalt/granite contact zones within 300 ft east of the study area contained from 0.006 to 0.324 oz gold per ton and averaged 0.06 oz gold per ton. However, the contact zones are narrow and the gold values vary considerably.

All workings on the Silver Don property (fig. 2) are located along fault and breccia zones in granite and mafic gneiss, with the exception of one trench that exposed a 2.3-ft-wide quartz vein. Most of the fault and breccia zones have an average width of 0.3 ft; however, two fault zones exposed in the adits are 3 and 5 ft wide. Only 4 of the 26 samples from the

Silver Don property contained silver; values ranged from 0.2 and 0.4 oz silver per ton.

The Germanite property consists of four parallel trenches exposing allanite-pegmatite dikes up to 3 ft wide that cut amphibole schist. The last recorded work on the Germanite #2 claim was in 1965. Assays of 5 samples gave no anomalous geochemical values.

The Vanderbilt group of mines (located within the Vanderbilt mining district) is less than 1 mi southwest of the study area. Eighteen patented claims held by the Vanderbilt Gold Corporation are generally located along two parallel, northwest-trending vein systems that range in thickness from 3 to 12 ft and are composed of layers of brecciated quartz and gouge (Hewett, 1956; Balkwill, 1964).

In May 1982, mining companies were evaluating the area north of the Vanderbilt mines in the southwest part of the study area to determine the nature and extent of the northwest-trending shear zones; these may extend from the area of the Vanderbilt mines into Vanderbilt Gold Corporation's Red Barnacle Far North claims, which are predominantly located within the study area (Gese, 1984, pl. 1) along its southwest border. Two drill holes intercepted an 8-ft-thick mineralized interval that reportedly assayed 0.24 oz gold per ton (John Jordan, Jr., Heavy Metals Development Corporation, oral commun., 1983).

Eight trenches and six prospect pits located within the study area near Juniper Spring (fig. 2) resulted from exploration for uranium along several faults in altered Proterozoic granite and gneiss. Of the fourteen samples from this area, none yielded gold or silver; however, 4 samples were found to contain as much as 0.002 percent U_3O_8.

The study area was examined in 1978 during the Department of Energy's National Uranium Resource Evaluation (NURE) of the Kingman 1^o x 2^o quadrangle (Luning and others, 1982), and it was determined that no environment favorable for uranium deposits of at least 100 tons U_3O_8 at a grade of not less than 100 ppm U_3O_8 existed in the area.

Oil and natural gas leases and lease applications cover parts of the study area, mostly in Lanfair and Ivanpah Valleys (Gese, 1984, pl. 1). Originally, interest in this region was due to geologic and seismic data that suggested that it might be an extension of the oil-bearing Idaho-Wyoming overthrust belt (J.P. Calzia, written commun., 1981). Seismic-refraction, regional gravity, and magnetic measurements were interpreted to indicate that the Ivanpah Valley contained as much as 8,000 ft of sedimentary material that is primarily siltstone, sandstone, and mudstone interbedded with layers of gypsum and anhydrite (Carlisle and others, 1980).

Three oil and natural gas test wells were drilled between 2 and 4.5 mi west of the study area (Gese, 1984, pl. 1) in Ivanpah Valley. The deepest of the 3 wells penetrated sediments to a depth of approximately 6,500 ft. As of May 1983, no oil or natural gas was produced from these wells, although minor oil and gas shows were reported from two of the wells (Hodgson, 1980).

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By David M. Miller, James G. Frisken, and Robert C. Jachens, U.S. Geological Survey

Geology

Geologic Setting

The oldest rock in the study area is Early Proterozoic gneiss derived from highly metamorphosed volcanic rocks and volcanic-derived sedimentary rocks that were intruded by granitoid plutons and then deformed into the present broad zones of gneiss and narrow mylonitic zones at about 1.7 Ga (Wooden and others, 1986). Thin Paleozoic carbonate strata and early Mesozoic conglomerate and rhyolite were deposited in shallow seas on a craton of the Proterozoic gneiss. During late Mesozoic time, rocks in the area were thrust-faulted and metamorphosed as part of the Cordilleran thrust belt (Burchfiel and Davis, 1977). Following thrusting, parts of the Teutonia batholith (Hewett, 1956; Beckerman and others, 1982) were emplaced. Miocene volcanic and sedimentary rocks were deposited in mountainous terrain, faulted, and subsequently buried by huge alluvial fans shed from nearby mountains. Although the New York Mountains area is typically included in the southern Basin and Range province, neither the range-bounding normal faults that are typical of the province in southern Nevada nor the detachment faults that characterize the province in western Arizona are known in this area. Part of Ivanpah Valley (fig. 2) is underlain by a thick prism of Tertiary(?) sedimentary rocks and, therefore, probably is bounded by normal faults. However, other valleys in the area of Figure 1 are underlain by pre-Cenozoic rocks at shallow depths; thus these valleys probably were not formed by Miocene Basin and Range faulting.

Description of Rock Units

Proterozoic rocks in the New York Mountains consist of heterogeneous layered gneiss and amphibole-rich gneiss intruded by variably deformed granitoid plutons. Amphibolite (unit Xag) forms narrow bands of compositionally heterogeneous dark rocks containing abundant biotite, garnet, amphibole, orthopyroxene, and clinopyroxene. The amphibolite is interlayered with layered gneiss and locally occurs as pods in granitoid plutons. The layered gneiss (unit Xlg) ranges widely in composition, reflecting differences in both protolithic composition and metasomatic processes. The gneiss is generally quartzo-feldspathic and thinly layered with a garnet-bearing leucosome of syenogranitic composition. On the basis of the bulk composition, much of the gneiss is probably derived from volcanic parent rocks. Uncommon pelitic schist and quartz-rich rocks, representing either immature sedimentary rocks derived from the volcanic rocks or altered volcanic rocks, occur within the gneiss. Gneissic granitoid rocks are widely interlayered with the volcanic-derived gneiss as well. Leucocratic granite (unit Xg) is common in the eastern part of the study area (fig. 2), commonly ranges from medium grained to pegmatitic, and shows mutual intrusive relations with less widely distributed mesocratic granite (included in unit Xg). Together, these granitoid rocks constitute a large pluton that interfingers to the east with biotite-rich layered gneiss and to the northwest is bordered by a wide mylonitic zone passing through Juniper Spring (fig. 3). West of the mylonitic zone, the leucocratic granite is regionally deformed, comprising leucocratic granitoid gneiss (unit Xgg) that crops out in the northern part of the study area (fig. 3). Granodiorite augen gneiss (unit Xgg) near Willow Canyon represents another deformed pluton. Proterozoic rocks, including mylonitic rocks, contain mineral assemblages corresponding to granulite and high amphibolite metamorphic facies. Pegmatite and leucosome dikes are abundant in the Proterozoic gneiss and one widespread distinctive type of pegmatite contains as much as 15 percent allanite. Diabase dikes cut foliated rocks locally, but are uncommon. Rare quartz-magnetite-hematite veins cut gneiss near Willow Wash and granite north of the Castle Peaks.

Paleozoic and Mesozoic strata (unit MzPzm), metamorphosed to greenschist facies, occur as a fault block south of Ivanpah Road, where they were studied by Burchfiel and Davis (1977), and as fault-bounded slices enclosed within Proterozoic gneiss west of the Vanderbilt mine. These strata are Pennsylvanian, Permian, and early Mesozoic in age, and comprise a sequence of white marble, recrystallized cherty dolomite, calcsilicate rocks, metamorphosed conglomerate, and rhyolite tectonite.

The Mid Hills Adamellite (unit Kmh) of Beckerman and others (1982) is part of the Teutonia batholith; it intrudes Proterozoic to early Mesozoic rocks and postdates ductile structures and metamorphic fabrics. It is a porphyritic biotite monzogranite containing conspicuous zoned potassium feldspar phenocrysts. Beckerman and others reported three K-Ar ages ranging from 84 to 105 Ma for the Mid Hills Adamellite. We obtained a much younger K-Ar age of 69.0 ± 1.7 Ma (biotite) in a sample of sericitized and mineralized Mid Hills Adamellite from Fourth of July Canyon (fig. 1) south of the study area (J.K. Nakata, 1983, unpubl. data). Ed DeWitt (1985, oral commun.) obtained a preliminary U-Pb age on zircons of 93 ± 1 Ma for the unit.

Volcanic rocks (unit Tv) resting on Proterozoic gneiss form a sequence that generally ranges from silicic at the base to mafic at the top, but which has complex interfingering relations and pinch-outs caused by deposition on mountainous topography. At the base of the volcanic sequence and west of Castle Peaks is the Peach Springs Tuff of Young and Brennan (1971), but locally the Peach Springs overlies conglomerate. This rhyolite tuff is about 19 Ma (Dickey and others, 1980) and, although widespread, it is only locally present in the study area in topographically controlled outcrops. Overlying the rhyolitic tuff are dacitic tuff breccia, lahar, and conglomerate deposits. Overlying the dacitic rocks, and comprising most of the volcanic section, are brecciated andesite and basalt flows and lahars that locally include a single thin rhyolite tuff. Rhyolite, dacite, and andesite dikes lithologically similar to the Tertiary flows intrude the Mid Hills Adamellite near Slaughterhouse Spring.

A monolithologic breccia, consisting of Proterozoic granitoid gneiss, rests on volcanic rocks near the north corner of the study area. Near its base, lenses of volcanic rocks are partly incorporated into the breccia. Gravel deposits resting on volcanic rocks crop out widely south and east of the Castle Peaks; the clasts are predominantly Mid Hills Adamellite and metamorphosed Paleozoic rocks, suggesting derivation from a source to the southwest. Although the gravel and monolithologic breccia are undated, they are presumed to be Pliocene because they angularly overlie Miocene deposits and are overlain by Quaternary deposits. Quaternary alluvial-fan and stream deposits display a spectrum of landforms ranging from old dissected terraces to modern washes.

Structure

Proterozoic gneiss in the study area bears a well-developed fabric created by the ductile deformation of biotite, quartz, amphibole, and feldspar grains. The resultant plane of foliation generally dips steeply west. Mineral elongation lineations within foliation planes generally trend north to west. The gneissic fabric formed during high-grade metamorphism. Mylonitic zones as wide as hundreds of yards are superposed on the gneissic fabric and are nearly parallel to it. These zones contain strongly deformed, finely recrystallized rocks with extreme development of foliation and lineation that are indicated by strung out mineral aggregates or augen. The foliation and lineation orientations in these mylonitic zones are locally similar to those in gneissic rocks, as are the metamorphic assemblages. Gneissic fabrics developed in the early Proterozoic, as indicated by gneissic plutonic rocks dated at about 1,710 Ma that are cut by a slighty younger (1,660 Ma) less deformed pluton (Wooden and others, 1986). The younger pluton locally bears a mylonitic fabric. The metamorphic minerals in mylonitic rocks belong to the upper amphibolite facies (sillimanite + potassium feldspar zone), which is of a much higher metamorphic grade than the greenschist facies Paleozoic rocks. Therefore, mylonitization took place during the Proterozoic.

High-angle faults in the northern New York Mountains are divided into four categories on the basis of geometry and age: (1) Mesozoic faults striking north-northwest to northwest, (2) Mesozoic to Cenozoic faults striking about north, (3) Miocene faults striking northeast, and (4) Miocene to Pliocene(?) faults striking northwest.

A Mesozoic fault striking north-northwest to northwest is documented at Slaughterhouse Spring (fig. 3), where Burchfiel and Davis (1977) named it the Slaughterhouse fault and showed that it separated autochthonous Paleozoic strata on the southwest from Proterozoic gneiss on the northeast. They considered the fault to be a left-lateral strike-slip fault with a large amount of separation because no rock units matched across it. We mapped small bodies of the Mid Hills Adamellite and fault slices of Paleozoic and Mesozoic strata northeast of the fault; therefore, probably less than about 10 mi of offset has occurred. Although the fault locally cuts the Mid Hills Adamellite (Burchfiel and Davis, 1977), it is, in general, intruded by the adamellite. Further, marble juxtaposed with Proterozoic gneiss by the fault is coarsely recrystallized near the pluton, and evidently underwent contact metamorphism subsequent to faulting. Rocks along the fault include granite gouge, limestone breccia, and marble. Propylitized rocks along the fault, locally prospected for copper, only occur near Slaughterhouse Spring (Hewett, 1956).

North-striking faults near Willow Wash and Barnwell are oriented similarly to parts of the Slaughterhouse fault, and may be, in part, the same age, but near Barnwell these north-striking faults cut Tertiary strata. The faults caused brecciation of Proterozoic rocks, and, in places, they produced brown gouge zones containing chloritized and limonitized rocks.

Miocene faults striking northeast pass southward from Juniper Spring to Willow Wash, where their strike changes to east-northeast. Parallel normal faults dipping to the northwest occur near Moore and along Ivanpah Road (fig. 2). They cut Miocene strata but are overlain by Pliocene(?) gravel. Rocks occurring along these faults are red silicified breccia in the Moore and Willow Wash areas, and green chloritized breccia, phyllonite, and gouge in the Juniper Spring area. Several faults near Juniper Spring are located in a wide Proterozoic mylonite zone.

Miocene to Pliocene(?) faults striking about northwest, and locally northeast near Barnwell, are nonsystematic in dip and sense of separation, and may be coeval with the northeast-striking Miocene normal faults. In the northern part of the study area, a major hematite-stained breccia zone that cuts Proterozoic gneiss dips moderately southwest. Other northwest-striking fault zones within the study area are narrow and probably represent small offsets. A northeast-striking normal fault east of Barnwell cuts Pliocene(?) gravel.

Low-angle faults that cut Proterozoic and Mesozoic strata in the Sagamore Canyon area (fig. 2) belong to the Cordilleran fold and thrust belt, and probably are early and late Mesozoic in age (Burchfiel and Davis, 1977). No thrust faults were mapped in the study area.

Alteration

Minor hydrothermal alteration, probably deuteric, is widespread in Proterozoic and Mesozoic granitoid rocks throughout the study area, as indicated by development of sericite from feldspar and chlorite from biotite. By contrast, breccia zones associated with faults are strongly altered to various mineral assemblages. Quartz veins, in places showing limonitic alteration, occur near and within breccia zones. Gneiss and granite are pervasively chloritized along fault zones near Juniper and Slaughterhouse Springs. Limonitic alteration is widespread along north-striking fault zones near Willow Wash, where massive white quartz veins of similar orientation may be related to that alteration. Fault zones containing red hematite-rich breccia with varying amounts of silica, limonite, and epidote are common. Most such zones belong to the Miocene northeast-striking fault set, but the large fault zone at the north end of the study area also contains hematite-stained breccia. Most of the fault-zone alteration and quartz-vein development probably is Miocene or younger because the development is associated with faults cutting Miocene rocks.

Geochemistry

The reconnaissance geochemical study was based on analysis and evaluation of stream sediments, nonmagnetic heavy-mineral concentrates from stream sediments, and rock samples. The stream-sediment and concentrate samples were collected from 69 locations in active stream channels draining basins of 0.5 to 2 square miles. Background and altered geochemical samples from rocks at 31 sites were studied. All samples were analyzed for 31 elements by a six-step semiquantitative emission-spectrographic technique (Grimes and Marranzino, 1968).

No strongly anomalous concentrations of elements were observed for the panned concentrate samples, even for samples collected adjacent to the Vanderbilt mining district and other heavily prospected areas.

At 10 stream-sediment sample localities, lanthanum was detected at 1,000 to 3,000 parts per million (ppm), and tungsten at more than 100 ppm. Scheelite and allanite are widespread in low abundance in the Proterozoic rocks. Thorium was observed in concentrations of 1,000 to 3,000 ppm at two sites northeast of Barnwell where streams drain Tertiary gravel deposits and volcanic rocks. The consistently low concentrations of lanthanum, tungsten, and thorium indicate that these elements could not be recovered economically.

Uranium was detected at a level of 19 ppm from one rock sampled at a small fault zone one mile north of the mouth of Willow Wash.

Lead occurs in slightly anomalous concentrations of 100 to 500 ppm at 9 sites, 5 of which show concentrations of 200 to 500 ppm and are near prospected areas. Adjacent drainages less than 1/2 mi from small anomalous concentrations show background values for lead. In one case, the highest molybdenum concentration (15 ppm) is associated with high lead values. One sample adjacent to the Vanderbilt mines, about 1 mi south of Willow Wash near the study area boundary, yielded a higher lead value of 2000 ppm, and 1.5 ppm silver. Nearby samples showed no anomalous elements. Mineralized rock samples near Willow Wash yielded some scattered anomalous values: 50 to 3,000 ppm copper, 0.5 to 1.0 ppm silver, 700 ppm lead, and 1,000 ppm zinc. No lead minerals were identified in any concentrate samples. The lead detected is hydrothermal, probably occurring as cerussite.

Fluorspar was identified in concentrates from three sites in the northern extreme of the study area, and is probably derived from fluorspar veins at prospects located there. Barium in concentrations of

1,000 to 2,000 ppm was detected in this area, although no barite was identified in the samples. Barite probably is not a major vein constituent, but it may be associated with the fluorspar mineralization.

Gold, sulfides, and sulfosalts were not identified in heavy-mineral stream-sediment concentrates. The lack of unoxidized sulfides in the concentrates could be due to a lack of widespread disseminated sulfides in country rocks and the oxidation of fault-related mineral occurrences above a relatively deep water table. Mines at Vanderbilt encountered ores at depths of 250 to 500 ft (Vredenburgh and others, 1981). Many secondary ore minerals are not sufficiently dense to remain in the concentrate samples following processing.

The low values of elements characteristic of hydrothermal ore deposits and the absence of ore-related minerals in the concentrates--other than scheelite and fluorspar--indicate that any resource potential for these elements in the study area may be in the form of scattered high-grade veins, rather than large, low-grade, disseminated-sulfide deposits. If high-grade veins exist, their metal concentrations may have been modified by near-surface supergene processes, making geochemical detection more difficult.

Geophysics

Gravity Survey

Gravity data in the vicinity of the Castle Peaks Wilderness Study Area were obtained from Snyder and others (1982) and supplemented by 34 measurements. The observed gravity data were reduced to free-air gravity anomalies. Bouguer, curvature, and terrain corrections at a standard reduction density of 2.67 g/cm^3 were added to the free-air anomaly at each station to determine complete Bouguer gravity anomalies. The regional Bouguer gravity field over the study area reflects both shallow and deep crustal density distributions. In order to isolate that part of the gravity field that arises from near-surface density distributions, an isostatic residual-gravity map (fig. 3) was constructed by removing a regional gravity field computed by the method of Jachens and Griscom (1982).

Densities of the major geologic units within the study area were determined by measuring hand-samples. The average density of 24 samples of crystalline Proterozoic rocks (units Xg, Xgg, Xlg,), 2.67±0.07 g/cm^3, did not significantly vary between the units. However, two samples of amphibolite (unit Xag) yielded higher densities of 2.96 and 3.10 g/cm^3. Five samples of the Mid Hills Adamellite (unit Kmh) gave an average density of 2.63±0.02 g/cm^3, and twelve samples of Miocene volcanic rocks (unit Tv) averaged 2.41±0.12 g/cm^3. The bulk densities of the Tertiary gravel (unit Tg) and the Quaternary alluvium (unit Qa) are assumed to have density contrasts of about 0.35 to 0.55 g/cm^3 with the surrounding crystalline rocks based on studies of similiar basins (Oliver, 1980, p. 35).

The residual gravity field over most of the study area (fig. 3) is closely correlated with the densities of the exposed rocks. The highest gravity values (-16 mGal) occur as an elongate gravity high over the central part of the New York Mountains, where the densest rocks are exposed. From this central gravity high, the gravity values decrease to the south over outcrops of lower density volcanic rocks, gravel, and alluvium; to the southwest over the lower density Mid Hills Adamellite; and to the northwest over the alluvium of Ivanpah Valley. The decrease in gravity south of the central gravity high can be accounted for by a southward-thickening wedge of volcanic rocks, gravel, and alluvium that attains a thickness of a few thousand feet. Similarly, the gravity decrease between the southwest end of the crest of the central gravity high and the low (-40 mGal) located over Ivanpah Valley to the northwest can be explained by a northwestward-thickening section of Tertiary and Quaternary sediments that reaches a thickness of 7,500 ft near the bottom of the gravity low. A drill hole near the center of the low (fig. 3) penetrated 6,505 ft of sediment before reaching probable basement (Hodgson, 1980, p. 237). A prominent gravity gradient straddling the contact between the Mid Hills Adamellite and Proterozoic rocks along the southwest edge of the study area is compatible with a near-vertical contact between the two rock types that extends to great depth.

In contrast to the areas discussed above, the gravity field over the northern corner of the study area cannot easily be explained by densities of the exposed rocks. Although the average density of eight samples of Proterozoic rock from this area is identical to the average for all Proterozoic rocks, gravity values over outcrops of Proterozoic rock in this northern area are lower than values over similar rocks to the south and only slightly higher than the lowest values in Ivanpah Valley. Proximity of these stations to the low density sediments in Ivanpah Valley is not sufficient to explain these low gravity values or the gradual nature of the gravity increase to the east even if the valley is bounded by a vertical fault. One possible explanation of the low gravity values and the broad gradient is that a low density body of crystalline rock, such as the Mid Hills Adamellite, a Tertiary granite body, or a felsic Proterozoic rock, is concealed beneath the northern part of the study area. If such a body lies at depth, then the sedimentary section near the northeastern end of Ivanpah Valley may be much thinner than 6,500 ft, even though the gravity values in this part of the valley are nearly as low as those over the central part of the valley. An alternative interpretation is that the Proterozoic rocks in the northern part of the study area have been thrust over the Tertiary valley fill. The available geophysical data are not adequate for distinguishing between the alternative interpretations.

Aeromagnetic Survey

The aeromagnetic map (fig. 4) was constructed from data collected in two separate surveys. The California part of the map, including the Castle Peaks Wilderness Study Area, is based on a survey in which total field magnetic data were collected along east-west flight lines spaced approximately 0.5 mi apart and at a height of 1,000 ft above average terrain (U.S.

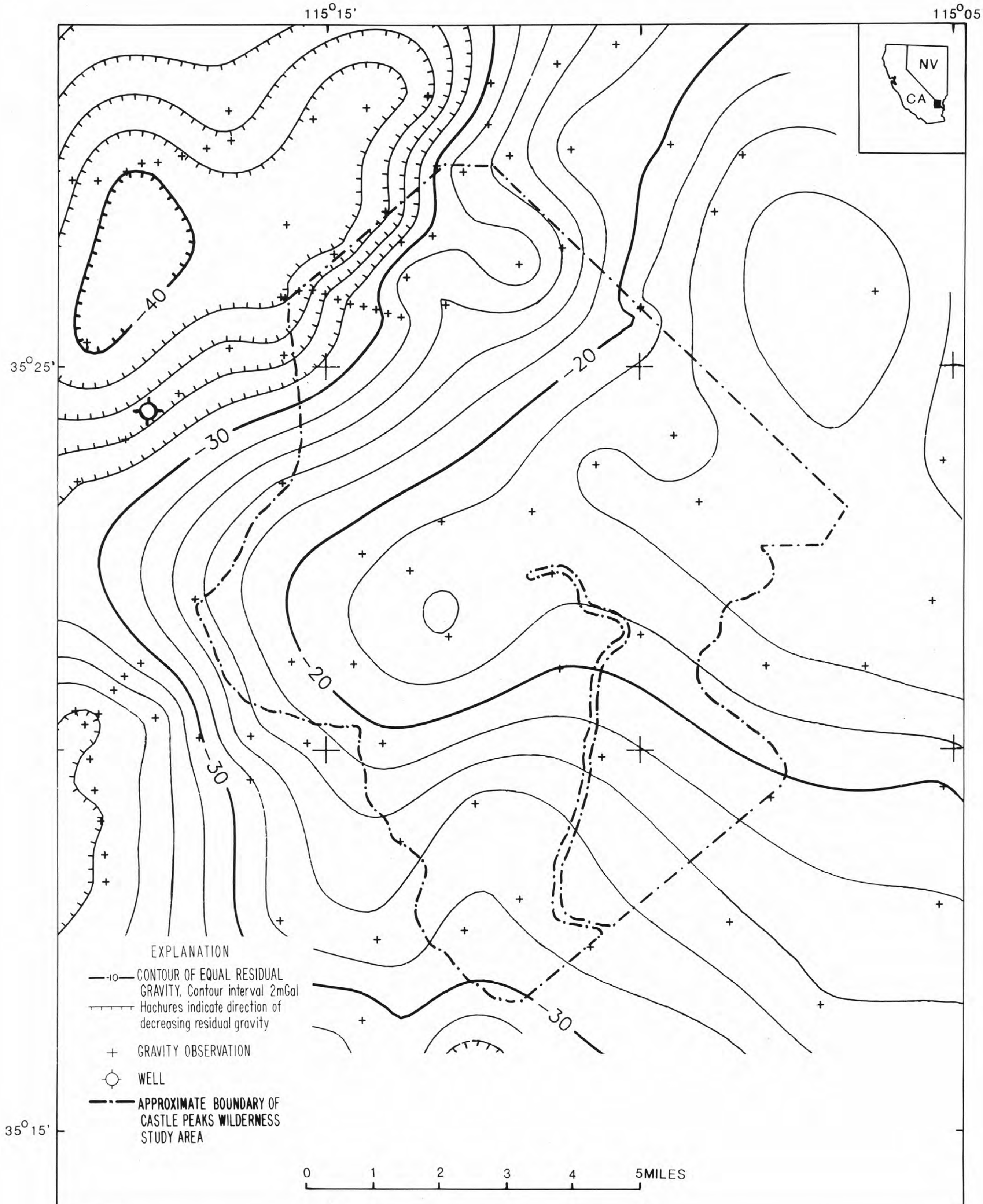


Figure 3. Map of the isostatic residual gravity for the Castle Peaks Wilderness Study Area.

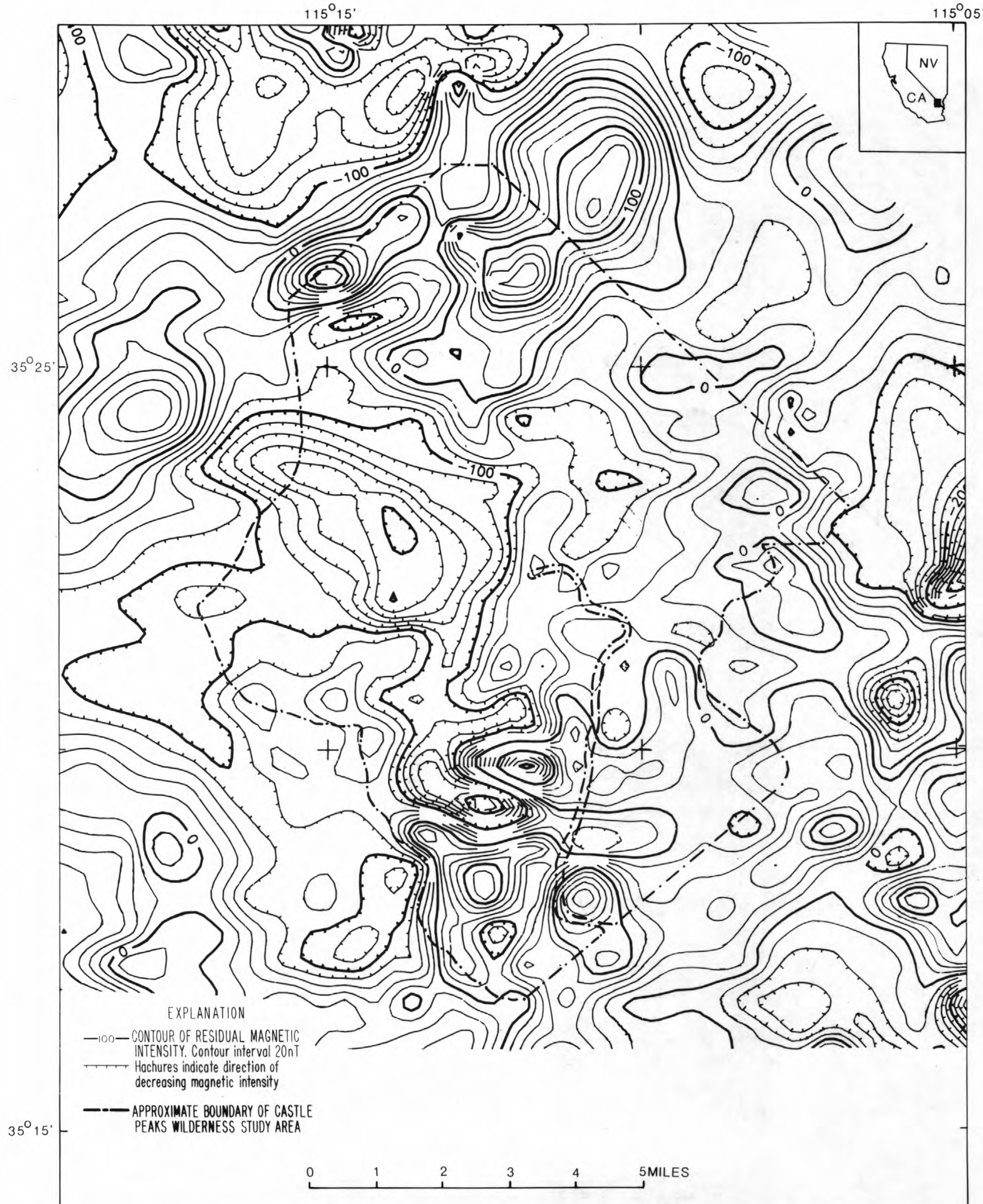


Figure 4. Residual aeromagnetic map of the Castle Peaks Wilderness Study Area.

Geological Survey, 1983). The Nevada part of the map is based on a survey with similar specifications, except that the flight lines were approximately 1 mi apart (Oliver and others, 1985). Because of the rugged topography, actual terrain clearance varied from about 400 ft to 2,500 ft. Corrections were applied to the data to yield a residual magnetic field. Data from the two surveys were merged and contoured by computer with a grid spacing of 1,300 ft (fig. 4).

Measurements of the magnetic susceptibility of hand samples indicate that the volcanic rocks are the most magnetic rocks in the area and that some of the Proterozoic rocks also are magnetic. No samples of the Mid Hills Adamellite were measured but the presence of a magnetic high over this unit along the southwest edge of the study area suggests that it is more magnetic than the adjacent Proterozoic rocks.

The shortest wavelength, highest amplitude magnetic anomalies occur over volcanic rocks exposed in the southern part of the study area. Anomalies over Proterozoic rocks tend to be broader (1-2 mi in width) and of slightly lower amplitude than those over the volcanic rocks. Individual anomalies do not correlate directly with specific Proterozoic rock units, indicating that the magnetic anomalies reflect secondary processes (metamorphism or hydrothermal alteration) that affected the magnetite content of the rocks.

Two local magnetic anomalies show an empirical spatial relation to mines and prospects. The first is a small, roughly circular magnetic low centered on the Albermarle mine in the north corner of the study area; it approximately coincides with the Blue Cystal property. The second anomaly is a broad, low-amplitude magnetic high about 2.5 mi in diameter that surrounds the Vanderbilt mines in the southwest part of the study area . Culminations on this high lie along two linear belts, one trending northwest from the Vanderbilt mines and the other parallel to the first and located 1.3 mi northeast of it. The eastern zone (confined to the areas with gold and silver commodity labels, fig. 2) includes the Vanderbilt Gold Corporation's Red Barnacle Far North claims.

Mineral and Energy Resources Potential

Geologic studies, geochemical sampling, geophysical investigations, and mine and prospect descriptions indicate that the Castle Peaks Wilderness Study Area is not significantly mineralized in comparison with many mountain ranges in the region. Base- and precious-metals occurrences are generally minor, and are associated with epithermal veins and fault breccias. (See fig. 5, appendix 1 for definitions of mineral resource potential and certainty levels.)

Fluorspar

Fluorspar occurring in sparse, nonsystematically oriented veins has a moderate resource potential in the Albermarle mine area. Anomalous values of fluorspar in panned concentrates occur in the area. Workings, reportedly located in rich veins, have been active intermittently. Because the geochemical, geologic, and mining data point to a potential resource, but the host rock is less favorable than the sedimentary rock-hosted deposits outside the study area (Crosby and Hoffman, 1951), fluorspar has a moderate resource potential in the study area, with a C certainty level (fig. 2). Stream-sediment studies indicate that similar Proterozoic rocks elsewhere in the study area apparently contain no fluorspar. For this reason, the area underlain by Proterozoic rocks and outside of the Albermarle mine area has a low potential for fluorspar resources, with a B certainty level.

Gold, silver, and lead

Hydrothermal quartz veins and fault breccias are the predominant modes of occurrence for base and precious metals in the study area. Lead and silver are common in the heavy-mineral concentrates of stream-sediment samples taken from drainages near prospected areas; copper, molybdenum, and zinc were also detected in a few samples. Analyses of chip samples from mineral occurrences yield the same elements, as well as gold. The tectonic setting, base and precious metal concentrations, and ore controls in the study area indicate an epithermal quartz-vein model (Taylor and others, 1984; Berger, 1982) for precious- and base-metal emplacement. The quartz veins are probably Tertiary in age, are associated with volcanic activity, are related to extensive north-south-striking faults and fractures, and show precious- and base-metal associations. A similar model for veins associated with Cretaceous felsite breccia pipes was described for the Clark Mountains, 24 mi west of the study area (Sharp, 1984). Carbonate rocks host the rich gold and silver veins in the Clark Mountains. In and near the breccia pipes, zoning is from gold to silver, tungsten, and fluorspar. The same metals are typical of the study area, but no large-scale zonation is apparent.

Variations of geochemical signatures and ore-minerals indicate that two principal hydrothermal-metal provinces exist within the study area. Most of the areas with anomalous concentrations of metals show a Ag-Pb±Cu±Au signature, but near the Vanderbilt mines, Au-Ag±Cu±Pb is a characteristic signature. The hydrothermal gold, lead, and silver category of mineral occurrence is correspondingly subdivided into silver-lead and gold-silver types.

The region around the Albermarle mine has a moderate potential (certainty level C) for hydrothermal vein-type silver-lead occurrences (fig. 2). Small, but widespread veins and fault zones characterize these mineral occurrences. The area's mining history, favorable geologic structure, and the richness of the ore all indicate a moderate resource potential; high resource potential is precluded by the nonsystematic location of the mineralized veins and the lack of anomalous mineral concentrations in nearby stream sediments. The remainder of the study area underlain by Proterozoic rocks has a low potential (certainty level C) for hydrothermal-vein silver-lead resources; two areas, the Silver Don and Germanite properties, have been prospected and have slightly anomalous geochemical values (fig. 2).

The area near the Vanderbilt mines has low and moderate potentials for hydrothermal gold-silver vein-type resources (fig. 2). Veins and fault breccia on the adjacent Vanderbilt mines property are sparse, but contain high-grade ore. Southeast of Willow Wash, similarly oriented but widely separated veins and fault zones in the study area show favorably high concentrations of minerals and a magnetic signature similar to that over the Vanderbilt mines property (fig. 4), indicating that gold and silver resources associated with lead and copper may occur in this part of the study area. On the basis of mining history, favorable geochemical values, structure, and magnetic signature, the area has a moderate resource potential (certainty level C) for gold and silver in hydrothermal veins and fault breccia. High resource potential is precluded by the nonsystematic occurrences of mineralized veins.

An area of low potential (certainty level C) for gold-silver hydrothermal vein-type resources northwest of Willow Wash (fig. 2) also has some anomalous geochemical values and contains veins and fault breccia; however, anomalous concentrations of gold were not detected, and the principal mineralized structures are oriented differently than those at Vanderbilt.

Placer gold

Low resource potential (certainty level C) for placer gold in Quaternary and Tertiary gravels in the study area is indicated by the presence of favorable host sediments shed from areas containing gold veins, including the Sagamore Canyon area, the Vanderbilt mines, and the Crescent Peak mining district (fig. 1). However, no gold was detected in stream-sediment concentrates.

Uranium

The area near Juniper Spring was prospected in the past for uranium occurring in brecciated mylonitic granitoid rocks that show extensive chlorite and clay mineral alteration and have been locally silicified. Stream-sediment samples revealed no anomalous concentrations of thorium, and only four of 18 chip samples yielded uranium as high as 0.002%, which was judged as below the "favorable" level, as defined by the National Uranium Resource Evaluation Program (NURE) (Luning and others, 1982). In addition, the NURE survey failed to identify the Juniper Spring area as favorable on the basis of airborne surveys (Luning and others, 1982). Accordingly, on the basis of prospecting history, part of the east corner of the study area (fig. 2) has low resource potential (certainty level B) for occurrences of uranium in brecciated granitoid.

Rare-earth minerals

The area underlain by Proterozoic rocks has a low resource potential (certainty level C) for rare-earth minerals occurring in pegmatite dikes. Geochemical analysis of stream sediments indicates that rare-earth and related elements are widespread in gneiss and granite, principally occurring in allanite-bearing pegmatite dikes. These dikes are the probable sources of scattered anomalous concentrations of lanthanum and thorium, and perhaps sources of relatively high strontium, vanadium, and yttrium values. The geochemical data, indicates that mineral concentrations in the pegmatites are low-grade. Volborth (1962) hypothesized that allanite pegmatite dikes in the New York Mountains are related to the Mountain Pass carbonatite intrusive complex, but our data indicate that the pegmatites are older, and therefore unrelated. Although the geologic environment is favorable for rare-earth element concentration, the occurrences are low-grade and widely separated.

Oil and Gas

Hydrocarbon may have accumulated in the study area in structural and stratigraphic traps within the Cordilleran fold and thrust belt, and in thick Tertiary sediments in Ivanpah Valley (fig. 1). Traps formed by the thrust belt are unlikely to underlie the study area because the rocks are part of the autochthon (Burchfiel and Davis, 1977). Any unrecognized thrusts within the autochthon probably are small and juxtapose Paleozoic strata that were metamorphosed to greenschist facies (such as those one mile west of Vanderbilt mines), and thus would have no potential (certainty level D) for oil and gas.

Low-density rocks, indicated to occur at depth in the northwestern part of the study area by gravity data (fig. 3), may be similar to Tertiary sediments (over 6,500 ft thick) underlying part of Ivanpah Valley in which there have been a few gas and oil shows. Alternatively, low-density granite may underlie this part of the study area. If the low-density rocks are sediments, the Proterozoic gneiss at the surface in this area represents either a massive slide block or a reverse-faulted basement wedge. In either case, the following data indicate an unknown resource potential (certainty level A) for oil and gas: (1) the extent of reservoir rocks is unknown, (2) the presence of sufficient hydrocarbon source rocks is unknown, (3) the thermal maturity of source rocks is unknown, and (4) the likelihood that geologic processes compatible with generating, migrating, and trapping hydrocarbons occurred is unknown.

Common varieties

Sand and gravel occur in moderate quantity in much of the study area, and possibly are useful locally for construction materials. Tuff near the base of the Tertiary volcanic section was quarried locally along Ivanpah Road to construct bridge abutments for a railroad; it may have restricted uses of this sort, but it is not present in large quantities. More accessible supplies of the same materials are available outside the study area.

Recommendations for Future Work

Despite a few isolated exceptions where resource potential is judged to be moderate, geological and geochemical analyses revealed that the study area has little resource potential, and so further work is not recommended.

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

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

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

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

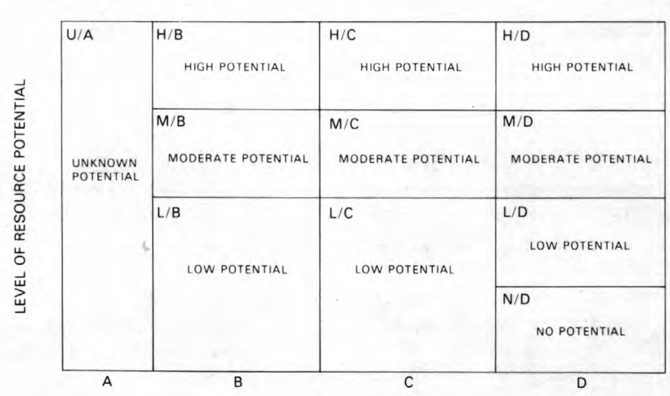

Figure 5. Major elements of mineral resource potential/certainty classification.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U. S. Geological Survey, 1986

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
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 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

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Miller; others—MINERAL RESOURCES OF THE CASTLE PEAKS WILDERNESS STUDY AREA, CALIFORNIA—U.S. Geological Survey Bulletin 1713–A