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Mineral resources and mineral resource potential of the Little Sand Spring Wilderness Study Area Inyo County, California

by

Chester T. Wrucke, R. Scott Werschky, Gary L. Raines
Richard J. Blakely, and Donald B. Hoover
U.S. Geological Survey

and

Michael S. Miller
U.S Bureau of Mines

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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 value 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 Little Sand Spring Wilderness Study Area (BLM No. CDCA-119), California Desert Conservation Area, Inyo County, California.

SUMMARY

The Little Sand Spring Wilderness Study Area, located in relatively subdued mountainous terrain that borders the east side of the north end of Death Valley, was studied in 1981-83 using geologic, geochemical, remote sensing, and geophysical techniques and mine and prospect surveys to evaluate the potential for mineral resources. The area has a moderate potential for silver in vein deposits, a low potential for the occurrence of gold in disseminated deposits, and a low potential for the occurrence of molybdenum in a molybdenum stockwork deposit. Lithium and nonmetallic commodities consisting of carbonate rock, clay, nitrate, perlite, and pumicite were identified in the wilderness study area, but no evidence of a resource potential for them or for oil and gas was identified. Large quantities of sand and gravel are available for local use.

INTRODUCTION

Field examinations were conducted by the U.S. Bureau of Mines in the fall of 1981 and the spring of 1983 and by the U.S. Geological Survey in the spring of 1982 and 1983 to determine the mineral resource potential of the Little Sand Spring Wilderness Study Area. The Bureau of Mines searched mining records, examined mines, prospects, mineral claims, and mineralized areas, and obtained rock samples for analysis. The Geological Survey conducted geologic mapping, geochemical sampling, remote sensing studies, and geophysical surveys.

The Little Sand Spring Wilderness Study Area occupies 33,500 acres in eastern California adjacent to the northern border of Death Valley National Monument (fig. 1). The eastern boundary of the area is the California-Nevada state line. Lida, 15 mi to the north, is the nearest settlement in Nevada, and Big Pine, 46 mi to the west, is the closest town in California. Nearby permanent facilities exist at Grapevine Ranger station and Scottys Castle (Death Valley Ranch), about 9 mi and 11 mi, respectively, south in Death Valley National Monument.

Access to the area is by paved and gravel roads from Big Pine, gravel roads from the northeast in Nevada, and a gravel and paved road from areas to the south in Death Valley. Within the wilderness study area, access is provided by a graded gravel road on the west side and by gravel roads across the northern part. Most of the area has no roads or trails but can be reached by foot along the major drainage channels.

The wilderness study area has hot, dry summers and cold to moderate winters. Vegetation consists principally of grasses and sparsely distributed low-growing shrubs and cactuses. The only surface water available in the immediate vicinity of the study area is at Sand Spring and Little Sand Spring.

The only previous study that has been published about the mineral resources of the Little Sand Spring Wilderness Study Area is by Miller (1983).

Physiography

The Little Sand Spring area is located in the western part of the Basin and Range province about 50 mi east of the Sierra Nevada. The eastern part of the study area consists of unnamed mountainous terrain along the east side of the north end of Death Valley. This mountainous terrain extends into the area from the higher and more rugged Grapevine Mountains to the southeast. The Last Chance Range, which bounds the west side of Death Valley, lies to the west of the study area. In contrast to the relatively high relief of much of the surrounding parts of the Death Valley region, the mountains in the study area are considerably more subdued. They rise a maximum of 2,700 ft in 5-1/2 mi from the mountain front on the west to the highest peak at an altitude of 5,658 ft on the California-Nevada border. Local relief commonly is about 300 to 600 ft above the adjacent major east-trending drainage channels. The mountainous terrain of the study area extends northeasterly into Nevada, where it reaches higher altitudes and culminates in Gold Mountain at an altitude of 8,152 ft. However, the adjacent lowlands also rise to the northeast so the relief is about the same as it is in the study area. Coalescing alluvial fans blanket the west side of the mountains and extend down slope to the floor of Death Valley, which at the western border of the study area has an altitude of 2,600 to 3,200 ft.

Mining activity

Although prospectors probably have explored the Little Sand Spring Wilderness Study Area since about 1860, little evidence of mining activity has been found. After the discovery of the Comstock Lode in 1859, a period of prospecting began in Esmeralda County, Nevada, east of the study area, and resulted in the development in the 1860s and 1870s of many mining districts (Albers and Stewart, 1972). One of these was the nearby Tokop district, centered 5 to 10 mi northeast of the study area and discovered in 1866. The Sylvia mine, at a small silver vein deposit in this district, lies about 0.5 mi beyond the eastern border of the study area, but the date it opened is unknown. Chalfant (1933) mentioned that mining activity was conducted in the 1870s in both the Sylvania district north of the study area and in the Ubehebe district southwest of the study area. Gold Point, a ghost town 12 mi north-northeast of the study area, had mining rushes in 1880, 1905, and 1906 (Jackson, 1976).

Placer claim staking and minor exploration took place in the study area as late as 1983. Placer and millsite claims staked in 1983 were at Sand Spring, Little Sand Spring, and on alluvium of Oriental Wash and Tule Canyon.

GEOLOGY, GEOCHEMISTRY, AND GEOPHYSICS PERTAINING TO MINERAL RESOURCE ASSESSMENT

General Geology

Well exposed Paleozoic carbonate and siliceous strata and Cenozoic volcanic, granitic, and sedimentary deposits occur in the Little Sand Spring Wilderness Study Area (pl. 1; fig. 2). A Mesozoic granitic pluton containing blocks of Proterozoic sedimentary rocks crops out in adjacent parts of Nevada just northeast of the study area. Because this pluton is mineralized and probably extends into the study area, although concealed beneath Tertiary volcanic rocks and Quaternary gravels, the geology of the area of the pluton has been mapped and included in the descriptions that follow.

The Wyman Formation of Proterozoic age is the oldest rock unit in the vicinity of the study area and in all of the northern Death Valley region. It crops out on and around the prominent mountain immediately north of the Sylvia mine. The formation consists of limestone, sandy limestone, and sandstone, most of which has been metamorphosed to marble, skarn, and hornfels by granitic rock intruded into the formation. A complete section of the formation is not exposed in the region. In the exposures described here, the greatest thickness of the formation is about 2,000 ft.

Cambrian, Ordovician, and Mississippian rocks crop out in the southern part of the area and include the Cambrian Bonanza King Formation, the Cambrian and Ordovician Nopah Formation, the Ordovician Pogonip Group, Eureka Quartzite, and Ely Springs Dolomite, and the Mississippian Perdido Formation. Most of these formations are composed of carbonate rocks; only the basal part of the Nopah, the Eureka Quartzite, and the Perdido consist of siliceous materials, and these total less than 10 percent of the exposed stratigraphic section. An undisturbed section of the Paleozoic formations probably would total a little more than 7,000 ft in thickness, but due to attenuation by low-angle faults they aggregate about 1,800 ft.

The Jurassic granitic rocks exposed just north of the study area were considered by Albers and Stewart (1972) to be part of the Sylvania pluton. The pluton is exposed widely north of Oriental Wash and has a total outcrop area of about 225 mi^2 in Esmeralda County and adjacent parts of Inyo County (Albers and Stewart, 1972). In the map area, rocks of the pluton are principally monzonite and quartz monzonite. Exposed parts of the pluton southeast of the Sylvia mine (figs. 2, 3) exhibit varying degrees of propylitic and sericitic alteration. Near the northern edge of the map area, the granitic mass appears to have engulfed irregular bodies of the Wyman Formation tens to a few hundred feet across and therefore to have penetrated the country rock extensively and intricately. The proportions of granite and metasedimentary rocks in that area vary widely, but commonly they are about equal and are shown on the map (pl. 1; fig. 2) as a single undifferentiated unit . The great abundance of included country rock is suggestive that the exposed granite is near the top of the pluton.

A stratified section consisting of a variety of Tertiary sedimentary and volcanic deposits rests uncomformably on the Paleozoic rocks and in the subsurface probably also on Mesozoic granitic rock. The oldest Tertiary deposits belong to the late Miocene Ammonia Tanks Member of the Timber Mountain Tuff (Byers and others, 1976), which in this area consists of welded and unwelded rhyolite ash flows that have an aggregate thickness of at least 1,000 ft. The Timber Mountain Tuff is grouped on the map with other Tertiary deposits in a unit of undifferentiated sedimentary and volcanic rocks. Included are overlying latite flows and poorly consolidated sandstone and conglomerate interlayered toward the top with rhyolite flows and tuffs. At the top of this undifferentiated unit are olivine basalt flows about 7.5 m.y. old (Elliott and others, 1984) that are interbedded with volcaniclastic sedimentatry rocks. The Tertiary deposits vary in thickness from a few hundred feet to possibly as much as 3,000 ft. Isolated exposures of sandstone, siltstone, and conglomerate along the Death Valley-Furnace Creek fault zone (fig. 2) have not been dated isotopically, but may be as old as Pliocene.

A Tertiary alkali-feldspar granite that intruded Paleozoic carbonate rocks is exposed in an area about 1,300 ft across, 1.4 mi north of the southern border of the study area and in several areas within Death Valley National Monument as far as 1 mi south of the monument border (Oakes, 1977). These exposures reveal the top of a pluton that is at least 2.3 mi long but whose subsurface dimensions may be considerably greater. Adjacent dolomitic rocks are bleached within a few tens of feet of the contact, and at a few localities they contain serpentine of contact metasomatic origin. On the basis of structural considerations, the pluton may have reached to within a few thousand feet of the surface when it was emplaced. A K-Ar determination on biotite from the alkali-feldspar granite indicates that the rock is 7.2 ± 0.2 m.y. old (E.H. McKee, oral commun., 1984).

Quaternary deposits include Holocene and Pleistocene fanglomerates, Pleistocene lake deposits (Clements, 1952), and Pleistocene pediment gravels. These deposits are shown on Plate 1 and Figure 2 and included with Holocene unconsolidated sand and gravel that occupy stream bottoms throughout the area.

The rocks and alluvial deposits of the Little Sand Spring Study Area record a history of complex faulting. The possibility that the Last Chance thrust of probable Triassic or Jurassic age may have reached as far east as the study area was suggested by Stewart and others (1966). In a description of the thrust, these authors described two localities about 6 mi southeast of the study area where lower Paleozoic strata of the Nopah and Bonanza King Formations are thrust over upper Paleozoic rocks. Presumably this thrust passes under adjacent terrain, including the exposed Paleozoic rocks of the study area, although no direct evidence for the fault was found during this investigation.

The Paleozoic rocks of the study area have been intensely brecciated and greatly attenuated as a result of movement on subhorizontal low-angle faults that commonly occur between rock units of differing competency throughout the Paleozoic section. The structural stacking of the rock units is younger over older. These faults are here interpreted as detachment faults that originated mainly before accumulation in late Miocene time of the Ammonia Tanks Member of the Timber Mountain Tuff. Possibly the detachment faulting continued into the late Miocene because parts of the Timber Mountain Tuff locally are brecciated along low-angle faults.

The Timber Mountain Tuff and overlying latite are broken along numerous steep faults into polygonal areas that in plan view have straight to gently curving traces. This fault pattern is suggestive of brittle fracture and differential settling in an extensional environment. Much of the faulting that produced the polygonal pattern took place in the late Miocene before deposition of the overlying sequence of conglomerate, rhyolite, and basalt, and is therefore older than 7.5 m.y. However, the 7.5 m.y. old basalt at the southeast corner of the study area has been broken in a similar though less dense fault pattern, indicating that some of the faulting continued into the latest Miocene. It is conceivable that the faulting may have extended into the Pliocene.

The youngest deformation in the area is associated with the Death Valley-Furnace Creek fault zone located along the western margin of the area. Right-lateral displacement along this well known fault has resulted in cumulative offsets of many miles (Stewart, 1967). Upper Tertiary and Pleistocene alluvial deposits are offset along the fault. Holocene fanglomerates in the western part of the area are cut by faults that parallel strands of the Death Valley-Furnance Creek fault.

Geochemistry

A geochemical study of the Little Sand Spring Wilderness Study Area was conducted using three sample media—stream sediment, heavy-mineral concentrates, and rock. Stream sediment was collected from 71 first- and second-order drainages at a density of approximately 1 sample per square mile. Heavy-mineral concentrates (>2.6 specific gravity) were collected from 70 sample localities to provide enhanced geochemical anomaly patterns and to provide information on mineral species such as oxides and ore-forming sulfides. Information on background geochemical values and on geochemical suites from mineralized areas were obtained from an aggregate of about 150 samples of outcrops, mines, prospect pits, and stream sediments.

Stream-sediment samples were sieved to -80 mesh, pulverized, and analyzed for 29 elements by semiquantitative emission spectrographic methods (Grimes and Marranzino, 1968). Stream sediments also were analyzed for mercury, arsenic, antimony, and zinc by wet chemical methods (Viets, 1978; Vaughn and McCarthy, 1964). The heavy-mineral-concentrate samples were sieved to -30 mesh and analyzed for 29 elements by the spectrographic method previously mentioned after removal of the magnetic and paramagnetic minerals. Rock samples were pulverized and analyzed for the same elements as the stream-sediment samples.

Anomaly threshold values were determined by using the break in slope of cumulative frequency plots and (or) the 95th percentile value for most elements. For some elements, such as gold, silver, tungsten, arsenic, and antimony, a trace was considered anomalous for spectrographic data.

Two geochemical suites were identified in the Little Sand Spring Wilderness Study Area. One suite consisting of mercury, arsenic, and antimony was found in the southern part of the study area, and another suite consisting of molybdenum, lead, tungsten, silver, and zinc was found in the northern part of the area. The geographic distribution of these suites overlap. The molybdenum-lead-tungsten-silver-zinc suite extends north and east into Nevada.

Remote sensing

The minerals pyrite and (or) hematite are commonly associated with hydrothermal alteration potentially related to mineralization; these minerals weather to produce limonite, which can be identified in LANDSAT images using a color-ratio-composite method (Rowan and others, 1974). This technique was used to map areas of hydrothermal alteration associated with limonitic materials and to help define potential mineralized systems. The term limonite is used, as defined by Blanchard (1968), as a general term for hydrous oxides but modified to include any material with the unique spectral reflectance properties of the ferric oxide minerals such as hematite and goethite as defined by Hunt (1980). Areas of hydrothermal alteration that lack limonitic materials will not be detected by this technique, but altered areas without limonite are believed to be small. All areas defined as limonitic from the satellite analysis were visited and sampled selectively to determine if the limonite was associated with hydrothermal alteration and, if so, with what type of alteration and (or) mineralization. To define the type and extent of any mineralizing process that could have produced the observed hydrothermal alteration, selected rock samples from limonitic areas were analyzed by a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968) and a modified wet chemical method for selected elements (Viets, 1978) to determine trace mineralization. From these hydrothermal alteration studies, several mineralized areas were identified, and the extent, distribution, and type of alteration were mapped.

An understanding of the hydrothermal alteration at the Sylvia mine was developed using an airborne spectrometer system to determine the distribution of important hydrothermal alteration products, such as carbonates, clay minerals, and sericite. The airborne spectrometer system has the capacity to make very high resolution spectral measurements in the 1.6 to 2.5 micrometer (μm) region of reflectance radiation wavelengths. Important hydrothermal alteration minerals were identified using this technique.

Geophysics

New aeromagnetic and gravity data were obtained during this study to supplement published geophysical data from the Little Sand Spring Wilderness Study Area. The new aeromagnetic data were from a survey flown at a constant barometric altitude of 7,000 ft along east-west flight lines spaced 1 mi apart (USGS, 1983). The previous survey was flown in 1967 at a constant barometric altitude of 9,000 ft (USGS, 1971). The new gravity data were added to data from the Department of Defense (DOD) gravity data set, which is available through the National Oceanic and Atmospheric Administration (NOAA) Data Center (NOAA, National Geophysical and Solar-Terrestrial Data Center, Boulder, Colorado 80302). The gravity data were used to compute complete Bouguer and isostatic residual values (Simpson and others, 1983) for each gravity station. A total field magnetic map and an isostatic residual gravity map were produced from the data by machine. Resistivity surveys consisting of audiomagnetotelluric (AMT) soundings and telluric traverses were conducted near the Sylvia mine and in the southern part of the area.

The geologic feature that dominates the gravity and magnetic maps of the Little Sand Spring Wilderness Study Area is the Death Valley-Furnace Creek fault zone. On the gravity map this zone appears as a linear steep gradient in the vicinity of Sand Spring and changes to a gravitational trough south of lat. 37°07' N. The magnetic map shows a string of small positive anomalies along the fault zone north of lat. 37°13 N., probably caused by isolated fragments of magnetic material caught within the fault zone and buried at relatively shallow depth below the alluvium.

Only one isolated gravity anomaly occurs within the confines of the study area. It is centered in the south-central part of the area at lat. 37°07' N. and long. 117°26' W., has a relative amplitude of about 5 mGal, and is probably caused by Paleozoic sedimentary rocks.

Several gravity and magnetic anomalies occur outside the Little Sand Spring Wilderness Study Area but near the area boundary. Positive gravity and magnetic anomalies occur over the Mesozoic monzonitic intrusion centered at lat. 37°12' N. and lat. 117°27' W. It is inferred from the absence of such magnetic anomalies farther south that the monzonitic rock does not extend south of the mapped extent of the intrusion, but may extend at shallow depth to the east and connect with similar intrusive rocks at Gold Mountain (fig. 1), approximately 10 mi east of the study area. This magnetic anomaly also continues to the west into the study area and merges with the positive anomalies along the Furnace Creek fault zone. Another magnetic anomaly occurs immediately south of the study area and is located over Paleozoic sedimentary rocks, which typically are relatively nonmagnetic. The source of the anomaly may be the Tertiary granitic body that crops out in small areas on both sides of the south border of the area. Rocks with similar magnetic properties do not extend any appreciable distance into the study area.

One of the AMT soundings was conducted in the Tertiary granitic rock located about 1.4 mi north of the south border of the study area, near the mountain front. Resistivity values measured were low at the surface and decreased with depth to the 5,000 ft maximum depth reached in the sounding. The low values found are typical of altered intrusive rocks.

AMT soundings in Mesozoic granitic rock 0.75-1.1 mi east and east-southeast of the Sylvia mine also revealed low resistivity values (100-190 ohm-meters) within 1,000 ft of the surface but higher values at depth, and soundings made in areas of pediment gravels interpreted to cover granitic rock 1-1.5 mi south and southwest of the Sylvia mine revealed resistivities of about 100 ohm-meters at depths of 1,500 ft and increasing resistivity values with greater depth. Telluric traverses in the area of exposed granitic rock and pediment gravel confirmed the low resistivities of the AMT soundings and showed that the resistivity has little variation in the area surveyed. The low resistivity values found in the vicinity of the Sylvia mine are those expected for altered granitic rocks.

A telluric traverse from the Sylvia mine west-southwest 1.5 mi into the study area had a fairly uniform profile, indicating that pediment gravels are thin. No evidence was found of a range-front fault in the granitic basement along the traverse.

MINERAL OCCURRENCES AND DEPOSITS

The Little Sand Spring Wilderness Study Area has a variety of metallic and nonmetallic mineral commodities. Occurrences of metallic commodities in the study area include lithium and lode and placer gold, and an adjacent area contains silver and possibly molybdenum that may extend into the study area. Occurrences of metallic minerals are found in three areas here designated as the southern area, the western area, and the Sylvia mine area (fig. 4). Occurrences of nonmetallic commodities identified in the study area are carbonate rock, clay, nitrates, perlite, pumicite, and sand and gravel. The nonmetallic commodities are found at scattered localities throughout the study area.

Metallic commodities

Gold

Southern area.—Anomalous concentrations of gold were found in a few vein samples collected in the southern area (fig. 4). Stream-sediment samples from this area have moderate concentrations of mercury, antimony, and arsenic, which are key elements in the well known gold suite found in epithermal disseminated gold deposits (Erickson and others, 1966; White, 1981). Anomalous concentrations of mercury in the range of 0.12-0.42 ppm were found in more than 50 percent of the stream-sediment samples, and five heavy-mineral concentrates contained cinnabar. One-third of the stream-sediment samples contained antimony in the range of 5-19 ppm. A high concentration of arsenic was detected in one stream-sediment sample, but nearly 80 percent of the samples were found to contain arsenic. Gold was detected in two samples, both collected in veins, and found to have 0.2 ppm gold. The high detection limit for gold of 10 ppm in stream-sediment samples and 20 ppm in heavy-mineral concentrates may have prevented the identification of gold in these sample media.

The southern area is underlain by Paleozoic sedimentary rocks and an Upper Miocene alkali-feldspar granite pluton. Most of the Paleozoic rocks, as described earlier, are limestone and dolomite that are shattered, commonly brecciated, locally bleached, and cut by low-angle and steep faults. Many of the faults are marked by zones of brecciated carbonate rock a few inches to several feet wide, stained brownish-red by iron oxides. Iron oxides also are abundant in certain brecciated stratigraphic intervals, particularly in shaly limestone of the Pogonip Group.

On the basis of spectral measurements and field studies, the iron oxides in rocks of the southern area are poorly ordered and are similar to ferrihydrite. No evidence was found of a sulfide precursor. The source of the poorly ordered iron oxide is unknown, but it could have been derived from oxidation of iron in the carbonate host rock or from primary hematite introduced by thermal waters. Such iron oxides are a common product in springs (Carlson and Schwertmann, 1980; Henmi and others, 1980). The iron-oxide-rich areas commonly have minor amounts of kaolinite and sericite.

Orange and red jasperoid is found locally in small amounts on fracture surfaces in areas rich in iron oxides. The jasperoid contains the same suite of elements as the stream sediment samples collected throughout the southern area; namely, arsenic, antimony, and mercury, and in some cases silver, manganese, and zinc.

The veins in which gold was detected occur in the Tertiary alkali-feldspar granite near its contact with Paleozoic carbonate rocks. These and similar veins are sparsely distributed, contain quartz at the margins and dark calcite in the interior, and in addition to gold, they contain anomalous amounts of silver, manganese, molybdenum, and beryllium. A sample of serpentine skarn adjacent to the pluton was found to have anomalously large amounts of zinc, manganese, antimony, and arsenic.

The granite, as discussed earlier, probably reached shallow crustal levels where interaction with ground water and the development of hot spring systems would likely result. A hot spring environment would account for bleaching of the carbonate rocks and the precipitation of jasperoid as well as the derivation of iron oxides.

Western area.—The western area encompasses all of the Little Sand Spring Wilderness Study Area west of the mountain front (fig. 4). Quaternary alluvial gravel covers almost all of this part of the study area. Some of the alluvial deposits in the eastern part of the western area, within about two miles of bedrock exposures are pediment gravels (B. C. Moring, personal commun., 1983), but most of the gravels, especially those distant from the mountain front, are alluvial fan deposits. Materials in the alluvial fans in the northern and western parts of the western area came from sources that drain into Oriental Wash and Tule Canyon, which are alluvial channels that extend into California from Nevada on the north and east of the study area. Several areas of lode gold in Nevada occur in the area drained by Oriental Wash and Tule Canyon (Albers and Stewart, 1972). Samples collected to determine if placer gold exists in the alluvial fan deposits in the western area were found to contain low concentrations of gold. Of 40 bulk panned concentrate samples, 12 scattered throughout the western area were found to contain detectable gold averaging 6.4 cents[1] gold per cu yd. The maximum amount of gold found in the placer samples was calculated to have a value of 66[1] cents per cu yd, and was from a sample collected about 1 mi southeast of the Sylvia mine.

1Assuming gold valued at $400.00 per troy ounce.

Silver and molybdenum

The Sylvia mine area, located mainly east of the north end of the study area (fig. 4), contains a variety of metallic mineral deposits in zones centered on a possible molybdenum stockwork deposit. The Sylvia mine itself is in a lead-silver deposit and seemingly part of a zone enriched in base metals and silver. Copper-tungsten skarn deposits lie nearby. The Sylvia mine and the possible molybdenum stockwork occur in monzonitic rock of the Jurassic Sylvania pluton, which is the principal rock exposed in the Sylvia mine area. The skarn copper and tungsten occur in masses of the Wyman Formation that are incorporated into the pluton.

The Sylvia mine (fig. 3) consists of five adits in mineralized shear zones in the granitic rock. These zones each average about 3 ft in thickness, strike north, and dip at various angles to the east and west. Vein minerals are quartz, galena, anglesite (and other secondary lead minerals), copper carbonate minerals, and native silver. Skarn, composed mostly of brown andradite garnet intergrown with calcite, occurs near the mine in the Wyman Formation at the contact with granitic rock. Surface samples of weathered vein material were found to contain an average of 2.2 oz silver per ton, 0.005 oz gold per ton, 0.11 percent lead, 0.054 percent zinc, and 0.047 percent copper. Stream-sediment samples collected near the mine were found to have anomalous concentrations of silver, lead, molybdenum, and tungsten.

Altered parts of the granitic body east and southeast of the Sylvia mine exhibit abundant indications that the host rock is mineralized; however, only a few mine workings and prospects exist there. The mine workings consist of shallow shafts and short adits and may date from the early 1900s, based on the badly weathered and disintegrating character of the timbers for head frames and other structures. Quartz, fluorite, pyrite, copper sulfides, and secondary copper minerals can be found on dumps. Skarn bodies have been prospected at a few old workings close to the southeastern exposures of the pluton. Copper minerals, epidote, tremolite, garnet, and calcite have been identified in the skarn.

Identification of a possible molybdenum stockwork deposit of small size east and southeast of the Sylvia mine is based in part on anomalous concentrations of molybdenum in stream-sediment samples and heavy-mineral concentrates in areas of altered monzonitic rock. Other characteristics associated with stockwork molybdenum deposits also are present and include rocks that are uraniferous and contain fluorine but only minor amounts of copper. One sample had gold. Concentrations of molybdenite in intensely altered rock at the Magruder Mountain deposit (also known as the Cucomungo deposit), near Magruder Mountain in the Sylvania pluton about 11 mi north of Little Sand Spring (Schilling, 1962), are suggestive that the Sylvia mine area is in a region of molybdenum-rich intrusive rocks.

Information obtained on the ground and by aircraft spectrometer show that the altered granitic rock of the Sylvia mine area consists of two altered zones—an outer propylitic zone and an inner sericitic zone (fig. 3). The propylitic zone typically contains chlorite, epidote, and supergene kaolinite, and sericite is present and locally abundant. The sericite-rich rocks in the propylitic zone also contain fluorite. Other features of the propylitic zone include (1), dolomite that formed by magnesium metasomatism of carbonate inclusions of the Wyman Formation near contacts with granitic rocks, and (2), lead-silver enrichment as typified by silver-lead deposits at the Sylvia mine. The sericitic zone is pervasively sericitized and includes veins of biotite, potassium feldspar, and fluorite, as well as minor veins and irregular patches 1 to 4 in. wide of porphyritic granitic rock containing potassium feldspar phenocrysts in a fine-grained aplitic groundmass. Evidence of local silica flooding is provided by concentrations of quartz stockworks in areas a maximum of a few hundred feet across. In places the stockwork veins have conspicuous fluorite and copper sulfides. Quartz in some stockwork veins has a sugary texture, but in most veins the quartz is medium to coarse grained. Only sparse quartz veins exist in areas of altered rock outside the stockworks. The granitic host rock in areas of quartz stockworks has narrow veins containing limonite after pyrite and anomalous concentrations of silver, zinc, and mercury, and in places silver, copper, molybdenum, arsenic, and antimony. These are the same elements found in the silver-lead veins.

Fluid inclusions were examined in one thin section of a quartz-fluorite stockwork vein that contains pyrite, chalcopyrite, hematite (from pyrite), and chrysocolla (from chalcopyrite). Most of the quartz forms irregular crystals and has an early generation of sparse inclusions 10-30 µm across that at room temperature contain liquid water, liquid carbon dioxide, and vapor phase carbon dioxide (T. G. Theodore, oral commun., 1984). Spatially and probably temporally associated with these inclusions are similar inclusions that have highly birefringent, diamond-shaped daughter crystals, probably a carbonate mineral. Late fluid inclusions in the early-formed quartz are abundant and have uniform amounts of liquid and vapor water. No signs of a boiling history are evident in either of the two generations of fluid inclusions. Late quartz is euhedral and barren of fluid inclusions.

Alteration in monzonitic rock of the Sylvia mine area proceeded far enough to form propylitized and sericitized zones but did not advance significantly into the stage of potassic alteration. For all practical purposes, only medium- to coarse-grained granitic rock showing no signs of venting was available for alteration. The altered rock was overprinted with a small quartz stockwork, and small amounts of late metal-rich fluids deposited silver and base metals in veins peripheral to the zone of sericitic alteration and quartz flooding. Evidence that fluid inclusions in early stockwork veins did not form in a boiling environment and that late quartz has no fluid inclusions suggests that alteration and silica transport did not immediately follow cooling in the main igneous phase of the monzonitic host but more likely was related to a late phase of the Sylvania pluton represented by the sparsely distributed porphyritic rock found in veins and irregular patches.

Nonmetallic commodities

Carbonate rock

Light- and dark-gray, fine-grained, carbonate strata crop out in an area of several square miles in the part of the wilderness study area labeled the southern area (fig. 4). An estimated 1 percent, or less, of the carbonate rocks are bleached white; most are limonite stained. The light-hued carbonate rocks are dolomitic and contain on the order of 20 percent magnesium oxide (Mg-O) and 34 percent calcium oxide (CaO). Loss on ignition averaged about 45 percent, and the insoluble residue was about 3 percent.

Clay

Montmorillonitic clay is an alteration product of volcaniclastic rock in the south-central part of the wilderness study area and of nonwelded to lightly welded tuffs in the eastern part of the area. The clay is not a high-swelling variety desired in commerce.

Lithium and nitrates

Samples of Pleistocene lake sediments in the southwestern part of the wilderness study area were found to contain as much as 0.16 percent lithium and 1.5 percent nitrate (NO_3), but most samples had less than 0.03 percent lithium and 0.1 percent nitrate. No concentrated salt deposits were found in exposures of the lake sediments.

Perlite

Layers of perlite that occur locally in vitrophyre zones of ash-flow tuffs in the south central part of the wilderness study area are sporadic and small.

Pumicite

Beds of glassy, friable, white and brown fragmental pumice (pumicite) are found in the volcaniclastic rocks of the wilderness study area. Alteration to clay minerals, notably montmorillonite, has adversely affected the pumicite for commercial use.

Sand and gravel

Sand and gravel for local road construction have been produced from several pits along the road bounding or near the west side of the wilderness study area. The pits are in alluvial fans derived from granitic, volcanic, and carbonate rocks. Clasts in the fan deposits vary in size from silt to boulders and are mostly subangular and moderately to poorly sorted. The deposits are weakly consolidated and locally cemented by caliche. They are extensive in the wilderness study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

The Little Sand Spring Wilderness Study Area has resource potential for gold, silver, and molybdenum. These resources are found in two areas shown on Plate 1 and in Figure 4—the Sylvia mine area and the southern area.

The resource potential of mineralized areas in and adjacent to the Little Sand Spring Wilderness Study Area is ranked using the following scheme:

Low mineral resource potential is assigned to areas in which geologic, geochemical, or geophysical characteristics define a geologic environment permissive for resource occurrence but where there is a little evidence of the existence of a mineral resource. This broad category embraces areas of dispersed mineralized rock as well as areas that have few indications of having been mineralized.

Moderate mineral resource potential is assigned to areas in which 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 or descriptive models indicates favorable ground.

High resource potential is assigned to areas in which geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support genetic or descriptive models indicating the presence of resources, and where evidence indicates that mineral concentration has taken place.

Identified resources are those whose location, grade, quality, and quantity are known or estimated from specific geologic evidence (U.S. Bureau of Mines and U.S. Geological Survey, 1980).

The procedure used for determining mineral resource potential in this investigation was described by Shawe (1981). It involves comparison and evaluation of features found in mineralized rocks of the study area with criteria developed for descriptive models of similar deposit types. In this kind of evaluation, attempts are made to determine if the features found in deposits used in developing the model are present in the rocks of the study area. The absence of key criteria can be important in establishing the degree of favorability for resource potential and may be as significant as the recognition of positive criteria. The resource potential that best classifies an area is a measure of the probability of the existence of a resource, which is defined as a concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's surface in such form or amount that economic extraction of a commodity from the concentration is currently or potentially feasable (U.S. Bureau of Mines and U.S. Geological Survey, 1980).

Metallic commodities

Gold

Southern area.—The Paleozoic rocks of the southern area have some features suggestive of a disseminated gold deposit. An important characteristic of this type of deposit is the geochemical suite of mercury, arsenic, and antimony. These elements, in some cases including thallium and other metals, are present in anomalous amounts in and around the ore zone of disseminated gold deposits (Erickson and others, 1966; White, 1981). High concentrations of silver and base metals may be present in these deposits, and in the southern area anomalous amounts of silver, manganese, and zinc have been found. Disseminated gold deposits typically occur in fractured carbonate rocks. The Carlin deposit, developed in fractured thin-bedded Silurian and Devonian carbonate rocks in north-central Nevada, is the best-known example of this type deposit (Radtke and others, 1980). The intensely fractured, brecciated, bleached, and faulted limestone and dolomite in the southern area are favorable host rocks. Jasperoid and silicified rocks, also common in disseminated gold deposits, are not abundant in the southern area, where only thin films of jasperoid on fracture surfaces have been found. Gold in disseminated deposits occurs as particles a few microns in size and commonly in association with pyrite or carbon. No information is available on the abundance, form, or occurrence of gold in bedrock of the southern area, other than that gold exists in veins in granite that intruded the carbonate rocks. Because the pluton, an upper Miocene alkali-feldspar granite, was emplaced at high crustal levels, heat from it would have had the opportunity to drive a hydrothermal system incorporating meteoric waters. The granite is considered as the most likely heat source to be associated with the gold mineralizing event in the southern area.

Although this area has several characteristics of disseminated gold deposits, clear evidence of a gold resource has not been found, and the potential for the occurrence of undiscovered gold resources is low. Detailed geochemical sampling to determine the abundance and distribution of gold would be required in order to learn if the geochemical suite of mercury, arsenic, and antimony found in this study are in fact manifestations of a gold resource.

Western area.—Some of the gold detected in the alluvial gravels in the western area could have been derived from mineralized granitic rock in the Sylvia mine area (figs. 3, 4). Other bedrock sources include the northern Death Valley region many miles from the Little Sand Spring Wilderness Study area (Albers and Stewart, 1972). Despite these potential source areas, the small amount of gold detected in alluvial gravels in the western area is not considered indicative of a resource. Evidently gold has not been concentrated greatly in the exposed upper parts of the fanglomerates of the western area. Although the available evidence indicates that little promise exists in the western area for gold resources in placer deposits, sampling at the base of pediment gravels near the mountain front or near the concealed contact with bedrock elsewhere, especially in fossil stream channels, might reveal greater resource potential.

Molybdenum and silver

Sylvia mine area.—Altered and mineralized rock in the Sylvia mine area (figs. 3, 4) are here considered to belong to the fluorine-deficient type of porphyry molybdenum deposit of Theodore (1982) and the low fluorine, calc-alkaline molybdenum stockwork deposits of Westra and Keith (1981). This type of deposit is widely distributed in Mesozoic and Tertiary rocks of the North American cordillera, including the western part of the Basin and Range province. Important characteristics of the fluorine-deficient molybdenum deposits are listed here.

1. Low fluorine content compared to the Climax-type molybdenum deposit.
2. Abundant quartz veins forming a stockwork in a large volume of rock.
3. Quartz-bearing porphyritic igneous rock associated with mineralized rock. A few molybdenum stockwork deposits do not have porphyritic rocks (Westra and Keith, 1981).
4. Widespread sericitic alteration.
5. Abundant, relatively large, moderately saline fluid inclusions showing evidence of boiling. Halite and sylvite daughter products are absent. Inclusions of this type occur in the igneous quartz of the host rock and in the vein quartz of the stockwork.

Details of the chemistry of these deposits are not listed because chemical analyses of the fresh and mineralized rocks in the Sylvia mine area are not available.

Most of the attributes listed here for fluorine-deficient deposits are poorly developed in the Sylvia mine area. A quartz stockwork of closely spaced veins crops out only in a few areas, each on the order of several hundred feet across, and porphyritic igneous rocks are sufficiently sparse as to be easily overlooked. These features and the absence of a fluid inclusion signature typical of stockwork molybdenum deposits indicate that the Sylvia mine area has a low potential for a molybdenum resource. Based on map patterns, the altered rock extends to the south beneath volcanic rocks and west beneath gravels, possibly into the wilderness study area, but no evidence was found that the potential for a molybdenum resource would be greater in those areas.

The silver-lead veins at the Sylvia mine, as described earlier, probably are genetically related to the nearby molybdenum-enriched zone. Because of this genetic association as well as the existence of silver-bearing veins large enough to have been exploited in the past and the high silver values obtained from samples at the mine, a moderate potential exists for additional silver resources in veins of the Sylvia mine area outside the mine. Because the silver-bearing veins are peripheral to the area mineralized in molybdenum, silver deposits might reasonably be expected to the west in bedrock beneath gravels in the wilderness study area. If present, the silver deposits probably would be of small size but have high-grade zones.

Nonmetallic commodities and lithium

No evidence of a potential for resources of nonmetallic commodities and lithium was found in this study. The small occurrences and poor quality of light-colored carbonate rock and of clay, perlite, and pumicite in the area and the low concentrations of lithium and nitrates indicate that the area is unfavorable as a source for these commodities. The study area is unlikely to have potential for oil and gas resources because of the large volume of Mesozoic intrusive rocks in the region would have provided sufficient heat to drive off or degrade any accumulations of hydrocarbons in the pre-Teritary rocks, which are the only rocks in the study area that at once time reasonably could have contained petroleum deposits. Sand and gravel more than ample for local use are available in and adjacent to the wilderness study area.

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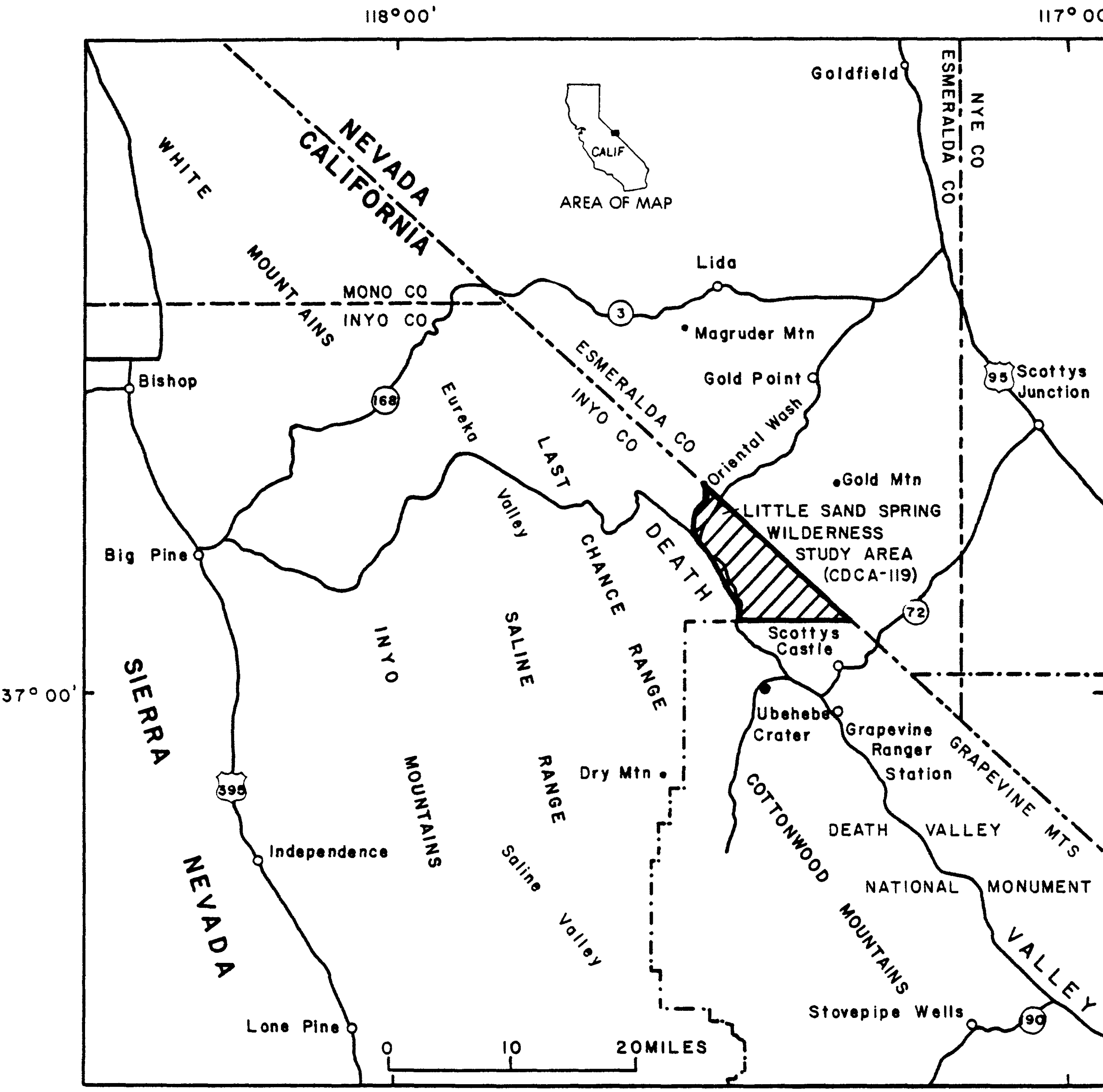


Fig.1--Map showing location of Little Sand Spring Wilderness Study Area, California.

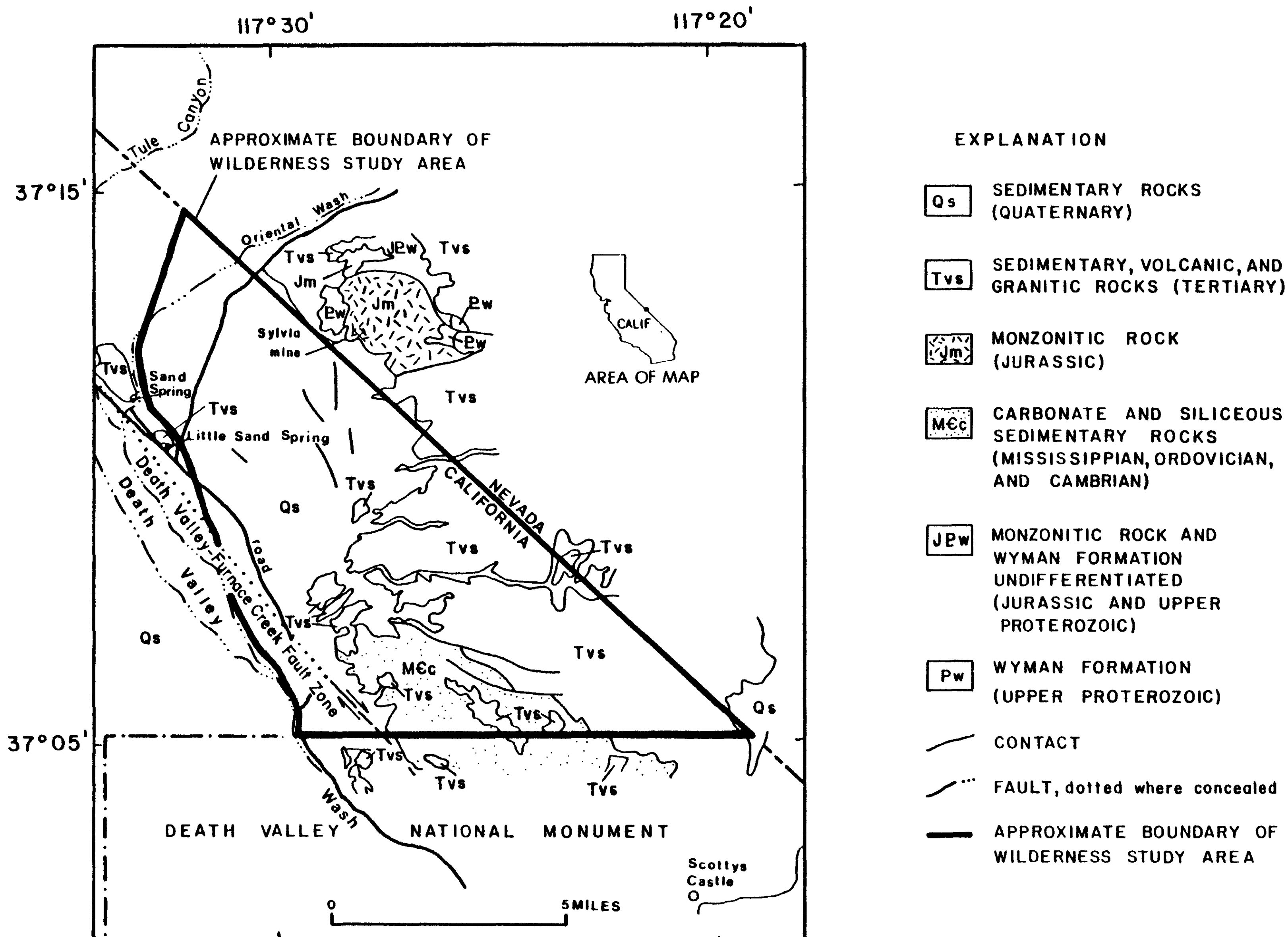
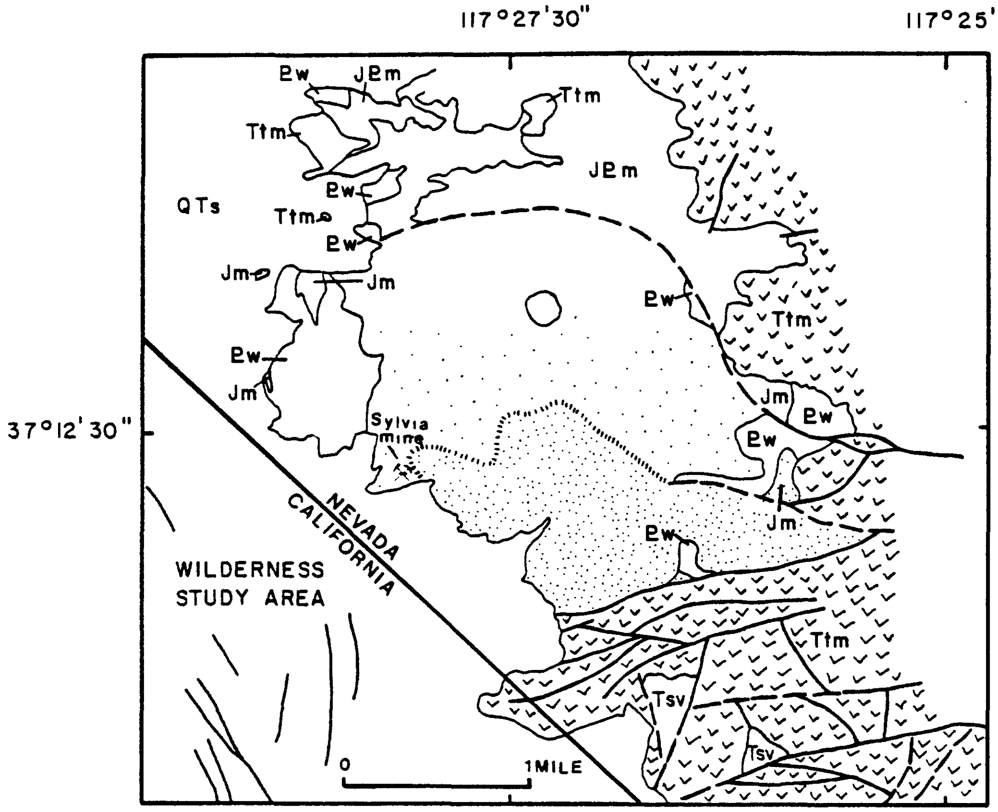


Fig 2-- Generalized geologic map of the Little Sand Spring Wilderness Study Area



EXPLANATION

- QTs — GRAVEL (QUATERNARY AND TERTIARY)
- Tsv — SEDIMENTARY AND VOLCANIC ROCKS (TERTIARY)
- Ttm — TIMBER MOUNTAIN TUFF (TERTIARY)
- Jm — MONZONITE AND QUARTZ MONZONITE (JURASSIC)
  - Propylitic alteration zone. Northern limit not determined.
  - Sericitic alteration zone.
- JPm — MONZONITIC ROCK AND INCLUSIONS OF WYMAN FORMATION (JURASSIC AND PROTEROZOIC)
- Pw — WYMAN FORMATION (PROTEROZOIC)
- CONTACT
- FAULT, dashed where approximately located
- Approximate boundary of altered area

Fig 3-- Geologic map of the Sylvia mine area. and vicinity.

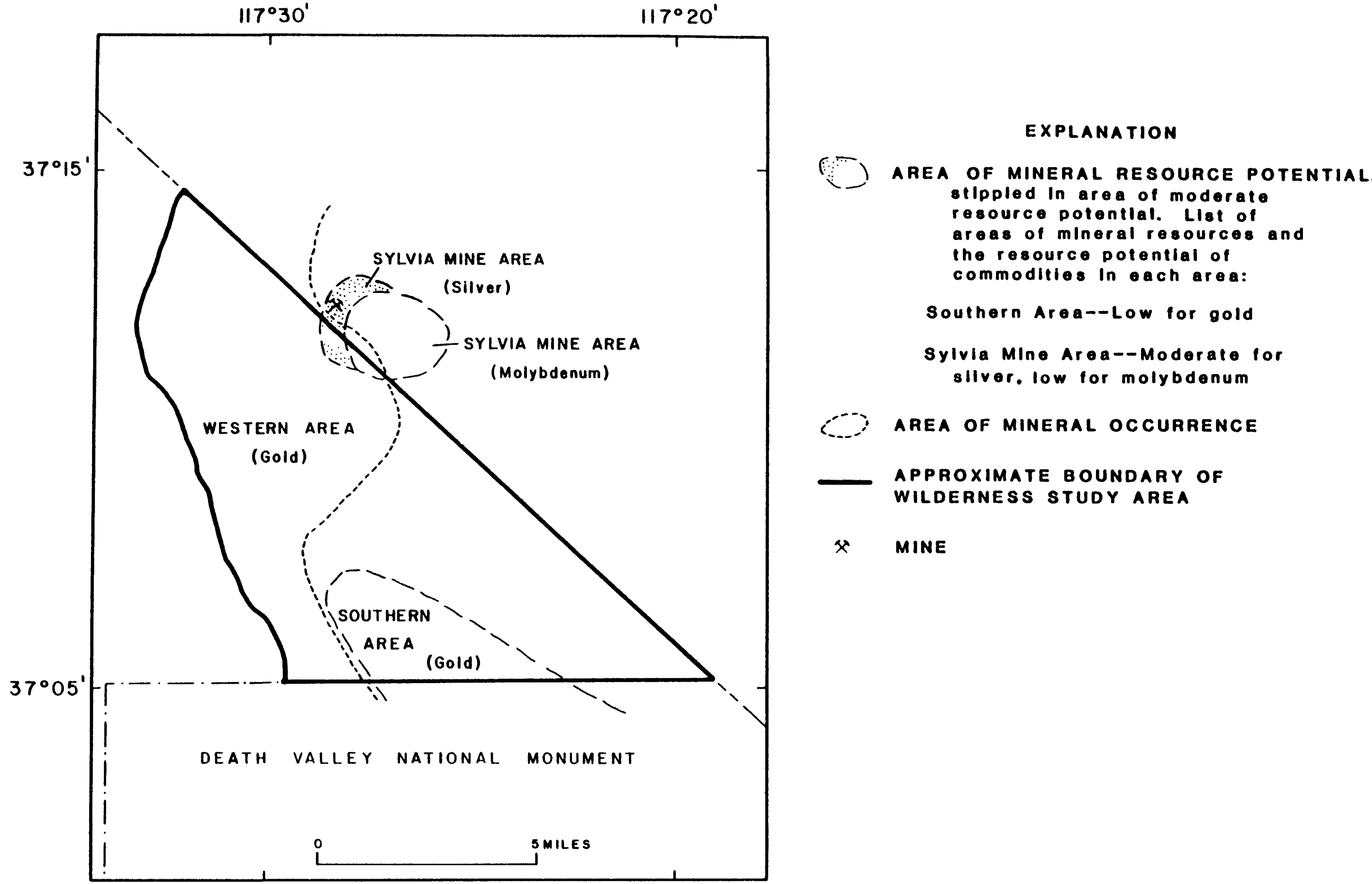


Fig 4-- Map showing areas of mineral occurrence and mineral resource potential in the Little Sand Spring Wilderness Study Area and vicinity