Mineral Resources of the South Pequop Wilderness Study Area, Elko County, Nevada

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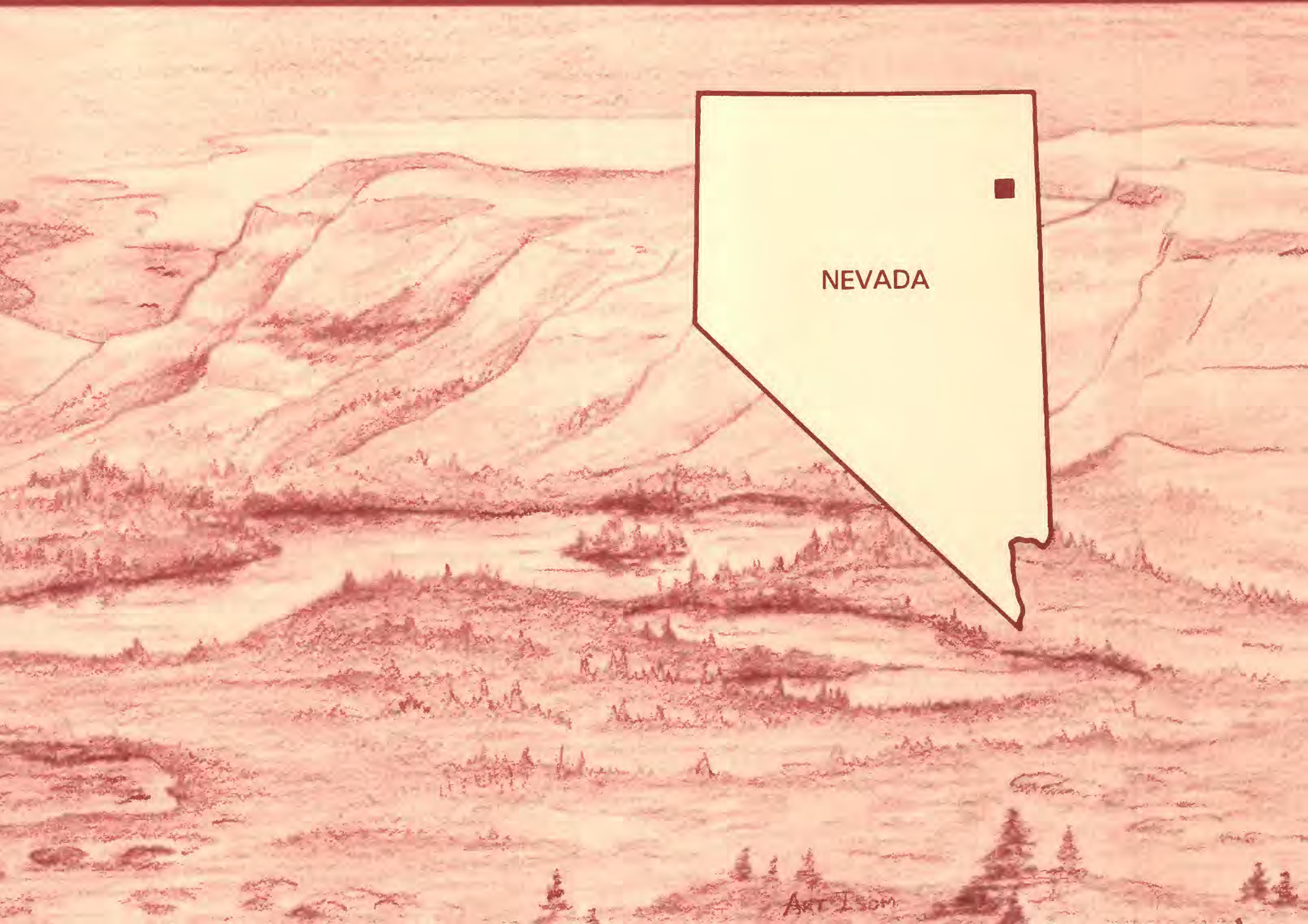

Chapter B

Mineral Resources of the South Pequop Wilderness Study Area, Elko County, Nevada

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
NORTHEASTERN NEVADA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study 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 the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of a part of the South Pequop Wilderness Study Area (NV-010–035), Elko County, Nevada.

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Mineral Resources of the South Pequop Wilderness Study Area, Elko County, Nevada

By Keith B. Ketner, Carol N. Gerlitz, *and* Richard W. Saltus
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SUMMARY

Abstract

The South Pequop Wilderness Study Area (NV–010–035) is in the Pequop Mountains, in northeastern Nevada. The area studied, 34,544 acres (approximately 54 square miles), is about equally divided by the crest of the range into east- and west-sloping tracts sparsely covered by pinyon pines and junipers. The geology was mapped in 1965–1971, and the mineral resource potential was investigated in 1984–1985. The geologic formations are mainly limestone and dolomite units, but one heterogeneous sequence, the Plympton Formation, includes beds of chert, shale, and phosphatic rocks. The area occupied by this formation is regarded as having a moderate mineral resource potential (likelihood of occurrence of undiscovered concentrations) for phosphate deposits. However, such deposits, if they exist, are not likely to be very large. In two areas within the study area, geochemical data suggest the possibility of concealed deposits of gold, silver, lead, zinc, and copper. The areas are regarded as having a moderate resource potential for these metals, but there is no indication of the grade or dimensions of these hypothetical deposits. Thermal history and structural conditions in the wilderness study area do not favor the formation and accumulation of oil and gas, and the study area is therefore regarded as having a low energy resource potential for these commodities. Common limestone and dolomite underlie almost the entire area of the wilderness study area, but they are of poor quality for all uses except as road metal. The resource potential of the study area for thick beds of high-purity limestone and dolomite is low. Common sand and gravel deposits are plentiful in the study area, but they are in no way unique, and no local demand is likely to materialize that cannot be supplied by deposits outside the study area. The study area has a low resource potential for specialty sand and gravel.

Character and Setting

The area studied covers 34,544 acres (about 54 square miles) of the southern Pequop Mountains, a northeast-trending range in the central part of the Great Basin (fig. 1). The relief within the area from the lowest point on the northwest border to the highest peak is 3,281 feet, and the highest point is 8,952 feet above sea level. Most of the area is covered by a thin growth of stunted pinyon pines and junipers. Lower slopes are covered by grasses and bushes, mainly sagebrush.

The wilderness study area is far from towns and ranches, but it can be reached quite easily by gravel and dirt roads from Interstate Highway I–80, which crosses the Pequop Mountains 24 miles to the north, and from U.S. Highway 93 to the west and southwest. Unimproved roads and trails traversable by four-wheel-drive vehicles and pickup trucks penetrate the study area in some canyons, border it on the south and west, and reach its boundary at several points on the east side. The area is therefore quite accessible, but its remoteness from towns and ranches keeps human traffic to a minimum.

The geologic terrane in the wilderness study area is one principally of folded limestone and dolomite beds that form north-south-trending ledges and ridges. Among these predominantly carbonate beds is a stratigraphic unit known as the Plympton Formation, a heterogeneous sequence that includes chert, silty beds, shale, and phosphatic beds. This formation is of interest because of its content of phosphorus, an essential ingredient of fertilizer. A small granitic intrusive stock is present in the central part of the area.

Identified Resources

An identified resource is one whose location, grade, quality, and quantity are known or can be estimated from specific geologic evidence (see resource/reserve classification chart in appendix). Identified re-

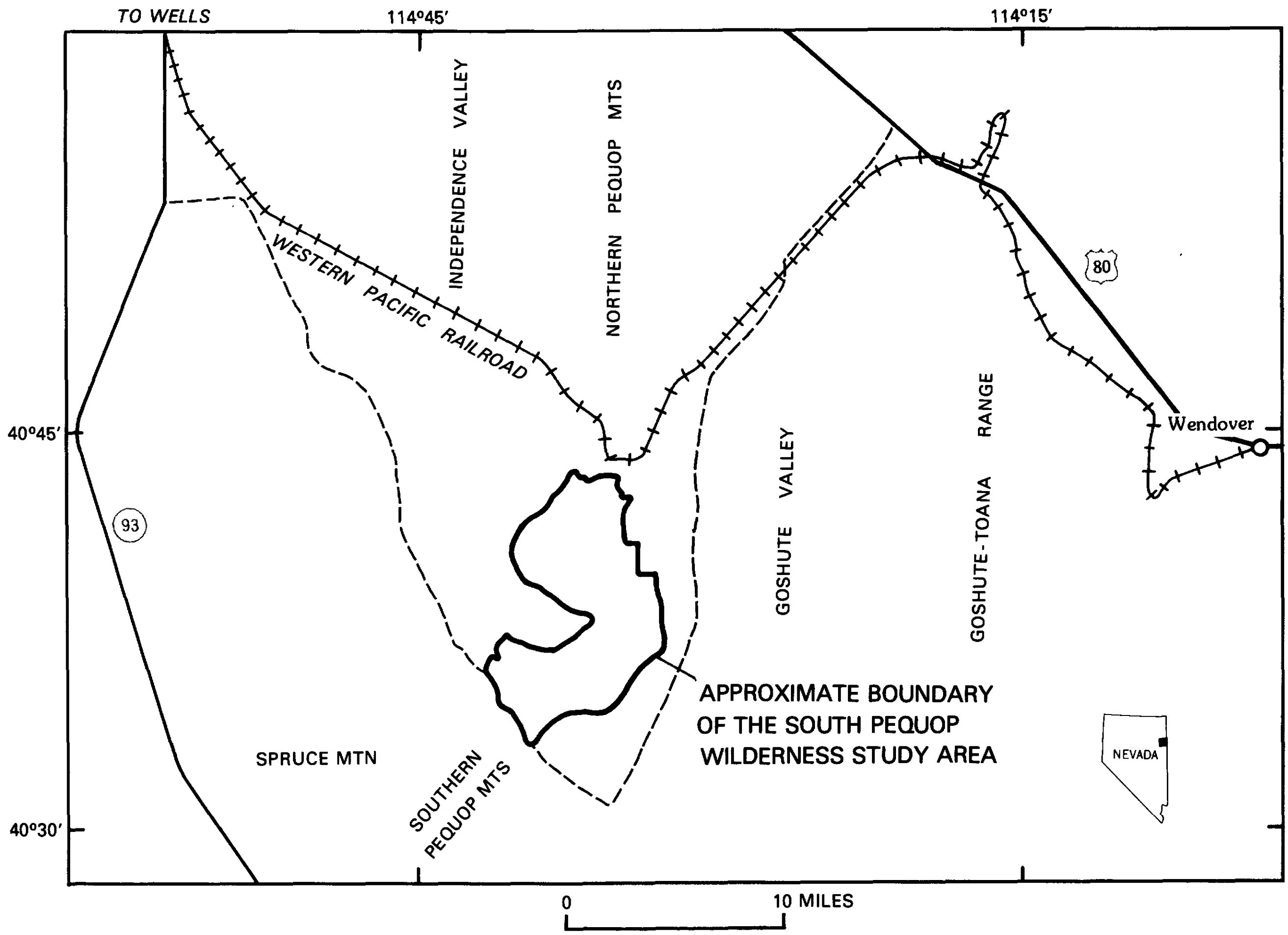


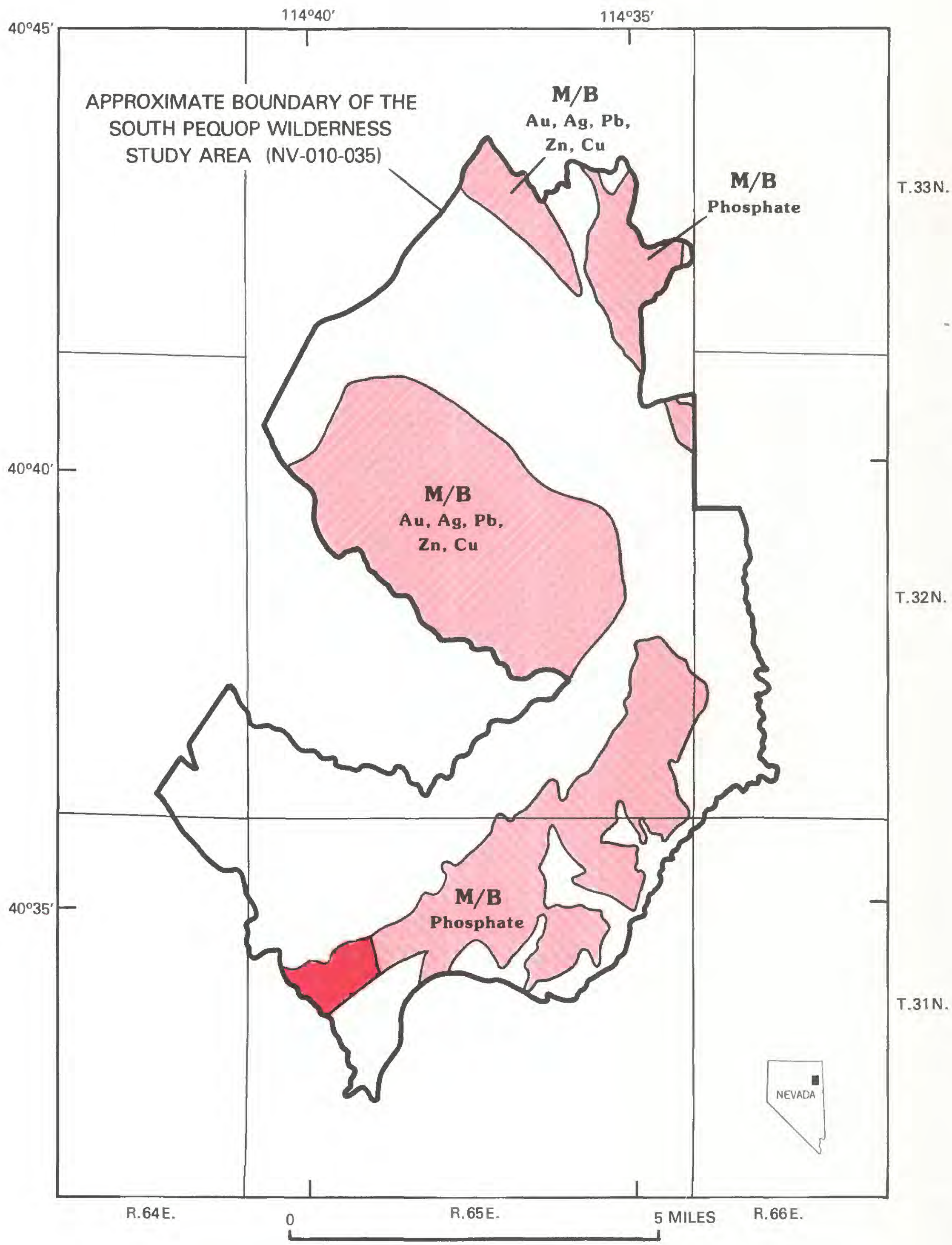
Figure 1. Index map showing location of the South Pequop Wilderness Study Area, Elko County, Nev.

sources include economic, marginally economic, and subeconomic components. Phosphate, common limestone and dolomite, and common sand and gravel are identified resources of the wilderness study area (Wood, 1985). None of these has been exploited in the past although phosphate prospecting permits were in effect between 1965 and 1972. During the present investigation phosphate-bearing rocks were sampled and measured in trenches that had been dug during previous exploration efforts. Common limestone and dolomite were sampled and analyzed, and are suitable for crushing and use as road metal. Their utility as raw material for cement and chemicals is almost nonexistent because of their impurity and the availability of better material in more convenient locations. Sand and gravel deposits were not investigated in detail, but their presence and nature are quite obvious from observation of surface exposures. They are suitable as road metal or concrete aggregate but only in the unlikely event that a local need should arise. In any case, such deposits are available immediately outside the study area. As of September 1984, there were no patented or unpatented mining claims within the wilderness study area.

Potential for Undiscovered Resources

Although parts of the Plympton Formation are classed as identified resources of low-grade phosphate because they have been trenched, measured, and analyzed, extensive areas within the wilderness study area that are underlain by the Plympton Formation (fig. 2) have not been thoroughly explored and are classified as having a moderate resource potential for undiscov-

Figure 2 (facing page). Mineral resource potential map of the South Pequop Wilderness Study Area, Elko County, Nev. Parts of the study area underlain by limestone, silty limestone, and conglomerate (symbols ₮ Pl and PMl, pl. 1) have identified resources of common limestone and dolomite and low mineral resource potential for undiscovered high-purity limestone and dolomite, with certainty level C. Parts underlain by Quaternary deposits (symbol Qal, pl. 1) have identified resources of common sand and gravel and low mineral resource potential for specialty sand and gravel, with certainty level D. Entire study area has low resource potential for oil and gas, with certainty level C.



EXPLANATION

Area of identified phosphate resources

M/B Geologic terrane having moderate mineral resource potential for gold, silver, lead, zinc, and copper, with certainty level B

M/B Geologic terrane having moderate mineral resource potential for phosphate, with certainty level B (outcrop area of Plympton Formation) ered phosphate deposits. The tonnage of individual deposits within the wilderness study area is expected to be small.

Two areas within the wilderness study area have a moderate mineral resource potential for gold, silver, lead, zinc, and copper (fig. 2). In both areas geochemical data suggest the possible presence of concealed deposits of these metals. Both areas are adjacent to, and possibly related to, certain high-angle faults that extend far into the study area. However, there is no indication that these possible deposits are of potentially exploitable grade and dimensions.

Paleozoic and Triassic (see geologic time chart in appendix) formations that underlie most of the wilderness study area are not likely to contain oil and gas accumulations owing to the synclinal structure of the range. Temperatures attained by rocks in the Pequop Mountains are regarded as unfavorable for proper maturation of petroleum (Sandberg, 1983), but the data are too sparse to be conclusive. Post-Triassic sedimentary rocks that lap up on the lower slopes of the Pequop Mountains are probably too thin within the study area to contain significant accumulations of oil or gas. The wilderness study area is regarded as having a low potential for the presence of oil and gas.

Common limestone and dolomite underlies almost the entire study area. The wilderness study area has a low resource potential for high-purity limestone and dolomite.

Common sand and gravel deposits are present in parts of the wilderness study area. The wilderness study area is regarded as having a low resource potential for specialty sand and gravel.

INTRODUCTION

Area Description

The U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM) studied 34,544 acres (about 54 square miles) of the South Pequop Wilderness Study Area (NV–010–035). The study of this acreage was requested by the U.S. Bureau of Land Management (BLM). In this report the studied area is called the "wilderness study area" or simply the "study area."

The southern Pequop Mountains, like most in the Great Basin, trend north-northeast and are flanked on both sides by broad, flat valleys: Independence Valley on the west and Goshute Valley on the east. The entire region is arid, but because it lies in the rain shadow of the much higher Ruby Mountains and East Humboldt Range, the study area is uncommonly arid.

The altitude within the wilderness study area ranges from 5,671 to 8,952 ft (feet) above sea level, and the local relief is therefore 3,281 ft. Most of the higher slopes are covered by a thin growth of stunted pinyon pines and junipers, and lower slopes are covered mainly by grasses and stunted bushes.

Although the wilderness study area is in a relatively desolate part of the Great Basin far from towns and ranches, it is not far from major lines of transportation (fig. 1). The Western Pacific Railroad crosses the Pequop Mountains through a tunnel less than 1 mi (mile) from the northern border of the study area. Interstate Highway 80 (I–80) crosses the mountains at Pequop Pass, 24 mi north of the study area; U.S. Highway 93 parallels the Pequop Mountains about 20 mi to the west and crosses foothills on the trend of the range about 15 mi to the southwest. The study area can be reached by gravel and dirt roads from I–80 at the Shafter, Oasis, and Independence Valley exits and from U.S. Highway 93 at a point 15 mi south of the town of Wells.

Unimproved roads or trails, traversable in good weather by pickup trucks or four-wheel-drive vehicles, penetrate the wilderness study area in some canyons, border it on the south and west, and reach the study area boundary at several points on the east side. The area is therefore quite accessible, but its remoteness from towns and ranches keeps human traffic to a minimum.

Previous and Present Investigations

The study area is entirely within the Spruce Mountain 4 (15-minute) quadrangle. The geologic map of this quadrangle, recently published at a scale of 1:24,000 (Fraser and others, 1986), serves as the principal source of geologic data for the present report.

Smith (1976) summarized all available data on metallic mineralization in the neighboring Spruce Mountain mining district (fig. 1), which is about 10 mi southwest of the study area, and on phosphate occurrences within and adjacent to the study area. Erickson and others (1966) gave results of geochemical sampling in the Pequop Mountains, both within the study area and adjacent to it on the north. Sandberg (1983) estimated the petroleum potential of wilderness lands in Nevada largely on the basis of assessment of thermal histories of the rocks.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the USBM and the USGS. Identified resources are classified according to the system of the U.S. Bureau of Mines and the U.S. Geological Survey (1980), which is shown in the appendix. Mineral resource potential is the likelihood of occurrence of undiscovered concentrations of metals and nonmetals, of unappraised industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984), which is shown in the appendix.

In 1984, personnel of the U.S. Bureau of Mines collected data from official records of mining claims, from the published literature, and from analyses of bedrock samples collected as part of field investigations within and adjacent to the wilderness study area (Wood, 1985).

In 1985, personnel of the U.S. Geological Survey systematically sampled stream sediments from primary drainage basins in the study area and analyzed concentrations of heavy minerals from the samples (Gerlitz and others, 1986).

Acknowledgments.—We thank Gregory N. Green for help in collecting stream-sediment samples.

APPRAISAL OF IDENTIFIED RESOURCES

By Robert H. Wood II
U.S. Bureau of Mines

Identified resources are those whose location, grade, quality, and quantity are known or can be estimated from specific geologic evidence. Identified resources include economic, marginally economic, and subeconomic components.

Phosphate, carbonate rock, and sand and gravel are the principal commodities found in the wilderness study area. Under economic conditions similar to those prevailing in 1980, and according to tonnage and grade requirements specified at that time (U.S. Bureau of Mines and U.S. Geological Survey, 1982), no economic mineral resources were present in the study area.

Present Investigation

Prior to this U.S. Bureau of Mines field investigation, a detailed literature search was made for geologic and mining information pertinent to the South Pequop Wilderness Study Area. Information on mineral leases, prospecting permits, and mining claims was obtained from the U.S. Bureau of Land Management in Nevada. Elko County records were checked for recent mining-claim location notices.

The USBM field study focused on examining prospects, mineral occurrences, and mineralized areas inside and within 1 mi of the wilderness study area. Accessible prospects were mapped by the compass-and-tape method and sampled. Chip samples were taken across veins and other potentially mineralized structures. Prospect dumps were sampled on a grid pattern from about 0.5 ft below the surface to determine what metals may be present. Selected samples of dump material were used to characterize the mineralization. Selected beds of limestone and phosphate rock were sampled to determine their composition. Fifty-seven rock samples were analyzed by the USBM Reno Research Center, Reno, Nev. (Wood, 1985). Thirteen of the samples were carbonate rock and were analyzed by inductively coupled plasma spectrometry for aluminum oxide, calcium oxide, iron oxide, magnesium oxide, silica, and sulfate. Loss on ignition was determined by chemical analysis. The remaining 44 samples were fire assayed for gold and silver and analyzed spectrographically for 40 elements. Additional analyses for antimony, arsenic, and thallium were by atomic-absorption spectrophotometry, for phosphorus and vanadium by X-ray fluorescence, and for uranium by fluorometric methods.

Mining Activity

The wilderness study area is not within an organized mining district. The nearest is the Spruce Mountain district, 3–10 mi to the southwest (fig. 1). There, between 1869 and 1949, copper, gold, lead, silver, and zinc minerals were mined from small, bedded, replacement-type deposits in limestone, and from fissure vein deposits. Prospecting in the mid-1950's resulted in the discovery of two deposits of barite and a contact deposit of scheelite, the chief tungsten ore mineral (Smith, 1976, p. 151–156).

Evidence of metals exploration within the study area consists of three small prospects (pl. 1, sample sites 7–8, 12, and 13) near the northern boundary. Six other prospects, one southeast of the boundary (sites 51 and 52), and the rest north of the boundary (sites 1, 5, 6, and 9–11), are within 1 mi of the wilderness study area.

Six phosphate prospecting permits covering part of the southern end of the study area were in effect between January 1965 and August 1972 (pl. 1). According to Smith (1976, p. 130), the evidence of phosphate exploration at 15 locations in the southern Pequop Mountains includes nine trenches and several drill holes. One trench was found in the wilderness study area (pl. 1, sites 28–47). Two additional trenches are within 1 mi of the southern boundary (pl. 1, sites 48–49 and 54–57). No phosphate production has been reported for the study area.

As of September 15, 1984, there were no patented or unpatented mining claims within the wilderness study area. U.S. Bureau of Land Management records show that the nearest mining claim is about 2 mi south of the study area (Wood, 1985, pl. 1). It is not known for what commodity this claim was originally staked.

Extensive areas of Independence and Goshute Valleys flanking the Pequop Mountains are leased for oil and gas. Some leases extend to the lower slopes of the mountains, and as of May 1984 they cover about 20 sq mi (square miles) in the study area (pl. 1).

Phosphate

Phosphate occurs on the surface and subsurface in the Plympton Formation, which crops out over an area of about 10 sq mi of the wilderness study area (pl. 1 and Fraser and others, 1986). Phosphatic beds are easily weathered and therefore have a subdued topographic expression and are generally covered with soil. Exploration is best done by trenching across the strike of the steeply dipping beds. Phosphatic beds in the Plympton Formation are exposed over a width of 164.5 ft in the one trench within the study area and over a similar width in two trenches less than 1 mi south of the study area. Thirty-two samples were collected and analyzed for phosphate (Wood, 1985, table 1); twenty samples were from the trench inside the study area (pl. 1, sites 28–47).

The P_2O_5 content of the phosphatic beds in the area ranges from 0.21 percent over a 7.7-ft interval (sample 44) to 27.49 percent over a 2.7-ft interval (sample 30). A 1-ft sample interval south of the wilderness study area represented the highest amount of P_2O_5 sampled (sample 57, 29.49 percent).

Marine phosphatic rocks characteristically have a large suite of associated elements. Some elements associated with phosphate in the Western United States are cadmium, chromium, copper, molybdenum, nickel, selenium, strontium, vanadium, uranium, zinc, and rare-earth elements (Gulbrandsen, 1967, p. 102). Small amounts of gold (trace), silver (as much as 0.2 oz/ton), uranium (1–20 ppm (parts per million)), and vanadium (as much as 220 ppm) are present in the study area phosphatic beds (Wood, 1985, table 1; pl. 1, samples 25–47).

Specified minimum physical and chemical criteria are required to identify a reserve base (current and marginally economic reserves) and a subeconomic resource for phosphate deposits in the Northwestern United States. The criteria described by the U.S Bureau of Mines and U.S Geological Survey (1982, p. 7 and 9) are as follows:

> The minable unit of phosphate rock must be weathered or oxidized and must average greater than 18 percent P_2O_5; the rock must have a ratio of CaO to P_2O_5 of less than 1.55, and MgO content of less than 1.0 percent and a combined Fe_2O_3 and Al_2O_3 analysis of less than 3 percent; the thickness of the bed must be more than 5 feet; the stripping ratio of cubic yards of overburden per ton of phosphate rock must be less than 3.5; and the size of the deposit must be greater than 20 million tons of rock.
>
> Subeconomic resources include both strippable deposits and underground deposits. Strippable subeconomic resources must be made up of a phosphate bed greater than 3 feet thick, contain greater than 15 percent P_2O_5, and have a stripping ratio of cubic yards of overburden per ton of phosphate rock less than 9. Underground subeconomic resources must be made up of a phosphate bed greater than 3 feet thick, contain greater than 24 percent P_2O_5, and occur in beds not more than 1,000 feet below entry level.

Phosphatic beds cropping out and sampled in the wilderness study area do not meet these tonnage and grade reserve base requirements (Wood, 1985); however, surface sampling in an outcrop belt of Plympton Formation (pl. 1, sites 25–49) more than 7 mi long indicates that the criteria for a subeconomic phosphate resource are nearly met in some beds. Sample 30 (Wood, 1985, table 1) exceeds the required 15 percent P_2O_5 content, but the bed is less than 3 ft thick. If two beds (sites 30 and 32) could be selectively mined, so as to eliminate an intervening bed (the interval at site 31), a subeconomic phosphate resource of 250,000 short tons containing 16.4 percent P_2O_5 can be calculated in the study area along an outcrop 2 mi long and 8.1 ft thick, projected down dip for 34.4 ft (3:1 stripping ratio at a 45° dip measured in the area). Similar outcrop belts of Plympton Formation throughout the wilderness study area (pl. 1; and Fraser and others, 1986) would increase the estimated tonnage of phosphatic rock by at least 1,250,000 tons. Larger tonnages of still lower grade material are present in other beds (Wood, 1985, table 1).

Sample results from other locations (pl. 1, sites 48, 49, and 54–57) indicate that grade and thickness of the phosphatic layers change rapidly. Fraser and others (1986) indicate that low-angle faulting is common in the Plympton Formation and could have eliminated some of the phosphatic beds elsewhere in the area. Detailed surface and subsurface sampling would be needed to establish continuity, grade, and effects of weathering that relate to economic minability.

Demand will determine if phosphate from the study area will ever become economic. Large quantities of phosphate rock occur throughout the world, including the United States, and are mined extensively in Florida, Idaho, Montana, North Carolina, Tennessee, and Utah. In 1985, domestic mine production of phosphate rock was 51 million metric tons, and United States consumption was about 41 million tons. The Western States produced about 5 million metric tons of phosphate rock in 1985, about 10 percent of the total marketable phosphate rock produced in the United States. All of the phosphate produced in the West came from the Phosphoria Formation (W. F. Stowasser, U.S. Bureau of Mines, oral commun., 1986). From a 1983 base, demand for phosphate rock is expected to increase at an annual rate of about 1.8 percent through 1990. The major byproducts of phosphate processing are fluosilicic acid, vanadium, and uranium. Lower grade deposits may become more appealing when high-grade deposits are exhausted and as advances in mining and processing technology permit utilization of lower grade ores (U.S. Bureau of Mines, 1985, p. 114–115).

Past exploration indicates that there has been considerable interest in phosphate present in the study area, but our research indicates that the grade of this phosphate, where sampled, is lower than that mined elsewhere in North America. One significant positive factor in developing the phosphate would be the existing railroad transportation, which is within 3 mi of the wilderness study area.

Carbonate Rocks

Limestone (calcium carbonate) and dolomite (calcium-magnesium carbonate) are the most abundant rocks in the wilderness study area. Chemical analyses and descriptions of sampled carbonate rocks are given by Wood (1985, table 2 and fig. 5). The highest grade limestone sampled is 90.86 percent $CaCO_3$, and the highest grade dolomite sampled is 25.53 percent $MgCO_3$. Most of the carbonate rocks of the study area are suitable for road metal after crushing, and the limestone beds that are greater than 85 percent $CaCO_3$ are suitable for agricultural uses. Common carbonate rocks such as those of the study area are readily available closer to industrial centers.

Sand and Gravel

Common sand and gravel occur along the flanks and along the streams of the Pequop Mountains. The most common uses of sand and gravel are as aggregate in concrete and as road metal, or fill. Transportation costs limit the marketing range, and only local uses would be feasible for these commodities. Sand and gravel similar to that of the study area are abundantly available elsewhere outside the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Keith B. Ketner, Carol N. Gerlitz, and Richard W. Saltus
U.S. Geological Survey

Geology

The South Pequop Wilderness Study Area is in the southern part of the Pequop Mountains, one of the ranges in the central part of the Great Basin geomorphic province. It is underlain by marine sedimentary rocks of Mississippian to Triassic age (see geologic time chart in appendix) and by scattered sand and gravel deposits of Quaternary age (Fraser and others, 1986). The Mississippian rocks, consisting of limestone, shale, and conglomerate, are exposed low on the west side of the range. Pennsylvanian, Permian, and Triassic units consisting mainly of silty and sandy, or cherty, limestone underlie most of the area. The Permian Plympton Formation (pl. 1) includes much siliceous dolomite, siltstone, phosphatic chert, phosphatic shale, and thin beds of phosphorite. The phosphorite is of interest because of its high content of phosphorus, a principal ingredient of fertilizer. Igneous rocks are notably scarce. The single intrusive body in the wilderness study area is a coarse-grained granodiorite that crops out in an area about 400 ft wide and 600 ft long. Extrusive rocks, with the exception of a thin tuff bed in the Triassic unit, were not observed in the wilderness study area, although a few very small patches are present just outside of it. Quaternary sediments consist mainly of sand and gravel deposits along streams, coalesced fans that slope gently away from the range, and lake sediments in the valleys on both sides of the range.

Strata of the study area form a complex synclinal fold, the Pequop syncline, which has a sinuous north-northeast trend and a complexly wrinkled southeast limb (Fraser and others, 1986). Other structures in the study area include two types of low-angle faults and two types of high-angle faults, which are shown in Fraser and others (1986). Low-angle faults of one type emplaced older over younger beds, apparently in response to compressional stress. Low-angle faults of another type tended to follow a particular bed low in the Plympton Formation but in places departed from that unit and cut down section, emplacing younger on older beds as if in response to tensional stress. In the Plympton Formation this latter type of low-angle fault is identified by the presence of a calcite-cemented breccia. The breccia is probably the product both of faulting, which tended to follow an evaporite bed, and of collapse resulting from solution of the evaporites either during or after faulting.

High-angle faults of one type, most abundant on the western slopes of the range, are nearly straight in plan view, trend perpendicular to the axis of the synclinorium, and display strike-slip movement. The two faults of this type in the study area, shown on plate 1, are associated with anomalously high concentrations of lead, zinc, and copper. High-angle faults of another type, most abundant on the eastern slopes of the range, are subparallel with the axis of the Pequop syncline and with the trend of the range. These faults, which do not seem to be mineralized, are commonly concave toward the valley in plan view and are probably incipient extensional faults that formed late in the deformational history of the area.

Geochemistry

Concealed hydrothermal gold and silver veins and replacement deposits may be discovered by detection of "pathfinder" elements. These are relatively mobile elements occurring in close association with elements being sought (Levinson, 1980). Pathfinders for gold and silver include arsenic, bismuth, and antimony. Some of the pathfinders for lead are silver, arsenic, barium, cadmium, copper, antimony, and zinc. Those for zinc include fluorine, mercury, manganese, and lead. Both stream-sediment and bedrock samples were collected and analyzed for these and other elements to evaluate whether previously unknown deposits might exist in the study area.

Stream Sediments[1]

Stream-sediment samples were collected at 53 sites (pl. 1 and Gerlitz and others, 1986) during September 1985. Analyses of the heavy-mineral concentrates from these samples were used in the geochemical evaluation of the wilderness study area. The heavy minerals contained in the concentrates were derived by natural processes from rocks of the drainage basin upstream from each sample site. The drainage basins sampled range in area from 0.25 to 5 sq mi.

The nonmagnetic fractions of the concentrates were analyzed for 31 elements by the six-step semiquantitative emission spectrographic method of Grimes and Marranzino (1968). Determination limits and estimated anomaly thresholds of these elements are shown in table 1. Descriptions of sampling and analytical techniques are included with the analytical data in Gerlitz and others (1986).

Samples containing anomalously high silver, and the highest amounts of yttrium (200–500 ppm) and chromium (500–700 ppm) are from localities on the east side of the southern Pequop Mountains. These high values probably reflect the presence of phosphorite and organic-rich shale beds in the Plympton Formation, which crop out principally on the east slopes of the mountains (pl. 1 and Gulbrandsen, 1967).

Anomalously high concentrations of zirconium and titanium, found in samples taken from drainage basins scattered throughout the study area, are due to the presence of zircon and rutile, identified under the binocular microscope and by the scanning electron microscope. These are common, ubiquitous minerals and are not regarded as pathfinders for valuable mineral deposits.

In general, samples containing significantly high concentrations of the following elements are from localities grouped on the west side of the range: antimony, arsenic, barium, beryllium, cobalt, copper, lanthanum, lead, molybdenum, nickel, scandium, vanadium, and zinc. Samples having the highest content of these elements are clustered in Ninemile Canyon and the first large canyon to the north (figs. 3, 4, pl. 1). Five of the six samples containing anomalous concentrations of antimony are from localities in these two canyons. These samples also yielded the four highest arsenic contents (1,000–1,500 ppm) and two of the highest silver contents (1–1.5 ppm) in the range. In addition, samples from these two canyons contained anomalous concentrations of barium, copper, lead, molybdenum, nickel, and zinc, as well as some of the highest concentrations of beryllium, lanthanum, scandium, and vanadium found in the study area. Another group of samples, taken from drainage basins near the southwest corner of the study area, contained anomalous concentrations of copper, lead, zinc, and arsenic.

A geochemical reconnaissance study of the Pequop Mountains conducted by Erickson and others (1966) included stream sediments, bedrock, and scattered fragments of rock. Their stream sediments contained very low concentrations of metals; however, the outcome of their stream-sediment survey cannot be directly compared to our results because the sample medium used (minus-50-mesh fraction of stream sediments) was not the same as ours, and sample sites were limited to the canyon mouths of major drainage basins. On the basis of analyses of scattered fragments of rock and bedrock samples, Erickson and others (1966) detected no significant lead or zinc anomalies in the southern Pequop Mountains, but they did find a few drainage basins in which such samples contained anomalous amounts of arsenic, antimony, mercury, and tungsten. Anomalous concentrations of antimony, mercury, and tungsten in samples from Ninemile Canyon and the canyon immediately to the north indicate, as did our heavy-mineral concentrate samples, that these two drainage basins may contain mineralized rock.

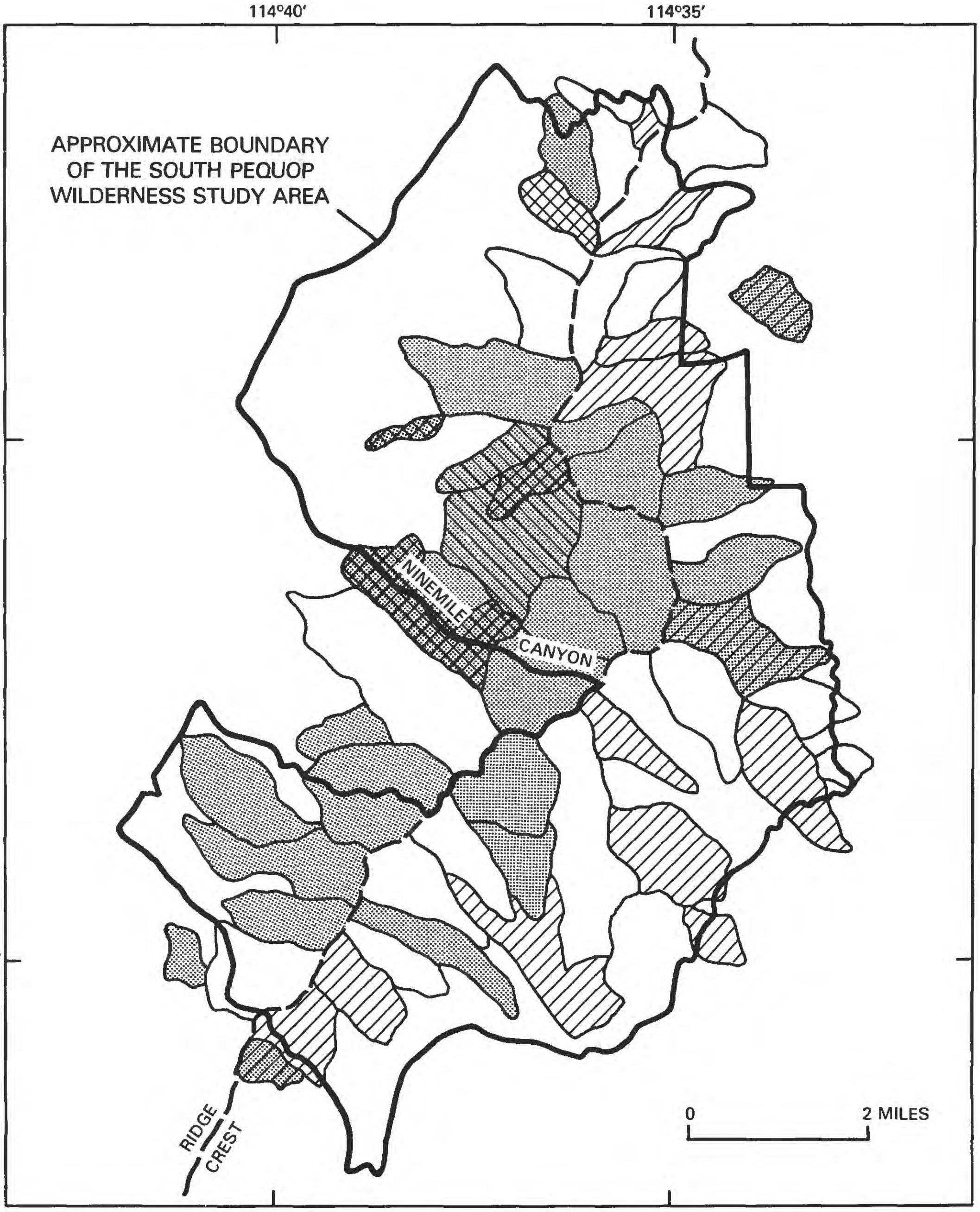
We examined the heavy-mineral concentrates from Ninemile Canyon and the canyon immediately to the north by means of a binocular microscope and a scanning electron microscope. These studies failed to reveal any ore minerals. However, numerous cube- or pyritohedron-shaped grains composed of iron-oxide represent original pyrite crystals (iron sulfide) and suggest possible sulfide mineralization in the area. Our survey revealed high concentrations of iron (15 percent or more) and manganese (1,000 ppm or more) in heavy-mineral concentrates along the west side of the southern Pequop Mountains. Metals present in high concentrations in heavy-mineral concentrates may have been adsorbed on, or coprecipitated with, iron and manganese oxides, which are reflected in the high iron and manganese values. This possibility is also suggested by the fact that the anomalous values for arsenic, antimony, tungsten, and tellurium reported by Erickson and others (1966) are for samples of iron-stained (purplish-red) calcite veins and masses, iron-stained (yellow and red) clastic dikes, and scattered fragments of iron-stained limestone.

Bedrock[2]

Seven small prospect pits, from which most of the bedrock geochemical samples were taken, are in or adjacent to the northwest boundary of the study area (samples 5–13, pl. 1). One of two more pits is 1.0 mi outside the northeastern boundary (sample 1, pl. 1), and the other is 0.2 mi outside the southeastern boundary (samples 51, 52, pl. 1). All of the prospects are on identified or sus-

[1]This section by C. N. Gerlitz, U.S. Geological Survey.

[2]This section by R. H. Wood II, U.S. Bureau of Mines.



EXPLANATION

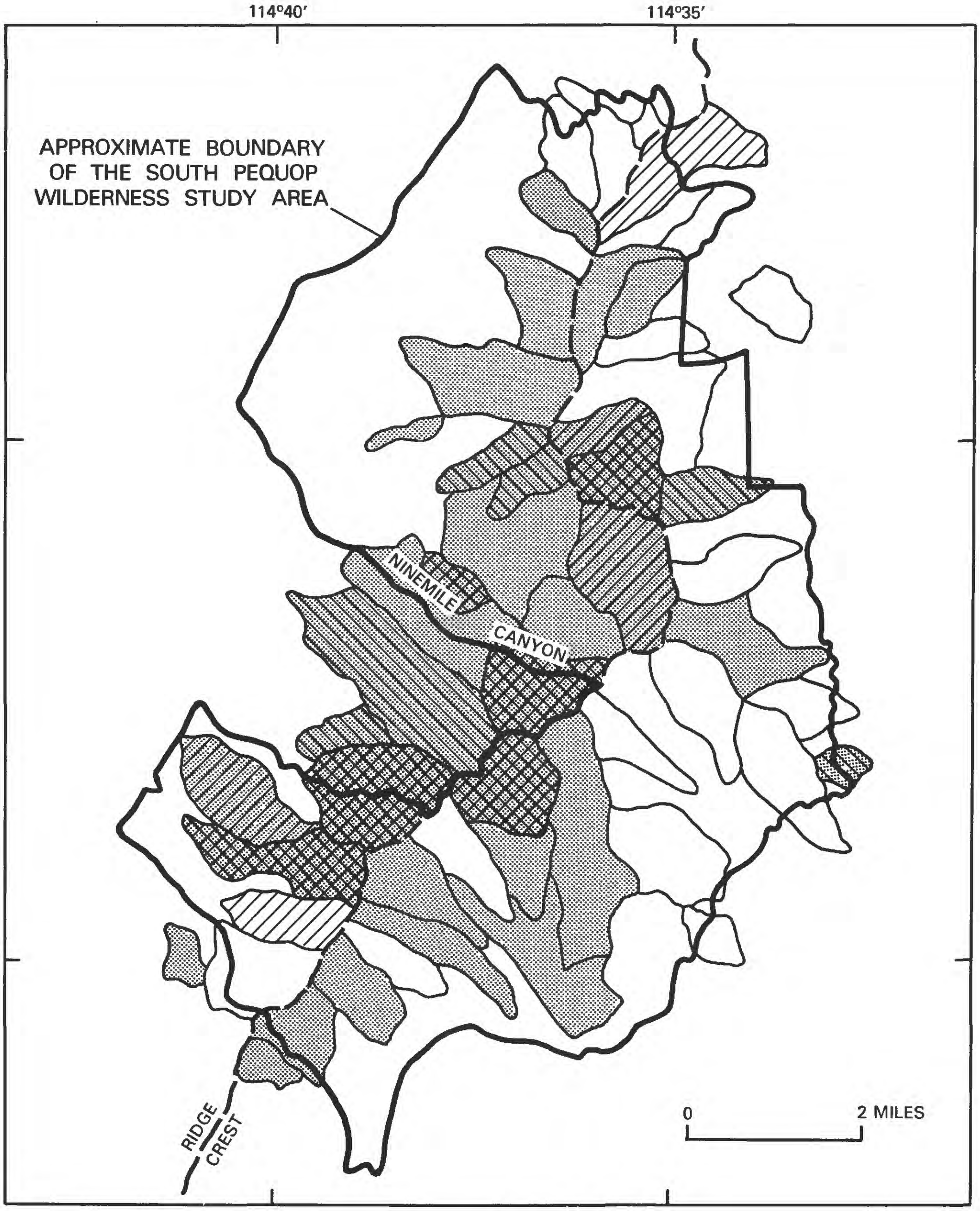
Drainage basin showing geochemical anomaly

Arsenic—Concentrations of less than 500 to 1,500 ppm (parts per million)

Antimony—Concentrations of less than 200 to 1,500 ppm

Silver—Concentrations of less than 1 to 1.5 ppm

Figure 3. Map showing drainage basins of the South Pequop Wilderness Study Area for which levels of arsenic, antimony, and silver in the nonmagnetic fractions of heavy-mineral concentrates of stream-sediment samples are anomalously high.



EXPLANATION

Drainage basin showing geochemical anomaly

Copper—Concentrations of 200-300 ppm (parts per million)

Lead—Concentrations of 100-500 ppm

Zinc—Concentrations of less than 500 to 1,500 ppm

Figure 4. Map showing drainage basins of the South Pequop Wilderness Study Area for which levels of copper, lead, and zinc in the nonmagnetic fractions of heavy-mineral concentrates of stream-sediment samples are anomalously high.

pected faults or fractures. Those near the northwestern boundary at the tip of the study area are close to a major high-angle fault that projects southeastward into the study area. Iron oxide is associated with each prospect, and calcite, manganese oxides, and silica in fractures were seen in some of the prospects. Samples 2–4 and 15–24 (pl. 1) are altered rock from outcrops.

Concentrations above background for average limestone were detected for arsenic, barium, manganese, antimony, and zinc. In the prospects sampled in and adjacent to the northwest border of the study area (samples 5–13, pl. 1), concentrations detected are as high as 0.05 percent arsenic, 8.0 percent barium, 5.0 percent manganese, 3.0 ppm antimony, and 0.06 percent zinc (Wood, 1985, table 3). These anomalous concentrations of elements in bedrock suggest the possibility of a nearby deposit of gold, silver, lead, and zinc within the study area. Anomalous values obtained for arsenic, barium, antimony, and zinc in the prospect outside the southeast boundary of the study area (samples 51, 52) suggest the possible presence of metal deposits in the study area.

Geophysics[3]

Gravity-station coverage within the study area is limited to only five gravity measurements. A residual gravity map of a 30-minute by 30-minute area containing the wilderness study area is shown on figure 5. This map area contains approximately 100 gravity stations, most from the U.S. Defense Mapping Agency data base (available from the National Geophysical and Solar-Terrestrial Data Center, Boulder, CO 80303). A few of the stations in Goshute Valley are from Saltus and Harris (1986).

A closed isostatic residual gravity high of 6–12 mGal (milligals) in amplitude connects the southern Pequop Mountains with Spruce Mountain to the southwest. This gravity high is flanked by lows of 20–25 mGal caused by low-density Cenozoic alluvial fill in the adjoining valleys. Steep gravity gradients on the eastern side of the range suggest the location of a high-angle range-front fault. There is insufficient gravity-station coverage on the western side of the wilderness study area to locate a fault, but the existence of one to the north is suggested by a steep gradient between Independence Valley and the northern Pequop Mountains (fig. 5). The thick dashed lines on figure 5 trace the maximum horizontal gradient. The maximum horizontal gradient of the gravity field occurs over steep boundaries between blocks of contrasting density (Cordell, 1979).

Two aeromagnetic surveys provide partial coverage of the study area: (1) a survey flown at a 12,000-ft constant barometric altitude with a north-south flight-line spacing of 5 mi (U.S. Geological Survey, 1978) and (2) a survey flown at 400 ft above ground with an east-west flight-line spacing of 3 mi as part of the National Uranium Resource Evaluation (NURE) program (Geodata International, 1979). The wilderness study area is crossed by four of the low-level east-west NURE flight lines.

A contour map constructed from the NURE profiles is shown as figure 6. An east-west-trending elongate (20 km (kilometers) by 8 km wide), low-amplitude (20–40 nanoteslas) magnetic low over the southern part of the wilderness study area suggests an area of relatively deep magnetic basement. A sharp magnetic high (width 1.5 km and amplitude 100 nanoteslas) is present in flight line 280 west of the study area. The anomaly correlates with a small area of Tertiary volcanic rocks mapped at the surface (Fraser and others, 1986).

Analysis of the aeromagnetic profiles by a method involving Hilbert transforms and Burg autocorrelation techniques (Phillips, 1979) yields the following estimates of depth to magnetic basement (the positions are labeled A, B, C, and D on figure 6): (1) flight line 340, position A, about 100 m (328 ft); (2) flight line 320, position B, about 300 m (984 ft); (3) flight line 300, position C, about 700 m (2,297 ft); (4) flight line 280, position D, more than 1,500 m (4,921 ft).

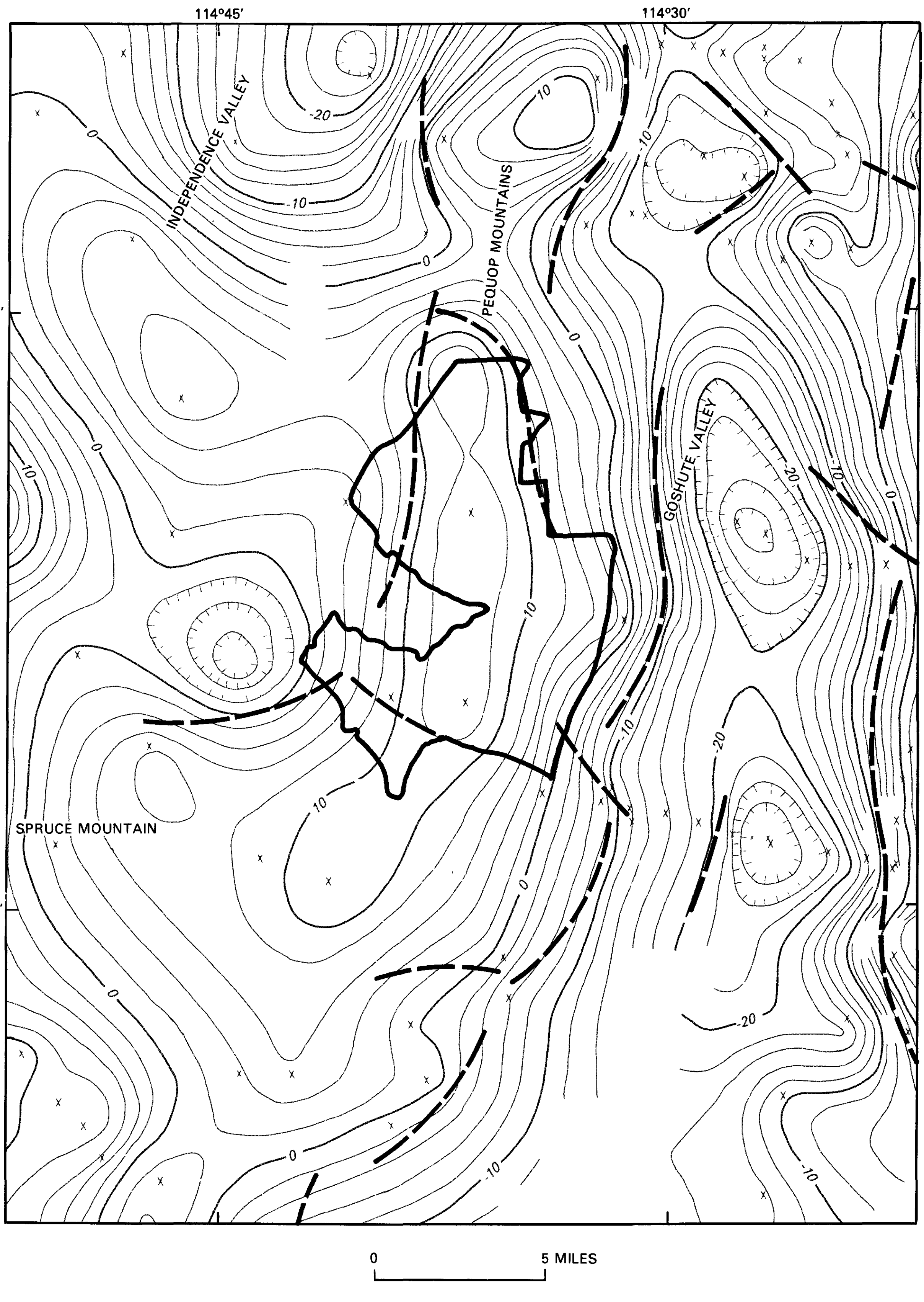
On the basis of aerial gamma-ray spectroscopy measured along the NURE profiles, we have determined that the wilderness study area has overall moderate radioactivity with values of 0.5–2.0 percent potassium, 2.5–3.5 ppm equivalent uranium, and 3–10 ppm equivalent thorium. There are no gamma-ray anomalies within the boundaries of the wilderness study area or in the immediate vicinity (J. S. Duval, U.S. Geological Survey, written commun., 1985).

Potential for Undiscovered Resources

Phosphate

The Plympton Formation is the lithic and approximate time equivalent of the Phosphoria Formation of southeastern Idaho and adjacent parts of Utah and Wyoming. Some beds of the Phosphoria Formation, especially in Idaho, are rich in phosphorus and have been an important commercial source of phosphate. Several beds of the Plympton Formation in the wilderness study area are lithically very similar to the phosphatic beds of the Phosphoria Formation, but those in parts of the Plympton Formation exposed by trenching tend to be much thinner and not as rich in phosphorus as the productive beds in the Phosphoria. Although part of the Plympton must be regarded as an identified resource because the grade and thickness of certain phosphorite beds are known, most of the area occupied by the formation has not been trenched, drilled,

[3]This section by R. W. Saltus, U.S. Geological Survey.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114°30′
40°45′
40°30′
INDEPENDENCE VALLEY
PEQUOP MOUNTAINS
GOSHUTE VALLEY
SPRUCE MOUNTAIN
0
5 MILES

or analyzed (pl. 1), and there is a distinct possibility that significant undiscovered resources are present in unexplored parts of the formation.

The mineral resource potential for discovery of phosphate deposits similar to, or better than, in grade and thickness, those already observed is regarded as moderate at a certainty level of B (pl. 1) but, on the basis of what is already known about the Plympton Formation in the Pequop Mountains and in other nearby ranges, such deposits are not considered likely to be large enough to qualify as a minable deposit (as defined by the U.S. Bureau of Mines and U.S. Geological Survey, 1982).

Certain factors adversely affect the prospect for commercial development of the phosphatic deposits in the Pequop Mountains: The beds dip steeply and therefore would have to be mined mostly underground, and the tonnage apparently available is far below the minimum requirements for a viable commercial deposit (U.S. Bureau of Mines and U.S. Geological Survey, 1982; Wood, 1985). Although it is close to a railroad, the wilderness study area is far from agricultural and industrial markets.

Gold, Silver, Lead, Zinc, and Copper

Geochemical indicators in two areas, one just north of Ninemile Canyon and another at the northern tip of the wilderness study area (pl. 1), suggest the possible presence of concealed metal deposits.

Anomalously high levels of silver, arsenic, antimony, lead, zinc, and many other metallic elements in heavy concentrates of stream sediments seem to be unusually concentrated in the area around Ninemile Canyon and in the drainage basins of the canyon just north of Ninemile Canyon and parallel to it (Gerlitz and others, 1986). Anomalously high concentrations of mercury in bedrock samples from this area were reported by Erickson and others (1966). Antimony, arsenic, and mercury are regarded as indicators of the presence of gold deposits. The exact source of these elements within the drainage basins is unknown, but the canyon just north of Ninemile Canyon is the locus of a major west-northwest-trending high-angle fault (pl. 1) whose presence is revealed by offset beds (Fraser and others, 1986). It seems likely that hydrothermal solutions rising along this fault are the source of the anomalous metal concentrations in the stream sediments and that any mineralized bedrock would occur along the fault or near it. Although the metallic content of heavy-mineral concentrates from stream-sediment samples from the area around this fault is somewhat above the average for the wilderness study area, it is nevertheless only a faint indicator of mineralization. No mineralized bedrock was observed in the drainage basin, and the area must be regarded as having, at best, a moderate mineral resource potential for gold, silver, lead, and zinc, at a certainty level of B (pl. 1).

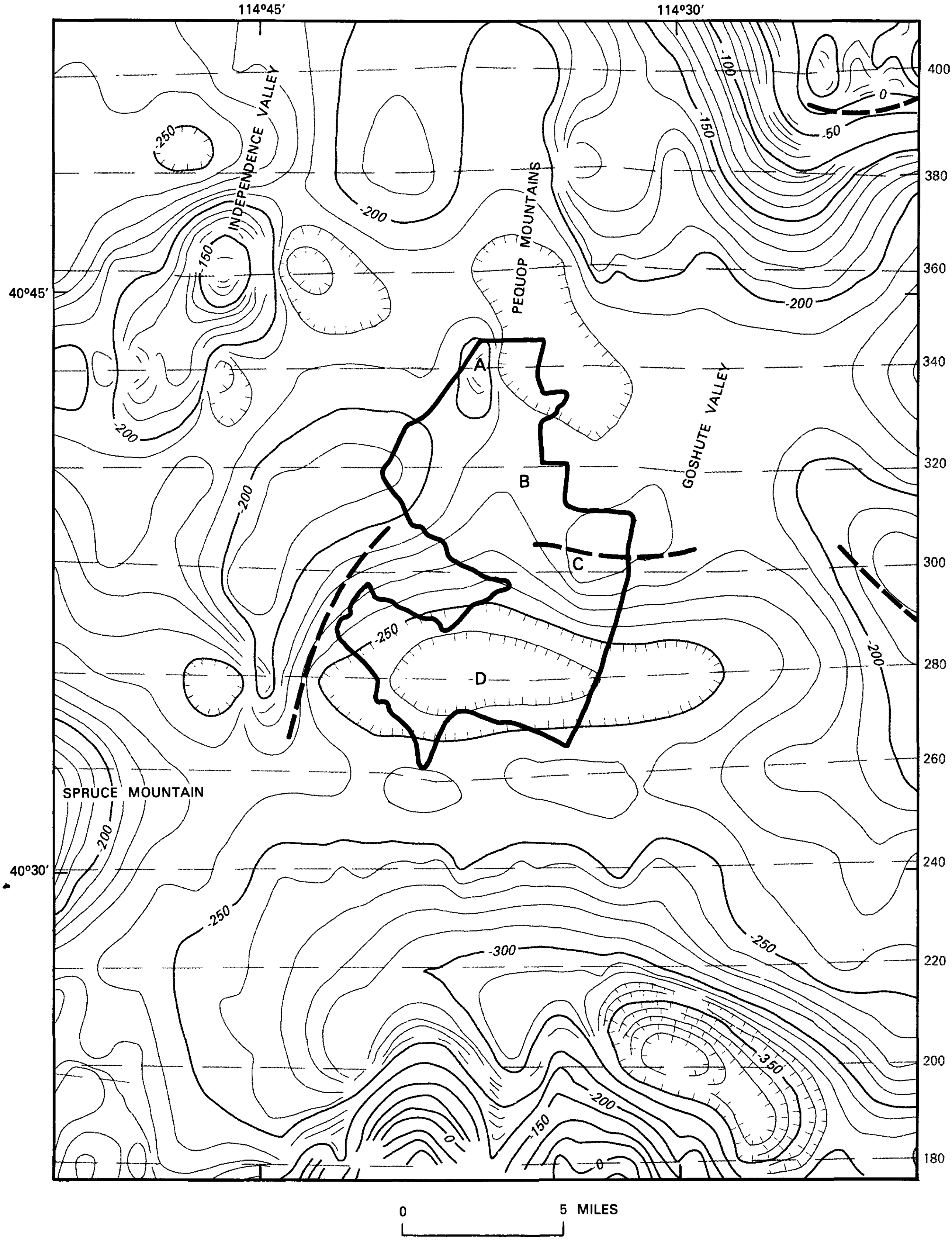
Figure 5 (facing page). Map showing isostatic residual gravity in the region of the South Pequop Wilderness Study Area. Contour interval, 2 milligals; hachured lines indicate area of closed gravity low; X, gravity-measurement location. Heavy dashed lines mark maximum horizontal gradients indicating nearly vertical density contrasts. Heavy solid line is approximate boundary of wilderness study area.

Field observation and geochemical anomalies in prospect pits at the northern tip of the South Pequop Wilderness Study Area indicate the same type of mineralization as that in the Spruce Mountain district 15 mi to the southwest (fig. 1). In the Spruce Mountain district much of the ore is in veins in faulted limestone (Smith, 1976). In the northern tip of the wilderness study area the metal-bearing minerals are similarly in veins in faulted limestone (Wood, 1985) (pl. 1). Both areas were notably mineralized with arsenic, antimony, zinc, barium, and manganese. In the Spruce Mountain district small bodies of coarse-grained granitic rock are closely associated with the ore deposits (Hope, 1972). No such intrusive rocks are known at the northern tip of the wilderness study area, but about 6 mi to the southeast is a small intrusive stock of coarse-grained granitic rock somewhat similar to the bodies in the Spruce Mountain district. Aeromagnetic data (fig. 6) can be interpreted to indicate a near-surface intrusion at the northern tip of the wilderness study area (fig. 6, position A). The northern tip of the wilderness study area and the Spruce Mountain district apparently are roughly similar in some respects but not in the intensity of mineralization.

Metals extracted from ores in the Spruce Mountain district are gold, silver, lead, zinc, and copper. Conceivably, the relatively weak mineralization at the northern tip of the wilderness study area represents the distal or surficial extremity of a significant deposit of these same metals. However, no ore minerals were seen, and the area is therefore regarded as having only a moderate resource potential for gold, silver, lead, zinc, and copper. This estimate is made with a level of certainty of B (pl. 1).

Oil and Gas

Extensive areas of Independence and Goshute Valleys flanking the Pequop Mountains are leased for oil and gas (pl. 1). Some leases extend to the lower slopes of the mountains, and, as of May 1984, they cover about 20 sq mi in the study area. Although dry exploratory oil and gas wells have been drilled in the valleys adjacent to the Pequop Mountains, no wells have been drilled in the study area. In May 1985 a seismic survey was extended from the valley into the study area, but data from that effort are not available.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PEQUOP MOUNTAINS
GOSHUTE VALLEY
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Although there may be some possibility of oil and gas discoveries in or beneath the post-Triassic strata of the valleys, it seems very unlikely that significant amounts of oil and gas exist within the boundaries of the study area. Post-Triassic strata are not extensive within the study area on the east side, and both geomorphic and geophysical data indicate that post-Triassic sediments in the western parts of the study area probably cover a high-angle fault zone. High-angle fault zones bordering the mountain ranges of Nevada have been active in the recent past and would therefore be likely to serve as avenues of escape for oil and gas rather than serving to create structural traps.

The Paleozoic and Triassic rocks of the study area are generally synclinal in structural form, a condition that discourages the accumulation of oil and gas in significant amounts. Although the data are scanty, temperatures attained by rocks in the southern Pequop Mountains are thought to be too high for the proper maturation of oil (Sandberg, 1983). The possibility that small-scale structural traps and stratigraphic traps in the Paleozoic-Triassic sequence might contain small amounts of oil and gas cannot be completely ruled out, but because thermal and structural conditions in the study area are not generally favorable for the formation and accumulation of petroleum, the study area is regarded as having a low energy resource potential for oil and gas, with a certainty level of C.

Limestone, Sand, and Gravel

Nearly the entire area of Paleozoic and Triassic rocks (units PMl, ₮Pl) shown on plate 1 is underlain by impure siliceous or argillaceous limestone and dolomite; the area must be regarded as having a low mineral resource potential for thick beds of high-purity limestone. This estimate is based on field observations and a small amount of analytical data and is therefore classed at a certainty level of C.

Figure 6 (facing page). Map showing residual total magnetic-field intensity in the region of the South Pequop Wilderness Study Area. Map constructed from National Uranium Resource Evaluation (NURE) aeromagnetic profiles by minimum curvature technique. Contour interval, 10 nanoteslas; hachured lines indicate area of closed magnetic low. Flight lines are indicated by the light dashed lines, numbered at right side of map for reference in text. Heavy dashed lines mark maximum horizontal gradient derived from pseudogravity map constructed from these data. Heavy solid line is approximate boundary of wilderness study area. Letters A–D mark locations discussed in text.

Table 1. Determination limits for spectrographic analysis and anomaly thresholds for elements detected in the nonmagnetic fraction of heavy-mineral-concentrate samples from the South Pequop Wilderness Study Area

[NA, not anomalous; ND, not detected; L, any detected quantity, including amounts below determination limit]

Element	Lower determination limit based on 5-mg sample	Anomaly threshold
	Percent	
Iron (Fe)	0.1	--
Magnesium (Mg)	.05	--
Calcium (Ca)	.1	--
Titanium (Ti)	.005	1.5
	Parts per million	
Silver (Ag)	1	L
Arsenic (As)	500	L
Gold (Au)	20	ND
Boron (B)	20	--
Barium (Ba)	50	10,000
Beryllium (Be)	2	--
Bismuth (Bi)	20	ND
Cadmium (Cd)	50	ND
Cobalt (Co)	10	--
Chromium (Cr)	20	700
Copper (Cu)	10	200
Lanthanum (La)	50	--
Manganese (Mn)	20	--
Molybdenum (Mo)	10	70
Niobium (Nb)	50	--
Nickel (Ni)	10	200
Lead (Pb)	20	100
Antimony (Sb)	200	L
Scandium (Sc)	10	--
Tin (Sn)	20	--
Strontium (Sr)	200	--
Thorium (Th)	200	ND
Vanadium (V)	20	--
Tungsten (W)	100	ND
Yttrium (Y)	20	--
Zinc (Zn)	500	L
Zirconium (Zr)	20	2,000

The area designated as Quaternary alluvium (Qal) on plate 1 is underlain by heterogeneous, poorly sorted sand and gravel and has a low mineral resource potential for deposits of monomineralic or well-sorted sand and gravel for specialized uses, with a certainty level of D.

RECOMMENDATIONS

Because the mineral resource potential of the study area is moderate for a number of commodities, but the level of certainty is B (geologic environment indicated and resource potential level indicated), the following additional investigations are recommended.

The Plympton Formation should be explored by trenching across the strike of the bedding in areas where chips of phosphatic material are found in the soil. The bedrock in the drainage basins of Ninemile Canyon and of the canyon just to the north of Ninemile Canyon should be thoroughly explored for mineralized bedrock. The northern tip of the wilderness study area should be further explored geochemically and drilled.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

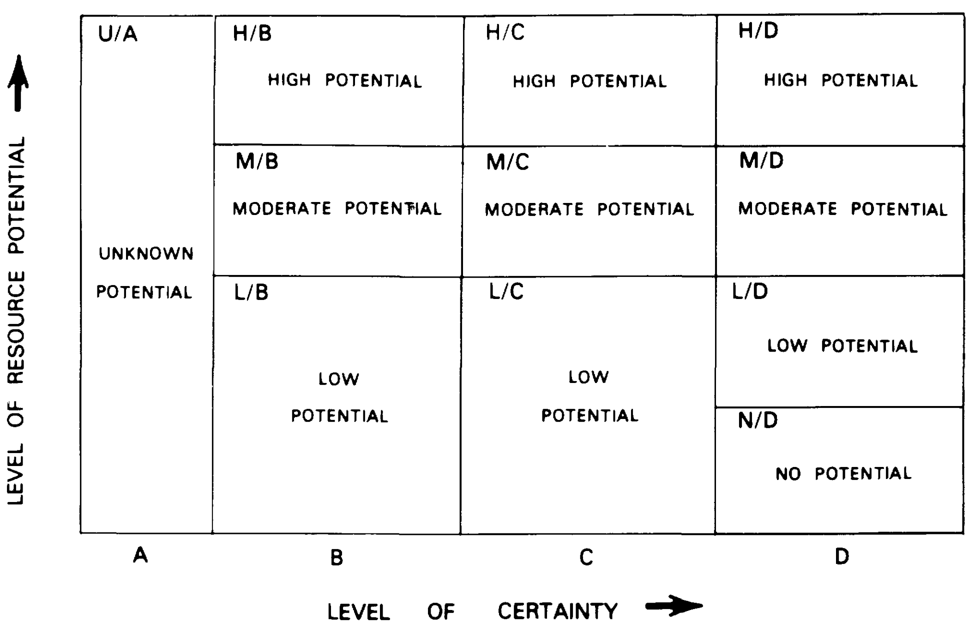
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

Abstracted with minor modifications from:

Taylor, R. B., and Steven, T. A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

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RESOURCE / RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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