Mineral Resources of the Antelope Wilderness Study Area, Nye County, Nevada

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
BUREAU OF MINES
BUREAU OF LAND MANAGEMENT

U.S. GEOLOGICAL SURVEY BULLETIN 1731–E

Chapter E

Mineral Resources of the Antelope Wilderness Study Area, Nye County, Nevada

By RICHARD F. HARDYMAN, FORREST G. POOLE,
FRANK J. KLEINHAMPL, ROBERT L. TURNER,
DONALD PLOUFF, and JOE S. DUVAL
U.S. Geological Survey

FREDRICK L. JOHNSON and DAVID A. BENJAMIN
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1731

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
CENTRAL NEVADA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1987

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Mineral resources of the Antelope Wilderness Study Area, Nye County, Nevada.

(U.S. Geological Survey bulletin ; 1731) (Mineral resources of wilderness study areas—Central Nevada ; ch. E)
Bibliography: p.
Supt. of Docs. no.: I 19.3:1731–E
1. Mines and mineral resources—Nevada—Antelope Wilderness Area.
2. Antelope Wilderness Area (Nev.) I. Hardyman, Richard F. II. Series. III. Series: Mineral resources of wilderness study areas—Central Nevada ; ch. E.
QE75.B9 no. 1731–E 557.3s 87–600242
[TN24.N3] [553'.09793'34]

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 Antelope (NV–060–231/241) Wilderness Study Area, Nye County, Nevada.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

Mineral Resources of the Antelope Wilderness Study Area, Nye County, Nevada

By Richard F. Hardyman, Forrest G. Poole, Frank J. Kleinhampl, Robert L. Turner, Donald Plouff, *and* Joe S. Duval
U.S. Geological Survey

Fredrick L. Johnson *and* David A. Benjamin
U.S. Bureau of Mines

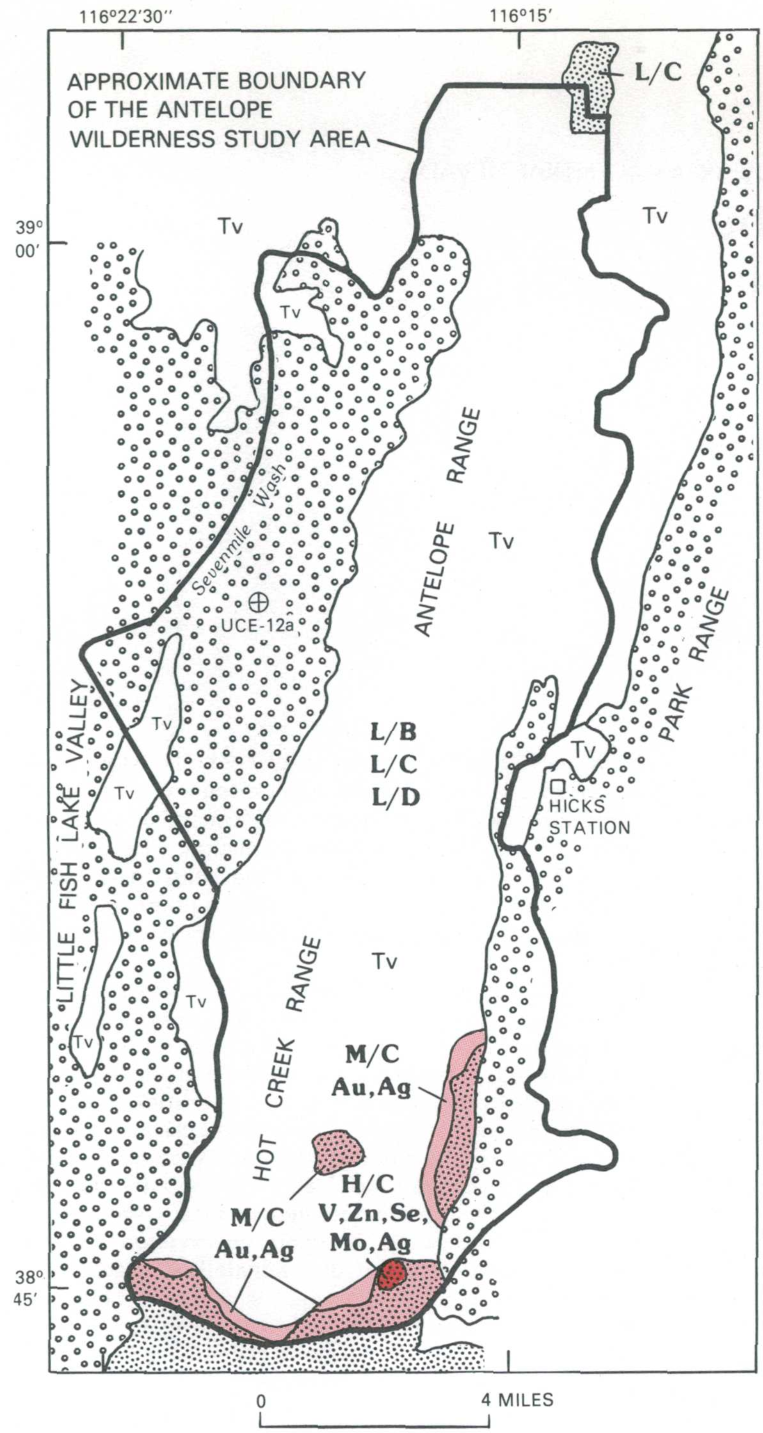
SUMMARY

At the request of the U.S. Bureau of Land Management, 83,100 acres of the Antelope Wilderness Study Area (NV–060–231/241) was studied. In this report the studied area is called the "wilderness study area," or simply the "study area." No identified mineral or energy resources occur within the study area. The southern part of the area has moderate mineral resource potential for undiscovered gold and silver, and the Woodruff Formation in the southern part of the area has high resource potential for undiscovered vanadium, zinc, selenium, molybdenum, and silver (fig. 1). This assessment is based on field geochemical studies in 1984 and 1985 by the U.S. Bureau of Mines and field geochemical studies and geologic mapping by the U.S. Geological Survey in 1984 and 1985. The remainder of the study area has low resource potential for undiscovered gold, silver, lead, zinc, manganese, tin, and molybdenum. The study area also has low resource potential for undiscovered oil and gas resources.

The Antelope Wilderness Study Area is about midway between Tonopah and Eureka, Nev., in the northern Hot Creek Range and southern Antelope Range of central Nevada. It is accessible by unimproved dirt roads extending 20 mi (miles) north from U.S. Highway 6 and 40 mi south from U.S. Highway 50 (fig. 2). Most of the study area consists of rugged mountainous terrain having approximately 2,600 ft (feet) of relief. The mountain range is a block tilted gently to the east and bounded on both sides by normal faults that dip steeply to moderately west and have major displacements. Most of the study area is underlain by a thick sequence of Tertiary volcanic rocks that predominantly consist of silicic ash-flow tuff, the Windous Butte Formation. Paleozoic and lower Mesozoic (see geologic time chart in appendix) marine sediments occur along the southern margin of the study area, and lower Paleozoic rocks are exposed in the northeast corner.

The areas of exposed Paleozoic-Mesozoic rocks along the southern margin of the study area have moderate mineral resource potential for gold and silver in sediment-hosted, disseminated, epithermal (low-temperature) gold-silver deposits (fig. 1). These rocks consist of folded and thrust-faulted, fine-grained clastic sediments and limestone and dolomite that locally have been brecciated and hydrothermally[1] altered. The alteration (locally, strong silicification) and geochemical associations of these rocks indicate a favorable environment for such deposits. Exploration for disseminated gold deposits in the same geologic environment is currently being conducted just south of the study area. The remainder of the study area has low resource potential for epithermal gold and silver vein deposits in the Tertiary volcanic rocks. The Cenozoic sedimentary basins adjacent to the fault-bounded mountain block have moderate potential for petroleum resources; the study area itself has low potential for petroleum resources.

[1]As used in this report, "hydrothermal" refers to those geologic processes of mineralization and rock alteration that involve the interaction of rock with hot aqueous solutions.



EXPLANATION

H/C Geologic terrane having high mineral resource potential for vanadium (V), zinc (Zn), selenium (Se), molybdenum (Mo), and silver (Ag), with certainty level C

M/C Geologic terrane having moderate mineral resource potential for gold (Au) and silver (Ag), with certainty level C

L/B Geologic terrane having low resource potential for oil and gas, with certainty level B—Applies to entire study area

L/C Geologic terrane having low mineral resource potential for gold (Au) and silver (Ag), with certainty level C, in Paleozoic rocks exposed in the northeast corner of the study area, and for silver (Ag), lead (Pb), zinc (Zn), and manganese (Mn), with certainty level C, in areas underlain by Tertiary volcanic rocks

L/D Geologic terrane having low mineral resource potential for gold (Au), tin (Sn), and molybdenum (Mo), with certainty level D, in areas underlain by Tertiary volcanic rocks

UCE-12a ⊕ Exploratory drill hole

Geologic contact

Quaternary alluvium

Tv Tertiary volcanic rocks

Mesozoic-Paleozoic sedimentary rocks

Levels of certainty

B Data indicate geologic environment and suggest level of resource potential

C Data indicate geologic environment and resource potential, but do not establish activity of resource-forming processes

D Data clearly define geologic environment and level of resource potential and indicate activity of resource-forming processes in all or part of the area

Figure 1. Summary map showing mineral resource potential of the Antelope Wilderness Study Area, Nye County, Nev.

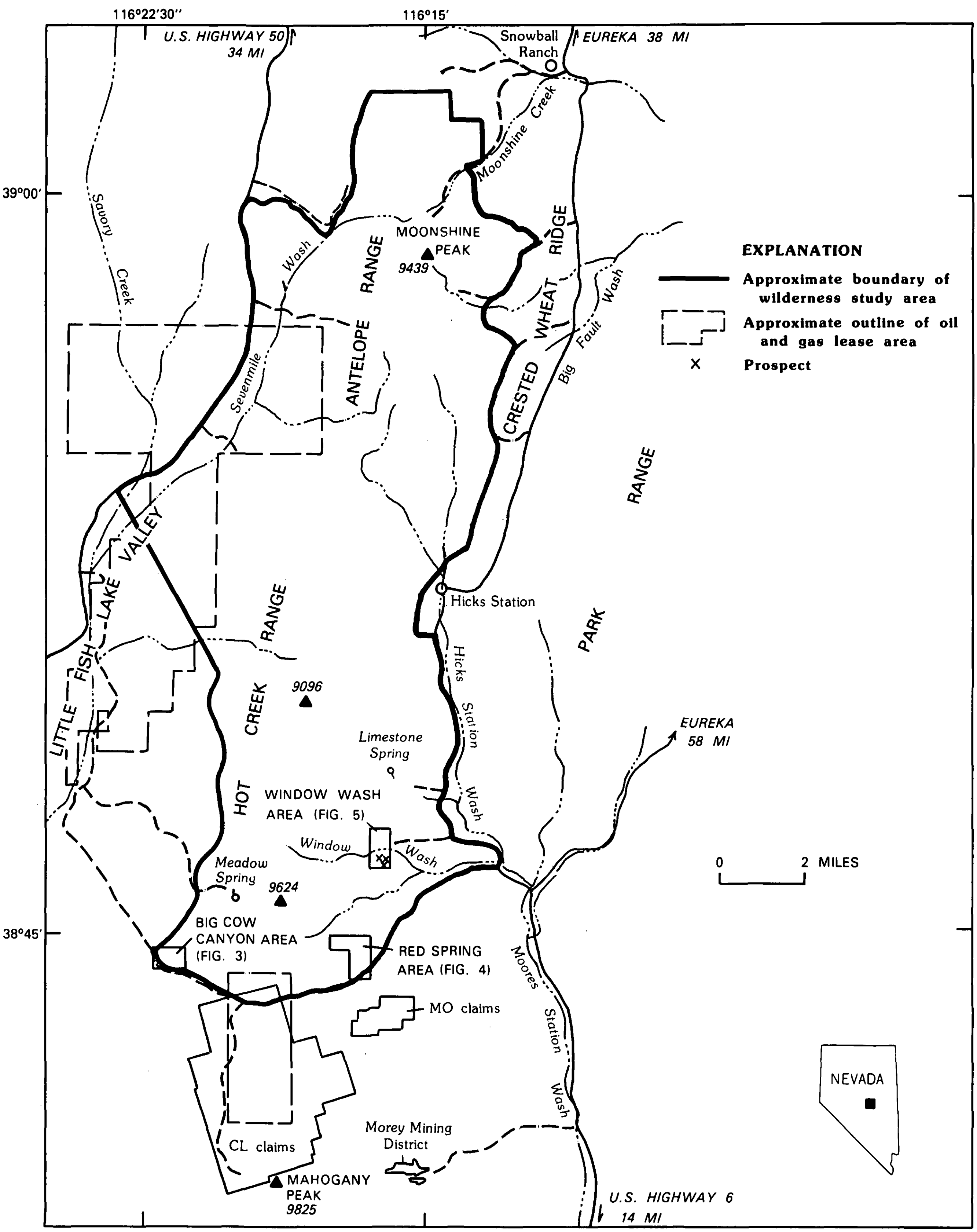


Figure 2. Index map showing prospects, active mining claims, and oil and gas lease area in and adjacent to the Antelope Wilderness Study Area, Nye County, Nev.

INTRODUCTION

The Antelope Wilderness Study Area (NV–060–231/241) encompasses 87,400 acres in the northern Hot Creek Range and southern Antelope Range of central Nevada and lies about midway between Tonopah and Eureka, Nev. An 83,100-acre portion was investigated at the request of the U.S. Bureau of Land Management (BLM) (fig. 2). In this report the studied area is referred to as the "wilderness study area" or simply the "study area."

Except for gentle slopes of the adjacent valley margins of Little Fish Lake Valley on the west and narrow valleys of Hicks Station Wash and Big Fault Wash on the east, the bulk of the wilderness study area consists of rugged mountainous terrain. Elevations of the mountains range from 9,439 ft above sea level at Moonshine Peak near the north end of the area to 8,624 ft for an unnamed peak at the south end. The lowest elevations in the study area are approximately 6,400 ft in Hicks Station Wash on the east and 6,800 ft in Little Fish Lake Valley on the west, which is the highest valley in the Great Basin of the Western United States. Vegetation within this semi-arid terrain consists of grasses, sagebrush, and mountain mahogany, and juniper and limber pine at higher elevations.

Access to the area is by episodically maintained dirt roads through Little Fish Lake Valley and Hicks Station–Big Fault Wash valleys and from an unimproved dirt road, in places requiring use of four-wheel-drive vehicles, following Luther Waddles Wash–Big Cow Canyon along the southern margin of the area. Access within the area is limited to a few jeep trails extending from the main roads in the valleys on either side of the mountain range to the mouths of some of the major intermittent drainages issuing from the mountains or for a short distance up these drainages (fig. 2).

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 U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (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 of this report. 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 also shown in the appendix of this report.

Investigations by the U.S. Bureau of Mines

The Antelope Wilderness Study Area was examined by the U.S. Bureau of Mines in 1984 and 1985. Prior to field investigation, all available information pertinent to the geology, mining, and mineral exploration in the area, including BLM and county mining claim records, was reviewed. Claimants were contacted, when possible, for permission to examine properties and publish the results.

Field studies included investigation of all claims, prospects, and mineralized areas (there are no mines) within the study area. In addition, ground and air reconnaissance of the area was conducted for areas of obvious rock alteration. A total of 370 samples of three types were collected throughout the area: (1) chip samples, a series of continuous rock chips taken in a line across a mineralized zone or outcrop; (2) random chip samples, an unsystematic series of rock chips taken from an exposure of apparently homogeneous rock; and (3) grab samples, rock pieces taken unsystematically from a mine dump, prospect pit, ore stockpile, outcrop, or float (loose rock lying on the ground). All samples were crushed, pulverized, mixed and split, and checked for radioactive and fluorescent minerals. Each sample was analyzed for gold and silver content by fire-assay and inductively coupled plasma (ICP) methods. The detection limit by these methods is 0.007 ppm (parts per million) gold and 0.3 ppm silver. A total of 229 samples were also analyzed for arsenic and mercury. The arsenic content was determined by ICP/atomic-absorption methods. One of several special methods, determined by rock lithology and inferred mercury concentration, was used for mercury analyses. The detection limit for arsenic and mercury by these methods is 2.0 ppm.

Complete sample descriptions and analytical results are available for public inspection at the U.S. Bureau of Mines Western Field Operations Center, E. 360 3rd Avenue, Spokane, WA 99202.

Investigations by the U.S. Geological Survey

The Antelope Wilderness Study Area covers parts of the Fish Springs NE, Fish Springs SE, and Morey Peak 7.5-minute topographic quadrangles, and the Horse Heaven Mountain, Cockalorum Wash, and Pritchards Station 15-minute quadrangles, Nevada. Published geologic maps of the Cockalorum Wash (Hose, 1983; 1:31,680 scale) and Pritchards Station (Dixon and others, 1972; scale 1:48,000) quadrangles cover small parts of the north and northeast sides of the study area. Information from these published maps was field checked, locally modified on the basis of more detailed mapping, and compiled for this study. In addition, information from published regional geophysical maps (U.S. Geological Survey, 1968, aeromagnetic; and Healey and others, 1981, gravity) were utilized in the mineral resource potential assessment. Published reconnaissance geologic maps and topical geologic studies in areas adjacent to or incorporating parts of the wilderness study area include Kleinhampl and Ziony (1967, 1984); Lenzer (1972); Potter (1976); Ekren and others (1974); and U.S. Geological Survey (1970, p. A39–A40). All of these reports were reviewed for this study.

The U.S. Geological Survey carried out field investigations in the study area during the summers of 1984 and 1985. The work included field checking existing geologic maps, new mapping at 1:24,000 of the Fish Springs NE and Fish Springs SE quadrangles and parts of the Horse Heaven and Morey Peak quadrangles, and geochemical sampling. A total of 122 stream-sediment samples were collected in the study area along with 52 rock-chip samples. The rock samples and heavy-mineral concentrates panned from the stream-sediment samples were analyzed for trace-element signatures that may be indicative of mineralized systems. These data, together with the new geologic mapping, were reviewed in light of permissive and favorable mineral-deposit models acceptable for the area, based on the geologic environment, present mineral exploration just south of the study area, and past mining activity in the region.

Acknowledgments.—We thank Mr. Bob Bennett, Long Lac Mineral Exploration, Inc., for guided tours of the mineralized area actively being explored by that company just south of the wilderness study area. Appreciation is also extended to pilot Jack Fulton, El Aero Services, Inc., Elko, Nev., for his expert flying ability. We especially thank local residents Arshal Lee of Hicks Station and Richard and Anna McKay of Snowball Ranch for their generous hospitality and much appreciated logistical help.

APPRAISAL OF IDENTIFIED RESOURCES

By Fredrick L. Johnson and David A. Benjamin
U.S. Bureau of Mines

Mining and Mineral Exploration History

No mineral resources were delineated during investigation of the Antelope Wilderness Study Area. Only a few claims have been located in the area and only four workings were found. There has been, however, considerable exploration and mining activity south of the study area.

The Morey mining district (fig. 2), about 5 mi southeast of the wilderness study area, is the nearest place having recorded mineral production. The first discovery there was in 1865 and the district was organized in 1866. Silver, with lesser amounts of gold and lead, was produced sporadically until about 1966 from a series of parallel, east-striking quartz veins in Tertiary volcanic rocks. The district was most active from 1866 to 1891 and from 1937 to 1947; total production is valued at less than $1 million (Kleinhampl and Ziony, 1984).

Exploration activity in the Antelope Wilderness Study Area has been low. A search of Nye County and BLM mining records revealed that no historical claims and only part of a block of active mining claims were located in the study area. Many of the location descriptions for historical claims are very vague, however, and some could have been located in the study area. Old claim corners and prospect pits were found during reconnaissance of the southern part of the area. Oil and gas leases extend into the western and southern part of the study area (fig. 2), and are evaluated later in this report.

The active claim block (CL claims, fig. 2) held by Long Lac Mineral Exploration, Inc., Reno, Nev., is mostly south of the study area, but about 14 claims extend into it. Long Lac is exploring the area for disseminated, sediment-hosted epithermal gold deposits. Their exploration program has included detailed geologic mapping, geochemical sampling, and drilling.

Prospects and Mineralized Areas

The only prospect workings in the wilderness study area are four small pits dug in altered Paleozoic sedimentary rocks. The area containing these prospects and two other areas in Paleozoic rocks within the southern part of the study area show evidence of having been claimed. These areas also have higher concentrations of precious (gold, silver) and pathfinder (arsenic and mercury, for example) elements relative to other samples taken in the Paleozoic rocks and appear to contain alteration and host-rock structures generally associated with disseminated, epithermal (sediment-hosted type), precious-metal deposits[2]. Analytical results of samples collected in these three areas are discussed below.

[2]Whether hosted by sedimentary or volcanic rocks, disseminated, epithermal, precious-metal (gold, silver) deposits are probably related to fossil hot-springs-type hydrothermal systems. Characteristics and terminology of these ore deposit models are reviewed in U.S. Geological Survey Bulletin 1646 (E. W. Tooker, editor, 1985).

Big Cow Canyon Area

This area is underlain by Paleozoic carbonate rocks, Mesozoic fine-grained clastic rocks, and minor amounts of Tertiary volcanic rocks (fig. 3). Hydrothermal alteration has affected many of the rocks. Some outcrops as large as several hundred feet across are moderately brecciated and silicified, locally to jasperoid, where the original rock texture is not visible in hand specimen. Parts of the brecciated and silicified outcrops are heavily stained with limonite and hematite.

Fifty-five rock samples were collected in the Big Cow Canyon area (fig. 3). Of this total, 14 contained gold above the detection limit, 8 contained silver above the detection limit, 11 contained anomalous arsenic (greater than 50 ppm (parts per million)), and none contained mercury. The highest concentrations found in the 55 samples were 0.2 ppm gold, 1.8 ppm silver, and 1,890 ppm arsenic.

Red Spring Area

The Red Spring area is underlain by Paleozoic carbonate and siliceous clastic rocks and minor amounts of Mesozoic fine-grained clastic rocks. Tertiary ash-flow tuff overlaps the pre-Tertiary rocks along the north edge of the area, and most of the pre-Tertiary rocks have been subjected to hydrothermal alteration and brecciation, the brecciation being chiefly the result of folding and thrust faulting of the pre-Tertiary rocks. Brecciation and silicification is most intense in area A (fig. 4) and less intense, with a marked decrease in the amount of silicification, in area B.

Forty-six rock samples were collected in the Red Spring area (fig. 4). Of the 24 samples taken in area A, 6 contained gold above the detection limit, 12 contained silver above the detection limit, 7 contained anomalous arsenic (greater than 50 ppm), and none contained mercury. The highest concentrations found in the 46 samples were 0.4 ppm gold, 5.8 ppm silver, and 7,700 ppm arsenic.

Of the 16 samples collected in area B, 8 contained gold above the detection limit, 5 contained silver above the detection limit, only 1 contained anomalous arsenic, and none contained mercury. The highest concentrations found in the 16 samples were 0.4 ppm gold, 0.8 ppm silver, and 650 ppm arsenic.

Window Wash Area

"Window Wash" is an informal name used in this report for the unnamed drainage between Limestone Spring and Luther Waddles Wash. The Window Wash area (fig. 2) is underlain predominately by moderately deformed, folded and thrust-faulted lower and middle Paleozoic carbonate and quartzitic rocks that are faulted along the range front against Tertiary and Mesozoic(?) clastic rocks on the east and Tertiary volcaniclastic sedimentary rocks on the west (fig. 5). Brecciation, hydrothermal silicification, and limonitic alteration are locally intense within this area, especially near the faults. Four small prospect pits were found in this area. Three were dug in hematitic and limonitic gossan; the fourth and southernmost pit was dug in brecciated quartzite heavily stained with hematite.

Forty-three rock samples were collected in the Window Wash area (fig. 5). Of these, 5 samples contained gold above the detection limit, 12 contained silver above the detection limit, 6 contained anomalous concentrations (greater than 50 ppm) of arsenic, and 8 contained mercury. The highest concentrations found in the 43 samples were 0.02 ppm gold, 5.3 ppm silver, 390 ppm arsenic, and 28 ppm mercury.

Nonmetallic Resources

Extensive sand and gravel and stone occurrences in the study area are suitable for many construction purposes. However, transportation cost to current markets, a major part of total production cost for these high-bulk, low-unit-value commodities, would far exceed their value. Adequate material is available closer to major markets in this region of Nevada.

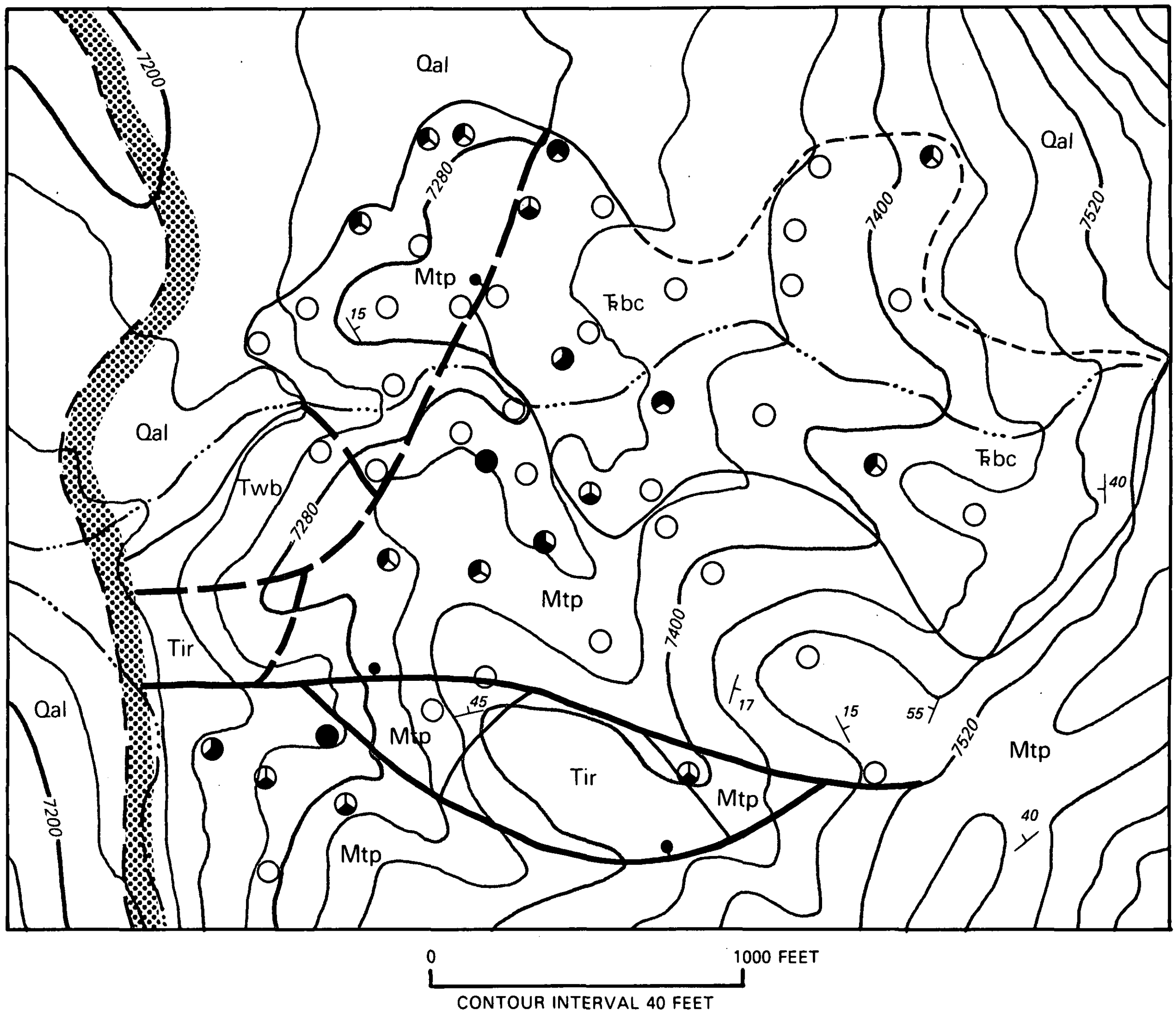
ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Richard F. Hardyman, Forrest G. Poole, Frank J. Kleinhampl, Robert L. Turner, Donald Plouff, and Joe Duval
U.S. Geological Survey

Geology

Regional Setting

The Antelope Wilderness Study Area is within the northernmost part of the Hot Creek Range and the southern part of the Antelope Range, which form a north-northeast-trending mountain block bordering Little Fish Lake Valley on the east. At the latitude of the study area, Little Fish Lake Valley forms an apical graben in a regional anticlinal structure within the central Great Basin that is defined by the general tilt of the mountain blocks on either side of the valley (Ekren and others, 1974). For the most part the Tertiary volcanic rocks forming the mountain block in the Antelope Wilderness Study Area dip gently to moderately to the east and form the eastern limb of the regional anticlinal structure.



EXPLANATION

○ **Sample locality**—Analytical values for gold, silver, and (or) arsenic shown where determined

Gold (0.007 ppm or more)

Silver (0.3 ppm or more)

Arsenic (anomalous concentrations, 50 ppm or more)

Qal **Alluvium and colluvium (Quaternary)**

Tir **Intrusive rhyolite (Tertiary)**

Twb **Windous Butte Formation (Tertiary)**

TRbc **Siltstone of Big Cow Canyon (Lower Triassic)**

Mtp **Tripon Pass Limestone (Lower Mississippian)**

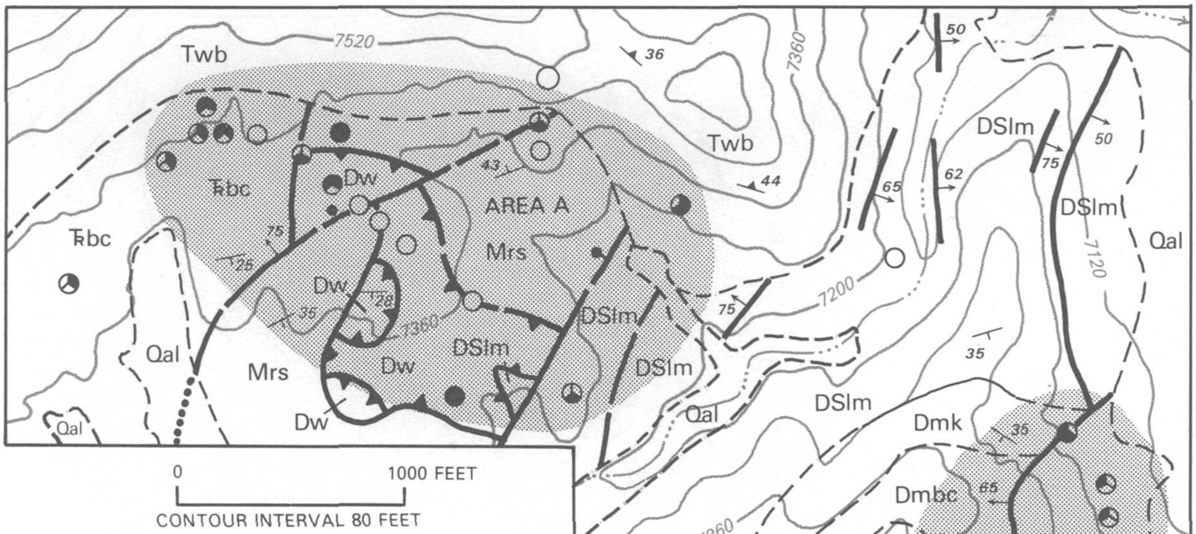
Contact—Dashed where approximately located

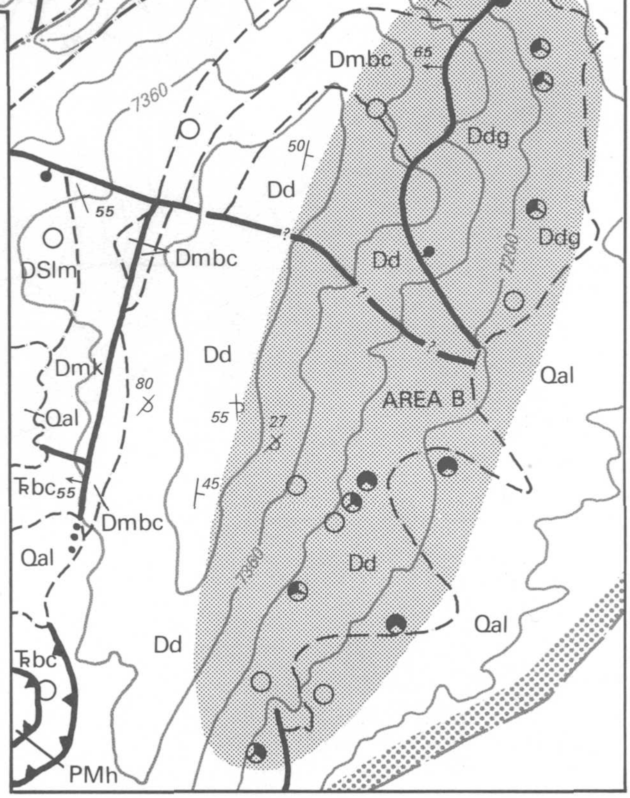
Fault—Dashed where approximately located. Bar and ball on downthrown side

30 **Strike and dip of bedding**

Approximate boundary of wilderness study area

Figure 3. Geologic map showing sample sites and gold, silver, and arsenic values in the Big Cow Canyon area, Antelope Wilderness Study Area, Nye County, Nev. See figure 2 for location of area. Geology mapped by F. G. Poole, 1985. Base from U.S. Geological Survey, 1:24,000, Morey Peak, 1967.





EXPLANATION

○ **Sample locality**—Analytical values for gold, silver, and (or) arsenic shown where determined

Gold (0.007 ppm or more)

Silver (0.3 ppm or more)

Arsenic (anomalous concentrations, 50 ppm or more)

Qal **Alluvium and colluvium (Quaternary)**

Twb **Windous Butte Formation (Tertiary)**

Ꞧbc **Siltstone of Big Cow Canyon (Lower Triassic)**

PMh **Havallah assemblage (Permian, Pennsylvanian, and Mississippian)**—Chert, argillite, and conglomerate

Mrs **Limestone of Red Spring (Upper Mississippian)**

Dw **Woodruff Formation (Upper Devonian)**—Chert and argillite

Ddg **Devils Gate Limestone (Upper Devonian)**

Dd **Denay Limestone (Middle Devonian)**

McColley Canyon Formation (Lower Devonian)

Dmk **Kobeh Member**—Dolostone

Dmbc **Bartine and Coils Creek Members**—Limestone and dolostone

DSlm **Lone Mountain Dolostone (Lower Devonian and Upper Silurian)**

Contact—Dashed where approximately located, dotted where concealed

Approximate boundary of wilderness study area

75 **Fault**—Showing dip of fault plane. Bar and ball on downthrown side. Dashed where approximately located, queried where uncertain

Thrust fault—Sawteeth on upper plate

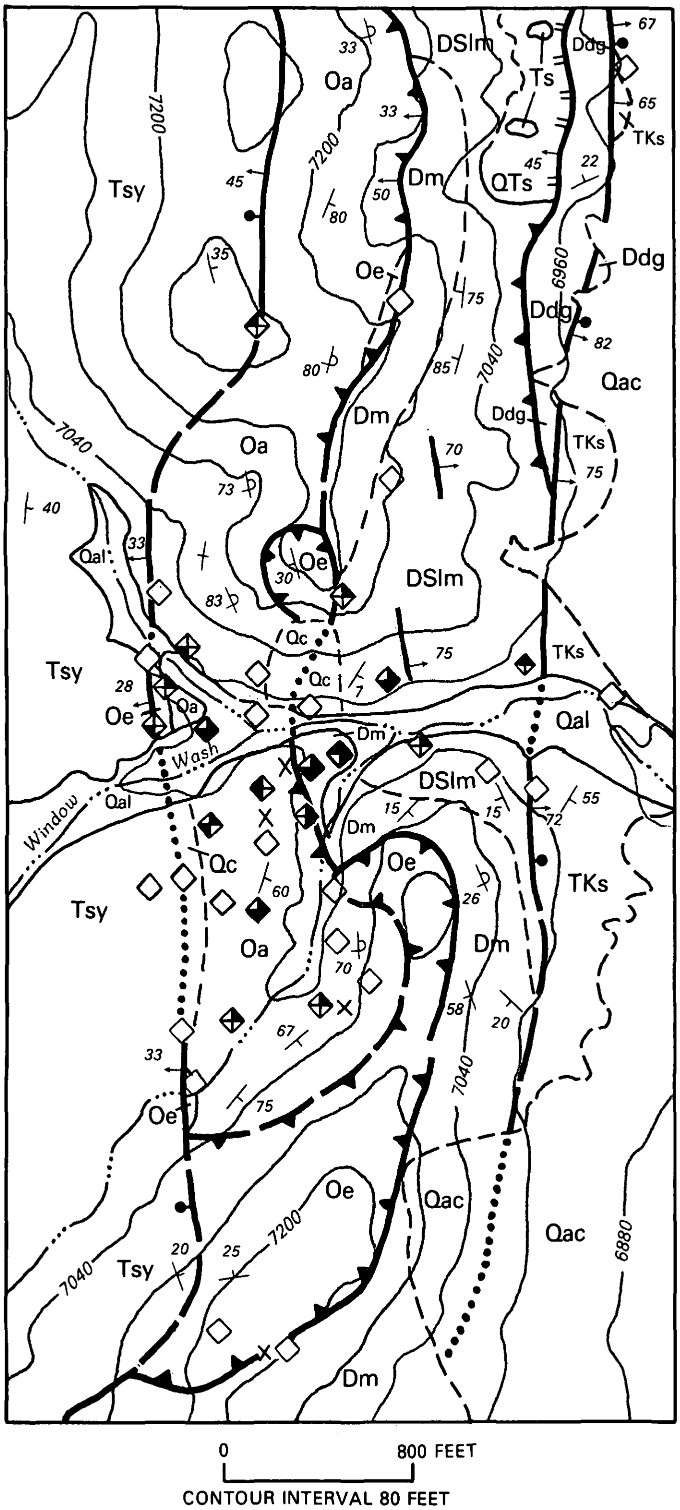
30 **Strike and dip of compaction foliation in ash-flow tuff**

Strike and dip of bedding

32 **Inclined**

67 **Overturned**

Figure 4. Geologic map showing sample sites and gold, silver, and arsenic values in the Red Spring area, Antelope Wilderness Study Area, Nye County, Nev. Areas A and B are discussed in text. See figure 2 for location of area. Geology mapped by R. F. Hardyman and F. G. Poole, 1985. Base from U.S. Geological Survey, 1:24,000, Morey Peak, 1967.



EXPLANATION

◇ **Sample locality**—Analytical values for gold, silver, arsenic, and (or) mercury shown where determined

- **Gold (0.007 ppm or more)**
- **Silver (0.3 ppm or more)**
- **Arsenic (anomalous concentrations, 50 ppm or more)**
- **Mercury (2 ppm or more)**

X **Prospect pit**

Qal — **Alluvium in active stream channels (Quaternary)**

Qc — **Colluvium (Quaternary)**

Qac — **Older alluvium and colluvium, undivided (Quaternary)**

QTs — **Unconsolidated sediments, undivided (Quaternary and (or) Tertiary)**

Tsy — **Younger volcaniclastic sedimentary rocks of Window Wash (Miocene)**

Ts — **Sediments, undivided (Tertiary)**

TKs — **Sedimentary rocks (Tertiary and (or) Cretaceous)**

Ddg — **Devils Gate Limestone (Upper Devonian)**

Dm — **McColley Canyon Formation (Lower Devonian)**

DSlm — **Lone Mountain Dolostone (Lower Devonian and Upper Silurian)**—Dolostone and limestone

Oe — **Eureka Quartzite (Middle Ordovician)**

Oa — **Antelope Valley Limestone (Middle and Lower Ordovician)**

Contact—Dashed where approximately located

Strike and dip of bedding

- 30 **Inclined**
- **Vertical**
- 67 **Overturned**

60 **Fault**—Showing dip of fault plane. Dashed where approximately located, dotted where concealed. Bar and ball on downthrown side

45 **Fault**—Showing dip of fault plane. Hachures on side of fault against which younger unconsolidated sediments were deposited

Thrust fault—Dashed where approximately located. Sawteeth on upper plate

Figure 5. Geologic map showing sample sites and gold, silver, arsenic, and mercury values in the Window Wash area, Antelope Wilderness Study Area, Nye County, Nev. See figure 2 for location of area. Geology mapped by R. F. Hardyman and F. G. Poole, 1985. Base from U.S. Geological Survey, 1:24,000, Fish Springs SE, 1968.

Except for exposures of pre-Tertiary rocks limited to the south, southeast, and extreme northeast margins of the study area, the mountain range is underlain by Tertiary volcanic rocks, the bulk of which are pyroclastic rocks of the Windous Butte Formation (pl. 1). This thick ash-flow-tuff sheet apparently filled a broad paleotopographic low between a highland composed of older Tertiary andesitic lavas on the north and a basement highland to the south that is composed of complexly folded and thrust-faulted Paleozoic and lower Mesozoic rocks. This pre-Tertiary basement high separates the volcanic rocks of the study area from the inferred northern margin of the Hot Creek Valley–Morey–Williams Ridge cauldron complex from which the Windous Butte Formation is believed to have erupted (U.S. Geological Survey, 1970, p. A39–A40). The north margin of this cauldron complex is approximately 4 mi south of the southern boundary of the Antelope Wilderness Study Area.

Rock Units

Lower Paleozoic to lower Mesozoic sedimentary rocks crop out in a narrow band along the south and southeast margins of the study area and are exposed in a small erosional window in the Window Wash drainage basin in the southern part of the area (pl. 1). Ordovician limestone and quartzite also crop out in the extreme northeast corner of the study area at the south margin of another erosional window of Paleozoic rocks just west of Snowball Ranch (pl. 1).

The pre-Tertiary rocks in the southern part of the study area are contiguous with the main mass of pre-Tertiary basement rocks farther south (from Mahogany Peak north; see fig. 2), separating the volcanic terrane of the Antelope Wilderness Study Area from the volcanic terrane within the Hot Creek Valley–Morey–Williams Ridge cauldron complex. The pre-Tertiary sedimentary rocks in the area range in age from Early Ordovician to Early Triassic. For the most part, these rocks are Devonian to Ordovician carbonate shelf-facies rocks, but include minor amounts of quartzite and calcareous shale. These rocks were deformed during a Late Devonian-Early Mississippian (post-Antler) and Late Permian-Early Triassic (pre-Sonoma) orogenic deformation that locally thrust siliceous western basinal-facies rocks (Devonian Woodruff Formation) over eastern-facies carbonate rocks of equivalent age (see, for example, fig. 4). Permian to Mississippian western-facies rocks (Havallah assemblage) were also thrust eastward over the predominately eastern facies Devonian to Ordovician carbonate strata and Lower Triassic siltstones during the Triassic (Sonoma) orogeny or the Jurassic-Cretaceous (Sevier) orogeny. For the most part, these periods of deformation produced the structural and stratigraphic complexities now preserved in the pre-Tertiary rocks and locally prepared them for invasion by hydrothermal solutions, which in this part of the Great Basin are generally considered to be Tertiary in age. The Paleozoic and Mesozoic sedimentary rocks within the study area are locally strongly brecciated and hydrothermally altered. The carbonate rocks are so strongly silicified locally that they have been converted to jasperoid.

The Paleozoic rocks in the Luther Waddles Wash–Big Cow Canyon area (pl. 1) are locally unconformably overlain by Lower Triassic fine-grained clastic rocks (siltstone of Big Cow Canyon) that were deposited on a faulted and eroded pre-Triassic terrain that exposed strata as old as the Upper Silurian-Lower Devonian Lone Mountain Dolostone.

Tertiary volcanic rocks within the study area are dominated by ash-flow tuffs of Oligocene and Miocene age. The Windous Butte Formation is as much as 2,000 ft thick and constitutes the bulk of the mountain range in the study area. Crested Wheat Ridge, along the eastern margin of the study area and north of Hicks Station (fig. 2, pl. 1), is composed of several relatively thin ash-flow-tuff units younger than the Windous Butte Formation. These younger tuffs represent outflow facies of volcanic eruptions from unknown sources. The younger tuffs also occur in isolated outcrops depositionally overlying or faulted against the Windous Butte Formation along the southeast flank of the mountain range, south of Hicks Station, and in the southern part of the area. Stratigraphic relationships of these younger ash flows in the area indicate considerable erosion occurred between periods of volcanic activity that deposited the younger tuffs on the Windous Butte Formation.

In the northern part of the study area, the Windous Butte Formation unconformably overlies a thick sequence of andesitic lavas that apparently formed topographic highlands prior to deposition of the tuff. In the south, as in the Window Wash drainage basin and locally along the south margin of the study area, the Windous Butte overlaps Paleozoic-Mesozoic sedimentary rocks. The overlap locally appears to be a normal depositional contact, but in other places the contact relations are not clear. Tertiary dacite and rhyolite intrusive bodies obscure much of the contact between the Windous Butte and pre-Tertiary strata in the area from Red Spring to Big Cow Canyon. These intrusive rocks, younger than Windous Butte, define a narrow, east-trending belt along the south margin of the study area and are not found elsewhere in the study area. The restricted occurrence of these intrusive rocks suggest they were emplaced along a structural flaw coincident with the east-trending Tulle Creek–Pritchards Station lineament proposed by Ekren and others (1974).

The Tertiary volcanic rocks, which constitute the exposed bedrock in most of the wilderness study area, show little indication of having been affected by hydrothermal alteration. Deuteric alteration (in-place alteration during cooling) has locally affected flows within the older andesite lava sequence in the northern part of the area. Tectonically brecciated ash-flow tuffs are locally silicified in the Limestone Spring–Window Wash area (pl. 1). They are rarely brecciated and generally remain unaltered elsewhere to the north and south where they are faulted along the range front. Even where the Windous Butte Formation overlaps hydrothermally altered Paleozoic and Mesozoic rocks along the south margin of the study area, the volcanic rocks, however structurally complicated, are not obviously altered. The nearest intensely hydrothermally altered Tertiary volcanic rocks lie just south of the wilderness study area (John and others, 1987).

Structural Geology

The Antelope Wilderness Study Area encompasses a generally east tilted mountain block that is bounded on the west by the graben of Little Fish Lake Valley, a major intermontane basin, and on the east by the lesser strike valleys of Big Fault Wash and Hicks Station Wash. The narrow strike valleys separate the mountain block of the study area from the Park Range to the east (fig. 2), another east-tilted mountain block composed predominantly of Windous Butte Formation (Brooks and others, 1987). The eastward tilt of the Antelope block is shown by the generally east dip of the Windous Butte and younger tuffs and the presence of the younger tuffs in east-dipping cuestas, like Crested Wheat Ridge, along the east margin of the mountain block. In the southern and southwestern part of the study area, and generally west of the range crest, the Windous Butte Formation dips moderately to the west. This local west dip of tuff units persists to the south along the west flank of the central Hot Creek Range (John and others, 1987). The change in attitude of the Windous Butte from generally east dipping in the north and central parts of the study area to west dipping in the southern and southwestern part of the area is not fully understood. This may be explained in part by differential uplift of the mountain block concurrent with formation of the Little Fish Lake Valley graben. Complexities in attitudes of the Windous Butte Formation along its southernmost exposures, where it overlaps the Paleozoic and Mesozoic rocks farther south, may be partly the result of mild deformation during emplacement of the younger dacite and rhyolite intrusive bodies (pl. 1).

Faults within the study area can be divided into two types: (1) moderate- and high-angle faults that cut both Tertiary volcanic and volcaniclastic rocks and pre-Tertiary sedimentary rocks, and (2) thrust faults restricted to the pre-Tertiary sedimentary sequence. A complex series of thrust faults involving the Paleozoic and Mesozoic sedimentary rocks was identified through detailed stratigraphic work in pre-Tertiary rocks during this study. These thrust faults, with few exceptions, now dip gently to moderately to the west and displace older over younger Paleozoic rocks and, locally, upper Paleozoic rocks over Mesozoic rocks (pl. 1). Specific thrust relationships exposed in the southern part of the study area consist of Ordovician Antelope Valley Limestone emplaced over Silurian and Devonian Lone Mountain Dolostone, Middle Ordovician Eureka Quartzite emplaced over Lower Devonian McColley Canyon Formation (carbonates), Upper Devonian Woodruff Formation (siltstone) over Upper Mississippian limestone, and Permian to Mississippian Havallah assemblage (clastic rocks) over Lower Triassic siltstone (figs. 4 and 5, pl. 1). Both upper and lower plate rocks within the thrust sheets are commonly tightly folded and locally intensely brecciated and silicified. Nearby, just south of the wilderness study area, similar but hydrothermally altered pre-Tertiary strata are also folded and thrust faulted and are currently (1985–86) being explored for disseminated gold deposits.

Moderate- to high-angle normal faults and locally reverse faults are the dominant structures in the study area. Tertiary ash-flow tuff and volcaniclastic sedimentary units younger than the Windous Butte Formation on the east flank of the mountain range have been extended and rotated along moderately dipping normal faults that have been cut by younger high-angle, range-bounding faults. Numerous high-angle faults also cut Tertiary volcanic units (principally the Windous Butte Formation) within the mountain block (pl. 1). These high-angle faults trend predominantly north to northeast, and a few trend east. The general lack of stratigraphic markers within the extensive Windous Butte Formation makes recognition of faults within this unit difficult, and it is suspected that more faults, not recognized during this study, probably exist within the uplifted mountain block. Several lineaments within the Windous Butte that are visible on aerial photographs probably represent faults, but most of them may be major fractures across which there has been no displacement. Local moderate- or high-angle faults juxtapose Tertiary volcanic rocks against pre-Tertiary sedimentary rocks, such as in the Limestone Spring drainage and Window Wash areas (pl. 1), where a north-trending, moderately west dipping, normal fault has placed post-Windous Butte ash-flow tuffs and a volcaniclastic unit against structurally complex Paleozoic carbonate rocks. A volcanic breccia in the hanging wall of this fault is interpreted to be a tectonic breccia (pl. 1). Rocks in the breccia and ash-flow tuff units in the hanging wall of this fault near the breccia unit are locally strongly silicified. Carbonate rocks in the footwall of this fault are also locally brecciated and limonitically altered. In Window Wash this low- to moderate-angle fault, along with thrust faults in the Paleozoic rocks of the footwall and Tertiary volcanic rocks in the hanging wall, are not laterally offset across the wash. These relationships do not support the presence of an east-west strike-slip fault in the wash as interpreted in reconnaissance by Johnson and Benjamin (1986).

Normal faults in Tertiary volcanic rocks within the study area are not mineralized. Even where rocks along these faults are brecciated and oxidized, zones of extensive alteration were not observed, indicating that the faults probably have not had large amounts of hydrothermal fluids migrate along them. Quartz veins or other gangue mineral veins along such faults are uncommon. Moderate- to high-angle normal faults within pre-Tertiary rocks in the southern part of the area, however, are locally associated with areas of brecciated and silicified carbonate rocks. These faults may have provided passageways for the solutions that altered the adjacent rocks.

Although no ore deposits are known to exist in the study area, the complexly faulted and locally intensely brecciated pre-Tertiary rocks in the southern part provide the most favorable environment for ore deposition. Mineralizing solutions, perhaps migrating along fault structures, have introduced silica into these rocks (converting them to jasperoid) and locally small amounts of gold, silver, arsenic, and mercury.

Geochemistry

Analytical Methods

A reconnaissance geochemical sampling program by the U.S. Geological Survey was conducted in the Antelope Wilderness Study Area during the spring of 1984. A total of 122 heavy-mineral concentrates from stream sediments and 12 rock samples were collected from 123 sites during the reconnaissance study. An additional 40 rock samples were collected during the geologic mapping conducted in 1985.

Geochemical analyses of stream-sediment samples reflect the chemistry of rocks underlying the drainage basin upstream from each sample site. The sites selected for sampling are in drainages along the mountain front and far enough up these drainages to eliminate any dilution from adjacent valley fill, which may contain material from other areas and would not be representative of rocks from the drainage basins above the sample sites. Where necessary, tributaries of the main drainage channels were sampled in order to attain a sample density of approximately one sample per square mile of drainage basin area.

Stream sediment was collected from active stream channels for a distance of as much as 30 ft around each sample site. Each sample was sieved with a 2-millimeter (10-mesh) screen to remove the coarse material, and the less-than-2-millimeter fraction was panned until most of the quartz, feldspar, organic material, and other material of clay size was removed. The remaining heavy-mineral concentrate was subsequently purified of any remaining quartz and feldspar by a settling process utilizing the heavy liquid bromoform (specific gravity 2.8) and then processed through an isodynamic separator to obtain a nonmagnetic fraction (primarily any nonmagnetic ore minerals and accessory minerals such as zircon, sphene, apatite, allanite) for geochemical analysis. The nonmagnetic fraction is analyzed because it is a concentrate of nonmagnetic ore minerals that generally can be interpreted as being related to mineralizing processes or to accompanying alteration. The rock samples were crushed and then pulverized to less than 0.15 millimeters prior to analysis.

The nonmagnetic fractions of panned concentrates of stream-sediment samples and the rock samples were analyzed for 31 elements by means of a six-step, semiquantitative emission-spectrographic method (Grimes and Marranzino, 1968). In addition, some rock samples were analyzed for arsenic, bismuth, antimony, and zinc, and some rock samples were analyzed for gold and mercury by means of a modified analytical technique of Viets (1978). Several rock samples were also analyzed for various heavy trace elements by energy-dispersive X-ray fluorescence spectroscopy. Element concentration levels judged to be anomalous were determined by comparison with crustal abundance data for rocks analogous to those exposed in the study area.

Results of Study

The geochemical evaluation is based on analyses of concentrates of stream-sediment samples from 123 sites (Day and others, 1986) and of rocks from 52 sites sampled by the U.S. Geological Survey and of rocks from about 250 sites sampled by the USBM (for availability of results, see introductory section of this report). The geochemical data are interpreted in the framework of geochemical studies conducted by the U.S. Geological Survey in the surrounding Tonopah 1°×2° quadrangle (Siems and others, 1986), including the Morey mining district and adjacent areas (Saunders and others, 1986; Nash and others, 1986). The geochemistry of the study area is thus interpreted in a regional context by comparison with the geochemical signatures of areas containing the same or very similar rock units and of areas with known mineral deposits or mining activity. In this evaluation, sites characterized by anomalous concentrations of multiple elements, especially those associations of elements that are recognized in known ore deposits in the region or that are otherwise consistent with ore-deposit models, are considered significant for mineral resource assessment.

Rock samples collected from Paleozoic and lower Mesozoic units exposed along the southern and southeastern margin of the study area are enriched in gold, silver, arsenic, antimony, barium, and, locally, mercury. A few samples are also enriched in zinc, and molybdenum content is anomalous in samples from three isolated localities. Concentrates from stream-sediment sample sites in areas of exposed Paleozoic and Mesozoic rocks, or downstream from them, contain ubiquitously anomalous concentrations of barium, and a few of these samples contain anomalous concentrations of strontium. The anomalous barium content in the stream-sediment concentrates undoubtedly reflects the presence of crystalline barite observed in these rocks (for example, in limestone beds in the siltstone of Big Cow Canyon, unit ₮bc, pl. 1).

Analyses of rock samples collected from Tertiary volcanic units in the study area show no enrichment in precious (silver, gold) or base (lead, zinc, copper, molybdenum) metals. Concentrates of stream-sediment samples from drainages assumed to have been eroding only the volcanic terrane, however, show scattered enrichments in such single elements as tin, bismuth, or barium. Only three concentrate samples contained anomalous amounts of tin and bismuth and two contained tin and barium. One sample from the northwest flank of the Antelope Range, where andesite lava dominates the bedrock, contained anomalous concentrations of strontium (10,000 ppm) and lead (100 ppm). With minor exceptions, the samples containing anomalous concentrations of tin or bismuth coincide with areas where ash-flow tuff units younger than the Windous Butte Formation are exposed. The above geochemical anomalies appear to be inherent in the volcanic units exposed in the study area and compare with similar anomalies noted from essentially unaltered ash-flow-tuff terranes exposed elsewhere in the Tonopah $1° \times 2°$ quadrangle (Siems and others, 1986). Enrichments of these elements are often related to non-ore-forming processes in magma chambers that produce silicic pyroclastic rocks (Hildreth, 1979). These geochemical anomalies are generally scattered throughout the volcanic terrane and are apparently not related to specific mineralized structures or areas of hydrothermal alteration; therefore, we do not consider them significant for purposes of mineral resource assessment.

Geophysics

Methods

Geophysical studies consisted of examination and interpretation of data from aeroradiometric, gravity, and aeromagnetic surveys.

Radioelement concentrations of potassium, equivalent uranium, and equivalent thorium were estimated by examining composite-color maps of gamma-ray spectrometric data (J. S. Duval, U.S. Geological Survey, unpub. data, 1985). The maps were prepared at a scale of 1:1,000,000 from aeroradiometric data acquired in regional surveys contracted by the U.S. Department of Energy as part of the National Uranium Resource Evaluation Program. The surveys were flown at altitudes ranging from about 400 to 800 ft above the ground (Geodata International, Inc., 1979). One north-south and six east-west flightlines spaced at intervals of about 3 mi traversed the area. The following estimates of radioelement concentrations were based on criteria discussed by Duval (1983). The study area has moderate radioactivity: values of 2–3 percent potassium, 2.5–4.0 ppm equivalent uranium, and 12–16 ppm equivalent thorium. These concentrations are normal for intermediate to silicic volcanic rocks. Ratios of these elements to one another in the context of the regional radioelement concentration levels shown on the gamma-ray spectroscopy maps, however, suggest a broad thorium anomaly encompassing the northern part of the area and the northern part of the Park Range to the east. No geologic or geochemical evidence was uncovered to explain this anomaly. We are inclined to attribute this thorium anomaly to lithologic variations in thorium content and not to any hydrothermal mineralizing process.

Results of Study

The gravity data coverage consists of about 30 gravity stations on hillcrests in the Antelope and Hot Creek Ranges and about 60 stations near roads outside the study area (Healey and others, 1981; Snyder and Healey, 1983; see fig. 6). Values of the Bouguer gravity anomaly are moderately higher near the crests of the ranges compared to values at stations along the east and west edges of the study area. A relatively steep gravity gradient that approaches 8 mGal/mi (milligals per mile) mostly reflects fault-controlled thickening of tuffaceous sediments between the northern part of the west flank of the Antelope Range and Sevenmile Wash. A southward increase of nearly 10 mGal between Limestone Spring and Meadow Spring generally reflects a southward thinning of Cenozoic volcanic rocks over the pre-Tertiary basement. At the scale of the survey, there are no apparent correlations between gravity anomalies and known occurrences of hydrothermally altered or mineralized rocks within the study area.

An aeromagnetic survey of the region was flown at an altitude of about 1,000 ft above mean ground level with east-west flightlines spaced at intervals of about 1 mi (U.S. Geological Survey, 1968; see fig. 7). The irregular pattern of high-intensity anomalies on a regional aeromagnetic map reflects large contrasts in magnetization of rocks in the study area. Most of the magnetic anomalies in the northern part of the study area are elongate north-south and are correlated with topography. Magnetic highs tend to occur over hilltops and ridges of volcanic rocks, and magnetic lows occur over valleys and saddles. A 500-nT (nanoteslas, unit of measure of magnetic intensity), 2- by 3-mi magnetic high over Sevenmile Wash in the northwest corner of the study area reflects a shallowly buried wedge of lavas and tuffs of intermediate composition, which are exposed in hills farther to the northwest.

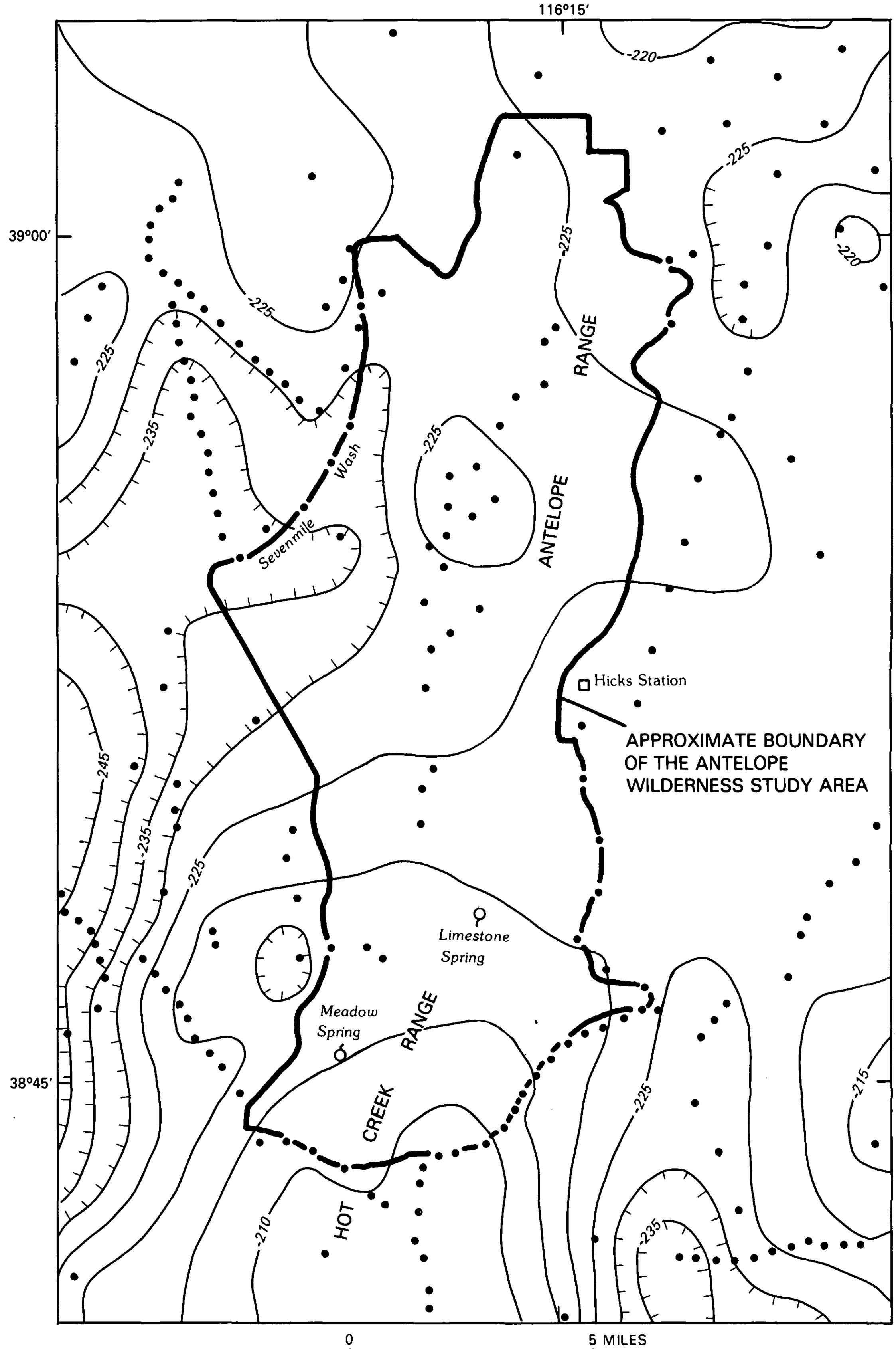


Figure 6. Bouguer gravity map of the Antelope Wilderness Study Area and vicinity, Nye County, Nev. Contour interval 5 milligals; hachured contours indicate area of closed gravity low; dot, gravity station.

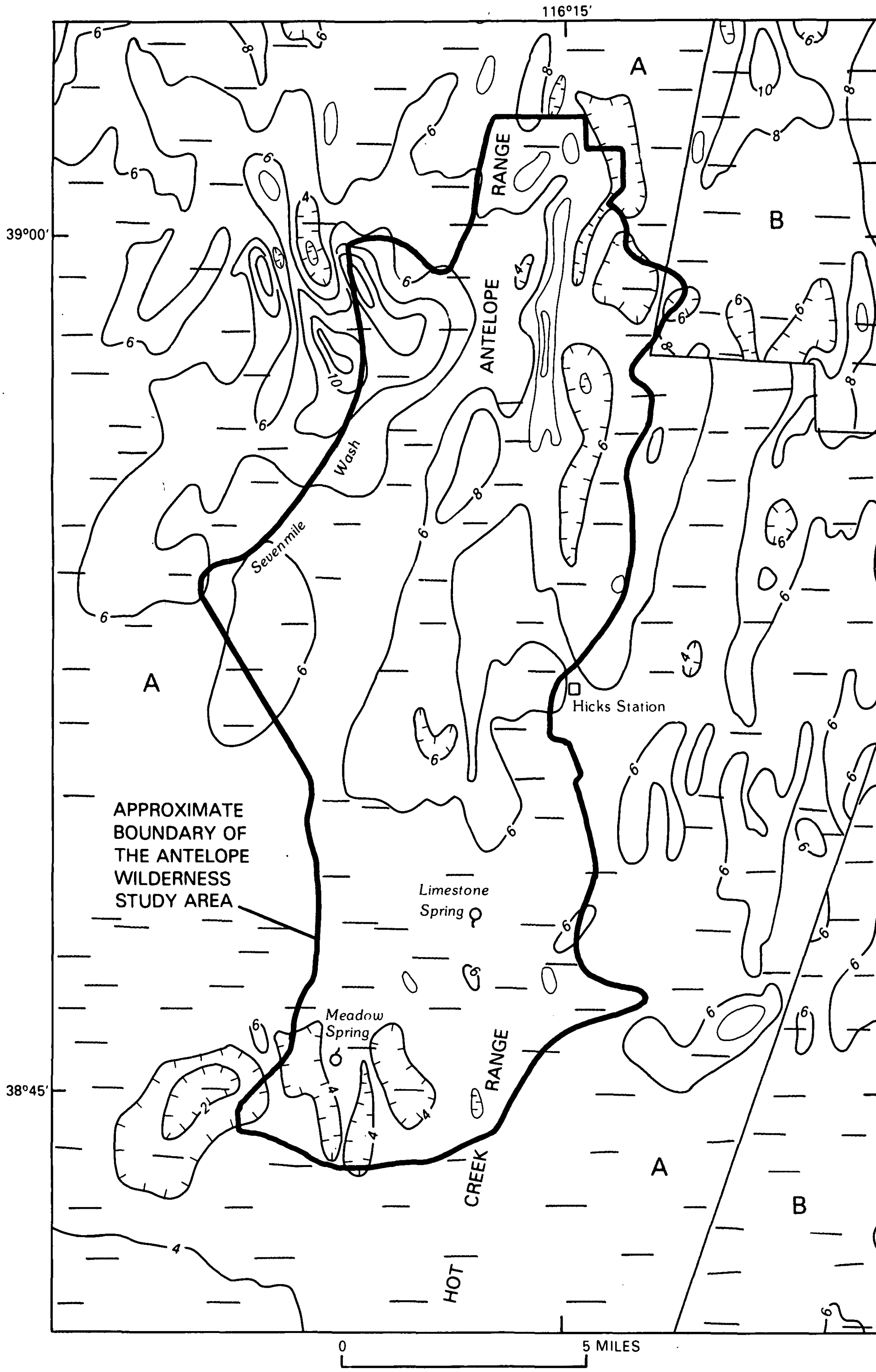


Figure 7. Aeromagnetic map of the Antelope Wilderness Study Area and vicinity, Nye County, Nev., showing total intensity of the magnetic field of the Earth relative to arbitrary datum. Contour interval 200 nanoteslas; hachured contour indicates closed area of lower magnetic intensity. Light dashed lines indicate flight paths, showing number, location, and spacing of data. A, area flown at approximately 1,000 ft above ground level; B, area flown at approximately 500 ft above ground level.

Similar rocks concealed beneath surficial sediments may be the source of a 100-nT, 2- by 4-mi magnetic high centered over Sevenmile Wash about 6 mi to the south-southwest of the 500-nT high. A conspicuous, north-northeast-trending magnetic low, which has a width of about 1 mi and a length of about 12 mi, is located between Sevenmile Wash and the west flank of the Antelope Range. The magnetic low apparently reflects rocks of low magnetization beneath a prominent fault zone along the west flank of the Antelope Range.

Intensities of magnetic anomalies near the latitude of Limestone Spring are small, due to low magnetization of near-surface rocks. It is not known if the low magnetization reflects pervasive rock alteration or inherently low magnetization of the underlying rocks. Farther to the south, intense magnetic lows reflect bodies of reversely magnetized rhyolite exposed on hillcrests or concealed at shallow depth beneath the surface. At the scale of the survey, there are no apparent correlations between aeromagnetic anomalies and known occurrences of hydrothermally altered or mineralized rocks within the study area.

Mineral and Energy Resource Potential

Geologic and geochemical studies indicate the possibility of gold-silver deposits in several areas of exposed Paleozoic-Mesozoic rocks in the southern part of the study area.

Metal Deposits in Paleozoic-Mesozoic Sedimentary Rocks

A sediment-hosted, disseminated gold deposit model is most applicable to these rocks and the local geologic environment. These rocks and associated structures are continuous south of the study area where favorable areas (the claim blocks indicated on fig. 2) are currently being explored for sediment-hosted, disseminated gold deposits.

This type of gold deposit (see reviews in Tooker, 1985) commonly occurs in hydrothermally altered zones in thin-bedded siltstones, calcareous shale, and limestone that have been favorably prepared by faulting and brecciation. Most disseminated gold deposits probably formed from shallow (epithermal), low-temperature, silica-rich hydrothermal solutions that are comparable in part to those associated with hot-spring systems. Alteration common to these deposits consists of strong silicification, formation of jasperoid, argillization, carbonization, and later oxidation. Associated geochemical signatures include anomalous concentrations of gold, silver, mercury, arsenic, antimony, and locally of thallium, fluorine, and tungsten.

At least three localities (fig. 2) within the area of exposed Paleozoic-Mesozoic sedimentary rocks in the study area display geologic and geochemical characteristics similar to those associated with sediment-hosted, disseminated gold deposits. These areas (Big Cow Canyon area, fig. 3; Red Spring area, fig. 4; Window Wash area, fig. 5) contain fine-grained clastic and carbonate rocks that are folded and faulted, locally brecciated or crackled, and hydrothermally altered, with areas of strong silicification (silica stockworks and local jasperoid) and limonite and hematite staining. Rocks in these areas contain anomalous concentrations of gold, silver, arsenic, and locally mercury, antimony, and zinc. Geologic and geochemical data indicate that the above three areas have moderate resource potential (certainty level C) for gold and silver (pl. 1). Although not systematically sampled, areas of exposed Paleozoic-Mesozoic rocks adjacent to the above localities contain local hydrothermally altered zones, silica stockworks, jasperoid, iron staining, and brecciated zones and are included in the area of moderate potential for gold and silver resources. These other areas include the erosional window of Paleozoic rocks at the head of Window Wash and the ridge of Paleozoic rocks extending north and south along the range front from the prospected area near the mouth of Window Wash (fig. 5). Silicified volcanic breccia and adjacent tuff outcrops faulted against Paleozoic carbonate rocks near the mouth of the Limestone Spring drainage (pl. 1) are also included in the area of moderate resource potential although the origin of the silicification here is uncertain.

The exposures of Paleozoic limestone and minor amounts of quartzite at the extreme northeast corner of the study area are essentially unaltered and lack the structures found in the mineralized rocks at the south end of the study area. Stream-sediment samples from this area show no anomalous concentrations of metals except barium. This area of exposed Paleozoic rocks is considered to have a low potential (certainty level C) for gold and silver deposits.

The Devonian Woodruff Formation (siltstone interbedded with minor sandstone and chert) contains anomalous vanadium, zinc, selenium, molybdenum, and silver at the Bisoni-McKay property (not shown), about 3 mi northeast of the northern boundary of the study area (Desborough and others, 1987), and in North Sixmile Canyon (not shown), about 2 mi south of the southern boundary (Poole and Claypool, 1984). The Woodruff Formation is exposed at only one locality (east of Red Spring) in the study area. It has a high mineral resource potential (certainty level C) for low-temperature vanadium, zinc, selenium, molybdenum, and silver occurrences. These metals occur as trace elements in sulfide grains, such as pyrite and sphalerite, or as trace elements fixed in organic materials that were incorporated as sedimentary particles during deposition of this unit.

Metal Deposits in Tertiary Volcanic Rocks

Viable models for possible mineral deposits in the Tertiary volcanic rocks of the study area that are consistent with the geologic setting and past mining activity in the region include epithermal vein, porphyry, or volcanic-hosted disseminated occurrences. The most applicable model for potential mineral deposits in the Tertiary volcanic rocks is an epithermal vein model comparable to the vein-type silver, gold, and lead deposits in the Morey district southeast of the study area.

The ash-flow tuffs within the study area display only the effects of normal devitrification of the glassy matrix component of these rocks and locally the effects of deuteric vapor-phase crystallization. No areas of pervasive alteration, pyrite mineralization, or concentrated quartz veining were observed in the Tertiary rocks of the study area. Panned concentrates and limited rock analytic data for samples from the volcanic terrane indicate no unusual anomalous concentrations. Scattered samples enriched in tin and (or) bismuth, as mentioned previously, are not interpreted to be related to areas of hydrothermally altered, mineralized rock, but rather to be inherent in the rocks and the volcanic processes that produced them. The lack of significant hydrothermal alteration, quartz veining, and indicative multi-element geochemical anomalies and the lack of prospects in the volcanic rocks indicate a low potential with a certainty level of C for silver, lead, zinc, and manganese resources of the Morey vein-type deposit in the volcanic rocks of the study area. The above criteria, together with the lack of other geologic features (favorable host rocks or structural preparation) common to porphyry tin or molybdenum deposits or volcanic-hosted, disseminated gold deposits, indicate the volcanic terrane of the study area also has low potential (certainty level D) for deposits of gold, tin, and molybdenum.

Petroleum Resources

Conodonts in several marine limestone beds of Paleozoic and early Mesozoic age in the northern Hot Creek Range have a color-alteration index of 1 indicating a low thermal history, less than 60 °C, since deposition (Epstein and others, 1977). In addition, many limestone beds contain oil-stained sparry calcite, and solid bitumen occurs in some fractures, voids, and fossil cavities. These petroliferous occurrences in outcropping limestone indicate that some oil and possibly gas was generated from active source rocks in the area and that thermal flux has not been high enough to destroy the hydrocarbons. Principal likely source-rock units in the region are the Devonian Woodruff Formation and the Mississippian Chainman Shale (Poole and Claypool, 1984). Petroleum generation would be possible in the rocks underlying the valleys adjacent to the Antelope Wilderness Study Area if these organic-rich shales were heated to 100 °C or higher. Rock temperatures exceeding 100 °C could be reached below a depth of 8,000 ft or near Tertiary intrusive centers. Petroleum-filled traps may occur in basinal rocks beneath Quaternary and Tertiary valley fill. Known oil fields in Nevada are located within Neogene-Quaternary basins that formed during Neogene basin-and-range block faulting (Poole and Claypool, 1984).

The alluvium in the Sevenmile Wash area, along the northwest boundary of the study area (see fig. 1), is contiguous with the alluvial fill of Little Fish Lake Valley (a Neogene basin) to the west and southwest of the study area. Basinal rocks potentially favorable for petroleum accumulation, however, are not present beneath the alluvium within the Sevenmile Wash area. An exploratory drill hole (UCE–12a, fig. 1) encountered 1,500 ft of alluvium, 330 ft of tuffs younger than the Windous Butte Formation (Tty, pl. 1), 1,300 ft of the Windous Butte Formation (Twb, pl. 1), and bottomed in andesitic lava (Td, pl. 1) at a depth of 3,200 ft (Ekren and others, 1974, p. 114). No oil or gas shows were reported from this drill hole. The rocks in this hole were apparently downfaulted from the Antelope Range immediately to the east. Thus, geologic conditions favorable for accumulation of crude oil may be present locally in the valleys adjacent to the Hot Creek and Antelope Ranges; however, the rocks in the study area, including those beneath alluvium in the Sevenmile Wash area, have a low energy resource potential for petroleum.

The organic analytic data on rocks in the study area indicate that they may be a source rock for petroleum. However, no significant accumulations of petroleum have been found within or adjacent to the study area. Therefore, the study area has low energy resource potential for oil and gas, with a certainty level of B.

Industrial Minerals and Rocks

Extensive deposits of sand and gravel occur in alluvial-fan material extending away from the east and west flanks of the Antelope Range within the study area. At least 1,500 ft of alluvium consisting of sand and gravel (composed predominantly of quartz and feldspar grains and volcanic lithic fragments) and less than 10–20 percent siltstone and clay overlie ash-flow tuff bedrock in drill hole UCe–12a near the west margin of the study area (fig. 1). Similar alluvial deposits, which may be as thick, occur along the east flank of the Antelope Range in the Hicks Station Wash area.

Exposed bedrock (in particular, some of the ash-flow tuff units) that may be suitable for dimension stone or other construction use is likewise extensive within the study area.

Sand and gravel and bedrock, suitable for many construction purposes, constitute extensive occurrences of nonmetallic or nonpetroleum commodities that are appraised as identified resources in the study area (Johnson and Benjamin, 1986; see "Nonmetallic Resources," this report). These known occurrences are therefore not assigned a resource potential.

REFERENCES CITED

Brooks, W. E., Tucker, R. E., Goodhue, Christopher, Day, G. W., Plouff, Donald, Duval, J. S., Johnson, F. L., and Benjamin, D. A., 1987, Mineral resources of the Park Range Wilderness Study Area, Nye County, Nevada: U.S. Geological Survey Bulletin 1731–F.

Day, G. W., Turner, R. L., Briggs, P. H., and Conklin, N. M., 1986, Analytical results and sample locality map of heavy-mineral-concentrate and rock samples from the Antelope Wilderness Study Area (NV–060–231/241), Nye County, Nevada: U.S. Geological Survey Open-File Report 86–377.

Desborough, G. A., Poole, F. G., Hose, R. K., and Green, G. N., 1987, Metalliferous oil shale in the Upper Devonian Gibellini facies of the Woodruff Formation, southern Fish Creek Range, Nevada, *in* Bush, A. L., ed., Contributions to mineral resources research, 1984: U.S. Geological Survey Bulletin 1694–H, p. 91–104.

Dixon, G. L., Hedlund, D. C., and Ekren, E. B., 1972, Geologic map of the Pritchards Station quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I–728, scale 1:48,000.

Duval, J. S., 1983, Composite color images of aerial gamma-ray spectrometric data: Geophysics, v. 48, no. 6, p. 722–735.

Ekren, E. B., Bath, G. D., Dixon, G. L., Healey, D. L., and Quinlivan, W. D., 1974, Tertiary history of Little Fish Lake Valley, Nye County, Nevada, and implications as to the origin of the Great Basin: U.S. Geological Survey Journal of Research, v. 2, no. 1, p. 105–118.

Epstein, A. G., Epstein, J. B., and Harris, L. D., 1977, Conodont color alteration—An index to organic metamorphism: U.S. Geological Survey Professional Paper 995, 27 p.

Geodata International, Inc., 1979, Aerial radiometric and magnetic survey Tonopah national topographic map, Nevada: U.S. Department of Energy Open-File Report GJBX–104 (79), v. 2.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–787, 42 p.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Healey, D. L., Snyder, D. B., and Wahl, R. R., 1981, Complete Bouguer gravity map of Nevada—Tonopah sheet: Nevada Bureau of Mines and Geology Map 73, scale 1:250,000.

Hildreth, Wes, 1979, The Bishop Tuff—Evidence for the origin of compositional zonation in silicic magma chambers, *in* Chapin, C. E., and Elston, W. E., eds., Ash-flow tuffs: Geological Society of America Special Paper 180, p. 43–75.

Hose, R. K., 1983, Geologic map of the Cockalorum Wash quadrangle, Eureka and Nye Counties, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I–1410, scale 1:31,680.

John, D. A., Nash, J. T., Plouff, Donald, and McDonnell, J. R., Jr., 1987, Mineral resources of the Morey and Fandango Wilderness Study Areas, Nye County, Nevada: U.S. Geological Survey Bulletin 1731–A, 19 p., 1 pl., scale 1:62,500.

Johnson, F. L., and Benjamin, D. A., 1986, Mineral Resources of the Antelope Wilderness Study Area, Nye County, Nevada: U.S. Bureau of Mines Mineral Land Assessment Open-File Report MLA–14–86, 16 p.

Kleinhampl, F. J., and Ziony, J. I., 1967, Preliminary geologic map of northern Nye County, Nevada: U.S. Geological Survey Open-File Report 67–129, scale 1:200,00.

———1984, Mineral resources of northern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 99B, 243 p.

Lenzer, R. C., 1972, Geology and wallrock alteration at the Morey mining district, Nye County, Nevada: Madison, University of Wisconsin, Ph.D. thesis, 123 p.

Nash, J. T., John, D. A., Malcom, M. J., Briggs, P. H., and Crodk, J. G., 1986, Geochemistry of altered and mineralized rocks from the Morey and Fandango Wilderness Study Areas, Morey 15-minute quadrangle, Nye County, Nevada: U.S. Geological Survey Open-File Report 86–410, 52 p.

Poole, F. G., and Claypool, G. E., 1984, Petroleum source-rock potential and crude-oil correlation in the Great Basin, *in* Woodward, Jane, Meissner, F. F., and Clayton, J. L., eds., Hydrocarbon source rocks of the greater Rocky Mountain region: Denver, Colo., Rocky Mountain Association of Geologists, p. 179–229.

Potter, E. C., 1976, Paleozoic stratigraphy of the northern Hot Creek Range, Nye County, Nevada: Corvallis, Oregon State University, M.S. thesis, 129 p.

Saunders, J. A., Fairfield, R. F., Jr., and Siems, D. F., 1986, Analytical results and sample locality map for stream-sediment and panned-concentrate samples from the Morey and Fandango Wilderness Study Areas (NV–060–190/191), Nye County, Nevada: U.S. Geological Survey Open-File Report 86–196.

Siems, D. F., Marchitti, M. L., and Nash, J. T., 1986, Analytical results for samples of nonmagnetic heavy-mineral concentrates from the Tonopah 1° by 2° quadrangle, Nevada: U.S. Geological Survey Open-File Report 86–213, 94 p.

Snyder, D. B., and Healey, D. L., 1983, Interpretation of the Bouguer gravity map of Nevada, Tonopah sheet: Nevada Bureau of Mines and Geology Report 38, 16 p.

Tooker, E. W., editor, 1985, Geologic characteristics of sediment- and volcanic-hosted disseminated gold deposits—Search for an occurrence model: U.S. Geological Survey Bulletin 1646, 150 p.

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, 5 p.

U.S. Geological Survey, 1968, Aeromagnetic map of the Hot Creek Range region, south-central Nevada: U.S. Geological Survey Geophysical Investigations Map GP–637, scale 1:250,000.

———1970, Geological Survey Research 1970: U.S. Geological Survey Professional Paper 700–A, p. A39–A40.

Viets, J. G., 1978, Determination of silver, bismuth, cadmium, copper, lead, and zinc in geological materials by atomic absorption spectrometry with tricaprylylmethylammonium chloride: Analytical Chemistry, v. 50, p. 1097–1101.

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.

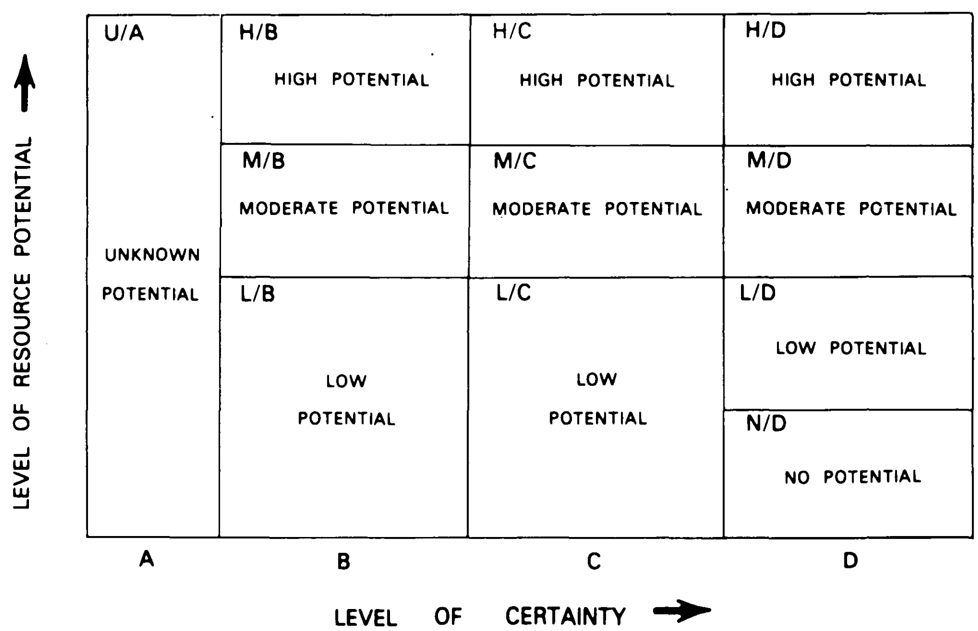
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application 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.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

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 in this report

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.

★U.S. GOVERNMENT PRINTING OFFICE: 1987-0-773-047/46064

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Hardyman and others—MINERAL RESOURCES OF THE ANTELOPE WILDERNESS STUDY AREA, NEVADA—U.S. Geological Survey Bulletin 1731-E