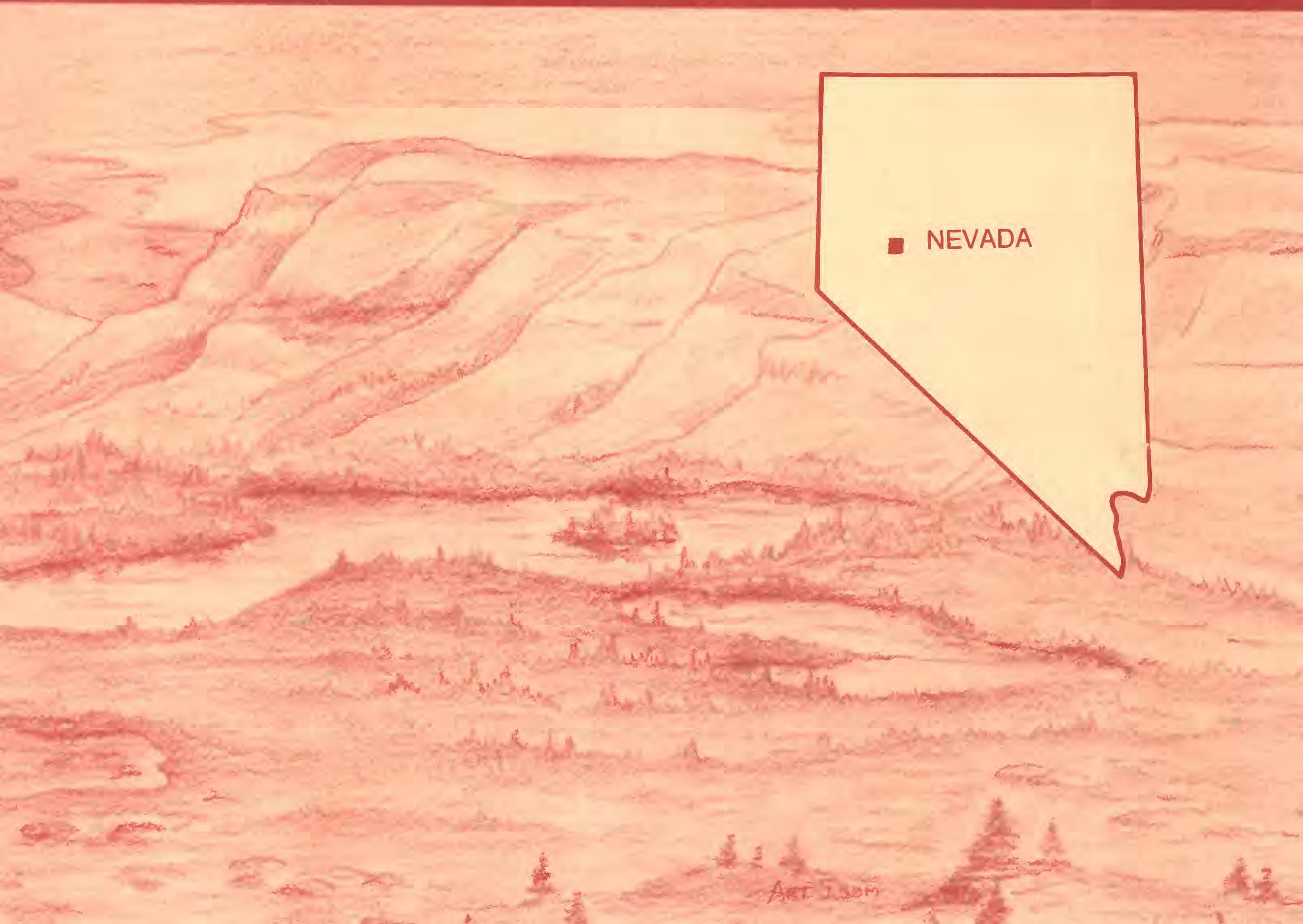
Mineral Resources of the Clan Alpine Mountains Wilderness Study Area, Churchill County, Nevada

U.S. GEOLOGICAL SURVEY BULLETIN 1727–B



Chapter B

Mineral Resources of the Clan Alpine Mountains Wilderness Study Area, Churchill County, Nevada

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U.S. GEOLOGICAL SURVEY BULLETIN 1727

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
WEST-CENTRAL NEVADA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine 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 Clan Alpine Mountains Wilderness Study Area (NV–030–102), Churchill County, Nevada.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

TABLE

Mineral Resources of the Clan Alpine Mountains Wilderness Study Area, Churchill County, Nevada

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ABSTRACT

The Clan Alpine Mountains Wilderness Study Area (NV-030-102) contains one area of high mineral resource potential and two areas of moderate mineral resource potential for undiscovered gold and silver resources, two areas of moderate mineral resource potential for undiscovered molybdenum resources, and two areas of moderate mineral resource potential for undiscovered antimony resources. The rest of the area has a low potential for these and all other undiscovered metals, and the entire area has a low resource potential for undiscovered oil and gas and geothermal energy. A small area along the east-central margin of the study area has low mineral resource potential for undiscovered zeolite resources (fig. 1).

SUMMARY

The wilderness study area is approximately 50 mi (miles) east of Fallon, Nev., in the southern part of the Clan Alpine Mountains. At the request of the U.S. Bureau of Land Management, 68,458 acres of the 196,128-acre Clan Alpine Mountains Wilderness Study Area was studied for its mineral endowment, including identified (known) resources and mineral resource potential (undiscovered resources). In this report the studied area is called the "wilderness study area" or simply the "study area." Limited access to the mountain range is provided by improved roads and four-wheel-drive trails. Elevations are from 3,600 ft (feet) in the northwest to 9,966 ft at Mount Augusta, in the south-central part of the range.

A reconnaissance geologic map of the Clan Alpine Mountains was included in geologic studies of Churchill County published cooperatively by the University of Nevada and the U.S. Geological Survey in 1974. Detailed mapping and geochemical and geophysical studies of the Clan Alpine Mountains Wilderness Study Area were carried out during the summer of 1986 by the U.S. Geological Survey. Geochemical sampling of mineralized areas was completed during the summer of 1985 by the U.S. Bureau of Mines.

Rocks exposed in the study area are chiefly Tertiary (see geologic time chart in appendix) igneous rocks and minor amounts of Mesozoic sedimentary rocks. Several workings were found in faulted and hydrothermally altered volcanic rocks east and northeast of Mount Augusta in the general area of Starr Canyon. Limited production of gold and silver was reported for this area in the 1860's. Mineralized zones also occur in faulted, silicified volcanic rock near the mouth of Florence Canyon, approximately 1 mi southeast of the wilderness study area boundary. Rock samples from several workings and other areas showing alteration in the study area were geochemically analyzed.

A small amount of gold and silver ore was produced from the Starr Canyon group (Nevada Lincoln mine) within the area classified as having high resource potential (fig. 1). No mineral resources were identified at this mine during this study; however, analytical results indicate that a significant mineralized zone situated between Florence Canyon and Cherry Creek may contain resources of precious metals (gold and silver). Anomalous amounts of gold and silver were detected at two other sites, and zeolite minerals were found inside the eastern study area boundary, but no resources were identified.

Geological mapping and geochemical sampling indicate that gold-silver mineralization occurred in a zone-trending northwest from the mines near the mouth of

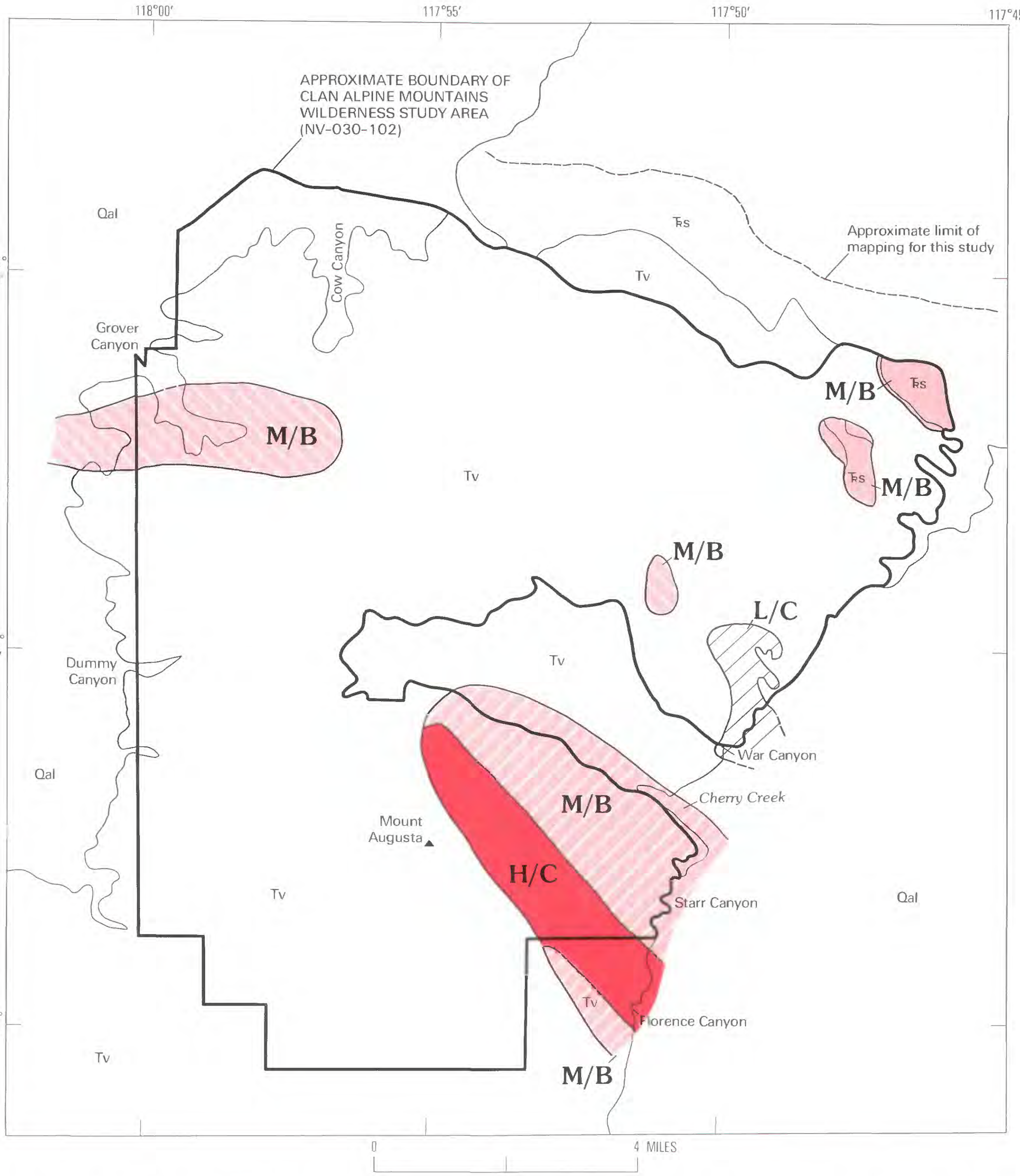

Figure 1 (above and facing page). Summary map showing mineral resource potential and generalized geology of the Clan Alpine Mountains Wilderness Study Area, Churchill County, Nev.

Florence Canyon, in the southeastern part of the study area. The locally intense alteration, known mineralization, and favorable anomalous rock geochemistry along this structure indicate a high mineral resource potential for gold and silver in this area. Weakly anomalous rock geochemical values and localized weakly altered rock along Cherry Creek

EXPLANATION

[Entire study area has a low mineral resource potential for all metals (except as noted below), at certainty level B, and for geothermal energy, oil, and gas, at certainty level C]

H/C	Geologic terrane having high mineral resource potential for gold and silver, at certainty level C
M/B	Geologic terrane having moderate mineral resource potential for gold and silver, at certainty level B
M/B	Geologic terrane having moderate mineral resource potential for molybdenum, at certainty level B
M/B	Geologic terrane having moderate mineral resource potential for antimony, at certainty level B
L/C	Geologic terrane having low mineral resource potential for zeolites, at certainty level C
Qal	Quaternary alluvium
Tv	Tertiary volcanic rocks
ŦRs	Triassic sedimentary rocks
———	Geologic contact
	Levels of certainty
B	Data indicate geologic environment and suggest level of resource potential
C	Data indicate geologic environment and give good indication of level of resource potential but do not establish activity of resource-forming processes

and adjacent to lower Florence Canyon suggest these two areas have moderate resource potential for similar gold-silver deposits.

In the northeastern part of the study area, two zones have a moderate mineral resource potential for antimony. Favorable host rocks are present and contain similar deposits north of the study area. Limited geochemical data indicate the presence of anomalous amounts of antimony.

One area on the east side and one area on the west side of the wilderness study area have moderate mineral resource potential for molybdenum. Favorable host rocks and anomalous geochemical samples support this rating.

Except for the areas of high to moderate resource potential discussed above, the available data suggest that the remainder of the wilderness study area has low mineral resource potential for all metals.

Zeolites are present in weakly altered volcanic rocks and minor amounts of volcaniclastic tuffaceous sedimentary rocks on the east-central margin of the study area. Because of the limited extent of apparent zeolite mineralization and the less favorable geologic processes having affected the rocks there, compared to those producing known zeolites south of the study area, the area on the east-central margin of the wilderness is judged to have a low resource potential for zeolites.

Because of the unfavorable geologic environment in terms of source rock combined with extensive Cretaceous and Tertiary igneous activity, the entire study area is assessed to have a low energy resource potential for oil and gas. No hot springs exist within the study area, and no evidence was found for previous hot spring activity. The study area has low resource potential for geothermal energy.

INTRODUCTION

At the request of the U.S. Bureau of Land Management (BLM) 68,458 acres of the Clan Alpine Mountains Wilderness Study Area were studied. The Clan Alpine Mountains Wilderness Study Area (NV–030–102), in west-central Nevada, approximately 50 mi east of Fallon, is east of the Stillwater Range and Dixie Valley and west of the Desatoya Mountains (fig. 2). Access is provided by improved roads that extend north from Nevada Highway 50 to Dixie Valley and Edwards Creek Valley and by four-wheel-drive trails that locally continue into the wilderness study area. Elevations are from 3,600 ft in the northwestern part of the wilderness study area near Dixie Valley to 9,966 ft at Mount Augusta, in the south-central part of the study area (pl. 1).

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 USBM and USGS (1980), which is shown in the appendix to this report. Identified resources are studied by the USBM. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, 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 also is shown in the appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

Investigations prior to field work included library research for pertinent literature, a search of BLM and Churchill County mining records for claim locations, and an examination of USBM mine production records. Claim owners were contacted for additional information and for permission to examine and publish data on their properties. The USBM Mineral Industries Location System was also searched for property locations within the area studied.

Field work, conducted in 1985, included searching for and examining all mineral properties and areas of indicated mineralization identified in the preliminary study. Ground and aerial reconnaissance of the entire

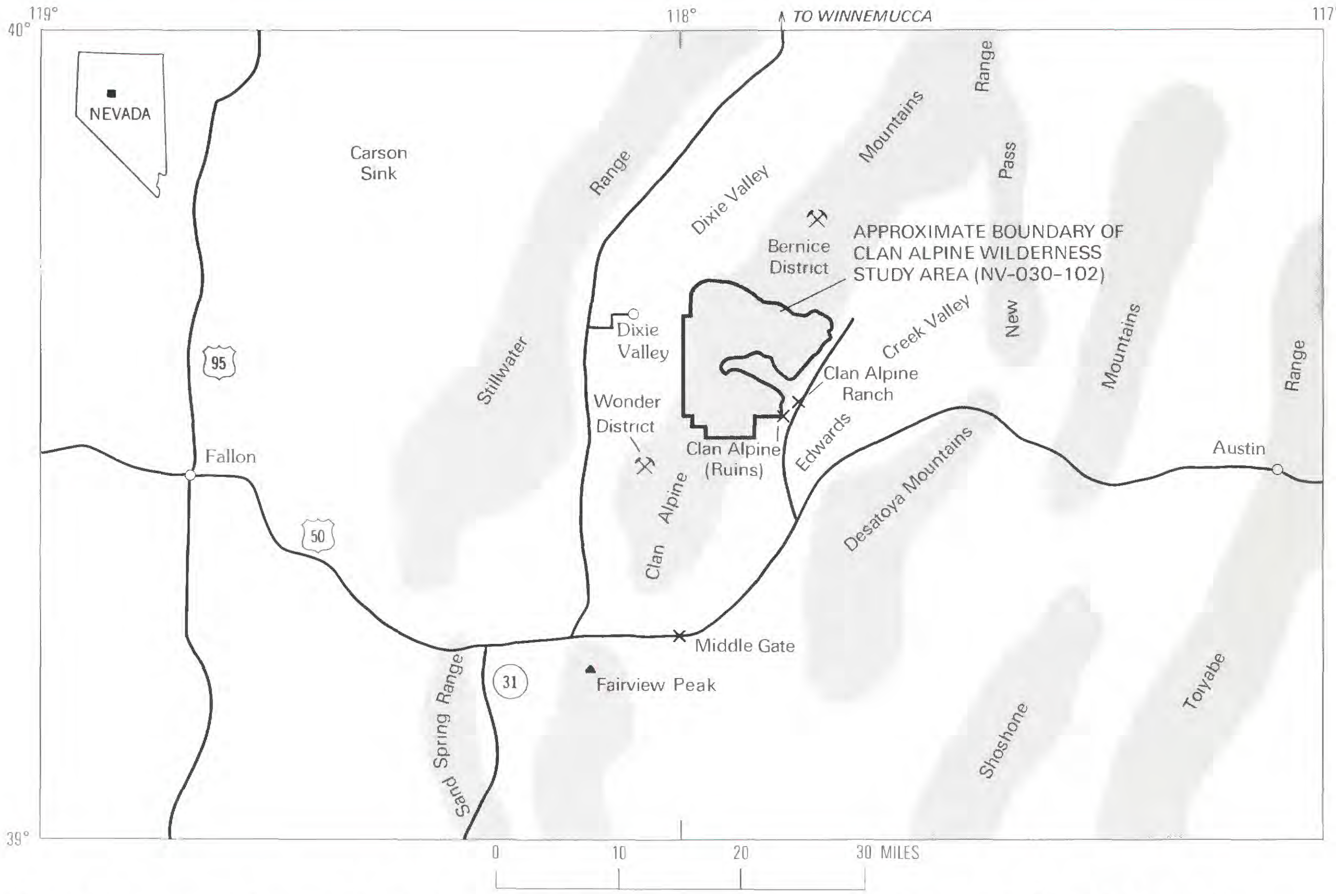

Figure 2. Index map showing location of the Clan Alpine Mountains Wilderness Study Area , Churchill County, Nev.

study area was also performed to locate unknown claims, prospects, or mineralized areas. All sites found were sampled and, if warranted, mapped (Olson, 1987). A total of 210 samples were taken during the course of the study. All were analyzed for gold and silver and, in certain areas, for uranium. Five samples were taken and analyzed for zeolites. Data for all samples analyzed are available at the USBM Western Field Operations Center, E. 360 Third Avenue, Spokane, WA 99202 and in USBM Open File Report MLA 04–87 (Olson, 1987).

USBM physical scientist David Benjamin assisted with prefield and field work. Appreciation is also extended to USBM supervisory physical scientist Nicholas T. Zilka, who assisted with part of the field work, and to Mr. P.A. Patnoude for facilitating a base camp at Cold Springs, Nev.

Investigations by the U.S. Geological Survey

The Clan Alpine Mountains Wilderness Study Area covers approximately two-thirds of the Clan Alpine Ranch 15-minute topographic quadrangle (102 mi^2 (square miles)), approximately 4 mi^2 of the Camp Creek Canyon 7.5-minute quadrangle, and approximately 0.5 mi^2 of the Dixie Valley SE 7.5-minute quadrangle. Published geologic investigations in this area are reconnaissance in nature and include a brief mention in a county report (Willden and Speed, 1974) and a more comprehensive review of the volcanic rocks (Riehle and others, 1972). Existing geologic maps of the area are the geologic map of Churchill County (1:250,000; Willden and Speed, 1974) and a somewhat smaller scale but more detailed map in the report by Riehle and others (1972). Geologic information contained in these reports was reviewed for this study.

The U.S. Geological Survey conducted field investigations in the wilderness study area during the summers of 1985 and 1986. The work included geologic mapping on topographic maps at scales of 1:62,500 and 1:24,000 and on aerial photographs at approximately 1:38,000. These data were compiled at a scale of 1:50,000 (pl. 1). Geochemical samples of altered rock were collected during the geologic mapping, and a stream-sediment geochemical sampling program covered the entire study area. All samples were analyzed for trace-element signatures that may be indicative of mineralized systems. These data, together with the new geologic mapping and geophysical surveys, were reviewed in light of permissive and favorable mineral deposit models acceptable for the area on the basis of geologic environment, present mineral exploration in the area, and past mining activity in the region.

APPRAISAL OF IDENTIFIED RESOURCES

By Jerry E. Olson
U.S. Bureau of Mines

Mining and Mineral Exploration History

Prospecting in Churchill County began about 1860 following the discovery of the Comstock lode in western Nevada. Although this discovery motivated a great deal of prospecting, no important deposits were found in the county until discovery of the Fairview deposit, south of U.S. Highway 50 near Middle Gate, and the Wonder deposit, near the southwest corner of the study area, in 1905 and 1906, respectively (Vanderburg, 1940, p. 10).

Prior to the Fairview and Wonder discoveries, numerous mining districts were established within the Clan Alpine Mountains. Of these, only the Alpine (also called "Clan Alpine") district is inside the study area. This district was created in 1864 as a result of the discovery of silver in the vicinity of Florence Canyon, in the southeastern part of the study area (pl. 1). In 1866, in support of this mining activity, the Silver Lode Mining Company built a 10-stamp mill at the mouth of Cherry Creek (Clan Alpine Canyon). Mining in the area was short lived, however, and the mill was abandoned within a few years. Total production from the mill was small, probably less than a few thousand dollars in gold and silver ore (Vanderburg, 1940, p. 15). Stone remnants of the mill buildings are still standing (pl. 1). Subsequent mining within the district has been on a small scale and sporadic, but deposits in lower Florence Canyon continue to sustain mining interest.

Other districts of importance near the study area include the Bernice district to the north, established about 1880, and the Wonder district to the southwest (fig. 2).

Mining Claims and Leases

BLM mining records indicate that three areas within the study area (pl. 1; B, C, and part of I) and three areas adjacent (pl. 1; E, H, and part of I) are under active or recent (1983) claims. Four other historical claims or claim groups (pl. 1; A, D, F, and G), located within and adjacent to the study area, were identified from Churchill County records.

Reserves and Identified Resources

Precious metals (gold and silver) occur both in veins and in low-grade disseminated deposits at the Starr Canyon group, between the head of Starr Canyon and the upper end of Cherry Creek. Two areas (pl. 1; sample Nos. 3–6 and 11–18, respectively), in the northeast corner of the study area and along Cherry Creek, are weakly anomalous for precious metals. Sample analyses and field examination of these areas and of claims or claim blocks within or adjacent to the area studied provided no evidence for identified mineral resources. Zeolite-bearing rocks on the eastern side of the study area may be of interest for their analcime content.

Recommendations for Further Study

Additional studies for disseminated gold-silver resources are recommended for the Starr Canyon group. These studies should include reopening of a caved adit and detailed mapping and sampling of underground workings, closely spaced rock-chip or soil sampling on the surface, and possibly a drilling program to delineate the grade and extent of mineralization. Additional closely spaced sampling and geologic mapping may also be warranted along Cherry Creek and in the northeast corner of the study area in order to determine if resources may be present.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Richard F. Hardyman, William E. Brooks, Michael J. Blaskowski, Harlan N. Barton, and David A. Ponce
U.S. Geological Survey

Geologic Setting

The Clan Alpine Mountains Wilderness Study Area is within the southern Clan Alpine Mountains, a northeast-trending range within the Basin and Range province of west-central Nevada. Dixie Valley and the Stillwater Range lie to the northwest of the wilderness study area, and Edwards Creek Valley and the Desatoya

Mountains lie to the southeast (fig. 2). Deformed Mesozoic rocks separated by thrust faults, a complex of mafic igneous rocks, and Cenozoic volcanic and intrusive rocks are exposed in the Stillwater Range (Willden and Speed, 1974). Faulting has occurred throughout Quaternary time, especially in the Dixie Valley–Fairview Peak area (fig. 2), where faulting accompanied the 1954 Dixie Valley earthquake (Page, 1965). The Desatoya Mountains consist principally of east- to southeast-dipping Tertiary volcanic rocks. However, in the southern part of the range the structures are more complex and pre-Tertiary metavolcanic and intrusive rocks are present (Willden and Speed, 1974).

The Clan Alpine Mountains are composed of Mesozoic sedimentary and Tertiary igneous rocks. The Mesozoic sedimentary rocks include Triassic siltstone and carbonate rocks and Triassic and Jurassic volcaniclastic rocks. These rocks have been variously folded and affected by intra-unit thrust faults and normal faults. The easternmost exposure of the igneous complex of Humboldt is in the northern part of the Clan Alpine Mountains (Willden and Speed, 1974).

Tertiary volcanic rocks found throughout the Clan Alpine Mountains are separated into two contemporaneous sequences by Riehle and others (1972). The northern part of the range consists of about 1,650 ft of well-stratified ash-flow tuffs, and the southern part contains a 10,000- to 16,500-ft assemblage of lava flows, domes, ash-flow tuffs, and volcaniclastic beds (Riehle and others, 1972).

Exposed within the Clan Alpine Mountains Wilderness Study area are Triassic siltstone; Tertiary basalt, andesite, dacite, rhyolite flows and intrusive bodies, and thick accumulations of ash-flow tuff that are related to two caldera complexes within the study area; and Quaternary alluvium and landslide deposits (pl. 1). Some of the volcanic rocks have been dated by Riehle and others (1972) and range in age from 35 Ma (million years old) for an andesite flow near Byers Canyon to 22 Ma for an intrusive rhyolite exposed in War Canyon.

The informally named ash-flow tuff of Railroad Ridge, approximately 25 Ma (Riehle and others, 1972), is overlain by a basalt flow that is presumed to be the youngest volcanic unit in the wilderness study area. The age of the basalt, between 10 and 16 Ma, is based upon correlation of this lava with lava flows of equivalent stratigraphic position in ranges to the east (Riehle and others, 1972).

Tertiary volcanic rocks make up more than 97 percent of the exposed bedrock within the study area. This sequence of rocks is dominated by two thick rhyolitic to quartz-latitic ash-flow tuff units, each representing a separate stage of caldera-forming volcanic activity. Following intense deformation of Mesozoic rocks (principally Triassic siltstone) deposited earlier, in Middle Jurassic time, coupled with limited granitic plutonism, voluminous volcanic activity affected the area now exposed within the Clan Alpine Mountains Wilderness Study Area. Explosive volcanic eruptions beginning in mid-Tertiary (Oligocene) time created a volcanic subsidence structure (caldera) that was filled with the tuff of Deep Canyon (unit Tdc, pl. 1). The northern margin of this caldera is defined by the abrupt juxtaposition (locally along high-angle fault contacts) of more than 1,200 ft (exposed thickness) of this tuff against Triassic siltstones in the vicinity of Deep Canyon (see also discussion of gravity signature of this boundary later in this report). This initial explosive activity was followed by emplacement of rhyolite intrusive bodies (units Tr and Trp), minor pyroclastic activity (unit Tdf, perhaps from a source outside the present-day Clan Alpine Mountains), and local faulting and erosion (that produced sedimentary breccia, unit Tsb). Eruption of the tuff of Railroad Ridge (unit Trr) and associated caldera collapse marked the last stage of voluminous explosive volcanism. Caldera collapse and infilling of tuff was again followed by rhyolite emplacement, primarily along ring-fracture faults (principally unit Tr rhyolites). The northern margin of the Railroad Ridge collapse feature is in part marked by the complex zone of intrusive rocks and complicated structure north of War Canyon (pl. 1). Elsewhere, this margin is buried beneath outflow facies of the tuff of Railroad Ridge or obscured by rhyolite intrusive bodies, such as along the west margin of the study area. Likewise, the southern margins of the Railroad Ridge or older Deep Canyon unit collapse structures are apparently buried beneath outflow deposits of the tuff of Railroad Ridge.

Faulting within the wilderness study area occurred in Tertiary and Holocene time as indicated by the uplift of the present Clan Alpine Mountains relative to the adjoining basins (basin-and-range structures) and by high-angle normal faults that have dropped blocks of the capping basalt down against the ash-flow tuff of Railroad Ridge near Starr Canyon and along Railroad Ridge. Quaternary deposits have been faulted and subsequently buried by younger Quaternary gravels between the mouths of Cherry Creek and War Canyon. Faulting occurred as recently as 1954 at Dixie Valley (Page, 1965).

Geochemistry

Stream sediments and heavy-mineral concentrates of stream sediments were the sample media used for the regional geochemical survey conducted for the Clan Alpine Mountains Wilderness Study Area during August 1985. Analyses of stream-sediment samples represent the chemistry of the rock eroded from the drainage basin upstream from each sample site. This information may be useful in identifying basins containing concentrations of elements related to mineralization. The nonmagnetic fraction of heavy-mineral-concentrate samples of stream sediments provides similar information about the rock eroded from the drainage basin but for only a limited number of nonmagnetic minerals of high specific gravity. These minerals, many of which are commonly components of ore, are selectively concentrated, thereby permitting the detection of elements that are not easily detected in stream-sediment samples.

Analytical Methods

Stream-sediment samples were analyzed for 31 elements by the semiquantitative emission spectrographic method of Grimes and Marranzino (1968) and additionally for antimony, arsenic, bismuth, cadmium, and zinc by an atomic-absorption spectroscopy method (O'Leary and Viets, 1986). Heavy-mineral-concentrate samples were also analyzed for 31 elements by the semiquantitative emission spectrographic method.

Stream-sediment and heavy-mineral-concentrate samples were collected from 124 stream-bed sites either within the wilderness study area or outside but in a drainage basin partly within the study area (H.N. Barton, unpub. data, 1987). The sample density was approximately 1.2 samples/mi^2 (square mile). A sufficient quantity of material was obtained in the nonmagnetic heavy-mineral samples from 91 sample sites for analysis by emission spectroscopy. Details of sample preparation and analysis, along with the presentation of data and sample sites, are available from the Branch of Exploration Geochemistry, U.S. Geological Survey, Denver Federal Center, Denver, CO 80225.

In addition to the stream-sediment and heavy-mineral concentrate samples, 57 rock samples were collected in or immediately adjacent to the wilderness study area. For the most part, these samples were collected from outcrops of altered or mineralized rock or outcrops having characteristics indicating that a mineralizing process had affected them. Analysis of rock samples showing evidence of alteration yields information on the suites of elements associated with mineralization. Samples of rock that appeared unaltered were also collected and analyzed to provide information on geochemical background values.

Rock samples were crushed and pulverized to less-than-100-mesh sieve size and were analyzed by semiquantitative emission spectrography for 31 elements and for antimony, arsenic, bismuth, cadmium, and zinc by atomic-absorption spectroscopy as noted above. Complete analytical results and sample sites are given in Brooks and others (1987).

Results of Study

Five specific geochemically anomalous areas were delineated within the Clan Alpine Mountains Wilderness Study Area. These were identified as anomalous by meeting any of several criteria: the clustering of high values within a geographical area, mutually reinforcing anomalous analytical data from different sample media, supporting alteration, and permissive geologic evidence (such as faults as conduits for solutions that altered the rocks). The geochemically anomalous areas (H.N. Barton, unpub. data, 1987, and Brooks and others, 1987) help define the areas identified as having mineral resource potential (pl. 1).

Florence Canyon–Starr Canyon–Cherry Creek Anomaly

This area, known to be mineralized, is defined by anomalous values of gold, silver, molybdenum, and (or) antimony in rock samples 758–761, 767–775, and 778–782; molybdenum in heavy-mineral-concentrate CB038; and silver in heavy-mineral-concentrate CB041 (pl. 1 and table 1). Structurally controlled, low-temperature (epithermal), vein-type silver-gold mineralization in this area apparently included deposition of minor amounts of molybdenum, copper, lead, antimony, and traces of arsenic as shown in the rock geochemistry (see Brooks and others, 1987, for metal values other than those shown in table 1).

Grover Canyon Anomaly

This area (pl. 1) is delineated by anomalous values (table 1) of molybdenum in heavy-mineral concentrate CJ032 and in rock samples 805 and 806, which are of porphyritic intrusive rhyolite or adjacent sedimentary breccia consisting primarily of rhyolite clasts. These anomalous values may indicate a possible disseminated molybdenum deposit associated with an intrusive rhyolite at depth.

War Canyon Anomaly

Sample CH075 (100 ppm (parts per million) Mo) from the upper part of War Canyon is a heavy-mineral concentrate of sediment probably derived from eroding intrusive rhyolite bodies exposed up drainage from this site and may possibly indicate a disseminated molybdenum deposit associated with intrusive rock at depth.

Sedimentary Rock–Hosted Antimony Anomaly (Northeastern Part of Study Area)

Heavy-mineral-concentrate sample CBO25 contains anomalous concentrations of antimony (1,000 ppm) and was collected downstream from exposures of

Table 1. Selected results of geochemical analyses of rock and stream-sediment samples from the Clan Alpine Mountains Wilderness Study Area, Churchill County, Nev., in ppm (parts per million).

[N, given element was not detected at lower limit of determination (lower detection limits are Au, 10 ppm; Ag, 0.5 ppm; Mo, 5 ppm; Sb, 100 ppm); L, given element was detected, but was below lower limit of determination. Method of analysis, semiquantitative emission spectroscopy; Roy T. Hopkins, analyst]

Sample No.	Au	Ag	Mo	Sb
Heavy-mineral concentrates				
CB020	N	100	N	N
CB025	N	N	N	1,000
CB038	N	N	50	N
CB041	N	100	N	N
CB043	1,000	1,000	N	N
CH054	200	200	N	N
CH059	N	15	N	N
CH075	N	N	100	N
CJ032	N	N	30	N
Rocks				
744	N	1	15	700
758	N	7	100	N
759	N	3	7	N
760	N	1.5	L	N
761	N	1	N	N
765	N	1.5	N	N
766	N	200	L	L
767	N	50	7	N
768	N	5	N	N
769	N	2	N	N
770	N	50	70	100
771	15	100	20	150
772	N	50	20	N
773	N	20	15	N
774	N	20	10	N
775	N	5	100	N
778	N	2	N	N
779	N	0.7	N	N
780	N	5	N	N
781	N	100	L	100
782	N	15	L	N
785	N	2	50	N
805	N		100	N
806	N	2	7	N

Triassic fine-grained sedimentary rocks (unit TRs, pl. 1) that may be favorable for antimony deposits in the Bernice district (fig. 2), approximately 7 mi north of the study area (Vanderburg, 1940, p. 16; see also Willden and Speed, 1974, p. 60–64).

Precious-Metal Anomaly (Northeastern Part of Study Area)

The weakly anomalous precious-metal values (0.021–0.120 ppm gold and 0.64–2.10 ppm silver) from rocks in the northeast corner of the study area (Olson, 1987) appear to reflect minor isolated occurrences of precious metals along faults in this area. Minor amounts of quartz veining and iron staining, with weak alteration of adjacent rocks, occur sporadically along some of the north-trending, high-angle range-front faults in this area. Only one shallow prospect pit (pl. 1) was observed along these structures and no other zones of altered or mineralized rocks were observed in the rocks in this vicinity. Approximately 0.75 mi up drainage west of this prospect pit, andesitic lava is locally altered adjacent to a small rhyolite intrusive body, but analysis of a pyritized rock sample from this altered area showed no anomalous metal contents.

Other Anomalies

In addition to the anomalies described above, anomalous values for samples from scattered isolated localities were obtained from the analysis of heavy-mineral concentrates and rock samples.

Heavy-mineral samples anomalous in gold, silver, molybdenum, or antimony are shown on plate 1 and listed in table 1. The two samples (CB043, CH054) containing both anomalously high gold and silver (200–1,000 ppm) are isolated samples for which the source of the gold and silver is uncertain. Areas of altered or mineralized rock or of geologic structures associated with ore deposition were not observed in the drainage basins from which these concentrate samples were collected.

Likewise, the source of the silver anomaly (15 ppm) in sample CH059 is unexplained. Sample CB020, containing 100 ppm silver and 100 ppm copper, is from a stream bed draining an area containing zeolitized volcanic rocks but otherwise showing no effects of alteration or mineralization associated with metal deposits.

The scattered occurrence of these high gold and silver values without any supporting evidence of alteration or mineralization or other favorable geologic indicators precludes the delineation of additional areas as anomalous without more closely spaced sampling.

The high values of molybdenum (50 ppm) and silver (2 ppm) for rock sample 785 are likewise insufficient to delineate a mineralized area. The sample is a composite of porphyritic intrusive rhyolite and adjacent breccia consisting primarily of rhyolite clasts.

Anomalous concentrations of lead (150–3,000 ppm) were determined in 13 heavy-mineral-concentrate samples, 4 of which also contained anomalous concentrations of tin or bismuth. The anomalous lead values are for samples from sites scattered throughout the study area, and only three of these sites are from drainages downslope from known altered or mineralized rock. Because of the scattered distribution of localities of samples yielding the anomalous lead values, general lack of anomalous multi-element associations, and the general background level (15–50 ppm) of lead in all rock samples from the study area, it is unlikely that the anomalous lead values determined for the concentrate samples indicate significant base-metal (copper, lead, zinc) mineralization within the study area.

Anomalous concentrations of zinc (2,000 ppm) occurred in one heavy-mineral-concentrate sample. Because of the lack of anomalous values for other base metals and the general background level (50–200 ppm) of zinc in unpanned stream sediments from the study area, it is unlikely that this single anomalous value indicates significant base-metal mineralization. No altered rock was observed upstream from this site.

Heavy-mineral-concentrate samples containing anomalous concentrations of tin (20–500 ppm) and bismuth (50–2,000 ppm) are from stream-bed sites scattered throughout the study area. Except for two, each of these sites is in a drainage immediately adjacent to, or downslope from, exposures of intrusive rhyolite. Neither tin nor bismuth was detected in rock samples, including altered rocks associated with known mineralized areas in the study area. Because of the dispersion of sample localities yielding anomalous tin and bismuth values and the lack of these metals in altered or mineralized rocks, we attribute these anomalous values to trace occurrences of tin or bismuth in intrusive rhyolite, perhaps as traces of cassiterite (for tin) in gas cavities or as a trace element substituting rock-forming minerals (for example, bismuth substituting for calcium in apatite), and not to processes associated with hydrothermal mineralization compatible with mineral deposit models applicable to the study area.

Analysis of the 124 unpanned stream-sediment samples collected from the study area showed no anomalous values. This information supports the above findings that mineralization was of only moderate extent.

Geophysical Studies

Airborne Gamma-Ray Spectrometric Data

Examination by J.S. Duval (written commun., 1985) of aerial gamma-ray maps, including composite-color maps previously described by Duval (1983), provide estimates of the apparent surface concentrations of potassium, equivalent uranium, and equivalent thorium. The maps were compiled at a scale of 1:1,000,000 as part of the National Uranium Resource Evaluation program. The study area has overall moderate radioactivity: values are 1.5–3 percent potassium, 2–6 ppm equivalent uranium, and 8–16 ppm equivalent thorium. There are no anomalies within the boundary of the study area nor in the immediate vicinity.

Gravity Data

A complete Bouger gravity anomaly map of the study area and vicinity (fig. 3) was prepared using existing data (Erwin and Berg, 1977; Erwin and Bittleston, 1977) and supplemented by recent data collected by the U.S. Geological Survey (R.N. Harris and J.M. Glen, unpub. data, this study). Gravity measurements are spaced at intervals of about 3 mi or less in the Clan Alpine Mountains.

The central Clan Alpine Mountains are characterized by a steep gravity gradient of about 12 mGal(milligals)/mi that is caused by the abrupt transition from Paleozoic rocks to Tertiary volcanic rocks. On the west edge of the central Clan Alpine Mountains is a local gravity high (A, fig. 3) having an amplitude of about 12 mGal. This anomaly might reflect the presence of an intrusion or Paleozoic rocks.

Gravity data suggest a marked increase in thickness of Tertiary volcanic rocks in the southern Clan Alpine Mountains as compared to the Tertiary volcanic rocks in the northern part of the range (Riehle and others, 1972). A two-dimensional gravity model by Riehle and others (1972) along the Clan Alpine Mountains, based on limited data, shows a gravity low of about 30 mGal, and suggests that the southern rhyolite sequence is about 13,000 ft (4,000 meters) thick. More recent gravity data (this study, fig. 3) indicate that the amplitude of the gravity low is about 40 mGal. The great thickness of the southern sequence, inferred from gravity data, supports the idea that the southern rhyolite sequence accumulated in a depression, probably a caldera.

No systematic correlation exists at the scale of the gravity survey between gravity anomalies and hydrothermally altered or mineralized rock within the study area.

Aeromagnetic Data

A total-intensity aeromagnetic survey of the wilderness study area was flown in 1985 at a nominal flight altitude of 1,000 ft above the ground and an east-west flightline spacing of 0.5 mi (U.S. Geological Survey, 1985). The actual flight altitude varied from about 400 to 2,300 ft above the ground. A comparison of the radar altimeter map, the topographic map, and the aeromagnetic map suggests that variations in flight altitude do not significantly correlate with magnetic anomalies. A previous aeromagnetic survey of parts of the Millett $1^\circ \times 2^\circ$ quadrangle was flown at a constant barometric elevation of 9,000 ft above sea level and an east-west flightline spacing of 2 mi (U.S. Geological

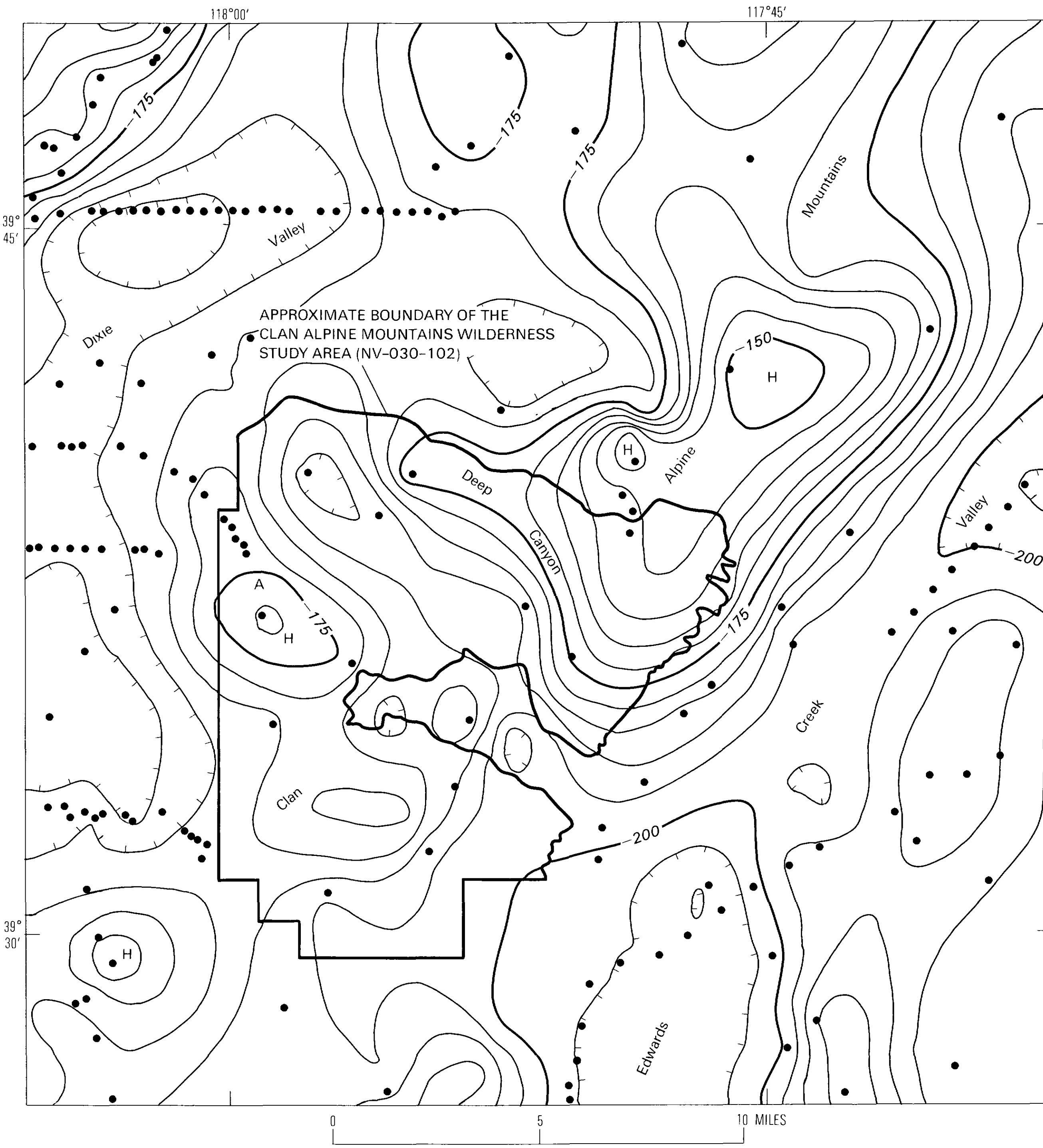

Figure 3. Complete Bouguer gravity anomaly map of the Clan Alpine Mountains Wilderness Study Area, Churchill County, Nev. Contour interval 5 mGal (milligals); hachured contour indicates gravity low; dot, gravity station. H, gravity high; A, gravity feature discussed in text.

Survey, 1972). Another survey, of the Reno 1°×2° quadrangle, was flown at constant barometric elevations of 9,000 and 11,000 ft above sea level and an east-west flightline spacing of 2 mi (Nevada Bureau of Mines and Geology, 1977). The aeromagnetic map of the wilderness study area (fig. 4) is generally complex, and anomalies generally reflect relatively magnetic intrusive rocks and Tertiary volcanic rocks.

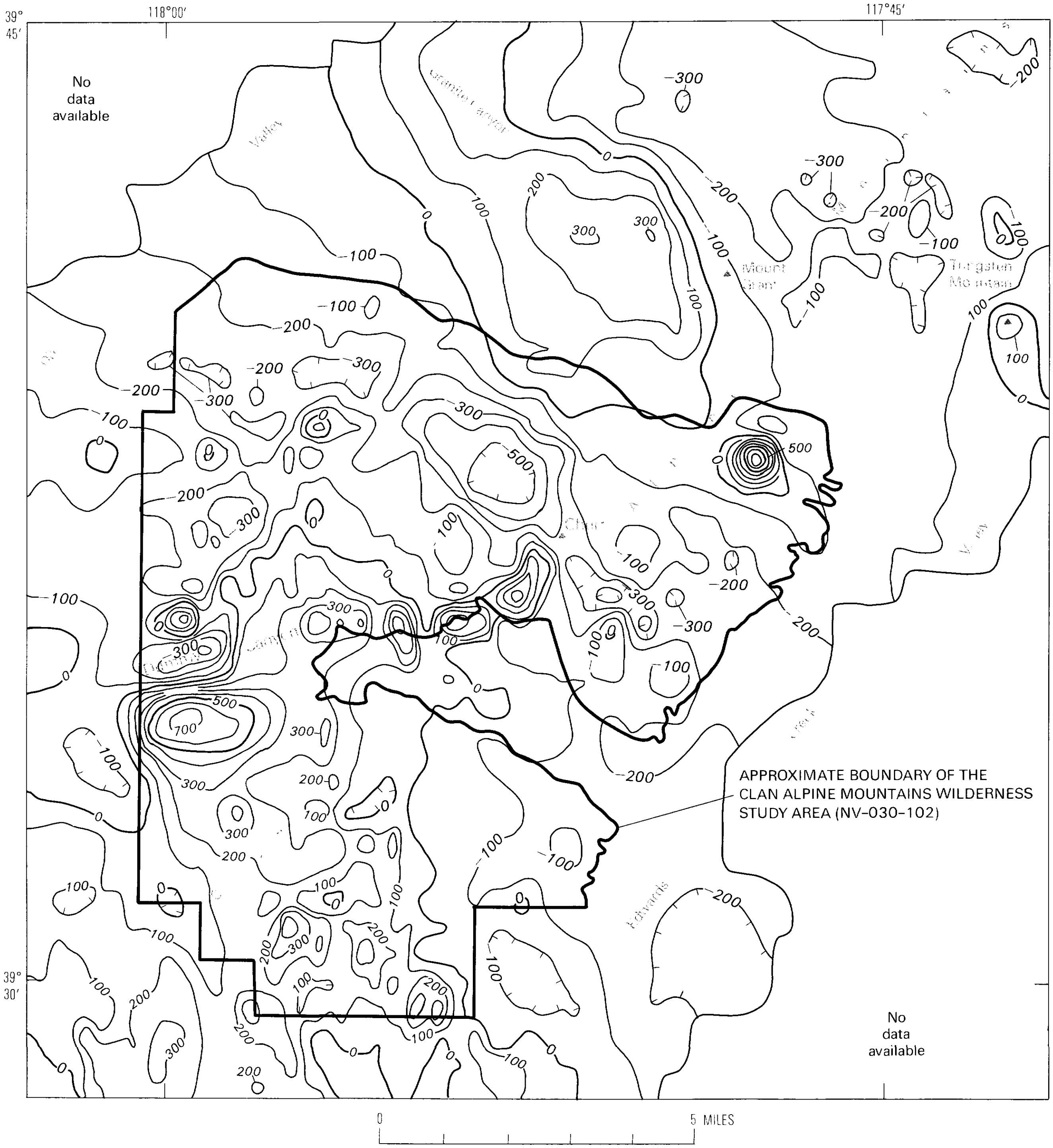

Figure 4. Total-intensity aeromagnetic map of the Clan Alpine Mountains Wilderness Study Area, Churchill County, Nev. Contour interval 100 nT (nanoteslas); hachured contour indicates magnetic low.

In the central Clan Alpine Mountains (north of the study area), granodiorite intrusions crop out in small areas at Tungsten Mountain and Granite Canyon, on the east and west flanks of the range, respectively. The granodiorite exposed at Tungsten Mountain (fig. 4) produces a dipole anomaly at an amplitude of about 150 nT (nanoteslas). A 200-nT anomaly occurs at the southern edge of the granodiorite at Granite Canyon between, and south of, Granite Canyon and Mount Grant (fig. 4). Both the lower and higher level aeromagnetic surveys indicate that the subsurface extent of the granodiorite at Granite Canyon is much greater than the outcrop area and that the intrusion may extend at intermediate depths below Dixie Valley.

In the northeast corner of the study area, 3 mi south of Mount Grant, a conspicuous magnetic anomaly occurs (fig. 4). This small circular anomaly has an amplitude of more than 700 nT. A comparison with the radar altimetry map suggests that the anomaly is partly affected by variations in the flight altitude and spacing. About 1 mi northwest of the anomaly a small Tertiary latite intrusion (unit Tl, pl. 1) crops out and at the southern border of the anomaly a small rhyolite intrusion is exposed. This small circular anomaly is at the southeast nose of the magnetic anomaly over the granodiorite at Granite Canyon and may be associated with it, or the anomaly could be caused by a contact metamorphic deposit at shallow depth, as suggested by the anomaly's high amplitude and proximity to Paleozoic sedimentary rocks.

A nearly continuous arcuate magnetic feature that extends east-northeast from the head of Dummy Canyon at the western edge of the study area to the vertical-angle benchmark Cherry (fig. 4) correlates with exposures of strongly magnetic Tertiary basalt (unit Tb, pl. 1). The basalt appears to be normally magnetized. This feature abruptly terminates along a northwest-trending magnetic lineament that correlates to a mapped fault (compare with pl. 1). Magnetic anomalies near the mouth of Dummy Canyon are in part related to a mapped intrusive rhyolite unit that contains about 0.5 percent disseminated magnetite.

Small, scattered anomalies near the southern margin of the study area, in the southern Clan Alpine Mountains, are associated with exposures of Tertiary volcanic rocks. The irregular pattern of anomalies reflects both topography and changes in rock magnetization.

At the scale of the aeromagnetic survey, there is no apparent correlation between aeromagnetic anomalies and hydrothermally altered or mineralized rock.

Mineral and Energy Resource Potential

Mineral-Deposit Models

Assessment of the potential for undiscovered metal deposits in the Clan Alpine Mountains Wilderness Study Area is based on interpretation of the geochemical and geophysical data in relationship to the mapped geology and an evaluation of these studies in the context of mineral-deposit models compatible with the geologic terrane and known ore deposits or mineral occurrences in the area.

The geologic characteristics and geochemical signatures of the study area are compatible with three mineral-deposit models: epithermal silver-, gold-, and base-metal (lead, zinc, copper) vein deposits, epithermal antimony-quartz vein deposits, and disseminated-porphyry molybdenum deposits.

Epithermal silver-, gold-, and base-metal vein deposits form in near-surface environments at low to moderate temperatures in the upper part of geothermal systems (Berger, 1982). The most important deposits of this type are Tertiary in age and, in the Basin and Range province of the Western United States, are commonly vein, stockwork, breccia fillings, and replacement deposits in volcanic rocks. Ore minerals include native gold and silver or electrum, telluride minerals, and sulfide minerals of arsenic, antimony, mercury, and base metals (lead, zinc, copper). Evidence of deposition in open spaces is common. Host rocks generally contain structures such as faults, fractures, and zones of brecciation that have allowed ease of movement of hydrothermal solutions through the rocks. Alteration of the rocks by these solutions typically involves silicification and argillization (clay alteration) near the veins.

Antimony deposits are formed by hydrothermal solutions at low temperature and shallow depth and typically occur as fissure-filling veins or pods in siliceous (quartz) gangue and as irregular replacement deposits (see, for example, Jensen and Bateman, 1981, p. 443–445). Stibnite is the common antimony ore mineral and is generally associated with pyrite, arsenopyrite, cinnabar, or scheelite and varying amounts of copper, lead, silver, and zinc sulphides. Some of the high-grade antimony deposits in the world are shallow quartz veins containing stibnite and base-metal sulphides that occur in fine-grained clastic sediments or limestone.

Disseminated-porphyry molybdenum deposits of the Climax type (see for example, discussions in Guilbert and Park, 1986, p. 429–433, and references therein) are characterized by association with high-silica (felsic) igneous rocks of multiple intrusive phases and generally contain one or more phases of intrusive porphyritic rhyolite. A zonation of pervasive hydrothermal alteration is generally associated with these deposits. Geochemical signatures consist of molybdenum nearest to the deposit, tin and tungsten anomalies in rocks just above the deposit, and zinc and lead peripheral to tin and tungsten (Theobald, 1982, p. 47–48). Fluorine is pervasive, with fluorite being the most common fluorine-bearing mineral in peripheral anomalies.

Characteristics of Known Deposits

Silver and gold have been mined from epithermal quartz veins and silicified shear zones in volcanic rocks in an area extending northwest from Florence Canyon on the south to Starr Canyon and including prospects in the upper part of the Cherry Creek drainage north of Starr Canyon (pl. 1). Mines and prospects in this area are included in the Clan Alpine mining district by Schrader (1947, p. 324–330), who reported that small amounts of silver and gold were produced from the area and that most deposits were predominantly silver-bearing. Most of the deposits are contained in quartz veins and mineralized shear zones in rhyolitic volcanic rocks. Ore minerals include cerargyrite, argentite, and native gold. Quartz and adularia are common gangue minerals. Rock samples of vein quartz and silicified rock in a shear zone from mine workings just south of the mouth of Florence Canyon (southeastern part of the mineralized zone) contain as much as 200 ppm silver and 3.5 ppm gold (Willden and Speed, 1974). Prospects and mine workings at the head of Starr Canyon (northwestern part of the mineralized zone) contain mineralized quartz vein material and altered volcanic rocks that yield values of 0.017–1.79 ppm gold and 0.36–15.3 ppm silver except for one sample analyzing 123 ppm silver (Olson, 1987).

Antimony-quartz vein deposits have been mined in the Bernice district, encompassing Bernice and Hoyt Canyons on the west flank of the Clan Alpine Mountains approximately 7 mi north of the north margin of the study area (fig. 2). Silver and antimony were mined in the district, silver being the principal ore produced. The district produced approximately 500 tons of antimony ore, primarily from the Antimony King and Lofthouse mines (Vanderburg, 1940). Antimony in these deposits occurs as pods (as much as 2 ft across), blebs, and veinlets of stibnite (antimony sulfide) in quartz veins (4 in. (inches) to 4 ft wide) that cut Triassic sedimentary rocks, principally siltstone but including interbedded limestone, fine-grained quartzite or sandstone, and chert conglomerate. Rock units similar to the host rocks in the Bernice district occur locally in the northeast corner of the study area.

Molybdenum deposits are not known to exist in the study area nor in the Clan Alpine Mountains in the vicinity of the study area. A prospect on the east flank of the range approximately 6 mi northeast of the study area was reported to contain molybdenum (Schrader, 1947). The molybdenum there, however, was probably associated with tungsten-bearing skarn adjacent to a granite intrusion. Deposits of disseminated molybdenum of the porphyry molybdenum or Climax-type are possible within the study area given its geologic environment. Porphyry molybdenum deposits associated with caldera-related volcanic piles, especially their ring-fracture or post-collapse intrusive rhyolitic-granitic rocks, are well documented elsewhere in the Western United States (Lipman, 1984) and suspected beneath other volcanic complexes (see, for example, Cocker and Pride, 1979). The post-caldera, collapse-related rhyolite intrusions in the northern and western parts of the study area provide a geologic environment compatible with porphyry molybdenum occurrences and may locally contain or overlie potential molybdenum deposits at deeper structural levels.

Potential for Undiscovered Metal Resources

Combined geologic and geochemical evidence suggests there is moderate resource potential for undiscovered, unexposed metalliferous deposits within the wilderness study area. Silver-gold epithermal vein, epithermal antimony vein, and disseminated-porphyry molybdenum are the deposit types most likely to occur in the area.

Geological mapping and geochemical sampling indicate that precious-metal (silver-gold) mineralization and associated hydrothermal alteration occurred in a zone trending northwest from the mines near the mouth of Florence Canyon, across Starr Canyon, and extending north to Cherry Creek (pl. 1). In this zone, volcanic rock shows weak to locally intense argillic (clay) alteration and locally strong silicification along faults, shear zones, and related fractures. Rocks adjacent to structures are commonly bleached and stained with iron oxide or manganese. Open-space mineralization and brecciation are common aspects of the structures in this zone. Quartz vein material, altered wall rock, and silicified fault gouge locally are anomalous in silver and gold along with some molybdenum, and contain minor, but anomalous, amounts of lead, antimony, arsenic, and copper. Most of the altered and mineralized rock in this zone, along with many of the observed prospect pits, occurs along or adjacent to a northwest-trending high-angle normal fault extending across Starr Canyon from the southeast and into the upper reaches of Cherry Creek (pl. 1). The locally intense alteration, known mineralization, and favorable anomalous rock geochemistry along this structure indicate high mineral resource potential for epithermal vein deposits of silver and gold in this area, with certainty level C. A detailed study of the alteration mineralogy and zoning along this fault is necessary to determine what mineralization level of the epithermal system is exposed along this fault and to determine the possible occurrence of metallic mineral deposits at depth. Weakly anomalous rock geochemical values and localized weakly altered rock along Cherry Creek and adjacent to lower Florence Canyon suggest these areas have moderate resource potential for similar epithermal silver-gold deposits, with certainty level B (pl. 1). More detailed geologic mapping and geochemical studies would be required to evaluate more fully the potential for metallic mineral deposits in these areas.

In the northeastern part of the study area (pl. 1), two zones have a moderate mineral resource potential, at certainty level B, for antimony in epithermal vein deposits. Favorable host rocks (unit TRs) are present here and contain such deposits north of the study area. Limited geochemical data indicate the presence of anomalous amounts of antimony but no anomalous amounts of silver. Local weak alteration of rocks in these areas, the presence of faults and proximity to a probable caldera margin providing the plumbing system for circulating hydrothermal fluids, and the geophysical evidence of a possible intrusive body at depth in this area, together, lend support to the possibility of an unexposed metallic mineral deposit. A more detailed geochemical study of these Triassic sedimentary rocks, along with more detailed geophysical surveys, would be required to evaluate more fully the potential of a metallic mineral deposit in the subsurface.

The geologic environment of parts of the study area is favorable for disseminated-porphyry molybdenum deposits. Two areas, upper War Canyon on the east side of the range and Grover Canyon on the west side, contain exposures of intrusive porphyritic rhyolite and limited amounts of altered rock. These occurrences, combined with traces of fluorite associated with the rhyolite intrusion in upper War Canyon and the presence of anomalous amounts of molybdenum in the heavy-mineral fraction of stream sediments collected downstream from this intrusion, suggest the possible presence of an unexposed molybdenum-mineralized system in upper War Canyon. Likewise, in Grover Canyon, exposures of intrusive porphyritic rhyolite are extensive, and nearby breccia that is dominantly composed of altered-pyritized rhyolite fragments contains anomalous amounts of molybdenum. Heavy-mineral stream-sediment concentrates from this area also yield anomalous molybdenum values. These geologic and geochemical factors suggest the possible presence of molybdenum mineralization in the subsurface.

Extrapolation of the geologic and geochemical data in terms of a disseminated-porphyry molybdenum deposit model indicates a reasonable possibility for the presence of molybdenum deposits in the War Canyon and Grover Canyon areas (pl. 1). These areas are assigned a moderate resource potential for molybdenum, with certainty level B. A more detailed study of the intrusive rhyolites in these areas combined with a systematic program of sampling altered and unaltered rock is necessary to evaluate more fully the possibility of molybdenum deposits in these areas.

Except for those areas of high to moderate resource potential discussed above, the available geological, geochemical, and geophysical data indicate the remainder of the study area has low mineral resource potential for all metals, with certainty level B.

Potential for Undiscovered Zeolite Resources

Zeolites have been identified in weakly altered volcanic rocks and minor amounts of volcaniclastic tuffaceous sedimentary rocks in the vicinity of the mouth of War Canyon on the east margin of the study area (pl. 1). The zeolite mineral clinoptilolite was identified by X-ray diffraction of pale-green to pale-yellowish-green rock samples collected just north of the mouth of War Canyon. Analcime likewise is reported in rocks from the same area (see section on appraisal of identified resources, this report). The zeolite occurrences appear to be associated with the weakly colored, green or yellow-green rocks as compared to the normally buff to pale-gray unaltered rocks in this area. The weak discoloration of rocks is not pervasive through the area but occurs in isolated patches or along fractures in rhyolite intrusions or flow rock and less commonly in isolated lenses of volcaniclastic sedimentary rock.

The nearest known actively prospected zeolite occurrence is approximately 17 mi south of War Canyon near Eastgate, Nev., on Nevada State Route 2 (Papke, 1972, p. 13). The zeolites there occur in Pliocene lake deposits consisting of mudstone, waterlaid tuff, ash, and conglomerate. The zeolite-rich beds in these deposits, which apparently have not proven to be economical, range in thickness from 6 in. to 7 ft.

In contrast to the subaqueously deposited lake beds of the Eastgate prospects, which were substantially altered to zeolites (most likely during diagenesis under saline water-saturated conditions (Sheppard, 1971, p. 303)), the intrusive and subaerially deposited volcanic and volcaniclastic rocks of the War Canyon area were only weakly altered by probable groundwater circulating along fractures in the rocks. Because of the limited extent of apparent zeolite mineralization in the War Canyon area and the less favorable geologic processes having affected the rocks there, compared to those producing the known zeolite deposits south of the study area, the War Canyon area is judged to have a low resource potential for zeolites, with a certainty level of C. More systematic sampling of rocks in the study area combined with X-ray diffraction and petrographic studies are required to be sure of the extent of the areas having low resource potential.

Potential for Undiscovered Petroleum Resources

Accumulation of petroleum (oil and gas) in any geologic environment is governed by the presence of source rocks, maturation history of hydrocarbons, reservoir rocks, and petroleum traps. Consideration of these parameters in the context of regional geology, known oil and gas occurrences in the Great Basin, and previous qualitative appraisals by petroleum geologists led to a petroleum resource potential assessment of "zero" for the Clan Alpine Mountains Wilderness Study Area (Sandberg, 1983a, b).

Virtually the entire study area lies within a Tertiary caldera complex that probably has roots in subvolcanic or plutonic igneous rocks. The Triassic sedimentary rocks exposed north of the study area consist primarily of deep-basin, distal turbidites[1] (Speed, 1978), which are unlikely petroleum source rocks and which have been invaded by granitic to gabbroic intrusions (Willden and Speed, 1974). Because of the unfavorable geologic environment in terms of potential petroleum source rocks and the extensive Cretaceous and Tertiary igneous activity affecting any potential source rocks, we consider the entire study area to have a low energy resource potential for petroleum (oil and gas), with a certainty level of C.

Potential for Undiscovered Geothermal Resources

Hot springs occur along the frontal fault system bounding the east side of the Stillwater Range (fig. 2), across Dixie Valley to the northwest from the Clan Alpine Mountains Wilderness Study Area. A geothermal well located along this fault system towards the north end of Dixie Valley (approximately 13 mi north of the study area) is currently being prepared for electrical power generation.

Geothermal resources in rift basins such as Dixie Valley occur where ground water descends into the sedimentary fill in the basin, is heated in response to the geothermal gradient, and is forced by the regional hydraulic gradient to issue along basin-margin faults. No hot springs exist within the study area nor along the range fronts paralleling the east and west study area boundaries. Likewise, no evidence was found for previous hot springs activity within the study area. The mountainous terrain encompassed by the study area is more likely an area of recharge to the hydrologic regime of the adjacent Dixie Valley basin than it is a discharge site for geothermal waters. The study area, therefore, is given a low potential for geothermal energy, with a certainty level of C.

[1]Moderately sorted, fine-grained sedimentary rocks generally having graded bedding, formed by density currents laden with suspended sediment moving down a subaqueous slope and spreading horizontally on the deeper floor of the body of water.

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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.

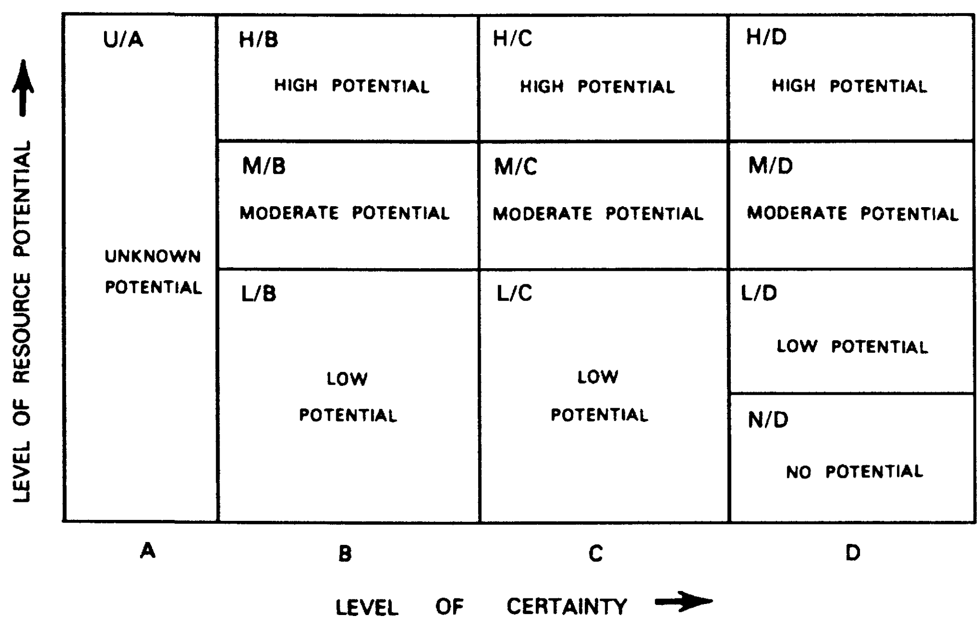
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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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 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.

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