Mineral Resources of the Charles Sheldon Wilderness Study Area, Humboldt and Washoe Counties, Nevada, and Lake and Harney Counties, Oregon

By U.S. GEOLOGICAL SURVEY *and* U.S. BUREAU OF MINES

STUDIES RELATED TO WILDERNESS—WILDERNESS AREAS

GEOLOGICAL SURVEY BULLETIN 1538

An evaluation of the mineral potential of the area

Summary and Chapters A through D

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STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS

In accordance with the provision of the Wilderness Act (Public Law 88–577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. Areas officially designated as "wilderness, wild, or canoe" when the Act was passed were incorporated into the National Wilderness Preservation System, and some of them are currently being studied. The Act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This report discusses the results of a mineral survey of some of the land in the Charles Sheldon Wilderness Study Area, Humboldt and Washoe Counties, Nevada, and Lake and Harney Counties, Oregon, that is being considered for wilderness designation.

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MINERAL RESOURCES OF THE CHARLES SHELDON WILDERNESS STUDY AREA, HUMBOLDT AND WASHOE COUNTIES, NEVADA, AND LAKE AND HARNEY COUNTIES, OREGON

By U.S. GEOLOGICAL SURVEY and U.S. BUREAU OF MINES

SUMMARY AND INTRODUCTION

A mineral survey of the Charles Sheldon Wilderness Study Area, in Humboldt and Washoe Counties, Nev., and Lake and Harney Counties, Ore., was conducted in 1974 and 1975 (figs. 1, 2, 3). The mineral-resource potential was evaluated by geological, geochemical, and geophysical studies by the U.S. Geological Survey, and by the examination of mines, prospects, and other mineralized localities by the U.S. Bureau of Mines. The investigation identified several areas of significant mineral potential within the study area, which includes the Charles Sheldon Antelope Range and the Sheldon National Antelope Refuge (fig. 2). The Virgin Valley area contains reserves of precious opal, small quantities of decorative building stone, and low-grade uranium resources. The investigation indicates that there are several areas of potential for the discovery at depth of mercury and for base and complex precious-metal sulfide deposits within the study area. Reservoir temperatures, estimated from the analysis of thermal springs, suggest that the area has low to moderate potential for geothermal resources. The potential for oil, gas, or coal is very low.

Outcrops within the study area consist entirely of volcanic and continental sedimentary rocks of late Tertiary and Quaternary age. These rocks rest on a burial basement that probably comprises Permian, Triassic, and Jurassic metavolcanic and sedimentary and Jurassic and Cretaceous granitic rocks. The thickness of the upper Tertiary and Quaternary rocks is variable but is on the order of 950 to 1,900 ft (feet) (300 to 600 m or meters). The Cenozoic units are flat lying or gently dipping and show much interfingering in local basins.

Volcanic rocks are andesite lava flows, rhyolite ash-flow tuffs, and

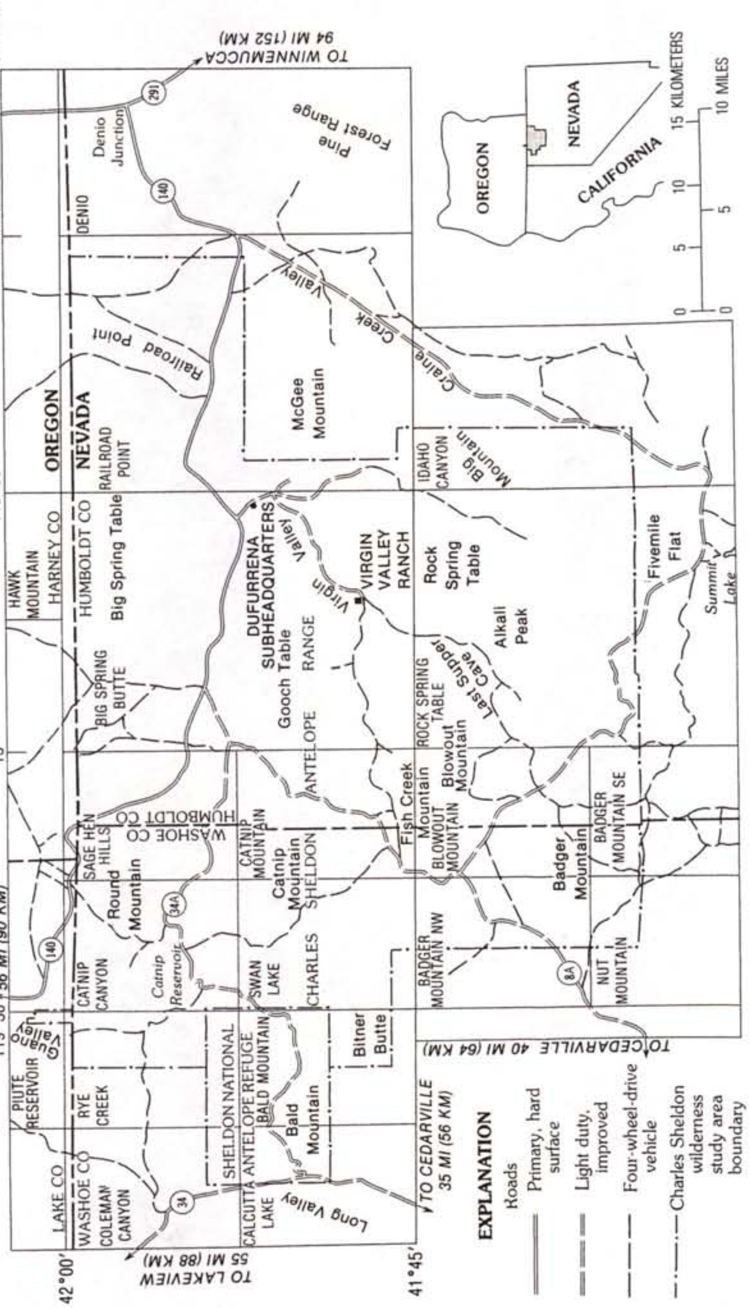

FIGURE 1.—Map showing location and geographic features of the Charles Sheldon Wilderness Study Area, Humboldt and Washoe Counties, Nev., and Lake and Harney Counties, Ore.

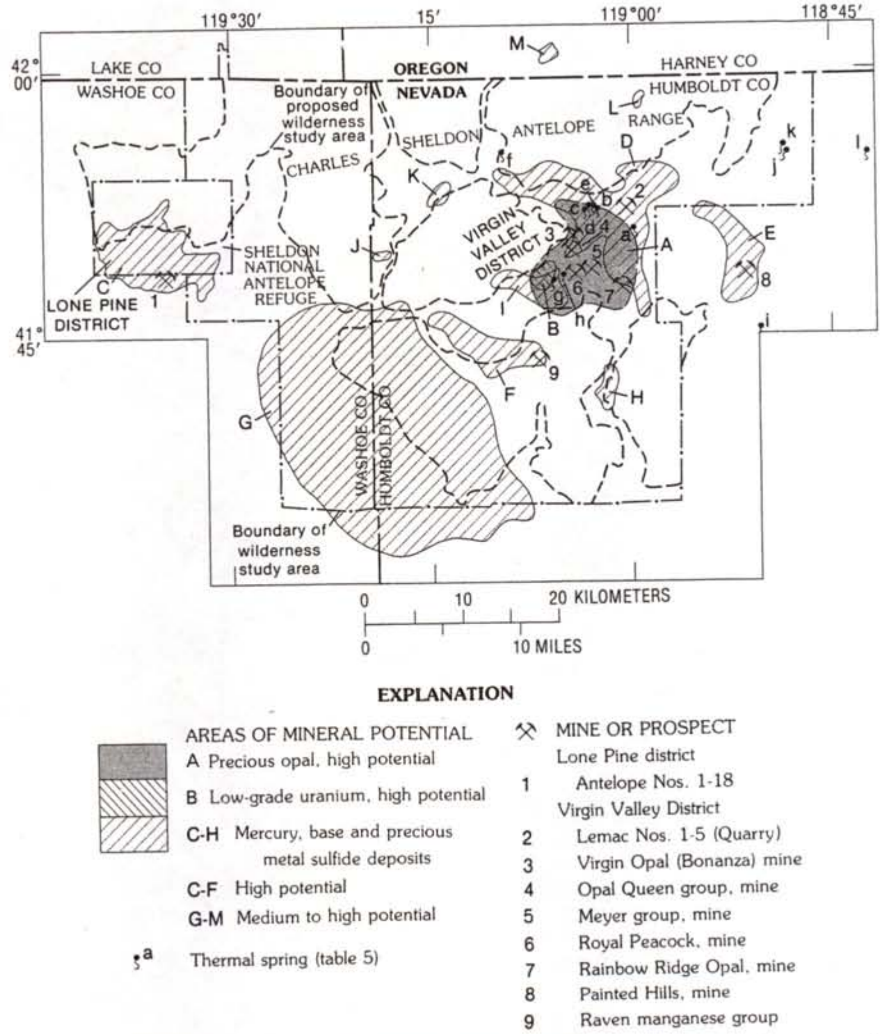

FIGURE 2.—Map showing areas of potential mineral resources in relation to the proposed wilderness boundaries within the Charles Sheldon Wilderness Study Area.

basalt flows. The andesitic rocks are the oldest and are middle Miocene (about 15–16 m.y., or million years, by potassium-argon methods) in age. The ash-flow tuffs are slightly younger and are parts of widespread tuff sheets recognized elsewhere in northwestern Nevada. Basalt flows that cap much of the area are variable in age; some are as old as about 9 m.y., and others are as young as about 1–2 m.y. Tuffaceous sedimentary strata are lenticular units at many horizons in the section and are especially thick in ancient valleys such as Virgin Valley.

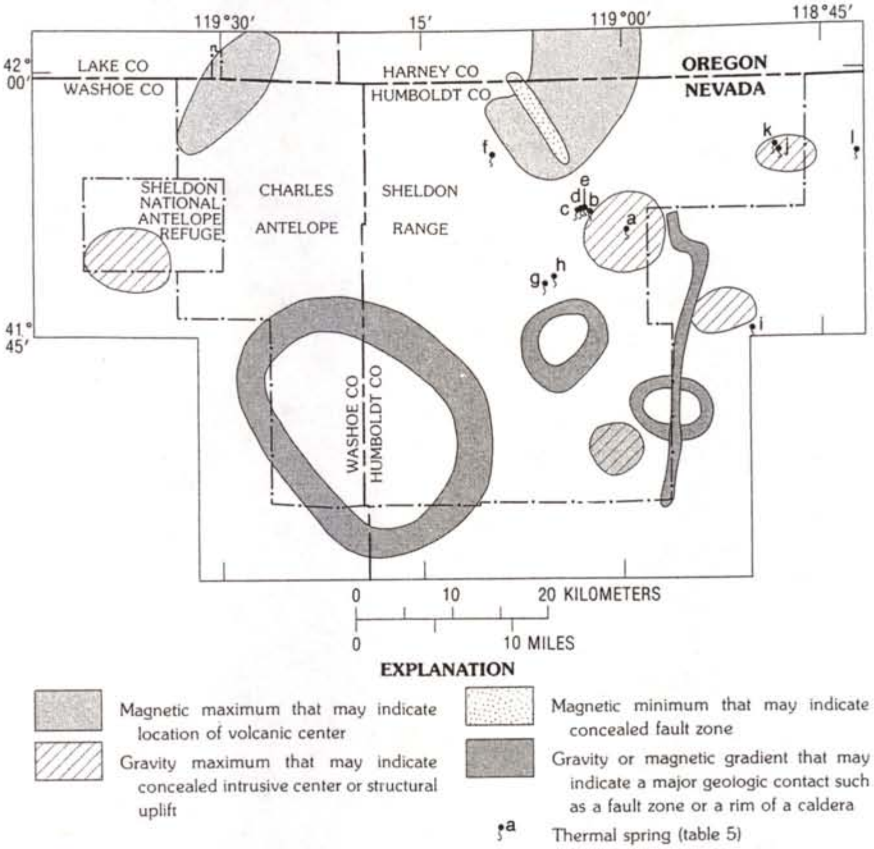

FIGURE 3.—Map showing prominent gravity and magnetic anomalies in the Charles Sheldon Wilderness Study Area.

Basin and range faults in the Charles Sheldon Antelope Range and the Sheldon National Antelope Refuge are fewer in number, have less offset, and have a different trend than in surrounding regions of the Great Basin. The general trend of the faults is northwest in the Range and Refuge; it is northeast in adjacent regions. There are no major mountains of block-fault origin in the study area.

Geophysical investigations consisted of gravity and aeromagnetic surveys (fig. 3). The gravity map shows a decrease in gravity-anomaly level of about 15 mgal (milligals) between the study area and the Pine Forest Range to the east, where pre-Tertiary rocks are exposed. If the observed difference in gravity level is entirely an effect of an estimated 0.2 g/cm^3 (grams per cubic centimeter) density contrast between the Tertiary and pre-Tertiary rocks, the study area is underlain by about 5,760 ft (1,800 m) of Tertiary and younger rocks. The 15-mgal change of gravity level mostly occurs within a north-trending 6.4 mi (10.3-km) zone along the west edge of the Pine Forest Range, indicating a major fault boundary. A fault zone also is indicated by northwest-trending gravity contours centered about 9.6 mi (15.5 km) northeast of the Charles Sheldon Antelope Range headquarters. Fault zones or major geologic contacts similarly are indicated by the occurrence of approximately linear magnetic contours near the east and northeast edges of the study area. The rather linear zones of high gravity or magnetic gradients are considered possible sites for future mineral exploration.

The occurrence of four gravity maxima in or along the edge of the study area suggest the presence of concealed intrusive centers or uplifted localities. The westernmost gravity anomaly occurs at a structurally uplifted location near the Lone Pine mining district at the west edge of the study area. Two gravity maxima that occur near thermal springs along the east edge of the study area seem too broad to be explained wholly as an effect of local densification of the underlying tuffaceous sedimentary rocks by compaction and filling of preexisting pore space with precipitates from mineral-rich thermal waters. A magnetic maximum nearly coincides with the location of the fourth gravity maximum in the southeast corner of the study area. Two broad magnetic maxima near the northeast and northwest corners of the study area probably reflect concealed extensions of volcanic centers that are exposed to the north of the study area. The localities of gravity or magnetic maxima are considered possible sites for future possible mineral exploration, if such studies are undertaken.

Three prominent closed gravity minima along the south edge of the study area may reveal underlying calderas, which are masked by younger Tertiary rocks. The largest possible caldera is about 10.52 by 15.5 mi (17 by 25 km) in size, and, if the assumed underlying tuffaceous sedimentary rocks are, on the average, 0.2 g/cm^3 less dense than the surrounding volcanic rocks, the caldera extends to a depth of about 1.7 mi (2.7 km). The areas along the edges of the postulated calderas are considered sites for possible future mineral exploration.

Identified by geochemical sampling, anomalous concentrations of gold, mercury, antimony, arsenic, tungsten, molybdenum, manganese, and barium, and anomalous cadmium:zinc ratios form dispersion patterns that delineate target areas for possible exploration for concealed mineral deposits. The areas of possible potential metallic resources within the study area are shown on figure 2, letters C–M.

The south part of the Sheldon National Antelope Refuge (area C, fig. 2) has possible potential for mercury deposits and for concealed base and complex precious-metal sulfide deposits. A mercury anomaly occurs in a large part of the area. In addition, the anomalous concentration of the other elements mentioned above and the anomalous cadmium:zinc ratios form dispersion patterns that are contiguous with normal faults and with some magnetic or gravity highs, or both.

Additional areas that may contain mercury and concealed base and complex precious-metal sulfide deposits are the areas encompassing the Subheadquarters (area D, fig. 2) and Painted Hills mine (area E, fig. 2). The geochemical dispersion patterns and their relationship to geological structures, geophysical anomalies, and alinement of thermal springs suggests that the Subheadquarters and Painted Hills mineralized areas may be joined at depth and may extend northwestward beneath younger volcanic rocks.

Area F in figure 2 has a possible potential for similar metallic resources. Most of the valley of Hell Creek from its source to its junction with Virgin Creek is fault controlled. The area near the junction of Hell Creek and Virgin Creek is contiguous with a geophysical anomaly. Anomalous amounts of mercury, arsenic, antimony, molybdenum, barium, gold, and manganese, anomalous cadmium:zinc ratios, as well as several mercury prospects, seem to be associated with the faults and the western edge of a geophysical anomaly.

In the southwestern part of the Range, gravity and magnetic anomalies of substantial size suggest the possible existence of a caldera or buried pluton. The widespread geochemical anomalies in this area are similar in size and magnitude to the mineralized McDermitt Caldera approximately 82 mi (132 km) to the northwest in the Opalite mining district. Whether a caldera or buried pluton is present in the area, the geochemical data suggest that area C shown on figure 2 has a possible potential for concealed mercury and complex precious-metal sulfide deposits.

Areas H through M on figure 2 are other localities where anomalous concentrations of some of the elements discussed, anomalous ratios, and detectable gold occur in either stream sediments or rocks.

The study area contains two mining districts: the Virgin Valley near the eastern edge of the Range, and the Lone Pine near the southern part of the Refuge. Production from the study area is estimated to have been several million dollars, nearly all production coming from the Virgin Valley district. Precious opal accounted for more than 75 percent of the total. Significant deposits are at the Rainbow Ridge Opal, Royal Peacock, and Virgin Opal (Bonanza) mines in the Virgin Valley district (area A, fig. 2). More than 18,000 tons (16,000 t, or metric tons) of ornamental dimension stone valued at \$60/ton (\$66/t) and about 15 tons (14 t) of fluorescent opalite have also been produced from the Virgin Valley district. A small amount of mercury reportedly was produced from the Lone Pine district.

One thousand six hundred fifty-six lode and 98 placer claims have been located within the study area. Three hundred ninety-three claims are being actively worked.

Precious opal reserves and resources in the Virgin Valley district are estimated to be several million dollars in the following mines: Meyer group, Opal Queen group, Rainbow Ridge Opal, Royal Peacock, and Virgin Opal (Bonanza) (area A, fig. 2). Resources of ornamental dimension stone adjacent to the quarry in the Virgin Valley district are estimated to be more than 250,000 tons (227,000 t) of poor-quality stone.

A submarginal uranium resource in tuffaceous sediments (area B, fig. 2) in the Virgin Valley district may contain 15–20 million tons (14 to 18 million t) of uranium ore. Uranium may occur in tuffaceous sediments beneath younger volcanics adjacent to the Virgin Valley uranium occurrences (area B, fig. 2) or in tuffaceous sediments associated with hot springs. Anomalous concentrations of some of the elements discussed, anomalous element ratios, and detectable gold are associated with the known uranium occurrences.

INTRODUCTION

LOCATION AND ACCESS

The Charles Sheldon Wilderness Study Area is in the vicinity of the junction of California, Oregon, and Nevada in Humboldt and Washoe Counties, Nev., and in Lake and Harney Counties, Ore. (fig. 1). The study area includes the Charles Sheldon Antelope Range and Sheldon National Antelope Refuge, which are approximately 82 mi^2 (2,140 km^2) in size. In this report, these areas are referred to as the "Range" and the "Refuge." The Range and Refuge have been under the dual management of the U.S. Bureau of Sport Fisheries and Wildlife, whose headquarters are in Lakeview, Ore., and the U.S. Bureau of Land Management, whose headquarters are in Cedarville, Calif.

The study area is far from any large town. Virgin Valley, location of the Dufurrena Subheadquarters and principal focus of activity in the Range, is 120 mi (192 km) from Winnemucca, Nev. (paved road), 95 mi (153 km) from Lakeview, Ore. (paved road), 88 mi (142 km) from Cedarville, Calif. (56 mi or 90 km of gravel road), and 51 mi (82 km) from Fields, Ore. (paved road). Denio Junction, with a combined gas station, motel, and restaurant, is 25 mi (40 km) away (paved road). In this report the Dufurrena Subheadquarters is referred to as the Subheadquarters.

Access within the Range and Refuge is provided by a network of gravel and dirt roads, branching from the paved Nevada-Oregon Route 140 (fig. 1). Nevada routes 8A and 34A are fair to good gravel roads and are also arterial routes. Other good gravel roads lead up Virgin Valley to the Virgin Valley Ranch (Wilson ranch), between Badger and Blowout Mountains to Fivemile Flat and Summit Lake, and from Thousand Creek up Craine Creek valley to Summit Lake.

Other roads in the Range and Refuge are rough and require four-wheel drive vehicles. Access to the tops of Big Spring, Gooch, and Rock Spring Tables is poor.

PROPOSED WILDERNESS

In 1971 certain parts of the Range, Refuge, and adjacent areas were first proposed for wilderness status. By 1974, the proposed wilderness was expanded to include eight units totaling 533 mi^2 (1,380 km^2) inside the Range and Refuge and 29 mi^2 (75 km^2) adjacent to it for a total of 562 mi^2 (1,455 km^2) (fig. 1B).

WILDLIFE AND VEGETATION

Wildlife in the area is diversified, but antelope is the species chiefly associated with the Refuge and Range. About 1,500 antelope are present at the peak period of winter use. Antelope of an interstate herd move in considerable numbers from Oregon to winter on the Refuge and Range. Summer populations are lower and usually total about 800 animals. Deer use the higher mountains extensively in summer and fall but many move off the Refuge and Range to winter at lower elevations farther east. The California bighorn sheep, originally indigenous, was extinct in the area by 1930. Sheep were reintroduced in 1968, and a small herd is becoming established in the Hell Creek drainage. Other native mammals include the coyote, bobcat, mountain lion, and a host of smaller mammals characteristic of the region. Free-roaming horses and burros are also present in substantial numbers. More than 145 species of birds have been recorded. Birds vary seasonally in numbers and species but are always most abundant and diverse around springs or other water sources. The ponds, reservoirs, and intermittent lakes total about 67,900 acres (27,500 ha) and are favored by migrating ducks, geese, swans, and a variety of other waterfowl. Peak waterfowl populations may be as large as 20,000. The native sage grouse and introduced chukar partridge are periodically abundant. Fishery resources are meager, but Catnip Reservoir supports the endangered Lahontan cutthroat trout. It is reserved exclusively for restocking purposes. A number of amphibians and reptiles have been recorded, but like small mammals, no extensive inventory has ever been made.

Sagebrush and some grasses cover most of the valley areas. The table tops are covered with low sagebrush and some stands of big sagebrush and grass. Patches of mountain mahogany clothe some slopes at higher elevations, giving way to willow, cottonwood, and aspen in some drainages at lower elevations. Springs and seeps are often associated with small meadows.

ARCHAEOLOGICAL SITE

Early man's presence in the area dates to at least 10,000 years ago—to the great pluvial lakes of the Pleistocene Epoch. Caves such as the Last Supper Cave in Hell Creek canyon provide a chronology of occupancy. This cave is the only known archaeological site of major size still intact.

CLIMATE

The Charles Sheldon Wilderness Study Area is classified by Sthraler (1969) as having a middle-latitude desert climate, in an interior region shut off by mountains from invasions of maritime air masses but dominated by continental tropical air masses in summer and continental polar air masses in winter. This climate has an annual temperature range from less than –4°F (–20°C) in winter to more than 99°F (37°C) in summer. The high altitude produces a daily summer temperature change frequently exceeding 50°F (10°C) and an abnormally short frost-free period. Precipitation ranges from 5 to 15 in. (13 to 38 cm) annually, mostly falling as snow or winter rains. During the summer the relative humidity averages about 20 percent and may fall to 10 percent. The lower elevations may have an average growing season of about 75 days, and higher elevations may have frost in any month of the year.

TOPOGRAPHIC AND GEOLOGIC SETTING

The Range and Refuge are in the northwestern part of the Great Basin section of the Basin and Range province (Fenneman, 1931, p. 326). Topographically, the Range and Refuge are mostly flat plateaus and rounded mountains, locally broken by steep scarps or cut by canyons. High fault scarps adjacent to flat alluvial valleys, a characteristic feature of the Great Basin, are present both on the east (McGee Mountain–Craine Creek valley) and west (Round Mountain–Guano Valley and Bald Mountain–Long Valley) sides of the area.

Several peaks (Catnip, Bald, Badger, and Fish Creek Mountains) have summit elevations slightly higher than 6,890 ft (2,100 m) above sea level; total relief in the area is slightly more than 2,950 ft (900 m).

The Range and Refuge are on the southeast flank of a broad basin filled with sedimentary and volcanic rocks of Tertiary and Quaternary age that occupies northwesternmost Nevada, northeastern California, and south-central Oregon. Pre-Tertiary rocks adjacent to this basin to the southeast include Cretaceous granitic rocks and Permian, Triassic, and Jurassic volcanic and sedimentary rocks. These are found in the Pine Forest Range and Pueblo Mountains 6.2–9.3 mi (10–15 km) east of the Range boundary. Paleozoic and Mesozoic metamorphic and Cretaceous granitic rocks of the Sierra Nevada Mountains, more than 93 mi (150 km) away, bound the southwestern side of the basin.

This basin is dominated by northwest-trending normal faults. The structural break between this area and the northeast-trending fault-block ranges to the east occurs at the Pine Forest Range and the Black Rock Desert to the south.

PREVIOUS STUDIES

Reconnaissance mapping in 1971 (unpublished) by D. C. Noble covered the Humboldt County part of the Range, and mapping for a thesis by W. G. Wendell (1970) included the Virgin Valley and McGee Mountain areas. The Washoe County part of the Range and Refuge is included on the county map by Bonham and Papke (1969).

Several investigators have reported the occurrence of valuable minerals in or near the Charles Sheldon Wilderness Study Area.

Ross (1941, p. 23) reported on numerous mercury prospects and mines in the vicinity of the junction of California, Oregon, and Nevada. The nearest occurrence of cinnabar to the study area is in the Lone Pine district approximately 6.4 km southwest of the headquarters of the Sheldon National Antelope Refuge (fig. 2). The main occurrences of mercury are just south of the Refuge, although several small prospects are just within the boundary (Holmes, 1965, p. 269). Sporadic exploration since 1929 has not resulted in production. Bonham and Papke (1969, p. 70) reported that trace amounts of gold occur with cinnabar in the Lone Pine district; however, mineable amounts of gold were not found by prospecting.

Wendell (1970, p. 109) indicated that cinnabar was found along a major fault that is adjacent to the Painted Hills mine (fig. 2). He reported that recent movement along one of the associated faults is indicated by steam emission; temperatures in a drill hole within the fault zone were 131°F (55°C) at a depth of 200 ft (60.9 m) (Wendell, 1970, p. 98).

Staatz and Bauer (1951) reported the discovery of uraniferous opal in the Virgin Valley district (fig. 1). This district has produced some of the best gem opal found in the United States; however, no production of uranium has been reported.

Harold Stager (U.S. Geological Survey, written commun., 1976) reported visiting the Raven manganese claims (fig. 2) in June 1959. The deposit consists of beds of cryptomelane interbedded with volcanic ash, silt, fine sand, and diatomite. No production has been reported from these claims.

U.S. Geological Survey and Nevada Bureau of Mines (1964) mentioned fire opal, dimension stone, and uranium occurrences in Virgin Valley.

PRESENT INVESTIGATIONS

A new geologic map of the Range, Refuge, and vicinity was prepared for the present mineral-resource study (pl. 1). It includes all areas mentioned in the various wilderness proposals. In much of the Humboldt County part, the map is identical with the 1971 mapping by D. C. Noble; elsewhere it differs.

Field mapping was done by R. C. Greene in October 1974, and May and June 1975, and by R. C. Greene assisted by K. L. Stark in July 1975. Uranium deposits were investigated by J. E. Peterson in May 1975.

The present geochemical investigations were conducted by J. B. Cathrall assisted by D. F. Siems, Steve Taylor, and Dwight Rhiner during the summer of 1975. About 6 weeks were spent in the field collecting samples and examining areas reported to be mineralized. A total of 1,280 rock and stream-sediment samples was collected and analyzed in a mobile laboratory in the field by E. F. Cooley, G. L. Crenshaw, and James Hurrell. These results were supplemented by additional analyses in the Geological Survey laboratories in Denver, Colo.

Analytical data, type of materials sampled, and coordinates of sample localities were entered into the Geological Survey computer data storage system RASS (Rock Analysis Storage System) from a field-based computer station operated by R. J. Smith and M. L. Marchitti. The analytical data were retrieved from the RASS system and were analyzed statistically by a variety of computer programs. These programs consisted of graphical analyses, simple linear correlation coefficients among logarithms, and cumulative frequency plots.

Listing of analytical results for rock, stream-sediment, and water samples; calculated minimum thermal-reservoir temperatures; statistical summary of the analytical results for rock and stream-sediment samples; and the stream-sediment and rock sample sites are in Cathrall and others (1977).

A gravity survey was carried out by S. L. Robbins and K. D. Holden in October 1975. Interpretations of geophysical data were done by Donald Plouff.

No systematic attempt was made by the Geological Survey to sample prospects or claims for quantitative estimation of mineral content, as these aspects were covered by personnel of the U.S. Bureau of Mines under the supervision of E. T. Tuchek, assisted by F. L. Johnson and M. D. Conyac (Chap. E of this report).

ACKNOWLEDGMENTS

The field party was headquartered at the Subheadquarters of the Range and at the adjacent Virgin Valley campground. The authors appreciate the many courtesies extended by the ranger at the Subheadquarters and his wife, Henry and Happy John, who also provided a historical sketch of the area. The authors extend appreciation to claim holders, property owners, and local residents Ed and Louise Mitchell and Harry and Joy Wilson. Special acknowledgment is due Harry Wilson and Keith Hodson for providing historical background data on precious opal. Special thanks are due to our colleagues who assisted in retrieving and restoring critical geochemical data destroyed by the fire at the Denver Federal Center in March 1976.

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Geologic Appraisal of the Charles Sheldon Wilderness Study Area, Nevada and Oregon

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GEOLOGICAL SURVEY BULLETIN 1538–A

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MINERAL RESOURCES OF THE CHARLES SHELDON WILDERNESS STUDY AREA, HUMBOLDT AND WASHOE COUNTIES, NEVADA, AND LAKE AND HARNEY COUNTIES, OREGON

GEOLOGIC APPRAISAL

By R. C. GREEN, U.S. Geological Survey

INTRODUCTION

The Charles Sheldon Wilderness Study Area is underlain entirely by volcanic and continental sedimentary rocks of late Tertiary and Quaternary age. The rocks are flat lying or gently dipping and lap in and out against each other. In most areas the stratigraphic succession can be easily deciphered. The rocks are broken by numerous normal faults (pl. 1).

STRATIGRAPHIC NOMENCLATURE

Both formal and informal names for rock units that have already appeared in the literature are adopted wherever possible. A few local units are left unnamed and several new informal names are introduced.

Canon (also spelled Canyon by some) Rhyolite is an old name introduced by Merriam in 1910 as Cañon Rhyolite. Idaho Canyon Tuff, Summit Lake Tuff, and Soldier Meadow Tuff were proposed by Nobel and others in 1970; these tuffs and his informal tuff of Big Mountain and tuff of Trough Mountain are used here. New informal names include the following: rhyolite of Cottonwood Canyon, andesite of Round Mountain, andesite of Bald Mountain, rhyolite of Catnip Mountain, rhyolite of Badger Mountain, rhyolite of Nut Mountain, basalt of Catnip Creek, and basalt of Railroad Point.

STRATIGRAPHY

INTRODUCTION

The Miocene rock units shown on plate 1 are divided into three broad sequences. The lowermost of these units consists of the andesite of Round Mountain and generally correlative older units of rhyolitic to basaltic composition, which appear only in windows (isolated areas surrounded by younger rocks). The middle sequence is the main sequence of rhyolites and welded tuffs with intercalated sediments (Idaho Canyon Tuff through rhyolite of Nut Mountain). The upper sequence consists of basalts which cap the tables on the east and the broad areas on the west, plus immediately underlying and intercalated sediments. The upper sequence is overlain by Quaternary surficial deposits.

LOWER SEQUENCE

RHYOLITE OF COTTONWOOD CANYON

The rhyolite of Cottonwood Canyon occurs on the steep, west-facing scarp separating Bald Mountain and the adjacent plateau from Long Valley. It may be as much as 1,082 ft (330 m) thick and appears to underlie the andesite of Bald Mountain.

The rhyolite of Cottonwood Canyon contains both rhyolite and quartz latite. Exposed low on the scarp and along the road as it enters Cottonwood Canyon is a medium- to light-gray quartz latite with banded to mottled texture and containing trace amounts of plagioclase, hornblende, biotite, and magnetite phenocrysts in a groundmass of plagioclase microlites and cryptocrystalline material. Light-gray rhyolite is exposed higher on some spurs. It contains sparse phenocrysts of quartz, alkali feldspar, plagioclase, biotite, and magnetite in a cryptocrystalline groundmass.

ANDESITE OF ROUND MOUNTAIN

Andesite of Round Mountain underlies Round Mountain and a few square miles or kilometers to the northwest, including part of the major scarp separating the Round Mountain-Antelope Butte area from Guano Valley. It extends as far north as Oregon Highway 140 where it curves west to cross Guano Valley. This unit is at least 885 ft (270 m) thick on the scarp bordering Guano Valley, and an additional 460 ft (140 m) is present on Round Mountain.

A dense, uniform, medium- to dark-gray, greenish-speckled platy andesite is the predominant rock on Round Mountain. Greenish speckles are characteristic. The rock contains 1 to 30 percent microphenocrysts of plagioclase containing trace amounts of clinopyroxene, and, locally, trace amounts of orthopyroxene, olivine, and magnetite, in a groundmass of alined plagioclase microlites, and clinopyroxene, magnetite, and glass.

In addition to the platy andesite, there is a large amount of vesicular, cindery, andesitic agglomerate or breccia exposed in the scarp overlooking Guano Valley, particularly along Oregon Highway 140. Near the short canyon that joins Guano Valley at the State Line, tuffaceous sedimentary rocks interbedded with the andesite are also prominent. Many of the sedimentary layers are baked red where in contact with andesite.

ANDESITE OF BALD MOUNTAIN

Bald Mountain, Bald Mountain Canyon, and a part of the scarp bordering Long Valley directly west of the now abandoned Refuge headquarters is composed of the andesite of Bald Mountain. It is about 1,082 ft (330 m) thick on the main scarp, and there is 394 ft (120 m) more on Bald Mountain. The mineralization of the Lone Pine district in Bald Mountain Canyon is entirely in this unit.

The most typical rock is grayish-red to brownish-gray andesite or dacite containing prominent rudely alined plagioclase phenocrysts that form 5 to 10 percent of the rock. Other phenocrysts present in trace amounts include olivine, clinopyroxene, orthopyroxene, hornblende, biotite, and magnetite. The groundmass is mostly plagioclase microlites and glass, with olivine, clinopyroxene, and apatite locally recognizable. Some of the andesite is vesicular, and black vitrophyre is present locally.

The unit also contains interbedded tuffaceous sedimentary rocks. These are poorly exposed on Bald Mountain, but crop out in Bald Mountain Canyon and on the scarp adjacent to Long Valley (fig. 4).

DACITE

This unnamed unit is exposed in two small areas in the flats immediately southwest of Alkali Reservoir. It consists of dense gray dacite, inflated gray dacite, and red-cinder agglutinate. Some of the dacite is porphyritic and contains a few percent each of quartz and plagioclase phenocrysts, trace amounts of clinopyroxene and magnetite phenocrysts, and a groundmass of plagioclase and glass with minor clinopyroxene and magnetite.

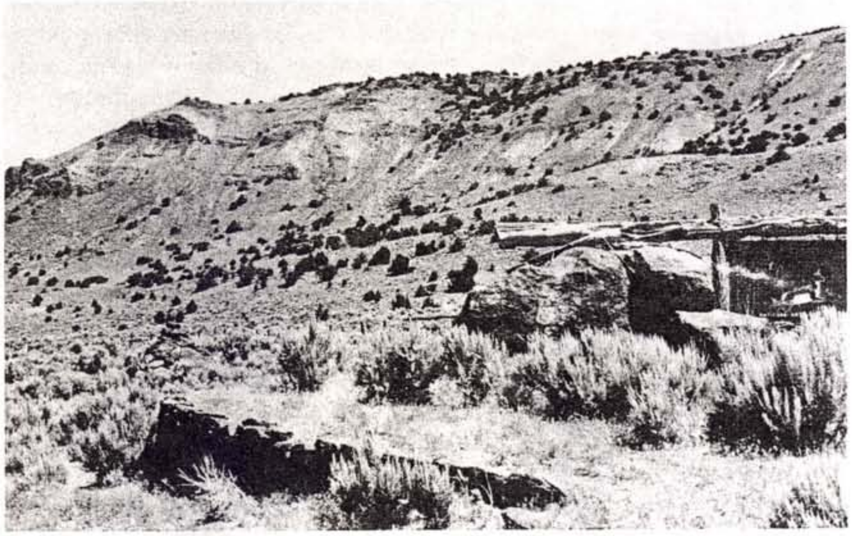

FIGURE 4.—Scarp east of Long Valley (near Calcutta Lake) at Refuge boundary. Exposed in scarp is andesite of Bald Mountain, and abundant interbedded tuffaceous sedimentary rocks, Charles Sheldon Wilderness Study Area.

PORPHYRITIC BASALT

Porphyritic basalt is exposed at the mouth of Idaho Canyon and to the south near the southeast corner of the Range. The porphyritic basalt is characterized by large plagioclase phenocrysts and is similar to Steens Basalt on Steens Mountain north of Denio and in the Bilk Creek and Trout Creek Mountains to the east.

AGE OF LOWER SEQUENCE

Andesite of Round Mountain and porphyritic basalt are both overlain by the Idaho Canyon Tuff and thus are older than it; however, stratigraphic control is poor on the andesite of Bald Mountain and the unnamed dacite. The andesite of Bald Mountain is geographically close to the andesite of Round Mountain and has a similar structural setting; it seems most likely that they are nearly contemporaneous.

A potassium-argon date for the andesite of Bald Mountain, 15.3±0.9 m.y. (table 1), is the same as the age of the tuff of Craine Creek, 15.7±0.5 m.y. (Noble and others, 1970). The tuff of Craine Creek locally underlies the Idaho Canyon Tuff, and Noble believed that they are closely related. These ages are also in the same range as those for the Steens Basalt on Steens Mountain (15.1±0.3 m.y., Gunn and Watkins, 1970; 15.3±1.0, Greene and others, 1972; Watkins and Baksi, 1974; Evernden and others, 1964). Therefore, the stratigraphy and

TABLE 1.—*Potassium-argon ages on some rock units in and near the Charles Sheldon Wilderness Study Area, Humboldt and Washoe Counties, Nevada, and Lake and Harney Counties, Oregon*

Sample locality	Unit	Age (m.y.)	Locality	Latitude	Longitude
1	Basalt of Railroad Point	[1]1.2±0.1	State line, Railroad Point----	41°58'55"	118°50'50"
2	Basalt of Railroad Point	[2]1.58±0.2	South end of Railroad Point---	41°53'50"	118°53'10"
3	Basalt of Catnip Creek--	[2]8.84±1.1	Rim of Guano Valley-----------	41°58'55"	119°29'20"
4	Basalt of Catnip Creek--	[2]9.87±1.2	Gooch Table-------------------	41°52'10"	119°13'30"
5	Soldier Meadow Tuff-----	[3]14.7±0.5	Southeast of Soldier Meadow---	41°21'25"	119°04'40"
6	Canon Rhyolite, glass---	[1]13.7±1.4	Thousand Creek gorge----------	41°54'00"	118°57'00"
6	Canon Rhyolite, feldspar	[1]16.3±1.3	Thousand Creek gorge----------	41°54'00"	118°57'00"
7	Summit Lake Tuff--------	[3]15.1±0.5	Craine Creek, Summit Lake Road	41°34'00"	119°01'15"
8	Summit Lake Tuff--------	[4]15.6	East of Long Valley-----------	41°39'00"	119°44'48"
9	Tuff of Craine Creek----	[3]15.7±0.5	Craine Creek------------------	41°35'15"	118°55'00"
10	Andesite of Bald Mountain	[2]15.3±0.9	North side, Bald Mountain-----	41°50'15"	119°35'50"

[1]McKee and Marvin, 1974.
[2]E. H. McKee, written communications, 1977.
[3]Noble and others, 1970.
[4]Evernden and others, 1964.

radiometric ages suggest that the lower sequence is only slightly older than the lower units of the middle sequence.

MIDDLE SEQUENCE

IDAHO CANYON TUFF

The Idaho Canyon Tuff underlies a small area in the southeast part of the Range, which includes the type locality (fig. 5) and a much larger area in the north-central part. It is about 394 ft (120 m) thick at the type locality (Noble and others, 1970) and probably is 197–394 ft (60–120 m) thick to the north, where partial sections are well exposed in scarps and canyons such as Catnip Canyon.

The Idaho Canyon Tuff consists mostly of densely welded, devitrified tuff. Most is streaky, banded, and medium gray to light brownish gray, and contains very narrow lenticular gas cavities. In certain zones the rock is very inflated, containing spherical cavities that are locally partially filled to form lithophysae. In the northern area of the unit, a threefold sequence—dense-lithophysal-dense—is characteristic.

The tuff is sparsely porphyritic; principal phenocrysts are alkali feldspar (2–5 percent) and quartz (trace to 2 percent). Other phenocrysts in trace amounts include fayalite, magnetite, and other altered ferromagnesian minerals. The groundmass is cryptocrystalline, and has local weak granophyric texture and local indistinct shard forms. At only one outcrop in the northern part does vitric tuff have prominent shard and pumice textures.

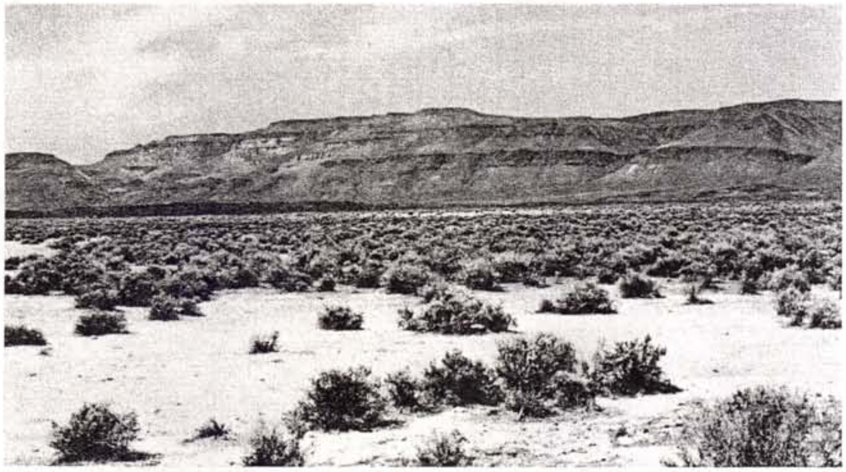

FIGURE 5.—Scarp of Big Mountain from Craine Creek valley, Charles Sheldon Wilderness Study Area. Mouth of Idaho Canyon at left. View is to the west.

SUMMIT LAKE TUFF

The Summit Lake Tuff is present in a small area near Idaho Canyon in the southeast part of the Range. The type locality is along the road between Craine Creek valley and Summit Lake (sec. 35, T. 43 N., R. 26 E.); the unit is about 98 ft (30 m) thick (Noble and others, 1970).

The rock is light brownish gray to pale yellowish brown, is commonly mottled, and contains abundant phenocrysts and rock fragments. The phenocrysts are alkali feldspar and plagioclase (10–15 percent total), and there are trace amounts of quartz, clinopyroxene, hornblende, biotite, and magnetite. The groundmass is part vitric and part devitrified, and shard and pumice textures are prominent.

RED WELDED TUFF

A striking reddish-brown, dense welded tuff crops out along the east face of McGee Mountain. It occurs high in the section of sediments beneath the Canon Rhyolite. The tuff contains trace amounts of alkali feldspar phenocrysts in a cryptocrystalline groundmass that has compressed shard texture.

CANON RHYOLITE OF MERRIAM (1910)

The Canon Rhyolite is an extensive unit in the east part of the Range. It underlies much of McGee Mountain, Big Mountain, and the hills both north and south of Gooch Table. The type locality is

Thousand Creek Gorge, secs. 24 and 34, T. 46 N., R. 26 E. (Merriam, 1910).

The Canon Rhyolite is a resistant rock that forms many bold cliffs, as on McGee and Big Mountains, and forms vertical-walled canyons such as Thousand Creek Gorge and parts of Virgin and Sagebrush Creek valleys. Lobate pressure ridges, mostly stripped of former sediment cover, show strikingly on aerial photographs and from certain vantage points in the field.

The rhyolite is characteristically streaked and mottled grayish red, brownish gray, and medium to light gray. Banded, brecciated, lithophysal, and various vesicular to cavernous textures are common. Much of the rock is silicified and contains secondary quartz and agate. Phenocrysts, where present, are minute and inconspicuous. They include trace amounts of quartz, alkali feldspar, fayalite, and magnetite. The groundmass is a cryptocrystalline aggregate of alkali feldspar and silica minerals, dominated by radial texture.

Tuffaceous sedimentary rocks and welded tuffs are interbedded with the rhyolite of this unit, particularly on McGee and Big Mountains. The welded tuff is separately mapped and is described below (tuff of Big Mountain). The sedimentary rocks are also similar to those separately mapped and described below (tuffaceous sedimentary rocks, Tst, of pl. 1).

The Canon Rhyolite is about 394 ft (120 m) thick at the mouth of Thousand Creek Gorge. The section thickens to the south as more sedimentary rocks and the tuff of Big Mountain are interbedded with it, reaching about 984 ft (300 m) on the scarp below the summit of McGee Mountain. The rhyolite may be as much as 984 ft (300 m) thick on Big Spring Butte and 1,049 ft (320 m) thick in the hills south of Gooch Table.

RHYOLITE DIKE

A dike of rhyolite similar to the Canon Rhyolite crops out prominently on the northeast end of Big Mountain, crosscutting the sedimentary rocks underlying the Canon Rhyolite. It was obviously a feeder for part of the Canon Rhyolite.

RHYOLITE VITROPHYRE

Five partly coalescing domal masses of rhyolite vitrophyre are alined at about N. 65° E. in the Sagebrush Creek valley (sec. 24, T. 45 N., R. 26 E.). They appear to be spatially related to the Canon Rhyolite but have significantly different phenocryst mineralogy. The rather porous rock is medium light gray and contains trace amounts of each of the following phenocrysts: alkali feldspar, plagioclase, clinopyroxene, hornblende, biotite, and magnetite. The groundmass consists of about half plagioclase microlites and half glass.

TUFF OF BIG MOUNTAIN

The tuff of Big Mountain is present in several areas on McGee and Big Mountains. On the east-facing scarp of Big Mountain (fig. 5) near the mouth of Idaho Canyon, it forms prominent cliffs capping the scarp (Noble and others, 1970). It is about 787 ft (240 m) thick at this locality but is much thinner where interbedded with the Canon Rhyolite.

The unit consists of partially welded to densely welded tuff. At the type locality, the rock is pinkish gray and porous; on McGee Mountain it is denser and banded pale brown and light gray. The tuff contains trace amounts to 2 percent each of phenocrysts of alkali feldspar and quartz, and trace amounts of clinopyroxene and magnetite. The groundmass is cryptocrystalline; comby and radiating devitrification textures commonly obliterate the shard texture.

RHYOLITE OF CATNIP MOUNTAIN

The rhyolite of Catnip Mountain underlies a large area centered at Catnip Mountain (fig. 6) and reappears discontinuously to the southeast, notably in Virgin Creek Canyon at the mouth of Hell Creek (fig. 7), and in the hills north of Fivemile Flat. It is about 1,410 ft (430 m) thick on Catnip Mountain.

Rhyolite of this unit is characteristically finely banded and medium light to very light gray, and has fine porosity in the lighter bands. The banding is commonly steeply dipping or intricately folded. Platy and columnar jointing are both common, as are gas cavities of various sizes. The rhyolite crops out in the canyons of Catnip Mountain and Virgin Creek (fig. 7) and at higher elevations on Catnip Mountain.

The rhyolite is most commonly aphyric, but locally contains trace amounts of alkali feldspar and layered mafic-mineral phenocrysts.

An unusual exposure of the base of this unit occurs in a cliff overlooking Hell Creek about 1 mi (1.6 km) west of Virgin Creek. Here a basal zone of densely welded tuff having good shard and pumice textures and about 3.9 ft (1.2 m) thick apparently grades up into an irregular lithophysal zone about 12.7 ft (4.5 m) thick, which in turn grades into normal banded rhyolite.

A distinctive feature of the rhyolite of Catnip Mountain is the presence of obsidian nodules. These are not seen in outcrop, but are scattered irregularly on the surface underlain by the unit. The obsidian is black, translucent, and structureless.

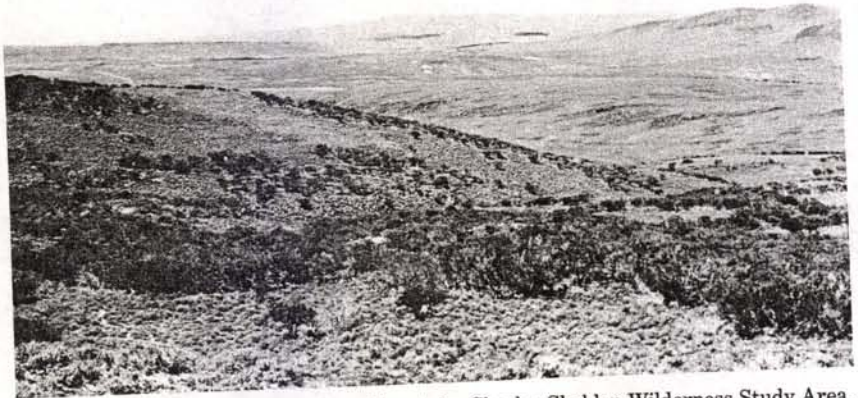

FIGURE 6—View north from Badger Mountain, Charles Sheldon Wilderness Study Area. Foreground underlain by rhyolite of Badger Mountain. In middle distance Badger Creek valley underlain by tuffaceous sedimentary rocks with local basalt caps; right side is Fish Creek Mountain underlain by rhyolite of Badger Mountain. Far distance in center is Catnip Mountain, underlain by rhyolite of Catnip Mountain. Extreme distance on left, Hart Mountain.

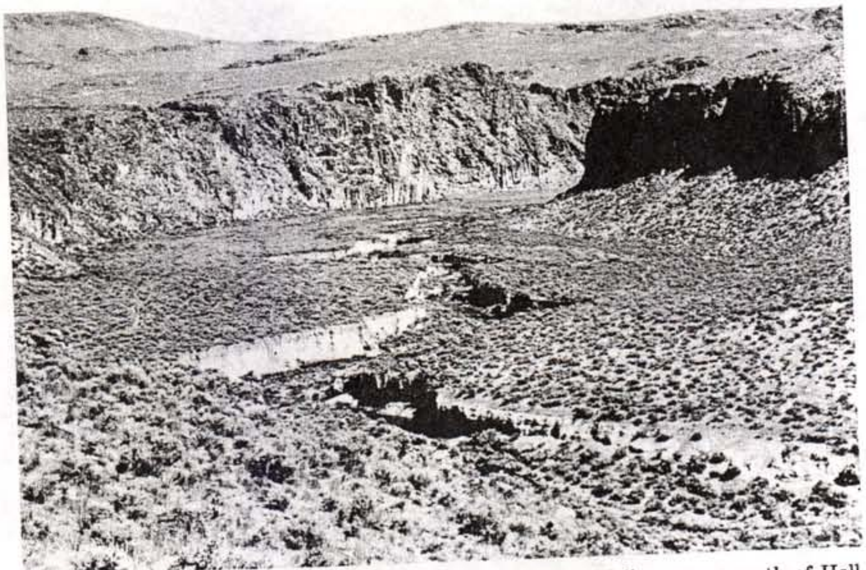

FIGURE 7.—Open canyon of Virgin Creek south of Virgin Valley, near mouth of Hell Creek, Charles Sheldon Wilderness Study Area. Main canyon wall is of rhyolite of Catnip Mountain; note whitish weathering and well-developed columnar joints. Floor of canyon is flat, and has been filled with alluvium to considerable depth; small inner canyon is cut in alluvium. View to the south.

TUFF OF TROUGH MOUNTAIN

The tuff of Trough Mountain was mapped in a small area directly west of Fivemile Flat. More is present to the southwest (Noble and others, 1970). The tuff is dense and strongly welded, light olive gray to dark yellowish brown, and characterized by a brecciated texture. Phenocrysts include trace amounts of alkali feldspar, quartz, and magnetite.

RHYOLITE OF BADGER MOUNTAIN

The rhyolite of Badger Mountain underlies a large area including Badger, Fish Creek, Blowout, and Mahogany Mountains that extends eastward to the canyon of Virgin Creek (fig. 8). Although these mountains are generally rounded in form, ridge crests and cliff lines provide abundant outcrop.

This unit consists of abundantly porphyritic rhyolite. Colors are varied, but are mostly medium to light gray and brownish gray. Flow-banded textures with considerable porosity in the lighter bands are characteristic. Most of the rhyolite contains 2–10 percent quartz phenocrysts (dark in hand specimen) and 5–20 percent alkali feldspar

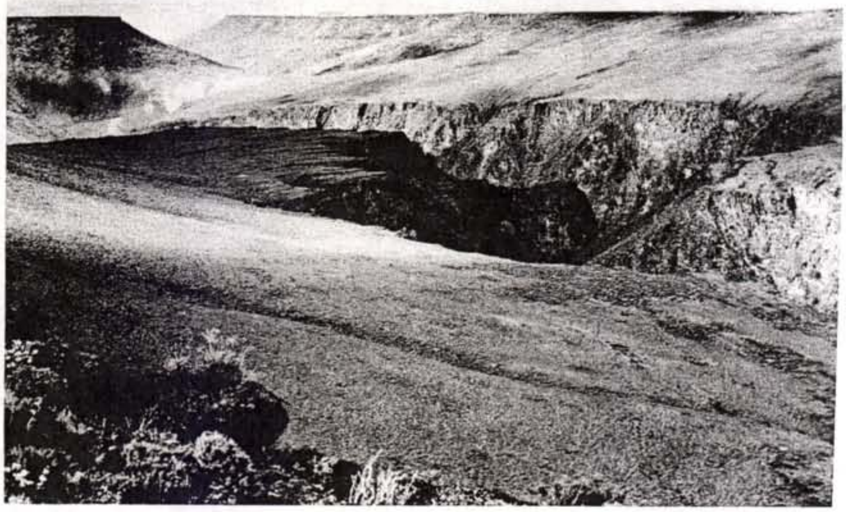

FIGURE 8.—Double canyon of Virgin Creek south of Virgin Valley, Charles Sheldon Wilderness Study Area. Photographer was standing on rim of upper part of rhyolite of Badger Mountain looking northeast; below him is slope underlain by tuffaceous sedimentary rocks and below that is inner canyon cut in lower part of rhyolite of Badger Mountain. Across canyon, slope is of tuffaceous sedimentary rocks capped by basalt of Rock Spring Table.

phenocrysts, with trace amounts of clinopyroxene and magnetite phenocrysts. The groundmass is cryptocrystalline with granular or radiating texture.

Some of the rhyolite has a vitric groundmass. This rock is dark gray with a greenish or yellowish mottle, dense, and abundantly porphyritic. Phenocrysts include 0–2 percent alkali feldspar, 0–3 percent quartz, 5–20 percent plagioclase, and trace amounts of clinopyroxene, magnetite, biotite, and hornblende.

The rhyolite of Badger Mountain is about 984 ft (300 m) thick on Badger and Fish Creek Mountains (fig. 6). In the canyon of Virgin Creek (fig. 8) it is split into distinct upper and lower parts. A tongue of the Soldier Meadow Tuff separates them locally. The upper part is about 984 ft (300 m) thick, and the lower part is about 590 ft (180 m) thick.

SOLDIER MEADOW TUFF

The Soldier Meadow Tuff is present at scattered localities in the south part of the Range. These are the northernmost occurrences of this extensive unit, which has been traced for 37 mi (60 km) to the southwest (Noble and others, 1970). Thickness in the area mapped is 98–196 ft (30–60 m).

The Soldier Meadow Tuff characteristically crops out along cliff lines that show widely spaced vertical joints. The rock is mostly light to very light brownish gray, somewhat porous, and abundantly porphyritic. Phenocrysts include 3–10 percent quartz, 10–20 percent alkali feldspar, and traces of magnetite and altered ferromagnesian minerals. The groundmass is granular and has weakly preserved shard texture. Pumice lumps in various stages of collapse are also characteristic.

RHYOLITE OF NUT MOUNTAIN

The rhyolite of Nut Mountain was mapped in a small area near the southwest corner of the Range, both on Nut Mountain and on an adjacent ridge. Its extent is poorly known. It is a heterogeneous unit, consisting of rhyolite flows and both sparsely and abundantly porphyritic welded tuffs.

The rhyolite flows are light-gray to light-brownish-gray aphyric rocks which resemble the rhyolite of Catnip Mountain. The sparsely porphyritic welded tuff is medium gray to brownish gray and contains trace amounts of phenocrysts of alkali feldspar, plagioclase, augite, and magnetite. The abundantly porphyritic welded tuff is brownish gray and contains about 15 percent alkali feldspar phenocrysts and trace amounts of plagioclase, biotite, and magnetite. Shard texture is prominent in the welded tuffs.

TUFFACEOUS SEDIMENTARY ROCKS

Tuffaceous sedimentary rocks are found at all levels of the middle sequence and are mapped where thick enough to show at the scale of the map (pl. 1). In the west part of the Range, tuffaceous sedimentary rocks are high in the section and are interlayered with the basalt of Catnip Creek of the upper sequence.

The tuffaceous sedimentary rocks are mostly claystones and poorly sorted coarser rocks, all weakly consolidated. They range widely in color from white through various light grays, brown, and reds. The coarser rocks consist mainly of volcanic rock fragements, plagioclase grains, pumice lumps, and glass shards in a clay matrix. White pumice or shard (ash) beds are locally present. Palagonite tuff is abundant in this unit around Post Camp Spring south of Fish Creek Mountain. The palagonite tuff is similar to that in the vent areas described below except that the bedding is prominent and the tuff is interlayered with light-colored tuffaceous sedimentary rocks.

Tuffaceous sedimentary rocks are well exposed in Virgin Valley (fig. 9). Sections about 1,082 ft (330 m) thick lie beneath Gooch and Rock Spring Tables; however, these are much disturbed by landsliding (pl. 1).

Wendell (1970) divided the sedimentary rocks in Virgin Valley into two units, the Virgin Valley Formation (lower) and the Thousand

FIGURE 9.—Bedded tuffaceous sedimentary rocks, about 0.6 mi (1 km) south of Thousand Creek Spring, Charles Sheldon Wilderness Study Area. Badlands topography here contains many opal claims. Big Spring Table in background; basalt caps sedimentary rocks. Two levels separated by normal fault. View to the north.

Creek Formation (upper), both named by Merriam (1910). As there is no clear lithologic distinction between them, these units are mapped as one in this report.

AGE OF THE MIDDLE SEQUENCE

Potassium-argon ages for the Canon Rhyolite, and the Summit Lake and Soldier Meadow Tuffs, and the tuff of Craine Creek (table 1) indicate a middle Miocene age for this sequence. The Idaho Canyon Tuff is considered to be middle Miocene also (Noble and others, 1970). The rhyolite of Nut Mountain conformably overlies the Soldier Meadow Tuff and is probably only slightly younger.

Considerable fossil material has been recovered from the tuffaceous sedimentary rocks in the Virgin Valley-Thousand Creek area (Wendell, 1970). Wendell concluded that the Virgin Valley Formation is middle and late Miocene and early Pliocene and that the Thousand Creek Formation is Pliocene (late Clarendonian and early Hemphillian) (Wendell, 1970, p. 66; Merriam, 1910). More recent usage places the Clarendonian and early Hemphillian in the Miocene (Eusinga, 1975).

UPPER SEQUENCE

BASALT OF CATNIP CREEK

Many square kilometers of both the Range and Refuge are underlain by basalt. The basalt overlies and laps out around the volcanic and sedimentary rocks described previously. The basalt is thickest in the northwest part of the Range and north part of the Refuge (Catnip Creek, Rye Creek, and vicinity) and the basalt consists of many thin flows. At Catnip Creek (secs. 3, 4, 9, and 10, T. 46 N., R. 22 E.) the basalt is at least 98 ft (30 m thick). A more accessible section is at Racetrack Reservoir about 3.5 mi (6 km) to the southeast and consists of 24 flows in continuous vertical exposure in a fault scarp about 131 ft (40 m) high (fig. 10).

From the section at Racetrack Reservoir the basalt thins in all directions and is interbedded with tuffaceous sedimentary rocks in the southwest part of the Range near Badger Creek.

In the east part of the area, the basalt caps Big Spring, Gooch, and Rock Spring Tables (figs. 8, 9). It is 9.8–26 ft (3–8 m) thick and consists of one or two flows.

The basalt is dark to medium gray and aphanitic to fine grained. It contains 25–60 percent plagioclase, 7–30 percent olivine, 12–50 percent clinopyroxene, 2–12 percent magnetite, and 1–10 percent void space as openings between plagioclase grains (diktytaxitic texture). A few percent olivine and (or) plagioclase microphenocrysts are locally

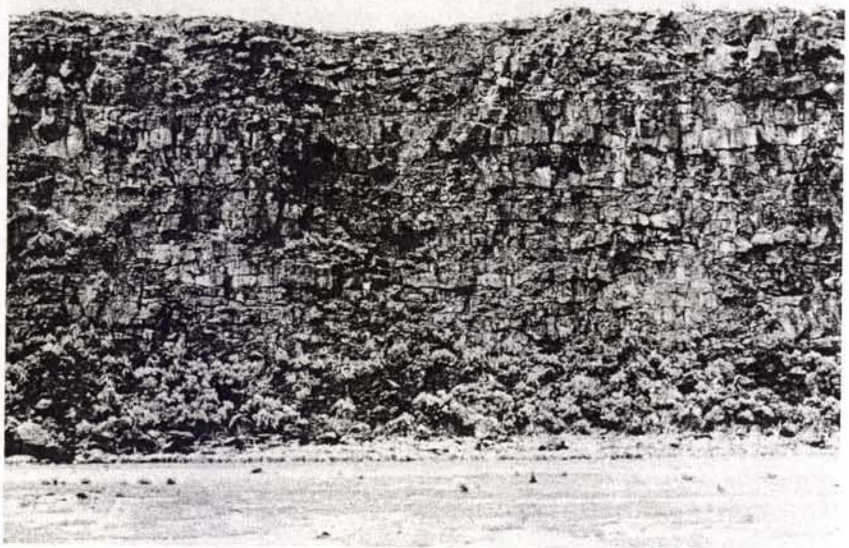

FIGURE 10.—Outstanding exposure of basalt flows at Racetrack Reservoir, Charles Sheldon Wilderness Study Area. Total thickness of section about 130 ft (40 m). Flows are as much as 9 ft (3 m) thick and pinch and swell noticeably. About 24 flows in vertical alinement, average thickness 5 ft (1.5 m).

present. Despite the wide range in mineral content, the range in SiO_2 content for most of these rocks is only 47.9–49.1 percent.

MAFIC VENT COMPLEXES

The mafic vent complexes include Bitner Butte and three smaller unnamed buttes in the southwest part of the Range. They consist mostly of highly vesicular basalt, in part reddish, and both black and reddish cinders. Basalt of less vesicularity is locally intermixed. These buttes, the palagonite tuff rings (described below) and Mule Mountain, a low shield volcano near Bald Mountain Lake, form a northwest-trending chain that marks probable vent localities for the basalt of Catnip Creek.

PALAGONITE TUFF

Three circular areas underlain by palagonite tuff have been mapped separately north and south of Badger Mountain. These are vent areas, where basaltic lava was erupted into water, was fragmented and altered, then piled up as cones or rings subsequently modified by erosion. The resulting tuff has a medium- to light-olive-gray matrix and dark-gray scoria fragments. Both fragments and matrix are glass and clays. The tuff is weakly consolidated and friable but nevertheless tends to stand topographically above surrounding light-colored tuffaceous sedimentary rocks.

BASALT OF RAILROAD POINT

Basalt caps Railroad Point, an elongate mesa in the northeast part of the Range, directly east of Big Spring Table. The basalt appears to have been an intercanyon flow, but subsequent erosion of the surrounding sediments have inverted the topography, producing a long capped ridge.

The basalt, a single flow about 16.4 ft (5 m) thick at the tip of Railroad Point, is dark gray and porous. It contains about 5 percent fresh olivine phenocrysts, which grade serially to groundmass olivine. The groundmass consists of about 45 percent plagioclase, 10 percent olivine, 15 percent clinopyroxene, 5 percent magnetite, and 20 percent void space. The distinctive groundmass clinopyroxene is dark, bladed, and peppered with magnetite.

AGE OF THE UPPER SEQUENCE

Two potassium-argon dates on the basalt of Catnip Creek (table 1) average 9.4 m.y., an age that agrees well with the early Hemphillian age of fossils in conformably underlying strata (Wendell, 1970). Potassium-argon dates on the basalt of Railroad Point are 1.2±0.1 m.y. (McKee and Marvin, 1974) and 1.58±0.2 m.y. (E.H. McKee, written commun., 1977) (table 1).

SURFICIAL DEPOSITS

Surficial deposits in the Range and Refuge include alluvium and alluvial fans, playa deposits, and landslide deposits of Quaternary age. These are indicated on the map only where thick and continuous enough to completely conceal underlying bedrock.

Alluvium is unconsolidated sand, gravel, and silt. Alluvial fans are similar, but commonly include coarser cobbles, slabs, and boulders. Playa deposits are fine clay and silt with a small amount of evaporite minerals.

Landslide deposits are locally prominent, particularly on the north and south sides of Virgin Valley. These large masses of tuffaceous sedimentary rocks have slid and tilted from their original positions higher on the edges of Gooch and Rock Spring Tables, commonly carrying with them some of the basalt caprock. Many of the opal occurrences are in these landslide masses.

The most spectacular landslide in the area is that on the south side of Blowout Mountain. Here a mass of the rhyolite of Badger Mountain has broken loose, apparently catastrophically, and formed a separate hill below separated by a moat from the mountain. Vertical joints in the displaced mass suggest that it has rotated very little.

STRUCTURE

FAULTS

The geologic structure of the Range and Refuge is dominated by normal faults. Near the southeast corner of the study area is a series of northeast-trending faults. These are on strike with Craine Creek valley, and in part are responsible for the major displacement between Big and McGee Mountains and that valley.

Northwest-trending faults are predominant over most of the area Areas near Fivemile Flat and on Badger Mountain have dominan northwest-trending faults with abundant cross faults, breaking th area into small blocks. To the north, the valley of Hell Creek is faul dominated, most faults trending northwest and north and joinin others of similar trend near the Sage Hen Hills to the north.

Northwesterly trends are also dominant near the Oregon-Nevad state line in the Sage Hen Hills, parallel to those on Big Spring Tabl to the east and to the major fault bounding McGee Mountain on th north.

In the west part of the area, north and south of Bald Mountair northwest-trending faults continue along strike with those on Badge Mountain. A crossing, northeast trend is also seen and is probabl related to adjustments at the end of north-trending Guano Valley.

The amount of faulting bears little apparent relationship to the ag of the rocks. The basalt of Catnip Creek is locally faulted as muc as the Idaho Canyon Tuff, the lowest unit in the middle sequenc Few faults were mapped (pl. 1) in the older andesites of Round Mour tain and Bald Mountain, but more might be detected by detailed maj ping. Faults in the basalt of Catnip Creek indicate that much faultir occurred after 9.4 m.y. B.P (before present); lack of faulting on Rai road Point indicates little faulting on northwest trends since abou 1.6 m.y. B.P.

VIRGIN VALLEY BASIN

A downwarp centered at Virgin Valley produced a major basin continental sedimentation in middle and late Miocene time. As mu as 984 ft (300 m) of tuffaceous sedimentary rocks accumulated ne its center. This basin, as expressed by its sedimentary content, e tends as far south as Onion Lake and as far west as Gooch Lal It is less well defined on the north side, as sedimentary rocks least a few hundred feet thick continue under Big Spring Table beyond the area mapped.

The main part of the basin is nearly surrounded by the Canon Rhyolite. This suggests that eruption of this unit may have contributed to the downwarp forming the basin through sinking of the land over a partially emptied magma chamber. This area is less faulted than its surroundings.

DEPTH TO PRE-TERTIARY ROCKS

In the Pine Forest Range directly east of the valley of Craine Creek (eastern limit of mapped area) the Idaho Canyon Tuff overlies 328–656 ft (100–200 m) of older basalt and welded tuff, which in turn overlie pre-Tertiary plutonic and metamorphic rocks (Smith, 1973). The top of the pre-Tertiary rocks dips westward from these basement exposures, and no older rocks crop out for 951 ft (290 km). The intervening basin is underlain almost entirely by Miocene, Pliocene, and Quaternary rocks; none as old as Oligocene have been identified except near its margins.

The andesites of Round Mountain and of Bald Mountain are thick units (as much as 1,500 ft (460 m) where fully exposed), but both disappear along strike within a few miles in a north-south direction and therefore appear to be local volcanic piles of no great areal extent.

These facts indicate that the depth to pre-Tertiary basement under the Range and Refuge is probably not great (cross sections, pl. 1). A basement having an upper surface near 3,937 ft (1,200 m) above sea level seems most probable.

CALDERAS

Geophysical data, discussed in the geophysical section of this report, provide permissive evidence for the possible existence of calderas in the study area.

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Interpretation of Aeromagnetic and Gravity Data, Charles Sheldon Wilderness Study Area, Nevada and Oregon

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MINERAL RESOURCES OF THE CHARLES SHELDON WILDERNESS STUDY AREA, HUMBOLDT AND WASHOE COUNTIES, NEVADA, AND LAKE AND HARNEY COUNTIES, OREGON

GEOLOGICAL SURVEY BULLETIN 1538-B

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MINERAL RESOURCES OF THE CHARLES SHELDON WILDERNESS STUDY AREA, HUMBOLDT AND WASHOE COUNTIES, NEVADA, AND LAKE AND HARNEY COUNTIES, OREGON

INTERPRETATION OF AEROMAGNETIC AND GRAVITY DATA

By DONALD PLOUFF, U.S. Geological Survey

INTRODUCTION

The aeromagnetic data, plate 2, is a part of more widespread surveys in adjacent areas of Nevada (U.S. Geological Survey, 1972a) and Oregon (U.S. Geological Survey, 1972b). Total-intensity magnetic data were obtained along east-west lines flown at a spacing of about 2 mi (3.2 km) and at a nearly constant barometric elevation of 9,000 ft (2,743 m) above sea level. The approximate effect of the Earth's normal magnetic field has been removed from the observed total-intensity data by subtracting a regional gradient of about 6 gammas/km in the direction of magnetic north.

Gravity data from a total of 269 stations were collected by S. L. Robbins and K. D. Holden during September and October 1975 as part of the geologic assessment of the mineral-resource potential of the study area. These data were supplemented by data from the U.S. Department of Defense Gravity Library (written commun., 1975) from 123 previously established stations and by data at eight gravity stations in the Crump Geyser area, Ore. (Plouff, 1975). The procedures used to combine the three sets of data and to calculate values of terrain-corrected Bouguer anomalies are described in a report by Plouff, Robbins, and Holden (1976). The datum of observed gravity is that of Behrendt and Woollard (1961). Bouguer corrections to sea level and terrain corrections to a distance of 103.5 mi (166.7 km) are based on an assumed average rock density of 2.5 g/cm^3. The largest errors incorporated in the values of complete Bouguer anomalies contoured on the resultant Bouguer anomaly map (pl. 2) are attributed to errors approaching 1.5 mgal in the determination of terrain corrections. The average error in the determination of terrain corrections probably does not exceed 0.5 mgal and, hence, this source of error would have a negligible effect on changing the interpretation of the gravity map.

References to the geologic map (pl. 1) are made in the following discussion of the geophysical data. Locations on the geophysical map (pl. 2) are labeled in six categories: "C" for possible calderas, "F" for possible faults, "G" for gravity anomalies, "H" for hot springs, "M" for magnetic anomalies, and "T" for magnetic anomalies that are correlated with topography. Interpretation of some labeled geophysical anomalies that occur outside the study area is made in order to facilitate interpretation of anomalies within the study area.

GENERAL FEATURES OF THE MAGNETIC MAP (PLATE 2)

A prominent U-shaped regional magnetic maximum with its vertex near the center of the south edge of the map and extending northwestward and northeastward along magnetic ridges toward locations M_1 and M_2 dominates the magnetic map (pl. 2). The magnetic ridges are separated by a broad minimum centered near M_3. The southwest edge of the U-shaped maximum is interrupted by a large magnetic minimum centered near location C_1. The interpretation of this closed minimum is discussed in a later section. A prominent, north-south-trending regional maximum along the east edge of the magnetic map is outside the study area. This major magnetic high is separated from the prominent U-shaped maximum in the study area by a broad minimum that follows the trend of Craine Creek valley.

Irregular-shaped local anomalies on the magnetic map generally are caused by variations of magnetization that typify rocks in volcanic terrane of the western United States. The most conspicuous area of relatively high magnetization occurs slightly north of the Range boundary at Hawk Mountain (T_1, pl. 2). Here an 800-gamma magnetic maximum appears to be caused by domal masses and related flows of rhyodacitic to dacitic rock shown on the geologic map of Walker and Repenning (1965). The near coincidence of the 3,000-gamma magnetic contour line with the 1,830-m topographic contour line and the small southward offset of the innermost magnetic contour from the location of the topographic peak suggests that most of the anomaly is caused by the topographic effect of the volcanic rocks exposed at the surface. The 2,600-gamma outermost closed contour, however, extends southward into the study area and indicates that magnetic rocks of this volcanic center extend beneath the Charles Sheldon Antelope Range. Therefore, based on the correlation between mineral deposits and volcanic centers observed in other areas of Nevada (Albers and Kleinhampl, 1970), this location may be a favorable target for mineral exploration.

The horizontal size of the double-peaked magnetic maximum in the northwest corner of the study area (labeled M_1) is similar to the broad maximum near Hawk Mountain, but the amplitude of about 400 gammas is smaller, and the shape of the anomaly is not strongly controlled by the topographic expression of volcanic rocks exposed at the ground surface. The magnetization of volcanic rocks exposed at the surface beneath the northern magnetic peak evidently is low, because several flight lines cross a 820–984-ft (250- to 300-m) thick sequence of volcanic rocks along the escarpment (T_9 and T_{10}) at the east edge of Guano Valley without discernible deflection of the observed magnetic field. A trachyandesite volcanic pile with a vent crops out at Antelope Butte (eastward of and between T_9 and T_{10}) in a 0.62-mi (1-km) circle shown on the map of Walker and Repenning (1965), and similar platy flows are exposed in the escarpment to the west. G. W. Walker (oral commun., 1978) mapped younger volcanic rocks that lap out against the trachyandesite and interpreted the occurrence of the trachyandesitic rock as a less magnetic differentiate of a composite volcanic center with underlying magnetic differentiates. Therefore, the broad magnetic maximum centered near M_1 (pl. 1) indicates that rocks associated with this volcanic center extend beneath the northwest corner of the study area.

Less prominent magnetic maxima that reflect near-surface rocks of moderately high magnetization occur over topographic maxima near the east edge of the magnetic map at T_2 and T_3, at Big Mountain (T_4), and at Bartlett Peak near the southeast corner of the map (T_5). The broad minimum between T_6 and T_7 seems too large to simply reflect the effect of lower ground elevations along Craine Creek. The north-south sequence of broad magnetic minima also indicates the occurrence of a zone of rocks of low magnetization between the study area and a favorable zone of previous mineral exploration indicated by a series of mines and prospect pits along the east edge of the map. An inverse correlation between a magnetic minimum and a topographic maximum near the northeast corner of the map (T_8) may indicate reversed remanent magnetization of layers within Tertiary basalt and andesite flows shown on the geologic map of Walker and Repenning (1965). Though the location is outside the study area, this interpretation demonstrates the possibility that reversely magnetized volcanic rocks may underlie isolated magnetic minima within the study area.

GENERAL FEATURES OF THE GRAVITY MAP

The Bouguer gravity anomaly map includes an irregular grouping of maxima and minima (pl. 2). No pronounced linear trends are present except at the east edge of the map outside the study area where a north-south-trending regional maximum, G_4–G_5, correlates with a similar magnetic ridge (T_2–T_3, pl. 2). The maximum, G_3, near the west edge of the gravity map is centered over rocks mapped as Tertiary andesite of Bald Mountain and the Tertiary rhyolite of Cottonwood Canyon (pl. 1). These rocks are older and structurally uplifted relative to the surrounding rocks. The north and east edges of the gravity maximum inside the study area may be favorable sites to extend existing mercury exploration indicated by the occurrence of more than a dozen mining prospects to the south and west that are enclosed by the gravity maximum.

The locations of two closed anomalies on the gravity map seem to be correlated with outcrops of specific rock units shown on the geologic map. Closer examination, however, indicates that the anomalies reflect lateral changes within deeper, underlying rocks. The Idaho Canyon Tuff south of the Nevada-Oregon border probably is no less dense on the average than the surrounding geologic units, and, hence, cannot account for the observed gravity minimum at G_2. The minus 175-mgal contour nearly outlines the northern part of an outcrop of Quaternary basalt near Rock Spring Table Reservoir (pl. 1), but the rock unit is too thin to explain the amplitude of the anomaly at G_1. An underlying structure that may cause the anomaly at C_1–C_2 is discussed later.

MAGNETIC AND GRAVITY ANOMALIES ASSOCIATED WITH FAULTING

Ore deposits are commonly in and near fault zones, because the crushing movement associated with faulting tends to provide channels for transportation of ore-bearing solutions. Fault displacements often iuxtapose rocks of contrasting physical properties at the same level on opposite sides of faults. Where faults are concealed by a cover of younger rocks, their locations can be revealed as fairly linear gravity or magnetic contours. Possible fault locations or concealed geologic boundaries, and hence areas that might be favorable for mineral exploration, were identified on the magnetic and gravity map (pl. 2) at locations labeled "F".

A steepened gradient between locations F_1 and F_2 on the magnetic map closely agrees with the location of a mapped fault with the downthrown side to the east. The magnetic map indicates the possibility of a largely concealed cross fault that apparently indicates a shift of the main fault to a location near F_3 rather than along the fault near F_4. Though there is a contrast of magnetization between the rocks on each side of the fault, there is no similar contrast in density, because the gravity map does not indicate a similar north-south trend between locations F_1 and F_3. A gravity gradient between locations

F_4 and F_5 agrees with the location of a mapped fault. The less dense rocks are on the downthrown northeast side of the fault. No similar contrast in intensities of magnetization of rocks on the two sides of the fault are indicated between F_4 and F_5. However, the trend of a saddle in the magnetic contours between F_8 and F_9 nearly parallels the northwest trend of a series of mapped faults to the northeast (pl. 1). This zone (F_8–F_9, pl. 2) of relatively low magnetization separates the magnetic nose which enclosed the two small maxima to the southwest from the major magnetic anomaly centered at Hawk Mountain (T_1) to the north. The low magnetization in this magnetic saddle may be a result of rock alteration related to the circulation of fluids in an underlying, concealed fault zone.

Though differing in specific detail, both the gravity and the magnetic maps indicate similar gradients between F_6 and F_7, with more dense and more highly magnetized rocks to the east. The width of both the gravity and magnetic maxima to the east are about 3.1 mi (5 km) and the location of the crestlines also agree. A north-south band of Mesozoic rocks (shown by Wilden, 1964; Walker and Repenning, 1965; and Smith, 1973), which forms an elongated structural and topographic maximum, nearly coincides with the crest, G_4–G_5, of the magnetic and gravity maxima. The decrease in level of the Bouguer gravity anomaly between the location of the Mesozoic rocks and the younger rocks to the west in the study area is at least 15 mgals. If the observed change in gravity level wholly is an effect of a westward thickening of the Tertiary section of rocks and if it is assumed that the Mesozoic and older rocks have an average density of 2.65 g/cm^3 compared to 2.45 g/cm^3 for the younger rocks, for example, then the combined thickness of Tertiary rocks beneath the Charles Sheldon Wilderness Study Area could exceed 5,900 ft (1,800 m).

GRAVITY AND MAGNETIC ANOMALIES RELATED TO HOT SPRINGS

All five hot or warm springs in or adjacent to the Charles Sheldon Wilderness Study Area occur near gravity maxima (labeled H on pl. 2). Two localities occur within closed gravity highs (H_1 and H_2), one occurs along the edge of a closed gravity high (H_3), one occurs on a gravity nose (H_4), and the last occurs on a gravity saddle (H_5) between lower gravity values to the northwest and southeast. There is no consistent relationship between magnetic anomalies (pl. 2) and the location of the hot or warm springs. One spring occurs within a closed magnetic maximum (H_4), one spring occurs near a closed magnetic minimum (H_3), two springs occur near relative magnetic highs (H_2 and H_5), and the last spring occurs near a relative magnetic low (H_1).

The occurrence of five hot springs near gravity maxima partly is a local densification effect of induration caused by precipitation and cementation within tuffaceous sedimentary rocks, which elsewhere are porous and of lower density. The occurrence of opal deposits and petrified wood in Virgin Valley near H_1 exemplifies the process of induration, which results in a local increase of density relative to the surrounding sedimentary rocks. The gravity anomalies, however, appear to be too broad in horizontal dimensions to be explained wholly as a result of a local increase of density due to induration of sedimentary rocks.

A correlation between gravity maxima and intrusive centers has been reported near the San Juan Mountains volcanic field in Colorado (Plouff and Pakiser, 1972). One may assume that underlying intrusive centers, as mapped by local gravity maxima, heat water that flows into the hot springs within the Charles Sheldon study area. But no intrusive rocks are exposed at the surface nor is there doming near any of the hot springs. The postulated intrusive rocks would be younger than the youngest age-dated surface igneous rocks (table 1) to have retained their heat without replenishment from radioactive sources or an underlying magma chamber. Therefore the possible correlation between hot springs and intrusive centers near the study area remains speculative.

An alternate explanation for the apparent correlation between gravity maxima and the localization of hot springs might be that the gravity maxima outline uplifted fault blocks. The concept of correlation with fault blocks is consistent with prevalent explanations for the origin of hot springs in northern Nevada that involve a cycle of descending meteoric water, heating at depth, and rising to the surface with deep circulation via crushed rock along Basin and Range faults (for example, Hose and Taylor, 1974). Three of the gravity maxima (H_2, H_3, and H_4) are along a fault zone or lineament suggested by Hose and Taylor (1974, p. 13). There are no mapped faults (pl. 1) that specifically correspond to the outlines of the gravity maxima, however, and consequently the possible correlation between fault blocks and the localization of hot springs remains speculative.

The gravity maximum H_2 occurs along the gravity ridge G_4–G_5, which, as discussed in the last section, probably is an effect of Mesozoic rocks that are structurally elevated and more dense than the surrounding Tertiary rocks. The four other gravity maxima that are near hot springs and the closed gravity maximum G_6, near Onion Lake, similarly might indicate the underlying presence of uplifted pre-Tertiary rocks or pre-Tertiary rocks that are more dense than the surrounding basement rocks.

As discussed above, the gravity maxima near hot springs could be caused by any combination of densified sediments, buried intrusive rocks or plutons, uplifted fault blocks, and pre-Tertiary basement highs. These possible anomalous conditions warrant further studies of localities H_1, $H_3(F_2)$, and H_5 as potential sites for geothermal and mineral deposits in the study area. Though no hot springs are shown near Onion Lake in the southeast corner of the study area, the adjacent gravity and corresponding magnetic maxima (G_6) similarly indicate the location of an area that warrants further study.

GRAVITY AND MAGNETIC ANOMALIES RELATED TO POSSIBLE CALDERAS

Four closed minima on the gravity map (C_1, C_2, C_3, and G_2, pl. 2) are within or along the border of the study area. Closed gravity minima in other parts of Nevada commonly are elongated parallel to Basin and Range faults and indicate anomalous thicknesses of alluvium or tuffaceous sediments underlying Basin and Range valleys. The gravity minima in the study area, however, do not overlie alluvial valleys nor do any of the anomalies seem to be correlated with mapped geologic units (pl. 1).

The most extensive gravity minimum, C_1, closely conforms in size and shape to a magnetic minimum (pl. 2). A curved line, drawn near the approximate average position of the center of the steepest gradients along the edges of the magnetic and gravity minima (pl. 2), shows how closely the two types of geophysical anomalies agree in shape and size. The equivalent ground positions used for the magnetic contours were displaced 0.24 mi (0.4 km) northeastward to adjust for the effect of the 66° inclination of the Earth's field at an average flight altitude of 0.9 km. The direction of elongation of the 10.5 by 15.5-mi (17 by 25-km) oval-shaped boundary is to the northwest.

The postulated caldera near C_1 is underlain by a large mass of rock that has a lower density and a lower magnetization than the surrounding rocks. A two-dimensional model of the gravity anomaly, using Bott's (1960) iterative method along section *C–C′* (pl. 2), provides an estimate of a possible subsurface mass configuration that fits the observed gravity anomaly. Assuming a constant density contrast of 0.2 g/cm^3 gives a better fit along the edges of the model than other contrasts. The model derived from the analyses is shaped like a saucer of low-density rocks that extends from the surface to a depth of 1.6 mi (2.7 km). Further refinement of the model using three-dimensional methods was not attempted because the derived two-dimensional model (pl. 2) is relatively thin compared to its width, and consequently, an insignificant increase of depth estimates using three-dimensional methods would be obtained.

Assuming a nominal magnetic susceptibility contrast of 0.002 emu (electromagnetic unit) between the interior and exterior rocks, the magnetic effect of the gravity model was calculated. The agreement with the observed magnetic anomaly, however, is imperfect due to the combination of the interfering effect of rocks of higher magnetization located to the southwest, possible contrasts of the magnetization of rocks within the model, and the approximation of absorbing the effect of three-dimensional anomalies into a two-dimensional model.

More than half of the rocks enclosed by the postulated caldera centered at C_1 are mapped as tuffaceous sedimentary rocks (pl. 1). Most of the remaining rocks are mapped as the rhyolite of Badger Mountain. Substantial amounts of Soldier Meadow Tuff and the basalt of Catnip Creek are also present. The less dense rocks within the area of the gravity model mostly might consist of a thickened sequence of tuffaceous sedimentary rocks. An assumed average density contrast of 0.2 g/cm^3 between the sedimentary rocks within the depression and the surrounding Tertiary volcanic rocks is reasonable, although the average density contrast could range from 0.1 to 0.5 g/cm^3 depending on the degree of interbedding, the compaction of the sediments, and the character of the concealed volcanic rock.

A saucerlike depression filled with tuffaceous sedimentary rocks indicates collapse associated with a previously unmapped caldera, which formed in response to the explosive release of large volumes of ash-flow tuffs during rapid depletion of an underlying local magma chamber. Both G. W. Walker (oral commun., 1976) and Norman MacLeod (oral commun., 1976) suspected that calderas are present in this area of northwest Nevada, to account for the observed distribution of ash-flow tuffs and associated rhyolite. At present, however, there essentially is no surface geologic evidence to outline the boundary of the postulated caldera that is identified by the geophysical anomalies. In retrospect, only a rather linear topographic low along the southwest rim of the caldera and a set of northwest-trending faults (pl. 1) parallel to the direction of elongation of the caldera may be related to the earlier formation of a caldera. Possibly the occurrence of the spectacular landslide on the southwest side of Blowout Mountain (Chap. A, this report) indicates a late response triggered by an increment of gradual basinward tilting of the land surface following compaction of the underlying tuffaceous sedimentary rocks or secondary slump over the caldera wall.

The 3.7 by 4.9 mi (6 by 8 km) closed gravity minimum centered at Rock Spring Table Reservoir (C_2) also may depict an underlying caldera. The shape of the corresponding magnetic minimum (pl. 2), however, is distorted by the effect of a superimposed dipole low related to the prominent magnetic maximum, G_1–T_4–G_6, to the southeast. The nearly 15-mgal amplitude of the gravity minimum indicates that the underlying rocks of relatively low density are about the same total thickness as the low-density rocks beneath Badger Mountain. Again, there appears to be no geologic evidence to suggest the presence of an underlying caldera. Most of the surface rocks near C_2 consist of a thin cap of the basalt of Catnip Creek (pl. 1), which would have been deposited after the active cycles associated with the postulated caldera ceased. In retrospect, the occurrences of a faulted 0.6 mi (1-km) diameter outcrop of rhyolite of Badger Mountain within the oval-shaped boundary, tuffaceous sedimentary rock along most of the edges, and huge landslides to the north and northeast may be related to the formation of a caldera.

A concealed caldera also may underlie the closed gravity low, C_3, near Idaho Canyon in the southeast corner of the study area. Small gravity and magnetic minima west of the study area between G_7 and G_8, separated from the main caldera at C_1 by maxima that strike northeast through G_9, may indicate the presence of a fault-controlled thick wedge of tuffaceous sedimentary rocks beneath the surficial basalts. A magnetic minimum centered near G_1 indicates the location of a possible connection between the main caldera and the minima near G_7 and G_8, but there are no gravity stations to substantiate this relation. The smaller magnetic minima also could be caused by underlying rocks having reversed remanent magnetization or, possibly, may be caused by locally altered rocks that are enclosed by rocks with higher magnetization.

If calderas underlie the Charles Sheldon Wilderness Study Area, faulting associated with collapse might have provided channels for warm ore-bearing solutions to migrate upward toward the surface. Furthermore, the apparent low level of magnetization of rocks within the postulated caldera at C_1 suggests destruction of former magnetization by rock alteration that could be associated with mineralization.

Calderas are believed to play an important role in the localization of ore deposits (Albers and Kleinhampl, 1970; Steven and others, 1974). The McDermitt caldera, about 62 mi (100 km) northeast of the Charles Sheldon Wilderness Study Area, for example, is the site of the largest operating mercury mine in North America (Rytuba, 1976; McKee, 1976). Five mercury mines are adjacent to ring-fracture faults and a uranium mine and other uranium occurrences are within rhyolite domes related to the McDermitt caldera (Rytuba, 1976).

The gravity anomaly associated with the McDermitt caldera (Plouff, 1976; Rytuba, 1976, fig. 3) is more complex than the symmetrically shaped gravity minima in the wilderness study area. The overall appearance of the anomaly at the McDermitt caldera is a 18.6 by 24.8 mi (30 by 40-km) horseshoe-shaped gravity maximum that opens to the north with superimposed gravity minima inside the north, northeast, and south rims that reflect thickened tuffaceous sedimentary rocks. Intense, elongated gravity minima that are caused by thick alluvial fill in bordering Basin and Range faulted valleys reduce the effect of the gravity minimum. The gravity minimum is further reduced because the process associated with resurgent doming probably has introduced more dense rocks into the McDermitt caldera and has uplifted the area so that previously overlying, less dense rocks have been removed by erosion.

The postulated calderas in the Charles Sheldon Wilderness Study Area, however, more nearly would resemble the erosional stage of the Silent Canyon caldera, Nye County, Nev., for example, which "is almost completely obscured by younger unrelated rocks from other nearby centers" (Noble and others, 1968). The shape of that caldera was revealed by a combination of detailed geologic studies, drill-hole data, and a 11 by 15 mi (18 by 24 km), 15-mgal gravity minimum (Orkild and others, 1968, fig. 2).

Geochemical data collected in the Charles Sheldon Wilderness Study Area, as reported in the following chapter, generally show high concentrations of mercury roughly in the same location as the postulated calderas. But additional geologic studies are needed to verify that the gravity and magnetic minima outline concealed calderas, which could have high mineral potential. Until further studies are made, alternative interpretations to explain the cause of the geophysical minima cannot be discounted. For example, the minima also might reveal underlying plutons of lower densities and magnetizations than the surrounding crystalline basement rock. It is unlikely, however, that the plutons could extend upward into the section of Tertiary volcanic rocks, because the average density of the plutons probably would exceed that of the surrounding Tertiary rocks. The combination of a mass excess in the Tertiary section and a mass deficiency within the pre-Tertiary basement, however, would tend to result in a more complicated gravity-anomaly pattern than indicated by the observed gravity anomalies.

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Geochemical Evaluation of the Mineral and Geothermal Resources of the Charles Sheldon Wilderness Study Area, Nevada and Oregon

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MINERAL RESOURCES OF THE CHARLES SHELDON WILDERNESS STUDY AREA, HUMBOLDT AND WASHOE COUNTIES, NEVADA, AND LAKE AND HARNEY COUNTIES, OREGON

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GEOCHEMICAL EVALUATION OF THE MINERAL AND GEOTHERMAL RESOURCES

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INTRODUCTION

Evaluation of the mineral-resource potential and geothermal potential of the Charles Sheldon Wilderness Study Area is based on the interpretation of (1) analyses of rock and stream-sediment samples, (2) analyses of spring-water samples and one algae sample collected from a thermal spring, (3) geologic mapping, and (4) geophysical (aeromagnetic and gravity) surveys. This chapter discusses the interpretations of geochemical results (items 1 and 2 above), which were evaluated in context with the results from the geological and geophysical studies. The results indicate that the area has low potential for the discovery of exposed mineral deposits; however, the results suggest that the area may contain concealed deposits.

METHODS OF EVALUATION

Evaluation of the mineral-resource potential of the Charles Sheldon Wilderness Study Area was made on the basis of speculative information in view of the problems caused by the blanket cover of volcanic rock. The geochemical association of many elements and the structural and geophysical features found here can only be interpreted in the light of their association with each other.

For the geochemical evaluation, a total of 884 stream-sediment samples were collected along the larger streams and near the confluence of small tributaries (Cathrall and others, 1977). Stream-sediment samples collected from dry stream channels consisted of several scoops of fine sediments. The sediments were taken across the width of the main channel. Stream-sediment samples from flowing streams were collected from midchannel, and where this was impractical, the sediment was collected at the side of the stream channel. The dry weights of samples ranged from 5.2 to 8.8 oz (150 to 250 g or grams).

Samples were placed in metal-free cloth bags or paper envelopes; wet samples were air dried, and all samples were prepared by shaking through an 80-mesh (0.007 in. or 0.18 mm) stainless-steel sieve. The minus-80-mesh fraction was saved for analyses.

In addition to stream sediments, 396 rock samples collected from 314 localities were taken and analyzed (Cathrall and others, 1977). Rock samples were collected from bedrock, but a few, particularly along escarpments, were taken from float (loose rock chips) shed from the escarpment. Representative samples of all types and varieties of rocks present in the study area were taken. Few, if any, showed visible indications of alteration or mineralization, although this type of rock was sought. Samples weighed from 0.5 to 1 lb (0.25 to 0.5 kg); all were crushed in a jaw crusher to approximately 0.23 in. (6 mm) in diameter and split through a Jones splitter; half of the split was pulverized to minus 250 mesh for analyses.

The procedures used in analyzing rock and stream-sediment samples were identical. Semiquantitative spectrographic methods were used for iron, magnesium, calcium, titanium, manganese, silver, boron, barium, beryllium, cobalt, chromium, copper, lanthanum, molybdenum, niobium, nickel, lead, scandium, tin, strontium, vanadium, yttrium, and zircon (Grimes and Marranzino, 1968). Atomic-absorption spectrophotometry was used to determine cadmium, gold, zinc (Ward and others, 1963, 1969), and antimony (Welsch and Chao, 1976). Mercury was determined by a flameless atomic-absorption spectrophotometry method described by Vaughn and McCarthy (1964). Arsenic was determined by colorimetry (Ward and others, 1963). Neutron activation, delayed neutron counting, was used for uranium and thorium (Millard, 1976).

The analytical results for stream-sediment and rock samples were evaluated to determine background and anomalous values in apparently unmineralized rock. Anomalous values may be related to mineral deposits. The lower limit of concentration of an element to be considered anomalous is called the threshold value and was determined by plotting the cumulative frequency of values on logarithmic paper similar to the methods described by Sinclair (1974), Lepeltier (1969), and Parslow (1974). The plot defines two populations (groups of values) represented by straight lines. The intersection of these lines defines the threshold value. Figure 11, an illustration of the cumulative frequency plot for mercury, is included as an example.

The cumulative frequency plots of those elements and the ratio of

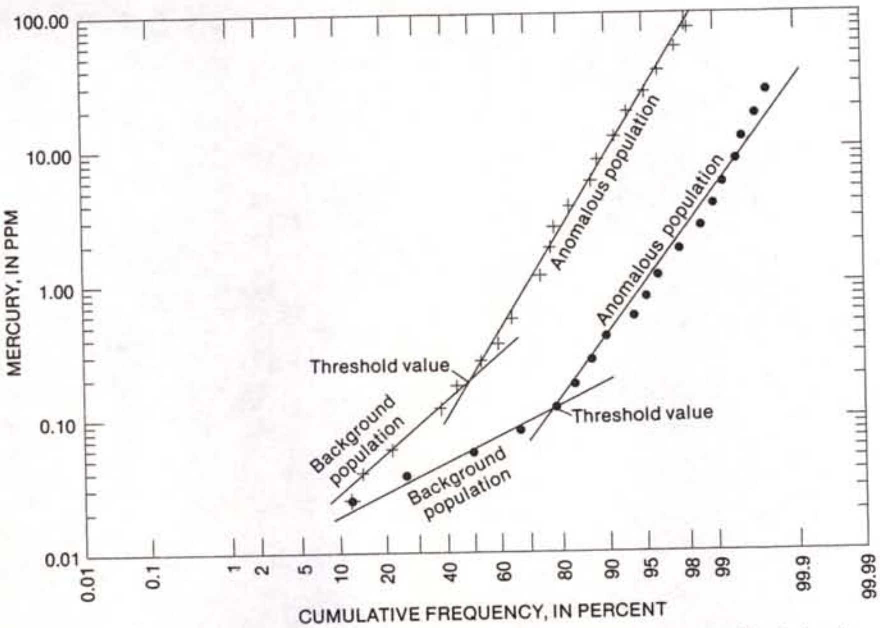


FIGURE 11.—Cumulative frequency plot for mercury for 396 rock samples (+) and 884 stream-sediment samples (.), Charles Sheldon Wilderness Study Area.

elements that showed definite threshold values are discussed in the following section of this report. Threshold values, crustal abundance, the range of values, the number of values, the percentile distribution, and the geometric means of these elements and the cadmium:zinc ratio are listed in table 2. The samples containing highly anomalous values of these elements, and anomalous cadmium:zinc ratios, were used to construct element-distribution maps (figs. 14–22, 25).

The low-level concentrations of those elements listed on table 3, when compared with their crustal abundance, suggests that the area has a very low potential for the discovery of exposed mineral deposits.

CONCEALED POTENTIAL MINERAL RESOURCES

Several elements, including gold, mercury, antimony, arsenic, tungsten, molybdenum, manganese, and barium, are present in anomalous amounts, and the cadmium:zinc ratio is anomalous, in the Charles Sheldon Wilderness Study Area. These elements and their association with one another suggest the possible presence of concealed mineral deposits.

Studies of hydrothermal deposits have shown that groups of elements are present in zones surrounding the source of mineralizing

TABLE 2.—*Threshold values, crustal abundance, range of values, number of values, percentile distributions, and geometric means of rock and stream-sediment samples for selected elements and for the cadmium:zinc ratio, Charles Sheldon Wilderness Study Area*

[Values for Hg, Sb, As, W, Mo, Ba, and Mn are expressed in parts per million. Cd:Zn values are expressed as a ratio. Lower limits of detection in ppm: Hg=0.02, Sb=0.5, As=10, W=50, Mo=5, Ba=20, Mn=0, Cd=0.4, Zn=0.6. N=396 for rocks and 884 for stream sediments. Analytical methods: Mn, Ba, Mo, and W by emission spectroscopy; Hg by flameless atomic absorption; Sb, Cd, and Zn by atomic absorption; As by colorimetry. Analysts: E. F. Cooley, G. L. Crenshaw, and D. F. Siems. Leaders (--), insufficient data]

Element or element ratio	Sample type	Threshold value	Mean crustal abundance	Range of detectable values	Number of detectable values	Selected percentiles based on number (n) of samples				Geometric mean
						25th	50th	75th	90th	
Mercury-----	Rock-------------	0.2	[1]0.06	0.02->100	358	0.1	0.2	1.4	11	0.44
	Stream sediment--	.15	--	.02->100	884	.04	.05	.11	.37	.08
Antimony----	Rock-------------	10	[2]1	.5-800	234	--	1	4	22	4
	Stream sediment--	10	--	.5-60	170	--	--	--	1.1	1.9
Arsenic-----	Rock-------------	80	[2]5	10-1400	372	10	21	40	86	24
	Stream sediment--	80	--	10-200	861	11	21	26	41	19
Tungsten----	Rock-------------	[3]<50	[2]1	[3]<50-500	21	--	--	--	--	81
	Stream sediment--	[3]<50	--	[3]<50-50	2	--	--	--	--	--
Molybdenum--	Rock-------------	7	[2]2.3	5-500	60	--	--	--	9	16
	Stream sediment--	7	--	5-20	74	--	--	--	--	8
Barium------	Rock-------------	1,500	[2]430	20->5000	387	120	410	1,040	1,840	370
	Stream sediment--	1,500	--	100-2000	884	460	620	770	1,030	620
Manganese---	Rock-------------	2,000	[2]1,000	20->2000	389	150	350	790	1,490	320
	Stream sediment--	2,000	--	20-5000	884	760	990	1,260	1,640	980
Cadmium:zinc ratio.	Rock-------------	.02	--	.002-.007	396	.01	.013	.018	.021	.014
	Stream sediment--	.02	[2].002	.002-1.91	882	.02	.04	.1	.025	.047

[1]Green (1959).
[2]Goldschmidt (1954).
[3]Less than value shown, but line observed by spectrographer.

fluids. In the Refuge area, the zonal arrangement of elements formed by the anomalous values of barium, mercury, manganese, arsenic, antimony, tungsten, and molybdenum parallels the metal zonation first presented by Emmons (1936). The distribution of these elements, when viewed in relation to a reconstructed vein-system model (table 4), is similar to the uppermost arrangement of metals in the model. As would be expected, no single mineralized area contains all of the mineral groups given in the model. Discrepancies—irregularities, reversals, and poorly defined zoning—between the observed and the model vein system may occur. These discrepancies may be caused by overlapping of deposits from two or more magmatic centers, by retreat or advance of magmatic centers during one period of deposition, by repeated periods of mineralization in a single area, by supergene enrichment, and by other causes not fully understood.

The association of mercury, arsenic, antimony, tungsten, and gold has been recognized in many ore deposits in Paleozoic rocks of north-central Nevada (Erickson and others, 1966). These elements are also associated with ore deposits in Tertiary volcanic rocks in northern and western Nevada. The mineral assemblages at Getchell, Bootstrap, Carlin, and Gold Acres, and the gold deposits of the Cortez area in north-central Nevada are of this type, as are the Aurora-Bodie, Comstock, Opalite, Goldfield, and Tonopah deposits in northern and western Nevada. This suite of elements is also typical of the epithermal deposits throughout the world. The geologic environment in the Charles Sheldon Wilderness Study Area is similar to the environment commonly associated with epithermal and Tertiary volcanic-center deposits of gold, silver, mercury, and antimony.

In the Refuge area, the anomalous concentrations of mercury, antimony, arsenic, tungsten, molybdenum, manganese, barium, and gold and anomalous cadmium:zinc ratios form dispersion patterns that are contiguous with many faults and with some magnetic and(or) gravity highs (figs. 12, 13, and 25). This assemblage of anomalous concentrations of metals may indicate the presence of concealed mineral deposits. The association of high metals with magnetic lows possibly reflects the destruction of magnetite by hydrothermal processes; the association of high metal values with gravity highs may be related to an underlying structure such as an intrusive center or may reflect a structural high on the pre-Tertiary basement. The occurrence of anomalously high metals along the fault planes suggests that the faults may have acted as the plumbing system for ascending metal-bearing solutions. A gravity high is centered over the exposed Tertiary andesitic rocks of Bald Mountain and the exposed Tertiary rhyolite rocks of Cottonwood Canyon (pl. 1). These rocks are older and structurally uplifted relative to the surrounding Tertiary basalt.

TABLE 3.—*Statistical summary of the analytical results for stream-sediment and rock samples as compared to the crustal abundance for the average igneous rock, Charles Sheldon Wilderness Study Area*

[Values for Fe, Mg, Ca, and Ti reported in percent; all other values reported in ppm (parts per million). Lower limits of detection for semiquantitative emission spectrographic analyses: Fe and Ca=0.05; Mg=0.02; Ti=0.002; Mn, Au, B, Bi, Cr, Pb, Sn, V, Y, and Zr=10; Ag=0.5; As and Zn=200; Ba, Cd, La, and Nb=20; Be=1; Co, Cu, Mo, Ni, and Sc=5; Sb and Sr=100; W=50. Upper limits of detection for semiquantitative emission spectrographic analyses: Ti=1; Mg=10; Fe and Ca=20; Cd and Au=500; Be, Bi, La, Sn, and Zr=1,000; B, Co, Mo, Nb, and Y=2,000; Mn, Ag, Ba, Cr, Sr, and Ni=5,000; As, Sb, W, V, and Zn=10,000; and Cu and Pb=20,000. Lower limits of detection for all other methods of analysis: Au=0.05; Zn=5; Cd=0.4; Sb=1; Hg=0.02; As=10; W=20. Upper limit of detection for Hg=100. Uncensored population is one in which the element concentrations fall within the sensitivity limits of the method used. Censored population is one in which element concentrations are coded with N, L, or G: N, not detected at limit of detection; L, detected but below limit of detection; G, greater than upper limit of detection. n, total number of samples analyzed for the particular element presented. This number is determined by adding columns headed N, L, G, and Number of values. Leaders (--), no data or insufficient data. Analysts: E. F. Cooley, G. L. Crenshaw, R. J. Knight, H. L. Millard, Jr., and D. F Siems]

Element	Sample type	Crustal abundance[1]	Data based on the censored population			Data based on the uncensored population				Percentile distribution in ppm based on n samples analyzed			
			N	L	G	Number of values	Range of values	Geometric mean	Geometric deviation	25th	50th	75th	90th
Semiquantitative emission spectrography[2]													
Fe---	Rock------------	5	0	6	0	390	002 - 20	1.5	3.9	0.7	2.0	4.1	5.5
	Stream sediment-	--	0	0	1	883	.5 - 20	4.4	1.5	3.3	4.3	5.3	7.1
Mg---	Rock------------	2.9	0	24	0	372	.02 - 3	.2	3.2	.1	.1	.4	.8
	Stream sediment-	--	0	0	0	884	.15 - 2	.9	1.5	.7	.9	1.1	1.4
Ca---	Rock------------	3.6	0	11	0	385	.05 - 10	.3	3.1	.1	.2	.5	1.0
	Stream sediment-	--	0	0	0	884	.05 - 5	1.0	1.5	.8	1.0	1.3	1.9
Ti---	Rock------------	.44	0	1	1	394	.005- 1	.15	3.7	.1	.2	.4	.7
	Stream sediment-	--	0	0	29	855	.1 - 1	.5	1.7	.4	.5	.8	1.1
Mn---	Rock------------	1000	3	4	7	382	20 -5,000	319	3.2	147	350	792	1,492
	Stream sediment-	--	0	0	0	884	150 -5,000	976	1.6	759	992	1,259	1,639
Ag---	Rock------------	0.02	394	0	0	2	1 - 3	--	--	--	--	--	--
	Stream sediment-	--	880	1	0	3	.7 - 1	--	--	--	--	--	--

As---	Rock------------	5	389	0	0	7	300 -1,000	--	--	--	--	--	--
	Stream sediment-	--	884	0	0	0	--	--	--	--	--	--	--
B---	Rock------------	10	1	107	0	288	10 - 150	21	2	--	13	26	44
	Stream sediment-	--	1	7	0	876	10 - 100	25	1.5	20	24	33	44
Ba---	Rock------------	430	0	9	2	385	20 -5,000	369	3.5	117	405	1,041	1,840
	Stream sediment-	--	0	0	0	884	100 -2,000	622	1.5	463	617	774	1,029
Be---	Rock------------	6	2	23	0	371	1 - 50	2.6	2.1	1.5	2.2	3.4	6.5
	Stream sediment-	--	4	26	0	854	1 - 7	1.7	1.4	1.3	1.9	2.3	2.6
Bi---	Rock------------	.2	395	0	0	1	10 -	--	--	--	--	--	--
	Stream sediment-	--	884	0	0	0	--	--	--	--	--	--	--
Co---	Rock------------	40	79	226	0	91	5 - 100	10.4	2.0	--	--	--	10
	Stream sediment-	--	1	9	0	874	5 - 70	15.7	1.7	11	18	23	29
Cr---	Rock------------	200	54	244	0	98	10 - 200	17	1.8	--	--	--	20
	Stream sediment-	--	0	3	0	881	10 - 200	41	1.7	31	44	53	71
Cu---	Rock------------	70	1	131	0	264	5 - 200	9	1.8	--	5.1	11	18
	Stream sediment-	--	0	0	0	884	5 - 50	21	1.5	18	23	30	35
La---	Rock------------	18.3	3	68	0	325	20 - 200	63	1.5	40	51	73	102
	Stream sediment-	--	3	3	0	878	20 - 200	55	1.4	43	50	62	79
Mo---	Rock------------	2.3	300	36	0	60	5 - 500	16	3.3	--	--	--	9.2
	Stream sediment-	--	723	87	0	74	5 - 20	8	1.5	--	--	--	--
Nb---	Rock------------	20	7	382	0	7	20 - 50	--	--	--	--	--	--
	Stream sediment-	--	24	814	0	46	10 - 50	21	1.6	--	--	--	--
Ni---	Rock------------	100	4	292	0	100	5 - 200	9	2.2	--	--	4	8
	Stream sediment-	--	0	12	0	892	5 - 100	19	1.7	14	21	26	37
Pb---	Rock------------	16	39	48	0	309	10 - 100	20	1.6	9	19	24	33
	Stream sediment-	--	1	3	0	880	10 - 70	22	1.4	20	23	30	37
Sb---	Rock------------	1	349	10	0	37	100 -1,000	215	1.9	--	--	--	--
	Stream sediment-	--	880	2	0	2	100 - 200	--	--	--	--	--	--

TABLE 3.—*Statistical summary of the analytical results for stream-sediment and rock samples as compared to the crustal abundance for the average igneous rock, Charles Sheldon Wilderness Study Area*—Continued

Element	Sample type	Crustal abundance[1]	Data based on the censored population N	L	G	Data based on the uncensored population: Number of values	Range of values	Geometric mean	Geometric deviation	Percentile distribution in ppm based on n sample analyzed: 25th	50th	75th	90th
Semiquantitative emission spectrography[2]													
Sc---	Rock------------	5	44	84	0	268	5 - 100	10	1.9	--	6	17	23
	Stream sediment-	--	1	1	0	882	5 - 30	15	1.4	13	17	21	24
Sn---	Rock------------	40	373	7	0	16	10 - 70	14	1.8	--	--	--	--
	Stream sediment-	--	866	15	0	3	10 - 100	--	--	--	--	--	--
Sr---	Rock------------	150	39	162	1	194	100 -1,500	232	1.9	--	--	249	413
	Stream sediment-	--	1	1	0	882	1 -1,000	360	1.5	286	372	467	533
V----	Rock------------	150	0	23	0	373	10 - 500	38	2.4	19	35	65	111
	Stream sediment-	--	0	0	0	884	20 -1,000	102	1.5	83	101	127	184
W----	Rock------------	1	375	7	0	14	50 - 500	81	1.9	--	--	--	--
	Stream sediment-	--	882	1	0	1	50 - 50	--	--	--	--	--	--
Y----	Rock------------	28.1	3	43	0	350	10 - 300	43	1.9	23	41	56	89
	Stream sediment-	--	0	1	0	883	10 - 200	47	1.5	28	38	48	55
Zn---	Rock------------	80	354	21	0	21	200 -1,000	--	--	--	--	--	--
	Stream sediment-	--	861	13	0	10	200 - 500	--	--	--	--	--	--
Zr---	Rock------------	220	0	15	9	372	10 -1,000	202	2.4	178	251	342	490
	Stream sediment-	--	0	0	5	879	50 -1,000	248	1.5	204	259	330	382
Atomic absorption													
Au[3]--	Rock------------	0.001	283	101	0	4	0.06 - 0.84	--	--	--	--	--	--
	Stream sediment-	--	152	0	0	0	-- --	--	--	--	--	--	--
Zn[3]--	Rock------------	80	0	2	0	394	.6 - 190	13	3.2	7	15	28	57
	Stream sediment-	--	0	0	0	884	9.8 - 216	30	1.4	23	30	37	49

Cd[3]--	Rock------------	.18	22	147	0	227	.4 - 6.8	1.1	1.9	--	.5	1.2	2.0
	Stream sediment-	--	28	273	0	581	.4 - 2	.5	1.3	--	.4	.5	.7
Sb[4]--	Rock------------	1	42	120	0	234	1 - 800	4	4.7	--	1.0	3.6	22
	Stream sediment-	--	309	404	0	170	.5 - 60	2	2.7	--	--	--	1
Hg[5]--	Rock------------	[6].06	11	27	8	350	.02 - 82	.44	7.3	.1	.2	1.4	10
	Stream sediment-	--	18	21	1	844	.02 - 38.5	.08	3.2	.04	.05	.11	.37
							Colorimetry						
As[3]--	Rock------------	5	0	24	0	372	10 -1,400	24	2.4	10	21	40	86
	Stream sediment-	--	14	9	0	861	10 - 200	19	1.7	11	21	26	41
W[3]--	Rock------------	1	192	199	0	5	-- --	--	--	--	--	--	--
	Stream sediment-	--	--	--	--	--	-- --	--	--	--	--	--	--
							Neutron activation[7]						
U----	Rock------------	4	0	0	0	90	0.36- 860	12	4.6	4	8	35	133
	Stream sediment-	--	0	0	0	44	2.6 - 13	5	1.4	3	5	6	7
Th---	Rock------------	11.5	0	0	0	60	3 - 25	17	2.3	10	17	24	56
	Stream sediment-	--	0	0	0	42	5 - 32	13	1.4	9	13	17	22

[1]Goldschmidt (1954).
[2]Ward and others (1963).
[3]Grimes and Marranzino (1968).
[4]Welsch and Chao (1976).
[5]Vaughn and McCarthy (1964).
[6]Green (1959).
[7]Millard (1976).

TABLE 4.—*A reconstructed vein system, from the surface downward*

[From Emmons, 1936]

1. Barren zone. Chalcedony, quartz, barite, fluorite, etc. Some of the veins carry a little mercury, antimony, or arsenic.
2. Mercury. Cinnabar deposits, commonly with chalcedony, marcasite, etc. Barite-fluorite veins.
3. Antimony. Stibnite deposits, often passing downward into galena with antimonates. Some carry gold.
4. Gold-Silver. Bonanza gold deposits and gold-silver deposits. Argnetite with arsenic and antimony minerals common. Tellurides and selenides at places. Relatively small amounts of galena, sphalerite, and chalcopyrite are present; gangue includes quartz, adularia, alunite, with calcite, rhodochrosite, and other carbonates.
5. Barren. Most nearly consistent barren zone; represents the bottoms of many Tertiary precious-metal veins. Quartz, carbonates, etc., with small amounts of pyrite, chalcopyrite, sphalerite, and galena.
6. Silver. Argentite veins, complex silver minerals with antimony and arsenic, stibnite, some arsenopyrite, etc.; quartz gangue, at places with siderite.
7. Lead. Galena veins, generally with silver; sphalerite generally present, increasing with depth; some chalcopyrite. Gangue of quartz with carbonates.
8. Zinc. Sphalerite deposits; galena and some chalcopyrite generally present. Gangue is quartz and in some deposits carbonates of calcium, iron, and maganese.
9. Copper. Tetrahedrite, commonly argentiferous; chalcopyrite present. Some pass downward into chalcopyrite. Enargite veins, generally with tetrahedrite.
10. Copper. Chalcopyrite veins, most with pyrite, many with pyrrhotite. The gangue is quartz and at some places carbonates and feldspar. Orthoclase and sodic plagioclase not rare, but high-calcium plagioclase very rare; generally carry precious metals. Uranium, probably main horizon of uraninite.
11. Gold. Deposits with pyrite, commonly arsenopyrite. Quartz, carbonates, and some with feldspar gangue. Some with tourmaline. Tellurides not uncommon and at places abundant. At places zones 10 and 11 are reversed.
12. Arsenic. Arsenopyrite with chalcopyrite, etc.
13. Bismuth. Bismuthinite deposits. Native bismuth, quartz, pyrite, etc.
14. Tungsten. Veins with tungsten minerals, arsenopyrite, pyrrhotite, pyrite, chalcopyrite. Tungsten occurs in higher zones in large amounts, but this is the main horizon.
15. Tin. Cassiterite veins with quartz, tourmaline, topaz, feldspar, etc.
16. Barren. Quartz, feldspar, pyrite, carbonates, and small amounts of other minerals.

Ranges or anomalous concentrations (ppm) in figure 12

[Leaders (—), not detected at limit of detection]

Element	Rock samples	Stream-sediment samples
Hg--------	0.2–>100	0.2–>100
Sb-------	10–1400	10–60
As-------	80–800	80–100
W--------	<50–100	---

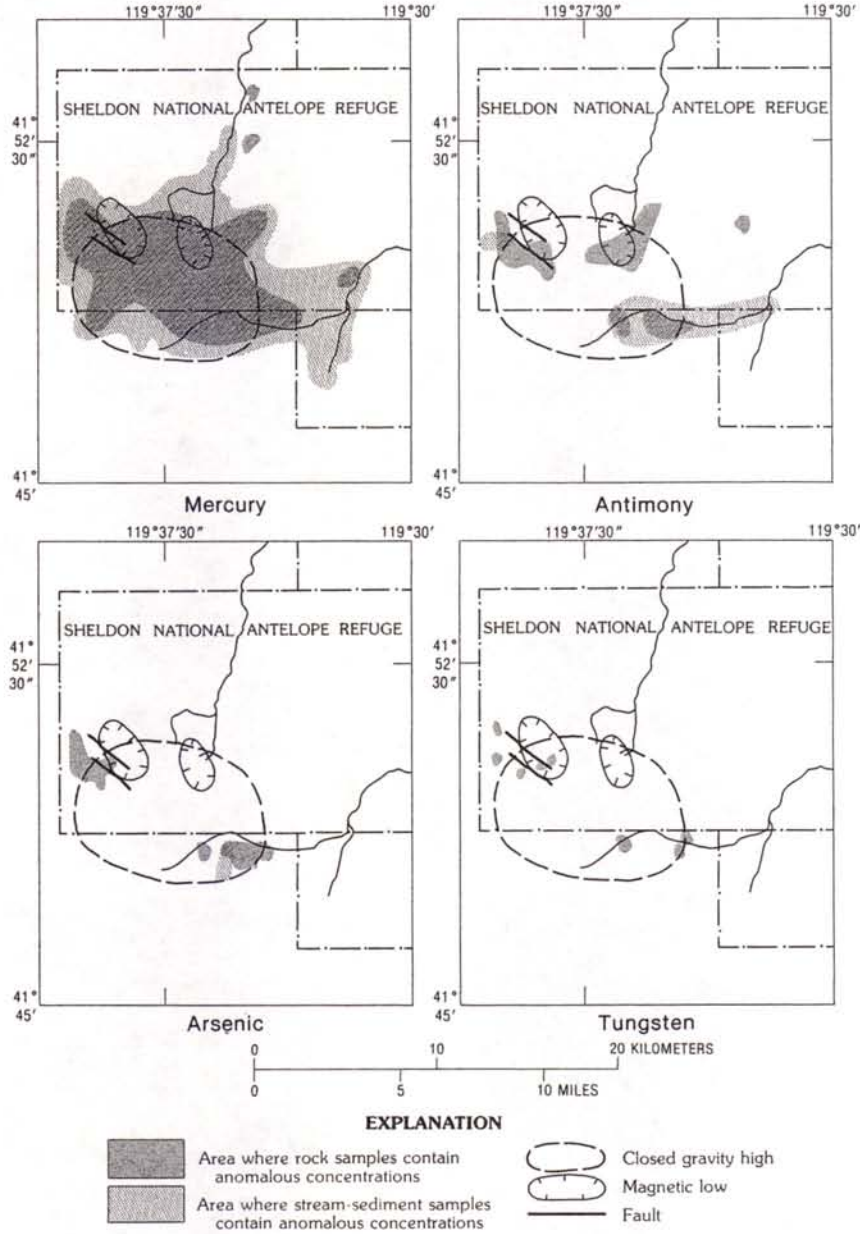


FIGURE 12.—Relationship between selected magnetic lows, faults, a gravity high, and anomalous concentrations of mercury, antimony, arsenic, and tungsten in rock and stream-sediment samples in the Lone Pine district, Charles Sheldon Wilderness Study Area. Method of analyes: Hg by flameless atomic absorption; As by colorimetry; W by emission spectroscopy; and Sb by atomic absorption. Analysts: E. F. Cooley, G. L. Crenshaw, and D. F. Siems.

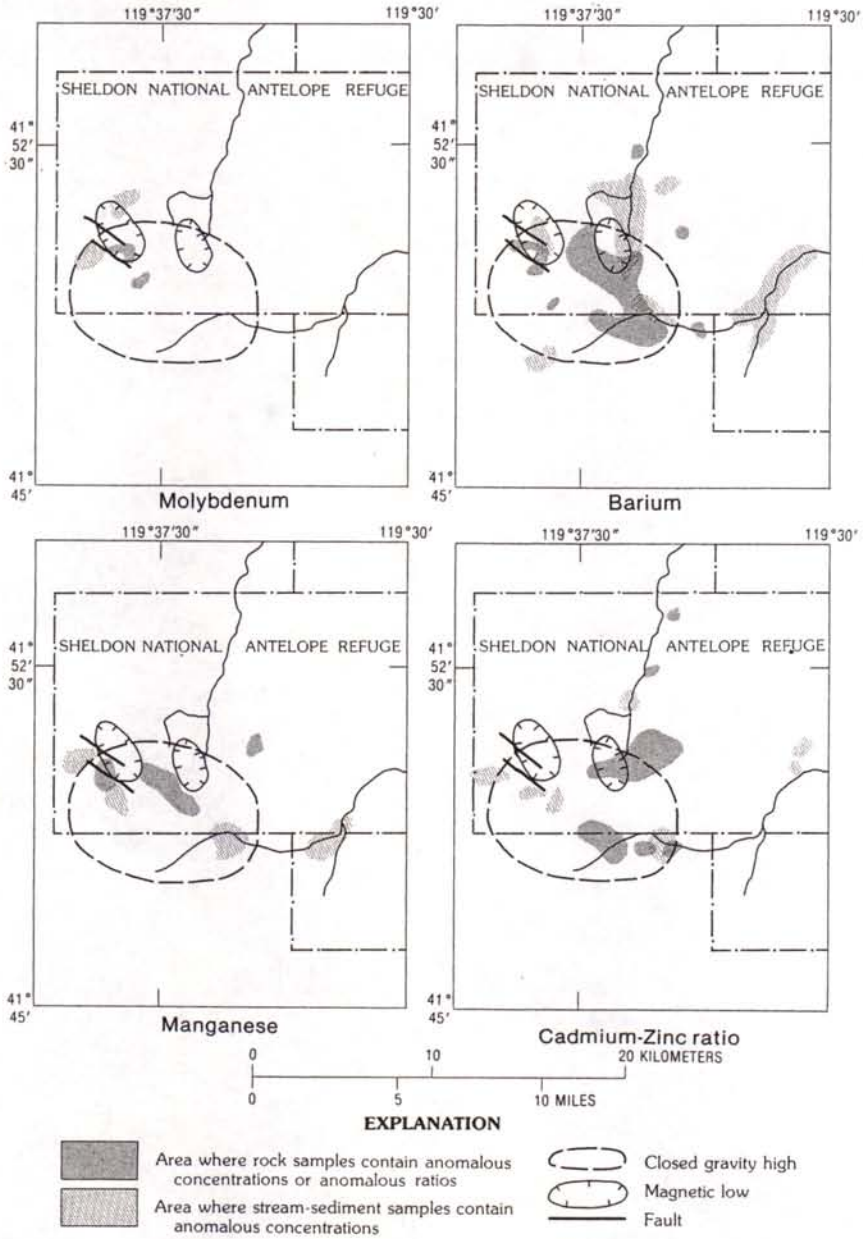


FIGURE 13.—Relationship between selected aeromagnetic lows, faults, a gravity high, and anomalous concentrations of molybdenum, barium, and manganese, and anomalous cadmium:zinc ratios ≥0.05 in rock and stream-sediment samples in the Lone Pine district, Charles Sheldon Wilderness Study Area. Method of analyses: Mo, Ba, and Mn by emission spectroscopy; Cd and Zn by atomic absorption. Analyst: E. F. Cooley, G. L. Crenshaw, and D. F. Siems.

Cadmium:zinc ratios are particularly helpful in the interpretation of centers of hydrothermal metallization. Cadmium, a strong chalcophile element, follows zinc in sulfide deposits much more closely than it does lead and copper, and it is contained chiefly in sphalerite. Cadmium is more sensitive to high temperatures than is zinc, and the two elements apparently fractionate near a heat source. According to Goldschmidt (1954, p. 271), sphalerite that forms at high temperatures will accept less cadmium in its crystal lattice than will sphalerite formed at lower temperatures. The cadmium-rich halo in the Refuge area probably resulted from elevated temperatures, which caused cadmium to move down the temperature gradient (away from the center of heat) and fractionate from the zinc (fig. 13).

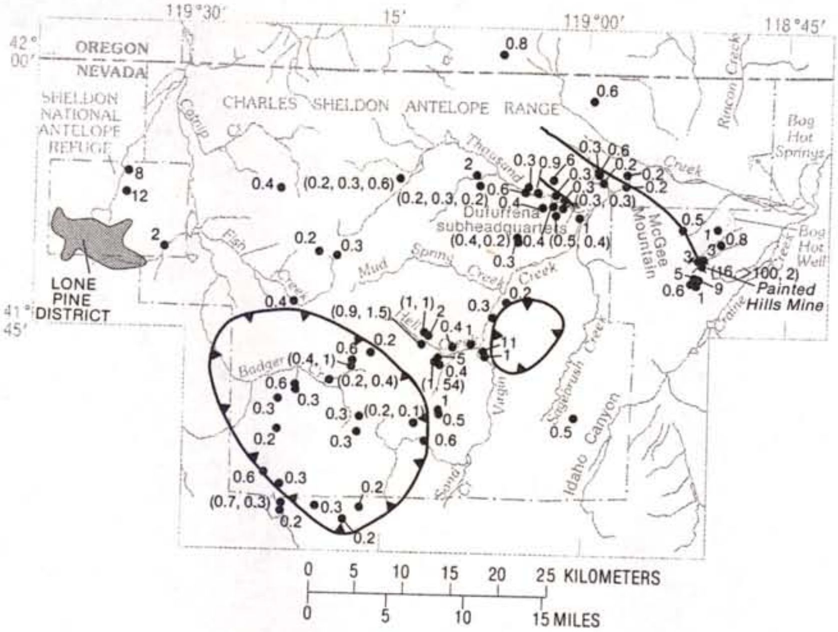
The distribution of anomalous values of mercury, antimony, arsenic, tungsten, molybdenum, barium, manganese, and gold, and anomalous cadmium:zinc ratios are shown by patterns in figures 12 and 13 and symbols in figure 25. In areas where these patterns and symbols are superimposed on the maps, the metals outline a geochemically anomalous area; in addition, we can speculate that this area may extend beneath younger volcanic rocks. The Tertiary andesitic rocks, in which the mineralized area appears to be restricted, are older and are structurally uplifted relative to the surrounding Quaternary basalts (pl. 1).

Additional slightly mineralized areas are adjacent to both the Painted Hills mine area and to the Subheadquarters of the Range (figs. 14–22, 25). The anomalous concentrations of mercury, arsenic, antimony, tungsten, molybdenum, barium, and gold, and anomalous cadmium:zinc ratios form dispersion patterns analogous to those formed in the Refuge area. The Subheadquarters and the Painted Hills mine areas are geologically and geochemically similar. Both areas have similar geochemical dispersion patterns and rock types, both are adjacent to faults, and both contain thermal-spring deposits (pl. 1; figs. 2, 14–22, 25). These similarities suggest that the two mineralized areas may be one continuous area. The magnetic map suggests a large concealed cross fault (F_3, pl. 2). This possible fault may be associated with a collapsed structure beneath the younger Canon Rhyolite (pl.

Range of anomalous concentrations (ppm) and anomalous ratios in figure 13

[Leaders (—), no data or insufficient data]

Element	Rock samples	Stream-sediment samples
Mo-------	7–100	10–15
Ba-------	1,500–>5,000	1,500–2,000
Mn-------	2,000–>5,000	2,000–5,000
Cd:Zn----	0.5–1.9	---



EXPLANATION

•0.2 Rock sample locality and concentration in parts per million. Multiple values in parentheses by sample locality indicate multiple sample

Area where rock samples have concentrations that range from 0.2–>100 ppm

Boundary of postulated buried caldera

Fault

FIGURE 14.—Distribution of anomalous concentrations of mercury in rock samples, Charles Sheldon Wilderness Study Area. Analytical method: flameless atomic absorption. Analyst: G. L. Crenshaw.

1). If it exists, it might have provided channels for the migration of mineral solutions. The thickening of the Canon Rholite and the decrease of mapped faults southward may have suppressed the surface expression of the metal concentrations below the established threshold values. Geochemical values lower than the established anomalous values are evident in the Canon Rhyolite in this area. The possible concealed fault forms an alinement with thermal springs in the Subheadquarters, Painted Hills Mine, and Gridley Lake areas. Figure 23 shows two local gravity highs which correlate with the location of the two geochemical anomalies, the alinement of thermal springs, and the suggested concealed fault. If these local gravity highs indicate buried intrusive centers, one could define the underlying source for mineralization or a heat source for the remobilization of elements for sulfide-type deposits; however, no intrusive rocks are exposed at the surface near the location of the gravity highs. Therefore, the relation

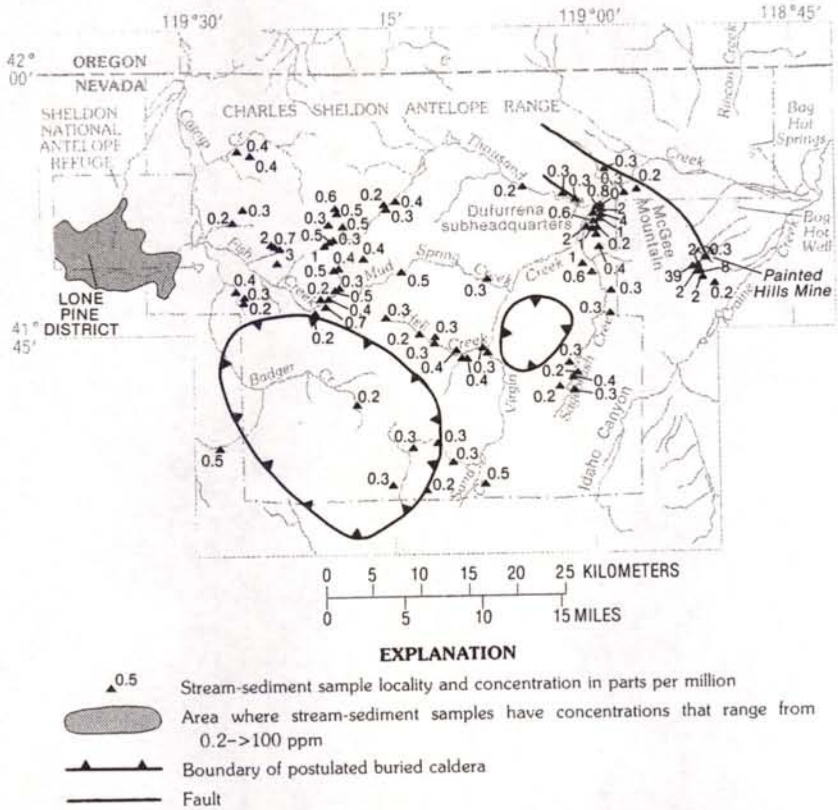
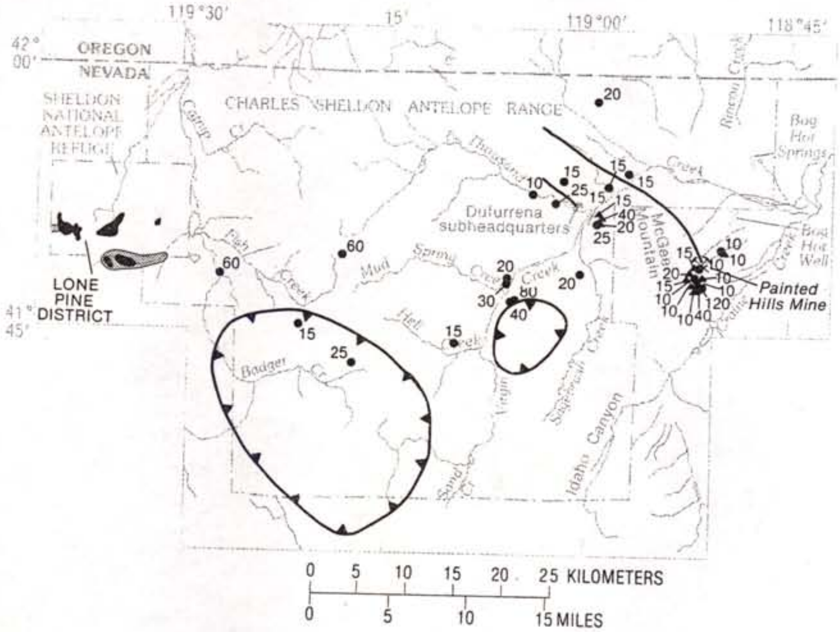


FIGURE 15.—Distribution of anomalous concentrations of mercury in stream-sediment samples, Charles Sheldon Wilderness Study Area. Analytical method: flameless atomic absorption. Analyst: G. L. Crenshaw.

between the geochemical anomalies and gravity highs remains speculative. Faulting in this area may have promoted circulation of meteoric waters to deep levels in the crust where rock temperature was high. These elevated temperatures could have been associated with shallow magma chambers as depicted by these gravity highs. The water could have then ascended as hot solutions that were responsible for the formation of the anomalous values in this area. North and northwest of the Subheadquarters, the mineralized area appears to terminate where younger basalts overlie the tuffaceous sedimentary or concealed host rocks; this mineralized area may extend northwestward beneath the younger basalt of Catnip Creek.

North of the Subheadquarters, a zone of relatively low magnetism is described in Chapter B, between the outer limit of a broad magnetic maximum centered over Hawk Mountain and two near-surface magnetic highs, which may be a result of rock alteration related to the



EXPLANATION

- •25 Rock sample locality and concentration in parts per million
- ▲40 Stream-sediment sample locality and concentration in parts per million
- Area where rock samples have concentrations that range from 10 – 1400 ppm
- Area where stream-sediment samples have concentrations that range from 10 – 60 ppm
- Boundary of postulated buried caldera
- Fault

FIGURE 16.—Distribution of anomalous concentrations of antimony in rock and stream-sediment samples, Charles Sheldon Wilderness Study Area. Analytical method: atomic absorption. Analyst: D. F. Siems.

circulation of fluids in an underlying concealed fault zone. This zone alines with the northwest-trending faults (mapped as a concealed postulated fault, F_3, pl. 2), thermal springs, gravity highs, and the two geochemically anomalous areas (fig. 23). The small patch of Canon Rhyolite which lies within the Subheadquarters mineralized area is cut by a northwest-trending fault. Samples collected from this rock unit adjacent to the fault contained anomalous values. Further studies would be required to evaluate these possibilities.

In the southwest corner of the Range, geophysical data can be interpreted as indicating a buried caldera or pluton (pl. 2). Rock samples collected by the Geological Survey from within the boundaries of the inferred caldera contain anomalous values for mercury, gold, antimony, arsenic, tungsten, molybdenum, barium, manganese, and uranium,

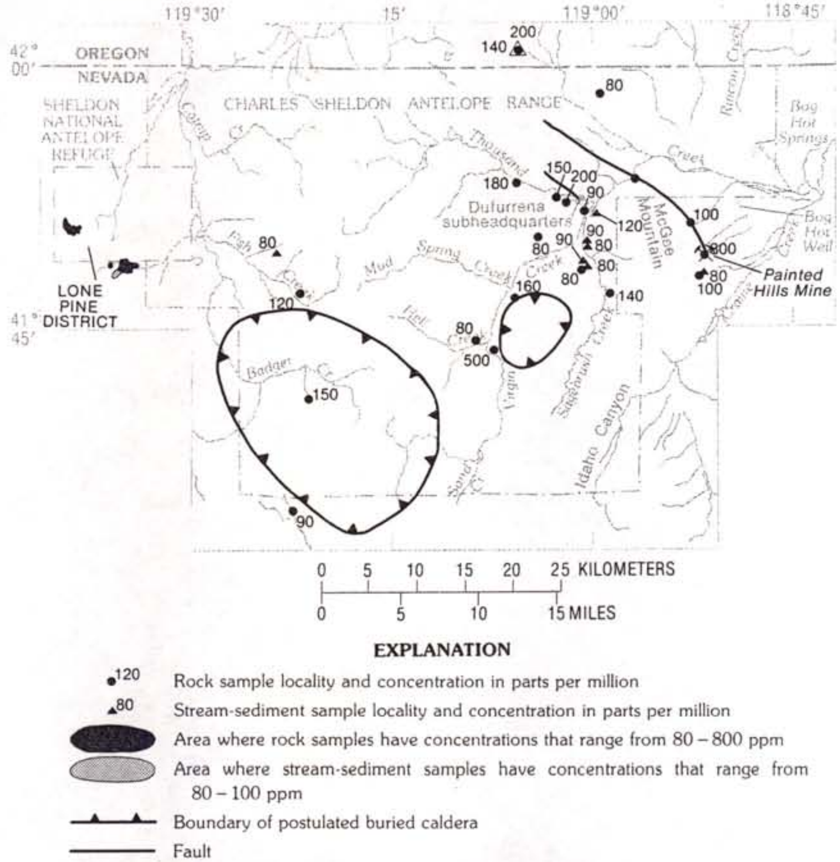


FIGURE 17.—Distribution of anomalous concentrations of arsenic in rock and stream-sediment samples, Charles Sheldon Wilderness Study Area. Analytical method: colorimetry. Analyst: G. L. Crenshaw.

and anomalous cadmium:zinc ratios (figs. 14, 16–22, 25, and 26). The Bureau of Mines collected rock samples within this boundary at seven sites not sampled by the Geological Survey. Their laboratories reported a trace of gold (0.083–0.283 ppm) and silver (more than 2–4 ppm) at six of seven sites sampled and uranium (more than 10 ppm-more than 50 ppm) at five of seven sites sampled (pl. 1, no. 8, 9, 36, 37, and 39–41). The distribution and association of the anomalous elements and ratios mentioned above and the elements detected by the Bureau of Mines laboratories suggest that this area has a potential for concealed deposits. The widespread geochemical anomalies are similar in size and magnitude to the mineralized McDermitt Caldera approximately 82 mi (132 km) to the northeast in the Opalite mining district (Rytuba, 1976). If a caldera is present, the set of parallel

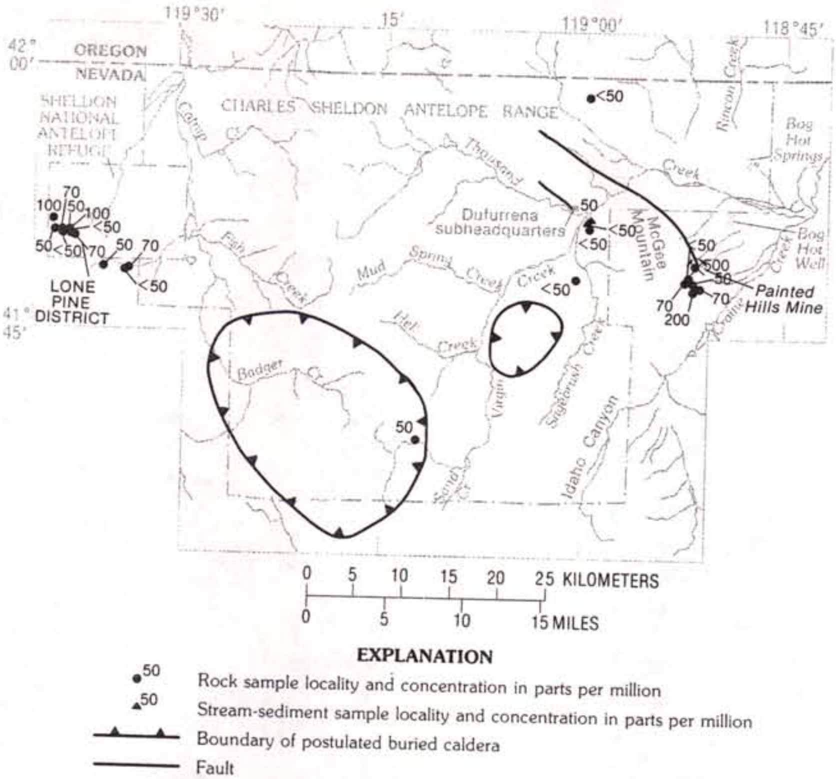


FIGURE 18.—Distribution of anomalous concentrations of tungsten in rock and stream-sediment samples, Charles Sheldon Wilderness Study Area. Analytical method: emission spectroscopy. Analyst: E. F. Cooley.

northwest-oriented faults, which occur within its boundaries, may have been associated with the caldera collapse. The faults then may have acted as the pathways for the migration of mineral-bearing solutions. The magnetic lows and faults northwest of the postulated caldera, interrupted by a gravity and magnetic high having a northeast strike, may represent the outer wall of the collapsed caldera (pl. 2). In this area, numerous stream-sediment samples are anomalous in mercury, and a few anomalous values for other elements were found in rock and (or) stream-sediment samples (figs. 15, 16, 17, and 21).

An alternate interpretation to the existence of the possible caldera is the presence of a buried pluton of lower density than the surrounding basement rock. If this interpretation is correct, one could then define an underlying source for ascending mineralizing solutions and a heat source for remobilization of precious-metal sulfide-type deposits.

The geochemically anomalous values present in rock samples, the

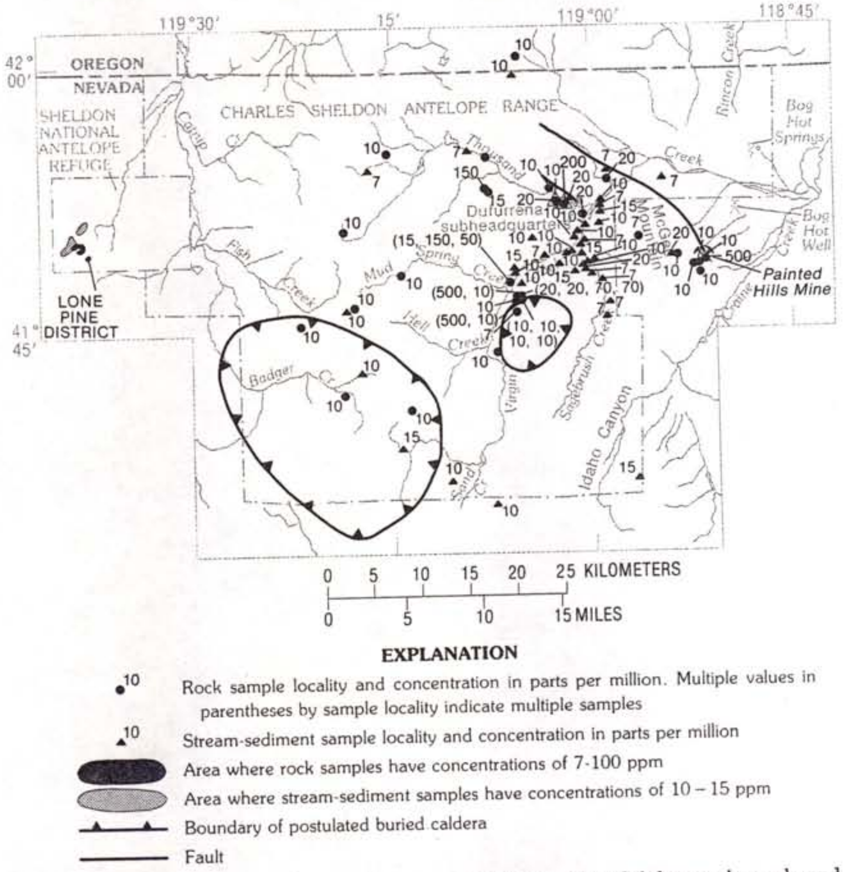
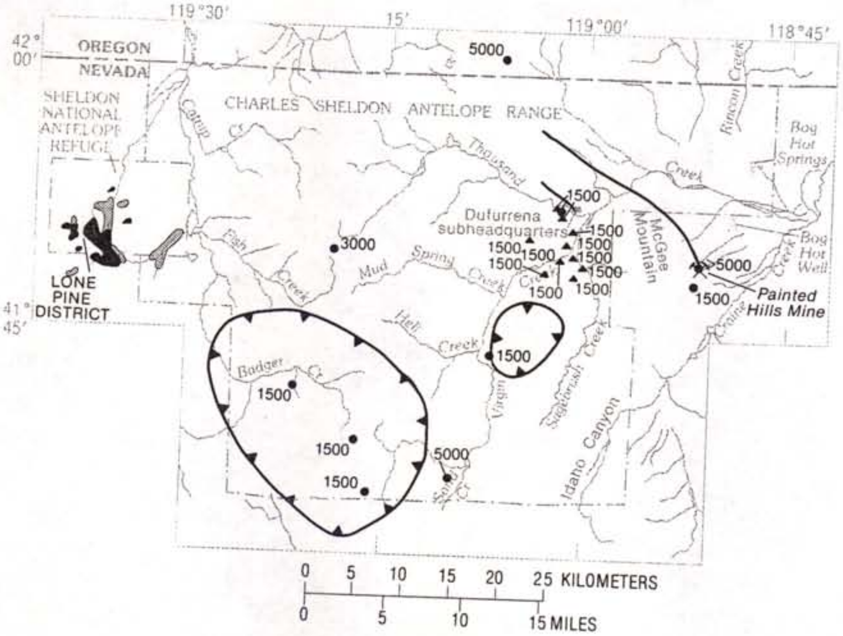


FIGURE 19.—Distribution of anomalous concentrations of molybdenum in rock and stream-sediment samples, Charles Sheldon Wilderness Study Area. Analytical method: emission spectroscopy. Analyst: E. F. Cooley.

association of these anomalous elements, and the elements detected in rock samples collected by the Bureau of Mines suggest that this area, whether a caldera or a buried pluton exists, has a potential for concealed mineral resources. Further exploration by geochemical, geophysical, and geological methods are suggested to determine the degree of potential and if there is a spatial and genetic relationship to the present geophysical evidence and the geochemically anomalous areas.

Figure 24 shows a northwest-trending chain of mafic vents, palagonite tuff rings, and a low shield volcano, which appear to aline with five volcano vents, to the southeast, described by Korringa (1973). This northwest-trending chain appears to lie between magnetic highs and to be associated with magnetic lows and the postulated caldera



EXPLANATION

1500 — Rock sample locality and concentration in parts per million

5000 — Stream-sediment sample locality and concentration in parts per million

Area where rock samples have concentrations of 1500->500 ppm

Area where stream-sediment samples have concentrations of 1500-2000 ppm

Boundary of postulated buried caldera

Fault

FIGURE 20.—Distribution of anomalous concentrations of barium in rock and stream-sediment samples, Charles Sheldon Wilderness Study Area. Analytical method: emission spectroscopy. Analyst: E. F. Cooley.

or buried pluton. A northwest-trending fault system has a similar relationship. The association of these features with each other outlines a more than 50-mi (80-km)-long northwest-trending lineation. This linear feature may represent a major structural zone at depth. If this structural feature does exist and if it is a zone of weakness in the Earth's crust, then alternate channels for the ascending mineral solutions seem plausible.

Anomalous concentrations of mercury, antimony, arsenic, molybdenum, barium, manganese, and gold, and anomalous ratios of cadmium to zinc are found in the Hell Creek drainage basin and in the area contiguous with the junction of Hell Creek and Virgin Creek (figs. 14–17, 19–22, and 25). Most of the valley of Hell Creek from its source to its junction with Virgin Creek is fault controlled. The anomalous amounts of elements and ratios mentioned above, as well as several

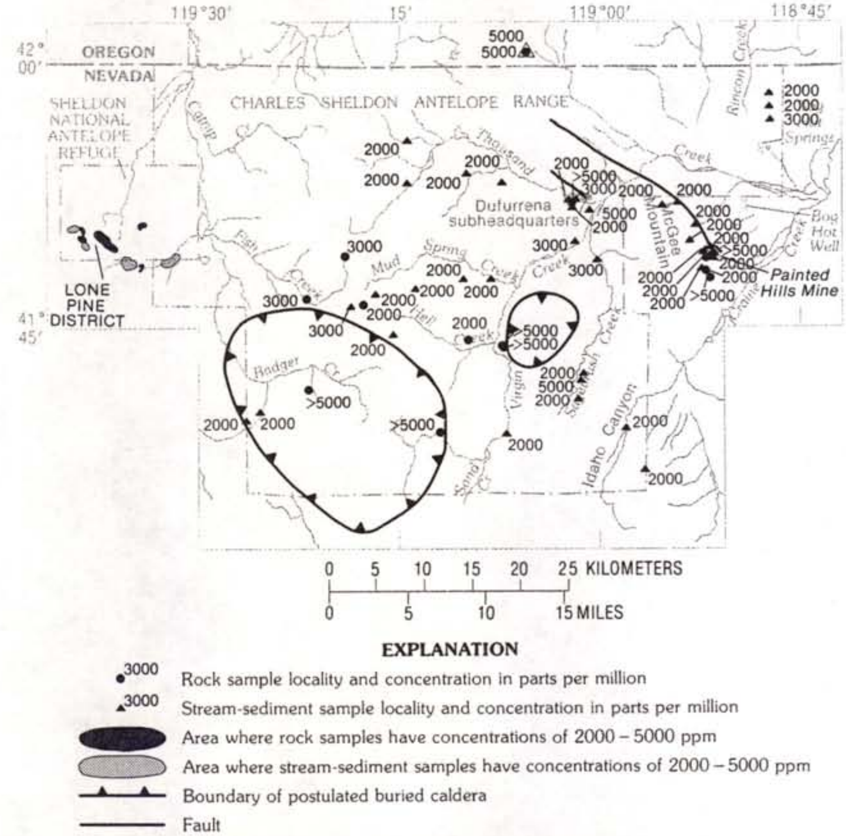
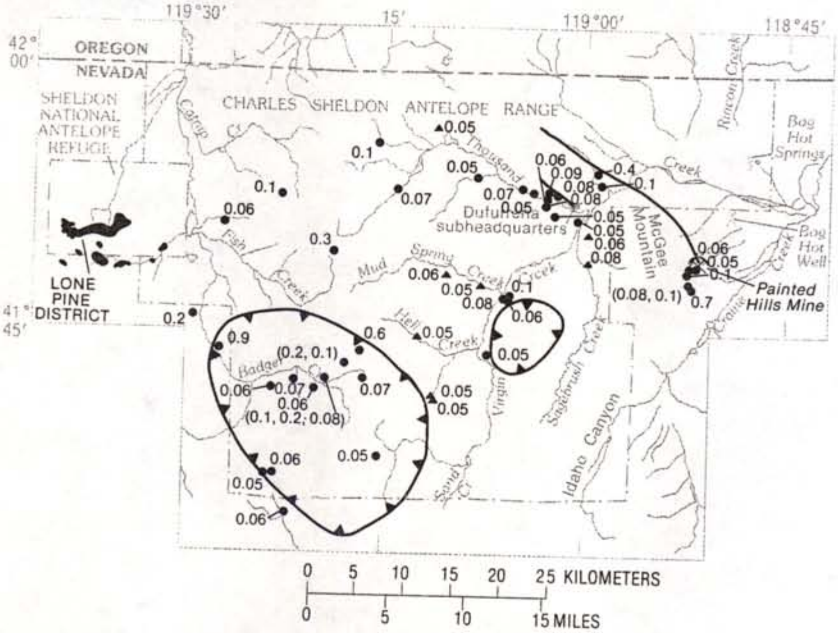


FIGURE 21.—Distribution of anomalous concentrations of manganese in rock and stream-sediment samples, Charles Sheldon Wilderness Study Area. Analytical method: emission spectroscopy. Analyst: E. F. Cooley.

mercury prospects, seem to be associated with the faults. The area near the junction of Hell Creek and Virgin Creek is contiguous with C_2, a geophysical anomaly (pl. 2).

The Bureau of Mines collected numerous rock samples at eight sample sites not visited by the Geological Survey in the Hell Creek drainage basin and on the eastern borders of the C_2 geophysical-anomaly area (pl. 1, no. 13, 28, 31, 32, 33, 34, 35, and 38). Their laboratories reported that the silver values in rocks ranged from a trace (more than 2–4 ppm) to 16 ppm at five of the eight sites sampled. A trace of gold (0.08–0.2 ppm) was detected at three sites, uranium (10–400 ppm) at four sites, and manganese (400–100,000 ppm) at one site.

The geochemically anomalous values detected in rock and stream-sediment samples, the elements reported in rock samples collected by the Bureau of Mines, the association of these elements, and the



EXPLANATION

•0.07 Rock sample locality and ratio; multiple ratios in parentheses by sample locality indicate multiple samples

▲0.08 Stream-sediment sample locality and ratio

Area where rock samples have ratios that range from 0.05 – 1.9

Boundary of postulated buried caldera

Fault

FIGURE 22.—Distribution of anomalous cadmium:zinc ratios in rock and stream-sediment samples, Charles Sheldon Wilderness Study Area. Threshold ratio, 0.020. Analytical method: atomic absorption. Analyst: G. L. Crenshaw and D. F. Siems.

proximity of the sample sites to the C_2 geophysical-anomaly area, mercury prospects, and faults suggest that possible potential areas for concealed deposits exist in this area.

The headwater drainage basins of Sagebrush Creek, Thousand Creek, and Mud Spring creek are other areas where anomalous concentrations of some of the elements discussed earlier in the text occur in stream sediments and rocks (figs. 14–22, and 25).

GOLD

Gold was detected in levels below 0.05 ppm in 101 samples, and four samples had concentrations of 0.06, 0.1, 0.14, and 0.84 ppm. Figure 23 shows the rock-sample localities at which gold was detected in levels above and below the 0.05 ppm level. The samples containing

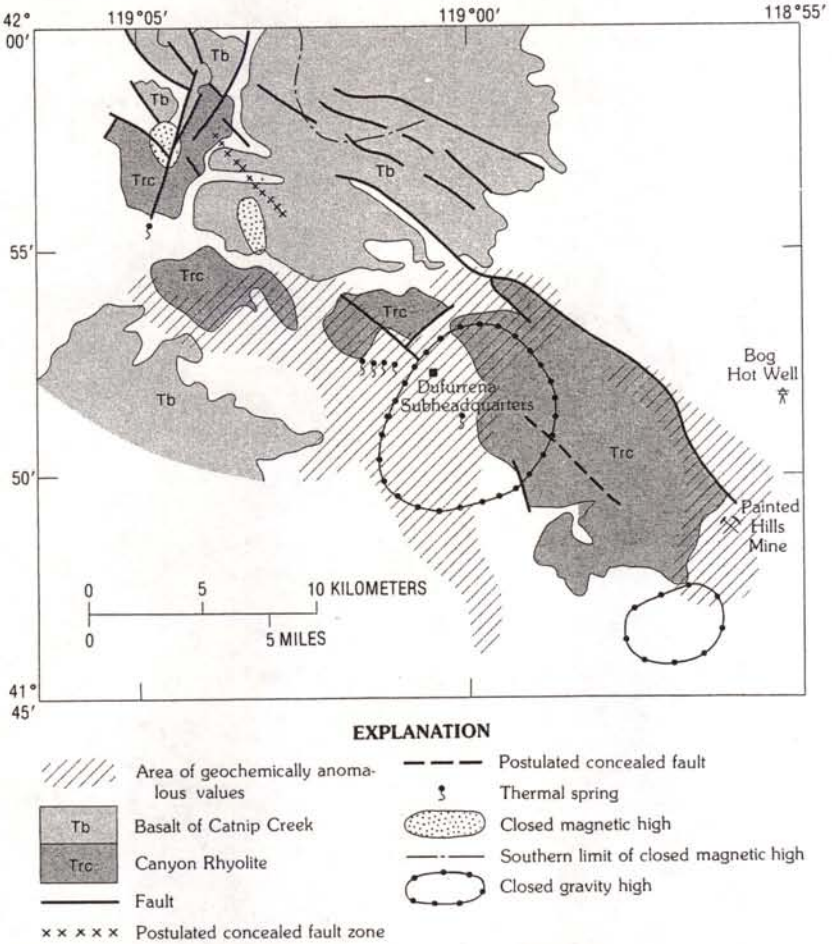


FIGURE 23.—Relationship of geochemically anomalous areas of the Painted Hills mine and Subheadquarters, Charles Sheldon Wilderness Study Area.

gold correlate well with anomalous levels of mercury, antimony, arsenic, tungsten, manganese, barium, molybdenum, and the anomalous cadmium:zinc ratios (figs. 14–22).

URANIUM

Studies of the uranium occurrences in the Virgin Valley district near theVirgin Valley Ranch show that this area contains a large, low-grade uranium resource. These occurrences may exist in tuffaceous sediments beneath Gooch Table or Rock Spring Table adjacent to the Virgin Valley occurrences or in tuffaceous sediments associated with thermal springs.

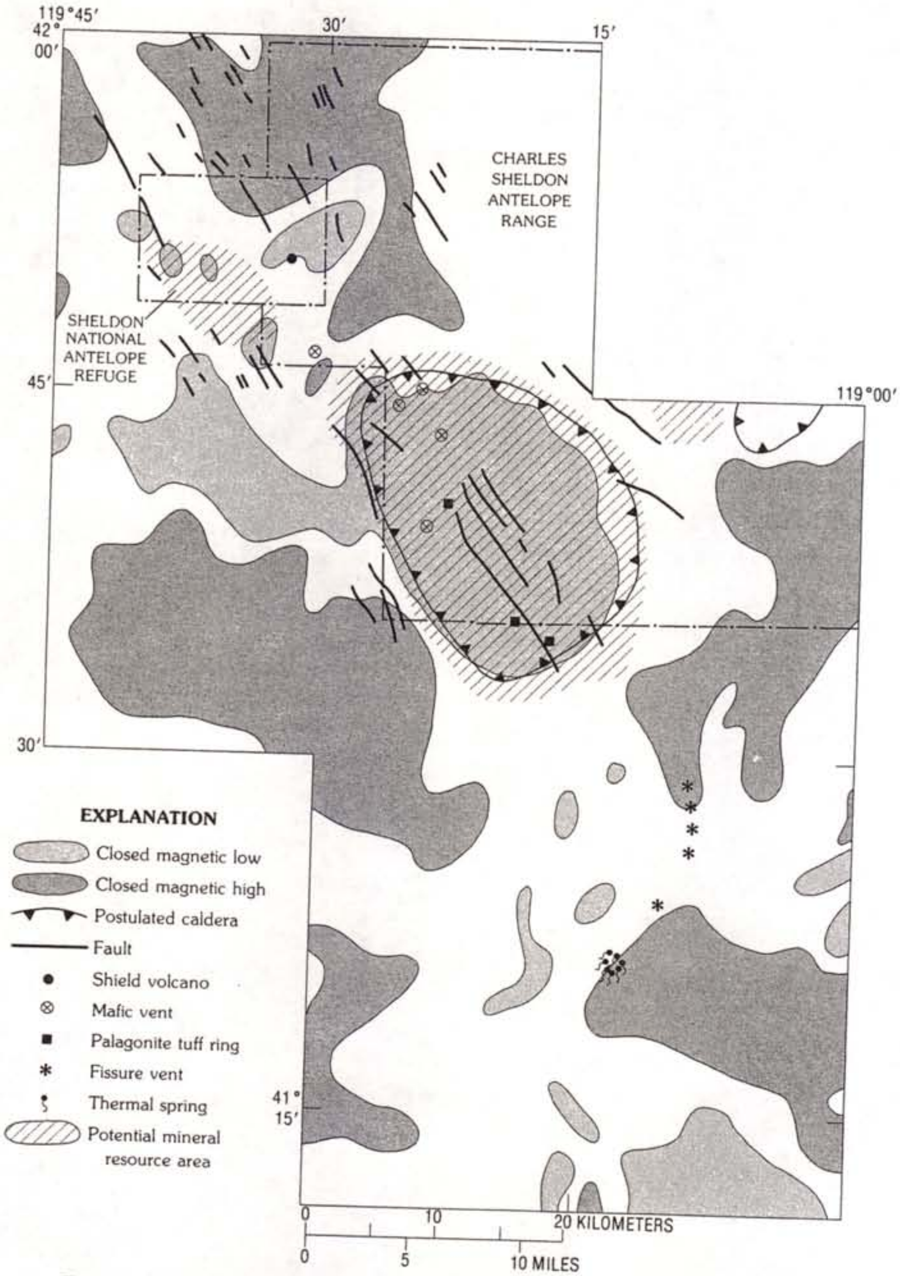


FIGURE 24.—Relationship of geophysical and geological data, and mineral-resource potential areas in the western part of the Charles Sheldon Wilderness Study Area.

Twenty scintillation counter traverses were made within the Virgin Valley by J. E. Peterson of the Geological Survey in May 1975. No anomalous scintillation counter readings were obtained except at the localities where rock samples yielded high uranium values. Uranium was analyzed for in 94 rock samples and 45 stream-sediment samples. A threshold value was arbitrarily chosen as 10 ppm, which is 2.5 times the average crustal abundance concentration (Goldschmidt, 1954, p. 75). Of the 94 rock samples analyzed, the concentrations of 37 rock samples ranged from 10 to 860 ppm as shown below.

Parts per million	Number of samples
860	1
500	1
300	3
200	4
150	4
100	7
70-10	17

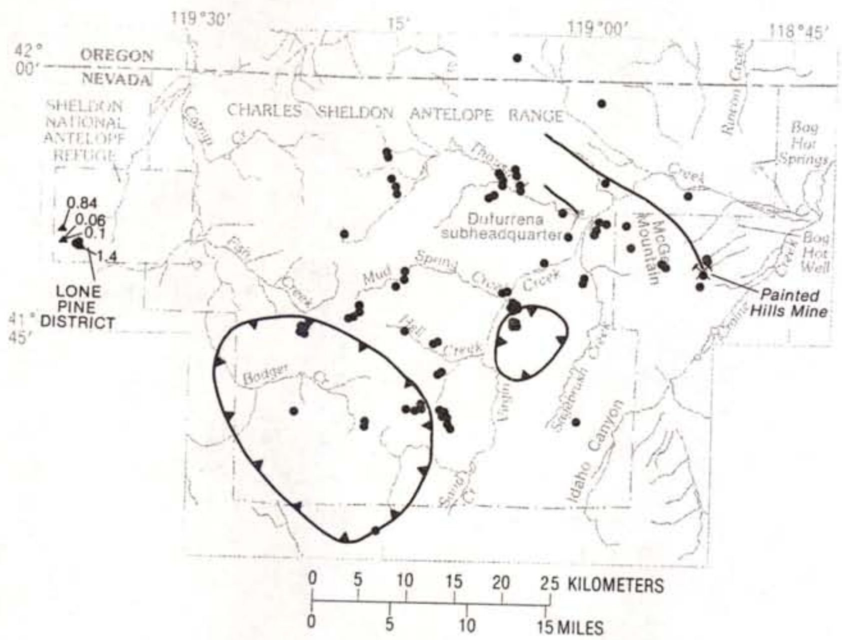
Of the 45 stream-sediment samples analyzed, only one sample had a value of 13 ppm (fig. 26). Only seven of the 38 rock and stream-sediment samples showing anomalous values are from outside the uraniferous opal areas investigated by Staatz and Bauer (1951). The anomalous uranium localities shown in figure 24 are contiguous with the anomalous molybdenum localities (fig. 19). The uranium probably was leached from rhyolite tuffs and lavas and concentrated in certain opal layers within the tuffaceous sediments.

Uranium occurrences are discussed further in this report in Chapter D.

POTENTIAL GEOTHERMAL RESOURCES

The principal thermal springs and adjacent cold springs of the Charles Sheldon study area were sampled for chemical analyses in order to determine the potential for geothermal resources (fig. 2).

Water samples were collected as close as possible to the orifice of 11 springs. If the spring had several orifices, the discharge from the orifice having the highest temperature was sampled. Water temperatures were determined by using a thermistor-probe thermometer. Water samples were collected in 1.056-quart (1-liter) containers that had been rinsed several times with water from the sampled spring.



EXPLANATION

• Stream sample locality in which gold in quantities of less than 0.5 ppm was detected

▲0.84 Rock sample locality and concentration in parts per million.

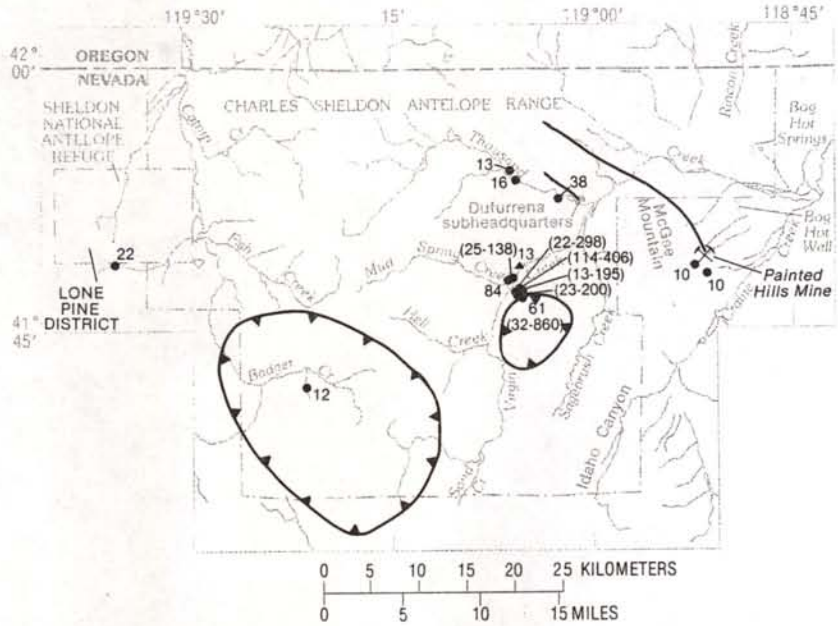
—▲—▲— Boundary of postulated caldera

——— Fault

FIGURE 25.—Localities of rock samples from which gold was detected, Charles Sheldon Wilderness Study Area. Analytical method: flameless atomic absorption. Analyst: G. L. Crenshaw.

All samples were collected on the same day and no fixating agents were added. The water samples were analyzed by the Geological Survey in Salt Lake City, Utah, by methods of Brown, Skougstad, and Fishman (1970). Analytical data for water samples are on file at the Geological Survey in Reston, Va. Table 5 lists the location, chemical composition, and calculated minimum thermal-reservoir temperatures of the springs or wells.

Water chemistry has proved valuable in estimating subsurface temperatures, and the various techniques are described by Mahon (1970), Fournier and Rowe (1966), and Fournier and Truesdell (1973). The most quantitative temperature indicators have been shown to be (1) the variation in solubility of quartz as a function of temperature, and (2) the temperature dependence of base exchange or partitioning of alkalies (sodium and potassium) between solutions and solid phases



EXPLANATION

- •12 Rock sample locality and concentration in parts per million
- ▲13 Stream-sediment sample locality and concentration in parts per million
- (32-860) • Minimum and maximum content given for localities where two or more samples were located
- Boundary of postulated buried caldera
- Fault

FIGURE 26.—Distribution of uranium ≥10 ppm in rock and stream-sediment samples, Charles Sheldon Wilderness Study Area. Analytical method: neutron activation. Analyst: H. L. Millard, Jr., and R. J. Knight.

with a correction applied for the calcium content of the water (the sodium-potassium-calcium geothermometer). Some ambiguity and uncertainty exist with both methods, and, in any particular area, subsurface information may be necessary in order to determine the most effective method. Fournier, White, and Truesdell (1974) presented a set of guidelines for determining which subsurface-temperature estimate may best indicate the thermal-aquifier temperature, which is based on the temperature and the discharge of the spring.

Where knowledge of subsurface reactions and discharge rate was lacking, calculated subsurface temperatures were determined using both the quartz-solubility and sodium-potassium-calcium geothermometers. For the quartz-solubility geothermometer (Fournier and Rowe, 1966), the empirical equation is:

TABLE 5.—*Location, chemical composition, and calculated minimum thermal-reservoir temperatures of springs in the Charles Sheldon Wilderness Study Area, Humboldt and Washoe Counties, Nevada and Lake and Harney Counties, Oregon*

[Analyses by U.S. Geological Survey; methods of analyses of Brown, Skougstad, and Fishman (1970); temperatures in degrees Farenheit (F) and Celsius (C). Springs are identified on the following 15-minute topographic quadrangles: A-H, Big Spring Butte; J-K, Railroad Point; and L, Denio]

Spring or well, sample no., latitude, longitude	Temperature		Milligrams per liter									
			Cations				Anions					
	(F)	(C)	Calcium	Magnesium	Potassium	Sodium	Bicarbonate (HCO_3)	Carbonate (CO_3)	Chloride	Fluoride	Sulfate (SO_4)
a. Virgin Valley campground[1], 1, 41°51'12", 110°00'03"	89.6	32	3.7	0	0.4	29	64	0	4.7	1.8	12
b. Roadside rest[1], 2, 41°52'34", 119°02'25"	64.4	18	1	0	1.8	31	69	0	4.9	1	9
c. Roadside rest[1], 3, 41°52'31", 119°02'51"	64.4	18	2.1	0.1	2.8	31	74	0	5	.9	9
d. Roadside rest[1], 4, 41°52'28", 119°02'45"	62.6	17	12	.7	3.7	32	109	0	6	.8	10
e. Roadside rest[1], 5, 41°52'29", 119°02'42"	62.6	17	2.7	.2	2.9	30	73	0	5.2	.9	9.1
f. Big Springs cold[1], 6, 41°55'25", 119°09'30"	55.4	13	5.3	1.1	2.4	8.2	34	0	3.1	.2	4.3
g. Virgin Valley Ranch hot[1], 10, 41°47'26", 119°06'27"	69.8	21	3.2	.3	4	21	50	0	5.9	.6	11
h. Virgin Valley Ranch cold[1], 11, 41°48'16", 119°05'26"	50	10	3.0	.6	7.4	45	90	0	11	.5	28
i. Bog Hot Spring, 7, 41°55'25", 118°48'16"	129.2	54	0	0	.9	77	125	0	15	1.7	46
k. Bog cold[1] 8, 41°55'57", 118°48'29"	50	10	11	1.8	12	56	145	0	19	1	17
l. Baltazor Hot Spring, 9, 41°55'18", 118°42'33"	181.4	83	14	.2	8.6	180	163	0	48	6.6	220

[1]Informal geographic name.

TABLE 5.—*Location, chemical composition, and calculated minimum thermal-reservoir temperatures of springs in the Charles Sheldon Wilderness Study Area, Humboldt and Washoe Counties, Nevada and Lake and Harney Counties, Oregon*—Continued

Milligrams per liter													Calculated reservoir temperature			
Alkalinity as $CaCO_3$	Hardness total (Ca, Mg)	Hardness, noncarbonate	Silica	Lithium	Boron	Antimony	Arsenic	Mercury	Calculated sum of dissolved residues	Dissolved solids (Short tons per acre foot)	Sodium adsorbtion ratio	Percent of sodium	Temperature, quartz conductive-cooling geothermometer (F)	Temperature, quartz conductive-cooling geothermometer (C)	Temperature, sodium-potassium-calcium geothermometer (F)	Temperature, sodium-potassium-calcium geothermometer (C)
52	9	0	32	0.03	0.08	0.002	0.007	0.0000	115	0.16	4.2	87	179.6	82	78.8	26
57	3	0	54	.03	.07	.000	.010	.0000	137	.19	8.5	93	221	105	204.8	96
61	6	0	57	.02	.07	.000	.014	.0000	144	.20	5.7	88	226.4	108	199.4	93
89	33	0	56	.03	.07	.000	.019	.0000	175	.24	2.4	65	224.6	107	149	65
60	8	0	57	.02	.07	.000	.018	.0000	144	.20	4.7	85	226.4	108	192.2	89
28	18	0	32	.002	.05	.001	.002	.0001	73	.10	.8	46	179.6	82	131	55
41	9	0	53	.01	.08	.002	.008	.0000	124	.17	3	76	221	105	197.6	92
74	10	0	54	.02	.09	.000	.012	.0000	194	.26	6.2	83	221	105	393.8	201
103	0	0	56	.02	.71	.004	.033	.0000	259	.35	.0	99	224.6	107	213.8	101
119	35	0	56	.02	.10	.000	.020	.0000	260	.35	4.1	71	224.6	107	408.2	209
134	36	0	130	.20	2	.007	.180	.0007	690	.94	13	89	305.6	152	296.6	147

$$T^{\circ}_{C} = \frac{1.30 \times 103}{5.19 - \log_{10} C_{SiO_2}\ (aq)} - 273,$$

where T°_{C} = temperature in centigrade,
C_{SiO_2} = concentration of silica in milligrams per liter, and
aq = aqueous.

For calculations of subsurface temperatures from sodium-potassium-calcium concentrations (Fournier and Truesdell, 1973), the equation is:

$$T^{\circ}_{C} = \frac{1{,}647}{\log_{10}(M_{Na^+}/M_{K^+}) + \beta \log(\sqrt{M_{Ca}} + 2/M_{Na^+})} - 2.24,$$

where T°_{C} = temperature in centigrade,
M_{Na^+} = molality of sodium ion,
M_{K^+} = molality of potassium ion,
M_{Ca^+} = molality of calcium ion,
$\beta = 1/3$ for water equilibrated above 212°F (100°C), and
$\beta = 3/4$ for water equilibrated below 212°F (100°C).

Test to see if $\beta = 4/3$ yields a temperature below 212°F (100°C); if it does not, use $\beta = 1/3$ to estimate the equilibration temperature. Molality is a molal concentration (one mole of solute per 35.27 oz (1,000 g) of solvent).

The results of these calculations for individual springs are given in table 5. The quartz-conductive-cooling geothermometer shows a range of 82°C to 152°C. The sodium-potassium-calcium geothermometer shows a range of 78.8°F to 408.2°F (26°C to 209°C). The difference between temperatures measured by the two geothermometer methods for any one spring ranges from 41°F to 215.6°F (5°C to 102°C). The median of the ranges is 95°F (35°C). The maximum temperatures calculated are 305.6°F (152°C) for the quartz-conductive method and 408.2°F (209°C) for the sodium-potassium-calcium. The subsurface temperatures calculated by the quartz-conductive method are low compared with subsurface temperatures of geothermal fields presently being exploited. These temperatures are below the minimum temperature of 356°F (180°C) currently thought necessary to drive steam-turbine generators (Muffler, 1973). All but two of the subsurface temperatures calculated by the sodium-potassium-calcium geothermometer method are lower than the 356°F (180°C). Although the subsurface temperatures calculated by both methods are low, except for the two mentioned above, a system has been devised whereby the geothermal heat is used in a heat exchanger to boil a secondary fluid (as a gas) to drive a turbine. This fluid is then condensed and returns to the heat exchanger (Jonsson and others, 1969). A generating unit based on this heat-exchange principle and using intake water of 177.8°F (81°C) was reported by Faaca (1974).

Springs having surface temperatures below boiling may have either mixed water or water which has equilibrated at depth with rock only slightly hotter than the measured spring temperature. Mixed waters are a mixture of water hotter than 212°F (100°C) and cold meteoric water. Thus, the thermal-aquifier temperature estimated from the water compositions may be below the actual true minimum thermal-reservoir temperature at depth.

Surface data suggest that the area has a low potential for geothermal resources. All springs in the Charles Sheldon study area had surface temperatures below boiling. If the springs contain mixed waters, the estimated minimum thermal-reservoir temperatures may be low, and the area could have a moderate to good potential for geothermal resources. Subsurface measurements and drilling would be required to evaluate the former possibility.

As reported in the geophysical section of this report, gravity highs occur near five thermal springs (fig. 3, springs a, g, i, j, and l). These springs, except one near Gridley Lake, and seven others were sampled and their waters were analyzed. The seven additional springs (fig. 3, springs b, c, d, e, f, h, and k) are also associated with these and other gravity highs. There is no consistent correlation between magnetic anomalies and the location of these springs. If local gravity highs indicate young buried intrusive centers, one could define the underlying source that heats the water; however, no young intrusive rocks or other intrusive rocks are exposed at the surface. Therefore, the relationship between these springs and gravity highs remains speculative.

The concept for the origin of hot springs in northern Nevada involves a cycle of descending meteoric water, heating at depth by the high geothermal gradient, then ascending along faults; therefore, structure would be a much more important control of geothermal systems than local heat sources. The area between the major fault along the McGee Mountain front and the postulated buried fault beneath the Canon Rhyolite on McGee Mountain suggests a possible horst or doming structure. These faults could be part of the channelways for both the ascending mineralizing solutions discussed earlier and the ascending thermal waters.

Thermal water is water generally from a spring whose temperature is appreciably above the local mean annual temperature. If mixed waters are present, other springs not sampled in the area may not fit this general definition. The location of Bog Hot Well in the alluvial fan northeast of the McGee Mountain fault suggests that springs along this fault may be of thermal origin as is also suggested by the steam emission reported from a drill hole in the vicinity of this fault near the Painted Hills Mine (Wendell, 1970, p. 98).

The surface data, the estimated minimum thermal-reservoir temperatures that may be low if mixed waters are involved, the possibility that springs not sampled are of thermal origin, and the speculations concerning heat sources for these waters indicate that the area could have a low to moderate potential for geothermal resources.

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Economic Appraisal of the Charles Sheldon Wilderness Study Area, Nevada and Oregon

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U.S. BUREAU OF MINES

MINERAL RESOURCES OF THE CHARLES SHELDON WILDERNESS STUDY AREA, HUMBOLDT AND WASHOE COUNTIES, NEVADA, AND LAKE AND HARNEY COUNTIES, OREGON

GEOLOGICAL SURVEY BULLETIN 1538-D

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U.S. Bureau of Mines

SETTING

The Charles Sheldon wilderness study area is underlain by volcanic rocks consisting of basalt, rhyolite, andesite, and associated ash, tuff, and tuffaceous sandstone. Within the study area are two mining districts: the Virgin Valley near the eastern edge of the Range and the Lone Pine in the southern part of the refuge (fig. 27).

Significant deposits of precious opal are found at the Rainbow Ridge Opal, Royal Peacock Opal, and Virgin Opal (Bonanza) mines of the Virgin Valley district.

Humboldt and Washoe County records list more than 1,656 lode and 98 placer claims within the study area; 393 are active. The placers were all located for precious opal. The earliest known prospecting in the study area took place in the Lone Pine district in 1897. Many claims have been relocated, some several times; six were patented in 1929.

Claims are concentrated in the Lone Pine and Virgin Valley districts, but smaller clusters, located mainly for uranium, are present throughout the study area.

Nearly all past mineral production in the study area, estimated to have been worth several millions of dollars, has been from the Virgin Valley district. Raw and finished precious opal accounted for more than 75 percent of the total. More than 18,000 tons (16,000 t) of tuffaceous sandstone, valued at $60 per ton ($66/t) retail, have been shipped to cities as far away as eastern Washington for use as building facings (Bob Wegman, oral commun., 1976). More than 15 tons (14 t) of fluorescent opalite, found on the April Fool claims, was sold as hand specimens.

Although no production has been recorded, low-grade uranium and

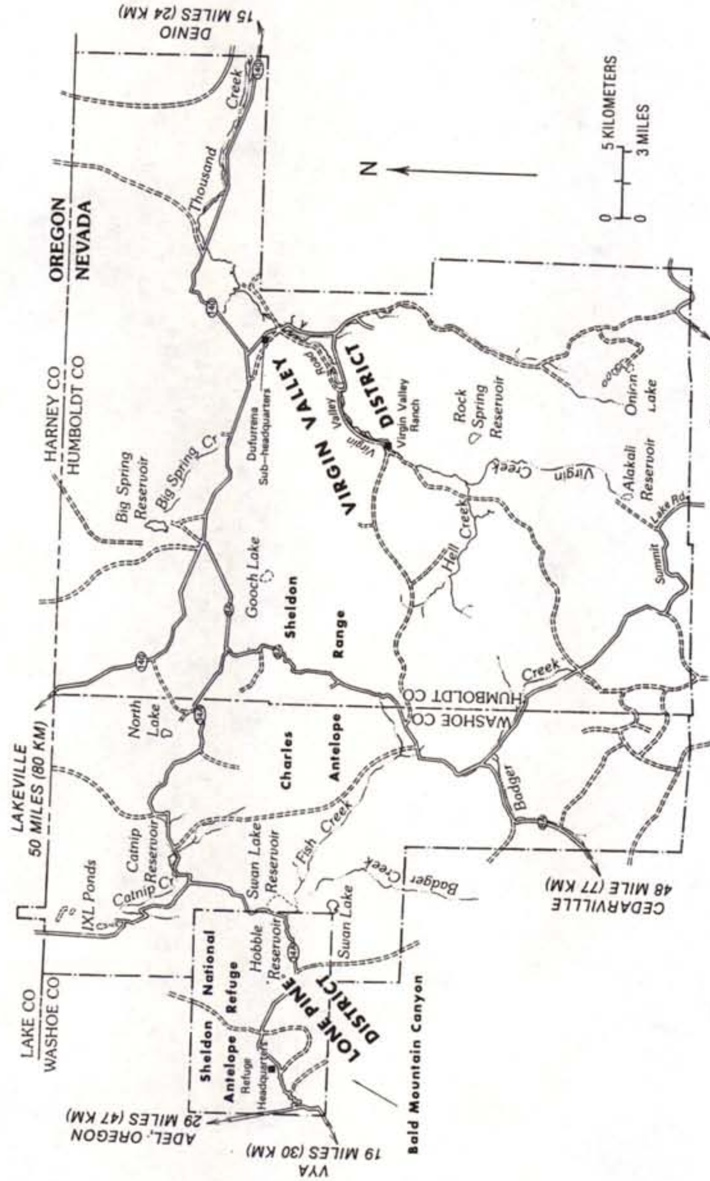

FIGURE 27.—Map showing mining districts, Charles Sheldon Wilderness Study Area.

diatomaceous-earth deposits occur in tuffaceous beds of the Virgin Valley district. Bentonite is found in several horizons but is of low quality and has no value.

The Antelope mercury mine, adjacent to the Refuge in the Lone Pine district, reportedly has had only minor production.

VIRGIN VALLEY DISTRICT

The Virgin Valley district (fig. 27) is near the east edge of the Range. The district is bounded on the north, west, and south by basalt tablelands and on the east by a rhyolite ridge. Elevations range from 4,800 feet (1,460 m) on the valley floor to 6,100 ft (1,860 m) on the basalt tables. Nevada State Highway 8A passes through the northern part of the district, and a road along Sagebrush Creek toward Virgin Valley extends through the southern part.

Most of the area is underlain by horizontal beds of bentonite, ash, tuff, tuffaceous siltstone, and sandstone. Rhyolite crops out on the north and east sides of the valley, and basalt caps all the surrounding tablelands. All opal and most uranium claims are on the sedimentary beds; however, a few uranium claims are on rhyolite.

The Virgin Valley district produced precious opal and building stone and has the potential to produce uranium. Mining activity began in the 1870's, when sandstone, quarried from the valley's north end, was used as building material on local homesteads. Opal was discovered in 1905 or 1906; in the following years, more than 486 opal claims were located. Total production value of precious opal is estimated to have been several millions of dollars, mainly from the Virgin Opal (Bonanza), Rainbow Ridge, and Royal Peacock mines. Single precious opals, found at each of these mines, have been valued at as much as, or more than, $250,000 each (Keith Hodson, 1975, and Harry Wilson, 1976, oral communs.). Opal is presently mined at several localities in the district.

Field investigations show that precious opal is associated with a bentonitic horizon that formed as a result of airborne ash and tuff falling into Miocene lakes (Merriam, 1910). Common opal is not restricted to one horizon. The bentonite is light gray to green and contains varying amounts of ash, sand, rhyolite pebbles, and petrified wood. Limonite and manganese stain and fibrous gypsum are found on joint surfaces. The thickness of the bentonitic horizon is as much as 8 ft (2.4 m). The horizon is divided into three zones: an upper zone containing very little partially petrified wood, a middle zone containing partially petrified wood and voids where wood has rotted away, and a lower zone containing well-petrified wood. Most of the precious opal fills voids in the middle zone. These occurrences are found in pockets. The pockets are theorized to mark the locations of calm places along the shores of ancient lakes where driftwood collected and was subsequently covered with ash (Hodson and Dake, 1950). Precious opal mined in Virgin Valley is usually found as casts of limbs, twigs, cones, or small logs.

The best exposure of the opal-bearing horizon is on the east side of Virgin Creek from Pond No. 13 south to a canyon directly east of Virgin Valley Ranch, a distance of nearly 3 mi (5 km). Twenty claims (Royal Peacock Nos. 1 and 2, Kelly No. 1, Skajwm, Northern Light, Peacock Nos. 2–4, Phantom, Pebble, Little Pebble, Angel Nos. 1 and 2, Red Ball, Yellow Ball, Blue Ball, Starfire, Starbright, Beckey, and Mucket) are along this exposure. Mining has been concentrated on the Royal Peacock Nos. 1 and 2, Northern Light, Pebble, Angel No. 1, Beckey, and Mucket claims, with most of the precious opal coming from the Northern Light and Royal Peacock claims. In 1970 the famous Royal Peacock opal, weighing 191 carats (1.35 ounces or 38.2 g) and reportedly worth $250,000, was found.

Another opal-bearing area, one which includes the Virgin Opal (Bonanza) mine, is northwest of Virgin Creek and about 4 mi (6 km) southwest of Dufurrena Subheadquarters. Unlike the east side of the Virgin Creek area where the opal-bearing horizon is nearly horizontal, the area around the Virgin Opal (Bonanza) mine shows extensive past movement which is indicated by slump blocks. A broken opal weighing 7.25 lb (3.3 kg) was found at the Virgin Opal (Bonanza) mine by Keith Hodson, the present owner.

The Rainbow Ridge mine is on the east side of Virgin Valley, approximately 4 mi (6 km) south of the Virgin Valley campground. Here the opal-bearing horizon is nearly horizontal and averages more than 4 ft (1.2 m) in thickness. Two exceptionally large opals, the Roebling and the Hodson, were found at the Rainbow Ridge mine in 1917 and 1952, respectively.

The district's precious opal is some of the finest in the world, both in color and opalescence. In the past, most precious opals were sold as collector's items and were not cut into cabochons[1]. Their high water content, 16 to 23 percent, causes poor stability within the gem. According to H. W. Wilson, a method requiring a year has been found to reduce water content to less than 5 percent without damaging the gem.

A quarry on the Lemac group of claims in the northern part of the district has produced dimension stone. Permission for the Bureau

[1]A gem cut in convex form and highly polished, but not faceted.

of Mines to examine the claims was not received. The reddish-brown, tuffaceous sandstone is relatively unfractured, splits easily along bedding planes, and is as much as 20 ft (6 m) thick (Wendell, 1970). Beyond the claims' boundaries, the sandstone unit thins rapidly to a thickness of 2.5 ft (0.8 mm) and becomes a poor-quality ornamental stone. However, resources in an area adjacent to the claims are estimated to be more than 250,000 tons (227,000 t).

Dimension stone is also found 2 mi (3 km) southeast of the Lemac group. These beds are thinner than those in the vicinity of the Lemac group and show local folding.

Diatomaceous earth occurs in several places in the district. Beds are as much as 8.0 ft (2.4 m) thick on the April Fool claim group and 7.0 ft (2.1 m) thick near the Rainbow Ridge mine. A sample analyzed by Johns-Manville in 1935 showed that the diatoms are of wrong types for use as filter aids (Johns-Manville, written commun., 1975).

Since 1950, 720 uranium claims have been located in the Virgin Valley district. They are concentrated in two areas; one, referred to as the McKenney Camp uranium claims, is in rhyolite and has no value as a uranium resource. The second, the Virgin Valley uranium claims, covers an area about 0.25 mi (0.4 km) wide that extends north from the Virgin Valley Ranch for approximately 1 mi (1.6 km). Studies show this to be a large low-grade uranium resource.

LONE PINE DISTRICT

The Lone Pine district occupies the southern half of the Refuge and extends beyond the southern boundary into Bald Mountain Canyon (fig. 27). Elevations range from 6,000 ft (1830 m) on the western and eastern study-area boundaries to 7,191 ft (2192 m) at the summit of Yellow Peak. State Highway 34A, from Cedarville to Denio, skirts the district's north side.

The country rock is principally andesite and associated tuffs, with most of the latter altered to a bentonitic clay. Gold and silver prospecting began in 1897 and continued through 1909. The district has had no reported gold or silver production; however, studies indicate it has potential. In 1929 mercury was discovered; soon thereafter, the Antelope claims were located south of the Refuge boundary. The Antelope mine produced a small amount of mercury, but assays showed the ore is low grade. A total of 353 claims were located in the district, 80 of which are south of the study-area boundary.

In 1954 and 1955 a total of 142 uranium claims were located; however, little activity followed, and the district is now idle.

MINERAL COMMODITIES

Opal, building stone, and uranium are the principal commodities in the Charles Sheldon Wilderness Study Area. Except where noted, national and world data and other technical data for the following section are from U.S. Bureau of Mines (1975, 1978, 1979).

PRECIOUS OPAL

Opal constituted approximately 1 percent of the domestic gemstone production in 1970 and less than 2 percent of the total production (excluding diamonds and pearls) in the world (Jahns, 1975). Annual domestic gemstone production from 1880 to 1970 constituted from 0.2 to 1.3 percent of the world's total output in terms of value (Jahns, 1975). In 1978 domestic gemstone production was estimated to be $9.0 million, and apparent consumption, including diamonds, was estimated to be $1,442 million. Estimated imports were $2,141 million, while exports and re-exports were $708 million. United States precious-opal deposits occur principally in Nevada and to lesser extents in Idaho, Oregon, and Washington (Schlegel, 1957). Nearly all imported precious opal comes from Australia (Zale's Jewelry Co., Spokane, Wash., oral commun., 1978).

Precious opal's greatest utilizations are in the jewelry industry and as collector's items. Common opal and opalized wood are sometimes cut and polished for ornaments. Precious-opal jewelry has become increasingly popular, and the demand is expected to increase. Synthetic opals are of low quality and of little, if any, commercial importance.

Opal prices vary greatly, according to the matrix color, and intensity and color of opalescence. Prices increase as matrix color darkens and intensity of opalescence increases. Prices per carat also increase for larger cabochons. A transparent opal with intense opalescence may be valued from $10 to $35 for a 1-carat cabochon and $30 to $90 per carat for a 10-carat cabochon. A very dark opal with intense opalescence may be valued from $130 to $4,000 for a 1-carat cabochon and $400 to $7,200 per carat for a 10-carat cabochon (Jahns, 1975).

Although opal is mined in several places, the Virgin Valley district's most productive mines are the Rainbow Ridge, Royal Peacock, and Virgin Opal (Bonanza).

DIMENSION STONE

Dimension stone's major uses are: rough blocks, monuments, building stone, curbing, and rubble. Estimated domestic production in 1978 was 1.43 million tons (1.3 million t) valued at $116 million. Of the total, 39 percent was granite, 31 percent limestone, and 17 percent sandstone. United States demand for dimension stone is not expected to grow through 1985. The estimated average price in 1978 was $81.70 per ton ($86/t).

During production years, tuffaceous sandstone was quarried from the north end of Virgin Valley and reportedly sold for $60 per ton ($66/t) at the quarry site (Bob Wegman, oral commun., 1976).

URANIUM

In 1978 primary United States demand for uranium for nuclear fuels was estimated to have been 14,400 tons (13,060 t) U_3O_8. An additional 5,500 tons (4,990 t), from depleted uranium stocks, was consumed in nonnuclear uses such as ballast, counterweights, radiation shielding, alloys, catalysts, glass colorant, and electrical components. Recoverable mine production was 18,500 tons (16,780 t) U_3O_8. Imports of uranium concentrates and other compounds for consumption totaled approximately 6,900 tons (6,260 t) and came primarily from Canada. United States reserves are estimated to be 690,000 tons (630,000 t) of U_3O_8 at $30.00/lb ($66/kg). In 1977, the average price of U_3O_8 was $18.50/lb ($44/kg). On February 1, 1980, the spot market price was about $40.75/lb ($89.84).

To meet the requirements of commercial power reactors during the next decade, domestic U_3O_8 production is expected to continue its rapid growth. Demand is anticipated to increase at an annual rate of 15 percent through 1985.

The average grade of ore mined by 120 operations in 1975 was 0.18 percent U_3O_8.

Uranium claims are scattered throughout the Range and Refuge. The main group is in an area about 1 mi (1.6 km) wide and 2 mi (3.2 km) long extending north from the Virgin Valley Ranch.

PREVIOUS STUDIES

Most of the studies in the area were limited in scope. Merriam (1910) described the geology of the Virgin Valley and Thousand Creek Formations. Frock (1963) and Wendell (1970) described the stratigraphy and structure of the Virgin Valley-McGee Mountain-Thousand Creek area. Ross (1941), Bailey and Phoenix (1944), and Holmes (1965) discussed mercury potential in the Bald Mountain area, Lone Pine district. Staatz and Bauer (1951) conducted a limited reconnaissance of the uranium potential in Virgin Valley.

PRESENT STUDIES

METHODS OF EVALUATION

Courthouse records and mineral reports were used to determine the historical significance of the mining districts, and sites of claims and mineral deposits. Past and present owners of mineral properties were contacted; historical property data and production records were obtained where available. Permission to examine the properties and publish data was sought from owners of active claims. Most of the owners denied permission to examine their properties. The descriptions of properties for which permission was not granted are taken from earlier reports and, therefore, are not supported or augmented by Bureau of Mines field examinations.

All mines, prospects, and claims were sought in the field. Where permitted, the properties were examined, and where warranted, they were sampled and mapped.

Resources have been classified according to the following definitions adopted by the U.S. Bureau of Mines and U.S. Geological Survey (1976):

Resource.—A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.

Reserve.—That portion of the identified resource from which a usable mineral and energy commodity can be economically and legally extracted at the time of determination. The term "ore" is used for reserves of some minerals.

Indicated.—Reserves or resources for which tonnage and grade are computed partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout.

Inferred.—Reserves or resources for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geologic evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geologic evidence of their presence. Estimates of inferred reserves or resources should include a statement of the specific limits within which the inferred material may lie.

Paramarginal.—The portion of Subeconomic Resources that (1) borders on being economically producible or (2) is not commercially available solely because of legal or political circumstances.

Submarginal.—The portion of Subeconomic Resources which would require a substantially higher price (more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology.

SAMPLING AND ANALYTICAL METHODS

Four-hundred and three lode samples ranging from 5 to 10 lb (2.2 to 4.5 kg) were collected during field evaluations. Four types were taken: chip, a series of continuous rock chips across or along exposure; random chip, a collection of rock chips from an exposure; grab, an unselected assortment of rock pieces from a rock pile or exposure; and select, hand-picked material of the highest grade rock available. Most of the lode samples were fire assayed to determine their gold and silver content. Samples containing visible metallic minerals were analyzed by atomic-absorption, colorimetric, or X-ray fluorescence methods. At least one sample from each mineralized structure on a property was analyzed by semiquantitative spectrographic methods. If anomalous amounts of economic elements were detected in a sample by spectrography, the sample was further analyzed by more accurate means. All were checked for the presence of radioactive and fluorescent minerals.

Claims located for uranium were checked for radioactivity with a hand-held scintillation counter. Readings were recorded in milliroentgens per hour.

ACKNOWLEDGMENTS

The authors express their appreciation to claim holders, property owners, and local residents for their cooperation. Special acknowledgment is due H. W. Wilson and Keith Hodson for their historical data on precious opal and to Henry John for his historical sketch of the area.

MINES AND PROSPECTS

Described in alphabetical order are the 41 mines, prospects, and claimed areas within or immediately adjacent to the study area that were examined.

ANTELOPE NOS. 1–18 (Lodestar Nos. 1–60)

Map reference.—Plate 1, no. 1.

Location.—Secs. 22, 23, and 24, T. 45 N., R. 21 E., a short distance outside the south boundary of Refuge.

Elevation.—5,800 to 6,400 ft (1,770 to 1,950 m).

Access.—By jeep road 6 mi (10 km) southwest from Refuge headquarters.

History.—The Antelope claims, located by Curtis Mathews and W. S. Miller in December 1929, marked the first reported discovery of mercury in the Lone Pine mining district. Little exploratory work was done until the Colton Log and Lumber Co. took a bond on the property in 1939 (Bailey and Phoenix, 1944). Reportedly they recovered a small amount of mercury from a 10-pipe retort. During 1955 and 1956, a batch-type furnace plant was installed, and in 1958 development of alluvial material was undertaken (U.S. Bureau of Mines, 1965). Little work has since been done on the property.

In 1969 the Lodestar Nos. 1–60 were located by Frank Margrave. The claims reported lie slightly south of the Refuge and probably overlap the Antelope group.

Previous production.—Reportedly a small amount of mercury has been produced (Bailey and Phoenix, 1944).

Geology of deposit.—The country rock is north-striking, east-dipping andesite flows and associated tuffs and agglomerates. The andesite is red to black and fine grained. The tuffs are light gray and contain a few layers of conglomerate. Andesite in the southern part of the area is overlain by a basalt flow 20 to 50 ft (6 to 15 m) thick. Mineralized rock is restricted to a series of steeply dipping, northwest-trending shear zones, and to a lesser extent, alluvial material (Ross, 1941). Structures reported by Ross (1941) are obscured by colluvium.

Development.—One caved, inclined shaft, reported to have been 70 ft (21 m) deep (U.S. Bureau of Mines, 1965), 113 pits, and 39 trenches were observed (fig. 28). Nearly all workings are caved. Most excavation was done by bulldozer.

Sampling.—In 1940 the Geological Survey cut four samples across seams 48, 36, 15, and 10 in. (122, 91, 38, 25 cm) thick that assayed 0.29, 0.07, 0.18, and 0.70 percent mercury, respectively (Ross, 1941).

Four samples cut by the Colton Log and Lumber Co. contained 0.35, 0.33, 0.075, and 0.075 percent mercury (Ross, 1941).

During the present field investigation, 59 samples from rock in place and dumps of workings assayed as much as 0.073 percent mercury, averaging 0.005 percent.

Conclusions.—Sampled material was probably diluted by weathering and resultant sloughing of the workings. A random grab sample

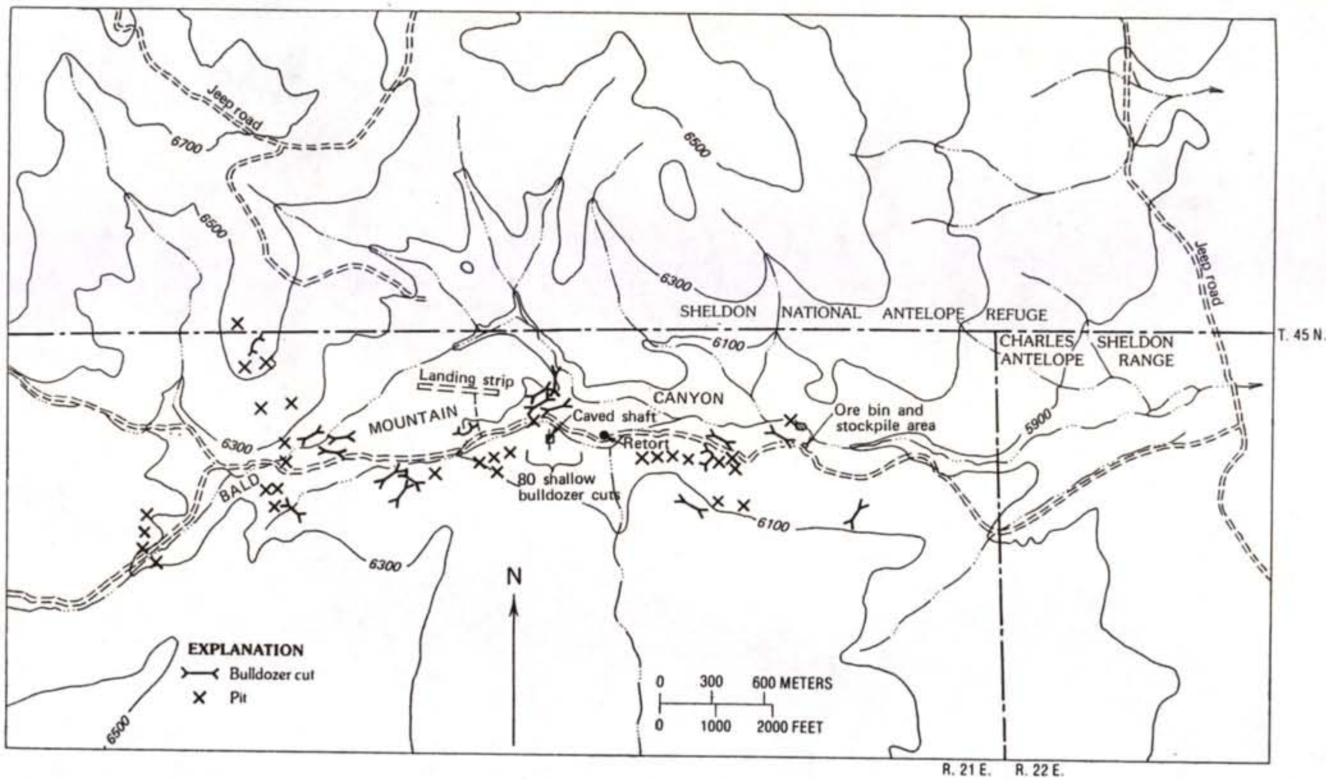

FIGURE 28.—Antelope group workings, Charles Sheldon Wilderness Study Area.

from the ore bin assayed 0.073 percent mercury. Mercury-bearing structures do not extend into the Refuge.

BALD MOUNTAIN CLAIMS

Map reference.—Plate 1, no. 2.

Location.—Secs. 5, 6, 7, 8, 9, 10, 15, 16, 17, and 18, T. 45 N., R. 21 E.

Elevation.—From 6,000 to 7,191 ft (1,830 to 2,190 m).

Access.—By jeep road 2 mi (3 km) south from Refuge headquarters.

History.—Early gold and silver prospecting, from 1897 through 1909, led to the location of 109 claims on and adjacent to Bald Mountain. In the two years 1911 and 1918, 25 claims were located. In December 1929, the discovery of mercury, south of the Refuge boundary, sparked exploration for it in the Refuge. Courthouse records show that 30 claims were located from 1930 through 1941. During the uranium boom years of 1954 and 1955, 140 claims were located. Five groups (Nevada Guy Nos. 1–43, Lone Pine Nos. 1–29, Jim Bum Nos. 1–22, Amar Nos. 1–20, and Hades Nos. 1–13) on the south side of Bald Mountain make up most of the claims. Some groups appear to overlap others. No claims have been located since 1955.

Geology of deposit.—Country rock is predominantly andesite and associated tuff and ash beds, although rhyolite crops out in the southwest corner of section 8. Most of the gold and silver claims are in an area underlain by tuff. The tuff is mostly vitric. The textures grade from very fine to coarse and sugary; some are welded. Colors are cream, light green, yellow, pink to purple, brown, and red. Much of the tuff has altered to bentonitic clay. Most of the uranium claims are underlain by fine-grained, dark andesite.

Development.—Four caved adits, two shafts, five cuts, 36 pits, and 60 trenches were found in the area (fig. 29). Most of the workings are caved.

Sampling.—A total of 86 samples were taken. Of extremely altered volcanic rocks, one grab sample assayed 0.04 oz/ton gold (1.4 g/t), three others assayed 0.01 oz/ton gold (0.3 g/t), and still another 3.3 oz/ton silver (113 g/t).

A chip sample from a 0.5- to 2-in (1.3- to 5-cm)-thick quartz vein in light-purple to brown welded tuff assayed 0.06 percent mercury. A 4.4 ft (1.34-m) chip sample taken across a shear zone striking N. 55° W. and dipping 80° S. in a purple welded tuff assayed 0.023 percent mercury, and a grab sample of highly altered green and pink silicified ash assayed 0.02 percent mercury.

Conclusions.—Assay results of anomalous gold, silver, and mercury

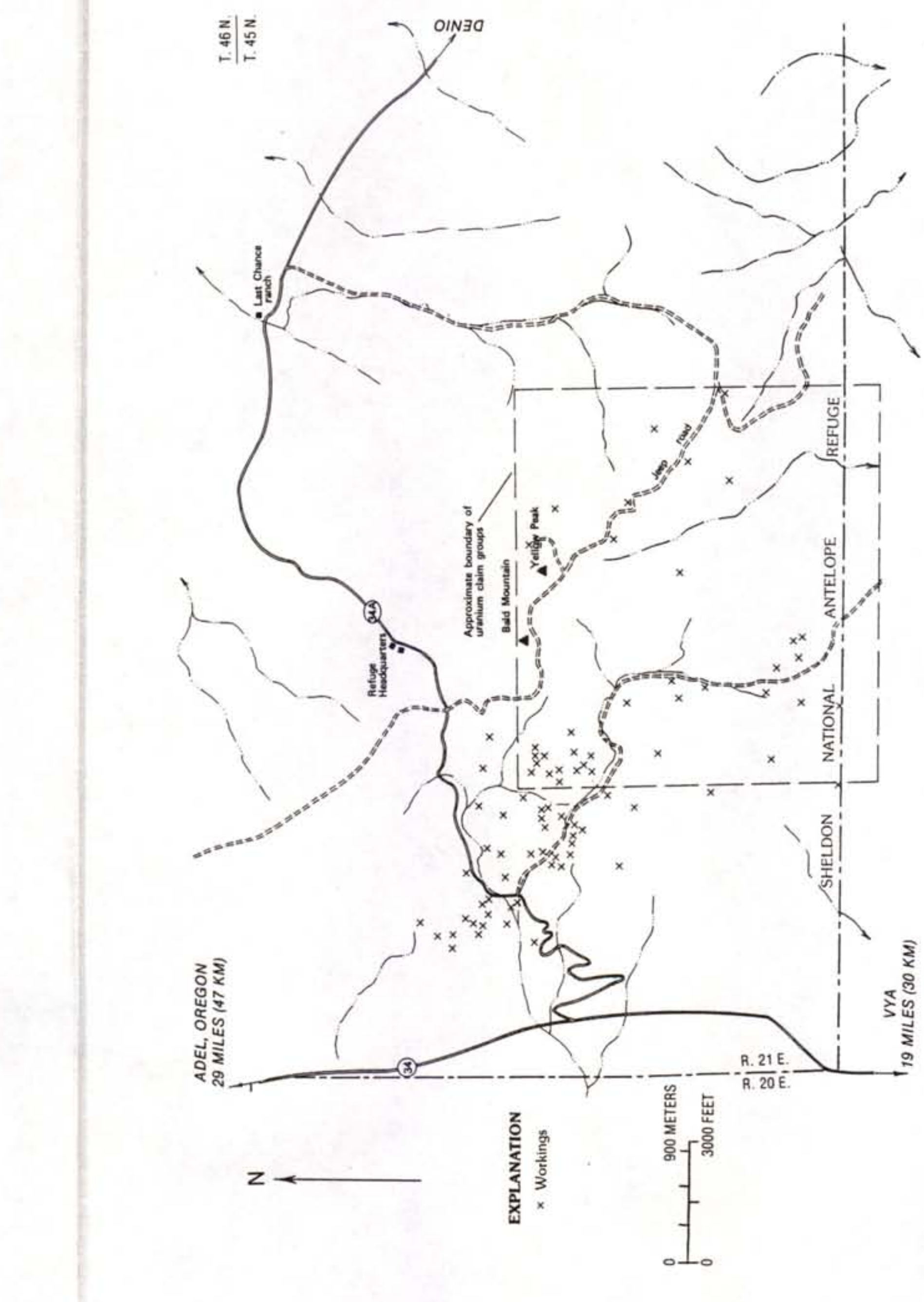

FIGURE 29.—Bald Mountain claims workings, Charles Sheldon Wilderness Study Area.

suggest low-grade recovery potentials. Geochemical work by the Geological Survey indicates a high potential for deposits of mercury and for concealed base and complex precious-metal sulfide deposits.

BIGHORN GROUP

Map reference.—Plate 1, no. 13

Location.—Sec. 2, T. 44 N., R. 24 E.

Elevation.—6,000 ft (1830 m)

Access.—By jeep road 10 mi (16 km) southwest from Virgin Valley Ranch, then by cross-country travel 1 mi (1.6 km) east.

History.—The Big Horn, Little Horn, and Mountain Sheep claims were located in 1960 by Mr. Vottero.

Geology of deposit.—Weathered rhyolite.

Development.—None.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.02 to 0.03 mR/hr (milliroentgens per hour) were observed. Four random chip rhyolite samples each had less than 0.001 percent U_3O_8 and a trace silver.

Conclusions.—No economic mineral potential.

BLUE DRAGON NOS. 1–3

Map reference.—Plate 1, no. 35.

Location.—Sec. 24, T. 44 N., R. 24½ E.

Elevation.—5,600 to 5,900 ft (1710 to 1800 m).

Access.—By jeep road 16 mi (26 km) southwest from Virgin Valley Ranch.

History.—The claims were located for mercury by Vincent Palmer in 1968.

Geology of deposit.—The area is underlain by ash beds that have been partially altered to montmorillonite. A silicified breccia zone crops out over a 600 ft (183-m) square area. The zone has angular fragments of cream to pink ash in a matrix of clear to light-pink silica. Mercury minerals are scarce.

Development.—One shaft, 44 ft (13.4 m) deep, three bulldozer cuts, one pit, four trenches, and one caved adit or trench.

Sampling.—Nine samples from rock in place and from workings dumps assayed a trace of gold and as much as 0.3 oz/ton silver (10 g/t) and 0.006 percent mercury.

Conclusions.—Low mineral potential.

CHARLINE NOS. 1 AND 2

Map reference.—Plate 1, no. 5.

Location.—Secs. 14 and 15, T. 46 N., R. 23 E.

Elevation.—6,600 ft (2012 m).

Access.—By Nevada State Highway 34A, 6 mi (10 km) west from the junction with Nevada State Highway 8A, then by cross-country travel 1 mi (1.6 km) north.

History.—Located by Charline Brown in 1956.

Geology of deposit.—Gray to reddish-brown banded rhyolite.

Development.—None.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding the background count of 0.025 to 0.03 mR/hr were observed. Three random chip samples from rhyolite outcrops had no anomalous metallic content.

Conclusions.—No economic mineral potential.

CRATER GROUP

Map reference.—Plate 1, no. 36.

Location.—Secs. 15, 16, and 22, T. 44 N., R. 24 E.

Elevation.—6,920 to 7,120 ft (2110 to 2170 m).

Access.—By jeep road 15 mi (24 km) southwest from Virgin Valley Ranch.

History.—Thirty-one claims were staked in 1954 by H. W. Wilson and others.

Geology of deposit.—Iron oxide-stained light-gray rhyolite.

Development.—Twenty discovery pits observed.

Sampling.—Discovery pits were checked for radioactivity with a scintillation counter. Background readings of 0.04 to 0.045 mR/hr were observed. One small area near the summit of Blowout Mountain had a reading of 0.07 mR/hr. Sixteen samples of rhyolite and residual soil each contained a trace of silver and less than 0.001 percent U_3O_8.

Conclusions.—No economic mineral potential.

ECHO GROUP

Map reference.—Plate 1, no. 6.

Location.—W½ sec. 31, T. 46 N., R. 24 E.

Elevation.—6,100 ft (1860 m).

Access.—By Nevada State Highway 8A, 4 mi (6.4 km) west from junction with Nevada-Oregon State Highway 140.

History.—Twelve mining claims were located in 1955 by S and S Exploration Co.

Geology of deposit.—The area is underlain by Tertiary rhyolite and Quaternary alluvium. No mineralized structures were observed.

Development.—Eight shallow bulldozer cuts in alluvium.

Sampling.—All bulldozer cuts and outcrops were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.03 to 0.035 mR/hr were observed. Four samples from bulldozer cuts and six from rhyolite outcrops assayed a trace of silver and less than 0.001 percent U_3O_8 each.

Conclusions.—No economic mineral potential.

EDDY GROUP

Owner.—C. L. Eddy and others.

Map reference.—Plate 1, no. 23.

Location.—Secs. 5 and 8, T. 45 N., R. 26 E.

Elevation.—5,100 ft (1555 m).

Access.—By Virgin Valley road 5 mi (8 km) south from junction with Nevada State Highway 140, then by good dirt road 0.5 mi (0.8 km) northwest.

History.—The group consists of 21 claims: West Gem Hill, Mayday, Bluebird, Richard, Patrick, Crazy Indian, Lil Abner, Daisy Mae, No. 2 Opal, Hidden Valley, Lu Lu, Sparkle Plenty, Windfall, Marvelous, Lorrie Lee, East Gem Hill, Nancy's Nightmare, Sun Valley, Evening Star, Opal Valley, and New Moon. One claim was located in 1948, the others in 1969 through 1974.

Previous production.—Mr. Eddy stated that some precious opal has been produced but did not specify the amount.

Geology of deposit.—An opal-bearing horizon is in slump blocks of bedded volcanic tuffs, ash, and tuffaceous sandstone and siltstone. The horizon is bentonitic and greenish, and contains wood fragments and pebbles. In places it is 6 ft (1.8 m) thick. Sediments range in dip from flat lying to as much as 30°. The opal-bearing horizon is difficult to trace because it is slumped and tilted.

Development.—Approximately 70 pits and bulldozer trenches were observed. Some trenches are several hundred feet long (fig. 30).

Sampling.—Sampling consisted of digging into exposed beds and observing the presence or absence of indicators of precious opal. Common opal was observed at numerous places.

Conclusions.—The likelihood of additional precious opal is high.

FORTUNE GROUP, URANIUM KING, AND LUCKY JACK

Map reference.—Plate 1, no. 18.

Location.—Secs. 29, 31, and 32, T. 46 N., R. 27 E.

Elevation.—4,360 to 4,650 ft (1330 to 1420 m).

Access.—By Nevada State Highway 140, 23 mi (37 km) west from Denio.

History.—The Fortune group, consisting of 20 claims, was located in 1955 by Charles Baker. The Uranium King and Lucky Jack claims were located in 1955 by Jack Neal and Roy Clifton.

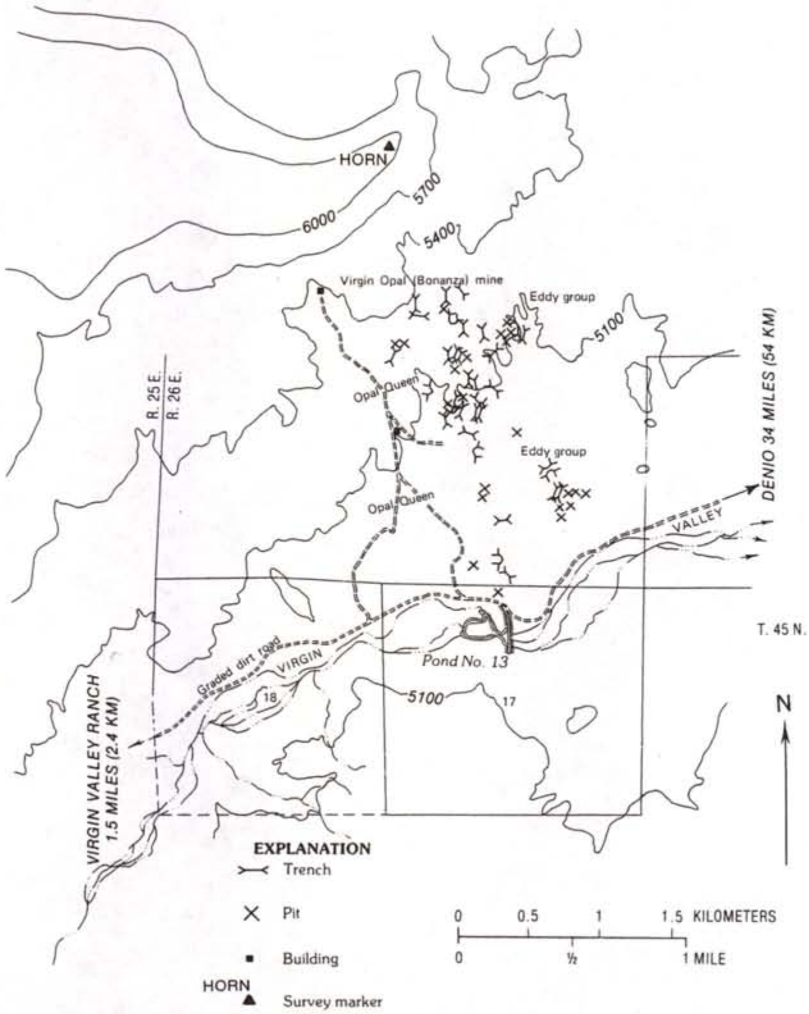

FIGURE 30.—Eddy group workings, Charles Sheldon Wilderness Study Area.

Geology of deposit.—Alluvium containing abundant rhyolite and basalt cobbles overlies tuffaceous sediments. Rhyolite crops out on the south end of the claim block.

Development.—Approximately 45 bulldozer cuts.

Sampling.—All workings were checked for radioactivity with a scintillation counter. No reading exceeding a background count of 0.015 to 0.03 mR/hr was observed. Twelve samples from bulldozer cuts had no anomalous metallic content.

Conclusions.—No economic mineral potential.

GOLDEN CASH, JACKPOT, BURIED TREASURE, AND GOLDEN HORDE

Map reference.—Plate 1, no. 39.

Location.—Sec. 36, T. 44 N., R. 24 E.

Elevation.—6,200 ft (1890 m).

Access.—By jeep road 10 mi (16 km) south from Virgin Valley Ranch.

History.—C. A. Stone and D. J. Alford each located two claims in 1954.

Geology of deposit.—Gray to green rhyolite.

Development.—None.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.025 to 0.035 mR/hr were observed. Four random chip samples of rhyolite each contained a trace gold and silver and less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

GOODWILL

Map reference.—Plate 1, no. 20.

Location.—Sec. 2, T. 45 N., R. 26 E.

Elevation.—4,900 ft (1490 m).

Access.—By dirt road 1 mi (1.6 km) south from Dufurrena Subheadquarters.

History.—The claim was located as a "mercury and hydrothermal lode" in 1974 by H. W. Wilson.

Geology of deposit.—The claim is underlain by beds of ash, ash partially altered to montmorillonite, and tuffaceous sandstone striking N. 10° W. and dipping 1° to 5° SW. The ash bed contains numerous geodes.

Sampling.—One sample was taken from the pits and contained 20 ppm mercury.

Conclusions.—The claim has no economic potential for mercury. The geodes may have some economic value. The tuffaceous sandstone is relatively unfractured and its thickness, cleavability, and horizontal dimensions are such that it may be suitable for dimension stone.

GRUBSTAKE NOS. 1–4

Map reference.—Plate 1, no. 29.

Location.—Secs. 22, 26, and 27, T. 45 N., R. 25 E., south of Mud Spring Canyon, 1 to 2 mi (1.6 to 3.2 km) west of Virgin Valley Ranch.

Elevation.—5,250 to 5,630 ft (1600 to 1720 m).

Access.—By dirt road 1 mi (1.6 km) west from Virgin Valley Ranch.

History.—The Grubstake group was located in 1955 by Grace Cummings and Meed Cooley.

Geology of deposit.—Colluvium overlying gray to reddish rhyolite bedrock.

Development.—Sixteen bulldozer cuts in colluvium. Most are shallow, range from 20 to 350 ft (6 to 107 m) in length, and are along the north side of the road a distance of about 1.5 mi (2.4 km).

Sampling.—All workings were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.03 to 0.06 mR/hr were observed. Five grab samples of soil and rock from the bulldozer cuts and one chip sample of rhyolite assayed no anomalous metallic content.

Conclusions.—No economic mineral potential.

HOPE GROUP

Map reference.—Plate 1, no. 30.

Location.—Sec. 21, T. 45 N., R. 25 E.

Elevation.—5,900 ft (1798 m).

Access.—By jeep road 4 mi (6 km) west from Virgin Valley Ranch.

History.—Thirty-five claims were located by E. Plaskett in 1956.

Geology of deposit.—Gray to reddish-brown banded rhyolite and alluvium.

Development.—Thirteen shallow bulldozer cuts in alluvium along the jeep road.

Sampling.—Bulldozer cuts and rhyolite outcrops were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.025 to 0.03 mR/hr were observed. Ten samples of alluvium and rhyolite assayed no anomalous metallic content.

Conclusions.—No economic mineral potential.

KIM NOS. 1–9

Map reference.—Plate 1, no. 14.

Location.—Sec. 23, T. 45 N., R. 24 E.

Elevation.—6,020 to 6,040 ft (1830 to 1840 m).

Access.—By Nevada State Highway 8A, 11 mi (18 km) south from junction with Nevada State Highway 140, then by dirt road 5 mi (8 km) east.

History.—The claims were located in September 1955 by Kenneth Arnold.

Geology of deposit.—Basalt cap rock over rhyolite breccia and tuff.

Development.—Five shallow bulldozer cuts.

Sampling.—Bulldozer cuts were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.02 to 0.04 mR/hr were observed. Five samples from bulldozer cuts each contained a trace of gold and silver and less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

LADD AND SHEPARDSON'S GROUP

Map reference.—Plate 1, no. 26.

Location.—Secs. 24 and 25, T. 45 N., R. 26 E.

Elevation.—5,000 to 5,500 ft (1520 to 1670 m).

Access.—By dirt road 5 mi (8 km) south from Dufurrena Subheadquarters.

History.—A group of 12 claims was located in 1956 by Ladd and Shepardson.

Geology of deposit.—Alluvium overlies rhyolite and light-gray, green, and yellow welded tuffs. No mineralized structures were observed.

Development.—Three pits, two bulldozer cuts, and three roads or cuts totaling about 2 mi (3 km) in length.

Sampling.—Five samples taken from rock in place and from dumps of bulldozer cuts assayed only a trace of uranium.

Conclusions.—No economic mineral potential.

LEMAC NOS. 1–5

Owner.—Tom Conner.

Map reference.—Plate 1, no. 19.

Location.—Sec. 2, T. 45 N., R. 26 E.

Elevation.—4,850 ft (1478 m).

Access.—By Virgin Valley road 1 mi (3 km) south from junction with State Highway 140.

History.—Stone was first quarried from the deposit in the early 1870's; it was used in the construction of homesteads in northwestern Nevada. Prior to 1952, Mr. Turner held the claims (Henry John, oral commun., 1976); in 1952, Bob Wegman and his brothers, William and Theron, started production at the site. A cable saw capable of cutting 90 tons (82 t) without being moved, three mud saws for slabbing, and a guillotine crusher were installed. The Wegmans worked the quarry for 15 years before abandoning the claims (Bob Wegman, oral commun., 1976). The claims were relocated in 1970 by Mike Lee and were acquired in 1972 by Tom Connors, the present owner (Henry John, oral commun., 1976).

Previous production.—The only recorded production was that of the Wegmans. Approximately 50 percent of the stone mined was suitable for shipping. During 15 years of operation, about 18,000 tons (16,000 t) were shipped to outlets from as far away as Spokane, Wash., and southern Nevada. At the quarry site stone sold for $60/ton ($66/t) (Bob Wegman, oral commun., 1976).

Geology of deposit.—Permission for the Bureau of Mines to examine the claims was not received. According to Wendell (1970), "One of the flaggy volcanic siltstone units within the Red Member of the Virgin Valley Formation was commercially quarried for ornamental building stone until 1967. The unit is 15 to 20 ft (5 to 6 m) thick in the vicinity of the quarry and thins rapidly in all directions."

Outside the claim boundaries, the flaggy siltstone unit ranges from 1.5 to 3 ft (0.5 to 0.9 m) thick, averaging 2.5 ft (0.8 m) thick, and underlies at least 130 acres (53 h) north and northwest of the quarry. The unit is essentially flat lying but locally dips as much as 8° both northwest and southeast. The siltstone beyond the claim boundaries is too thin and broken for use as quality ornamental stone.

Development.—A quarry that appears to be 200 ft by 400 ft (61 by 122 m).

Conclusions.—Under favorable economic conditions, production probably could be resumed.

LUCKY FOUR

Map reference.—Plate 1, no. 17.

Location.—Sec. 33, T. 47 N., R. 26 E.

Elevation.—5,600 ft (1,710 m).

Access.—By State Highway 140, 27 mi (43 km) west from Denio, then by cross-country travel 4 mi (6 km) northwest.

History.—One 80-acre (32.4-ha) placer claim was located by Claude Noble in 1951.

Geology of deposit.—The claim is underlain by Quaternary alluvium and Tertiary basalt. No mineralized structures were observed.

Development.—None.

Sampling.—One sample assayed a trace of silver and less than 0.005 percent U_30_8.

Conclusions.—No economic mineral potential.

LUCKY HORSHOE GROUP

Map refererence.—Plate 1, no. 38.

Location.—Sec. 6, T. 43 N., R. 25 E.; sec. 31, T. 44 N., R. 25 E.; and sec. 36, T. 44 N., R. 24½ E.

Elevation.—6,250 to 6,710 ft (1905 to 2045 m).

Access.—By jeep road 8 mi (13 km) south from Virgin Valley Ranch.

History.—Fourteen claims were located in 1955 by P. B. Meyers, J. Meyers, W. W. Ware, and G. Kendricks.

Geology of deposit.—Gray to green rhyolite.

Development.—None.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.025 to 0.030 mR/hr were observed. Ten random chip samples of rhyolite each contained a trace of gold and silver and less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

LUCKY JIM NOS. 1–8 AND APEX

Map reference.—Plate 1, no. 11.

Location.—Sec. 32, T. 45 N., R. 24 E.

Elevation.—6,230 ft (1900 m).

Access.—By Nevada State Highway 8A, 12 mi (19 km) south from junction with Nevada State Highway 140, then by jeep road 2 mi (3 km) east.

History.—The Lucky Jim group was located in 1955 by Ralph Peterson and the Apex in 1955 by Gus Pearson.

Geology of deposit.—Colluvium and alluvium over rhyolite bedrock.

Development.—Four bulldozer pits in alluvium.

Sampling.—All bulldozer pits were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.015 to 0.03 mR/hr were observed. Four samples of soil from bulldozer pits each contained a trace of gold and silver and less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

LUCKY STRIKE

Map reference.—Plate 1, no. 33.

Location:—Sec. 12, T. 44 N., R. 24½ E.

Elevation.—6,300 ft (1920 m).

Access.—By Nevada State Highway 8A, 12 mi (19 km) south from junction with Nevada State Highway 140, then by jeep road 9 mi (14 km) east.

History.—Located in 1949 by Mary Lamb and Vincent Marconi.

Geology of deposit.—The claim is underlain by ash beds. A 16-ft (4.9-m)-wide fault zone trending N. 74° W. and intermittently exposed for 320 ft (97.5 m) contains brecciated ash layers in a siliceous matrix.

Development.—A trench 25 ft (7.6 m) wide, 110 ft (33.5 m) long, and 12 ft (3.7 m) deep is the principal working. Eight other small trenches and pits are on the zone.

Sampling.—Two chip samples across the zone each contained a trace of gold and 0.1 oz/ton (3.4 g/t) of silver.

Conclusions.—No economic mineral potential.

MCKENNEY CAMP URANIUM CLAIMS

Map reference.—Plate 1, no. 15.

Location.—Secs. 15, 21, 22, 23, 27, and 28, T. 46 N., R. 25 E.

Elevation.—5,100 to 5,500 ft (1550 to 1680 m).

Access.—By Nevada State Highway 140, 39 mi (62 km) west of Denio.

History.—The area contains 116 mining claims located from 1955 through 1969 by various persons. Many are relocations.

Geology of deposit.—The claims are underlain by alluvium and gray to dark-purplish rhyolite. No mineralized structures were observed.

Development.—Fifteen shallow bulldozer cuts in alluvium.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.02 to 0.04 mR/hr were observed. Thirty-two samples from rock in place and bulldozer cuts contained no more than a trace of gold and silver and less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

MESA

Map reference.—Plate 1, no. 31.

Location.—Sec. 31, T. 45 N., R. 26 E.

Elevation.—6,200 ft (1890 m).

Access.—By jeep road 2 mi (3 km) southeast from Virgin Valley Ranch.

History.—Located in 1953 by MacDonald.

Geology of deposit.—Flat-lying basalt caps volcanic sediments.

Development.—Shallow bulldozer cuts in residual soil overlying the basalt.

Sampling.—One bulldozer cut; grab sample had no anomalous metallic content.

Conclusions.—No economic mineral potential.

MEYER GROUP MINE

Owners.—John and Virgie Meyer.

Map reference.—Plate 1, no. 24.

Location.—Sec. 17, T. 45 N., R. 26 E.

Elevation.—4,920 to 5,160 ft (1500 to 1570 m).

Access.—By Virgin Valley road 4 mi (6 km) south from Dufurrena Subheadquarters.

History.—The group consists of five claims. The Becky, Mucket, and White Hills claims were located in the summer of 1954, and the Moon Walk in July 1969. Former owners of the Black Hope quitclaimed to the Meyers in 1971. The Meyers leased the Becky and Mucket claims to Opals Inc. about 1969 to 1971.

Production.—Owners' income from the Becky and Mucket claims during 1969 to 1971 was approximately $3,500, $1,500 of which was from leasing and $2,000 from opals produced by the lessee. The $2,000 represents 5 percent of the total opal value.

The owners themselves mined $2,000 worth of opal from the Black Hope, White Hills, and Moon Walk claims.

Total opal value produced from the Meyer group is estimated to be $42,000.

Geology of deposit.—Nearly horizontally bedded lacustrine sediments of volcanic tuff, ash, and ashy sandstone and siltstone have some layers of gypsum and pieces of wood in various stages of petrification. Tuff layers exposed to weathering are altered to montmorillonite. Petrified wood and small fragments of precious opal were found in the tuff exposed by the largest bulldozer cut on the Moon Walk claim. The opal-bearing tuff horizon is 10 ft (3 m) thick in places. A well-exposed contact between tuff and an overlying bed of ash has an apparent dip of 3° N.

Development.—Thirteen bulldozer cuts and one pit were observed (fig. 31). A small wooden storage shed is on the White Hills claim.

Sampling.—Sampling consisted of digging into the exposed beds and observing the presence or absence of indicators of precious opal. Small fragments of precious opal were observed.

Conclusions.—The Meyer claims have a precious-opal potential. About 30 acres (12 ha), underlain by the opal-bearing horizon, are minable. This area estimate is based on a strike length of 6,000 ft (1,830 m) and an economic width limit of 200 ft (60 m). Beyond 200 ft (60 m), the stripping ratio would be excessive.

OBSIDIAN GROUP, COLUMBIA AND LOISE

Map reference.—Plate 1, no. 9.

Location.—Secs. 2 and 11, T. 44 N., R. 23 E.

Elevation.—6,000 to 6,400 ft (1830 to 1950 m).

Access.—By Nevada State Highway 8A, 14 mi (22 km) south from junction with Nevada State Highway 140.

History.—The Obsidian group consists of eight claims located in 1955 by C. H. Ripattee and H. E. Alloway. The Columbia and Loise claims were located in 1956 by C. J. Hicks.

Geology of deposit.—Alluvium overlies gray rhyolite containing feldspar phenocrysts. No mineralized structures were observed.

Development.—One shallow bulldozer cut in alluvium.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.02 to

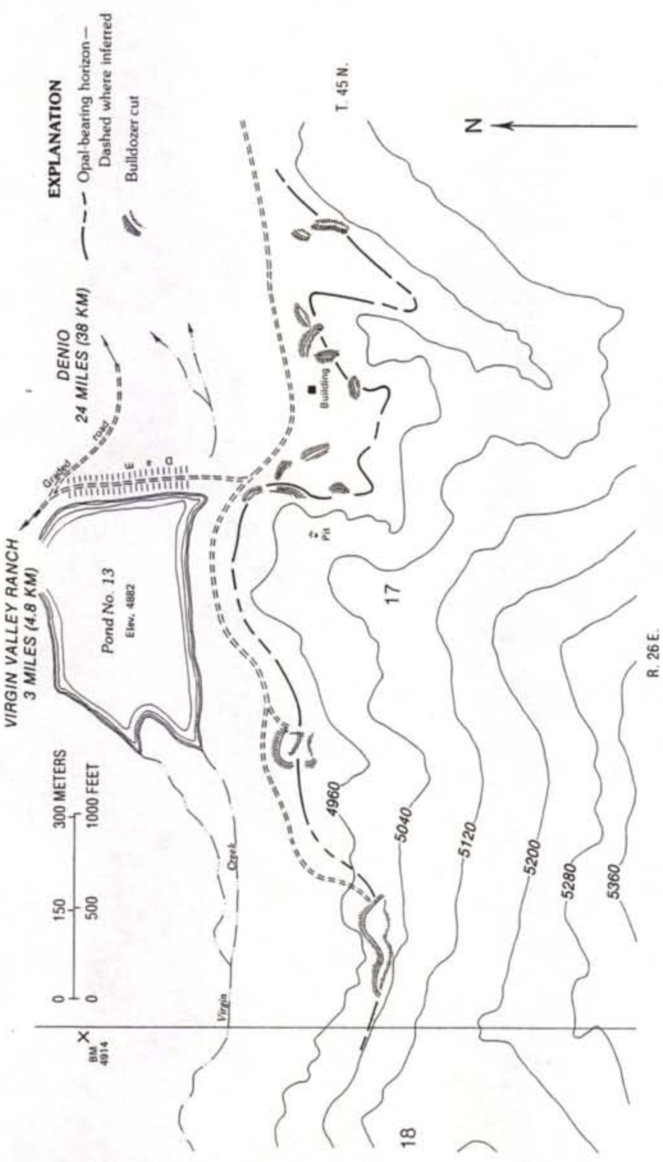

FIGURE 31.—Meyer group mine workings, Charles Sheldon Wilderness Study Area.

0.03 mR/hr were observed. Ten samples of alluvium and rhyolite had traces of gold and silver and less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

OPAL QUEEN GROUP MINE

Owners.—Ed and Louise Mitchell.

Map reference.—Plate 1, no. 22.

Location.—Secs. 7 and 8, T. 45 N., R. 26 E., on the north side of Virgin Valley.

Elevation.—5,100 ft (1555 m).

Access.—By Virgin Valley road 4 mi (6 km) south from Dufurrena Subheadquarters, then by dirt road 0.5 mi (0.8 km) north.

History.—The mine consists of seven claims. The Opal Queen claim, located October 30, 1908, may be the earliest mineral location in Virgin Valley. The Lucky Lou, Miserable Mitch, Bell, Le-Bob, Black Beauty, and Beautiful Opal were located by the Mitchells in 1969 and 1970.

Production.—Precious opal has been produced from the property for many years. The amount is unknown.

Geology of deposit.—An opal-bearing horizon is in slump blocks of bedded volcanic tuff, ash, and tuffaceous sandstone and siltstone. Some tuff layers exposed to weathering are highly altered to montmorillonite. The opal-bearing horizon is bentonitic and greenish, and carries wood fragments and pebbles. The horizon is as much as 6 ft (1.8 m) thick. The sedimentary rocks range in dip from flat lying to 45°. Slumping and rotation of the blocks make the opal-bearing horizon difficult to trace.

Development.—Approximately 50 pits and trenches were observed (fig. 32). Most of the work has been done on a slump block, which tilts as much as 45°. Actual depth of mining cannot be measured because of caving. However, the opal-bearing horizon has been mined for a distance of 600 ft (180 m). Many old workings have been obliterated by more recent bulldozer work. The claimants are presently (1976) working on an area 250 ft (76 m) south of the main workings in nearly horizontal sediments.

Sampling.—Sampling consisted of digging into exposed beds and observing the presence or absence of indicators of precious opal. At the time of examination, the claimants removed several precious opals. One specimen of the black variety measured about 2 in. by 1 in. by 1.5 in. (5 cm by 2.5 cm by 3.8 cm) and was valued at several hundred dollars.

Conclusions.—The likelihood of additional precious opal is high. The area presently being mined and developed is 1 to 2 acres (0.4 to 0.8 ha).

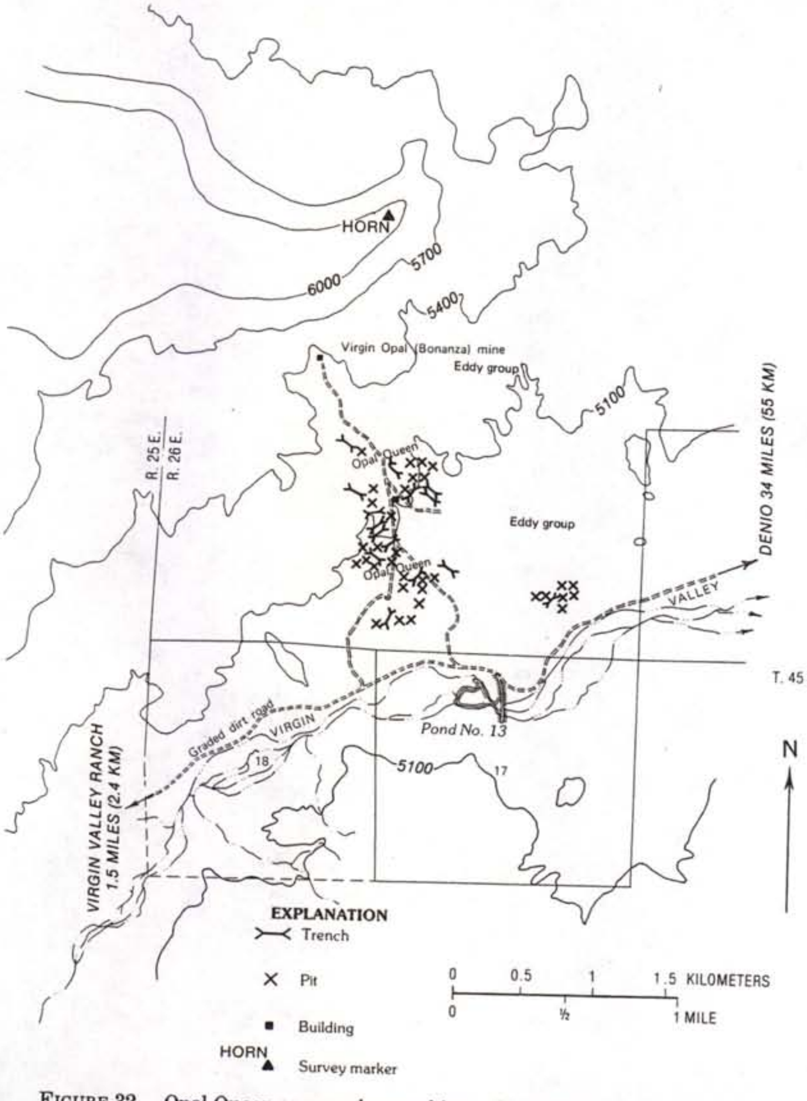

FIGURE 32.—Opal Queen group mine workings, Charles Sheldon Wilderness Study Area.

PRETTY ROCK GROUP

Map reference.—Plate 1, no. 41.
Location.—Sec. 28, T. 43 N., R. 23 E.
Elevation.—5,850 ft (1783 m).
Access.—By Nevada State Highway 8A, 17 mi (27 km) south from

junction with Nevada State Highway 140, then by dirt road 11 mi (18 km) southeast.

History.—Four claims were located in 1955 by B. D. Steward.

Geology of deposit.—Tuffaceous rock and rhyolite.

Development.—One bulldozer cut.

Sampling.—The bulldozer cut and outcrops were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.015 to 0.02 mR/hr were observed. Two random grab samples had traces of gold and silver and less than 0.001 percent U_3O_8.

Conclusions.—No economic mineral potential.

PROSPECT

Map reference.—Plate 1, no. 4.

Location.—Sec. 28, T. 46 N., R. 23 E.

Elevation.—6,850 ft (2088 m).

Access.—By Nevada State Highway 34A, 5 mi (8 km) west from junction with Nevada State Highway 8A, then by cross-country travel 2 mi (3 km) south.

Geology of deposit.—Gray rhyolite with iron oxide surface coatings.

Development.—Claim monument.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding a background of 0.02 to 0.03 mR/hr were observed. One random grab sample had no anomalous metallic content.

Conclusions.—No economic mineral potential.

PROSPECT

Map reference.—Plate 1, no. 8.

Location.—Sec. 3, T. 44 N., R. 23 E.

Elevation.—6,300 ft (1920 m).

Access.—By Nevada State Highway 8A, 15 mi (24 km) south from junction with Nevada State Highway 140, then by cross-country travel 1 mi (1.6 km) west.

Geology of deposit.—Basalt capping volcanic sediments.

Development.—15-ft (4.6-m)-diameter pit.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.025 to 0.03 mR/hr were observed. Two chip samples of basalt contained traces of gold and silver and less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

RAINBOW RIDGE OPAL MINE

Owner.—Keith Hodson.

Map reference.—Plate 1, no. 25.

Location.—Secs. 22 and 23, T. 45 N., R. 26 E.

Elevation.—5,000 ft (1524 m).

Access.—By dirt road 5 mi (8 km) south from Dufurrena Subheadquarters.

History.—The first discovery of precious opal in Virgin Valley reportedly took place in 1905 or 1906 where the Rainbow Ridge opal mine is presently located (Hodson and Dake, 1950). The original claims were owned by D. Roop, E. McGee, and G. T. Hill (U.S. Geological Survey, 1914).

Opal chips were found on the east side of a small hill in 1908, and a tunnel, about 330 ft (100 m) long, was dug (Hodson and Dake, 1950). A large open cut is at the site of the original portal.

In 1917, the Roebling opal, weighing 2,665 carats (553 g), was found at the Rainbow Ridge mine. It was purchased by the late Colonel Roebling and is on display in the U.S. National Museum in Washington, D.C. At the time of discovery, the opal was valued between $50,000 and $250,000 (U.S. Geological Survey and Nevada Bureau of Mines, 1964).

In 1929, six claims were patented: the Royal Opal, Rincon Belle, Black Opal Nos. 1, 2, and 3, and Pandora.

Little work was done at the Rainbow Ridge opal mine from 1920 until 1949 when Keith Hodson purchased the claims, installed electric lights in the underground mine, and started several crosscuts and a drift. He also excavated two large open cuts. In 1952, while working underground, he discovered the Hodson black fire opal weighing 6.5 lb (2.95 kg), then valued at $50,000 (U.S. Geological Survey and Nevada Bureau of Mines, 1964).

During the past several years, Mr. Hodson has been working the Virgin Opal claim, which he purchased in 1955, and consequently, little work has been performed at the Rainbow Ridge opal mine.

Production.—Two very large, and numerous smaller precious opals.

Geology of deposit.—The Rainbow Ridge opal mine is underlain by nearly horizontal ash, tuff, and tuffaceous sandstone beds. The opal-bearing horizon averages 4 ft (1.2 m) thick and is predominantly bentonite containing pods of ash, rhyolite pebbles, petrified wood, and opal. The amount of petrified wood increases downward within the opal-bearing horizon. Precious opal at the Rainbow Ridge opal mine occurs as "conk" and as void fillings left where wood has rotted away. Conk is formed when opal fills the voids between growth rings in partially petrified wood.

Development.—Two large cuts and eight smaller pits were observed (fig. 33). The largest cut is 320 ft (97 m) long and 250 ft (76 m) wide, and exposes a 34-ft (10.4-m) vertical section; the smaller cut is 150 ft (46 m) long, 230 ft (70 m) wide, and exposes a 22-ft (6.7-m) vertical section. Undergound workings total an estimated 750 ft (228 m). The Hodsons have a home, house trailer, workshop, and rock-display room on the property.

Sampling.—Sampling consisted of digging into exposed beds and observing the presence or absence of indicators of precious opal. Fragments of precious opal were observed at numerous places.

Conclusions.—The precious-opal potential is high. More than 20 acres (8.1 ha) are underlain by the precious-opal-bearing horizon, and

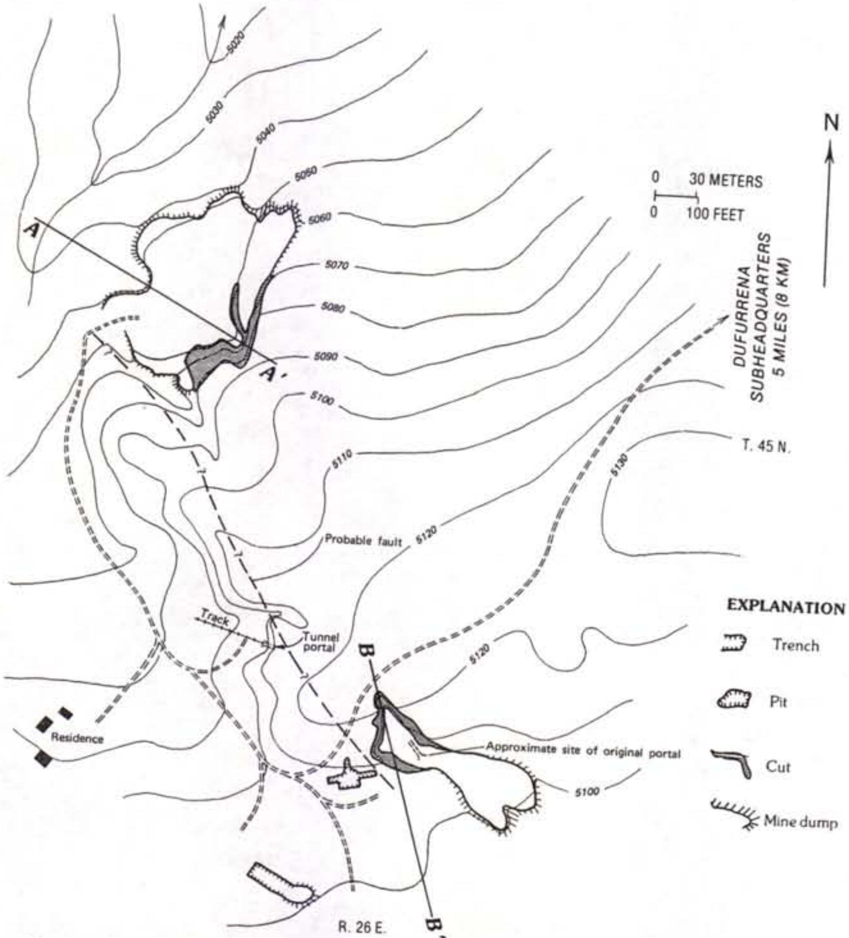

FIGURE 33.—Rainbow Ridge opal mine, Charles Sheldon Wilderness Study Area.

projections of the strike and dip suggest substantially more. The opalescence of the black fire opals found at Rainbow Ridge opal mine is equal to the best in the world; however, the quality of the opal for cut gems is poor. Cabochons cut from the opal usually check within five years (Hodson and Dake, 1950).

RAVEN MANGANESE GROUP

Map reference.—Plate 1, no. 34.

Location.—Sec. 15, T. 44 N., R. 25 E.

Elevation.—5,720 to 5,800 ft (1743 to 1768 m).

Access.—By jeep road 4 mi (6 km) south from Virgin Valley Ranch.

History.—Three claims, the Raven Manganese, Black Bird, and Eagle, were located July 8, 1953, by C. S. DuChemin, D. S. Symington, and A. G. Knab. In June 1959, at the request of the owners, H. K. Stager of the U.S. Geological Survey examined the claims under the Defense Minerals Exploration Adminstration (DMEA) program.

Geology of deposit.—The claims are in an area of moderate relief underlain by volcanic flows and tuffs. Most of the volcanic rocks are rhyolitic to andesitic in composition and are flat lying or dip a few degrees north.

One sample submitted to the U.S. Geological Survey by Mr. Knab

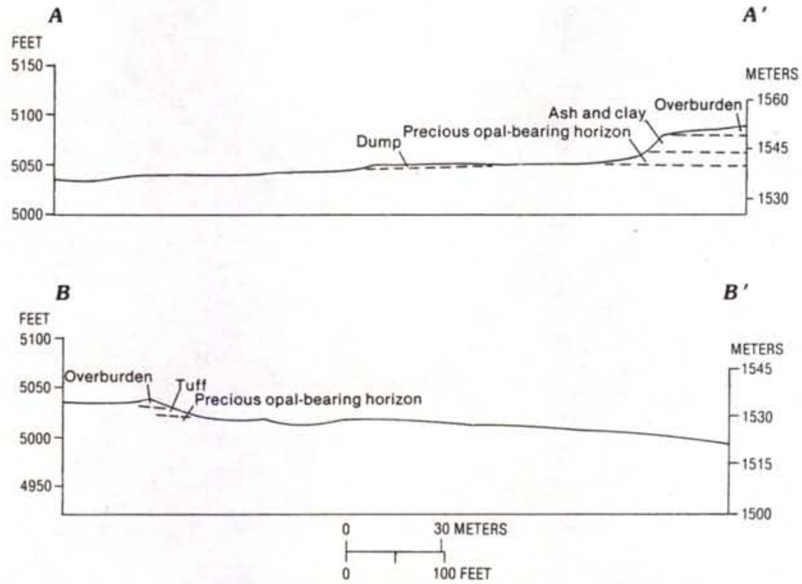

FIGURE 33.—Rainbow Ridge opal mine, Charles Sheldon Wilderness Study Area—Continued.

was identified as cryptomelane ($K(Mn^{2+},Mn^{4+})_8O_{16}$). In 1959, 17 beds of cryptomelane-rich material were exposed by shallow trenches and pits. They averaged 6 in. (15 cm) in thickness and cropped out in an area 300 ft (91 m) long and 100 ft (30 m) wide. The exposures are now obscured by the weathering and sloughing of pits and trenches.

The workings expose three beds of brown to black, earthy to slaty, cryptomelane-bearing material. The beds, conformable with the bedding of the volcanics, range from 3 to 5 in. (8 to 13 cm) in thickness and can be traced for 80 ft (24 m). The upper crytomelane-bearing bed is 12 ft (3.7 m) stratigraphically above the other two. The two lower beds are separated by 1 ft (0.3 m) of glassy ash.

Development.—Three sloughed, shallow, hand-dug trenches 14 to 75 ft (4 to 23 m) long.

Sampling.—Seven samples of the mineralized layers and adjacent rock assayed a trace gold, no more than 0.4 oz/ton (14 g/t) silver, and from 0.04 to 10 percent manganese.

Resource estimate.—H. K. Stager (written commun., 1959) estimated an aggregate thickness of 8 ft (2.4 m) of mineralized rock in about 50 ft (15 m) of sediments. Assuming this aggregate thickness is persistent over the 300 ft (91 m) of strike length and that it extends downdip 100 ft (31 m), there are about 20,000 tons (18,000 t) of mineralized rock containing as much as 10 percent manganese in about 125,000 tons (113,000 t) of material.

Conclusions.—Because the mineralized rock is in thin beds throughout nonmineralized material, considerable dilution would occur during mining. This dilution, together with the small tonnage and low grade, makes the resource submarginal at best.

ROYAL PEACOCK MINE

Owner.—H. W. Wilson.

Map reference.—Plate 1, no. 27.

Location.—Secs. 17, 18, 19, and 30, T. 45 N., R. 26 E.

Elevation.—4,900 to 5,500 ft (1494 to 1676 m).

Access.—By Virgin Valley road 8 mi (13 km) south from junction with Nevada State Highway 140.

History.—The date of the original location and the name of the locator are unknown. During the 1920's and 1930's, Mr. Rhinehart and Dan Arachevaleta owned a group of claims where the present group is located: Kelly, Skajwm, Royal Peacock Nos. 1 and 2, Northern Light, Peacock Nos. 2–4, Phantom, Little Pebble, Pebble, Angel Nos. 1 and 2, Starfire, Red Ball, Yellow Ball, Star Bright, and Blue Ball. F. H. Locheed and Mark Foster relocated the claims in 1937. In 1939, F. H. Locheed quitclaimed her interest to Mark Foster. H.

W. Wilson's father purchased the group in 1942. In 1968, the claim group was leased by W. J. Kelley. Mr. Kelley formed Opals Inc., and with the help of Allan Carlson, discovered a method of stabilizing Virgin Valley opal. Opals Inc. last worked the claims in 1973. H. W. Wilson bought the company in July 1974 and produced a small amount of opal during the remainder of the year. In 1975, Wilson stripped overburden in preparation for production in 1976.

Production.—There is no record of production prior to 1969, but a small amount of opal was mined and sold locally, according to H. W. Wilson.

Opals Inc. produced 800 lb (363 kg) of opal in 1970 and 780 lb (354 kg) in 1971. Although the total 1972 yield is unknown, it included one rich pocket which sold for more than $90,000 (wholesale price). In 1973, 500 lb (227 kg) were reported. The Royal Peacock opal, weighing 191 carats (38.2 g), was found in 1970 and may be worth $250,000. The higher quality opals were purchased by Beverly Hills Gems. Production through 1972 was from the Royal Peacock Nos. 1 and 2 and thereafter from the Northern Light. Approximately one percent of the mined opal was classified as precious opal, and it brought from $250 to $500 per carat wholesale. In 1974 Wilson's total production was 40 lb (18 kg), of which slightly more than 6 lb (2.7 kg) were precious opal. There was little production during 1975, but it was scheduled to be resumed in 1976.

Geology of deposit.—The claims are underlain by ash, tuff, and tuffaceous sandstone beds, which strike northwest and dip 2° to 4° NE. The opal-bearing horizon is as much as 8 ft (2 m) thick and is predominantly greenish bentonite containing pods of ash, rhyolite pebbles, petrified wood, and opal. At the Pebble claim, only slight amounts of petrified wood are associated with the opal. Wilson said the water content of mined opal was found to increase westward from the Royal Peacock No. 1 to the Northern Light.

Development.—Seven large cuts and many smaller pits and trenches were observed (figs. 34 and 35). According to H. W. Wilson, when Opals Inc. began production, seven adits were on the property. They apparently date back to the late teens and early 1920's. The largest cut on the Royal Peacock Nos. 1 and 2 claims is 930 ft (283 m) long and 80 ft (24 m) wide, and exposes a 29-ft (8.8-m) vertical section.

Sampling.—Sampling consisted of digging into exposed beds and observing the presence or absence of precious-opal indicators. Fragments of precious opal were observed at numerous places.

Conclusions.—About 55 acres (22 ha) underlain by the opal-bearing horizon are minable. This area estimate is based on a strike length of 12,000 ft (3,660 m) and an economic width limit of 200 ft (61 m).

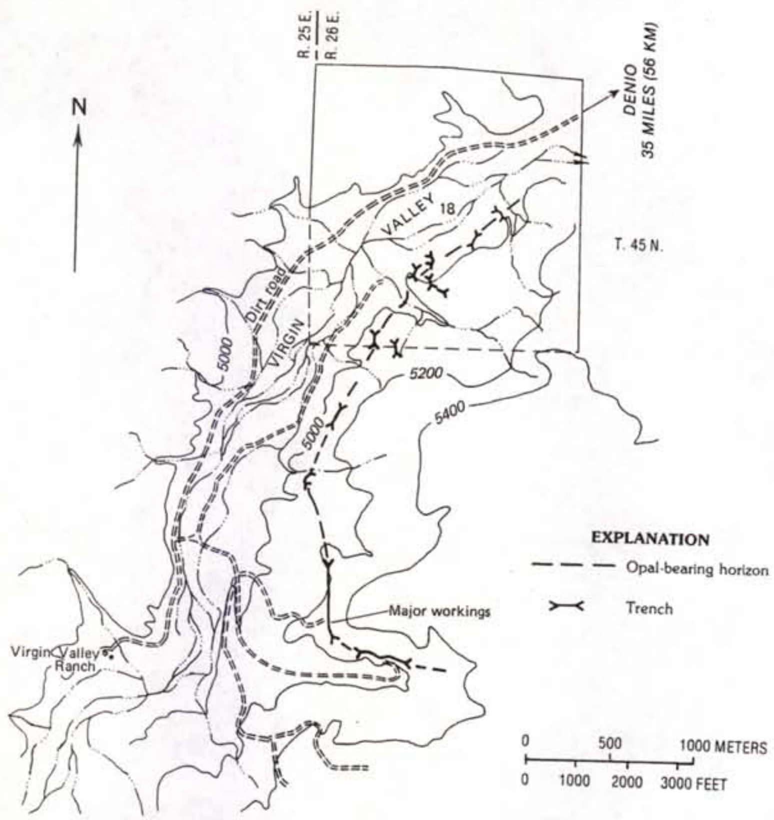

FIGURE 34.—Royal Peacock mine workings, Charles Sheldon Wilderness Study Area.

Beyond 200 ft (61 m), the stripping ratio would be excessive. The likelihood of additional precious opal is high.

SKYLINE GROUP

Map reference.—Plate 1, no. 7.

Location.—Secs. 17, 21, 28, and 33, T. 46 N., R. 24 E.

Elevation.—5,800 ft (1768 m).

Access.—By Nevada State Highway 8A, 2 mi (3 km) southeast from junction with Nevada State Highway 140.

History.—The group consists of nine claims, the Skyline, Nine, Sally, Grace, Dorothy, and Maud J. Nos. 1–4, which were located in 1941 by Mr. Mustard for manganese.

Geology of deposit.—The claims are underlain by alluvium and rhyolite that contains vugs, some of which are filled by agate.

Development.—One pit.

Sampling.—Six samples from rock in place and from the dump of the pit showed as much as a trace of gold and silver and 0.4 percent manganese.

Conclusions.—No economic mineral potential.

STEAMBOAT GROUP

Map reference.—Plate 1, no. 32.

Location.—Secs. 3 and 10, T. 44 N., R. 25 E.

Elevation.—5,400 ft (1646 m).

Access.—By dirt road 0.5 mi (0.8 km) from Virgin Valley Ranch, then by cross-country travel 1 mi (1.6 km) south.

History.—Eleven claims were located by H. W. Wilson during May and June, 1955.

Geology of deposit.—A prominent point consists mostly of coarse-grained, light-gray, bedded tuff capped with a resistant ignimbrite. The tuff and ignimbrite strike northeast and dip 15° SE. At the west end of the point the tuff is about 60 ft (18 m) thick; however, 800 ft (244 m) to the east, it is completely covered by talus.

Development.—None.

Sampling.—Tuffaceous and ignimbrite outcrops were checked for radioactivity with a scintillation counter. Background readings were 0.025 to 0.03 mR/hr. Two 6-in. (15-cm)-thick lenses of yellow to cream tuff within the light-gray tuff had readings of 0.11 to 0.12 mR/hr. Six samples of tuffaceous material were taken. Four had a trace of U_3O_8 and two from the yellow to cream-colored lenses assayed 0.032 and 0.037 percent U_3O_8.

Conclusions.—Insufficient uranium-bearing material to constitute a mineral resource.

SUNI NOS. 1–3

Map reference.—Plate 1, no. 12.

Location.—Secs. 32 and 33, T. 45 N., R. 24 E.

Elevation.—6,170 to 6,190 ft (1881 to 1887 m).

Access.—By Nevada State Highway 8A, 12 mi (19 km) south from junction with State Highway 140, then by dirt road 3 mi (5 km) east.

History.—Located in 1955 by Kenneth Arnold.

Geology of deposit.—Residual soil and colluvium over rhyolite bedrock.

Development.—Five shallow bulldozer cuts.

Sampling.—Bulldozer cuts were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.015 to 0.03 mR/hr were observed. Three samples of soil containing rhyolite and obsidian float were taken from bulldozer cuts. All had values of less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

SUNNY JIM

Map reference.—Plate 1, no. 10.
Location.—Sec. 32, T. 45 N., R. 24 E.
Elevation.—6,250 ft (1905 m).
Access.—By Nevada State Highway 8A, 12 mi (19 km) south from

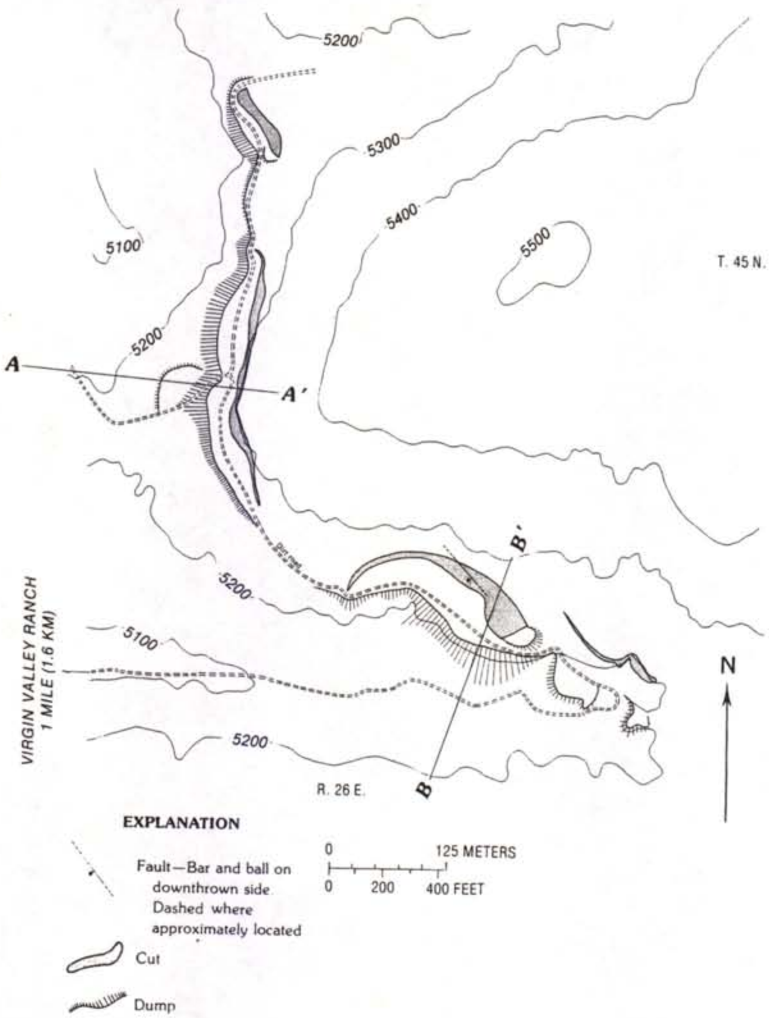

FIGURE 35.—Map and sections of major workings, Royal Peacock mine, Charles Sheldon Wilderness Study Area.

junction with Nevada State Highway 140, then by dirt road 2 mi (3.2 km) east.

History.—Located in 1955 by Bob Wees.

Geology of deposit.—Colluvium and alluvium over rhyolite bedrock.

Development.—Shallow bulldozer cuts.

Sampling.—Bulldozer cuts were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.02 to 0.04 mR/hr were observed. A sample of soil and rhyolite float from a bulldozer cut had less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

VIOLA AND NELLIE GROUP

Map reference.—Plate 1, no. 40.

Location.—Sec. 7, T. 43 N., R. 24 E.

Elevation.—6,625 ft (2019 m).

Access.—By Nevada State Highway 8A, 17 mi (27 km) south from junction with Nevada State Highway 140, then by dirt road 7 mi (11 km) south.

History.—The Viola Nos. 1–3 and Nellie Nos. 1–3 claims were located in 1955 by Leo Roessler.

Geology of deposit.—Weathered rhyolite.

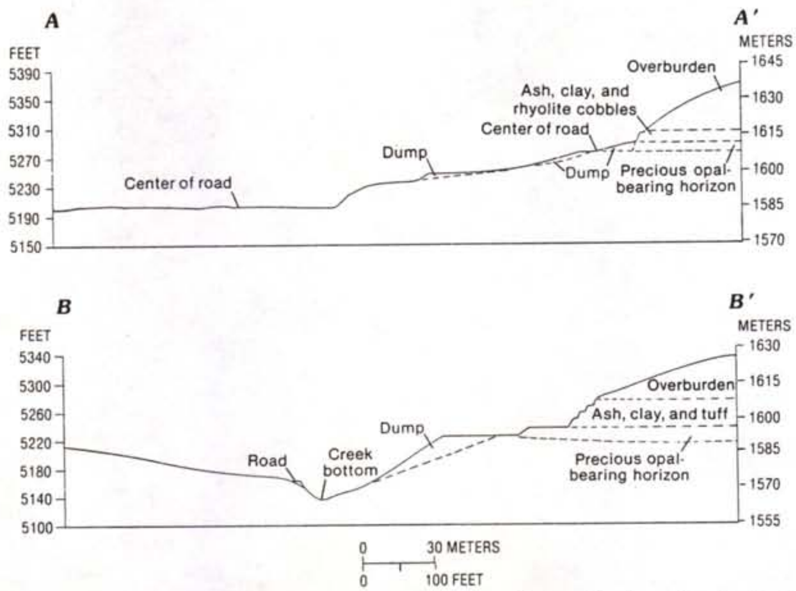

FIGURE 35.—Map and sections of major workings, Royal Peacock mine, Charles Sheldon Wilderness Study Area—Continued.

Development.—None.

Sampling.—The area was checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.02 to 0.03 mR/hr were observed. Five random chip samples of rhyolite each contained less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

VIRGIN DUFF GROUP, PRONGHORN GROUP, AND BEVERLY NO. 1

Map reference.—Plate 1, no. 16.

Location.—Secs. 30 and 31, T. 46 N., R. 26 E., and secs. 25 and 36, T. 46 N., R. 25 E.

Elevation.—5,000 ft (1524 m).

Access.—By Nevada State Highway 140, 32 mi (51 km) west from Denio.

History.—The groups consist of 17 claims, located in 1955 and 1956 by Paul Viles, Cliff Poulsen, Harold Gleason, and Dan Thompson.

Geology of deposit.—The area is underlain by alluvium and gray to dark-purplish rhyolite. No mineralized structures were observed.

Development.—Sixteen bulldozer cuts in alluvium.

Sampling.—All bulldozer cuts and outcrops were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.025 to 0.035 mR/hr were observed. Nine samples from rock in place and from bulldozer cuts assayed no more than a trace of silver and less than 0.005 percent U_3O_8.

Conclusions.—No economic mineral potential.

VIRGIN OPAL (BONANZA) MINE

Owner.—Keith Hodson.

Map reference.—Plate 1, no. 21.

Location.—Secs. 6 and 7, T. 45 N., R. 26 E.

Elevation.—5,200 to 5,600 ft (1585 to 1707 m).

Access.—By Virgin Valley road 5 mi (8 km) southwest from Dufurrena Subheadquarters, then by dirt road 2 mi (3 km) northwest.

History.—The early history of the claim, locally referred to as the Bonanza, is vague. The original location was probably in 1908 by Ivan Dow, George Mathewson, Alfred Thompson, and others. In 1943, it was relocated as the Virgin Opal claim by Mr. Garaventa. Keith Hodson, the present owner, purchased it in 1955 (U.S. Geological Survey and Nevada Bureau of Mines, 1964).

Production.—One broken precious opal weighing a total of 7.25 lb (3.3 kg) was discovered by Mr. Hodson. Many smaller precious opals have been recovered.

Geology of deposit.—The claim is underlain by nearly horizontal ash, tuff, and tuffaceous sandstone beds. The opal-bearing horizon averages more than 4 ft (1.2 m) thick and consists primarily of light-colored bentonite containing varying amounts of petrified wood, rhyolite pebbles, ash, and opal. Precious opals are usually found in the upper half of the horizon.

Development.—Two large cuts, one small cut, one adit, and one storage building were observed (figs. 36, 37, and 38). The larger cut is 405 ft (123 m) long and 50 ft (15 m) wide, and exposes a 53-ft (16-m) vertical section. The other large cut is 290 ft (88 m) long and 100 ft (30 m) wide, and exposes a 68-ft (21-m) vertical section.

Sampling.—Sampling consisted of digging into exposed beds and observing the presence or absence of precious-opal indicators. Fragments of precious opal were observed at numerous places.

Conclusions.—About 4 acres (1.6 ha) underlain by the opal-bearing horizon are minable. This area estimate is based on a strike length of 1,800 ft (550 m) and an economic width limit of 100 ft (30 m). Beyond 100 ft (30 m), the stripping ratio would be excessive. The potential of additional precious opal is high.

VIRGIN VALLEY URANIUM CLAIMS

Owners.—Gus Kreiger, Mitchel V. Ruedy, Jack Crane, and H. W. Wilson.

Map reference.—Plate 1, no. 28.

Location.—Secs. 2, 3, T. 44 N., R. 25 E.; secs. 12, 13, 24, 25, and 36, T. 45 N., R. 25 E.; secs. 30, 31, T. 45 N., R. 26 E.

Elevation.—5,000 to 6,200 ft (1524 to 1890 m).

Access.—By Virgin Valley road 7 mi (11 km) south from Dufurrena Subheadquarters.

History.—Having discovered uranium minerals early in the summer of 1950, Jack Crane located claims on the east and west sides of Virgin Valley (Staatz and Bauer, 1951). Between 1950 and 1954, Crane located the Fourth of July 1 and 2, April Fool 1 and 2, Wee Wee Marie, Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Tony, David B., Afterthought, Dixie 1–5, Suprise, Rosalee, Big Hole, Reno, Buckhorn, Sweetwater, Cameron, Holiday, Lucky Four, Barney, January, February, March, August, September, October, November, December, Fourth of July, Fangle, Little Virgin, Jackknife, Maverick, Ace 1–3, Bing 1 and 2, Pluto, Venus, Saturn, Neptune, and Mars. Of these 52 claims, 13 are shown on the Humboldt County surveyor's plat, all on the west side of Virgin Valley.

On the west and north sides of the Crane group claims, the Lone Star Uranium Co. located 36 mining claims in 1954 and 1955. The

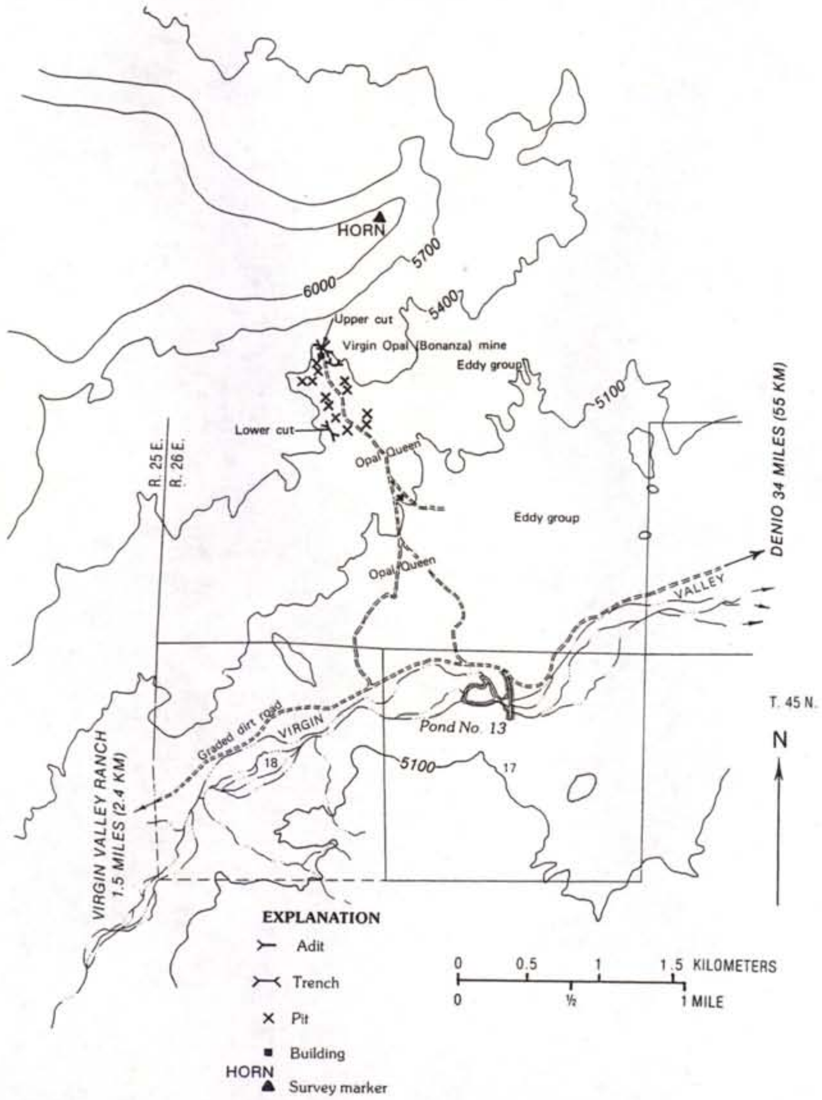

FIGURE 36.—Virgin Opal (Bonanza) mine workings, Charles Sheldon Wilderness Study Area.

claims are the Jackal, Kismet, Todos, Amigos, Alamo, Big Virgin. Jeep, Little Big Horn, Tatie, Jo Jo, Tadpole, Hepto, Bongo, Moon Glow, Sunset, Sunrise, Sunny Jim, Lucky Dog, Sprite, Hillbilly, Pacific, Alpha, Beta, Delta, Gamma, Epsilon, Zeta, Eta, Theta, Kappa, Omega, Iota, Mu, Gladys M., Faun P., Paiute, and Vad-ore.

About 5 mi (0.8 km) east of the Virgin Valley ranch and on the

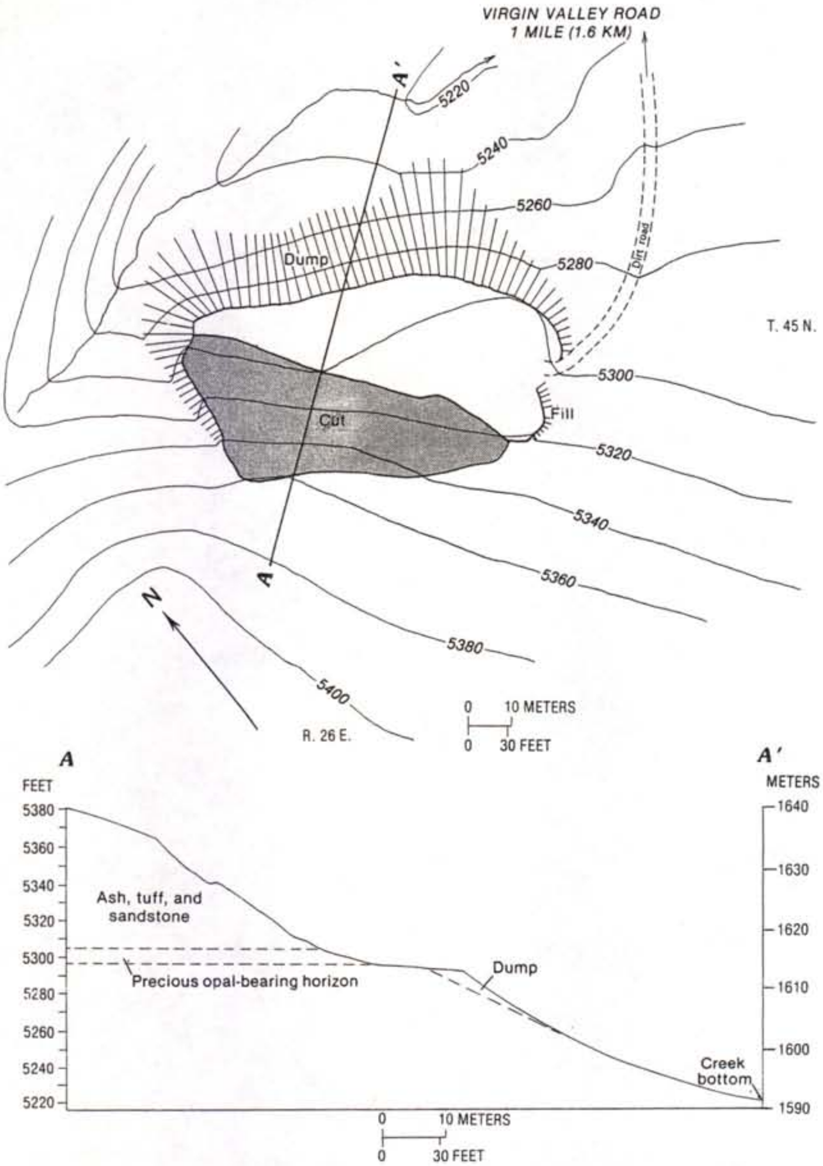

FIGURE 37.—Lower cut, Virgin Opal (Bonanza) mine, Charles Sheldon Wilderness Study Area.

east side of Virgin Valley are the April Fool 1, 2, and 3. The original locator is unknown. Mark Foster relocated the claims in 1937. In 1942, the H. W. Wilson family bought them from Foster; H. W. Wilson is now the sole owner.

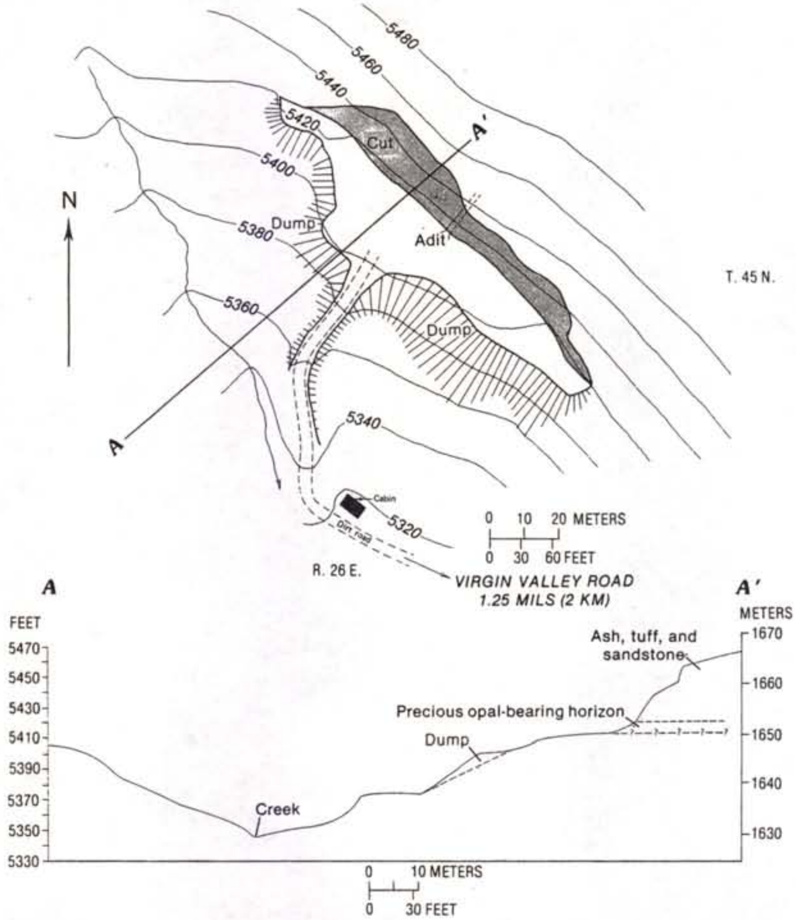

FIGURE 38.—Upper cut, Virgin Opal (Bonanza) mine, Charles Sheldon Wilderness Study Area.

H. W. Wilson has relocated some of the claims north of Virgin Valley Ranch previously claimed by Jack Crane as the Angie 1, 2, and 3 in 1976.

H. W. Wilson and Gus Kreiger located 11 claims around the Angie group in 1976. The claims are the Barbara, Barbara 1–4, Hal, and Hal 1–7.

Gus Kreiger located a block of 132 claims southeast of Virgin Valley Ranch in 1976. They were the Mule, Jackass, Donkey, Charlawne, Charlotte 1–22, Jane 1–13, East Rim 1–11, 13- 23, 25–35, 37–47, 49–59, South Rim 1–20, Mars, Neptune, Saturn, Venus, and Pluto.

During 1976, Kreiger, Mitchell, Ruedy, Crane, and Wilson made

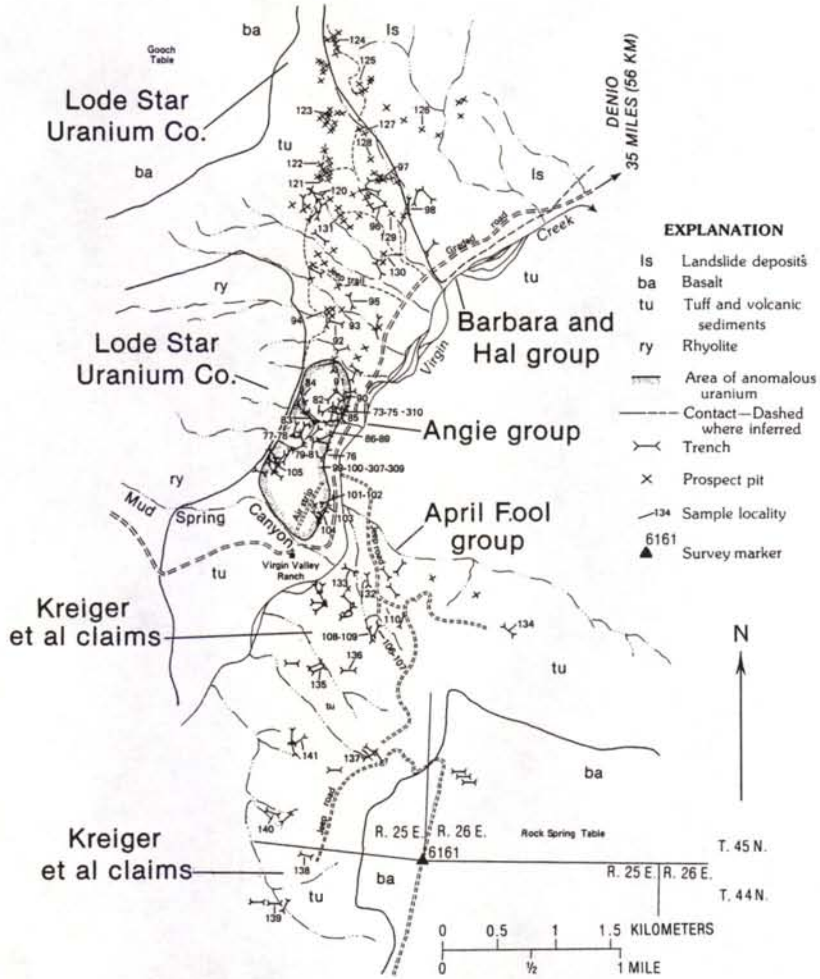

FIGURE 39.—Virgin Valley uranium-claims workings, Charles Sheldon Wilderness Study Area.

an agreement to promote all their claims as a unit to interested mining companies. To date, several companies have expressed an interest.

Production.—Greenish-yellow, translucent, fluorescent opalite that occurs at the top of a diatomaceous earth bed on the April Fool group was sold for 35 cents/lb (77 cents/kg) from 1937 to 1942 to rock collectors and the Ultraviolet Corp., in San Gabriel, Calif. After H. W. Wilson purchased the group, he also sold opalite to Raytech, Inc., in Massachusetts. Between 15 and 20 tons (14 and 18 t) have been sold since 1942.

TABLE 6.—*Sample analyses for Virgin Valley uranium claims, Charles Sheldon Wilderness Study Area*

[Tr., trace; N, not detected; —, not analyzed; <, less than shown. Metric conversions: feet×0.3048=meters; ounce per ton×34.285=grams per metric ton.]

Sample No.	Type	Length (ft)	Description	Gold (oz/ton)	Silver (oz/ton)	U_3O_8 (percent)
73	Chip---	0.4	Brown to dark-gray opalized tuff	N	N	0.033
74	-do----	.6	----------do--------------------	N	N	.009
75	-do----	1.3	----------do--------------------	N	N	.005
76	-do----	.7	----------do--------------------	N	N	<.002
77	-do----	1.2	Gray opalized tuff with wood fragments.	N	N	<.002
78	-do----	1.0	----------do--------------------	N	N	.064
79	-do----	.4	Red to gray opalized tuff-------	N	N	.033
80	-do----	1.0	----------do--------------------	N	0.2	.027
81	-do----	.9	White and gray massive opalite--	N	.2	.007
82	-do----	.9	Gray tuff with black carbonaceous fragments.	N	N	.048
83	-do----	2.3	----------do--------------------	N	N	.021
84	-do----	.9	----------do--------------------	Tr.	N	.020
85	-do----	2.1	Tan to brown opalized tuffs-----	N	N	.036
86	-do----	.7	Olive-green opalite-------------	N	N	.004
87	-do----	1.3	----------do--------------------	N	Tr.	<.002
88	-do----	1.0	Brown opalized tuff-------------	N	tr.	.046
89	-do----	1.3	Brown to gray opalized tuff-----	N	N	<.002
90	Chip---	1.1	Gray, partially opalized tuff---	N	N	<0.002
91	-do----	1.8	Green, massive opalite and white to cream tuff.	Tr.	N	.017
92	-do----	1.9	Brown to green opalite----------	tr.	3	.011
93	-do----	.9	----------do--------------------	N	N	.017
94	-do----	.9	----------do--------------------	N	N	.012
95	-do----	4.0	Brown, opalized tuff------------	N	N	.013
96	-do----	.7	Gray opalite--------------------	N	N	<.002
97	-do----	1.6	Brown, orange, and gray opalized tuff.	N	N	<.002
98	-do----	2.0	Brown, orange, and gray opalized tuff.	N	N	<.002
99	-do----	1.8	Gray, opalized tuff and gray tuff	N	N	.030
100	-do----	.9	Gray, opalized tuff-------------	N	N	.078
101	-do----	2.0	Brown to gray opalized tuff------	N	N	.008
102	-do----	2.7	Gray, opalized tuff and white tuff.	N	N	.030
103	-do----	3.3	Yellow to brown opalite and white tuff.	tr.	N	.080

Geology of deposit.—A sequence of gently dipping tuff and ash beds at least 300 ft (91 m) thick are capped by basalt and terrace gravel. The tuff layers are mostly greenish-gray, friable, and porous; traces of fibrous gypsum, and iron and manganese oxides coat fracture surfaces. The ash beds are generally thinner, lighter colored, and finer grained than the tuff. The beds strike northwest and dip 5° to 10° NE. Forty-five discontinuous layers of opalite were observed. Some had anomalous amounts of uranium. The layers of opalite occur parallel to the bedding of the ash and tuff and range in thickness from 0.1 to 3.9 ft (0.03 to 1.2 m). The length of the exposed opalite layers is from 8 ft (2.4 m) to more than 1,200 ft (366 m). Many stages of silicification were observed. Less silicified beds resemble shale, whereas thoroughly silicified beds are massive and translucent. The opalite has a distinctive conchoidal fracture and is gray, brown, tan, black, white, and pale green. Irregular and lenselike layers of

TABLE 6.—*Sample analyses for Virgin Valley uranium claims, Charles Sheldon Wilderness Study Area*—Continued

Sample No.	Type	Length (ft)	Description	Gold (oz/ton)	Silver (oz/ton)	U_3O_8 (percent)
104	Chip---	0.5	Yellow to brown opalized tuff----	N	N	0.027
105	-do----	2.6	Yellow to brown-stained zone in white tuff.	N	N	.036
106	-do----	5.0	Diatomite------------------------	--	--	--
107	-do----	2.0	Cream to reddish translucent opalite.	N	N	.010
108	-do----	2.5	Diatomite------------------------	--	--	--
109	-do----	.6	Cream, yellow, and brown translucent opalite.	N	N	.017
110	-do----	1.0	Orange, brown, greenish opalized tuff.	N	N	.007
120	-do----	2.2	Light-gray, bedded tuff----------	N	N	.002
121	Grab---	--	Brownish tuff--------------------	N	N	<.002
122	-do----	--	Light-gray tuff------------------	N	N	<.002
123	-do----	--	-----------do--------------------	N	N	<.002
124	-do----	--	White to gray tuff---------------	N	N	<.002
125	-do----	--	-----------do--------------------	N	N	<.002
126	-do----	--	-----------do--------------------	N	N	<.002
127	Random chip.	--	Light-gray tuff------------------	N	N	<0.002
128	Grab---	--	White to gray tuff---------------	N	N	<.002
129	-do----	--	-----------do--------------------	N	N	<.002
130	-do----	--	White to gray tuff---------------	N	N	<.002
131	-do----	--	-----------do--------------------	N	N	<.002
132	-do----	--	Orange to brown opalized tuff----	N	N	<.002
133	Chip---	2.3	Gray tuffaceous siltstone--------	Tr.	N	<.002
134	Grab---	--	Gray tuff------------------------	N	N	<.002
135	Chip---	4.0	Thinly bedded white ash----------	N	N	<.002
136	Random chip.	--	Light-brown tuff-----------------	N	N	<.002
137	Grab---	--	Dark-gray basalt-----------------	N	N	<.002
138	-do----	--	Light-brown tuff and dark-gray basalt.	N	N	<.002
139	-do----	--	-----------do--------------------	N	N	<.002
140	-do----	--	-----------do--------------------	tr.	N	<.002
141	-do----	--	Brown and gray tuff--------------	tr.	N	.002
307	Chip---	1.5	Yellow to light-brown opalite----	--	--	.035
308	Random chip.	--	Yellow to brown opalized stump---	--	--	.053
309	Chip---	4.0	Gray opalized tuff---------------	--	--	.002
310	-do----	1.0	White tuff-----------------------	--	--	.007

diatomaceous earth, some 7 ft (2.1 m) thick, are exposed for more than 2,000 ft (610 m) on the April Fool 1, 2, and 3 claims.

Development.—One hundred eighty-eight shallow bulldozer cuts and trenches were observed (fig. 39). Three bulldozer cuts on a hillside below the airstrip have a combined length of more than 2,000 ft (610 m).

Sampling.—All workings and opalite beds were checked for radioactivity with a scintillation counter. Background readings ranged from 0.015 to 0.05 mR/hr. Of the 48 opalite beds checked, 10 had anomalous readings in a few places, and the highest was 0.90 mR/hr. Sixty-four samples of opalite and tuff contained from less than 0.02 to 0.08 percent U_3O_8. Seventeen samples had 0.02 percent or more U_3O_8 (table 6). The highest sample results came from a hillside exposure near the airstrip. Table 6 also gives analytical results for gold and silver. Analyses of the diatomaceous earth indicated good brightness but no potential as a filter aid.

Resource estimate.—An area north of Virgin Valley Ranch, which is approximately 1 by 0.25 mi (1.6 by 0.4 km) and 50 ft (15 m) deep, may contain 15 to 20 million tons (14 to 18 million t) of low-grade uranium-bearing material, constituting a submarginal resource.

Conclusions.—The uranium mineralization found indicates potential for discovery of additional submarginal resource and possibly discovery of an ore-grade uranium deposit.

WILD ROSE

Map reference.—Plate 1, no. 3.

Location.—Sec. 1, T. 45 N., R. 22 E., 2 mi (3.2 km) east of Swan Lake.

Elevation.—5,900 ft (1798 m).

Access.—By Nevada State Highway 34A 6 mi (10 km) west from junction with Nevada State Highway 8A, then by cross-country travel 1 mi (1.6 km) north.

History.—Located August 7, 1927, by D. D. McLeod.

Geology of deposit.—Slightly vesicular basalt.

Development.—None.

Sampling.—One grab sample assayed a trace of gold and less than 0.001 percent U_3O_8.

Conclusions.—No economic mineral potential.

YELLOW ROCK GROUP

Map reference.—Plate 1, no. 37.

Location.—Sec. 21, T. 44 N., R. 24 E.

Elevation.—6,190 to 6,225 ft (1887 to 1897 m).

Access.—By Nevada State Highway 8A 17 mi (27 km) south from junction with Nevada State Highway 140, then by dirt road 8 mi (13 km) east.

History.—Ten claims were located in 1955 by Yellow Rock Uranium Co.

Geology of deposit.—Rhyolite and whitish volcanic tuff containing cinders.

Development.—Shallow bulldozer cuts.

Sampling.—All bulldozer cuts were checked for radioactivity with a scintillation counter. No readings exceeding a background count of 0.02 to 0.025 mR/hr were observed. Six random soil grab samples from bulldozer cuts and two random chip samples of rhyolite assayed a trace of gold and silver and less than 0.001 percent U_3O_8.

Conclusions.—No economic mineral potential.

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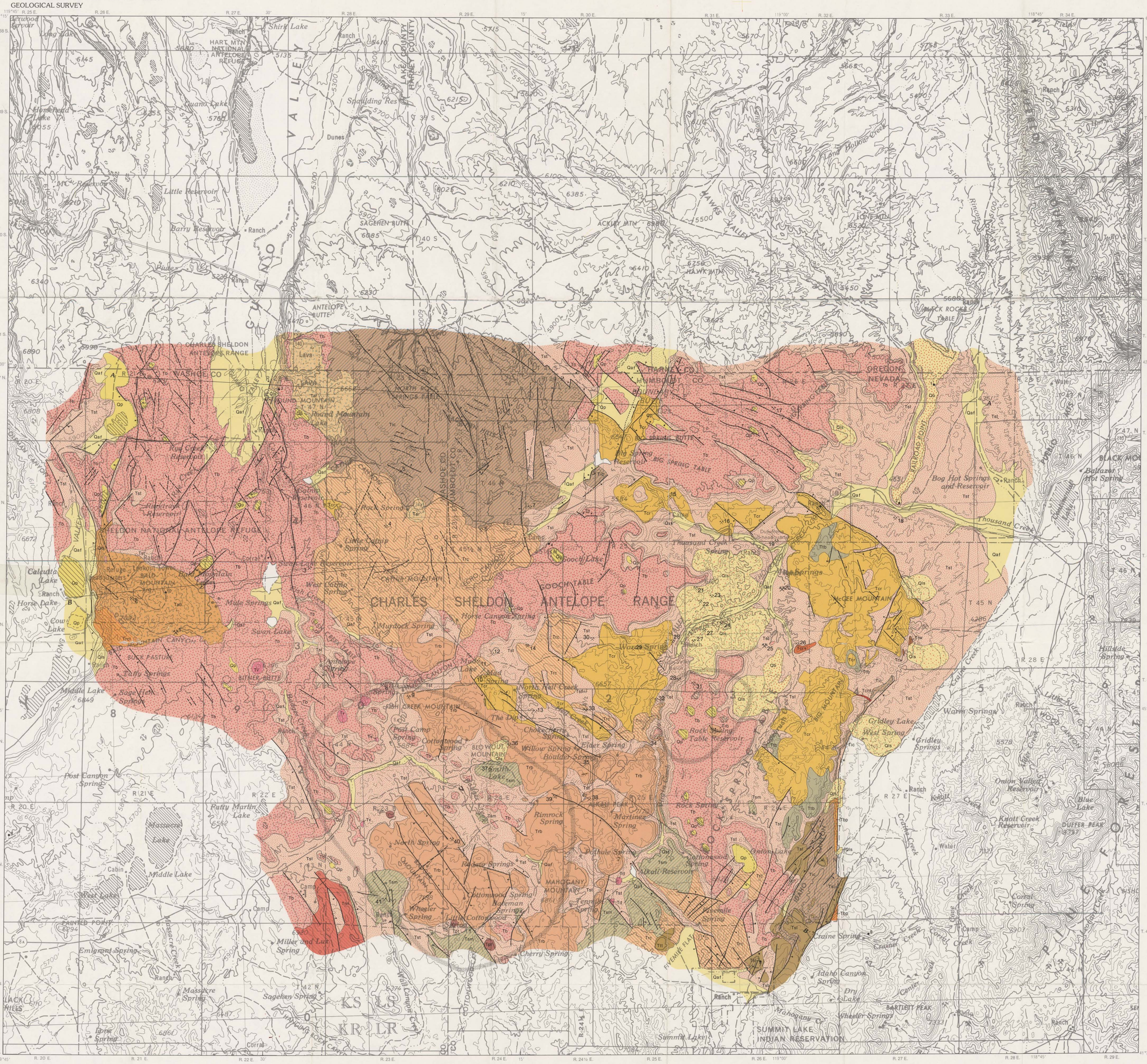
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



Base from U.S. Geological Survey 1:250,000
Adel, Oregon, 1955 (rev. 1970)
Vya, Nevada, Oregon, California, 1954
(rev. 1970)

Geology by R. C. Green, 1974-75

SCALE 1:125 000

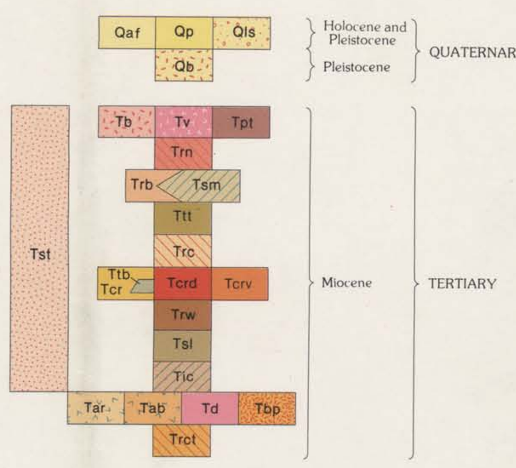
2 0 2 4 6 8 MILES

2 0 2 4 6 8 KILOMETERS

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

1983 MAGNETIC DECLINATION VARIES FROM TRUE NORTH FROM 17°30' EASTERLY FOR THE NORTHWESTERN CORNER TO 17°00' EASTERLY FOR THE SOUTHEASTERN CORNER

CORRELATION OF MAP UNITS



LIST OF MAP UNITS

Qaf	ALLUVIUM AND ALLUVIAL FANS (HOLOCENE AND PLEISTOCENE)
Qp	PLAYA DEPOSITS (HOLOCENE AND PLEISTOCENE)
Qls	LANDSLIDE DEPOSITS (HOLOCENE AND PLEISTOCENE)
Qb	BASALT OF RAILROAD POINT (PLEISTOCENE)
Tst	TUFFACEOUS SEDIMENTARY ROCKS (MIOCENE)
Tb	BASALT OF CATNIP CREEK (MIOCENE)
Tv	MAFIC VENT COMPLEXES (MIOCENE)
Tpt	PALAGONITE TUFF (MIOCENE)
Trn	RHYOLITE OF NUT MOUNTAIN (MIOCENE)
Trb	RHYOLITE OF BADGER MOUNTAIN (MIOCENE)
Tsm	SOLDIER MEADOW TUFF (MIOCENE)
Ttt	TUFF OF TROUGH MOUNTAIN (MIOCENE)
Trc	RHYOLITE OF CATNIP MOUNTAIN (MIOCENE)
Tcr	CANON RHYOLITE OF MERRIAM, 1910 (MIOCENE)
Ttb	TUFF OF BIG MOUNTAIN (MIOCENE)
Tcrd	RHYOLITE DIKE (MIOCENE)
Tcrv	RHYOLITE VITROPHYRE (MIOCENE)
Trw	RED WELDED TUFF (MIOCENE)
Tsl	SUMMIT LAKE TUFF (MIOCENE)
Tic	IDAHO CANYON TUFF (MIOCENE)
Tar	ANDESITE OF ROUND MOUNTAIN (MIOCENE)
Tab	ANDESITE OF BALD MOUNTAIN (MIOCENE)
Td	DACITE (MIOCENE)
Tbp	PORPHYRITIC BASALT (MIOCENE)
Trct	RHYOLITE OF COTTONWOOD CANYON (MIOCENE)

CONTACT—Contacts in cross section inferred

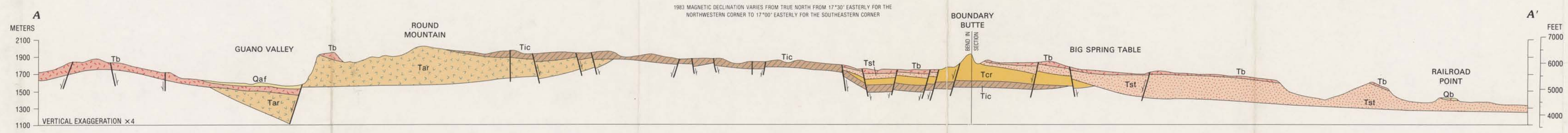
FAULT—Bar and ball on downthrown side, dashed where inferred, and dotted where concealed

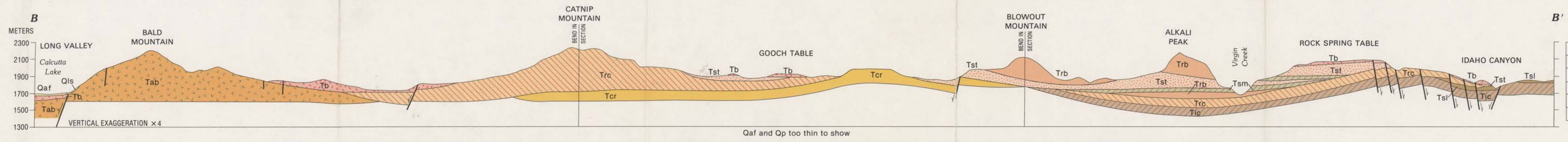
BOUNDARY OF CALDERA INFERRED FROM GEOPHYSICAL DATA (PLATE 2)

SAMPLE LOCALITY FOR POTASSIUM-ARGON DATES (TABLE 1)

MINE OR PROSPECT

1 Antelope Nos. 1-18 (Lode Star Nos. 1-60)
2 Bald Mountain claims
3 Wild Rose
4 Prospect
5 Charline Nos. 1 and 2
6 Echo group
7 Skyline group
8 Prospect
9 Obsidian group, Columbia and Loise
10 Sunny Jim
11 Lucky Jim Nos. 1-8 and Apex
12 Suni Nos. 1-3
13 Bighorn group
14 Kim Nos. 1-9
15 McKenny Camp uranium claims
16 Virgin Duff group, Pronghorn group, and Beverly No. 1
17 Lucky Four
18 Fortune group, Uranium King, and Lucky Jack
19 Lemac Nos. 1-5 quarry
20 Goodwill
21 Virgin Opal (Bonanza) mine
22 Opal Queen group mine
23 Eddy group
24 Meyer group mine
25 Rainbow Ridge opal mine
26 Lad and Shepardson's group
27 Royal Peacock mine
28 Virgin Valley uranium claims
29 Grubstake Nos. 1-4
30 Hope group
31 Mesa
32 Steamboat group
33 Lucky Strike
34 Raven Manganese group
35 Blue Dragon Nos. 1-3
36 Crater group
37 Yellow Rock group
38 Lucky Horseshoe group
39 Golden Cash, Jackpot, Buried Treasure, and Golden Horde
40 Viola and Nellie group
41 Pretty Rock group





Qaf and Qp too thin to show

INDEX MAP

GEOLOGIC MAP OF THE CHARLES SHELDON WILDERNESS STUDY AREA, NEVADA AND OREGON

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1985—

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BULLETIN 1538
PLATE 2

Base from U.S. Geological Survey 1:250,000
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Vya, Nevada, Oregon, California, 1954
(rev. 1970)

SCALE 1:125 000

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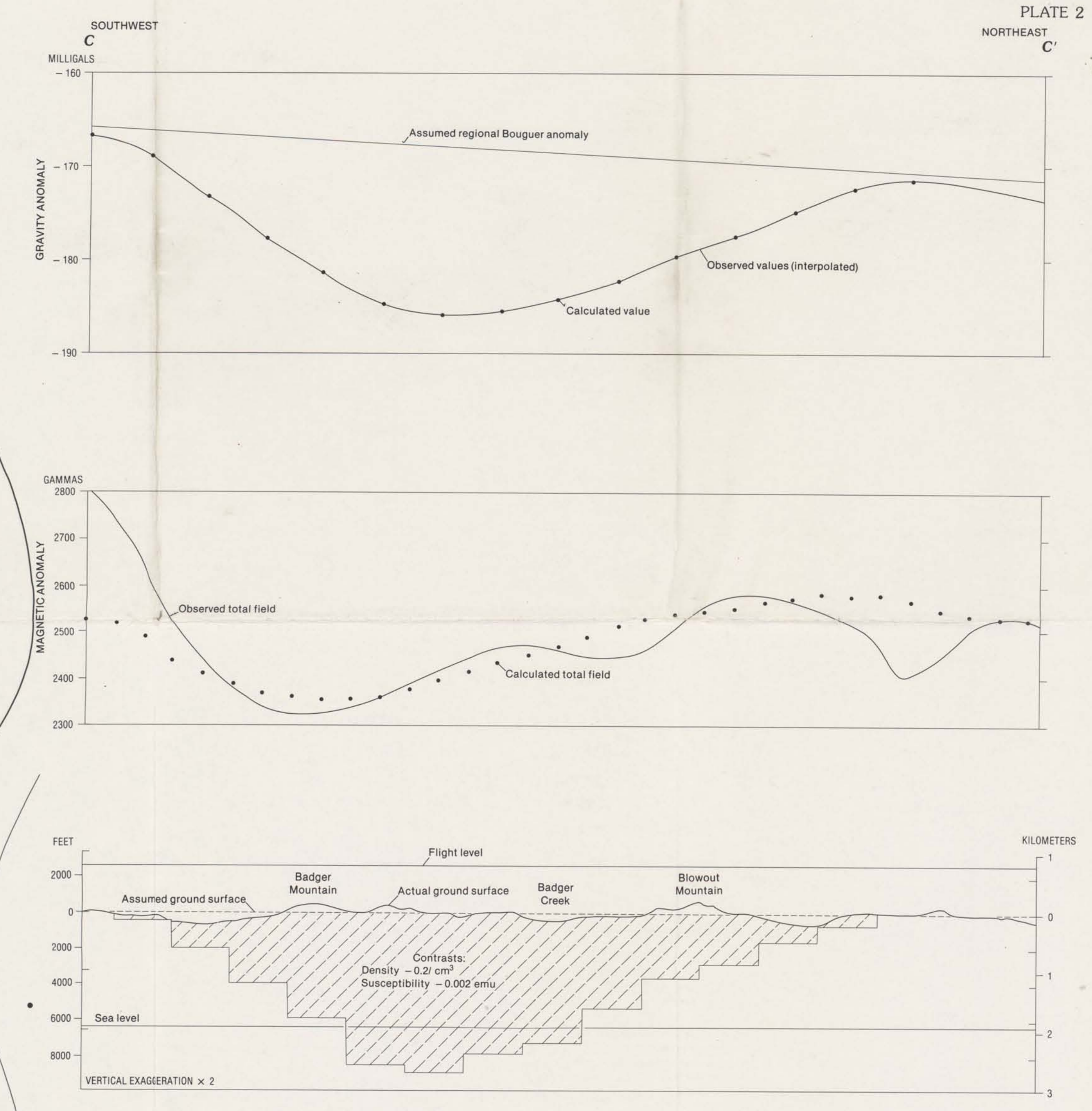

EXPLANATION

—-150— BOUGUER GRAVITY CONTOURS—Contour interval 5 milligals. Hachured contours enclose gravity minima

△ GRAVITY BASE STATION

■ GRAVITY STATION ESTABLISHED IN 1975 NEAR BENCHMARK OR SPOT ELEVATION

■ GRAVITY STATION IN CRUMP GEYSER AREA (PLOUFF, 1975)

● GRAVITY STATION ESTABLISHED BEFORE 1975 OR WITH ELEVATION DETERMINED BY CONTOUR ESTIMATE

OUTLINE OF POSTULATED CALDERA

C_4 POSSIBLE CALDERA

F_{11} POSSIBLE FAULT

G_{11} GRAVITY ANOMALY

H_2 NEAR HOT SPRINGS

—2000— MAGNETIC CONTOURS—Showing the total-intensity magnetic field of the earth relative to an arbitrary datum. Regional gradient of about 6 gammas per km removed. Hachures enclose ma netic minima. Contour interval 100 gammas, with intermediate, dashed contours at interval of 20 gammas

FLIGHT PATH—Showing location and spacing of data. Constant barometric elevation was 9000 feet (2743 m) above sea level

M_2 BROAD MAGNETIC HIGH

T_9 ANOMALY CORRELATED WITH TOPOGRAPHY

INDEX MAP

Field data of 269 stations collected by S. L. Robbins and K. D. Holden, 1975; supplemented by data obtained from U.S. Department of Defense Gravity Library, written commun., 1975. Compiled by Donald Plouff, 1976.

Aeromagnetic data compiled from U.S. Geological Survey, 1972. Aeromagnetic map of the Vya and part of the McDermitt 1° × 2° quadrangles, Nevada; and Aeromagnetic map of the Adel and part of the Burns, Boise, and Jordan Valley 1° × 2° quadrangles, Oregon: U.S. Geological Survey Open-file reports, scale 1:250,000.

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AEROMAGNETIC AND COMPLETE BOUGUER GRAVITY ANOMALY MAP OF THE CHARLES SHELDON WILDERNESS STUDY AREA, NEVADA AND OREGON

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1985—G82627