STUDIES RELATED TO WILDERNESS

MINERAL RESOURCES OF THE STRAWBERRY MOUNTAIN WILDERNESS AND ADJACENT AREAS, GRANT COUNTY, OREGON

GEOLOGICAL SURVEY BULLETIN 1498

Mineral Resources of the Strawberry Mountain Wilderness and Adjacent Areas, Grant County, Oregon

By THOMAS P. THAYER *and* JAMES E. CASE, U.S. GEOLOGICAL SURVEY
and by RONALD B. STOTELMEYER, U.S. BUREAU OF MINES

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An evaluation of the mineral potential of the area

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STUDIES RELATED TO WILDERNESS

In accordance with the provisions 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 national forest lands in the Strawberry Mountain Wilderness and adjacent areas that are being considered for addition to the Wilderness in Grant County, Oregon.

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SUMMARY

In the summer of 1975, U.S. Geological Survey and U.S. Bureau of Mines personnel examined and sampled the Strawberry Mountain Wilderness and adjoining areas in Grant County, Oreg., for mineral deposits of possible economic value. The wilderness and study area comprises 280 km^2. The Geological Survey staff evaluated the potential resources by detailed geological mapping, by determining the kinds of deposits present, and by geochemical sampling of rocks and stream sediments. The study area was surveyed aeromagnetically as part of a larger project. The Bureau of Mines staff compiled mineral production data, searched records of mining claims, and sampled and surveyed mines, prospects, and placer deposits. These investigations indicated the presence of only small subeconomic chromite and copper deposits.

The Strawberry Mountain Wilderness study area covers the higher northern parts and the southern slopes of the Strawberry Range, which forms part of the southwestern border of the Blue Mountain region. The range trends east-west, has relief of 1,200–1,500 meters (m), and the crest is between 2,200 and 2,750 m in altitude. The Strawberry Range is a complex faulted anticlinal block in which Tertiary volcanic rocks lie unconformably on a core of Permian and possibly Lower Triassic igneous rocks.

All the pre-Tertiary rocks in the wilderness belong to the Canyon Mountain Complex, of igneous origin, and fall into two distinct groups. The older group consists of medium- to coarse-grained plutonic ultramafic (peridotitic) and gabbroic rocks that commonly are layered and intergraded, but have been intensely folded and are gneissic in texture and structure. The younger group is made up of two contrasting kinds of rocks: (1) dark, fine- to medium-grained basaltic dikes, and (2) gray to white silicic rocks that range from medium-grained quartz diorite and albite granite to dense flow-banded keratophyre (Na_2O-rich rhyolite). The basaltic and silicic rocks intruded the plutonic rocks after they were folded, and together form a complicated swarm of dikes, or dike complex. The rocks of the two groups form three east-west belts; the ultramafic rocks are on the north, gabbro is in the middle, and the dike unit is on the south.

Volcanic rocks of Pliocene to Eocene age, the Strawberry Volcanics and the Clarno Formation, respectively, form the cover over the Canyon Mountain Complex. The western half of the Strawberry Range is an anticline bounded on the north by the John Day fault, and covered on the south limb by the Clarno Formation and the Strawberry Volcanics. The eastern half of the range is a southward-tilted fault block that is partly separated from the western half by the transverse Indian Creek fault. Although the Indian Creek fault cuts the Clarno flows and the lower part of the Strawberry Volcanics, the upper part of the Strawberry flows buried the southern end of the fault and extend continuously along the southern flank of the range. Complex faulting accompanied

eruption of the Strawberry Volcanics. Both the Strawberry and the Clarno contain flows and breccias that range from olivine basalt to rhyolite. No mineral deposits have been found in the Tertiary rocks, which cover 70 percent of the study area.

Although the northern part of the Canyon Mountain Complex has yielded gold and some silver and platinum and is the site of several chromite deposits that have been mined, only two small deposits of chromite are known to have been mined in the study area. The Strawberry Range has been the source of about 26,000 kilograms (kg) (850,000 ounces) of gold, more than 400 kg (13,000 ounces) of silver, and some platinum, mostly mined from placers in Canyon Creek and along a 16-kilometer (km) stretch of the John Day River in the vicinity of John Day. The gold deposits are all in the Canyon mining district, which adjoins the study area on the northwest. Chromite production, mostly from mines adjacent to the north side of the study area, totals approximately 30,000 metric tons (t). About 60 percent was mined during World War I. The Canyon Creek mercury mine, 0.8 km southwest of the study area, produced 3,830 kg (111 flasks) of mercury in the period 1963-1968.

The chromite deposits occur in the peridotite as pods and lenses that range in size from a ton or less to 115,000 t or more. Although the study area covers 8-10 km² of peridotite, it includes only two chromite deposits from which ore has been shipped, the Celebration and Ray (Tip Top), and a few small prospects that appear to have been

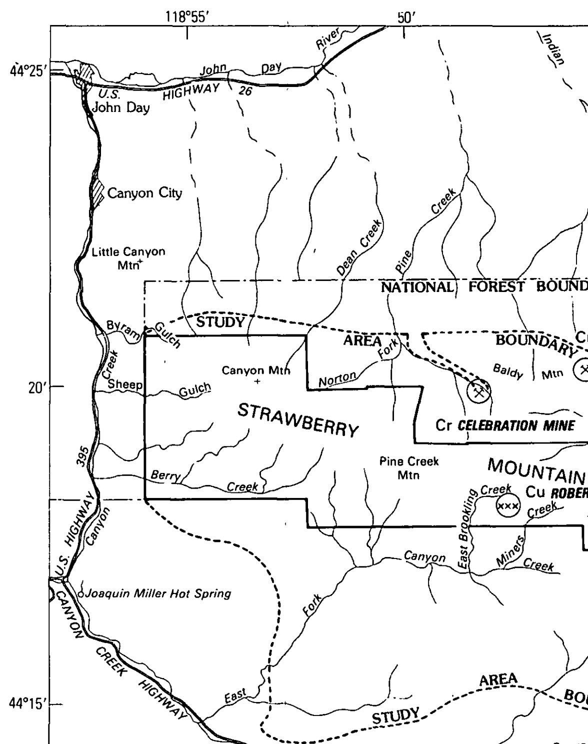


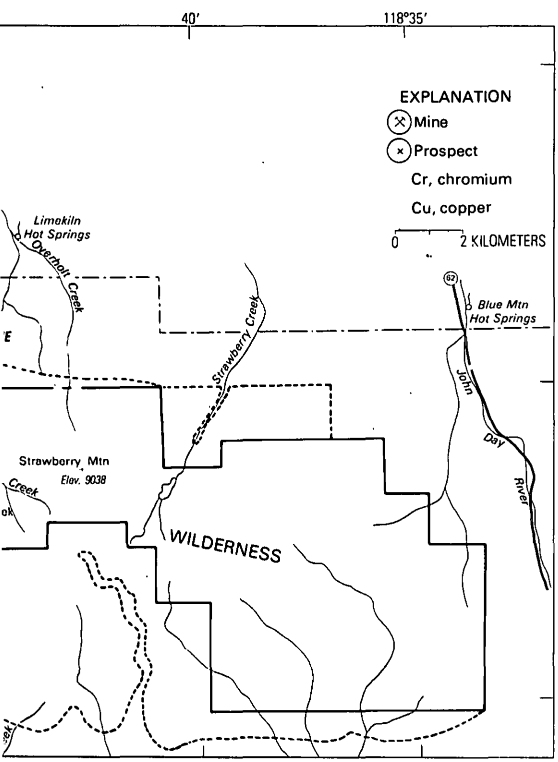
FIGURE 1.—Strawberry Mountain Wilderness study aı
Celebration and Ray mines have a small potential
of Robert L. prospect has a small potential for subeconon

mined. The Celebration and Ray together have yielded about 1,600 t of ore, and inferred resources are a few thousand tons (fig. 1). In the study area there is a potential for discovery of small chromite deposits like those found in the past.

Nickel and platinum-group metals that occur in the peridotite probably will not be recoverable in the near future. Nickel content, ranging from 0.1 to 0.25 percent in the peridotite, is in silicate form for which no economic recovery process is known. Platinum occurs mainly in chromite ore; one analysis showed 0.69 g/t or ppm.

Copper occurs with vein quartz in shear zones in gabbro, associated with basaltic dikes and albite granite at eight places along the crest of the range between Canyon Mountain and Indian Creek Butte. Traces of silver occur with the copper, but no gold. The copper veins appear to be much older and are quite different mineralogically from the gold veins in the Canyon mining district. The Robert L. claims at the head of Miners Creek in the wilderness are estimated to contain about 33,600 t of subeconomic rock averaging 0.31 percent copper, and potential resources on the Blue Rock claim, 0.8 km west of the wilderness, contain 10,300 t of rock averaging 0.33 percent copper.

The Canyon Creek Mercury Mine, 0.8 km outside the southwestern corner of the study area, has yielded 3,830 kg (111 flasks) of mercury. It is in Triassic graywacke that is buried under Strawberry andesite within the study area. Samples from a mercury prospect in a landslide below Wildcat Basin contained no mercury. Magnesite veins in



wing potential chromium and copper resource localities.
economic chromite in peridotite near the two mines. Vicinity
per veins in gabbro.

dunite just northwest of the wilderness may be related to gold veins in Little Canyon Mountain; the dunite host rock does not extend into the wilderness.

Two thermal springs, one hot and one warm, on the John Day fault system are more than 3 km from the study area. A third warm spring, on Canyon Creek, also is 3 km from the boundary of the study area.

INTRODUCTION

The Strawberry Mountain Wilderness is in Grant County, Oreg., about 160 km from the eastern border of the State, and 210 km from the northern border. The area is served by U.S. Highways Nos. 395 and 26 which cross in John Day, about 10 km northwest of the wilderness (fig. 2). The wilderness is in the Malheur National Forest, and can be reached by several gravelled roads leading from the paved roads that encircle it.

The wilderness extends 29 km along the crest of the Strawberry Range and comprises 133.7 km^2. An additional area of 148 km^2 was investigated at the request of the Forest Service. The Strawberry Range is a mountain block 32 km long by 13-16 km wide that trends

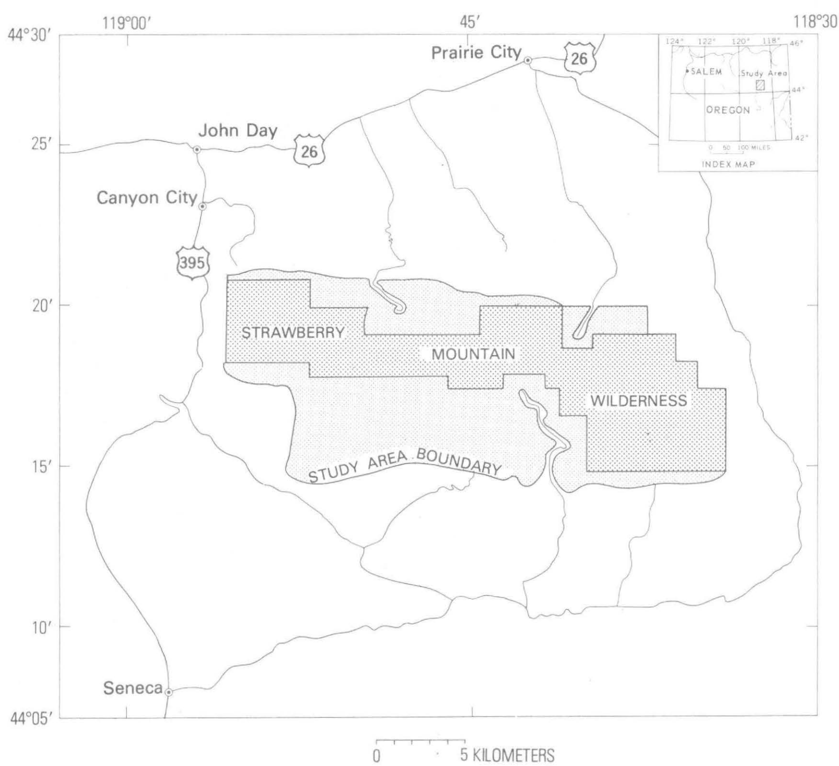


FIGURE 2.—Location of the Strawberry Mountain Wilderness study area.

nearly east-west between the valleys of Canyon Creek on the west and the John Day River on the east (see pl. 1*C*). The main crest is between about 2,200 and 2,450 m in altitude, except for Strawberry Mountain, which reaches 2,755 m above sea level. On the north, the range presents a straight front that stands about 1,500 m above the John Day River valley, and is incised by deep transverse valleys. On the south, the range has a relief of about 1,050 m, and the slopes, which are eroded on lava flows, merge with a rolling volcanic plateau.

The scenery of the wilderness is related directly to altitude and rainfall. In the surrounding area, the climate at altitudes of less than 1,200–1,350 m is semiarid, and grasses, sagebrush, and juniper are the dominant vegetation; irrigation is necessary for farm crops. Between altitudes of about 1,200 and 2,150 m, southward-facing slopes support beautiful forests of Ponderosa pine, whereas northern slopes are characterized by mixtures of Ponderosa pine, Douglas fir, and hemlock at lower altitudes, and lodge pole or tamarack pine, spruce, and larch at higher elevations. Above about 1,800 m, the scenery is alpine, with many open slopes, U-shaped glacial valleys, and bold outcrops (frontispiece, fig. 3). Glacial cirques head most stream valleys (fig. 5) along the range crest. The wilderness and nearby areas are an important source of water for the John Day River valley during the summer.

FIGURE 3.—Sheep Rocks viewed across the head of Cougar Creek showing rugged exposures of gabbro on the southern slope of Canyon Mountain.

In this report, the term "study area" refers to the existing wilderness area plus the areas proposed as additions. The term "wilderness" refers only to the already established Strawberry Mountain Wilderness as it existed in 1975.

GEOLOGY AND MINERAL RESOURCES

By THOMAS P. THAYER, U.S. GEOLOGICAL SURVEY

PREVIOUS STUDIES

Before about 1945, all geological investigations in the vicinity of the Strawberry Range were directed to gold or chromite deposits. During his study of the Blue Mountain gold belt, Lindgren (1901, p. 712–720) provided the first description of the geology of the Strawberry Range and called attention to the occurrence of chromite. Swartley (1914, p. 200–209) quoted Lindgren's description of the Canyon mining district, and mentioned activities that took place at a few of the mines before 1912. Parks and Swartley (1916, p. 111) briefly described the Great Western gold mine in Little Canyon Mountain. Brooks and Ramp (1968, p. 144–147) provided current information on production of gold and accessible workings in mines.

The chromite deposits in the John Day area were first described by Westgate (1921), after the mining during World War I. In 1939, the Geological Survey mapped the chromite-bearing rocks of the John Day-Mount Vernon area and cooperated with the Bureau of Mines in a drilling program at the Iron King, Chambers, and Dry Camp mines (Thayer, 1941); in 1943, the Bureau of Mines drilled the first two deposits more thoroughly and, later, ran utilization tests on the chromite (Hundhausen and others, 1956). Allen (1941, p. 53–67), in a statewide report on chromite resources, described the Grant County deposits.

Geological mapping of the Strawberry Range at a field scale of about 1:24,000 by the Geological Survey has progressed intermittently since about 1945. Geological maps of the John Day (Thayer, 1956) and Prairie City quadrangles (Thayer, Brown, and Hay, 1967) and a regional geological map (Brown and Thayer, 1966) have been released. Papers describing the rocks in the Canyon Mountain Complex have been published by Thayer (1977); Thayer and Himmelberg (1968); and by Avé Lallemant (1976).

PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

In view of earlier detailed mapping, fieldwork by the Geological Survey staff for this study was concentrated on geochemical sampling of stream sediments and bedrock that might indicate the presence of mineral deposits of economic interest. The extensive dike zone in the southern part of the Canyon Mountain Complex was examined in some detail for the possible presence of pillow lavas that might be hosts for copper mineralization. The fieldwork took 5 weeks in July and August 1975. The field party consisted of the author, R. R. Carlson, E. R. Force, and T. L. Robyn. L. M. Force assisted the party on a part-time basis in the field and in laboratory studies of heavy minerals in stream samples. Spectrographic analyses were made by Leung Mei, Norma Rait, E. F. Cooley, and R. R. Carlson; R. Moore and J. W. Budinsky made the analyses by atomic absorption and fire assay. The Bureau of Mines and Forest Service assisted greatly by providing helicopter service to several of the more inaccessible parts of the wilderness area. Investigations by the Bureau of Mines are described in "Economic Appraisal."

GEOLOGY

SETTING

The Strawberry Range is the highest segment of a 240-km-long east-west mountain range that forms the southwestern border of the Blue Mountain region in Oregon (Thayer and Wagner, 1969). The range, like most of the others in the region, is a complex anticline that rose first in Oligocene(?) time and again in early Pliocene time, after eruption of the Strawberry Volcanics and the basalts that form the Columbia Plateau. The Strawberry Range is bounded on the north by the John Day fault system (Brown and Thayer, 1966), which probably has a throw of 900–1,500 m, and is divided into eastern and western blocks by the transverse Indian Creek fault. Pre-Tertiary rocks of the Canyon Mountain Complex form the higher parts of the western or Canyon Mountain block (pl. 1*C*). Tertiary volcanic rocks form the eastern, or Strawberry Mountain block, overlap across the southern end of the Indian Creek fault, and cover the southern slopes of the Canyon Mountain block. The older rocks occupy about 83 km^2 or 30 percent of the study area, and Tertiary volcanic rocks cover about 197 km^2, or 70 percent.

CANYON MOUNTAIN COMPLEX

The Canyon Mountain Complex occupies an area of about 155 km^2 between Canyon Creek, on the west, and the Indian Creek fault, on the east; it is 17–20 km long by 8–13 km wide (pl. 1*C*). The complex consists of four main kinds of rocks: ultramafic rocks or peridotite[1], gabbro, basaltic dikes, and Na_2O-rich silicic volcanic and intrusive rocks. The rocks are distributed essentially in three east-west belts—the peridotite on the north; the gabbro in the middle, forming the highest parts of the range; and the basaltic dikes and silicic rocks together forming the rugged southern slopes down to the valleys of Berry Creek and the East Fork of Canyon Creek. The proportions of the different rocks are approximately as follows: olivine-rich peridotite and serpen-

[1] Including dunite, pyroxenite, and serpentinite.

tinite derived from it, 40–45 percent; pyroxene-rich peridotite and pyroxenite, about 5 percent; gabbro, 30–35 percent; basaltic dikes and silicic rocks combined, about 20 percent. The rocks fall into two groups: (1) peridotite and gabbro, and (2) basaltic dikes and silicic rocks, which occur mainly together in a sheeted dike complex or unit. Rocks of the kinds that constitute the Canyon Mountain Complex are widely associated in folded mountain belts of the world and are recognized as major components of the so-called ophiolite assemblage. Although the two groups of rocks are spatially associated worldwide, they differ consistently in textures and internal structure, chemical composition, and intrusive relations. The peridotite and gabbro are plutonic rocks that crystallized deep in the crust or upper mantle, whereas the sheeted dike unit is characterized by features of volcanic rocks or related shallow intrusions. The study area covers part of the southern edge of the peridotite belt, most of the gabbro, and the entire width of the belt of basaltic dikes and silicic rocks.

PERIDOTITE AND GABBRO

The peridotite and gabbro form a continuous lithologic series in which they are interlayered, interfinger along strike, and intergrade across layering (Thayer, 1977; Thayer and Himmelberg, 1968). They form a tectonic unit the length of the complex and 6.5–8 km wide. These rocks range in grain size from fine (2–3 mm) to coarse (10–100 mm), are massive to well layered, and most are moderately to intensely deformed and gneissic. In places, primary layered textures formed by crystal settling during crystallization are well preserved, especially in chromite deposits, pyroxene-rich peridotite, and gabbro. The peridotite weathers brown and reddish brown, whereas gabbro and anorthositic layers in it weather brown to gray or white, depending upon the ratio of feldspar to pyroxene or olivine. Layering is shown best in transitional zones between peridotite and gabbro. All the peridotite, especially dunite, is at least partly serpentinized, and in many places it has been serpentinized completely and sheared intensely. Much of the gabbro appears fresher than it really is; over large areas, it has been metamorphosed and hornblendized to rock resembling diorite, which has been called epidiorite (Thayer, 1972). Relict layering, gneissic banding, and foliation help in distinguishing epidiorite from younger intrusive quartz diorite and from recrystallized basaltic dikes.

ROCKS OF THE SHEETED DIKE UNIT

The sheeted dike unit consists primarily of hundreds of intrusive sheets (dikes or sills) of basalt or diabase, albite granite, and keratophyre. The sheets range in thickness mostly from 0.3 m to 3 m, alternate singly or in groups in any order, dip 60° or more, and interfinger irregularly along strike (fig. 4). All three kinds of rocks are known to

FIGURE 4.—Alternating dikes of albite granite (white) and basalt or diabase in the sheeted dike unit, near the head of Tamarack Creek. At lower left, albite granite cuts across diabase; the other basaltic dikes appear to cut the albite granite.

form dikes, but in many outcrops the order of emplacement is uncertain. Few individual dikes are traceable more than 100 m, although groups can be followed much farther. The proportions of the basaltic and silicic rocks vary widely from place to place and have not been determined. Plagiogranite, however, appears to be most abundant near the gabbro, whereas keratophyre predominates 0.8 km or more south of the gabbro; diabase probably is most abundant 0.8-1.6 km from the gabbro.

The rocks that form the sheeted dike unit are of two contrasting kinds; few rocks are of intermediate (andesitic) composition. The basaltic dikes are of dark-gray massive rock that grades from very fine grained or aphanitic at the borders to medium grained (1-2 mm) in centers of dikes less than about 2 m wide, and to coarse grained (3-5 mm) in dikes more than 6 m wide. Most dikes show even-grained diabasic texture, but some are porphyritic, with equant or tabular plagioclase phenocrysts.

The silicic rocks are believed to have constituted a volcanic pile in which all facies from subvolcanic intrusive rocks to near-surface dikes are represented. Some flows may be present in the southernmost part of the complex, but none were identified with certainty. The coarse-grained rocks (5-8 mm in grain size) are granitoid in appearance and range in composition from quartz diorite to albite granite. The quartz diorite contains 30-40 percent dark minerals, mainly hornblende, whereas the albite granite consists almost entirely of quartz and albite, and of only 5-10 percent chlorite and epidote. All textural gradations from albite granite to porphyritic flow-banded keratophyre and quartz keratophyre are present, and in many places sheets of albite granite cut keratophyre. All rocks of this suite are notably deficient in potassium compared with normal granite and rhyolite. The term plagiogranite has been proposed for the coarse-grained intrusive facies, and accordingly, the silicic rocks will be called the plagiogranite-keratophyre suite.

The field and petrologic relationships between the peridotite-gabbro sequence, on one hand, and rocks of the sheeted dike unit, on the other, are very complex. Two small stocks of quartz diorite, each less than 300 m across, cut gabbro north and west of Canyon Mountain, and the West Fork of Pine Creek (Norton Creek) follows a granitic migmatite zone in gabbro about 2.5 km long. Hornblendic and albitic alteration caused by solutions accompanying intrusion of plagiogranite is widespread in the gabbro, and along the southern border much of the gabbro has been completely recrystallized to epidiorite (hornblende-andesine rock: Thayer, 1972). Basaltic dikes are numerous in the southern part of the gabbro belt, and are scattered widely in peridotite. Some basaltic dikes were followed by plagiogranite; many dikes in both peridotite and gabbro have been partly or completely altered to amphibolite (Thayer, 1972) and sheared into lenses. All basaltic dikes consistently show fine-grained chilled margins against peridotite and gabbro, but recrystallization of dike rocks and gabbro commonly forms intermediate textures that are very similar and may not be diagnostic.

STRUCTURE

Two classes of structural features are distinguishable within the Canyon Mountain Complex: (1) primary igneous textures and other features formed in peridotite and gabbro by deformation before emplacement into their present position, and (2) structures formed during and after emplacement of peridotite and gabbro as a large tectonic unit. Internally, the peridotite and gabbro show very complex high-temperature deformation that modified or obliterated primary features over large areas (Avé Lallemant, 1976; Thayer, 1977). In the northwest corner of the map area, the distribution of peridotite, pyroxenite, and gabbro indicates an anticlinal nose that plunges southwestward exposing olivine-rich peridotite and dunite in the core and gabbro on the flanks, cut off by a transverse fault along Canyon Creek. The southern limb of the fold is broken along an east-west strike fault system that extends from Canyon Creek to Dog Creek, across structures in both peridotite and gabbro. A split of this system was intruded by a 60 m wide dike of recrystallized basalt south of the Iron King chromite mine. The intricate mingling of peridotite with gabbro in the basins of Pine and Indian Creeks is believed to be due to a complex system of large east-west folds which plunges westward as a whole. The peridotite as a unit probably extends southward under the gabbro, although most exposed contacts appear to be about vertical (see pl. 1*C*, sections *A-A′* and *B-B′*).

Major fractures that probably were related to the large folds in the peridotite and gabbro apparently controlled or guided intrusion of the basaltic and silicic rocks. In general, the boundary between the sheeted dike unit and the gabbro dips steeply and strikes westward parallel to the main peridotite-gabbro contact. Most dikes within the sheeted unit follow the same westward trends and dip 60° or more, either north or south. Where dikes in peridotite or gabbro do not follow local foliation or layering, most commonly they follow west-trending fractures or shear zones. In places, within the gabbro and near the border, closely spaced rudely parallel diabase dikes equal gabbro in volume. The southern border of the gabbro is so splintered by dikes and larger plagiogranite intrusions of the dike unit that no definite contact can be plotted. Screens or slivers of gabbro and epidiorite were found in the sheeted dike unit as much as 1.6 km from the main gabbro contact between Berry and East Brookling Creeks. The distances between screens and the main gabbro contact indicate the aggregate expansion caused by intrusion of the intervening basaltic and silicic sheets. No pillow lavas, tuffaceous materials, or fragmental rocks definitely of surface origin were found during the fieldwork in 1975, despite a specific search for them as possible hosts for copper mineralization of the Cyprus type.

In accordance with plate-tectonic theory, the Canyon Mountain Complex is believed to have originated as oceanic crust in which the present gabbro-peridotite contact approximately marks the ancient boundary between crust and upper mantle. Volcanic and sedimentary rocks of Permian age in the surrounding region (Thayer, 1977) presumably formed ocean floor over the present complex, and the basaltic and plagiogranite dikes and intrusive rocks were feeders for submarine volcanoes. During an early stage of this volcanism, a large block of the ocean floor was raised to bring deformed peridotite and gabbro up into the upper crust. The boundary fault that cut off the gabbro became a focus for eruption of both basaltic and silicic magma in a spreading zone. Basaltic dike intrusion (and eruptions) began before and continued after eruption of the plagiogranite-keratophyre suite. Numerous dikes were intruded along subsidiary fractures in peridotite and gabbro parallel to the main fault. Radiogenic dates of 225–250 million years on plagiogranite and amphibolitic basaltic dikes (M.A. Lanphere, written commun., 1973) suggest a Late Permian age, and middle-Permian fossils have been found in sedimentary rocks just north of the complex. By Late Triassic or Early Jurassic time, the Canyon Mountain Complex probably had its present structural form, and the postulated volcanic cover probably had been stripped from the peridotite-gabbro block.

TERTIARY VOLCANIC ROCKS

CLARNO FORMATION

Volcanic rocks believed to be equivalent to the Clarno Formation of Eocene and Oligocene age, but possibly equivalent to the John Day Formation of Oligocene and Miocene age, lie unconformably on the southern edge and eastern end of the Canyon Mountain Complex and crop out in the lower parts of the northern slopes of the Strawberry Mountain block (pl. 1*C*).

The formation varies markedly along the strike; it includes rocks that range from flows of olivine basalt to rhyolite and thick fragmental units. Within the John Day quadrangle, the Clarno Formation dips southward off the Canyon Mountain Complex in the valleys of Berry Creek and the East Fork of Canyon Creek. The thickness of the formation increases westward from 30 to 60 m at the northern base of Indian Creek Butte to about 900 m in Berry Creek. At the Berry Creek-East Fork divide, coarse tuff and bouldery mudflow breccias of hornblende andesite and dacite constitute the entire thickness; toward the west, olivine basalt flows interfinger in the lower part, and rhyolitic pumice flow breccia and ash flows form the upper part. Eastward from the Berry Creek divide to the southern slope of Indian Creek Butte, mudflow breccias and rhyolite make up the formation; in the butte, dense andesite flows are present below the rhyolite.

In the Prairie City quadrangle and the Strawberry Mountain block, the Clarno Formation forms the lower slopes of the high mountain front south of the Onion Creek fault. Clarno flows, about 1,200-m thick, are exposed in the slopes of Strawberry Mountain; the lower half of this section comprises flows of basalt, andesite, and rhyolite, and the upper part consists entirely of thick aphanitic andesite flows. Northeast of Graham Mountain, the exposed section consists of two rhyolite units, a basalt unit, and andesite that total 250–300 m in thickness.

Where fresh, rocks of the Clarno Formation are very similar to those of the overlying Strawberry Volcanics, and in many places alteration is the most useful distinguishing feature. Platy andesite and rhyolite flows in the slopes northwest of Strawberry Camp show intense hydrothermal bleaching and iron staining that are common in parts of the Clarno Formation. Where thoroughly bleached, platy andesite may resemble rhyolite except for the abundance of staining by iron oxides.

STRAWBERRY VOLCANICS

The Strawberry Volcanics, of Miocene and Pliocene age, form the higher parts of the Strawberry Mountain block and the prominent southern dip slopes that extend westward across the John Day quadrangle to Canyon Creek. The formation consists mostly of fresh, porous, pale-gray-weathering flows that range from olivine-bearing basalt and basaltic andesite through hypersthene andesite to dacite, and includes two members, the Slide Creek and Wildcat Basin Rhyolite (new name). The greatest exposed thickness of andesitic flows is about 750 m in the northern slopes of the range (pl.1*C*, section *C–C′*). The andesitic flows formed a broad cone 15-20 km in diameter that was centered on the large volcanic plug exposed in the cliffs above Little Strawberry Lake (pl. 1*C*, fig. 5). The plug is 1,100–1,200 m in diameter, and consists of pale-gray to almost white medium-grained (2–3 mm) hypersthene microgabbro. The so-called Rabbit Ears are pinnacles of vent agglomerate that was dragged upward to vertical dips along the side of the plug.

The Slide Creek Member is a distinctive group of brown-weathering thick olivine basalt flows of middle Miocene age that extend across the northern face of the Strawberry Mountain block. The basalt flows are the basal unit east of Strawberry Creek and reach 275 m in thickness in the valley of Slide Creek. The Wildcat Basin Rhyolite Member here named of late Miocene age (± 12 m.y., Thomas L. Robyn, oral

FIGURE 5.—View east along the cirque wall at the head of Strawberry Creek valley. Massive microgabbro of the Strawberry volcanic plug forms the vertically jointed cliff, and thin flows form the slopes on either side. The crags to the right of the plug are formed by massive steeply dipping vent breccias. The crest of the cirque stands about 450 m above the valley floor.

commun., 1977) consists of white or pale gray to pinkish rhyolitic tuffs and flows that extend southwestward from a vent complex in the head of Indian Creek, just north of Wildcat Basin, its type locality. Two or more platy rhyolites of this unit, which have spherulitic glassy tops, appear to be about 300 m thick in the valley of the Middle Fork of Canyon Creek, and south of Berry Creek, obsidian breccia flows extend west to Canyon Creek. In the narrow ridge between the head of Indian Creek and the East Fork, tuffs of the rhyolite vent complex interfinger with andesite flows from the main Strawberry vent through a vertical distance of 275 m. Basaltic cinder cones formed around parasitic eruption centers in the head of Lake Creek and at Dead Horse Basin were buried by andesite flows and have been exhumed by erosion.

STRUCTURE

The Tertiary volcanic rocks reveal a complex history of volcanism that was accompanied by folding and faulting. The Canyon Mountain block, west of the Indian Creek fault, is shown to be an anticline by the patch of Clarno Formation west of the Indian Creek fault, below Sheep Rock, and dips of 40° to 70° in Clarno breccias along Berry Creek. Northward thinning of the Clarno Formation in the western face of Indian Creek Butte shows that the Clarno was folded and eroded before eruption of the Strawberry Volcanics. The Strawberry Mountain block essentially is a tilted pile of lavas (pl. 1*C*, section *C-C'*) bounded on the west by the Indian Creek fault and on the north and east by the John Day fault system. A 3.25-5 km-wide segment across the north end of the block has been dropped 1,000 m or more on the Onion Creek fault (pl. 1*C*, section *C-C'*). The Strawberry Volcanics in the main block dip southward at angles of about 5°-13°, unconformably over Clarno flows that dip as much as 25°. The north-south faults in the triangular block between the Indian Creek, Onion Creek, and Lake faults seem to have been related to cauldron subsidence toward the Strawberry plug during volcanism. Although the Lake fault displaced Slide Creek basalts 300-450 m, it does not cut younger flows in the cirque walls west of the plug. Likewise, although Slide Creek basalts were dropped 300-500 m against Clarno andesite along the Indian Creek fault, that fault does not cut the Wildcat Basin Rhyolite Member. The Wildcat Basin eruptive center appears to have been located at the intersection of the Lake and Indian Creek faults, which is now buried under the younger flows and tuffs. The upper andesite flows and Wildcat Basin Rhyolite Member of the Strawberry Volcanics form a continuous southward-dipping cover the entire length of the map area, in which individual flows may be traced 1.5 km or more. The final uplift of the Strawberry Range along the John Day fault probably took place during early Pliocene time.

SURFICIAL DEPOSITS

Within the study area, thin alluvial deposits are restricted to floors of a few narrow valleys, and most Pleistocene and Holocene deposits are related directly or indirectly to glaciation. Thin, poorly sorted stream deposits extensive enough to be mapped at 1:62,500 scale occur only in Strawberry Creek, Big Creek, and the East Fork of Canyon Creek. One significant stream terrace, 8 m above Big Creek, extends about 1.5 km into the study area. Glacial till, landslide deposits that resulted largely from glacial oversteepening of valley walls, and talus or colluvium on steep slopes are the predominant surficial materials. Upper Pleistocene glacial moraines end at about 1,700 m above sea level on both sides of the range. Most of the small lakes and ponds are dammed by glacial moraine, but Strawberry Lake was formed by landslides from both sides of the valley. The larger landslides formed in serpentinite and sheared gabbro or along tuffaceous units in volcanic rocks. Powdery white volcanic ash that was erupted from Crater Lake about 7,000 years ago forms thin layers and lenses as much as 2 m thick that are exposed in road cuts and stream banks across small alluvial fans.

MINERAL DEPOSITS

No deposits that are likely to be mined in the near future are known within the Strawberry Mountain Wilderness, and only two deposits within the study area, the Celebration and Ray (Tip Top) chromite mines, are known to have yielded ore. The northern part of the Canyon Mountain Complex adjoining the study area has produced approximately 30,000 t of chromite, and gold has been mined from lodes in Little Canyon Mountain, 1.5-3 km northwest of the wilderness. The Canyon Creek mercury mine, situated about 0.8 km beyond the southwest corner of the study area, has produced 3,830 kg (111 flasks) of mercury. The peridotite within the northern edge of the study area contains some chromite deposits, and nickel and platinum metals as minor elements. Copper mineralization has been found in veins in gabbro within the wilderness, and veins of magnesite occur in Byram Gulch within a few hundred meters of the northwestern corner of the wilderness.

CHROMIUM, NICKEL, AND PLATINUM-GROUP METALS

Chromium, nickel, and platinum-group metals are primary constituents of peridotite. Chromium is concentrated in the mineral chromite, which is black, heavy, and has the composition (Mg, Fe^{2+}) (Cr, Al, $Fe^{3+})_2O_4$. The ratios of metals in chromite may vary greatly; in the Canyon Mountain Complex, the composition of clean chromite from different deposits ranges from about 35-60 percent Cr_2O_3, and from about 2:1 to 3.3:1 in Cr:Fe. The chromite deposits in the Canyon Mountain Complex are of the so-called podiform type (Jackson and Thayer, 1972; Thayer, 1941, 1964) that forms irregular lenses and pods in olivine-rich peridotite, dunite, and serpentinite. Individual deposits in the Canyon Mountain Complex range in size from a few hundred kilograms to about 115,000 t (Hundhausen and others, 1956, p. 15), and range in grade from about 53 percent Cr_2O_3 in massive ore to 10 or 15 percent Cr_2O_3 in low-grade disseminated ore. Very few of the deposits contain or have yielded as much as 1,000 tons of ore.

Four chromite mines, the Iron King, Chambers, Celebration, and Ray are near the northern boundary of the wilderness study area (pl. 1*C*). The Iron King and Chambers have been drilled by the Bureau of Mines in cooperation with the Geological Survey (Hundhausen and others, 1956). All except the Celebration are at least 600 m from the periodotite-gabbro contact, and none are likely to extend as much as 100 m south of their original outcrops. The Iron King ore body is highly faulted, and the peridotite host rock is cut off by a massive dike of altered diabase that followed a major fault about 60 m south of the open cut (pl. 1*C*). The main ore body in the Chambers mine, although segmented by faults, as a whole dips 60°-65° southward to a depth of about 70 m.

The Celebration and the Ray (or Tip Top) mines together have shipped about 1,600 t of ore, and probably have similar amounts of chromite left. The small pits near the edge of the study area east of Indian Creek indicate that lenses perhaps 30-60 cm thick have been mined. The numerical ratio of minuscule lenses of chromite to sizable deposits in the complex is very large and, furthermore, almost all the ore will have to be concentrated.

Nickel and platinum-group metals occur as minor elements in peridotite. Nickel occurs predominantly in olivine and serpentine minerals isomorphously with magnesium, usually in amounts of 0.1-0.3 percent, and is not now economically recoverable. The mode of occurrence of platinum-group metals in peridotite is not well known, but they appear to be concentrated in chromite ore. Analyses of 26 samples of chromite from southwestern Oregon (Page and others, 1975) showed that only 3 contained >20 parts per billion (ppb) platinum, with a maximum of 850 ppb; 3 contained as much as 10 ppb palladium and a maximum of 16 ppb; only 4 contained as much as 58-91 ppb rhodium. Analyses of 21 peridotite samples showed a maximum of 23 ppb platinum, 13 ppb palladium, and <5 ppb rhodium. A small amount of platinum was recovered by gold dredges in the John Day River valley.

COPPER

All prospects for copper near or within the Wilderness are in gabbro of the Canyon Mountain Complex (pl. 1*A* and 1*C*), although thin coatings of oxidized copper minerals occur along fractures in a few chromite prospects. Chalcopyrite is the only primary copper mineral that has been recognized; it occurs with pyrite in lenticular quartz veins. Individual quartz veins reach a maximum of about 2 m in width and 30 m in length. The copper is erratically distributed, and values exceed 1 percent in very few places. The veins are closely associated with basaltic dikes, albite granite, and albite-chlorite-epidote alteration of gabbro along shear zones. Shearing of some basaltic dikes shows that they preceded mineralization and the quartz seems closely related to albite granite. Although small epidotic quartz veins and lenses with albite granite are common in the sheeted dike unit, few contain sulfides. Most of the copper prospects, and all the larger ones, are within 600 m of the contact between gabbro and the sheeted dike unit or the diorite zone in Norton (the West Fork of Pine) Creek. Most of the prospects along the line between Canyon Mountain and Indian Creek Butte, shown in figure 7, are within 300 m of the edge of the gabbro.

The Robert L. vein zone (see "Economic Appraisal") is in the gabbro but within 185-220 m of the contact with the sheeted dike unit. The portal of the adit is 25-30 m above the contact of gabbro and plagiogranite. To the west, 220-250 m along the strike of the zone, the contact swings northward and brings a group of diabasic dikes and albite granite on strike with the gabbro. The copper mineralization appears to have been localized along basaltic dikes and plagiogranite that followed a splinter fault into the gabbro. The gabbro has been highly sheared and altered, and a 3-4 m diabase dike crosses the entrance to the adit. The Crest pit (see fig. 10) is in a chloritic shear zone along the northern edge of a group of 3 or 4 vertical basaltic dikes that aggregate 12-13 m in width. A sample collected across 60 cm of copper-stained sheared chloritic rock contained 0.23 percent copper, a somewhat lower percentage than in some samples collected by the Bureau of Mines. The relatively large size of the Robert L. showings may be attributed to their structural setting.

The cupriferous quartz veins are believed to be related genetically to rocks of the sheeted dike unit, although they occur in gabbro. The quartz veins follow the same general east-west trends as the basaltic dikes and dikes of albite granite within the sheeted unit and are accompanied by much epidote. In other ophiolitic complexes, notably in Cyprus (Constantinou and Govett, 1973) and Newfoundland (Upadhyay and Strong, 1973), massive cupreous pyrite deposits occur in pillow lavas, and apparently were formed by reactions between volcanic emanations and seawater. In Newfoundland, the deposits are found in basalt flows very near the top of basaltic sheeted dikes; none have been found down in the sheeted complexes. The presence of the sheeted dike swarm south of the gabbro in the Canyon Mountain, rather than flows as described by Avé Lallemant (1976, p. 13), indicates that the area is not promising for copper deposits.

GOLD

Gold has been the focus of mining activities in the John Day area except for three wartime periods when chromite brought high prices. The principal lode mines and apparent source of most placer gold in Canyon Creek and the John Day River nearby have been in the vicinity of Little Canyon Mountain, which is centered about 2.5 km northwest of the Strawberry Mountain Wilderness (Thayer, 1956). The gold occurs in pockety quartz-calcite veins; although quartz veins without calcite are more numerous, they are low in grade or barren (Parks and Swartley, 1916, p. 111). The veins occur in carbonatized gabbro, pyroxenite, and serpentinite in Little Canyon Mountain, in carbonatized Paleozoic greenstone at Prairie Diggings (fig. 7), and in much younger (Triassic or Jurassic) greenstone, graywacke, and mudstone at the Miller Mountain mine, 4 km west of the wilderness boundary. Absence of copper from the gold veins, of calcite and gold from copper veins, and lack of carbonate alteration along copper-bearing veins in gabbro imply that the two kinds of veins are not related. The gold mineralization is believed to be of Late Jurassic age; the copper deposits probably formed in Late Permian or Early Triassic time.

The Oregon Wonder adit, near the wilderness boundary north of Strawberry Mountain, was driven into a thick rhyolite flow of the Clarno Formation, ostensibly for gold. Lack of gold in the rhyolite and the conspicuous mine site tend to confirm other information indicating that the mine was used in a promotion scheme (George Ray, oral commun., 1975). Analyses of bleached rhyolite from the same formation and a soil sample from the slope below (samples 71 and 70, table 2), west of Strawberry Creek, showed 0.05 ppm of gold. Brooks and Ramp (1968, p. 51) stated that "Cenozoic rocks in the [Blue Mountain] region are not known to contain lode-gold deposits."

MERCURY

Mercury has been found in at least 15 places in eastern Oregon along a belt that runs northeast between Harney Lake and John Day (Brooks and Bailey, 1969, p. 155). The Canyon Creek mercury mine, just outside the boundary of the study area, is one of a few deposits in Triassic or Jurassic graywacke in Grant County (Brooks, 1963, p. 207-216). The richest ores, according to Brooks, occur in highly shattered rocks and probably were formed at shallow depth. All the mercury mineralization in Oregon most probably is of Tertiary age.

The only mercury occurrence reported in the wilderness is one just below the southern lip of Wildcat Basin, which was discovered in 1927 (Brooks, 1963, p. 216). Three pits were dug about 12 m apart along the contour in shattered and hematite-stained flow-banded rhyolite. No cinnabar was identified, and an analysis of a composite sample (No. 109, table 2) showed no mercury. The prospect is in debris from a landslide that formed Wildcat Basin.

MAGNESITE

Magnesite, $MgCO_3$, used mainly as a refractory, occurs in serpentinized dunite in Byram Gulch, just outside the northwest corner of the wilderness. The dunite weathers to chips that slide easily and form smooth slopes. Only two pits out of several that were visible in 1939 can now be found. Whether the magnesite was formed by weathering or by hydrothermal alteration related to the nearby gold deposits in Little Canyon Mountain is not known. Scattered outcrops of barren bedrock in the area reduce the possibilities for economic deposits. The favorable dunite country rock does not extend into the wilderness.

GEOTHERMAL ENERGY RESOURCES

One hot spring and two warm springs are known around the edges of the Strawberry Range, 3.2-4.8 km from the Strawberry Mountain Wilderness. The largest, Blue Mountain Hot Springs, is just east of the

John Day River and 4.8 km northeast of the wilderness. The springs are believed to be on a branch of the John Day fault (Thayer and others, 1967). The flow of the springs is about 250 liters (l) per minute at about 58 degrees Celsius (°C). The estimated temperature of the thermal aquifer is in the range 99–126°C (Mariner and others, 1974, p. 15).

Limekiln Spring rises along the John Day fault where Indian Creek crosses it, near the west edge of the Prairie City quadrangle. The spring flows at a rate of only a few liters per minute at a temperature of about 21°C. Another warm spring is on Canyon Creek at the former Joaquin Miller resort, 16 km south of John Day. It flows at a rate of a few liters per minute at 39°C (Bowen and Peterson, 1970) from brecciated and altered graywacke below a large landslide.

GEOCHEMICAL INVESTIGATIONS

The Geological Survey collected 198 samples, distributed by rock types, as follows: 51 of stream sediments, 31 of pan concentrates, 21 of peridotite and gabbro, 16 of basaltic dikes from or related to the sheeted dike unit, 24 of plagiogranite and keratophyre, 20 of vein material or mineralized rock, and 35 of Tertiary volcanic rocks. Localities and types of samples are shown in plate 1*A*. The ranges in content of metals of possible economic interest are shown in tables 1 and 2. Considering the normal ranges of elements in the kinds of rocks present in the area and the distribution of rocks within stream drainages, very few geochemical anomalies are indicated. Anomalous values of 1 ppm or more of silver were found in three pan concentrates, and 300 ppm of gold in one sample. Stream sediment samples below known small low-grade prospects in gabbro gave Cu and Zn values somewhat above average.

Stream-sediment samples from all stream basins were collected, as much as possible, from the silt or mud fraction relatively free of organic material. Streams draining parts of the Canyon Mountain Complex were sampled at various intervals, but mostly less than 3 km apart. In fresh volcanic rocks, small drainage basins below well-exposed stratigraphic sections were sampled, but samples were taken at longer intervals along streams running downdip, where individual lava flows can be followed continuously for 1.5 km or more. Representative suites of all the kinds of rocks in the study area were analyzed to determine the normal ranges of metal content and variations related to alteration such as albitization (table 1). All rocks and the minus 80 mesh sieve fractions of stream-sediment samples were analyzed for 30 elements by semiquantitative spectrographic methods. Sixteen samples of vein quartz and wall rocks were analyzed for gold by a combined fire assay and atomic absorption method, and for copper, lead, zinc, and mercury by atomic absorption (table 2).

TABLE 1.—*Summary of analyses for selected metals in samples from the Strawberry Mountain Wilderness and adjacent areas*

[For sample localities, see plate 1A. Semiquantitative spectrographic analyses of stream sediments and rocks by Leung Mei, Norma Rait, E. F. Cooley, R. R. Carlson, and A. A. Chodos. All data in parts per million. Results are reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, which represent approximate midpoints of group data in a geometric scale. The assigned groups for the series will include the quantitative value about 30 percent of the time. The data should not be quoted without stating these limitations. Letter and other symbols: N, not detected; < detected but below limit of determination; > greater than upper limit of determination]

	51 stream sediments			31 pan concentrates			37 peridotite, gabbro, basaltic dikes			24 plagiogranite-keratophyre			35 Tertiary volcanic rocks			Average[1] basalt	Average[1] andesite
	Low	Median	High	Low	Median	High	Low	Median	High	Low	Median	High	Low	Median	High		
Ag	—	—	<0.5	<0.5	1	50	—	—	<0.1	<0.5	<0.5	0.7	—	—	<0.5	0.1	0.13
Au	—	—	<10	N	N	300	—	—	<10	—	—	<10	—	—	<10	.002	.001
Co	10	20	100	15	50	70	5	30	50	<1	7	200	<1	30	50	42	24
Cr	50	200	>6,800	70	500	>10,000	5	100	700	<1	3	500	2	100	700	233	68
Cu	15	50	200	30	70	150	5	30	150	<1	15	700	<1	50	200	78	55
Mn	700	1,500	3,000	300	500	700	500	1,500	2,000	100	700	5,000	200	2,000	3,000	1,338	1,160
Mo	<2	3	7	N	N	N	<2	3	5	<2	<2	3	<2	2	10	1	1.1
Nb	<15	—	20	—	—	<20	<3	50	150	—	—	<15	<15	<15	30	13	4.3
Ni	20	70	>1,000	30	100	1,000	7	50	70	<1	3	150	<1	50	300	126	20
Pb	<1	10	20	<10	15	20	<10	<10	50	<1	7	10	7	10	20	2.2	5.8
Sn	—	—	<20	N	N	N	<7	<7	20	—	—	<15	—	—	<15	1.2	1.2
Zn	70	100	200	N	<200	500	<22	70	200	<15	50	150	50	150	200	92	72.5

[1] Data from Wedepohl (1975, p. 169) for comparison.

TABLE 2.—*Analyses of vein and altered rocks from the Strawberry Mountain Wilderness and adjacent areas.*

[For sample localities, see plate 1*A*. Analyses by R. Moore and J. W. Budinsky. All data in parts per million. Cu, Pb, Zn, and Hg determined by atomic absorption. Au determined by combined fire assay and atomic absorption. Symbols: N, not detected; < detected but below limit of determination. Au and Hg looked for in all samples but found at detection limits in only two samples noted]

Sample Locality No.	Cu	Pb	Zn	Description of sample
7	140	<20	170	Quartz vein between gabbro and diabase dike
9	83	<20	67	Quartz ribbons in sheared gabbro
9	<10	<20	<10	Sheared vein quartz in gabbro
21	<10	<20	<10	Quartz vein, 1.2 m wide
24	920	<20	53	Limonitic sheared gabbro or diabase
24	150	<20	<10	Massive quartz vein 3-4 m wide
25	62	<20	84	Quartz vein, scattered small pyrite grains
25	63	<20	230	Sheared chloritic gabbro wall rock
44	230	<20	<10	Pyritic quartz vein in gabbro
57	14	<20	48	Iron-stained platy rhyolite; Oregon Wonder adit
[1]70	34	<20	100	Soil sample below Samples 85, 86
71	<10	<20	49	Iron-stained rhyolite (Clarno)
72	13	<20	80	Bleached, Fe-stained andesite
[2]109	4.4	<20	34	Hematite-veined rhyolite from Hg prospect
120	2,300	<20	48	Limonitic sheared zone 1.2 m wide in gabbro
121	85	<20	100	Epidote-veined basaltic dike Dump of Robert L. adit
124	53	<20	12	Pyritic epidote vein; 0.6-1 m wide
126	34	<20	13	2 quartz veins, each 1 m wide, in sheeted dike complex
190	290	<20	11	2 m quartz vein in gabbro
191	840	<20	780	Vein quartz from dump Blue Rock adit

[1] Au present but below limit of determination (<0.05)
[2] Hg present but below limit of determination (<0.01)

GEOCHEMICAL PATTERNS

The distribution of metals in samples of stream sediments and pan concentrates, naturally, reflects the distribution of bedrock. Samples from streams flowing over peridotite and olivine gabbro consistently are rich in chromium, nickel, cobalt, and platinum. Gabbro, pre-Tertiary basaltic dikes, and Tertiary volcanic rocks show similar ranges in copper content and have an apparent normal maximum of about 80 ppm. Tertiary basalt and andesite flows contain about twice as much zinc as the gabbro; the basalt and andesite contain 100 to 200 ppm zinc, and gabbro contains 50 to 100 ppm. In plagiogranite and keratophyre, the normal copper content does not exceed 30 or 40 ppm, but zinc shows a wide scatter from <15 ppm to about 120 ppm. Lead content reaches about 10 ppm in rocks of the sheeted dike unit (pre-Tertiary basaltic dikes, plagiogranite and keratophyre), about 15 ppm in gabbro, and about 20 ppm in Tertiary volcanic rocks.

The plagiogranite and keratophyre of the Canyon Mountain Complex are deficient not only in potassium, but also in the elements commonly associated with true granitic rocks, namely: antimony, arsenic, bismuth, boron, beryllium, the rare earths, molybdenum, niobium, tantalum, thorium, uranium, tungsten, and zirconium. Only 5 of the 83 samples of stream sediments and pan concentrates contained more than 300 ppm zirconium; the maximum amount was 420 ppm.

GOLD, SILVER, AND PLATINUM METALS

Gold above the determination limit of 0.5 ppm was found in only one pan concentrate; 300 ppm was found in sample No. 1, taken in Little Pine Creek. Above the point sampled, Little Pine Creek borders on the gold-bearing rocks in Little Canyon Mountain, and the stream basin includes some prospects. The sample was collected primarily to determine whether platinum metals are present. Most of the drainage area is outside the wilderness.

The gold-bearing sample from Little Pine Creek also assayed 50 ppm silver. Sample 4 contained 1 ppm silver, and sample 33, 1.5 ppm. Sample 4 was panned from Byram Gulch, whose northern edge skirts the base of Little Canyon Mountain. Sample 3 contained 300 ppm Zn as well as the silver; it is from the East Fork of Pine Creek, which heads near two prospects (fig. 7, Nos. 18, 19).

Analyses of pan concentrates for platinum group metals by combined fire assay and spectrographic methods indicate rather wide variation between stream drainages within peridotite, but low content overall. A magnetic fraction of sample 41, collected from the small creek northwest of the Ray mine, indicated 3 ppm of platinum and 0.8 ppm of palladium, but a similar split of sample 40 from the head of Little Indian Creek, just to the west, gave <0.01 of ppm of Pt and 0.016 ppm Pd. The magnetic fraction of sample 4, from Byram Gulch, yielded 0.3 ppm Pt, 0.2 ppm Pd, and 0.01 ppm Rh, compared with 0.07 ppm Pt and 0.07 Pd from sample 1. The two samples are from streams that drain contiguous areas of peridotite and gabbro, although Byram Gulch drains a somewhat larger proportion of gabbro than Little Pine Creek. Gabbro appears to contain only small amounts of platinum-group

TABLE 3.—*Semiquantitative spectrographic analysis of panned concentrates*

[For sample localities, see plate 1A. Analysis by R. R. Carlson, E. F. Cooley. Results are reported to the nearest scale. The assigned groups for the series will include the quantitative value about 30 percent of the time. The data G, greater than amount shown; L, detected, but below limit of determination; N, not detected]

	(percent)		(ppm)						
Sample No.	Fe (.05)	Ti (0.002)	Mn (10)	Co (5)	Cr (10)	Cu (5)	Mo (5)	Ni (5)	Pb (10)
1	30	.5	700	70	G7,000	100	N	500	L
3	30	.5	500	70	G7,000	50	N	500	L
4	30	.5	700	70	G7,000	70	N	300	L
32	30	.7	700	70	7,000	70	N	150	L
33	15	.2	500	70	G7,000	30	N	300	L
40	20	.5	700	70	G10,000	50	N	500	L
41	15	.15	500	50	G10,000	30	N	1,000	L
49	15	.3	700	70	G10,000	70	N	500	L
50	20	1.5	700	70	500	100	N	100	L
55	10	1	700	50	G10,000	70	N	300	L
66	10	1	300	30	500	70	N	50	L
67	7	1	500	15	70	50	N	30	L
68	15	1.5	700	30	150	70	N	50	20
69	15	.7	700	50	150	70	N	70	15
70				SEE TABLE 2					
84	15	1.5	700	50	300	100	N	100	L
93	15	1	700	50	150	70	N	100	L
94	15	.7	700	50	300	70	N	100	L
95	10	1	500	30	100	70	N	70	L
97	20	1	700	50	300	150	N	100	15
105	15	1	700	50	300	50	N	70	15
107	15	1	700	50	300	70	N	100	15
108	20	1.5	700	50	200	70	N	70	L
128	10	.5	300	30	500	50	N	30	L
146	7	.7	300	20	300	30	N	30	L
155	20	.7	700	50	700	70	N	70	L
156	7	1	500	30	200	50	N	70	L
162	20	1	700	70	2,000	70	N	100	L
180	10	.5	700	50	500	70	N	70	L
189	7	.5	500	30	500	70	N	100	L
192	7	.5	500	30	1,000	50	N	100	L

1/ Listed in decreasing order of abundance. Letter symbols same as on gabbro; Ts, Strawberry Volcanics, undifferentiated.

from the Strawberry Mountain Wilderness study area, Grant County, Oreg.

number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, which represent approximate midpoints of group data in a geometric should not be quoted without stating these limitations. Letter and other symbols: (), lower limit of determination;

Zn (200)	Zr (10)	Comments	Rocks in stream basin 1/
L	20	Ag 50 ppm, Au 300 ppm	um, gb
L	20		um
L	10	Ag 1 ppm	um, gb
L	30		gb, um, qd (bd)
300	L	Ag 1.5 ppm	gb, um
500	30		um
500	20	3 ppm pt, 0.8 ppm Pd in magnetic fraction	um
L	30		gb, um
N	70		Ts, gb, Tc
300	70		um, Ts, gb(Tc)
L	50		Ts, Tc
L	50		Ts, Tc
500	100		Ts, Tc
L	70		Tc
L	150		Ts, Tc
L	150		Ts
L	50		Ts
L	70		Ts
L	70		Ts
L	50		Ts, Tsw
L	70		Tsw, Ts
L	70		Tsw, Tc, Ts
L	20		sdu, gb
N	30		sdu, Ts, gb, Tc
L	50		sdu, Ts, gb, Tc
L	100		Ts
L	300		sdu, gb
N	70		sdu, Ts, gb, Tc
N	15		gb, (um, qd)
L	50		sdu, gb, qd, um

geologic map (pl. 1A) except: um, ultramafic rocks; bd, basaltic dikes in

TABLE 4.—*Semiquantitative spectrographic analyses of stream-sediment samples and rocks from the Strawberry Mountain Wilderness study area, Grant County, Oreg.*

[For sample localities, see plate 1*A*. Analyses by Leung Mei. Results are reported to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, which represent approximate midpoints of group data in a geometric scale. The assigned groups for the series will include the quantitative value about 30 percent of the time. The data should not be quoted without stating these limitations. Letters and other symbol: (), lower limit of determination; G, greater than amount shown; L, detected, but below limit of determination; N, not detected]

STREAM SEDIMENTS

Sample No.	(percent) Fe (0.005)	Ti (0.0005)	(ppm) Mn (1)	Co (1)	Cr (1)	Cu (1)	Mo (2)	Ni (1)	Pb (1)	Zn (15)	Zr (5)	Rocks in stream basin 1/
2	5	.5	2,000	70	7,000	30	L	G1,000	20	100	100	um, gb, qd
5	5	.3	2,000	50	5,000	50	L	300	15	70	100	gb, um
6	5	.3	1,000	30	700	100	3	150	7	70	100	gb
20	7	.3	2,000	50	1,500	200	L	200	20	100	100	gb; below tunnels at head of Norton Fork of Pine Creek
26	5	.5	1,000	20	200	30	3	50	10	70	100	gb, bd, qd
28	5	.4	1,500	20	100	30	3	30	10	70	150	gb, bd
30	3	.3	2,000	30	1,000	50	3	200	15	100	100	gb, qd, bd
31	3	.5	2,000	30	500	100	3	150	15	70	100	gb, um
35	5	.3	2,000	70	7,000	70	L	500	15	100	100	gb, um
36	3	.3	1,500	30	7,000	50	L	300	20	100	200	gb, um
37	5	.3	1,500	100	G7,000	30	L	G1,000	L	100	100	gb, um
47	10	.2	2,000	100	G7,000	70	L	G1,000	L	200	50	um, gb
48	5	.3	2,000	30	2,000	50	L	200	10	100	100	gb, um (bd)
52	5	.5	1,000	15	200	30	L	100	10	70	150	Tc, gb, Ts

53	5	1	1,500	20	100	30	3	70	15	100	300	Ts, Tsw, Tc
54	5	.7	1,500	20	100	50	2	50	15	100	200	Ts
56	7	1	2,000	20	100	20	5	50	20	150	200	Ts, Tc
62	7	1	1,500	20	100	30	3	50	15	100	200	Ts, Tc
63	5	.7	1,500	20	100	50	5	50	15	100	200	Ts
64	5	1.5	1,500	20	100	50	5	3	15	100	200	Ts, Tsi
65	10	2	2,000	30	500	30	3	100	10	150	200	Ts
85	5	.7	1,000	10	100	30	L	50	7	100	200	Ts, Tc
86	5	.7	1,500	20	100	30	5	70	15	100	300	Ts (Tc)
87	3	.7	1,000	15	70	30	3	30	15	100	300	Ts
88	10	1	2,000	20	200	50	3	70	15	200	300	Ts
89	10	1.5	2,000	30	150	50	7	70	20	150	300	Ts
90	5	1	1,500	20	150	50	L	70	10	150	300	Ts
91	5	1	1,000	20	100	50	3	50	15	100	300	Ts
92	5	1	1,000	20	100	30	5	70	15	100	300	Ts
96	5	1	1,500	20	100	30	5	50	15	100	200	Ts
98	5	1	2,000	30	100	50	5	70	15	100	200	Ts, Tsi, Tsp
103	5	1	1,500	15	50	20	L	20	15	70	200	Ts, Tsi
106	3	.7	700	15	300	15	5	70	15	100	300	Tsw, Ts
114	5	.5	2,000	15	100	20	5	30	10	100	200	Tc
122	10	.5	2,000	50	300	50	5	100	10	100	100	bd, gb, qd; below Robert L. prospects
127	5	.7	1,000	20	200	30	3	50	15	70	100	bd, gb, qd

TABLE 4.—*Semiquantitative spectrographic analyses of stream-sediment samples and rocks from the Strawberry Mountain Wilderness study area, Grant County, Oreg.*—Continued

129	5	.7	1,000	10	100	20	3	20	10	100	300	Ts, Tc, (sdu)
130	5	1	1,500	15	100	30	3	50	15	150	300	Ts, sdu, Tc
143	5	1	2,000	30	200	50	2	50	10	100	150	sdu, gb, qd
144	5	.7	2,000	30	300	50	3	70	10	100	100	sdu, gb, qd
147	5	1	1,500	20	100	30	3	50	10	100	150	sdu, gb
149	10	1.5	2,000	30	200	30	3	100	15	150	300	Tc
150	5	1.5	2,000	20	100	30	2	50	15	150	300	Ts
154	3	1	1,000	15	200	30	L	30	10	70	500	Ts, Tc
161	5	.5	700	15	150	50	3	70	7	100	200	Tc, Ts
164	5	.5	1,500	20	100	30	3	50	10	100	100	sdu, gb
166	5	.5	1,500	15	100	15	3	30	7	70	150	sdu, gb
176	5	.7	2,000	30	500	50	5	100	10	100	100	sdu, gb, qd
181	5	.7	1,500	20	500	50	3	100	10	100	200	Ts, Tc, sdu
183	10	1.5	2,000	20	700	50	L	100	10	100	300	Ts, Tc
188	5	.5	2,000	50	500	100	7	150	7	100	50	gb

1/ Listed in decreasing order of abundance. Letter symbols same as on geologic map (pl. 1A) except: um, ultramafic rocks; bd, basaltic dikes in gabbro; Ts, Strawberry Volcanics, undifferentiated.

TERTIARY VOLCANIC ROCKS

	(percent)		(ppm)									
Sample	Fe (0.005)	Ti (0.0005)	Mn (1)	Co (1)	Cr (1)	Cu (1)	Mo (2)	Ni (1)	Pb (1)	Zn (15)	Zr (5)	Rock Type
58	10	1.5	3000	20	5	7	5	7	20	200	500	Tc andesite
59	5	.5	1000	L	3	5	9	2	15	200	500	Tc andesite
60	10	1.5	3000	50	100	30	2	100	15	100	200	Tss olivine basalt
61	10	1.5	3000	30	150	50	3	50	15	100	300	Ts andesite
73	3	.5	2000	1.5	1.5	1.	5	2	10	100	500	Ts andesite
74	10	2.	3000	30	150	30	3	50	10	100	300	Tc andesite
75	7	1.	2000	30	200	70	L	150	10	100	300	Ts andesite
76	10	1.	2000	30	200	50	L	100	7	100	300	Tss olivine basalt
77	10	1.	3000	30	300	30	L	100	10	100	150	Tss olivine basalt
78	5	.7	1500	20	100	70	3	70	10	100	300	Ts andesite
79	7.	1.5	2000	20	50	30	3	30	7	100	500	Tss andesite
80	10	1.5	3000	30	70	50	L	50	7	100	500	Ts andesite
81	5	1.	2000	20	150	50	L	100	10	100	300	Ts andesite
82	7	1.5	2000	30	300	30	3	150	7	100	300	Tss basalt
83	5	1.0	1500	20	100	50	L	70	7	100	300	Tss olivine basalt
99	10	1.5	3000	30	100	50	3	70	20	150	300	Tsp olivine basalt
100	10	1.5	3000	30	100	50	5	50	15	150	500	Ts basalt
101	5	1.	1500	20	50	50	L	30	10	100	300	Tsi andesite
102	7	1.5	3000	30	100	50	L	50	10	100	300	Ts andesite
104	10	1.5	2000	50	150	50	L	150	10	100	200	Ts andesite

TABLE 4.—*Semiquantitative spectrographic analyses of stream-sediment samples and rocks from the Strawberry Mountain Wilderness study area, Grant County, Oreg.*—Continued

110	1.5	.3	500	2	2	3	2	2	10	100	1000	Ts andesite dike
111	7	1.5	2000	30	150	30	L	20	15	100	200	Ts basalt
112	5	.7	1500	20	150	50	L	100	10	100	200	Ts andesite
113	1	.3	200	1.5	5	L	3	3	10	100	700	Tsw rhyolite
115	10	1.	2000	30	150	20	L	70	7	100	200	Ts andesite
116	5.	.7	1500	5	3	2	5	5	10	150	700	Tc rhyolite
117	10	1.5	3000	30	70	30	5	70	15	200	300	Tc andesite
151	10	1.	2000	50	70	50	L	70	15	150	200	Tc olivine basalt
152	10	2.	3000	30	70	20	3	20	10	200	300	Ts andesite
153	10	1	2000	50	500	70	L	200	15	100	150	Ts andesite
157	7	1.	3000	3	2	2	10	L	20	200	500	Ts andesite
158	10	1.5	3000	30	50	70	3	50	10	200	300	Ts andesite
159	3.	.5	1000	10	30	30	L	20	10	50	300	Tc andesite
160	7	1.5	2000	50	500	50	L	150	15	100	300	Tc olivine basalt
182	7	1.	2000	50	700	70	L	300	20	150	300	Tc olivine basalt

QUARTZ DIORITE, ALBITE GRANITE, AND KERATOPHYRE

	(percent)		(ppm)									
Sample	Fe (0.005)	Ti (0.0005)	Mn (1)	Co (1)	Cr (1)	Cu (1)	Mo (2)	Ni (1)	Pb (1)	Zn (15)	Zr (5)	Rock type
18	5	.3	2000	20	300	7	L	200	7	100	30	albite granite
22	3	.2	700	5	1	L	L	3	7	30	10	albite granite

23	5	.3	1000	10	50	30	3	17	10	70	50	keratophyre
27	5	.3	500	3	1.5	30	2	2	7	100	10	albite granite
46	5	.2	1000	7	15	15	3	7	L	70	70	albite granite
51	1	.05	100	L	L	L	L	L	3	20	50	albite granite
125	10	1	3000	30	30	50	L	20	10	150	150	quartz diorite
131	3	.2	300	10	L	700	L	3	7	L	500	albite granite
132	10	1	4000	30	500	20	3	100	5	100	30	quartz diorite
133	2	.1	700	1.5	2	20	L	5	5	30	100	keratophyre
135	7	.5	1500	10	5	15	3	5	7	70	30	albite granite
142	2	.1	300	2	L	15	L	2	3	L	150	keratophyre
145	1	.2	300	2	L	10	L	2	L	L	150	albite granite
148	3	.2	500	1	L	L	L	2	5	30	300	keratophyre
163	3	.3	700	.3	L	15	L	1	3	70	200	keratophyre
165	3	.3	1000	2	2	.3	L	2	5	70	200	keratophyre
167	10	.7	3000	30	50	15	L	30	10	100	70	quartz diorite
168	3	.3	700	10	2	6	L	3	5	50	100	albite granite
170	7	.7	3000	30	30	300	L	30	10	100	70	quartz diorite
172	2	.2	700	5	3	200	L	3	10	20	200	albite granite
174	2	.1	500	1.5	L	1	L	1	L	L	300	albite granite
175	1.5	.15	500	5	10	10	L	7	<10	< 22	150	keratophyre
177	2	.1	200	2		15	L	5	3	L	100	albite granite
179	5	.3	1500	7	3	7	L	3	10	30	20	keratophyre

TABLE 4.—*Semiquantitative spectrographic analyses of stream-sediment samples and rocks from the Strawberry Mountain Wilderness study area, Grant County, Oreg.*—Continued

ULTRAMAFIC AND GABBROIC ROCKS

Sample No.	Fe (percent) (0.005)	Ti (percent) (0.0005)	Mn (ppm) (1)	Co (ppm) (1)	Cr (ppm) (1)	Cu (ppm) (1)	Mo (ppm) (2)	Ni (ppm) (1)	Pb (ppm) (1)	Zn (ppm) (15)	Zr (ppm) (5)	Rock type
10	10	.2	2,000	100	3,000	50	5	1,500	15	100	10	Peridotite
11	15	.5	2,000	100	1,500	100	5	1,000	15	100	20	"
12	7	.5	1,500	20	50	30	3	20	10	100	20	Epidiorite 2/
13	7	.5	1,500	30	700	70	3	150	15	70	20	"
15	3	.3	1,000	20	300	10	3	150	< 10	< 22	150	"
17	15	.7	1,500	50	5	20	5	20	15	100	20	"
19	2	.03	700	30	200	30	3	70	< 10	70	5	Norite (Gabbro)
29	5	.07	1,000	30	150	20	5	70	60	70	7	Epidiorite
34	10	.2	2,000	100	2,000	100	5	700	< 10	70	20	Peridotite
42	7	.3	1,500	50	300	20	5	100	< 10	50	15	Epidiorite
45	2	.2	500	5	7	20	L	7	< 10	50	70	Gabbro
118	10	.7	2,000	50	200	70	5	100	15	100	30	"
119	7	.1	1,000	50	150	70	5	50	< 10	70	10	"
134	6	.3	1,500	30	10	50	2	20	< 10	100	20	Epidiorite
136	10	.7	2,000	50	15	70	5	30	10	100	30	"
137	7	.3	1,500	30	200	50	5	100	< 10	100	20	"
169	7	.3	1,500	20	15	100	3	20	10	50	50	"
184	7	.3	1,500	30	200	15	3	70	< 10	50	30	"

185	7	.3	1,500	30	150	50	3	50	< 10	50	50	"
186	3	.05	700	20	500	30	3	70	< 10	70	7	"
187	2	.1	700	20	700	7	2	100	< 10	70	20	"
					PRE-TERTIARY BASALTIC DIKES							
8	10	1	2,000	30	70	70	3	30	10	100	300	Young 3/ 4/
14	2	.2	500	15	150	20	L	100	< 10	30	200	Old, amph
16	7	.7	1,500	30	70	100	3	30	< 10	100	100	Young
38	7	.7	1,500	30	150	100	3	50	< 10	100	200	Old, amph
39	7	.5	1,500	30	100	70	3	50	< 10	100	50	Old
43	7	1	2,000	50	100	70	3	50	< 10	150	150	Old, amph
123	20	.7	2,000	50	10	70	5	30	< 10	150	50	Old
138	7	.7	1,500	30	10	30	3	15	< 10	150	70	Young
139	7	.7	2,000	30	400	15	3	100	< 10	200	50	Young
140	7	.5	1,500	30	50	30	3	30	< 10	70	100	Old
141	7	1	2,000	30	300	30	3	100	< 10	100	200	Old
168	10	.5	2,000	30	10	7	3	15	< 10	100	70	Old
171	7	.7	1,500	30	100	30	3	50	< 10	100	150	Old, amph
173	5	.5	1,500	30	200	70	3	30	< 10	150	100	Young
178	7	.7	2,000	30	7	3	3	10	< 10	70	50	Young
184	7	.7	1,500	30	200	70	2	70	< 10	70	100	Old

2/ Hornblendic gabbro, altered by quartz diorite or albite granite; see text.

3/ Basaltic dike younger than quartz diorite or albite granite.

4/ Basaltic dike older than quartz diorite or albite granite; amph., dike largely or entirely altered to foliated amphibolite.

metals; the magnetic fraction of sample 189, from the mouth of Sheep Gulch, assayed 0.015 ppm Pd and 0.01 ppm Au; other platinum metals were not detected.

COPPER, LEAD, AND ZINC

Copper values as high as about 80 ppm in fresh Tertiary basalt and andesite and in gabbro and pre-Tertiary basaltic dikes are consistent with Wedepohl's (1975) figure of 78 ppm in average basalt, and are considered normal. Two samples of diabase from the sheeted dike unit that contain 100 ppm Cu are of petrologic interest only. Five stream sediments that assayed between 80 and 90 ppm Cu were all from areas of gabbro and peridotite. One stream sample (No. 20) containing more than 200 ppm Cu came from gabbro at the head of Dean Creek, about midway between the dioritic rocks in Dog Creek and Norton (the west fork of Pine) Creek.

Zinc content ranging from 50-200 ppm in fresh Tertiary basalt and pre-Tertiary basaltic dikes averages out to about Wedepohl's (1975) mean of 100 ppm Zn in tholeiitic basalt, and appears to be primary. The highest value found in gabbro was about 100 ppm, and appears normal. Sediment samples containing 150-200 ppm Zn from streams draining the Strawberry Volcanics are consistent with the content of the flows, but samples that contain more than 100 ppm from areas of gabbro could be considered anomalous. A sample (122) collected below the Robert L. prospects assayed 100-150 ppm Zn, and one (47) from the West Fork of Indian Creek, which drains peridotite and gabbro, contained 150-200 ppm Zn.

Lead content of less than 20 ppm in all samples shows that the mineralization associated with gabbro and rocks of the sheeted dike unit is limited essentially to quartz and copper.

CONCLUSIONS

Geochemical sampling of rocks and stream sediments confirms other field evidence that there is little likelihood of finding economically significant mineral deposits within the Strawberry Mountain Wilderness study area. Two relatively small chromite deposits, the Celebration and Ray (Tip Top), and six or eight prospects on lenses of subeconomic size are known within the study area. We believe that the probability of finding more than a few thousand tons of milling-grade chromite ore is very small. The nickel content and probable tenor of platinum-group metals in the small areas of peridotite within the study area are far below present economic recovery limits.

Contents of copper, lead, and zinc in stream samples are consistent with those of normal bedrocks: maximum values in both kinds of samples are mostly less than 100 ppm copper, 20 ppm lead, and 200 ppm zinc.

Quartz and epidote-bearing veins associated with basaltic dikes and plagiogranite in gabbro are lenticular and spotty; values of 0.5 percent or more copper are limited to veins a few decimeters or meters wide. These veins carry practically no gold or silver. Gold veins north and west of the wilderness area are associated with quartz and calcite, contain very little copper, and have not been recognized in the wilderness or proposed additions. They probably are younger than the copper-bearing veins in the wilderness. Although mercury has been mined from pre-Tertiary graywacke 0.8 km outside the study area, none was found in prospect pits in rhyolite below Wildcat Basin. Those pits, moreover, appear to be in a large landslide. Small magnesite veins in Byram Gulch, just outside the wilderness, are restricted to dunite that does not extend across the wilderness boundary.

Most of the Tertiary volcanic rocks that cover 70 percent of the study area are fresh and unmineralized. Bleached and altered rhyolite contained no gold; no lode gold deposits are known in Tertiary rocks of the Blue Mountain region.

No warm or hot springs are known within about 3 km of the study area; two of those outside the area are on the John Day fault system. There is no evidence of volcanic activity within the wilderness since Miocene time, 10-12 million years ago.

GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAP

By JAMES E. CASE and THOMAS P. THAYER, U.S. GEOLOGICAL SURVEY

An aeromagnetic survey of the Strawberry Mountain Wilderness and adjacent areas was made in 1975 as part of a larger regional study. North-south flight lines were spaced about 1.6 km apart, at an elevation of about 2,900 m above sea level. We removed a regional magnetic field of 4.25 gammas/km north and 2.66 gammas/km east from the observed magnetic data by using the international geomagnetic reference field (IGRF) updated to July 1975. The digital magnetic data were computer-contoured on a grid interval of about 0.8 km (pl. *1B*). Position control was provided by strip-film photography.

Two broad groups of aeromagnetic anomalies are present: one group of magnetic highs, in the northern part of the area, is caused by peridotite and gabbro of the Canyon Mountain Complex, and a second group of ovoid highs and lows, in the eastern part of the area, is caused by the Strawberry Volcanics. Several elongate zones of steepened magnetic gradient are related to concealed major geologic contacts.

Magnetic susceptibilities of peridotite, gabbro, and volcanic rocks vary greatly. Peridotite and gabbro commonly have susceptibilities of 1×10^{-3} to 3×10^{-3}emu (electromagnetic units)/cm^3, but they can be as high as 5×10^{-3}emu/cm^3 (Lindsley and others, 1966). Fresh dunite and peridotite commonly are less magnetic than serpentinite, but may have susceptibilities as high as 4×10^{-3}emu/cm^3. Magnetic susceptibility of gabbro varies with the proportion of magnetite; destruction of magnetite during alteration of gabbro to epidiorite on a large scale along the southern border of the gabbro may have a major effect on local magnetic fields. Tertiary volcanic rocks likewise show a wide range of magnetization. Although basalts tend to be more highly magnetic than andesites or rhyolites and have susceptibilities of about 2×10^{-3} to 4×10^{-3}emu/cm^3, many andesites have susceptibilities that range from 1×10^{-3} to 3×10^{-3}emu/cm^3. Field tests by T. L. Robyn (oral commun., 1976) showed that reversed magnetization is very common, not only in Tertiary volcanic rocks, but in basaltic dikes of the sheeted dike unit as well.

ANOMALIES OVER THE CANYON MOUNTAIN COMPLEX

Two of the more prominent positive anomalies shown in plate 1*B* (A, 306 and B, 255) are superimposed on a general high somewhat north of the topographic crest of Canyon Mountain, over the contact between gabbro and peridotite. The axis of the general high, moreover, approximately follows the contact as mapped. Analysis of a two-dimensional model across anomaly A(306) indicates that magnetite-rich rock at depth must extend well south of the exposed contact between the peridotite and gabbro, as discussed below.

We have attemped to model the general magnetic anomaly over the Canyon Mountain Complex along the line of cross section *A–A′* (pl. 1*B*), to the north edge of the peridotite and serpentinite (fig. 6). The profile extends about 5 km north of the wilderness area to the John Day fault. We have assumed that the anomaly is two-dimensional and that the topography can be represented by simplified planar surfaces that coincide with the upper parts of the model. It is clear from the "observed" magnetic map and profile that deep-seated geologic units have imposed a major south-sloping regional magnetic field on the earth's total field. Although regional in extent, this anomaly is too small to have been removed by the subtraction of the (IGRF). A huge positive anomaly just north of the area, having values as great as +750 gammas, partly contributes to the south-sloping field. In order to isolate the specific anomaly caused by the Canyon Mountain Complex, one must assume a regional field configuration. Because of geologic complexity in the study area, we have chosen the simplest possible planar field, one having a gradient of about 27 gammas/km, decreasing southward. Subtraction of this field leaves a maximum residual anomaly of about 350 gammas at a point just south of the mapped contact between gabbro and peridotite (fig. 6).

Successive trials were made to reproduce the anomaly by assigning a range of geologically reasonable magnetizations to the peridotite and

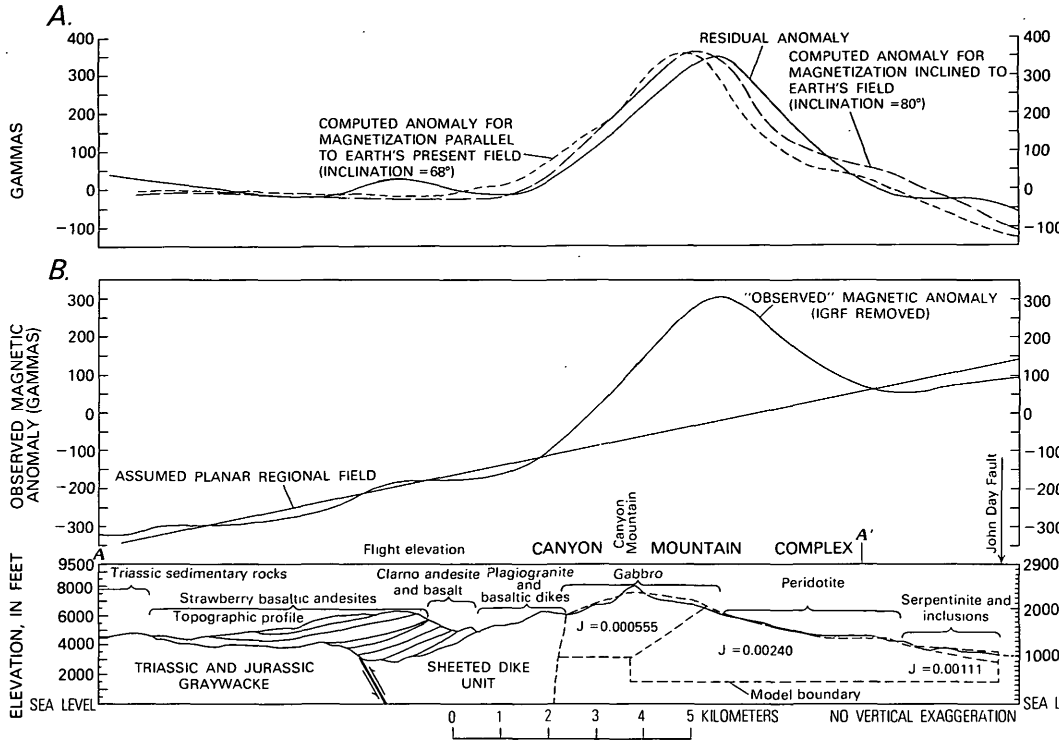


FIGURE 6.—Magnetic profiles along section *A-A'* and geologic interpretation of the aeromagnetic anomaly over the Canyon Mountain Complex. For location of section see Plate 1*B*. IGRF, international geomagnetic reference field; J, magnetization in electromagnetic units per cubic centimeter.

gabbro. The magnetic map (pl. 1*B*) shows that rocks in the sheeted dike unit are weakly magnetic,compared with peridotite and gabbro. Even though the Tertiary volcanic rocks and the sheeted dike terrain probably have low levels of magnetization, for this analysis we have assumed that they are unmagnetized. A magnetization of 0.555×10^{-3}emu/cm^3 was assumed for most of the gabbro mass; this corresponds to a susceptibility of 1×10^{-3}emu/cm^3, if its magnetization is induced entirely by the Earth's present field. The peridotite and the gabbro near the contact with peridotite were assumed to have a magnetization of 2.4×10^{-3}emu/cm^3, corresponding to an apparent susceptibility of about 4.3×10^{-3}emu/cm^3, which we believe is a reasonable upper limit for normal peridotite. The serpentinite block at the northern end of the profile was assigned a magnetization of 1.11×10^{-3}emu/cm^3, corresponding to a susceptibility of 2×10^{-3}emu/cm^3.

If the magnetization is assumed to be induced entirely by the Earth's present field at an inclination of 68°, declination of 19°, and intensity of 55,500 gammas, the model shown produces an anomaly (short-dashed on fig. 6*A*) of about the same amplitude as the residual anomaly. The gradient on the south flank of the computed anomaly is approximately parallel to that of the residual anomaly. However, discrepancies of more than 100 gammas occur between computed and residual anomalies on the north flank, and the peak computed anomaly lies at least 0.5 km south of the peak residual anomaly.

These discrepancies would be lessened considerably if the rock units were magnetized in a direction somewhat steeper than the Earth's present field, which might be true if a large component of remanent magnetization is present. For example, if the magnetization is inclined at 80°, rather than 68°, the computed profile (long-dashed on fig. 6*A*) agrees more closely with the residual anomaly, and especially with the position of the peak anomaly. A better fit could be achieved by making small changes in configuration or magnetization of the anomalous bodies. Considering the uncertainties in the analysis—configuration of regional field, real values of magnetization, inclination of magnetization, and dimensions and depths of the various rock units—we feel that modeling to achieve a perfect fit between residual and computed anomalies is not warranted.

Several conclusions follow from the analysis, however. First, the peridotite is strongly magnetic, perhaps more so than average peridotite. Second, the contact of strongly magnetic material appears to dip southward beneath Canyon Mountain. Third, if the assumed magnetizations are approximately correct, the Canyon Mountain Complex may bottom at relatively shallow depth—perhaps as high as 500 m above sea level.

Anomalies C(H134) and D(H149) are over, and are presumed to be caused by relatively large masses of pyroxene-rich peridotite that probably widen downward in a zone of mixed or interfolded peridotite and gabbro. Variability in magnetite content of partly serpentinized peridotite is suggested by the relative magnetic low or bench area (anomaly E) west of anomaly F(L38). There, the magnetic field is 150–200 gammas lower than at anomaly B, despite higher topography on the northeast shoulder of Baldy Mountain. Magnetic low F may be in part an effect of low terrain, and low G(L5) probably is due to a combination of low topography and alteration in gabbro.

Magnetic high H(H57) is on a gabbro ridge near the contact with Clarno Formation. The gradients on the flanks of the anomaly seem consistent with the configuration of the unconformity on gabbro that slopes south and east under andesite and rhyolite. Magnetic highs I and J(H107) are over volcanic rocks east of the Indian Creek fault, and are near or on the John Day and Onion Creek faults, respectively (see pl. 1*B*). Low gradients on the flanks of the anomalies and lack of correlation with topographic highs suggest buried peridotite under the Clarno Formation in the raised blocks.

A prominent negative anomaly, K(L86), occurs over gabbro of the Little Canyon Mountain mass in the northwest part of the map. Although the low coincides partly with the valley of Canyon Creek, it probably is caused by low or reversed magnetization of large basaltic dikes and shearing and alteration of the gabbro.

ANOMALIES OVER STRAWBERRY VOLCANICS

The complex "birdseye" pattern of magnetic anomalies over the Strawberry Mountain block is typical of patterns over Tertiary volcanic rocks in many parts of the western United States. These rocks have both normal and reversed remanent magnetization, and Q-values (the ratios of remanent to induced magnetization) tend to be high. Moreover, magnetite content commonly is rather variable in most extrusive volcanic rocks whether they are mafic, intermediate, or silicic. Steep gradients on the flanks of most of the anomalies indicate relatively shallow sources.

Reverse magnetization is clearly indicated by anomaly L(L245), east of Strawberry Mountain, and by anomaly M(L226), which do not correlate well with topography. More striking is the negative anomaly N(L177), which is over a topographic ridge. Anomalies 0(L207), P(L335), Q(L418), R(L372), S(L221), and T(L252) are caused partly by low topography, but also may be related to reversely magnetized rocks. Arcuate positive anomaly U(H192), on the other hand, occurs over topographically low areas south of Indian Spring Butte and Rabbit Ears; and the central part overlies the southern part of the Strawberry plug. Positive anomaly V(H8) is over the valley of Graham Creek, east of Slide Mountain, and anomaly W(H444) appears unrelated to topography. To determine the relations of these anomalies to the stratigraphy of the volcanic sequence will require detailed paleomagnetic investigations.

STEEPENED GRADIENTS

Two zones of steepened magnetic gradient in the southwest part of the area are associated with major geologic contacts. The northerly zone, labelled *AA* on plate 1*B*, occurs near the contact between the gabbro and sheeted dike unit. The gabbro is more magnetic than the sheeted dike unit, but whether the dikes differ in magnetization from the volcanic rocks farther south cannot be determined from the magnetic map alone. A second zone of steepened magnetic gradient, *BB*, lies south of a concealed projected extension of the Aldrich Mountain fault. The zone of steepened gradient strikes approximately parallel to the fault in the western part of the area, but diverges to a more southerly trend near lat.44°15′ N. Because the geologic relations to the west indicate that the Aldrich Mountain fault is a north dipping reverse fault, having the south side downthrown (Brown and Thayer, 1966; Thayer, 1956), we postulate that the buried trace of the fault lies near or south of the -200 gamma contour. Thus, at depth, the sheeted dike unit lies above the Mesozoic graywackes.

CONCLUSIONS

Although the magnetic data have provided additional information on the regional geology of the Strawberry Mountain Wilderness area, the anomalies over peridotite do not reflect distribution of known chromite deposits, probably because they are too small, and the chromite is of the low-iron nonmagnetic variety (Hawkes, 1951). Thus, the aeromagnetic data cannot be used as a direct guide in prospecting in this area. Detailed ground magnetic, gravity, and seismoelectric methods probably will be more informative.

ACKNOWLEDGMENTS

We thank R. J. Blakely for providing guidance in the modeling of the magnetic anomaly over the Canyon Mountain Complex and for helpful review of this manuscript.

ECONOMIC APPRAISAL

By Ronald B. Stotelmeyer, U.S. Bureau of Mines

SETTING

The Strawberry Mountain Wilderness and vicinity contains parts of the John Day chromite and Canyon gold mining districts, both on the north side of the study area. There is no record of mineral production from the existing Strawberry Mountain Wilderness. North of the wilderness in a proposed addition, one mine, the Ray, produced chromite. Another mine that produced chromite, Celebration, is in an excluded corridor that extends into the addition.

Ultramafic rocks that are hosts for the chromite extend into the study area. Copper occurs in the gabbro along the higher part of the main Strawberry Range; the resources are small and submarginal. One deposit, at the Robert L. prospect, is in the wilderness. Known gold and mercury deposits are no closer to the study area than 0.8 km.

Gold production from the Canyon mining district began in 1862 and reached its peak a few years later. Output, mainly placer, is estimated to have been about 20,000 kg (600,000 ounces) up to 1908; a few kilograms were recorded between 1908 and 1916. Dredge production was 3,854 kg (124,000 ounces) of gold and 406 kg (13,000 ounces) of silver from 1916 to 1942.

Mercury was produced from a mine about 0.8 km southwest of the study area. Between 1963 and 1968, 3,830 kg (111 flasks) were recorded.

Chromite mining in the John Day district began in 1916 when imports were cut off by World War I (Hundhausen and others, 1956). Total production from Grant County has been 30,000 t, mainly from the peridotite belt east of Canyon City. Production before 1925 is reported by Hundhausen to have been 18,000 t. The Iron King and Chambers mines (fig. 7) were the largest producers; output was about 5,000 t from each. The Ray mine produced 965 t. Between 1939 and 1944, 16 mines reported an output of 3,300 t of chromite ore; the Celebration and the Hanenkrats (Dry Camp) were the principal mines. From 1951 to 1958, county output was 8,393 t from about 23 mines, principally the Haggard and New, Dry Camp, and Ward mines (fig. 7).

The Bureau of Mines and the Geological Survey began exploration work in the John Day district in 1939. Drilling and trenching defined 68,000 t of ore reserves containing 22 percent Cr_2O_3 at the Iron King mine, 113,000 t containing 23 percent Cr_2O_3 at the Chambers mine, and 7,000 t containing 20 percent Cr_2O_3 at the Dry Camp mine. Another 11,000 t was estimated for various smaller properties. Less than 900 t of these reserves were mined (Hundhausen and others, 1956).

In 1942, the Government established a chromium ore-buying depot at Seneca, 40 km by road south of John Day (fig. 2). Under this impetus, a few thousand tons of chromite were produced. When the Government price support was withdrawn in 1944, production ceased. Output resumed in 1951 during the Korean War, when a chromium-ore stockpile was established at Grants Pass, Oreg. It operated until 1958. The Bureau of Mines conducted ore utilization tests in 1953 on samples from the Iron King and Chambers mines (Hundhausen and others, 1956).

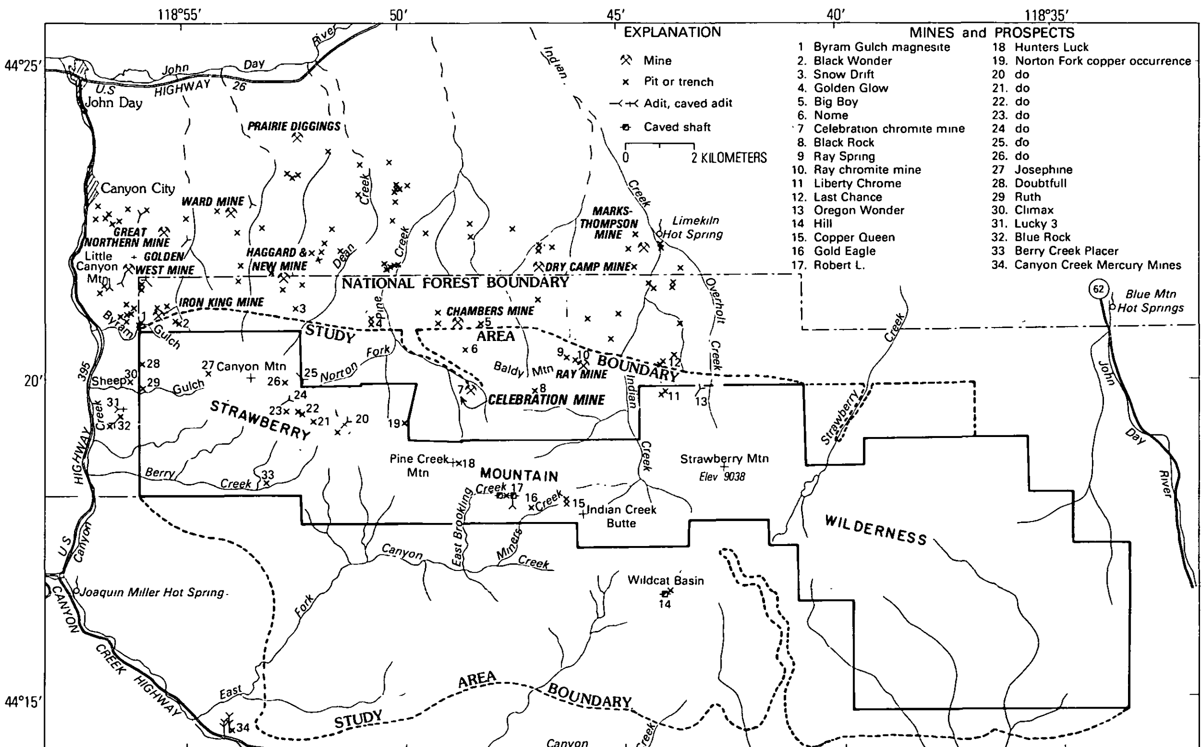


FIGURE 7.—Mines and prospects, Strawberry Mountain Wilderness and vicinity.

Current activities are restricted to annual assessment work. The Iron King and Ray mines, now known as the Billie Girl and Tip Top, are claimed by Clinton P. Haight, who also owns the patented Chambers claim. The last recorded assessment work at the Celebration mine was in 1958.

The chromium-iron ratios of chromite from the John Day district are relatively low. The 1953 tests by the Bureau of Mines showed that bulk samples from the Iron King and Chambers mines had chromium-iron ratios of approximately 1.5 to 1, which were upgraded by concentration to about 2.0 to 1. Tests on samples taken from six properties during our wilderness study yielded chromium-iron ratios ranging between 1.47 to 1 and 2.5 to 1 in concentrates. Imported ores range in ratios between 1.5 to 1 and 4 to 1.

PREVIOUS WORK

First mining near the wilderness was for gold. Several properties, including one in the study area, were described by Swartley (1914), and early operations were mentioned by Parks and Swartley (1916). Gold mining in the Canyon mining district was summarized by Brooks and Ramp (1968).

Although the area's chromite deposits were known in the 1800's, the first comprehensive published report on the John Day district was by Westgate (1921), following the production peak of World War I. Reactivation of mining and exploration at the onset of World War II lead to reports on the district's geology and ore deposits by Thayer (1941), Allen (1941), and the staff of the Oregon Department of Geology and Mineral Industries (1941). Bureau of Mines drilling programs during World War II, and ore utilization tests at the time of the Korean War, were reported by Hundhausen and others (1956). The John Day quadrangle, containing chromite- and copper-bearing rocks, was mapped by Thayer (1956), and the geology of the Canyon City quadrangle by Brown and Thayer (1966). This quadrangle includes a newly discovered mercury deposit near the southwest corner of the study area. The deposit is mentioned by Brooks and Bailey (1969).

PRESENT INVESTIGATIONS

The Bureau of Mines examined and sampled mines, prospects, and mineralized areas and estimated resources. In addition, they compiled mineral production data and searched mining claim location records.

Bureau of Mines work was done in 1975, principally by Ronald B. Stotelmeyer, assisted by Douglas W. Prihar. Ernest T. Tuchek, Fredrick L. Johnson, and Martin D. Conyac conducted part of the field investigation; they were assisted by Arthur J. Armstrong, Donald B. Kennedy, and Jeffrey D. Wilson.

Claim location data were compiled from courthouse records at Canyon City. Bureau of Mines statistical files were the source of production records from 1902 to the present. Production data prior to 1902 came from Brooks and Ramp (1968). Patented claim records were obtained from the U.S. Bureau of Land Management, Portland, Oreg.

MINING CLAIMS

Grant County records indicate that approximately 520 mining claims have been located since 1883 in the John Day and Canyon (Canyon City or Canyon Mountain) mining districts, parts of which were also called the Marysville or Strawberry Mountain districts. There are no patented claims in the study area. No claim ownership records for the main gold production period of the 1860's were found.

About 140 claims have been located in the wilderness. Of these, approximately 110 were located for gold in the Strawberry Mountain vicinity around 1900-1905, but not developed. No significant mineralization has been found in this area. The remaining claims were mostly located for copper.

About a dozen chromite claims have been located in the study area and the excluded road corridor north of the wilderness. Included are the Celebration and Ray (Tip Top) mines (fig. 7); both have recorded production. Most chromite claims were north of the study area. Nearly all gold lode claims, except the Strawberry Mountain groups, were on Little Canyon Mountain or at Prairie Diggings. The patented Great Northern, which is outside the study area, is the principal gold claim. No claims have been located at the Canyon Creek mercury mine because the land is privately owned. The only patented chromite claim is the Chambers (Mineral Survey 927), which is adjacent to the study area (fig. 7).

METHODS OF STUDY

Courthouse records and reports of mineral occurrences were used to determine the number and location of claims. Owners or others familiar with the mineral properties provided additional data, including history of development. Mines, prospects, mineralized areas, and claims were examined. All properties that were found were sampled and, if warranted, mapped.

Terms used in this report to classify individual mineral deposits are defined as follows (U.S. Geol. Survey, 1976):

Resource.—A concentration of naturally occurring solid, liquid, or gaseous material 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 or energy commodity can be economically and legally extracted at the time of determination. The term *ore* is used for reserves of some minerals.

Indicated resource or reserve.—Material for which estimates of the tonnage and grade have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

Inferred resource or reserve.—Material for which estimates of the tonnage and grade are based on geologic evidence for continuity, repetition, or projection.

Identified-Subeconomic Resources.—Materials that are not Reserves, but may become so as a result of changes in economic and legal conditions.

Paramarginal.—The portion of Subeconomic Resources that (a) borders on being economically producible or (b) 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

A total of 162 lode samples were analyzed. Most ranged from 2 to 5 kg, and were taken by chipping or cutting channels across veins, mineralized zones, and altered zones, or by digging small holes in mine dumps. Some selected material or specimens were chosen that would represent the maximum values present in the deposit—on the premise that if assays of the richest material are low, the deposit has little potential.

All samples were checked for the presence of radioactive and fluorescent minerals. All were fire assayed to determine gold and silver content. Other metal values were determined by atomic absorption, colorimetric, or X-ray fluorescence methods. At least one sample from each type of mineralized structure or zone at a property was analyzed by semiquantitative spectrographic methods. If anomalous amounts of economically significant elements were indicated, the sample was further analyzed by more accurate methods. Some were analyzed for platinum-group metals by a fire-assay spectrographic method.

Chromium-iron ratios were determined for sample concentrates from six chromite properties. Samples were crushed and ground to minus 65 plus 100 mesh, leached with hydrochloric acid, and processed in a Frantz[2] magnetic separator to obtain a concentrated chromite fraction. In one sample, fractions of four different magnetic susceptibilities were analyzed to determine the platinum source.

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[2] Any trade names in this publication are used for descriptive purposes only and do not constitute endorsement by the U.S. Geological Survey or the U.S. Bureau of Mines.

Alluvium was sampled in selected drainages, and the panned concentrate examined for placer gold and other heavy minerals. No significant amounts were found.

MINERAL COMMODITIES AND ECONOMIC CONSIDERATIONS

The principal mineral commodities in the Strawberry Mountain Wilderness study area are chromite, copper, and mercury. There are lesser amounts of platinum-palladium, nickel, and magnesite. Supply and demand data for this section are from Bureau of Mines Mineral Commodity Summaries, January 1978.

CHROMIUM

Chromite is present in a proposed addition and an excluded corridor north of the study area. Initially, mining would be by small-scale, open-pit methods that could be started quickly at the known deposits. The chromite occurrences are paramarginal. Possibly, mines would resume production if Government buying depots were opened (oral commun., Clinton P. Haight, 1975). Low chromium content and low chromium-iron ratios of the John Day deposits probably preclude development at current prices. Copper, platinum-palladium, nickel, and magnesite associated with the chromium probably would not be economically recoverable.

Domestic production of chromite ceased in 1961; however, one small mine in California was worked in 1976 and 1977. The United States continues to be one of the world's leading consumers. The metallurgical industry accounted for 60 percent of consumption; refractories, 20 percent; and chemicals, 20 percent.

Imports for consumption in 1977 were estimated to be 1.1 million t of chromite (22 to 38 percent Cr) and 227,000 t of chromium ferroalloys (36 to 70 percent Cr). Shipments from Government stockpile excesses were 490,000 t. Principal import sources between 1973 and 1976 were the Republic of South Africa (30 percent), U.S.S.R. (24 percent), Philippines (18 percent), and Turkey (14 percent). Ferrochromium imports were from the Republic of South Africa (34 percent), Rhodesia (24 percent), and Japan (16 percent). Prices for chromite in 1977 varied from $59 per metric ton f.o.b. from South Africa to $137 per ton f.o.b. from Turkey. Chromium-iron ratios ranged from 1.5:1 to 3:1.

Demand for primary chromium is expected to increase at an annual rate of about 3.4 percent through 1985. Along with other consuming countries, the United States will continue to rely on imports of chromium, but supply may be supplemented by sale of Government stockpile excesses (U.S. Bureau of Mines, 1978, p. 34–35).

COPPER

Copper occurrences, all of which are submarginal, are found mainly on the Strawberry Range crest and west of the wilderness. Copper is also associated with some chromite deposits. Known tonnage and grade are insufficient to justify construction of a mill or shipment of ore to custom smelters.

Estimated copper production in the United States in 1977 was 1.4 million t. The average price per pound in the United States was about 67 cents compared with 70 cents in 1976. Domestic demand is forecast to increase at an average rate of 3 percent through 1985.

MERCURY

A mercury mine outside the southwest corner of the study area is currently shut down. No occurrences were found in the study area.

Mercury mine production in the United States was 973 t in 1967. U.S. dependence on foreign mercury was lessened to about 46 percent by the end of 1977.

MINES AND PROSPECTS

CHROMITE DEPOSITS

More than 100 chromite deposits and occurrences are known in the John Day district, but few are believed to contain more than 100 tons (Hundhausen and others, 1956). They are confined to ultramafic rocks of the Canyon Mountain Complex (Thayer, 1956) that crop out along the north slope of the Strawberry Mountains in a zone 6.5-8 km wide and roughly 20 km long.

The typical deposit is an irregular lens or kidney of chromite concentration (Hundhausen and others, 1956). Less commonly, the bodies are tabular; most of them have been faulted, and apparently some displaced segments have not been found (Hundhausen and others, 1956). Chromium deposits are massive (can be selectively mined and hand-sorted) or disseminated (require milling and beneficiation). Mining has been mainly by open-pit or glory-hole methods. There is little apparent structural control to aid in prospecting or in predicting possible extensions of ore bodies. However, certain flow layers, or bands, of the intrusive rock contain richer segregations than others. Most of the chrome-rich rock seems to be localized along a zone about 1.5 km from the edge of the ultramafic unit. The wilderness study area locally includes part of the zone. Apparently, strongly jointed dunite is most favorable for prospecting. Ultramafic zones often support only grass and scattered pine trees; this vegetation is also used as a prospecting aid.

Workings of the major mines are caved or sloughed. Therefore, they were not examined in detail. Except for the Ray mine, they are outside the study area. Economically important properties within the study area and corridor, and those with occurrences possibly extending into the area, are described on the following pages. Those having little or no potential for discovery of resources are listed in the table at the end of this chapter.

Most of the known chromite deposits in the Strawberry Mountain ultramafic rocks are north of the wilderness study area. The boundary is near the Iron King and Chambers properties. At the Iron King, it is reported (Hundhausen and others, 1956) that the east limits of the main ore body are not well defined. Furthermore, drilling has not delineated the southeast limit of this deposit. At the Chambers mine, the bottom of the northeast ore body was not found during the drilling program, although chromite was intersected at a depth of 70 m. The northeast ore body dips 45° to 55° southeast toward the study area. If the deposit extends to a vertical depth of about 300 m, it would enter the study area.

CELEBRATION MINE

The Celebration mine (fig. 7, No. 7) can be reached by a good road in the excluded corridor. A dozer road extends at least another one-fourth mile (0.4 km) up the creek. Production of chromium ore, mostly during World War II, was 684 t. There is no indication of recent activity.

A sloughed opencut (fig. 8) and a caved inclined adit about 11 m long are the principal workings. Bulldozing has diluted a several-hundred-ton stockpile with about 50 percent dunite country rock. The bulldozed area is about 120 m square. A sample from a 1-ton stockpile assayed 40.6 percent Cr_2O_3 and 0.11 percent nickel. The chromium-iron ratio in a concentrate from our stockpile sample was 1.88 to 1. Three shipments in 1957 had ratios between 2.0 to 1 and 2.1 to 1.

According to Thayer (1941, p. 104):

> "The country rock is dunite, largely altered to serpentine, which a short distance to the west is intimately mixed with banded gabbro. The ore is high-grade nodular chromite in which equidimensional one-fourth inch nodules of chromite occur in a matrix of fresh green monoclinic pyroxene."

Allen (1941, p. 59) reported:

> "The ore body is from 5 to 8 feet thick, possibly thicker in places, and extends for at least 50 feet in length, dipping 25° SE. into the hillside, and striking N. 65° E. It is rather irregular in outline, being considerably jointed and faulted in blocks up to 4 to 5 feet across. Often the ore is infaulted with blocks of serpentine and dunite."

He also reported that 60 chip samples from the stockpiled ore and from the exposed faces of the ore body averaged 40 percent Cr_2O_3. Estimated inferred paramarginal resources are 1,000 tons at the mine, and another 1,000 tons of similar grade to the south.

Additional chromite can be expected to occur in ultramafic rocks in the vicinity of the Celebration mine. A chromite-bearing outcrop is

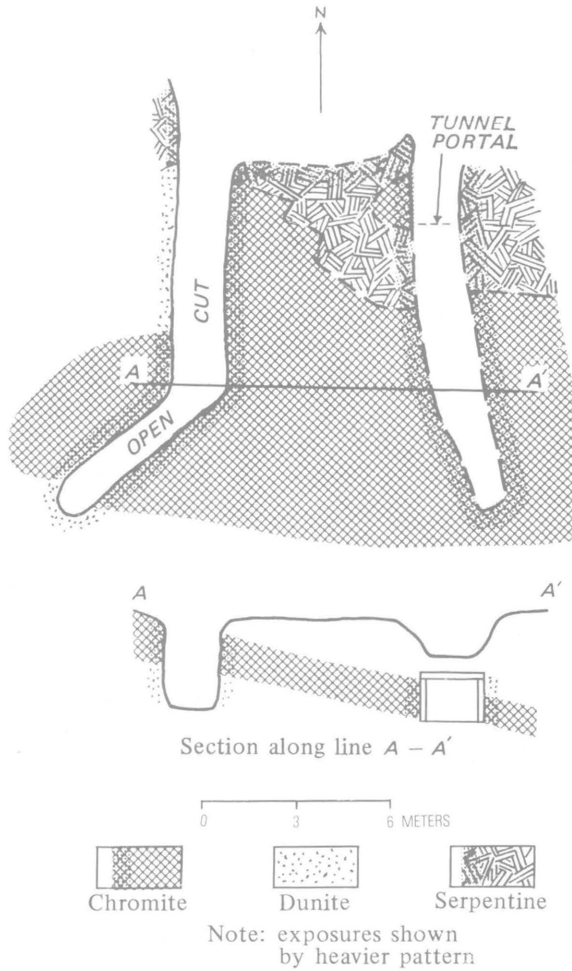

FIGURE 8.—Plan and section of the Celebration chromite mine (from Thayer, 1941).

about 150 m west of the mine. A 46-cm chip sample across the chromite-banded dunite assayed 8.7 percent Cr_2O_3 and 0.21 percent nickel.

RAY (TIP TOP) MINE AREA

The Ray mine (fig. 7, No. 10) is on the northeast end of Baldy Mountain. Access is by a good road from the north that intersects various mine and logging roads across the chromite belt.

The ore body mapped by Westgate (1921) is reported to have produced 965 t of chromite in 1918. Workings were mapped by Thayer (fig. 9); the outline of the workings has since been modified by bulldozing to the extent that it can no longer be recognized. The adit is now inaccessible, and the ore bin has been destroyed.

Thayer reported (1941) that the country rock is jointed olivinite. The chromite ore is surrounded by a dunite shell, and has a speckled appearance. According to Westgate, the ore assayed 32 to 44.7 percent Cr_2O_3.

A grab sample taken between the fourth and fifth dozer cuts from the top of the hill assayed 39.9 percent Cr_2O_3 and 0.18 percent nickel. The cuts, which were made after the mine was mapped by Thayer, are on the hillside just above the old opencut shown on figure 9. Chromite and olivinite constitute a 50-ton stockpile of material bulldozed apparently from slough at the face of what presumably was the old opencut. A grab sample of the pile, probably at the site of the ore bin, assayed 9.9 percent Cr_2O_3 and 0.22 percent nickel. Chromite in the inaccessible

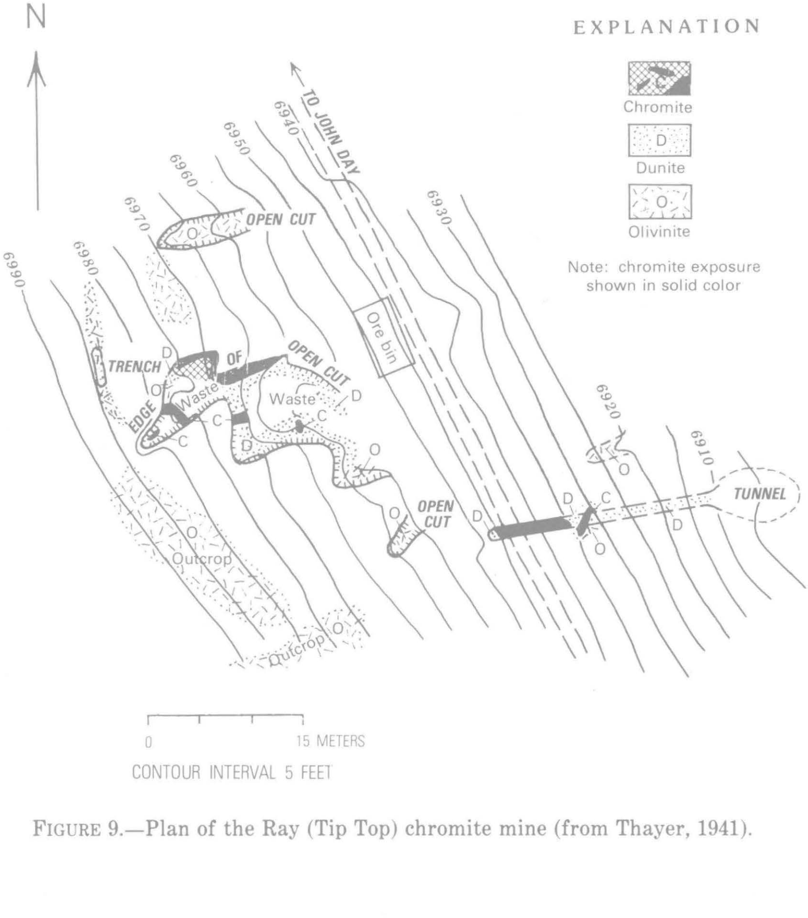

FIGURE 9.—Plan of the Ray (Tip Top) chromite mine (from Thayer, 1941).

highwall of the modified cut, and sloughed material and float in the dozed area suggest that there are several hundred tons of resources at the Ray mine.

A vertical chromite lens strikes toward the mine from a trench or short, caved, inclined shaft on the ridge about 200 m to the northwest. A chip sample across the 0.7-m width assayed 26.8 percent Cr_2O_3 and 0.20 percent nickel. It was not determined if the lens extends from the trench to the mine.

A sample of a 1-ton stockpile at the trench assayed 41.7 percent Cr_2O_3 and 0.19 percent nickel, and a concentrate of the sample had a relatively high chromium-iron ratio of 2.5 to 1. The stockpile material does not have the same physical appearance as the exposure in the trench. Also, semiquantitative spectrographic analyses show the high-grade material to be aluminum-rich, compared with the chromite in place. Therefore, the stockpiled material may have come from another location.

RAY SPRING CLAIM

Another possible chromite deposit, the Ray Spring claim, is about 450 m northwest of the Ray mine (fig. 7, No. 9). An old road connects the Ray Spring claim with the Ray mine road. Dozer trenches are cut in an area about 30 m square, but slough covers any occurrences that may be present. No scattered pieces of chromite were found in the dozed area. Two stockpiles totaling about 1 ton and of unknown origin were found. Assays of four stockpile samples ranged from 31.4 to 36.4 percent Cr_2O_3 and 0.17 to 0.21 percent nickel. Material in these stockpiles is similar to that stockpiled at the trench near the Ray mine. The material is aluminum-rich and also has an unusually high chromium-iron ratio of 2.5 to 1 in a concentrate. Its source could not be verified.

LIBERTY CHROME CLAIM AREA

Ultramafic rocks containing chromite and platinum-palladium crop out in the study area on the south slope of Sheep Rock (fig. 7, No. 11). Several chromite-bearing pods or lenses have been mined on the north slope outside the study area (fig. 7, No. 12); at least one pod contains minor amounts of platinum-palladium. Thayer (1941) reported the workings were known variously as the Hanenkrat, Morgan, Campbell, and Big Bertha. Claim records for the area include the Liberty Chrome located by C. H. Morgan in 1918; the claims were relocated in 1939 as the Province Chrome lode group; and the north working was located as the Last Chance in 1956.

There is a potential for discovery of chromite, and possibly platinum-palladium and copper resources, in the ultramafic rocks that extend about 0.8 km inside the study area in the vicinity of Sheep Rock. A sample from the stockpile at the east pit of the south workings suggests a 5- to 7.5-cm wide lens of chromite-rich serpentine and serpentinized pyroxenite. The stockpile sample assayed 22.7 percent Cr_2O_3, 0.069 ppm platinum per ton, 0.17 percent nickel, and 0.14 percent copper. Copper is not common in the peridotite belt, but most of it is found in the gabbro that forms the crest of the Strawberry Range.

Chromite samples were also taken from workings on the north slope of Sheep Rock (fig. 7, No. 12). At the north workings, a trench exposes a 3-m-wide chromite-bearing zone striking north. The zone contains 15-cm-wide bands of disseminated chromite in serpentinized peridotite. There is a 25-kg stockpile of high-grade material and a 20- to 25-ton pile of low-grade ore here. Two chip samples, 3.0 and 3.6 m long, taken along the trench walls assayed 8.3 percent and 18.7 percent Cr_2O_3, and 0.22 percent nickel each.

South of the trench are three small excavations. A sample from a stockpile near the sloughed northwest pit contained 0.69 g platinum per ton, 33.8 percent Cr_2O_3, and 0.25 percent nickel. In a concentrate from the sample, the chromium-iron ratio was 1.87 to 1. No chromite is exposed, but fragments indicate a width of at least 0.5 m.

A 120-ton stockpile was sampled at a 12 m-long trench about 100 m east of the three excavations. The sample assayed 12.9 percent Cr_2O_3 and 0.16 percent nickel. The trench extends along a lens striking about N. 10° W. Little chromite is exposed.

A short trench, about 150 m south of the stockpile, crosscuts a pod or lens 0.8 m wide. A sample taken across the pod assayed 33.2 percent Cr_2O_3 and 0.16 percent nickel. We could find no indication of continuity between this lens and the other workings.

BLACK ROCK CLAIM

A noteworthy chromite occurrence in the study area is exposed in a 9-m trench near the top of Baldy Mountain (fig. 7, No. 8). The site was accessible by primitive road from the Chambers mine until the autumn of 1975, when a barrier was constructed at the mine.

Chromite is disseminated in a lens or pod of serpentinized dunite, without obvious structural control of mineralization. A 1.9-m long chip sample taken across the north face of the trench assayed 2.2 percent Cr_2O_3 and 0.19 percent nickel. Another sample along 2.8 m of the southeast wall assayed 0.56 percent Cr_2O_3 and 0.17 percent nickel. A grab sample from a scattered stockpile assayed 6.4 percent Cr_2O_3 and 0.17 nickel. The samples also contained 10.3 to 20.6 g silver per ton. Although the chromite is of a low grade, it is significant because it indicates that deposits may be present in the ultramafic rocks that constitute Baldy Mountain.

SNOW-DRIFT CLAIM

The Snow Drift claim is 300 m beyond the study area (fig. 7, No. 3) and about midway between the Iron King and the Chambers mines. Access is by a dozer road. Workings consist of two trenches, 9.1 and 10.7 m long, and a dozer cut 27.4 m long, excavated in highly serpentinized dunite. Slough evidently covers a chromite occurrence. A random grab sample of broken rock from the 10.7 m trench assayed 19.2 percent Cr_2O_3, 0.11 percent nickel, and a concentrate of the sample had a chromium-iron ratio of 1.65 to 1.

COPPER OCCURRENCES

Copper minerals were noted at eight localities in the Strawberry Mountain Wilderness between Canyon Mountain and Indian Creek Butte, over a distance of 8.8 km, and at two chromite occurrences in the study area north of the wilderness. Copper is also present about 600 m west of the wilderness in sec. 25, T. 14 S., R. 31 E., on land administered by the Bureau of Land Management. No production has been recorded from the study area. Workings are mostly shallow shafts, pits, or short exploration adits. Two of the properties contain submarginal resources; others have a small potential for resources.

Copper mineral concentrations in the wilderness are in quartz-bearing shear zones, often associated with sheared, chloritized rock in the altered gabbro that forms the prominent crest of the Strawberry Range. The general N. 65° W. trend of copper occurrences is approximately parallel to the gabbro-sheeted dike contact and the chromite-rich zone. Shear zones containing copper vary from barely discernible fractures to prominent structures more than 300 m long.

The important occurrences are described on following pages. Properties that have little or no potential, or are insufficiently exposed, are listed in table 5.

ROBERT L. CLAIM GROUP

A copper-bearing shear zone, 750 m long, is thought to have been explored about 1935 in several workings on the Robert L., Marie Murry, and Brookling claims (fig. 7, No. 17). The structure crosses the divide between Miners Creek and East Brookling Creek. Workings include two caved shafts, 3.0 to 4.5 m deep, a 57-m adit, and a pit (fig. 10). The deposit is along the trend of copper-mineralized rock that is exposed in several places between Indian Creek Butte and Canyon Mountain.

At the west shaft, seven samples were taken across alternating quartz veins and serpentinous lenses in a shear zone at the faces of the collar. The quartz occurrences consist of veins 0.4 m and 0.3 m wide in the west face, and a vein 0.9 m wide in the east face. Assays from the zone ranged from 0.06 to 0.63 percent copper. The full width of

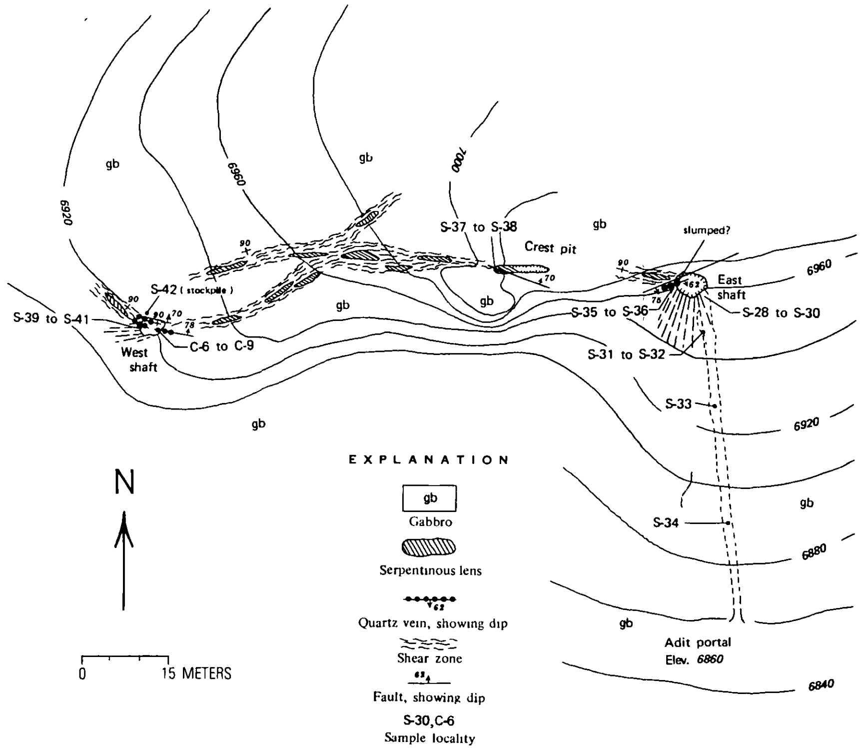

FIGURE 10.—Plan of the Robert L. copper prospect.

mineralization in the west face could not be determined because of sloughing. Weighted averages were 0.35 and 0.22 percent copper representing widths of 1 m and 2.5 m in the west and east faces, respectively. A grab sample from a stockpile of slightly more than 1 ton assayed 0.42 percent copper. The copper occurs principally as malachite fracture fillings in the lenses, and probably as disseminated chalcopyrite in the quartz. The ultramafic rock was analyzed for platinum; none was detected. The shear zone can be traced on the surface for about 300 m west of the shaft, but no copper mineralization was noted in the extension.

Chrysocolla is the main copper mineral at the pit on the crest of the ridge spur. The minerals occur in the chloritic lens, but also are sparsely disseminated in the albitized-gabbro hanging wall on the north. Average weighted grade of two adjacent samples was 0.56 percent copper across a width of 0.8 m.

Apparently, the adit was an unsuccessful attempt to find copper at depth in the east part of the shear zone. No copper was detected in a

An unnumbered table to accompany fig. 10, Robert L. copper prospect. Data for samples shown on figure 10

[—, not analyzed by quantitative methods]

Number	Chip Width (meters)	Description	Copper (percent)
S-28	0.03	Decomposed quartz vein striking N. 35° W. and dipping 72° NE. in east side of face of adit	—
S-29	.03	Decomposed quartz vein striking N. 30° W. and dipping 45° NE. in east wall at face of adit	—
S-30	.03	Amphibolite, with chlorite and other alteration products, in interval between quartz veins	—
S-31	.03	Fault gouge (80 percent) and decomposed quartz vein striking N. 30° W. and dipping 58° NE	—
S-32	.3	Quartz vein containing 10 percent altered country rock. Vein strikes N. 58° W. and dips 53° NE	0.09
S-33	.03	Quartz, fault gouge, and talc vein striking N. 85° E. and dipping 50° N	—
S-34	.03	Fault gouge. Fault strikes N. 80° W. and dips 45° N	—
S-35	.78	Across quartz vein	—
S-36	.84	Along strike of vein	.01
S-37	.09	Chrysocolla-rich zone in altered amphibolite lens. Zone is along hanging wall of albitized and malachite-stained gabbro	.67
S-38	.66	Brecciated and silicified chloritic rock in fault zone adjacent to chrysocolla-rich zone. Footwall not determined due to sloughing	.55
S-39	.27	Malachite-stained quartz vein in west collar of shaft	.16
S-40	.27	Platy, serpentine-and-chlorite-rich silicified rock on north side of quartz vein	.63
S-41	.42	Malachite-stained quartz vein on north side of S-40. Vein adjoins hanging wall of gabbro, also stained by malachite	.30
S-42	—	Stockpile grab sample	.42
C-6	.52	Malachite-stained, silicified, and serpentinized rock adjoining hanging wall in east collar of shaft	.39
C-7	.55	Altered and iron-oxide-stained serpentinous rock on south side of malachite-stained zone. Alteration grades into amphibolite wall rock	.27
C-8	.91	Quartz vein on south side of C-7. Vein contains blebs (35 percent) of serpentinous rock	.06
C-9	.52	Iron-oxide-stained and slightly serpentinized zone on south side of quartz vein	.28

quartz vein 0.8 m wide in the zone at the shaft collar. A fault at the collar, which is 30 m vertically above the face of the adit, offsets the zone. Copper stains are present where a quartz-bearing shear zone 30 cm wide crosses the adit 7.9 m from the face. A sample of the quartz vein assayed 0.09 percent copper. This vein strikes N. 58° W. and dips 53° NE., as compared with N. 76° E. and 62° SE. for the vein at the shaft collar, which may be slumped.

Indicated submarginal resources between the west shaft and the pit are 9,000 t with an average grade of 0.31 percent copper. An additional 25,000 t is inferred extending 150 m west of the west shaft and between the pit and one-half the distance to the east shaft. The vein averages 1.4 m in width.

NORTON FORK COPPER OCCURRENCES

Copper-bearing rocks occur at five localities on the crest of the Strawberry Range at the head of the east and west branches of Norton Fork of Pine Creek (fig. 7, Nos. 19–26). Country rock is hydrothermally altered gabbro that is sheared and intruded by mafic dikes. Mineralization was by fracture filling and replacement of wallrock or mafic dikes. Local silicification and pyritization accompanied the copper deposition. No apparent continuity was found from one copper occurrence to the next; each is in a distinct pod or is on a separate shear zone. These zones are as much as several thousand feet long and several hundred feet wide. As seen from the air, they appear to be controlled by a dike swarm. Cross-shearing suggests the potential for discovery of ore shoots at shear zone intersections.

The easternmost copper occurrence on the Norton Fork arête is exposed in a shallow pit a few feet from the Canyon Mountain Trail (fig. 7, No. 19). The minerals, malachite and chrysocolla, are at the contact between fresh gabbro and chloritized gabbro. A chip sample taken 1.2 m across the pit wall assayed 0.73 percent copper, and a grab sample of excavated rock assayed 0.71 percent. Little potential exists for discovery of resources at this locality, as mineralization was apparently localized.

The largest working at the head of Norton Fork is a caved adit about 75 m long (fig. 7, No. 20). Evidently, it was driven to test, at depth, mineralized rock cropping out at a pit on the ridge crest. The dump at the adit consists of albitized gabbro laced by numerous quartz stringers. No copper minerals were noted in six samples taken from the dump and pit.

Copper minerals were found at each end of a series of about a dozen quartz-albite pods cropping out on the ridge crest (fig. 7, Nos. 21–22). The pods or lenses range from a meter to as much as 12 m in length, and occur over a distance of more than 90 m. A chip sample 1.3 m long taken across the malachite-stained part of the east pod (fig. 7, No. 21) assayed 0.77 percent copper, and a chip sample across 3.35 m of the unstained part was essentially barren. The copper assay at the west pod (fig. 7, No. 22) was 0.21 percent over a distance of 3.5 m along a trench wall. A select sample of the excavated rock assayed 3.0 percent copper. Spotty copper distribution indicates that this locality has no resources near the surface. Samples from two other pits to the west (fig. 7, No. 23) contained no significant metal values.

Eight samples were taken from two adits in the cirque wall at the west end of Norton Fork (fig. 7, Nos. 24 and 25). One chip sample, from the east wall of the north adit and 6.4 m in from the portal, assayed 0.17 percent copper; the sample was taken over a 1-m length down a 0.3-m-wide zone of numerous intersecting pyrite-rich fractures. The adit was driven 10.7 m N. 6° W. at the contact of albitized gabbro with a porphyritic pyroxenite(?) lens, which dips 40° NE. Four other samples from this adit and three samples from the south adit, which is 3.4 m long, were barren.

Malachite stain occurs at a pit (fig. 7, No. 26) dug on a 13.7-m-long quartz vein or lens near the top of the arête separating the headwaters of Norton Fork and Dean Creek. A 1.2-m-long chip sample across the vein assayed 0.12 percent copper. The vein or lens strikes N. 60° W. and dips 68° NE., and swells to as much as 1.9 m in width. It is exposed for at least 6.9 m of depth in the pit highwall.

BLUE ROCK CLAIM

A 45.7-m adit (fig. 11) and two pits explore a copper-bearing quartz vein just west of the wilderness (fig. 7, No. 32). A primitive road extends nearly to the adit. Indicated resources at the adit, assuming a depth of mineralization equal to the length of the adit, are 4,700 t with an average grade of 0.33 percent copper. Average sample width was 0.8 m, but in many places the true vein width could not be determined (see fig. 11). Where it crops out above the end of the adit, the vein is 0.7 m wide, malachite stained, and assayed 0.03 percent copper. A pit several meters northeast of the vein exposes a shear zone striking N. 30° E. This may be a fault offsetting the vein. Quartz fragments in the sloughed pit assayed negligible copper.

Projection of the vein southwest from the adit portal intersects a pit 70 m downslope. Vein fragments in the pit assayed 0.27 percent copper. However, a barren 21-cm-wide quartz vein striking N. 30° E. and dipping 82° SE. in the pit suggests faulting. Inferred resources from the adit to the pit are 5,600 t, assuming a depth equal to one-half the distance between the two workings, and that width and grade of the vein are the same as at the adit.

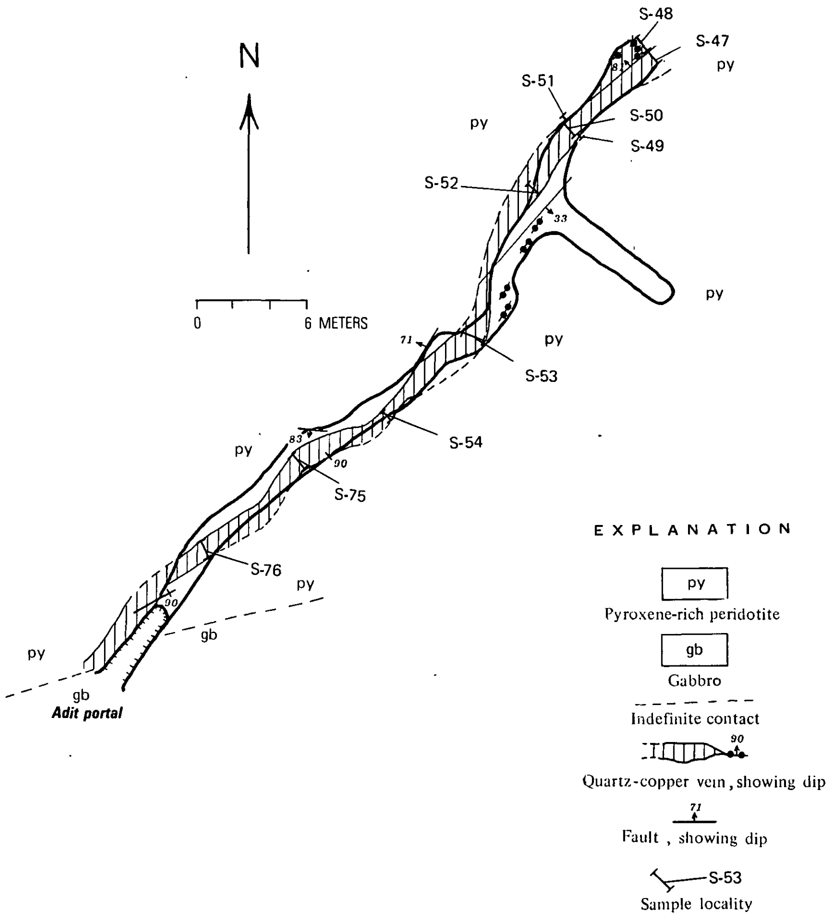

FIGURE 11.—Plan of adit at the Blue Rock copper prospect.

MERCURY DEPOSIT

The Canyon Creek mercury mine deposit, discovered about 1963, is 0.8 km outside the study area (fig. 7, No. 34). It is near the confluence of the East Fork of Canyon Creek and Canyon Creek on land owned by the Williams Ranch. Production by lessors totaled 3,830 kg in the period 1963-1968. The mine has been idle since the mercury price declined. No occurrences of mercury were found in the study area.

Cinnabar, the major ore of mercury, occurs in the Canyon Creek mine as fracture fillings or as replacements of the country rock. The two highest assays were 197.0 and 117.0 kg mercury per ton from a fracture 10 cm wide. Average grade at some mercury mines is as low as 1.5-4 kg per ton (U.S. Bureau of Mines, 1970). Host rock at the

An unnumbered table to accompany fig. 11, Blue Rock adit
[Data for samples shown on figure 11]

Number	Chip Width (meters)	Description	Copper (percent)
S-47	0.75	Quartz vein containing disseminated pyrite and chalcopyrite	0.24
S-48	.66	Highly-foliated and altered pyroxenite or peridotite	.01
S-49	.18	Shear zone containing highly foliated and serpentinized wallrock; 10 percent fine-grained pyrite	.05
S-50	1.02	Quartz vein	.23
S-51	.03	Gouge and brecciated peridotite	.03
S-52	.84	Quartz vein	.52
S-53	.90	do	.46
S-54	.39	Quartz vein containing 10 percent sulfides	1.40
S-75	1.05	Quartz vein	.08
S-76	.84	do	.01

workings is a dark-gray, thinly layered, fine-grained graywacke (Thayer, 1956), similar in appearance to basalt. The mercury deposit is at or near the unconformable contact of the graywacke with overlying volcanic rocks. Mineralization, including minor quartz, was localized along dilations in the bedding of the graywacke and in faults—particularly low-angle faults—crosscutting the bedding, which dips northeastward toward the study area. Some dilations are open where the bedding has been sheared and brecciated.

The mine is developed by four adits (figs. 12 and 13) at elevations ranging from 1,320 to 1,360 m. Dozer roads crisscross the area, and there are several sheds and ore bins. Tracked haulage was used in the upper three levels. Mining was by irregular stoping and by glory-hole methods. Diamond drilling had been done underground, but no core data are available. In addition to mine samples, one sample was taken of loose material in a dozer cut near the hilltop southeast of the mine. The sample was quartz containing inclusions of graywacke. Only 50 ppm mercury were detected.

Mercury mineralization at the deposit is not fully understood. Walls of the workings are stained in many places by bright-red hematite mud, probably the result of sulfide oxidation. Samples show, however, that the hematite does not necessarily indicate presence of mercury.

Twenty-four chip and channel samples were taken in the workings. They ranged in length from 0.06 to 2.13 m, but are not considered representative of the average width of mercury mineralization because the limits could not be determined visually. Inclined stope heights of 1.5 to 2.1 m probably indicate mining heights rather than thickness of

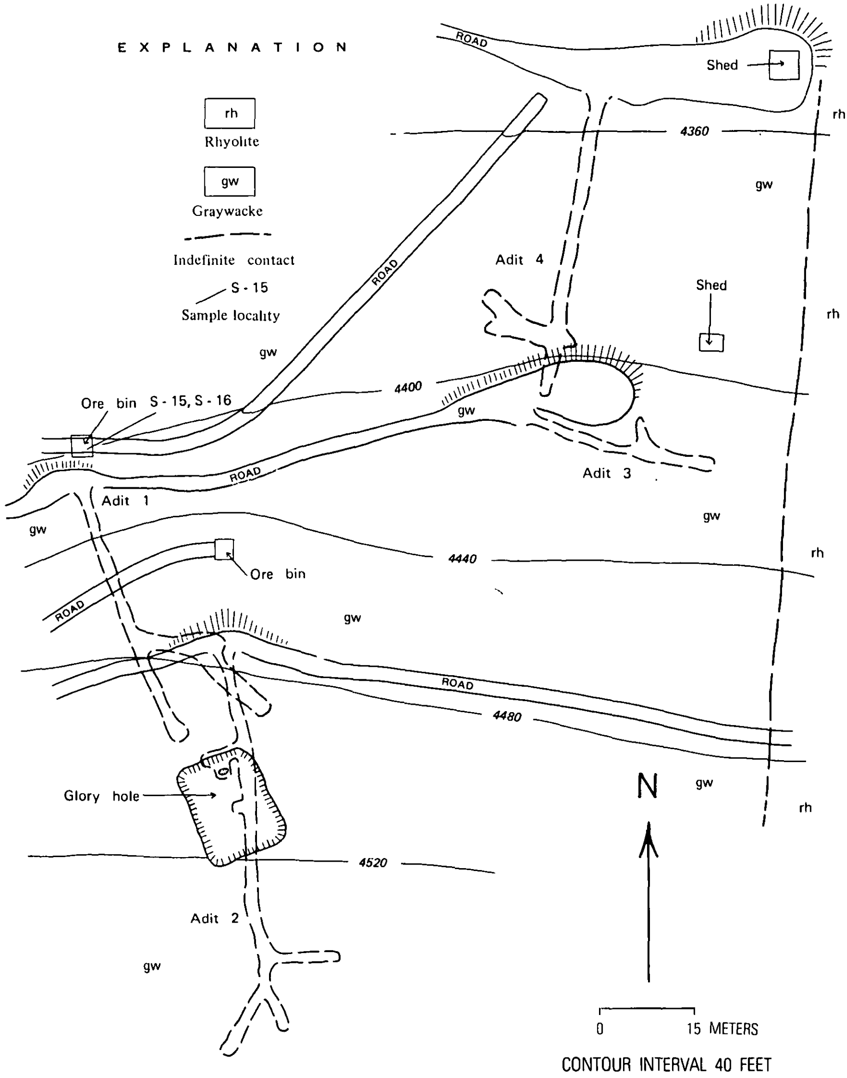

FIGURE 12.—Plan of surface workings at the Canyon Creek mercury mine.

the deposit. Weighted average grade of the samples is 3.8 kg mercury per ton, and average sample length was 0.4 m. The mercury mineralization and its controlling structures are not sufficiently exposed to permit an estimate of size and grade of the resource.

PLATINUM-PALLADIUM, NICKEL, AND MAGNESITE OCCURRENCES

Platinum production was reported in 1928 from a placer operation, probably associated with gold, on the John Day River, north of the study area. Output was very minor, and the source unknown. A mining company representative detected traces of the metal on lower Dean Creek during a geochemical exploration project in the 1970's. Platinum-group metals found in our samples from the Liberty Chrome deposit on Sheep Rock (fig. 7, Nos. 11 and 12) are probably not recoverable. One of those samples, which assayed 33.8 percent Cr_2O_3 and

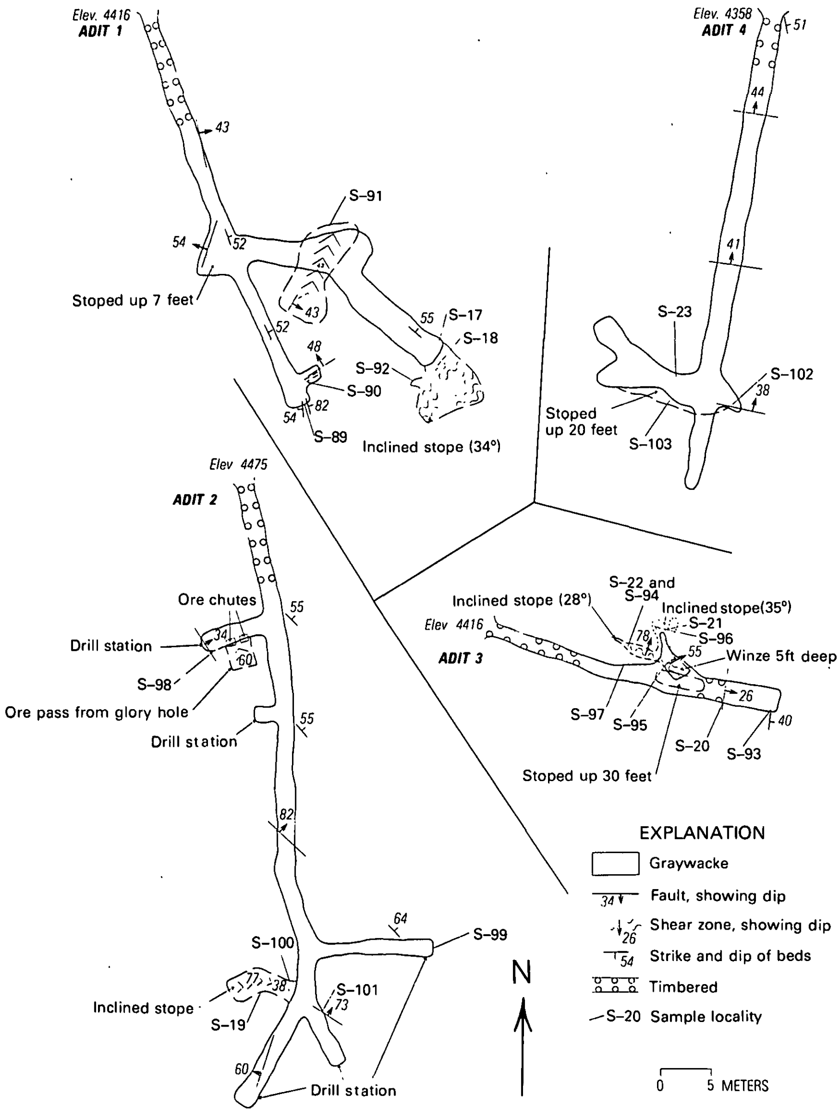

FIGURE 13.—Plans of underground workings at the Canyon Creek mercury mine.

An unnumbered table to accompany figs. 12 and 13, Canyon Creek mercury mine

[Data for samples shown on figures 12 and 13. <, less than]

Number	Type	Width (meters)	Description	Mercury (kilograms per ton)
S-15	Grab	—	Limonite gossan scattered under bin	1.4
S-16	do	—	Graywacke pile under bin	1.7
S-17	Chip	0.15	Sheared and brecciated layer in footwall of stope	4.1
S-18	Grab	—	Muck pile below brow of stope	1.0
S-19	Chip	.33	Shear zone on which raise driven	.1
S-20	do	.18	Shear zone crosscutting drift	.6
S-21	do	.09	Quartz vein crosscutting stope	.5
S-22	do	.09	Brecciated cinnabar and gossan in fracture	117.0
S-23	Grab	—	Muck pile	.3
S-89	Chip	2.10	Adit face	.1
S-90	do	.27	Shear zone	.6
S-91	do	.15	Projection of red layer exposed in brow of inaccessible stope	6.3
S-92	do	.12	Reddest part of iron-stained graywacke in which stope was driven	1.1
S-93	do	.57	Hematite-stained graywacke; typical of all walls in adit	.1
S-94	do	.09	Resample of locality S-22	197.0
S-95	do	.06	Hematite clay lining south wall of fissure	2.0
S-96	do	.09	Brecciated and hematite-stained graywacke in fissure	6.7
S-97	Chip	.12	Gouge lining adit wall. Thickness behind caving area could be several ft	.6
S-98	do	.06	Gritty, hematite-stained gouge in face of chute crosscut	15.6
S-99	Channel	1.77	Muck pile	.2
S-100	Chip	.24	Vertical sample in stope wall, 9 ft above drive floor	.3
S-101	do	.18	Brecciated graywacke and hematite-limonite gouge	.5
S-102	do	1.26	Bright red stained graywacke. Across tail-drift roof	.2
S-103	do	.09	Hematite-stained graywacke lining vug in stope wall, 12 ft above floor	.6

0.69 g platinum per ton, was processed on a Frantz magnetic separator to determine the platinum-bearing fractions. Fractions with different magnetic susceptibilities are listed below.

Sample No.	Field current (amps)	Percent total weight	Major constituents
6716a	0.1	27.1	Chromite and ferritchromite
6716b	.3	48.5	Chromite
6716c	.4	22.3	Chromite-olivine
6716d	.4	2.1	Olivine
		100.0	

Minerals with highest magnetic susceptibilities are separated at lowest field current. The platinum-palladium (1 part Pt to 3 parts Pd) occurs in the most highly magnetic fraction (6716a), which appears to contain intergrowths of chromite and ferritchromite.

Nickel assays ranging from about 0.1 to 0.25 percent were obtained in samples from the chromite belt. The platinum-bearing chromite occurrence yielded the highest assay. A reported nickel occurrence was examined by the Bureau of Mines and the Geological Survey personnel in 1957 near Dean Creek, 4 km north of the wilderness study area. No significant deposit was found. The nickel content of the John Day ultramafic rocks is typical of similar rocks elsewhere in Oregon, and the potential resource would be virtually inexhaustible, should a method be developed to economically treat the nickel silicate.

Magnesite occurs in two badly sloughed pits on the south slope of the ridge between the forks of Byram Gulch, adjacent to the northwest corner of the wilderness (fig. 7, No. 1). Magnesite is an earthy magnesium carbonate mineral formed by alteration of olivine and other minerals found in the John Day serpentinite. It is an ore of magnesium, and is used chiefly in making refractories and magnesia (MgO). Four dump samples from the pits consisted of a mixture of serpentine and magnesite. Magnesia content ranged from 29.0 to 39.0 percent. The only outcrop is a nearly pure magnesite vein striking N. 30° W. and dipping 53° NE., just above the north pit. A channel sample 0.4 m long across the vein assayed 38.1 percent magnesia. This is comparable to magnesia content of reserves elsewhere in the United States, but the deposit is too small to be minable. The veins do not extend into the wilderness.

GEOTHERMAL RESOURCES

Blue Mountain Hot Springs on the John Day River 4.8 km northeast of the wilderness, Limekiln Spring on Indian Creek near the Marks-Thompson mine 4.0 km north of the study area, and the Joaquin Miller warm spring about 3.2 km southwest of the area (fig. 7) are surface indications of geothermal energy. The Blue Mountain Hot Springs are on a branch, and the springs on Indian Creek are along the main east-west-trending John Day fault, north of the area. The Joaquin Miller spring is in sedimentary rocks not found in the study area. It is unlikely that a significant geothermal reservoir exists under the study area.

MISCELLANEOUS PROSPECTS

Mineral deposits having little or no potential for discovery of resources, or which are poorly exposed, are listed in table 5.

TABLE 5.—*Summary of data on miscellaneous prospects in or near the Strawberry Mountain study area*

[Underlined numbers refer to properties in, or extending into, the study area]

Map No. (Figure 7)	Name	Summary	Number and type of workings	Sample data
2	Black Wonder	Country rock of highly serpentinized pyroxenite. Pits probably dug to explore for extension of Iron King chromite deposit. Southeast pit shows high degree of foliation striking east and dipping 50° to 75° N. In pod 70 ft by 20 ft.	Two pits.	Three random chip samples; 0.29 to 0.44 percent Cr_2O_3, 0.08 to 0.12 percent nickel, 0.1 to 0.3 ounce silver per ton.
4	Golden Glow	Stockpile of less than 1 ton indicates banded and disseminated chromite in serpentinized, olivine-rich peridotite. The gabbro-ultramafic contact is between the workings and the study area.	Sloughed pit and 24-ft trench.	Stockpile sample; 23.1 percent Cr_2O_3, 0.15 percent nickel; Cr:Fe ratio of 1.47 to 1 in sample concentrate. Trench dump sample; 9.9 percent Cr_2O_3 and 0.17 percent nickel.
5	Big Boy	Iron-oxide stained, altered, peridotite slough. Humus covers bedrock.	Caved adit or timbered pit; and trench, 25 ft long.	Two random grab samples; 0.34 and 0.37 percent Cr_2O_3; 0.19 and 0.21 percent nickel.
6	Nome	Localized copper occurrence in chromite belt. Malachite fills fractures in serpentine country rock. Minor asbestos and copper-oxide stain on pit walls. Pit dug on shear zone striking N. 70° W. and dipping 25° NE. Six-inch-wide dike of gabbro(?) striking N. 25° E. and dipping 75° SE.	Pit.	One select sample; 0.98 percent copper, 0.45 percent Cr_2O_3, and 0.14 percent nickel.
13	Oregon Wonder	Iron-oxide stained rhyolite reported (Swartly, 1914) to contain traces of gold. Rhyolite flow shows very pronounced flow structure. More than 150 claims located, circa 1900-1903, on the rhyolite. No evidence of significant mineralization. Walls, and gouge in faults crosscutting adit, were sampled.	Adit, 105 ft long, partially caved.	Eight samples: no gold, nil to 0.3 ounce silver per ton.

TABLE 5.—*Summary of data on miscellaneous prospects in or near the Strawberry Mountain study area*—Continued

[Underlined numbers refer to properties in, or extending into, the study area]

Map No. (Figure 7)	Name	Summary	Number and type of workings	Sample data
14	Hill	Rhyolite in contact with underlying, gray, water lain, conglomeritic tuff. Rhyolite is yellowish, flow-banded, silicified, and vesicular or porphyritic. Vesicules, 90 percent filled with weathered porphyroblasts are locally amygdaloidal and finely brecciated; elongation is not controlled by flow banding. The rhyolite is locally stained bright red by hematite; no indication of mercury deposit as reported.	Caved shaft, 20 ft deep, and two pits.	Five samples; 2 to 27 parts per million (ppm) mercury, one sample contained 0.02 ounce gold per ton.
15	Copper Queen	Copper-bearing quartz and gossan in altered gabbro. Albitized gabbro is silicified, pyritized, and chloritized. No quartz or gossan exposed in place. Vein apparently strikes N. 75° W. in trench.	Pit, and trench, 20 ft long.	Two select samples and two random dump samples; 0.01 to 0.15 percent copper, as much as 0.01 ounce gold per ton.
16	Gold Eagle	Iron-oxide stained contact between gabbro and quartz diorite.	Pit.	One sample; no economic minerals.
18	Hunters Luck	Malachite-bearing shear zone, 15 inches wide, striking N. 50° W. and dipping 40° N. on summit of Pine Creek Mountain. Copper minerals in fractures and quartz lenses, in sheared albitized gabbro. Lenses as much as 1 inch thick and 2 to 3 ft long, containing phenocrysts of ferromagnesian mineral.	Trench, 12 ft long.	One stockpile sample and one sample of quartz lenses; 0.25 and 0.01 percent copper.
27	Josephine	Prospect in albitized gabbro containing calcite stringers.	Trench, 18 ft long.	One 13.5-ft-long chip sample; 0.1 ounce silver per ton.
28	Doubtful	Six-ft-wide quartz vein striking east-west in gabbro. Dump is highly iron-oxide stained from sulfides.	Pit.	Three samples; as much as 0.3 ounce silver per ton and 0.04 percent copper.
29	Ruth	Quartz-calcite vein, 0.2 ft wide, striking N. 78° W. in albitized gabbro.	Pit.	One sample; no economic minerals.
30	Climax	Quartz-rich gneissic country rock locally stained by malachite.	Pit.	One sample; 0.07 percent copper.
31	Lucky 3	Vein quartz scattered on dump suggests width of at least 12 inches. Also, a few pieces of aplite having phenocrysts of diopside (?). Adit driven in peridotite country rock.	Caved adit, 50 to 75 ft long.	One sample; no economic minerals.

TABLE 5.—*Summary of data on miscellaneous prospects in or near the Strawberry Mountain study area*—Continued

[Underlined numbers refer to properties in, or extending into, the study area]

Map No. (Figure 7)	Name	Summary	Number and type of workings	Sample data
33	Berry Creek	Trace of gold possibly derived from weathering of Norton Fork arete copper deposit. Scattered quartz fragments on dump.	Pit, cabin site, and 750-ft ditch as much as 6 ft deep.	Three lode samples and three placer samples; trace of gold in one placer sample.

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STRAWBERRY MOUNTAIN WILDERNESS,
OREGON

View south and west from Baldy Mountain across the basin of Pine Creek t
The bare slopes in th

:anyon Mountain, showing glacial topography developed mostly on gabbro. oreground are on peridotite.