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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

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Geology and Mineralization

OF THE

Morning Mine

AND

Adjacent Region, Grant County, Oregon

by

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FOREWORD

The accompanying bulletin is the result of a study, partially financed by the Department, making up a part of the author's doctorate requirements at Cornell University. It is the Department's policy to assist in the conduct of such studies to as great an extent as possible and to publish them when feasible.

Much of the State's area, particularly in eastern and southeastern Oregon, has had no detailed geological study so that all reports of the type of the present bulletin are of especial value to the State. They help to fill the many gaps in our knowledge of the areal geology of the State and they supply basic information very useful to the examining engineer, geologist, and prospector. They also provide authentic data of use in preparation of the State Geologic Map. This report describes the geology of an area between the Sumpter quadrangle, mapped in 1914 by J. T. Pardee of the U.S. Geological Survey, and the quadrangles in the John Day Valley being mapped by T. P. Thayer also of the Survey.

F. W. Libbey
Director

July 7, 1948

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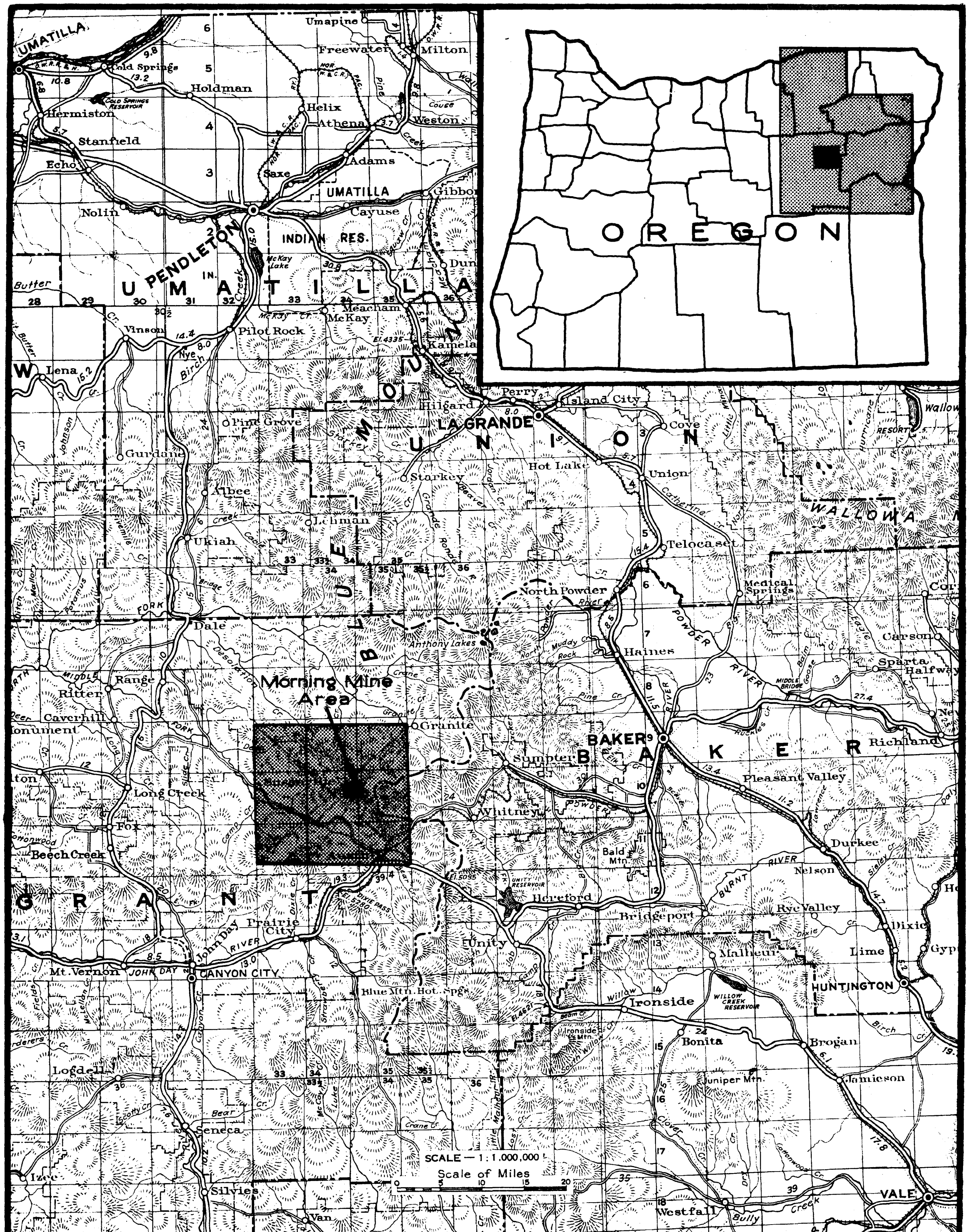

Index Map Showing Area Surrounding Morning Mine.

GEOLOGY AND MINERALIZATION OF THE MORNING MINE AND ADJACENT REGION, GRANT COUNTY, OREGON

Introduction

Scope of work

This report embodies the results of a detailed investigation of the geology and mineralization of the Morning and several other mines in northeastern Grant County, Oregon, and a less detailed study of about 30 square miles of the surrounding region.

The study has revealed that the geologic setting is much like that in the nearby Sumpter and Baker quadrangles where the rocks consist of late Paleozoic argillites and greenstones, Mesozoic ultramafics (including serpentine bodies) and biotite-quartz diorite, and perhaps early Tertiary (?) porphyritic dikes, all of which have been exhumed from beneath a covering of Tertiary volcano-sedimentary rocks. The local study has disclosed that emplacement of the biotite-quartz diorite was accompanied by widespread amphibolitization and that mineralization may be related genetically to early Tertiary (?) porphyritic intrusives which have been emplaced along a major zone of shearing that trends west-northwest. The ore deposits, consisting primarily of gold-quartz veins, occur in intimate association with the dikes and are along steep reverse faults of northeast bearing, commonly along the underside of the dikes.

Field work

The field work was carried on under the auspices of the Oregon State Department of Geology and Mineral Industries. Eight weeks during the summer of 1946 were spent in the district and another week in a review of the geology in the nearby Baker, Sumpter, and John Day regions. Work in the district was divided between four weeks in surface mapping and four weeks in mine examinations. Mines then in operation and therefore largely accessible were the Morning, Banzette, and Paramount. Other properties with semi-accessible workings were the Bi-Metallic, Snow Creek, Psyche, Windsor, and two mines in Morris Basin.

The field work was handicapped by the lack of adequate base maps. The only maps available were the Forest Service maps, Federal Land Office plats, and an old reconnaissance geologic map by Lindgren, published in 1901.* Aerial photographs were to be had, but since they were taken during the winter of 1939 when snow covered the ground, they could not be used exclusively for the work. The base map used consisted of an enlargement of the Forest Service map of the Whitman National Forest on a scale of one mile to the inch to which were added a few topographic details from the aerial photographs, Land Office plats, and field sketches. In the limited time it was only possible to approximate the geologic boundaries. Where the positions of such boundaries have been made with doubtful accuracy they are shown by dotted line on plate 1 (in pocket).

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*Bibliography in back of this bulletin.

Acknowledgements

The writer wishes to express his gratitude to his field assistant, Mr. John R. James, for his capable services; also to those living in the district, particularly Mr. William Gardner, owner of the Morning mine, and to Mr. Van E. Hallberg and Mr. I. Helmer of Greenhorn for their hospitality and assistance. He further wishes to acknowledge his gratefulness to Dr. T. P. Thayer of the U.S. Geological Survey for his many valuable suggestions offered during a visit to the district and also to the several staff members of the Oregon Department of Geology and Mineral Industries who gave freely of their time and knowledge of the region.

Grateful acknowledgement is also accorded Dr. Alfred L. Anderson of the Department of Geology at Cornell University who directed the laboratory studies and the preparation of the report; and to Dr. C. M. Nevin and Dr. J. D. Burfoot, Jr., members of the Cornell faculty, who offered valuable suggestions.

Previous work

Previous geologic work in the area was limited to a general reconnaissance study by Lindgren (1901), and a report on the mines of the Susanville area by Gilluly, Reed, and Park (1933). The Sumpter quadrangle, adjoining the Morning mine district on the east, has been described by Pardee and Hewett (1914), and their report has been of great value in interpreting the local geology.

Geography

Location and accessibility

The area covered by the investigation is in northeastern Grant County in the very heart of the Blue Mountains of eastern Oregon, close to the headwaters of the Middle Fork of the John Day River (see index map opposite p. 1). It is included in parts of Tps. 9, 10, and 11 S., Rs. 33, 34, and 35 E. Willamette meridian. The district is about 50 miles by U.S. Highway 28 from Canyon City, county seat of Grant County, and about 77 miles by State Highway 7 from Baker, county seat of Baker County.

The area is served by U.S. Highway 28 and a connecting system of county and Forest Service roads, most of which are usable only during dry weather. Bates and Austin, two small settlements within the area, are each within reach of the highway by a good road. The road from Canyon City to Bates is about 38 miles long. From Bates it is another 65 miles to Baker. The roads from Bates down river to Susanville and to the Morning mine, 12 miles up Vincent Creek, are usable only in good weather.

Population and industries

At the present time the only settlements within the district are Bates and Austin; the former is the present, and the latter the old, mill site of the Oregon Lumber Company. Bates has a population of several hundred and is served by a general store and postoffice. Austin, now reduced to a few families, still retains a combined general store and postoffice. During the early days of mining the area was more thickly populated than at present. Greenhorn, now a ghost town with a few weather-beaten frame shacks, once had several thousand inhabitants and many flourishing businesses, but can now boast of but one year-around resident.

The industries of the region are confined to an active timber-cutting program by the Oregon Lumber company, small scale farming along the Middle Fork valley, grazing of sheep on the upper mountain slopes during the summer, and a small amount of lode and placer mining.

Surface features

The district is in the so-called Greenhorn Mountains of the Blue Mountain group of eastern Oregon. The Greenhorns are distinguished as a series of rounded domes that extend for approximately 45 miles in a generally northwesterly direction across the northeastern part of Grant County. From the town of Greenhorn to Boulder Butte the mountains trend about due west but from Boulder Butte on, the trend is northwest (see pl. 1 in pocket). As shown in plate 2, figures 1, 2, and 3, the crests of the mountains are somewhat rounded, except where mountain glaciers have carved cirques with steep headwalls into north-facing slopes. The highest point in the range, Vinegar Hill (pl. 3, fig. 1), has an altitude of 8,120 feet. Several other peaks reach altitudes just above 7,000 feet. The average relief of the district is about 3,000 feet.

On the southwest border of the district is a ridge paralleling the Greenhorns which culminates in Dixie Butte (pl. 3, fig. 2) at an elevation of 7,400 feet.

The higher parts of the district consist of a rolling upland surface; the lower parts are deeply dissected by narrow valleys. On the north flank of the Greenhorns the valleys show evidence of widening by glacial erosion, but on south slopes, except for upper Granite Boulder Creek and Vinegar Creek, the valleys are narrow and typically V-shaped.

Much of the district is drained by the Middle Fork of the John Day River which flows in a northwesterly direction. However, the northwest slopes of the Greenhorns are drained by numerous branches of Clear Creek and by the south branch of Desolation Creek, tributaries of the North Fork of the John Day River. South of the town of Greenhorn the drainage is to the North Fork of Burnt River (see index map opposite p. 1).

Climate and vegetation

The climate of the Morning mine area varies according to the altitude, which ranges from about 4,000 feet at Austin and 3,500 feet on the Middle Fork near Susanville to 8,000 feet or more in the Vinegar Hill-Sunrise Butte region. The summers in the higher areas are delightfully cool throughout the day, but temperatures drop to freezing at night. Along the Middle Fork, days are somewhat hot, with a minimum of breeze, but the nights are cool. Snow covers the area from November through May, but temperatures are not severely low. Residents state that winter temperatures are much lower in the valley of the Middle Fork than on the higher slopes.

Precipitation varies with the altitude. Although no records are available, it is likely that the valley regions may receive no more than 15 inches of rainfall a year while the higher slopes may receive twice as much.

The entire area below 7,000 feet is forested. Up to approximately 5,500 feet the slopes are covered by yellow pine, now being cut by the Oregon Lumber Company. From that altitude to 7,000 feet the yellow pine is replaced by the smaller conifers, mainly black pine, lodgepole pine, and tamarack. Around 7,000 feet the trees disappear and sagebrush and mountain laurel flourish. Wild buckwheat covers the topmost ridges. In general, the north slopes have more vegetation and thicker underbrush than do those facing south.

Fig. 1. View northeast from Vinegar Hill looking down the glaciated valley of the East Fork of Clear Creek.
Photo courtesy U. S. Forest Service.

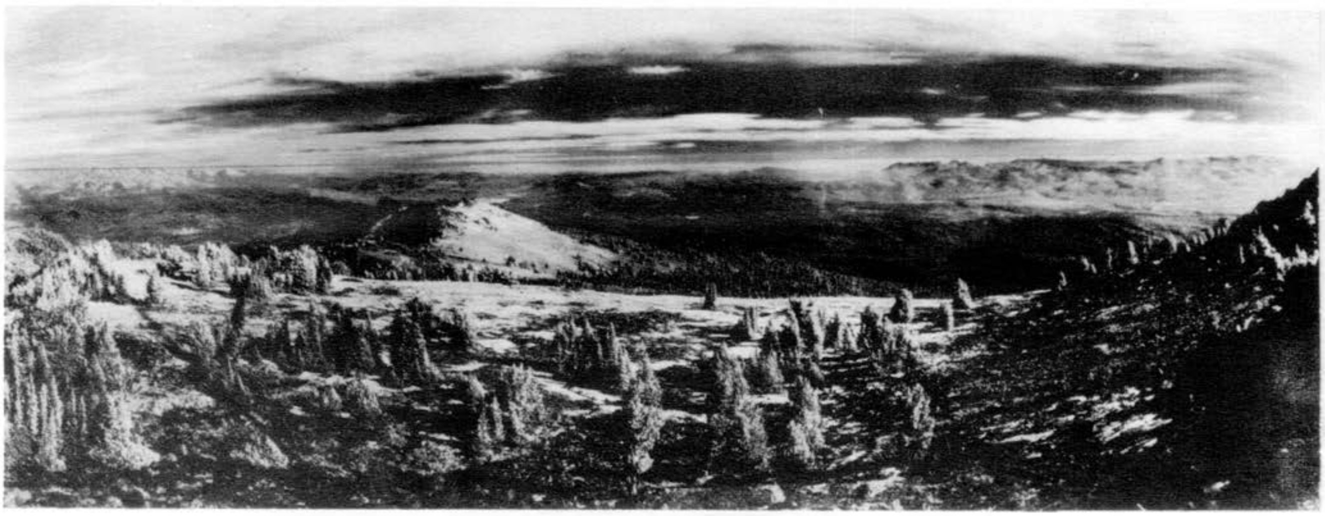

Fig. 2. View east from Vinegar Hill looking towards Psyche Butte in middle distance.
Photo courtesy U. S. Forest Service.

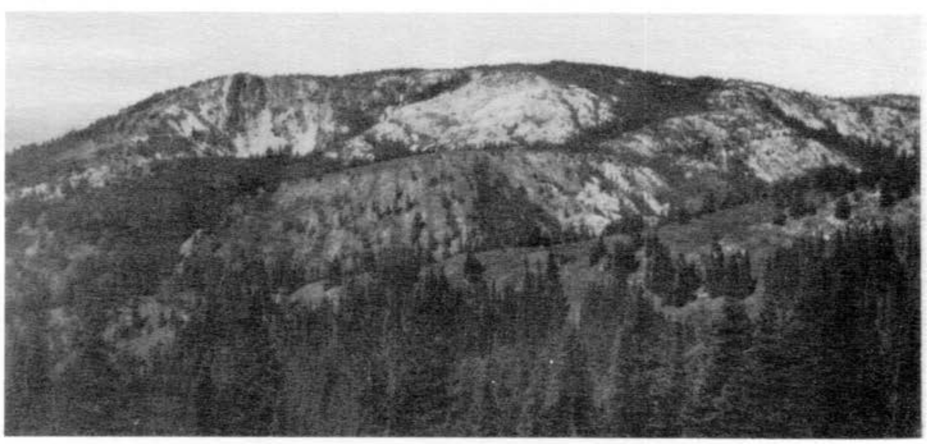

Fig. 3. Sunrise Butte from Vinegar Hill looking west.

Physical Geology

General features

The rocks of the district are represented by a varied assortment of sedimentary, volcano-sedimentary, flow, and intrusive types of diverse kind and composition. These are divisible into a group of pre-Tertiary sedimentary and igneous rocks and into a group of Tertiary rocks, largely extrusive, which is separated from the other by a profound erosional unconformity. The pre-Tertiary group consists of Paleozoic volcano-sedimentary rocks, chiefly meta-argillites and greenstones, which are intruded by Mesozoic ultramafics (including serpentine bodies), biotite-quartz diorite, and by early Tertiary (?) porphyritic dikes. The Tertiary group is made up of Miocene andesite tuff-breccia, rhyolite, Columbia River basalt, and intercalated lake and ash beds. Other deposits are of Quaternary age and are composed of Pleistocene glacial and Recent alluvial materials. The rocks of most pertinent interest are the older meta-argillites and greenstones, and the igneous rocks that intrude them, for the older rocks contain the ore deposits.

Because of severe folding, faulting, and intrusion of igneous bodies, the early group of rocks possesses complex structural relationships. In contrast, the Tertiary volcano-sedimentary rocks have been but mildly deformed. The main deformation apparently preceded the intrusion of the ultramafics and the biotite-quartz diorite, but another crustal disturbance of importance marked by shearing of the diorite and older rocks came before and directed the intrusion of the porphyritic dikes and the flow of mineralizing solutions.

Pre-Tertiary rocks (Paleozoic volcano-sedimentary series)

ARGILLITE

Distribution and thickness: The argillitic rocks are exposed over a broad belt extending in a westerly direction through the center of the mapped area (pl. 1 in pocket). These rocks are coextensive with the argillites of the Sumpter quadrangle and are reported by Pardee (1914) to exceed 3,000 feet in thickness, and are like those of the Baker quadrangle, where Gilluly (1937) has reported more than 5,000 feet of strata. Accurate measurement within the district could not be made, but the total thickness may reach several thousand feet.

Lithology: The argillite has a rather hetrogeneous makeup and contains much intercalated tuff, chert, conglomerate, slate, crystalline limestone, and greenstone. The tuffaceous members and greenstones (altered lava flows) are most abundant in the upper part. Limestone is confined to scattered lenses in the central part, but the chert is distributed throughout, and composes altogether a considerable part of the argillitic series. Bedding is not particularly pronounced in the more argillaceous facies but is conspicuous in the more siliceous members. Much of the rock shows good fracture cleavage (pl. 3, fig. 3). Gradations of argillite to chert, conglomerate, or tuff are not uncommon.

The argillite is for the most part a dark-gray to black, fine-grained silicious rock with obscure bedding. Its grains measure less than 0.01 mm in diameter, being subangular to rounded. They are composed of quartz, andesine, and finely divided mica with associated black carbonaceous matter.

The tuffaceous argillite differs from that described above in containing more feldspar, much of which is splintery, and also in containing material resembling finely divided glass. In addition it has volcanic material identical to that comprising the overlying greenstones, but the greenish color, which reflects the presence of chlorite or green mica common to the altered volcanic rocks, is masked by the carbonaceous matter. This rock is coarser grained than the normal argillites.

The ever-abundant chert usually exhibits a "ribbon" or bedded structure. The bedding as shown in plate 3 figure 4 is highly contorted wherever found. The chert is pale yellow to pinkish in color and is always characteristically dense and fine-grained.

Conglomerate beds apparently have a restricted distribution, but are conspicuous half a mile west of the Morning mine and in the upper valley of Vinegar Creek basin, where individual beds are from 10 to 50 feet thick. These beds are bluish gray and are composed largely of chert, and subordinately of argillite and volcanic rock pebbles, all of which average about half an inch in diameter. These pebbles are bound together by a dense, siliceous cement. The beds resist erosion and consequently tend to stand out in relief.

Limestone lenses are not conspicuous locally. There are three of them, however, in upper Vinegar Creek basin, each highly siliceous and changed in part to fine-grained white marble. A thick, white marble lens and several smaller limestone beds also occur in Morris basin. The less metamorphosed limestone is fine-grained, greenish to bluish-gray in color. Marble and limestone alike are cut by numerous seams of calcite. The largest of these lenses is shown on the geologic map (see pl. 1 in pocket), but on an exaggerated scale.

Age and relations to other formations: The argillite is thought to be Carboniferous on the basis of fossils, particularly *Fusulina*, present in some of the limestone members of the Baker area (Gilluly, 1937). Whether the tuffaceous beds into which the argillites grade upward are also of the same age is not known. There is no sharp line of demarcation between them. It is possible that some of the younger greenstones have been included with the argillites.

Conditions of deposition: The limestone lenses and bedded cherts indicate that much of the argillite had a marine origin, though some parts may be continental (Gilluly, 1937). The high proportion of tuffaceous material, however, is evidence of contemporaneous volcanism, during which much fragmental material was contributed to the sediments undergoing deposition.

Fig.1. Vinegar Hill from Tiger mine. Note steep north-facing cirque headwall.

Fig.2 Dixie Butte from Psyche mine. Strawberry Range in far distance. Middle Fork of John Day River in valley this side of Dixie Butte.

Fig.3. Bedding and fracture cleavage in argillite. Point of hammer rests on bedding, one set of cleavage faces reader. One mile southeast of Morning Mine.

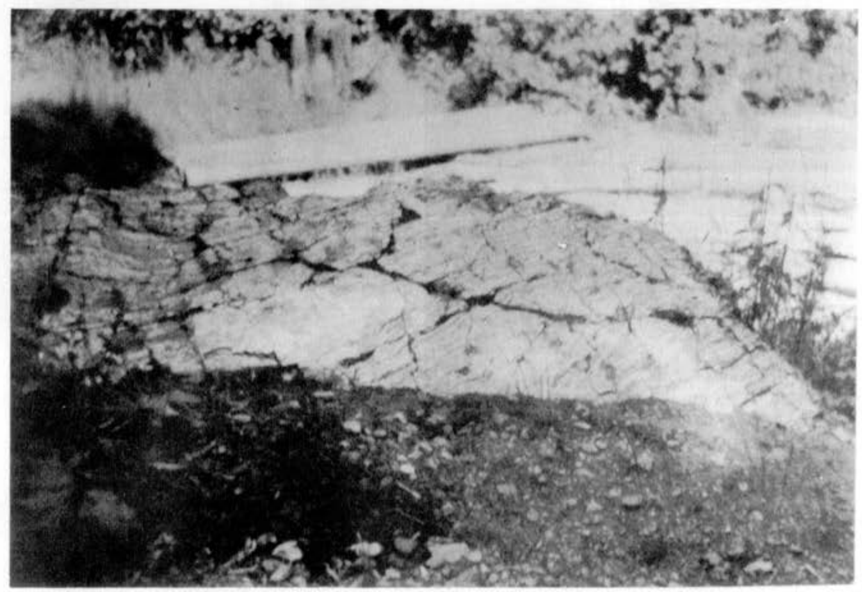

Fig.4. Bedded chert outcrop on Vincent Creek. Four miles northwest of Bates.

PLATE 3

GREENSTONE

Distribution and thickness: With an increase in the number of tuffaceous beds and altered lava flows, the argillite grades upward into massive greenstone. As mapped, the lower part of the greenstone contains about 100 feet of argillitic and cherty members; the upper part is entirely altered volcanic rock. Not less than 800 feet of these rocks are exposed on Vinegar Hill above the Morning mine. In the Baker quadrangle the equivalent rock may have a thickness of more than 4,000 feet (Gilluly, 1937). Good exposures of the greenstone other than on Vinegar Hill are found on the headwaters of Dry Creek and on the slopes extending west from Sunrise Butte to Susanville. The greenstone has poorly defined outcrops, except along craggy ridge crests.

Lithology: The greenstones are predominantly volcanic rocks that have been sheared, folded, highly albitized, and silicified. Much of the greenstone is light grayish-green and aphanitic, but some is dark green and locally porphyritic. Where the greenstones have been studied in considerable detail, as in the Baker quadrangle, they consist of quartz-keratophyre, keratophyre, spilite, albite diabase, keratophyre and quartz keratophyre tuff and breccia, and meta-andesite. Within the district they are composed dominantly of keratophyre, subordinately of meta-andesite.

The keratophyre is finely granular to aphanitic and is composed of oligoclase-albite, green hornblende, chlorite, epidote, clinozoisite, and subordinate magnetite and apatite. Much of the feldspar has been altered to sericite, but remnants of a calcic plagioclase within the oligoclase-albite suggests that the original feldspar was albitized and then sericitized. The meta-andesites are fine-grained with local porphyritic segregations and are composed of calcite andesine, sodic oligoclase or albite, biotite, chlorite green hornblende, pyroxene, and minor epidote, clinozoisite, sericite, apatite, and magnetite. The phenocrysts are andesine, but in general the andesine has been albitized.

Age and correlation: The greenstones on Vinegar Hill resemble those of the Baker quadrangle which Gilluly (1937) has called the Clover Creek greenstone and in which he has found a Permian fauna. Although no fossiliferous beds were found locally and the greenstones could not be traced into the Baker region, they are, on lithologic resemblance and stratigraphic succession, probably equivalent to the Clover Creek and therefore Permian.

Conditions of origin: According to Gilluly (1937) the association of marine limestones and fossiliferous tuffs in the Clover Creek greenstone in the Baker area indicates that parts of the formation are of submarine origin. This is further supported by the type of albitization which is that common to submarine extrusive rocks. Because of similar albitic alteration, the greenstones locally may also represent submarine extrusions.

Pre-Tertiary rocks (Mesozoic intrusives)

Bodies of Jurassic (?) intrusive rock are restricted to areas of argillites and greenstones, which they invade. These intrusives fall naturally into three groups in which the rocks differ in age and composition. The first or earliest group is represented by highly metamorphosed and serpentinized ultramafic rocks; the second, by two bodies of biotite-quartz diorite; and the third, by numerous dikes of aplite and pegmatite which intrude the genetically related biotite-quartz diorite.

ULTRAMAFIC ROCKS

Composition: The ultramafics include bodies of dunite, pyroxenite, and gabbro which have been extensively altered to hornblendite and serpentine. Near the biotite-quartz diorite, the dunites and pyroxenites have been changed largely to hornblende (pl. 6, fig. 1); elsewhere they have been changed to serpentine. Alteration of the gabbro has been less complete. The rock is more or less completely sheared and crushed and possesses a faint gneissic banding. Its feldspars have been largely altered to epidote, clinozoisite, and albite. Adjacent to the biotite-quartz diorite the gabbro is rich in hornblende and in part is a gneissic amphibolite.

As the ultramafics are now composed largely of serpentine, they may for the most part be classed as serpentine bodies. Some of the bodies are rather large and two of considerable prominence crop out northeast of the Morning mine, one at the head of Blue Gulch near the Psyche mine and the other at the head of Lightning Creek just west of Greenhorn.

The serpentine derived from pyroxenite has a knobby surface, a relic of the rather large pyroxene crystals; that derived from dunite has a smooth surface and a reddish-buff color. The latter appropriately has been called "buckskin" rock. Otherwise the serpentine is light greenish-tan ranging to almost black.

Most of the bodies are composed of antigorite in which are small seams of crysotile, talc, and calcite. Serpentine bodies invaded by the biotite-quartz diorite have locally been changed to massive amphibole. Those cut by early Tertiary (?) dikes have undergone more or less general silicification.

Age and magmatic relations: The various ultramafics and the gabbro are intimately associated, one showing gradations into the other. Apparently, the gabbro is a somewhat younger facies, for on the west side of Vinegar Hill it locally seems to cut the serpentinized dunite. However, the gabbro has there been so completely amphibolitized that its original character and its relations to the dunite are not entirely clear. The rocks, however, are probably products of a single magmatic cycle. The alteration to serpentine is very likely a closely related phenomena, coming at the end of the cycle, and resulting from the action of silica-rich ascending waters from the deeper magma region.

As the ultramafics and related rocks intrude the argillites and greenstones they are post-Carboniferous but they are not quite so young as the biotite-quartz diorites which intrude and alter them.

BIOTITE-QUARTZ DIORITE

Distribution and character: There are two bodies of biotite-quartz diorite within the area: one, about 10 miles long and 2 miles wide, extending in a westerly direction from a point half a mile northwest of Vinegar Hill to the head of Elk Creek; the other, a small body in the valley of Salmon Creek. These bodies are probably cupola extensions of the much larger batholithic mass exposed in the Sumpter and Baker quadrangles. They have apparently been intruded along a westerly trending zone of structural weakness which extends through the argillites, the greenstones, and the ultramafics.

Except at marginal zones, the rock shows little variation in texture and mineral composition and closely resembles the "granodiorite" of the Sumpter quadrangle and the biotite-quartz diorite of the Baker area.

Petrography: Much of the rock is medium grained, equigranular, and light gray. It is composed largely of quartz, plagioclase, and biotite, but also contains variable amounts of hornblende, the latter in places forming dark gray segregations. There is little potash feldspar in comparison with that contained in the rock on Bald Mountain in the Sumpter quadrangle (Pardee, 1914). The plagioclase, a zoned, calcic andesine (ranging between Ab_{65} and Ab_{45}), normally comprises about 75 percent of the rock, the quartz 15 to 20 percent, and the biotite and hornblende together 5 to 7 percent. The hornblende is most abundant in marginal zones (pl. 6, fig. 3). Orthoclase is rare, and apatite, sphene, zircon, and magnetite form microscopic accessories. The plagioclase shows minor alteration to clinozoisite and sericite, the more calcic centers being most altered. Biotite occurs alone or as irregular mantles on hornblende. The occasional grains of orthoclase generally are bordered by myrmekitic plagioclase.

Some of the dioritic rock near the northeast corner of the intrusive mass has been sheared and shows cataclastic textures (pl. 6, fig. 2).

Metamorphism: The intrusion of the biotite quartz diorite has provoked marked changes on the bordering rocks. It has caused widespread formation of hornblende and, locally, of feldspar. The most marked changes have taken place in the ultramafics, which have been converted largely to coarse-grained amphibolites, composed mostly of actinolite and subordinately of anthophyllite. This alteration has affected the serpentinized and non-serpentinized bodies alike, the degree of amphibolitization decreasing outward from the diorite contact.

The argillites have also been highly altered, but alteration has consisted largely of lit-par-lit injection and impregnation by grains of feldspar and quartz (pl. 4, fig. 1).

In the outer part of the "granitized" zone the rock shows gneissic banding with transition to dense hornfels. Still farther out the rock is entirely hornfels which grades into unaltered argillite.

The greenstone and tuff show an increase in feldspar and hornblende content near quartz diorite contacts but the alteration is not conspicuous as in the case of the other rocks.

Age: Gilluly (1937), following Ross' (1938) analysis of the age of the Mesozoic granitic rocks in Idaho and Lindgren's (1901) earlier work in the Blue Mountains, lists the age of the biotite-quartz diorite in the Baker quadrangle as doubtfully post-Jurassic. As the granitic rock of the Greenhorn Mountains is essentially a westward continuation of that in the Baker region, it must be considered as of the same doubtful age. Much work has been done on the Idaho batholith insofar as rock types and probable age of the rock are concerned. The biotite-quartz diorite of the Greenhorn district is very much like the early marginal rock of the Idaho batholith (Anderson, 1942) which is regarded as late-Jurassic or Cretaceous.

APLITE AND PEGMATITE DIKES

Aplite dikes are scattered through the biotite-quartz diorite, but are exceptionally numerous on Sunrise and Boulder Buttes. Most of the bodies are small and their thicknesses are measured in inches, less commonly in feet. The larger bodies generally have conspicuous outcrops along ridge lines, in places forming low ledges which may be traced from 50 to 100 feet. Float is everywhere abundant. Contacts between the aplitic rock and the enclosing dioritic wall rock are usually sharp, not gradational as is the case of the closely related pegmatites.

The aplitic rock is lighter in color and the grain size considerably finer than that of the normal biotite-quartz diorite. Most of the aplites are composed of about equal amounts of quartz and oligoclase, with minor amounts of orthoclase and muscovite.

Although not as abundant as the aplites, the pegmatite dikes are fairly numerous on Sunrise and Boulder Buttes. The dikes average about 6 inches thick. They may seldom be traced for more than a few score feet along their strike. Some of the dikes cross and some occur in and along the aplites. The contacts between pegmatite dikes and the diorite and aplite walls are poorly defined and gradational, suggesting that the pegmatite permeated into and partly replaced the bordering rock.

The pegmatite is usually coarsely granitic in texture, less commonly graphic. The fresh rock is milky white to light gray, with weathered surfaces appearing darker. The characteristic minerals are sodic oligoclase and quartz with minor microcline, albite, biotite, and muscovite. Some andesine and quartz grains are completely enclosed in sodic oligoclase and microcline, and frequently these grains are present as shadowlike inclusions. These inclusions match the plagioclase and quartz grains in the adjacent diorite and actually merge with them at contacts. These relations indicate a replacement origin for the

Fig. 1. Lit-par-lit injection of argillite. Bedding inclined to right. White layers are feldspar and quartz. One-half mile west of Tiger Mine.

Fig. 2. Boulders and matrix of andesitic tuff-breccia. On the Middle Fork of the John Day River near Dry Creek.

Fig. 3. Morning mine from dump at #1 level.

Fig. 4. Porphyry dikes near Tempest mine at head of Granite Boulder Creek. Light colored areas are northeast trending dikes in biotite-quartz diorite on Sunrise Butte.

pegmatites and it is very likely that the dikes have been formed from solutions of a greater fluidity and of a later age, and probably from a deeper source, than those which produced the aplites.

Early Tertiary (?) intrusives

Distribution and character: Porphyritic dikes of intermediate to acid composition are abundant in certain parts of the district. These dikes tend to aggregate in swarms, one of which occurs in the vicinity of the Morning mine. Other swarms are known in upper Vinegar Creek basin, in Morris basin near the headwaters of the East Fork of Clear Creek, at the headwaters of Granite Boulder Creek near the Tempest and Tiger mines, and in Salmon Creek valley. The dikes cut all pre-Tertiary rock, trend northeast across earlier trend lines, and measure up to 100 feet wide and several thousand feet long. They are composed preponderantly of quartz diorite and quartz monzonite porphyry and granophyre.

Petrography: The quartz diorite porphyry dikes, which are particularly numerous in the vicinity of the Morning, Tempest, and Tiger mines, in Vinegar Creek and Morris basins, and near Susanville, are composed of a grayish, porphyritic rock with such an abundance of plagioclase phenocrysts as to possess virtually a granular texture. The phenocrysts consist largely of white plagioclase crystals 1 to 2 mm long and lesser biotite, hornblende, and quartz crystals of similar size in a fine-grained, granular, light-gray groundmass composed largely of quartz and plagioclase and accessory magnetite, apatite, and zircon (pl. 7, fig. 1). The plagioclase phenocrysts, which make up slightly more than 50 percent of the rock, are zoned andesine crystals, considerably altered to sericite and clinozoisite; the plagioclase in the groundmass is little-altered sodic andesine or oligoclase.

Quartz monzonite porphyry dikes are most numerous near the Bi-Metallic, Snow Creek, Banzette, Paramount, and Psyche mines. The rock resembles the quartz diorite porphyry but has a distinct pinkish cast. It is conspicuously porphyritic, with andesine, hornblende, and biotite phenocrysts making up about 20 percent of the rock. The phenocrysts are embedded in a microgranular groundmass composed largely of orthoclase and quartz with subordinate oligoclase, and such accessories as apatite, zircon, and magnetite (pl. 7, fig. 2).

The granophyric dikes, which were noted in the vicinity of the Paramount, Baird, Lucky Strike-Elk, and Silver King properties at the head of the South Fork of Desolation Creek, are composed of a fine-grained, gray to pinkish, inconspicuously porphyritic rock with small, widely scattered oligoclase, quartz, orthoclase, and biotite phenocrysts in a groundmass of micrographic quartz and orthoclase (pl. 6, fig. 4). These dikes are smaller than the others, usually a few feet wide and only a few hundred feet long. Because of their small size they are easily overlooked and may actually be more widespread than realized.

Age: The precise date of dike intrusion is uncertain. Workers in the Sumpter and Baker quadrangles have related these dikes to the biotite-quartz diorite and have assigned them a pre-Tertiary age. The local conditions, however, suggest a lack of any genetic relationship between the dikes and the diorite. This lack of relationship is indicated by localization of dikes along regional zones of shearing which cut the dioritic rock, by evidence of rapid chilling against the cold diorite walls, and by consolidation at relative shallow depth, apparently after the diorite had been exposed by erosion. This would indicate a considerable time interval between the solidification of the diorite and the intrusion of the porphyritic dikes.

The dikes may perhaps be correlated with those of early Tertiary age which Anderson (1939) has recognized as cutting the Idaho batholith at Atlanta and at Rocky Bar (Anderson, 1943). Anderson (1940) has also found early Tertiary dikes cutting granite in Kootenai County, Idaho, and in the Clark Fork (Anderson, 1937) district of Idaho. Thayer,* in his work in the John Day region of eastern Oregon, has found a wide variety of fine-grained dikes that are unlike anything found in the older gabbroic sequence of that area. He has also found a series of porphyritic intrusives in the Aldrich Mountains which he thinks could very well be early Tertiary. Thus the dikes of the district may well be early Tertiary (?) and therefore without direct genetic relation to the biotite-quartz diorite. There localization may be along zones of structural weakness produced during the Laramide orogeny which came at the close of the Mesozoic.

Tertiary rocks

The Tertiary rocks are widespread in the valley of the Middle Fork of the John Day River and form ridge caps in many other parts of the district. These rocks formerly blanketed the entire region, having been laid down on the eroded surface carved in pre-Tertiary rock, and then partly removed by subsequent deep erosion. These rocks are mostly of volcanic origin, but there are some intercalated lake and fluviatile deposits. The basal rocks are composed of andesitic tuff-breccias and rhyolite flows which are overlain, apparently conformably, by flows of Columbia River basalts (middle-Miocene) and interbedded lacustrine and fluviatile deposits, some of which are diatomaceous.

ANDESITE TUFF-BRECCIA

The andesite tuff-breccia is widely distributed, particularly along the Middle Fork of the John Day River. It also occurs as remnant, isolated patches on valley slopes in other parts of the district. Good exposures are visible along US Highway 28 where it passes over Dixie Mountain.

Some of the tuffs show water stratification, but most of the tuff-breccia is an unassorted mixture of rock fragments of diverse sizes ranging from sand grains to boulders

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* Thayer, T. P., personal communication.

ten feet or more in diameter. The larger fragments are imbedded in a fine tuffaceous matrix, mostly volcanic ash composed of welded glass and in places of water-worked sands. The boulders consist of porphyritic hornblende and pyroxene andesite. During erosion the larger boulders tend to protect the material below and give rise to "hoodoo" forms or perched boulder pedestals. More commonly, however, the tuff-breccia is reduced to smooth slopes strewn with rock fragments of all sizes. The rock is predominantly gray to black, locally reddish-brown.

The tuff-breccia is evidently the product of local explosive eruptions. Considerable rock has since been carried away by erosion but at least 1,000 feet remain in the Dixie Mountain area. In the Sumpter quadrangle 1,800 feet of this rock is reported by Pardee (1914).

RHYOLITE FLOWS AND TUFF

Flows of rhyolite and intercalated tuff lie above the tuff-breccia and below the Columbia River basalt. In places the rhyolite rests unconformably on the tuff-breccias and contains a rubble of the underlying material; in other places it appears to be conformable with the tuff-breccias. Locally rhyolite has penetrated the older rock with sill-like relationships.

The rhyolite flows are light colored, commonly pinkish red, and are generally somewhat pumiceous. The flows are inconspicuously porphyritic but they contain scattered andesine, sanidine, and quartz phenocrysts in a groundmass that is composed largely, and in some cases entirely, of glass.

COLUMBIA RIVER BASALT

The Columbia River basalt forms extensive flows in the valley of the Middle Fork of the John Day River near Bates, and along the Middle Fork in the vicinity of Susanville. Remnant caps on upper valley slopes remain in other parts of the district. Flows are numerous and range from 10 to 50 feet in thickness. The flows probably blanketed the entire region but much of the blanket has been removed by erosion. In the eastern part of the district, however, more than 1,500 feet remain.

The basalt is of two kinds; (1) olivine basalt and (2) non-olivine basalt, the latter being rather siliceous. Tops of individual flows are generally reddish and scoriaceous, but the lower parts are gray and only slightly vesicular. The olivine basalt is dark-gray to black; the non-olivine basalt is a light gray. The olivine basalt, which comprises most of the flows, contains phenocrysts of olivine in a dense matrix of labradorite, augite, olivine, hypersthene, magnetite, and glass. The non-olivine basalt is composed of sodic labradorite (near andesine), augite, and glass, and rarely contains olivine.

The basalt rests unconformably on the older rocks, in some places directly on the pre-Tertiary formations. Thus considerable erosion must have intervened before the basalt flows were extruded. These basaltic extrusives may be traced eastward into the Sumpter region where they form a part of Pardee's younger basic lavas. They may also be correlated mineralogically and lithologically with the Columbia River lavas of the Baker quadrangle.

LACUSTRINE AND FLUVIATILE DEPOSITS

The lacustrine and fluviatile deposits are contained beneath and between the basalt flows. Farther east such deposits also lie above the basalt (Gilluly, 1937). These deposits consist of lenticular beds of clay, volcanic ash, and sands and gravels derived from erosion of older rock. The deposits also include beds of diatomite. Beds of diatomite near Austin are well exposed along the cuts of the Sumpter Valley Railroad and yield a flora in which have been noted leaves of oak, willow, maples, redwoods, and other plants similar to those in the Miocene Mascall formation (Pardee, 1914). Intercalated with the flows between Hunt Gulch and Windlass Creek is a 30- to 40-foot bed of clay that is bluish to yellowish gray in color and which is composed of an aggregate of small, brittle clay fragments, idenitfied by Dr. F. R. Hunter* as montmorillonite-beidellite derived from andesitic tuff.

Quaternary rocks

The Quaternary rocks are represented by Pleistocene glacial deposits and Recent stream alluvium. The former includes unstratified morainic material, ponded glacial lake sediments and stratified glacio-fluvial outwash. Till or morainic material is contained in all the north-facing valleys that were occupied by glaciers, in part as irregularly distributed drift on slopes or as moraines on valley floors with valley trains extending below. Much coarse, assorted material as well as some ponded silts and sand deposits are found in cirque basins. Glacial debris is also contained in two tributary valleys of Granite Boulder Creek. Two separate drift sheets have been recognized in the Sumpter area (Pardee, 1914), but no effort was made to distinguish between them in the local area.

The Recent alluvium is confined to the floodplain of the Middle Fork of the John Day and the lower parts of Clear and Dry Creeks in the northeastern part of the district. The deposits consist of unconsolidated silts, sand, and gravels.

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Structural Geology

By reason of severe folding, faulting, and penetration of igneous bodies, the Paleozoic and Jurassic (?) rocks are complexly deformed, quite in contrast with the mildly deformed Mesozoic diorite and the Tertiary volcano-sedimentary rocks. There have been three major structural disturbances. The earliest of these may have been associated with the late Jurassic (Sierra Nevada) orogeny and it was responsible for much of the folding and faulting of the older volcanic and sedimentary rocks. The intrusion by ultramafics and biotite-quartz diorite was a later phase of this deformation. The second may be a reflection of the Laramide orogeny at the close of the Mesozoic era and it produced the major zone of shearing west of Greenhorn. The third disturbance occurred during late Tertiary and Quaternary time and can be recognized in the folded and faulted Tertiary volcano-sediments.

Late Jurassic (?) structural features

The argillites and greenstones of the district are closely folded and intensely sheared. Beds are overturned and repetition of strata is evident in almost every outcrop. Chert beds show complicated, swirling folds within a few square feet and locally the argillitic beds have a pseudoconglomeratic texture which is indicative of intense shearing. This deformation produced an east-west structural trend. Fracture cleavage has broken the massive argillite beds into polygonal blocks (pl. 3, fig. 3). Trend lines of the fracture cleavage are generally north-northwest and east-northeast.

The ultramafic and gabbroic rocks were intruded into the argillites and greenstones along the general east-west structural trend. These basic intrusives are less deformed by folding and shearing than the argillites.

The biotite-quartz diorite and its satellite dikes cut the earlier ultramafics and gabbros and are therefore younger. The emplacement of the dioritic rock was also controlled by the general east-west structural trend. Igneous metamorphism accompanying this intrusion gave wide zones of gneiss and hornfels in the argillitic rocks, and extensive amphibolitization of the ultramafics and the gabbros.

From field relationships it is impossible to fix the exact age of the deformation responsible for the folding and faulting of the volcano-sedimentary rocks and the somewhat later intrusion of the ultramafics and diorite. Nolan (1943) discusses the various cycles of deformation that were active in the neighboring Basin and Range province and especially notes that there were recurrent periods of deformation from early Jurassic into early Tertiary, and that these affected a considerably greater area than the Basin and Range region. Recent studies of nearby mining districts in eastern Oregon (Gilluly, 1933) indicate that two Mesozoic orogenies may have been active and that there is also evidence of ultramafic intrusions in late Jurassic. It would seem that the deformation may well be correlated with the Sierra Nevada orogeny of California and Nevada of late Jurassic (?) time.

Laramide (?) structural features

A zone of west-northwest shearing may be traced from the head of the South Fork of Desolation Creek to the area between Lightning and Greenhorn Creeks west of Greenhorn, a distance of about 7 miles. The zone cuts across the northeast part of the larger diorite body and through the older sedimentary and igneous rocks; the shearing has produced fractures particularly favorable for the introduction of porphyritic dikes and ore-bearing solutions. The shear zone and its associated faults are shown in plate 1 (in pocket). In detail the shear zone is composed of a major strike-slip fault of west- northwest trend, several smaller northwest strike-slip faults, north-northeast high-angle reverse faults, and a few northeast high-angle normal faults. Along the major strike-slip fault and the smaller northwest strike-slip faults, the southwest side has always moved relatively to the southeast and the fault surfaces dip from 60 to 90 degrees to the northeast. Throws along these faults are about 100 feet, with horizontal displacements of from 200 to 300 feet.

The high-angle reverse faults of north-northeast trend are confined to the southwest margin of the shear zone. These faults can be traced for some 2000 to 3000 feet and dip northwest at variable but generally steep angles.

The northeast high-angle normal faults occur along margins of the shear zone. These faults may be traced for 200 or 300 feet and show displacements of a few tens of feet.

The presence of a major shear zone cutting the diorite and associated aplite and pegmatite dikes is indicative of a period of deformation that has heretofore received little notice in this general region. Ross (1938) mentions late Mesozoic orogenic disturbances in the Wallowa Mountains and Anderson* has recognized shearing, which he regards as Laramide, in the Idaho batholith. As the time of intrusion (Gilluly, 1937) of the diorite has been correlated with that of the Idaho batholith, the major shear zone may also have been caused by Laramide stresses. Recent studies have extended both the period of time involved and the area affected by the Laramide orogeny. Noble (1941) suggests Laramide movements in the Death Valley region and Merriam and Anderson (1942) have found evidence of Laramide thrusting in the Roberts Mountain region of Nevada. Thus eastern Oregon is apparently not out of alignment with the Laramide disturbance, and the transverse shearing therefore may be regarded, at least tentatively, as Laramide.

Late Tertiary and Quaternary structural features

The Columbia River basalt and associated rocks are much less severely deformed than the pre-Tertiary formations. The broad open folds follow earlier trend lines and strike west to northwest. Normal faults cut the folds with a north-northeast strike.

Folds: Three conspicuous folds originate near the western border of the Sumpter quadrangle and are traceable for some 12 miles to the northwest of Greenhorn. For convenience

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*Anderson, A. L., personal communication.

these folds are named the Greenhorn and Dixie Butte anticlines and the Middle Fork syncline (see pl. 1 in pocket).

The usual flank dips are from 20 to 30 degrees and the anticlines are steeper on their north flanks by about 5 degrees. These folds plunge at the rate of from 20 to 30 feet per mile northwest throughout the distance mapped. The Middle Fork of the John Day River lies in the Middle Fork syncline and is aligned with the plunge almost perfectly for over 25 miles.

Faults: Four normal faults of north-northeast trend are present along the Middle Fork of the John Day River. The faults average about one mile in length and all dip to the southeast at angles of 60 to 70 degrees. Two of the faults, one below Little Boulder Creek and the other below Tincup Creek, are evident on both sides of the river. The faults at Hunt Gulch and below Granite Boulder Creek could not be traced southwest of the river with certainty. All of the faults have throws of about 200 feet and three of them have brought basalt flows into juxtaposition with the andesitic tuff-breccia. These faults cut the Columbia River basalt and are therefore of post-Miocene age.

Historical Geology

Many gaps occur in the geologic record of the Greenhorn Mountain area. The oldest rocks exposed are Carboniferous argillites with interbedded tuffs and basic lavas that have been altered to greenstone. The deposition of silts and muds with local additions of gravels and fossiliferous limy material (Gilluly, 1937) occurred in a shallow marine sea. Towards the close of the period of sedimentation several hundred feet of volcanic ash showered over the sea and was incorporated in the deposits. Basic lavas were later extruded on the sea floor and formed a notable part of the series of rock. Triassic rocks are not present within the district but are found 75 miles to the east in the Wallowa Mountains (Ross, 1938) and in the Strawberry Range (Thayer, 1940), 25 miles to the southwest.

The deposition of the Carboniferous sediments is the last recorded invasion of the marine sea into the immediate area and subsequent events have been limited to periods of deformation, erosion, and continental sedimentation. In late Jurassic time it is probable that these argillitic and interbedded volcanic materials were severely folded and faulted. Subsequent to the deformation these rocks were intruded first by ultramafic and gabbroic bodies and later by the biotite-quartz diorite magma. A considerable period of erosion followed the orogeny, and apparently lasted throughout much of the Cretaceous. At the close of that period the area was again deformed; this time by horizontal shearing stresses, perhaps associated with the Laramide orogeny which caused the profound folding and faulting of the Rocky Mountains far to the east. Into the faults produced by the shearing were injected masses of partly crystalline magma, forming dikes of quartz diorite and quartz monzonite porphyry and granophyre. Intrusion of dike magma was followed by circulation of mineral-bearing solutions, utilizing the same zones of structural weakness. More than likely the dike intrusion and mineralization were carried over into early Tertiary time.

After the late Cretaceous disturbance and the emplacement of dikes and vein material, the region apparently underwent widespread erosion until early (?) Miocene, when large quantities of andesitic breccia and tuffaceous material erupted from local sources, forming a blanket over the deeply eroded basement rock. Contemporaneous with the formation of the tuff-breccias, were extrusions and local intrusions of rhyolite, with some intercalated siliceous tuffaceous material. In middle Miocene time the country was buried beneath flow upon flow of basalt, some of which emerged from fissures within the district. These flows caused local damming of streams and the formation of lakes in which were deposited clays and volcanic ash.

At the close of the Tertiary another crustal disturbance caused folding and faulting of the lava-formed plateau into mountains and valleys. Control by earlier trend lines is apparent in this last period of diastrophism as the structures strike generally west-northwest. The compressive forces formed folds and the later tensional phases were responsible for the normal faults.

Erosion has been active since this last disturbance. During the Pleistocene the higher mountain regions were sculptured by glaciers and the valleys partly filled with morainal and outwash material. The changes in relief brought about by glaciation and valley filling, however, have been slight.

Ore Deposits

History and production

Settlement of this general region began in 1862 with the discovery of gold near Auburn, a now deserted camp west of Baker. The early miners gave their immediate attention to the rich placers, and practically all of the streams descending the slopes from the higher elevations show evidence of placer operation. These placers were, in places, highly productive, especially in the area surrounding the now vanished camps of Winterville and Parkerville on the headwaters of Burnt River just to the southwest of Greenhorn. Several quartz claims were located in the Sumpter area during the period 1866-1880, but the real beginning of lode mining began with the completion of a railroad to Baker in 1886 and the advent of the Sumpter Valley railroad into the immediate area in the 1890's. The peak of gold-quartz mining in the immediate district was probably reached during the period 1895 to 1910. It was at this time that the town of Greenhorn was moved from its old location north of Sunrise Butte, where a silver strike had been made, to its present site. From 1915 to 1940 mining has been desultory, with an occasional rich strike. As legislation during the last war dealt a serious blow to the mining of gold and silver, the area has seen little activity in recent years. However, in the past year there has been an influx of prospectors into the district. Work at some of the larger mines, as the Morning, has been resumed.

Production figures are absent or sketchy for individual districts of the Blue Mountain region. Lindgren (1901) has given a figure of $3,258,197 for the production of gold and silver from both lode and placers in Grant County during the period 1880 to 1899. Gilluly (1933) has listed gold and silver lode and placer production in Grant County for the period 1903 to 1928 at $2,700,000.

Character of the deposits

The deposits may be classed as gold-quartz veins and lodes. They are chiefly fissure fillings; a few are combined fissure fillings and replacements. The term vein is applied to simple fillings of open fissures, whereas the term lode is applied to bodies composed of aggregates of small seams and stringers of quartz in zones of complexly fractured rock. Many of the deposits contain appreciable amounts of iron and most of them contain minor quantities of lead, copper, zinc, and silver. The gold is the only metal of commercial interest. However, there is one deposit that contains quicksilver, but the quicksilver is not contained in a gold-quartz vein or lode.

Distribution of the deposits

The veins and lodes are located within a broad, east-west trending zone that extends from Susanville eastward through Greenhorn. The gold-quartz deposits are segregated into four general localities: one embracing the region around Susanville on Elk Creek; one which includes the mines at the heads of Granite Boulder Creek and the East Fork of Clear Creek; one at the heads of the tributaries of Vinegar Creek; and another which includes the properties just to the west of Greenhorn. The area adjacent to Greenhorn contains the greatest number of deposits. Within this group is the only known quicksilver deposit of the district.

Veins are contained in all pre-Tertiary rocks and are most always intimately associated with early Tertiary (?) dikes, either within or alongside. The veins near the heads of Granite Boulder Creek and the East Fork of Clear Creek are in the biotite-quartz diorite as are a few in the Salmon Creek valley. Elsewhere the veins and lodes are in argillite and greenstone or in serpentinized ultrabasics. In all cases the distribution of the veins and lodes has apparently been controlled by the structure and not by the character of the rock.

Structural relations

The veins and lodes are confined to the same zone of structural weakness as the early Tertiary (?) dikes. They are most common and attain their greatest development on the underside of the dikes, forming what may be called "footwall" veins. The few that lie above the dikes might well be called "hanging wall" veins. The faults which directed the intrusion of the dikes, and later the flow of mineralizing solutions, are the high-angle reverse faults. Associated with these faults are minor gash fractures which also contain ore, forming gash veins. Some veins and lodes are along strike-slip faults and some are along minor bedding plane slips and fracture cleavage.

In general, the veins occupying the high-angle reverse faults trend about N. 40° E. and dip steeply northwest. There is, however, considerable variation in the strike and dip of individual veins and lodes, the strike showing deviations up to 20 degrees and the dip up to 50 degrees. Veins in Morris Basin strike in a more northerly direction (N. 10-15° E.). They occur in gash fractures along the footwall of porphyry dikes. Some veins at the head of Snow Creek have a westerly trend and a steep northerly dip. These veins are cut and displaced by the northeast fissure veins. Lodes in argillitic rock at the head of Blackeye Creek trend due west and dip steeply north.

Mineralogy

The deposits contain both primary and secondary minerals, but those of secondary origin are of little consequence or interest. In the gold-quartz veins and lodes the primary minerals are apparently the product of two stages of mineral deposition, the minerals of each stage being much the same. Quartz is the predominant mineral. It is accompanied by variable quantities of sulphides, which may comprise 10 to 40 percent of the filling, and locally by considerable carbonates. The mineralogy of the quicksilver deposits is notably different from that of the gold-quartz veins and lodes, the predominant minerals being chalcedony and cinnabar.

In the gold-quartz veins and lodes the primary minerals are quartz, pyrite, arsenopyrite, sphalerite, pyrrhotite, chalcopyrite, galena, specular hematite, tetrahedrite, calcite or dolomite, and gold. The minerals, except quartz, pyrite, and arsenopyrite, are present in small but variable quantities. The pyrrhotite, galena, specular hematite, and gold appear but once; all other minerals appear twice, marking two main stages of mineral deposition.

In the quicksilver veins the minerals are quartz, chalcedony, pyrite, and cinnabar.

Quartz: The quartz comprises 60 to 90 percent of the vein and lode fillings. It exhibits considerable variation in grain size and in textural and structural relations, reflecting its deposition in two stages, the later quartz cementing breccias and filling fractures in the earlier. In general the early quartz is not as abundant as the later; in places it is retained in the younger as shadowy inclusions.

The early quartz is distinguished by its coarse grain, its milky-white color, and its content of coarse-grained sulphides in fractures. The later quartz is distinguished by its much finer grain, its bluish-gray color, and by its content of minutely disseminated and intimately associated sulphides which also fill fractures and cement breccias.

Chalcedony: The chalcedony is present in only a few deposits, occurring in appreciable quantities only at the Paramount quicksilver mine. It possesses a distinct pinkish-gray color and occurs as a breccia cement and as narrow veinlets in earlier fillings.

Pyrite: The pyrite is present in all veins, usually comprising 60 to 80 percent of the metallic minerals. It is particularly abundant in the veins found in and along the quartz diorite porphyry dikes and is less abundant in veins associated with serpentinized rock. The pyrite occurs with both the older and younger quartz and is also found as scattered crystals in chalcedony.

The pyrite, in the older quartz, is coarse-grained and usually forms aggregates of cubic crystals which average a quarter of an inch across. The pyrite in the younger quartz is very much finer grained, and appears massive or compact. It is much more abundant than the early pyrite, the ratio being about 2 to 1.

The early pyrite is commonly fractured and cut by veinlets containing arsenopyrite, pyrrhotite, sphalerite, and chalcopyrite. Remnants of pyrite are also contained as inclusions within these minerals. The younger pyrite also is fractured and penetrated by its more or less closely associated arsenopyrite, sphalerite, and chalcopyrite. This pyrite is auriferous, the older contains little, if any, gold.

Arsenopyrite: The arsenopyrite, which is present in nearly all veins, is most abundant in the central part of the district. Locally it may comprise as much as 10 percent of the vein filling. Like the pyrite it is present in two generations; the earlier, which is the more abundant, forms fine-grained, steel-gray masses in the early quartz; the later occurs as sparsely disseminated microscopic crystals in the younger quartz.

The arsenopyrite generally accompanies pyrite, but in places it penetrates and holds inclusions of pyrite. Other sulphides present with it, however, usually vein it along fractures and hold it as engulfed, often somewhat corroded, inclusions. These relations are typical of both generations of arsenopyrite and associated sulphides.

Pyrrhotite: Pyrrhotite appears only in the veins in the Snow Creek area where it locally may comprise as much as 50 percent of the sulphides. It is irregularly distributed, forming fine-grained, bronze-colored crystalline aggregates in the earlier quartz. In addition to filling fractures in the quartz it also forms mantles on arsenopyrite grains. In places the pyrrhotite is penetrated by and is contained as remnant inclusions in irregular veinlets of sphalerite and chalcopyrite (pl. 8, fig. 3). Masses are also engulfed in the younger quartz.

Sphalerite: Sphalerite is present sparingly in most veins. It is most abundant in Morris Basin and is least abundant in the Snow Creek area. It occurs with both generations of quartz, in the older as fine, dark-gray to black grains, and in the younger, as small, dark-brown grains.

The sphalerite is one of the minerals that forms irregular veinlets in fractured pyrite and arsenopyrite, and is also one that contains the two as remnant inclusions (pl. 8, fig. 1). The sphalerite, similarly, is cut by and held as engulfed inclusions in veinlets of other sulphides. These relations pertain to both generations of sphalerite.

Chalcopyrite: In some veins the chalcopyrite occurs sparingly as isolated grains; in other veins it occurs as massive aggregates making up 10 percent of the filling. That occurring with the early quartz forms small, fine-grained masses; that with the later quartz is coarsely crystalline and fills fractures. The younger chalcopyrite is not nearly so abundant as the earlier.

The older chalcopyrite cuts and corrodes pyrrhotite and sphalerite and is in turn irregularly penetrated by small stringers of tetrahedrite. Most of the younger chalcopyrite is contained in the late quartz, but some also forms small blebs aligned along cleavage fractures in sphalerite. Supergene covellite penetrates chalcopyrite along fractures and along galena-chalcopyrite contacts (pl. 8, figs. 2 and 4).

Tetrahedrite: The tetrahedrite is present in small quantities in most veins and lodes, but is relatively abundant only at the Morris and Bi-Metallic mines where it is the only sulphide in some veins. In places the tetrahedrite contains up to 10 percent silver and locally may be classed as freibergite.

The tetrahedrite is contained in both generations of quartz. In the early quartz it forms small, isolated grains and masses, which commonly penetrate accompanying grains of sphalerite and chalcopyrite. In the younger quartz it occurs as minute, irregular veinlets in sphalerite (pl. 7, figs. 3 and 4).

Galena: The galena is most abundant in the veins in the eastern part of the district where it comprises as much as 2 or 3 percent of the sulphide filling. Grains of galena are usually small and scattered, but locally, as in the veins on the south fork of Desolation Creek, the galena may form small masses. It occurs only with the younger quartz, commonly as fillings of fractures, and locally is accompanied by sphalerite and chalcopyrite which are contained as remnant inclusions (pl. 8, fig. 2).

Specular hematite: The specular hematite occurs sparingly in a few mines but nowhere accounts for more than a fraction of one percent of the vein filling. It forms small, steel-gray, bladed grains in the younger quartz and microscopic mantles on pyrite. It also appears as minute laths along cleavage cracks in galena in the Snow Creek veins.

Cinnabar: Cinnabar has been found only at the Paramount mine where it has provided a small quicksilver production. It is distributed as small vermilion-red grains and aggregates in stringers of chalcedony and as thin coatings on bedding planes and cleavage surfaces of bordering argillite. The cinnabar is accompanied by a little pyrite whose grains are small and rounded.

Gold: The gold is contained in small but variable amounts in all veins throughout the district. Its distribution is erratic; it accompanies the second stage quartz, usually as microscopic grains associated with the young pyrite, being visible as free grains in the oxidized ore where it constitutes the "free-milling gold" of the early operators. The gold is not confined entirely to fractures in the young quartz or to the pyrite; it is found also with the other minerals, particularly in fractures. Its preferential association with pyrite would indicate, however, that it found this mineral a more favorable host than the other sulphides. The gold also shows a tendency to favor the more highly brecciated parts of the fine-grained, second-stage quartz.

Calcite and dolomite: In the eastern part of the district, calcite and dolomite may comprise as much as 50 percent of the gangue. The carbonates are especially abundant in the veins in serpentinized, basic igneous rocks, but the content is low in other kinds of rock.

The calcite and dolomite form white, coarsely crystalline masses, with grains measuring as much as half an inch across. They compose lenticular bodies and cement breccias of the earlier fillings. As observed in polished sections, thin calcite veinlets cut indiscriminately across all sulphides, filling fractures. The more massive bodies contain included fragments of earlier minerals. At, and near, the Paramount mine the carbonate minerals are cut by small veinlets of chalcedony.

Minerals of secondary origin formed by supergene processes are not abundant. Supergene covellite irregularly penetrates chalcopyrite and also forms thin seams between chalcopyrite and galena. Anglesite, lead sulphate, fills cleavage cracks in galena where that mineral is associated with covellite. Outcrops of many veins are stained by scattered films of greenish scorodite, hydrous iron arsenite, which has formed by oxidation of contained arsenopyrite. Because of the relatively large quantities of pyrite, the outcrops of most veins generally contain an abundance of limonitic oxides. Manganese oxides were not observed on outcrops or in underground workings, except in the upper stopes of the Morning mine where they are present in minute quantities. Malachite and azurite, hydrous copper carbonates, are usually present in the outcrops of chalcopyrite-bearing veins.

Paragenesis

From the description of the relations and associations of the minerals in the gold-quartz veins and lodes it is evident that there are two stages of mineral deposition, each stage represented by its own characteristic form of quartz and each also by its own particular assemblage of sulphides. The coarse, milky-white quartz was deposited during the first stage, and then, after minor fracturing, the sulphides - pyrite, arsenopyrite, pyrrhotite, sphalerite, chalcopyrite, and tetrahedrite - were deposited in the order indicated, by filling and replacement.

Reopening of the veins and lodes as a consequence of renewed faulting permitted the entrance of the bluish-gray, fine-grained quartz and its associated pyrite, arsenopyrite, sphalerite, chalcopyrite, galena, and calcite. Minor quantities of specular hematite were also deposited but its place in the sequence is not known. Gold apparently was a late introduction, being younger than the sulphides.

In both the first and second stages of deposition, much of the quartz was deposited before the sulphides, but, as quartz crystals are contained in the sulphides and as some quartz occurs in fractures in these minerals, the period of quartz deposition in both cycles must have been in part contemporaneous with, and must have outlasted, the sulphides. Deposition of calcite and dolomite ended the mineralization in most of the veins.

The order of deposition in the gold-quartz veins and lodes is shown diagrammatically in table 1 opposite p. 27.

Field and microscopic evidence argues against classing the fine-grained chalcedonic quartz and its associated pyrite and cinnabar with the early Tertiary (?) mineralization. It is very likely that the chalcedonic quartz is the product of an entirely different, and much younger, period of mineralization.

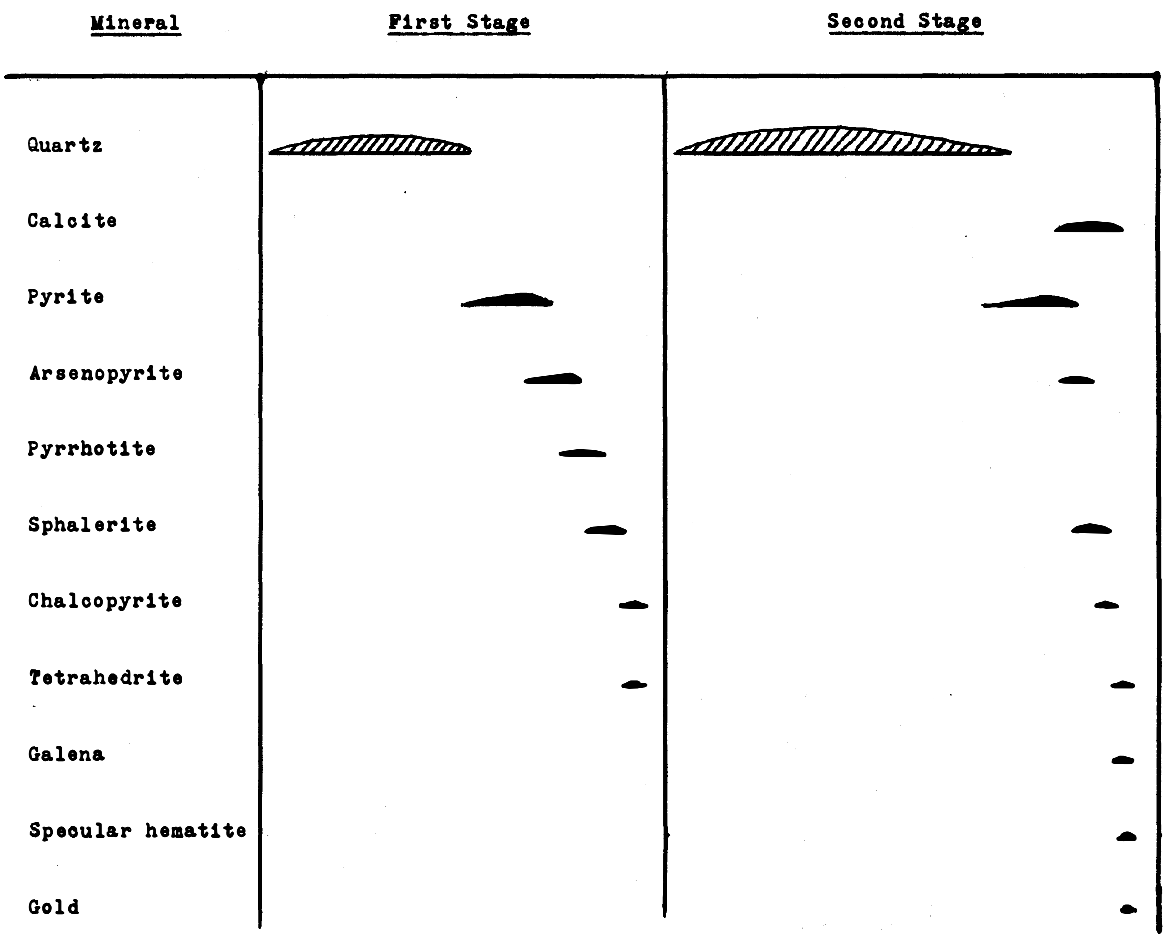


Table 1. Mineral sequence in the gold-quartz veins and lodes.

Mineral zoning

Mineral zoning is suggested by the distribution of minerals, particularly with reference to the porphyry dikes. Arsenopyrite is most abundant in the veins associated with the cluster of quartz diorite porphyry dikes near the biotite-quartz diorite and becomes less abundant outward therefrom. Galena, on the other hand, is more abundant remote from this area, a relation which suggests that the local area of quartz diorite porphyry dikes represents a thermal center with temperatures declining outward.

Distribution and occurrence of ore

As the gold was introduced with the second stage solutions, it is invariably found with the younger quartz and associated sulphides. The ore therefore is limited to those veins and to those parts of the veins that contain these younger minerals, the quantity of which depends entirely on the extent of intramineralization faulting which took place between the first and second stages of mineralization. Repeated movement and brecciation of vein material, which kept channels open and permitted free upward movement of solutions, created favorable sites for deposition of ore. Veins of early quartz that were only slightly reopened contain practically no ore - only barren, early vein quartz and sulphides; veins greatly brecciated after deposition of the early minerals comprise the auriferous bodies.

The ore occurs as small pods and lenticular masses distributed erratically within the tabular veins of early quartz. Locally the lenses of late quartz and its associated sulphides may make up as much as 60 percent of the vein filling, but usually the ore occurs as scattered stringers and small lenses in the early quartz. The footwall veins contain the greatest concentration of second-stage minerals, consequently they have been the most productive. The veins along the hanging walls of the dikes are composed essentially of first-stage quartz and associated sulphides, having been but slightly brecciated by intramineralization movement, and little enriched by younger minerals.

Localization of ore shoots

As the veins are chiefly fissure fillings, the ore is confined to favorable rock openings. These openings depend, in the case of the high-angle reverse faults, on local flattening of dip and to a lesser extent on minor changes in strike. Along the flatter parts, upward movement of the hanging wall has tended to separate the walls and hence has created openings favorable for the circulation of the mineralizing solutions and for the deposition of ore. In the steeper parts, the walls have been forced tightly together leaving no space for ore. Reverse faults that have subsequently suffered a reversal of movement also contain ore bodies along local flats, but the ore bodies are small.

The ore shoots are fillings of the second-stage minerals and generally form irregular pods or masses that may be traced along the fault as long as the fault maintains its local flattening. Shoots seldom measure more than 10 or 15 feet long nor more than a few feet wide. Some of these shoots contain pockets of relatively high concentrations of gold, but distribution of these pockets is so erratic that they cannot be found except by hit-or-miss mining methods.

Small pockets of ore are contained in gash fractures which extend from the footwall veins upward into the overlying rock, usually a porphyritic dike. The gash fractures, which are associated with the major reverse faults, rarely extend more than 10 to 15 feet from the footwall vein. In Morris basin, small, less-rich bodies of ore are also found in gash fractures of the major west-northwest shear zone.

The nature of the country rock apparently had little control in localizing ore shoots. Minor variations in trend and dip of faults were noted in passing from one type of rock to another, but the changes were not of sufficient magnitude to influence ore deposition. Favorable guiding structures and the quantity of ore carried and deposited by the mineral-bearing solutions seem to have been the factors controlling the localization of ore shoots and in governing their size.

Size of ore bodies

The lack of extensive underground workings, except at the Morning, Morris, and Bi-Metallic mines, made it difficult, and in most cases impossible, to determine the general size of the ore bodies. In the Morning mine, the main ore shoot is about 160 feet long and 5 feet wide. A shoot in the upper workings was stoped 90 feet to a height of 10 feet. In the Morris No. 1 mine, a north-striking vein was stoped for 60 feet horizontally and 15 feet vertically. Ore bodies along the Psyche, Big Johnny, and Windsor veins have been reported to be as much as 200 feet long and 4 to 6 feet wide.

Tenor of the ore

Because assay records were not available, little reliable data could be obtained regarding the richness or tenor of the ore mined either recently or in the early days. Samples were taken systematically at a number of properties during the present investigation. These were taken underground where the workings were open, otherwise from the dump. Results of this sampling are given in the description of individual properties.

According to the Oregon Metal Mines Handbook,* the values in the footwall shoot at the Morning mine are spotty, ranging from $15 to $50 per ton; along the hanging-wall vein the values range from $4 to $20 per ton. It is also reported in the Handbook that hand-picked ore at the Bi-Metallic mine assayed $75 to $300 per ton, that the Psyche mine grossed $90,000 in 1905 and that an 87,000-ton block of ore at the Ben Harrison mine averaged about $10 per ton.

*Oregon metal mines handbook - Grant, Morrow, and Umatilla counties: Oregon Dept. Geology and Min. Industries Bull. 14-B, 1941.

Samples taken by the writer at the Morning mine and assayed by the Oregon Department of Geology and Mineral Industries indicate that ore is spotty in distribution, with small but rich pockets interspersed with barren zones. Some high-grade pockets assay as high as several hundred dollars per ton, but the pockets are small and scattered. Assays taken along the stope in the footwall vein ranged from 2.02 ounces of gold and 4.00 ounces of silver to 0.56 ounce of gold and 1.10 ounces of silver per ton. An average for the entire stope (about 160 feet long, 65 feet high, 4 feet wide) was 0.33 ounce of gold per ton.

Wall-rock alteration

The rock bordering the mineralized faults has been more or less extensively altered. The porphyritic dikes associated with the veins have been thoroughly bleached. Inclusions within the veins and lodes retain nothing of their original appearance. The usual alteration involves the conversion of the hornblende to biotite, and the biotite, along with the feldspars, to coarse sericite. Pyrite also is formed in the rock. The alteration of the biotite-quartz diorite has not been conspicuous, but some quartz, sericite, and pyrite have formed along the walls, extending outward for several feet from the veins. Alteration is most conspicuous in the serpentine and gabbroic rocks where the ferromagnesian minerals bordering the veins and lodes have been converted to biotite and chlorite, and the plagioclase to saussurite. Much calcite, dolomite, and quartz have also been added. Serpentine has generally been extensively silicified.

The main processes of alteration have been saussuritization, pyritization, sericitization, silicification, and carbonatization.

Oxidation and enrichment

Oxidation is shallow; as revealed in underground workings it rarely extends down for more than 100 feet. In many places the primary sulphides appear among the oxidation products within a few feet of the surface.

Rich ore mined in the early days came from the oxidized zone where the gold had been partly or completely released from associated sulphides and therefore was readily amenable to stamp amalgamation. As soon as sulphides were encountered, gold recovery dropped.

Supergene enrichment apparently has been negligible. The absence of manganese oxides in most deposits and the small amount in those deposits which do contain it explain the lack of enrichment by solution of the gold and its deposition and concentration at lower levels. Such secondary enrichment as has occurred has been residual enrichment by mechanical concentration at the surface through removal of sulphides and other material during weathering. Rich pockets of gold in the unoxidized as well as in the oxidized zone probably represent primary deposition.

Origin of the deposits

The veins and lodes have the essential characteristic of hydrothermal deposits and were probably formed by hydrothermal solutions of deep magmatic origin which found the high-angle reverse faults favorable as channels and as sites for ore deposition. The mineralization followed soon after the intrusion of early Tertiary (?) dikes, and the close accord in structural relations between the dikes and the veins suggests a genetic connection between them. This close relationship further suggests that the dikes and mineral-bearing solutions have a common origin in a deeper magma. This magma was undergoing differentiation and was tapped at intervals by faults allowing fractions of the progressively changing magma and the end products of differentiation, or ore solutions, to move upward into the rocks above. Inasmuch as the structural data indicate a relatively short time interval between the intrusion of the early Tertiary (?) dikes and the formation of the veins and lodes, mineralization like the dike intrusions probably took place during the declining stages of igneous activity attendant upon the Laramide orogeny.

The ore solutions probably left their magmatic source at a high temperature, but by the time they had reached depositional levels they had apparently cooled to more moderate temperature. Although the presence of pyrrhotite and arsenopyrite suggests that temperatures were moderately high during early stages of deposition, the other sulphides are those more typical of moderate-temperature solutions and hence the ore was formed mostly within the mesothermal range. A considerable time interval must have existed between the two main stages of deposition, for when the younger solutions were introduced, after structural reopening of the earlier filling, they were chilled against cold walls and the minerals deposited were of fine grain. The presence of a small amount of arsenopyrite in the younger filling indicates that the solutions were about as hot as they had been before, differences being accountable only by more rapid cooling and crystallization.

The fine grain of most of the sulphides, particularly those of the second-stage ore, suggests rapid cooling such as usually takes place in cold rock relatively near the surface. A fairly shallow depth of deposition is also indicated by the extent of brecciation which all veins show, a depth probably within several thousand feet of the surface. Association with porphyritic (hypabyssal) dikes also indicates moderate depth relationships. The deposits could probably be classed as mesothermal, or deposits formed at moderate temperature and at moderately shallow depth (Lindgren, 1933).

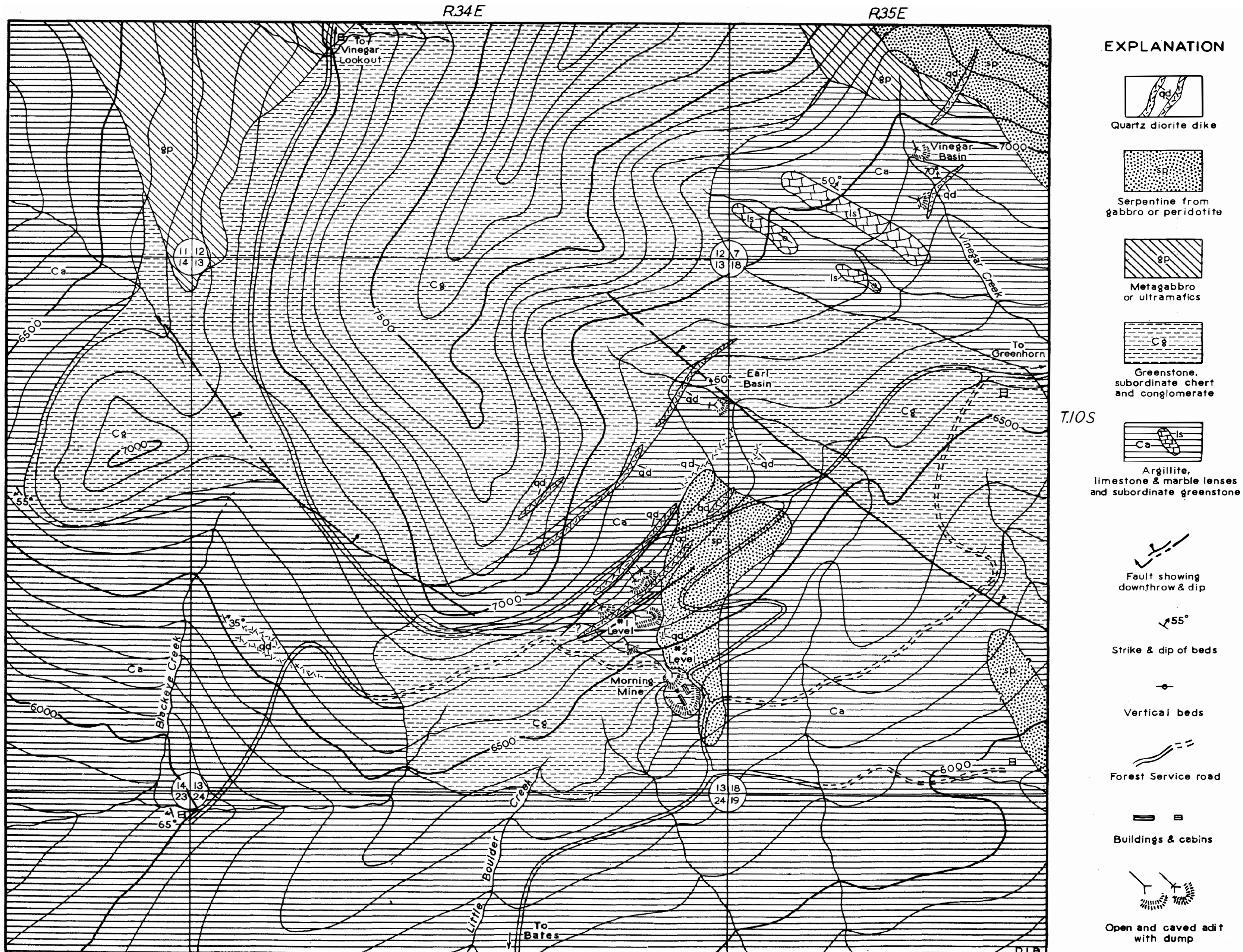
Fig.1. Fault zone at Morning mine. Hammer rests on sheared argillite.

Fig.2. Mines on the west side of Morris Basin.

Conclusions

The limited opportunity for underground study renders it difficult to make a satisfactory appraisal of the district. There are many old workings in the district, very few of which have made noteworthy production. The deposits are small and of moderate grade, but rich pockets did and do exist. The ore apparently has been localized along the less steeply dipping parts of the high-angle reverse faults and in association with, or close by, porphyry dikes. Ore may continue below the present deepest workings along the flatter parts of the guiding faults. However, where arsenopyrite in the younger quartz occurs in relative abundance, temperatures may have been too high for the deposition of much gold, the gold apparently favoring lower temperatures for its precipitation.

Exploration should be limited to areas containing porphyritic dikes. In those areas prospecting should be directed along northeast-trending fault zones. The presence of fine-grained sulphides, notably pyrite, in a fine-grained, bluish-gray quartz, seems to offer a more favorable situation for a high gold content than does the sulphide-free, early milky-white, coarse-grained quartz.



Topographic base from U.S. Forest Service Maps

MORNING MINE AND VICINITY

SCALE

1000 500 0 1000 2000 Feet

Contour interval 100 feet

Geology mapped with Brunton and Pace R.M. Allen 1946

Fig. 1

Mines and Prospects

Morning mine (1)*

Location and history: The Morning mine (pl. 4, fig. 3, opposite p. 10), the largest gold producer in the western Greenhorn district, is about 9 miles north and slightly west of Bates and 5 miles by road northwest of Greenhorn in the SE$\frac{1}{4}$ sec. 13, T. 10 S., R. 34 E., at an elevation of 6,400 feet (pl. 1 in pocket). The property comprises 8 unpatented claims which were located in 1893. The present operator, Mr. William Gardner, acquired the property in 1937 and, except during World War II, has kept the mine in virtually continuous operation.

Development: The development consists of two adits and an intermediate level connected with the lower adit by a raise. The workings and their extent are shown in plan, longitudinal, and transverse section in fig. 2 opposite p. 35 and fig. 3 opposite p. 37.

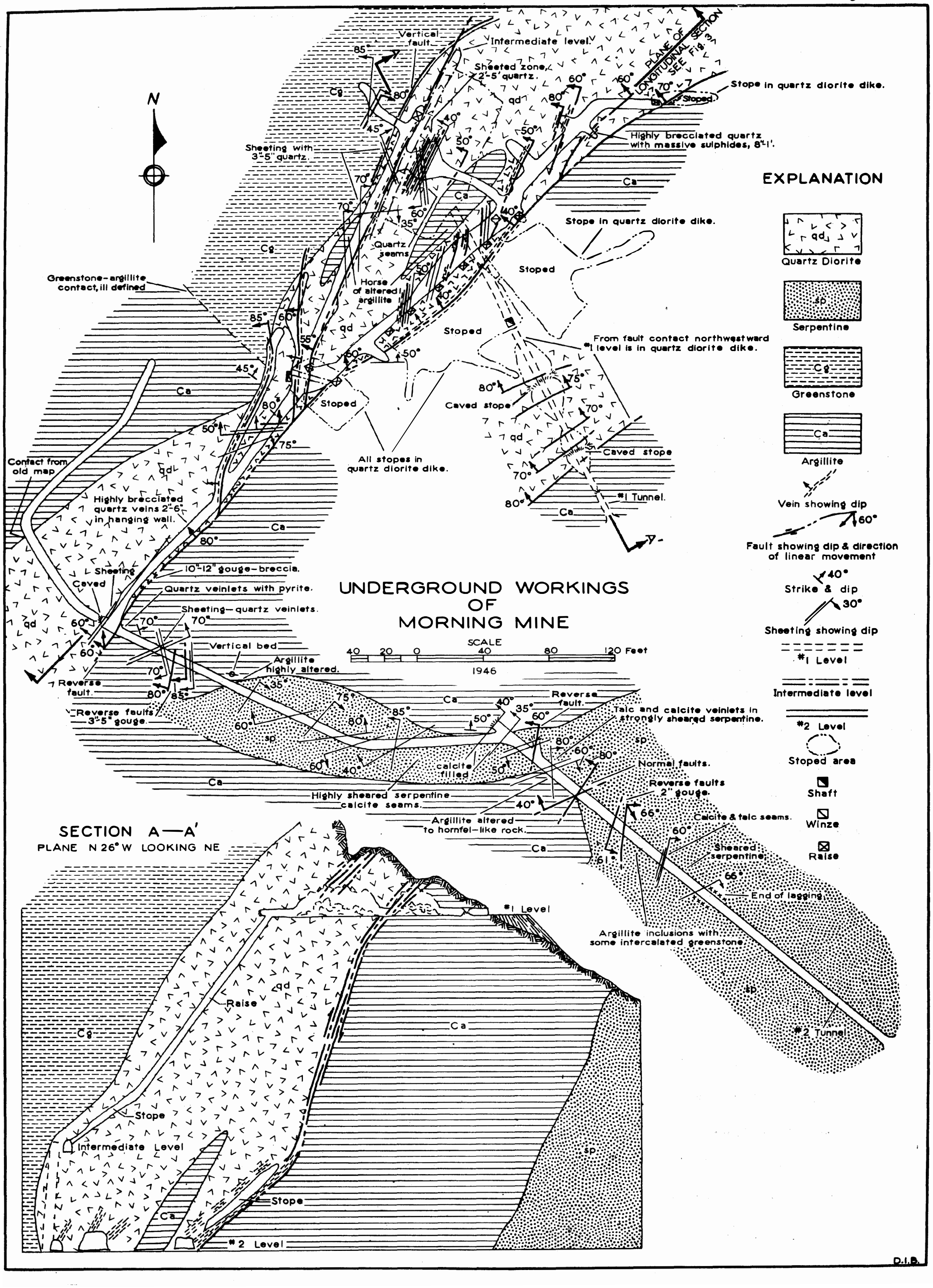
Geology: The rocks at and near the mine consist of highly altered argillites, greenstones, and serpentine intruded by quartz diorite porphyry dikes (fig. 1 on opposite page). The veins are closely associated with the porphyry dikes, and those which are being worked at the present time are contained within and along the footwall and hanging wall of a dike 100 feet wide. The dike, aligned along a high-angle reverse fault, strikes about N. 45° E. and dips 35° NW to 75° NW. Geologic relations underground are shown on the map of lower no. 2 adit level (fig. 2 opposite p. 35) and in the block diagram (fig. 4 opposite p. 39).

The most productive vein follows the underside of the dike for an explored distance of 440 feet and varies from 1 to 4 feet thick. It has a lenticular habit and pinches and swells along its trend, thickening where the dip flattens. Several smaller veins, 6 inches to 1 foot thick, lie above and parallel the vein for its entire exposed length. From the main vein two branch veins extend N. 25° E. through the dike and into the hanging wall for a distance of about 200 feet. These branch veins were drifted on and some stoping was done on the intermediate level along the more easterly of the two veins, but little ore was recovered. The vein along the underside of the dike has been stoped for a horizontal distance of 200 feet and upward for 65 feet, the stope width ranging from 3 to 6 feet. Most of the ore has come from lenticular shoots along the flatter parts of the vein. Small gash fractures, which here and there enter the overlying dike, contain early-stage quartz and sulphides.

The most productive veins are composed of breccias of early sulphides in a matrix of later quartz and associated minerals. The vein filling is about 80 percent quartz, with the younger variety making up nearly 55 percent of the total mineral assemblage. The earlier

*Numbers after mine names are the same as key numbers on pl. 1 in pocket.

Fig. 2


UNDERGROUND WORKINGS
OF
MORNING MINE
SCALE
40 20 0 40 80 120 Feet
1946
EXPLANATION
Quartz Diorite
Serpentine
Greenstone
Argillite
Vein showing dip
Fault showing dip & direction of linear movement
Strike & dip
Sheeting showing dip
#1 Level
Intermediate level
#2 Level
Stoped area
Shaft
Winze
Raise
Vertical fault.
Intermediate level.
Sheeted zone, 2'-5' quartz.
Stope in quartz diorite dike.
Highly brecciated quartz with massive sulphides, 8"-1'.
Sheeting with 3"-5" quartz.
Quartz seams
Horse of altered argillite
Greenstone-argillite contact, ill defined
Stoped
From fault contact northwestward #1 level is in quartz diorite dike.
Caved stope
All stopes in quartz diorite dike.
#1 Tunnel.
Contact from old map
Highly brecciated quartz veins 2"-6" in hanging wall.
10"-12" gouge-breccia.
Quartz veinlets with pyrite.
Sheeting–quartz veinlets.
Sheeting
Caved
Vertical bed
Argillite highly altered.
Reverse fault.
Reverse faults 3"-5" gouge.
Talc and calcite veinlets in strongly sheared serpentine.
calcite filled
Normal faults.
Reverse faults 2" gouge.
Highly sheared serpentine calcite seams.
Argillite altered to hornfel-like rock.
Calcite & talc seams.
Sheared serpentine
End of lagging
Argillite inclusions with some intercalated greenstone.
#2 Tunnel
LONGITUDINAL PLANE OF SECTION SEE Fig. 3
SECTION A—A'
PLANE N 26° W LOOKING NE
#1 Level
Raise
Stope
Intermediate Level
Stope
#2 Level
D.I.B.

sulphides make up about 5 percent of the vein material and consist mainly of pyrite with minor amounts of arsenopyrite, sphalerite, and chalcopyrite. The minerals accompanying the younger quartz are gold, fine-grained pyrite, sphalerite, chalcopyrite, specular hematite, and calcite. Pyrite is again the most widespread mineral of the group and also has the distinction of being the most favorable host for the gold.

Much surface prospecting has been done north and northeast of the main workings especially along porphyry dikes similar to the one in the mine. It is possible that rich pockets of ore may occur in fractures within and along the dikes, but it is doubtful that the ore obtained would be in sufficient quantity to meet the exploitation costs.

Samples taken by the writer from the stope above the No. 2 level showed an average of 0.33 ounce of gold per ton over a horizontal distance of 200 feet and a height of 65 feet. Average stope width was 4 feet. Samples from hanging wall veins assayed only a trace of gold, except for small, widely scattered pockets of fine-grained sulphides, notably pyrite. Some of these pockets carry as much as 0.70 ounce of gold per ton. Assays were made by the State Department of Geology and Mineral Industries.

Smelter returns* show that a shipment of 111,920 pounds of concentrates in 1941 yielded 67.781 ounces of gold and 240 ounces of silver. The concentrates carried 0.7 percent zinc, 0.98 percent arsenic, and 0.94 percent copper. Another shipment of 112,760 pounds of concentrates the same year contained 60.830 ounces of gold and 218 ounces of silver. A shipment of 55,000 pounds of concentrates in January 1942 had 42.688 ounces of gold and 119 ounces of silver.

Tempest mine (2)

Location and history: The Tempest mine consists of four unpatented claims located near the head of Granite Boulder Creek in sec. 3, T. 10 S., R. 34 E., about 3 miles northwest of the Morning mine (see pl. 1 in pocket). This is one of the older mines of the district and is known for its silver production rather than for its gold.

Geology: The country rock is gneissic biotite-quartz diorite which is cut by several northeast-trending quartz diorite porphyry dikes (see pl. 4, fig. 4, opposite p. 10). The underground workings are caved, but quartz veins in and adjacent to the dikes are visible on the steep, northeast flank of Sunrise Butte.

The ore on the dumps has been hand-picked. It consists of veinlets and stringers of second-stage, bluish-gray quartz 3 to 4 inches wide with fine-grained pyrite and sphalerite in fractured and brecciated masses of white, coarse-grained quartz, pyrite, and arsenopyrite. Accompanying the early sulphides are minor amounts of tetrahedrite and sphalerite. In the hand-picked ore, sulphides make up/to 50 75 percent of the vein material,

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*Tacoma smelter returns in possession of Mr. William Gardner, operator, Morning mine.

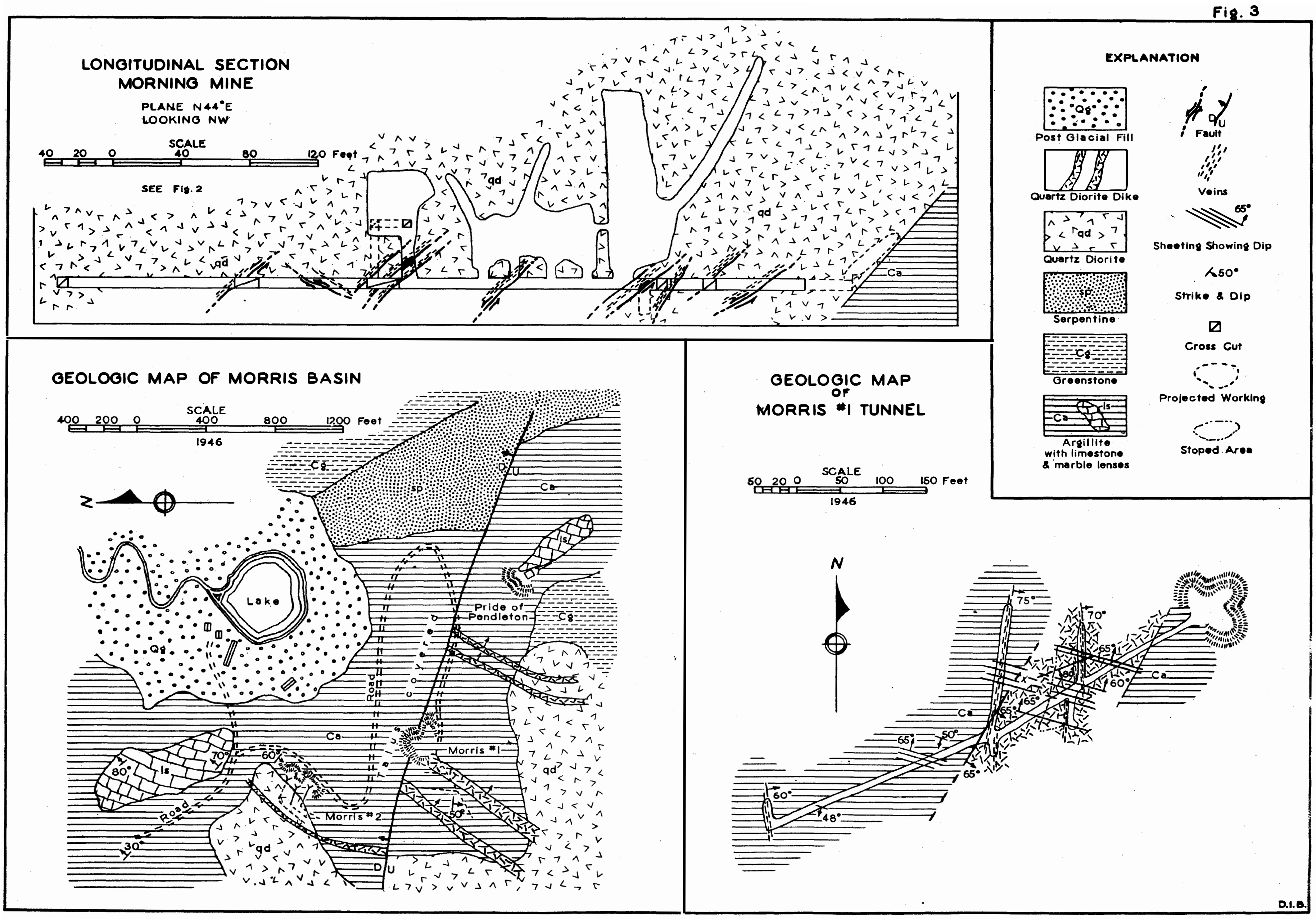


Fig. 3
LONGITUDINAL SECTION
MORNING MINE
PLANE N44°E
LOOKING NW
SCALE
40 20 0 40 80 120 Feet
SEE Fig. 2
qd
Ca
EXPLANATION
Qg
Post Glacial Fill
Quartz Diorite Dike
qd
Quartz Diorite
sp
Serpentine
Cg
Greenstone
Ca
ls
Argillite
with limestone
& marble lenses
D U
Fault
Veins
65°
Sheeting Showing Dip
50°
Strike & Dip
Cross Cut
Projected Working
Stoped Area
GEOLOGIC MAP OF MORRIS BASIN
SCALE
400 200 0 400 800 1200 Feet
1946
N
Cg
sp
D U
Ca
ls
Lake
Qg
Pride of Pendleton
Road
Covered
Talus
Morris #1
Morris #2
qd
70°
60°
80°
Road
30°
50°
GEOLOGIC MAP
OF
MORRIS #1 TUNNEL
SCALE
50 20 0 50 100 150 Feet
1946
N
75°
70°
65°
80
60°
65°
Ca
65°
50°
65°
60°
48°
D.I.B.

with the early sulphides comprising 75 percent of the total of all metallic minerals. Early quartz is twice as abundant as the late, fine-grained quartz.

Figures are not available for the production of the Tempest mine. Lindgren (1901) reports that shipments aggregating 180 tons of ore were made prior to 1901. Grab samples, which the author collected from the dump, assayed a trace of gold and about 4.00 ounces of silver per ton.

Tiger mine (3)

Location: The Tiger property of six unpatented claims is also located near the headwaters of Granite Boulder Creek in sec. 2, T. 10 S., R. 34 E., about one mile west of the Tempest mine (see pl. 1 in pocket).

Development: The workings consist of two adits driven in gneissic biotite quartz-diorite. The adits cut quartz diorite porphyry dikes which strike N. 30° E. and dip steeply northwest.

Geology: Coarse-grained, milky-white quartz stringers 3 to 5 inches wide are conspicuous in the dikes and in the country rock contiguous to the dikes. Some of the quartz stringers are cut by veinlets of the fine-grained, second-stage quartz. Arsenopyrite and pyrite occur as massive aggregates; sphalerite, tetrahedrite, and chalcopyrite, as disseminated grains and small masses in the later quartz. Calcite veinlets cut all the other minerals. Sulphides of both stages make up about 5 percent of the vein material.
A representative sample of the sulphide ore, collected by the author and quartered down for assay, contained 0.38 ounce of gold and 4.00 ounces of silver per ton.

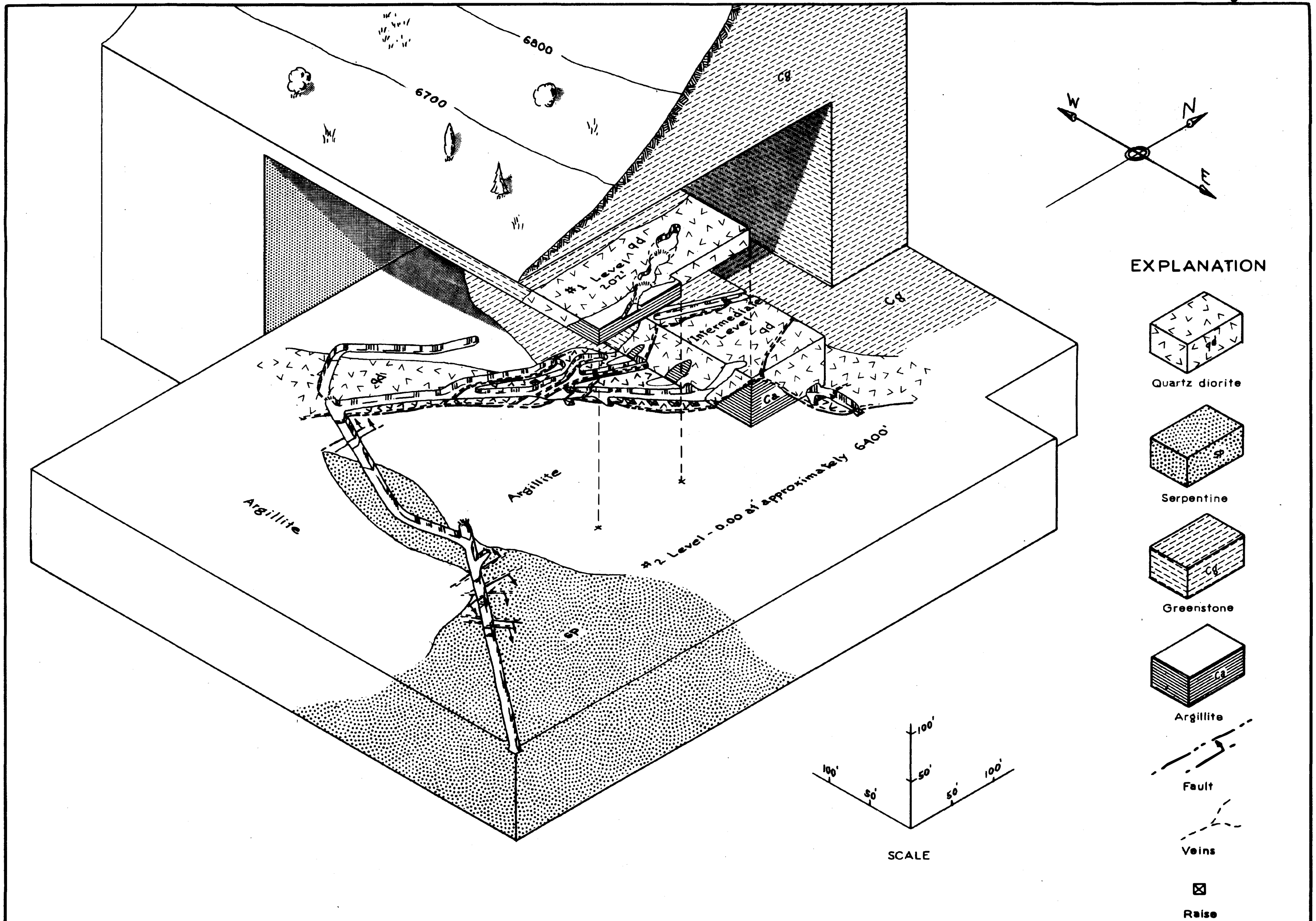
Morris Basin (4)

Location and history: The Morris Basin property lies at the head of the west branch of the East Fork of Clear Creek in the SW$\frac{1}{4}$ sec. 1, T. 10 S., R. 34 E., (see pl. 1 in pocket). It consists of one patented and 8 unpatented claims (including one fraction), and is accessible by road from Granite, 13 miles to the east. This property is also one of the older silver properties and was visited by Lindgren in 1900.

Development: Workings consist of approximately 1,000 feet of adits, cross-cuts, and stopes, most of which are accessible. The property is at an elevation of about 7,400 feet. The area receives heavy falls of snow and is subject to snow slides during the winter months.

Geology: The geology of the immediate area is complex (see fig. 3 on opposite page). Gneissic biotite-quartz diorite and early Tertiary (?) porphyry dikes intrude highly metamorphosed argillite, greenstone, and serpentinized ultrabasic rocks. The dikes, composed of quartz diorite porphyry and subordinately of quartz monzonite porphyry, occupy fractures which trend at right angles to the west-northwest shear zone which passes just to the south of the mines.

Fig. 4



BLOCK DIAGRAM OF MORNING MINE

1946

The group of workings on the west side of the basin, Morris No. 2 mine (see pl. 5, fig 2; opposite p. 30, and fig. 3 opposite p. 37), follow narrow gash fractures in the footwall of a quartz diorite porphyry dike. The fractures trend N. 35° E., dip steeply southeast, and are filled with brecciated quartz of two periods, each with its associated sulphides. The sulphides consist of pyrite, arsenopyrite, sphalerite, tetrahedrite, and galena, and constitute about 5 to 10 percent of the vein filling. The main vein averages about 15 inches thick and contains sulphides in lenticular masses and stringers.

The Morris No. 1 mine adit on the south side of the basin (fig. 3 opposite p. 37), which has been driven S. 50° W., cuts three well-defined, north-trending veins ranging from 6 to 12 inches thick. The most easterly vein has been stoped for a length of 60 feet to an average height of 15 feet. The minerals are similar to those noted in the No. 2 mine.

The Morris is credited in the mint report of 1891 with a production of $15,000 in silver and $3,400 in gold (Lindgren, 1901). Assays of sulphide-rich samples from the No. 2 mine average 0.14 ounce of gold and 1.15 ounces of silver per ton. Samples by the author of tetrahedrite-rich ore from the No. 1 adit assayed 0.10 ounce of gold and 39.18 ounces of silver per ton.

Bi-Metallic mine (5)

Location and history: The Bi-Metallic mine is located on the steep north slope of Salmon Creek valley in sec. 7, T. 10 S., R. 35 E., about 3 miles by wagon road from Greenhorn (see pl. 1 in pocket). There are several old adits on the property, but only one was open, and because of fallen rock, dislodged timbers, and bad air, only 300 feet of it could be examined.

Geology: The country rock consists of biotite-quartz diorite, serpentinized ultramafics (exposed across Salmon Creek), and dikes of quartz diorite and quartz monzonite porphyry. Most of the veins tend to follow the dikes, which trend north to northeast and dip steeply west, but some are in the highly sheared and fractured diorite. The latter strike easterly, average less than 6 inches thick, and are composed of both early and late quartz and minor amounts of pyrite, arsenopyrite, chalcopyrite, sphalerite, tetrahedrite, and galena. Quartz comprises from 80 to 90 percent of the vein filling, the older being much the more abundant of the two varieties. The veins have not been drifted on as the adits explore the dikes.

Windsor (7) - Psyche (6) - Big Johnny mines

Location: The Windsor-Psyche-Big Johnny mines comprise what is known as the Harrison group and lie at the head of Blue Gulch 3 miles west of Greenhorn in secs. 8 and 17, T. 10 S., R. 35 E. (see pl. 1 in pocket). The group consists of 16 unpatented claims.

The three mines are located along a north-northeast-trending zone of fractured rock, the Windsor mine at the southwest end at an elevation of about 6,800 feet, and the Big Johnny at the northeast end at an elevation near 7,500 feet.

Development: At the Windsor mine, a 50-foot inclined shaft and about 100 feet of tunnels are accessible, but bad air and water in the shaft prevented a detailed examination of the property.

The Psyche mine has been opened by two adits; both were caved at the time of examination. However, the large amount of dump material indicates that a considerable amount of work has been done on this property. Formerly a custom mill was operated in conjunction with the mine.

The one adit on the Big Johnny property was inaccessible at the time of examination, but Mr. William Gardner,* who had worked in the mine, reported over 1,000 feet of workings and that ore had been stoped from a short drift on a northeast-trending vein of flat to steep dip.

Geology: The country rock is almost exclusively serpentine with some silicified gabbroic facies. There are several, closely spaced quartz monzonite and quartz diorite porphyry dikes along the north-northeast fracture zone and a number of quartz veins are contained in or lie close to the dikes. The veins measure 3 to 8 inches wide and can be traced for several hundred feet. The Windsor vein strikes N. 22° E. and dips 75° to 50° NW. It lies within a highly crushed and fractured quartz monzonite porphyry dike which is highly sericitized. The veins at the Psyche and Big Johnny mines trend northeast and can be traced for several hundred feet. These veins are discontinuous and pinch and swell along their strike.

The ore from these mines shows the usual two stages of quartz, the early milky-white quartz and the younger fine-grained, bluish-gray variety; each has associated pyrite and chalcopyrite. The sulphides average about 10 percent of the vein filling; the remainder consists of younger quartz (60 percent), early quartz (20 percent), and calcite or dolomite (10 percent). At the Psyche mine the veins contain, in addition, small, lenticular masses of sphalerite and fine-grained veinlets of specular hematite. Calcite seams, 3 to 4 inches thick, are common in all veins.

A sample of sulphide-rich ore taken by the author from the lower adit dump at the Psyche assayed 1.40 ounces of gold and 5.80 ounces of silver per ton and 1.65 percent copper. A sample of oxidized carbonate ore, with sulphide inclusions, taken by the author from the dump

*Personal communication.

at the upper adit assayed 0.64 ounce of gold and 3.90 ounces of silver per ton, and 1.27 percent copper. At the Windsor, a sample taken by the author across 4 feet of altered dike containing quartz veinlets gave 0.02 ounce of gold per ton and a trace of silver.

Snow Creek mine (10)

Location and development: The Snow Creek mine is in the valley of Snow Creek in sec. 16, T. 10 S., R. 35 E., about 2 miles southwest of Greenhorn (see pl. 1 in pocket). The property has numerous adits and prospect pits. The largest adit is driven N. 37° W. and explores a zone of northeast-trending dikes and quartz veins. Workings are caved, but the size of the dumps indicates extensive underground development.

Geology: The country rocks are serpentinized pyroxenite, dunite, highly altered argillite, and greenstone. These rocks have been intruded by a quartz monzonite porphyry dike. The quartz veins, 1 to 6 inches thick, lie in or adjacent to the dike. Parts of the veins are made up of dolomitic calcite; other parts of quartz and sulphides. Except for a small amount of drusy and chalcedonic quartz, the carbonates seem to be the youngest minerals of the veins. Specimens of hand-sorted dump ore show pyrite, chalcopyrite, and minor amounts of pyrrhotite, sphalerite, galena, and covellite. A sample by the author containing these sulphides and brecciated, grayish quartz assayed a trace of gold, 7.30 ounces of silver per ton, and 3.97 percent copper.

Banzette (12)

Location and history: The Banzette property, one of the oldest in the district, is located in sec. 9, T. 10 S., R. 35 E., about 1½ miles southwest of Greenhorn (see pl. 1 in pocket). This property has been operated by Mr. Van E. Hallberg of Baker for many years. The Banzette, a consolidation of several of the district's early mines, has a considerable amount of underground workings, but only a few recent cuts are available for examination.

Geology: The country rocks, consisting of argillite, serpentine, and remnants of greenstone, are cut by a northeast fracture zone along which quartz monzonite porphyry dikes similar to those in the Snow Creek area have been intruded. The mineralization is largely confined to the fractured dikes and the rock immediately adjacent thereto. It consists of small veinlets of coarse-grained, milky-white quartz with associated pyrite, chalcopyrite, and sphalerite, which have been brecciated and cemented by fine-grained, grayish quartz and pyrite, chalcopyrite, and galena. The sulphides are generally sparsely distributed in the quartzose vein filling. Mr. Hallberg reports he has found free gold in oxidized ore.

Paramount mine (13)

Location and history: The Paramount mine, the only quicksilver mine of the district, is located on a ridge above the head of Snow and Greenhorn creeks in sec. 9, T. 10 S., R. 35 E. (see pl. 1 in pocket). It is about one mile by road southwest of Greenhorn.

The workings consist of an adit, which has been driven in a northerly direction, and several open cuts along the slope of the ridge. Numerous prospect pits have been dug in an effort to develop the property. The mine is equipped with a modern mill and was being operated in 1945 by its owner, Mr. I. Helmer of Greenhorn.

Geology: The ore consists of chalcedony stringers averaging a quarter of an inch thick which contain scattered grains and masses of cinnabar and pyrite. These stringers are confined to a northeast-trending shear zone some 30 feet or more wide and of unknown length in argillitic and serpentized rock. The argillite has been highly fractured and brecciated and has served as a favorable host for the chalcedony and cinnabar. Thin films of cinnabar occur on bedding planes and on cleavage surfaces of the argillite.

Vinegar Basin (16)

Development: The basin at the head of Vinegar Creek (see pl. 1 in pocket) has a number of old workings which have had little if any production. Several adits and shallow shafts have explored these dikes, but all shafts are caved and only a few adits are accessible, and these for only a few tens of feet.

Geology: These workings are along a discontinuous northeast zone of faulting in which there are many quartz diorite porphyry dikes identical to those in the vicinity of the Morning mine. The rock intruded by the dikes is argillite with conglomerate and limestone lenses, and serpentine. The dikes are only slightly fractured or altered.

Quartz stringers in the dikes and in the adjacent country rock are from 1 to 3 inches thick, pinching and swelling along their strike. Some stringers contain sporadically distributed grains of pyrite, which seldom make up more than 1 to 2 percent of the filling. Most of the veins are barren.

South Fork of Desolation Creek

A few small quartz veins occur on the ridge northeast of, and overlooking, the south fork of Desolation Creek in secs. 33 and 34, T. 9 S., R. 34 E. These veins trend N. 28° E. and are grouped along a zone of sheared argillite. At the time of the field examination, Messrs. Sayko and Laing had leased the Portland Consolidated (17) or Silver King group of claims and were driving a crosscut to explore the veins at depth (see pl. 1 in pocket). The veins are associated with and cut granophyric dikes, the dikes being less than 5 inches wide and 20 feet long. On the surface the veins form small lenticular masses that pinch and swell along the strike, reaching a maximum thickness of 3 or 4 inches. The quartz is largely the fine-grained, grayish variety that contains appreciable amounts of isolated podlike masses of galena. The quartz stringers appear but little fractured or brecciated.

An assay of the galena-bearing quartz by the State Department of Geology and Mineral Industries revealed 0.065 ounce of gold and 26.40 ounces of silver per ton; 25.65 percent lead and 1.10 percent zinc.

Other properties

There are a number of other properties scattered throughout the district; a few of them are reported to have produced some ore, but most of them are little more than prospects. Some have a few tens of feet of accessible workings, but generally adits and shafts are caved. Most of the mineralization is confined to fracture zones that strike N. 20° E. to N. 60° E. Many of them contain only occasional stringers or lenses of quartz in little-altered argillite or in serpentinized rock. Much of the quartz is the coarse, milky-white variety.

The Banner (11) at the head of Snow Creek is one of the larger properties along the Snow Creek-Banzette mineralized zone. Some 600 feet of workings are reported, but there has been no production. The Kit Carson (18) is located a few hundred yards east of the Windsor (7) mine in serpentinized rock. Platinum has been reported on this property, and a specimen of the ore is on display in the Baker office of the State Department of Geology and Mineral Industries. The Stalter mine (8) is near the head of Beaver Creek in gneissic biotite-quartz diorite, which locally is highly fractured and is cut by quartz diorite and quartz monzonite porphyry dikes and quartz veins. The Baird property (14) just west of Greenhorn at the head of Greenhorn Creek (see pl. 1 in pocket) is in serpentinized rock which is cut by small northeast-trending stringers of bluish-gray, chalcedonic quartz containing a little pyrite and galena. In the early days many acres of surface debris on this property were placered; the gold recovery is reported to have been high. A group of claims known as the Lucky Strike-Elk property (15) is located at the headwaters of Blackeye Creek. The argillite there is cut by many east-northeast granophyric dikes and quartz stringers, but no metallic mineralization was observed.

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Fig. 1. Photomicrograph of amphibolitized dunite. Fibrous masses of actinolite (A) replacing olivine (O). Magnetite (M) is formed in the amphibolitization process. Crossed nicols x 20.

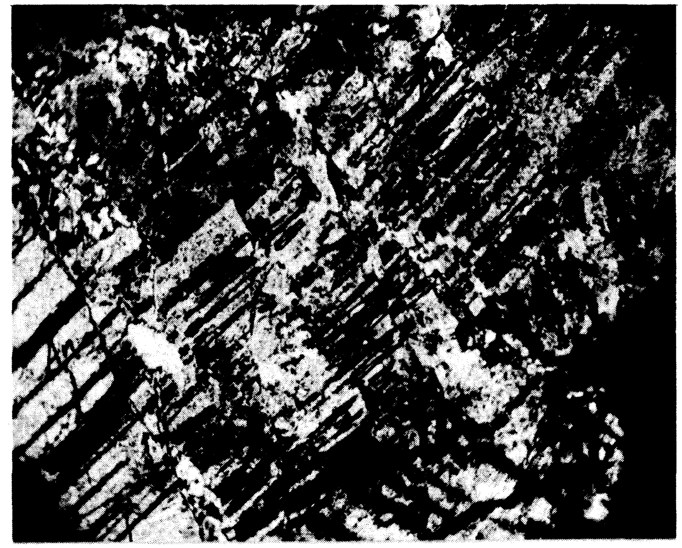

Fig. 2. Photomicrograph of sheared biotite-quartz diorite. A large crystal of andesine (An) crushed and sheared. Crossed nicols x 45.

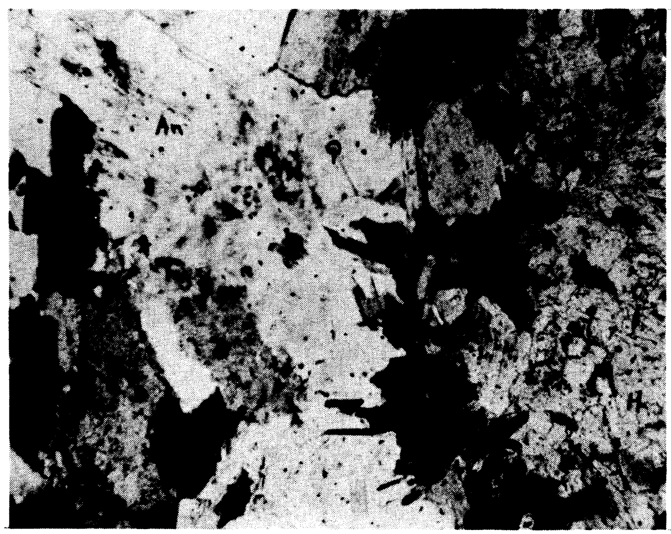

Fig. 3. Photomicrograph of biotite-quartz diorite. Segregation of hornblende crystals (H) mantled by biotite (B). Andesite (An) and quartz (Q) make up majority of the rock. Uncrossed nicols x 45.

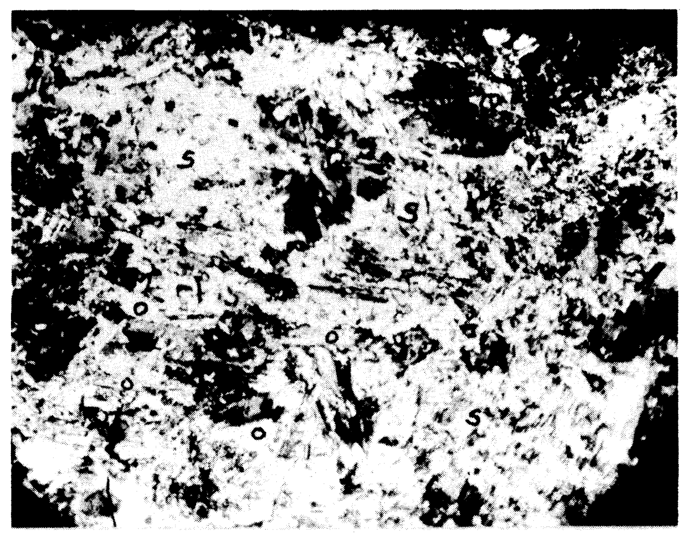

Fig. 4. Photomicrograph of altered granophyric dike. Sericite (S) and small orthoclase laths (O) surround rosettelike inter-growths of quartz (Q) and orthoclase. Crossed nicols x 45.

PLATE 6

PLATE 7

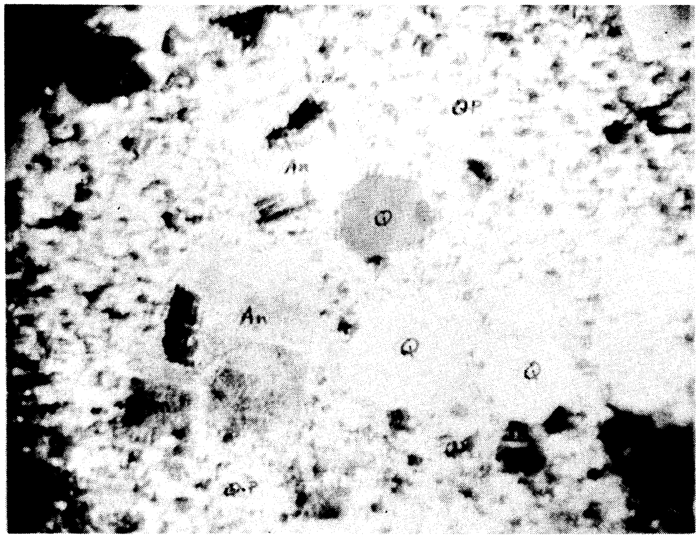

Fig. 1. Photomicrograph of quartz diorite porphyry. Quartz (Q) and andesine (An) phenocrysts in a fine-granular groundmass of quartz and plagioclase (Q-p). Crossed nicols x 20.

Fig. 2. Photomicrograph of quartz monzonite porphyry. Andesine (An), biotite (B), and altered hornblende (H) phenocrysts in a fine—grained groundmass of quartz and orthoclase (Q-o). Orthoclase has been sericitized. Crossed nicols x 20.

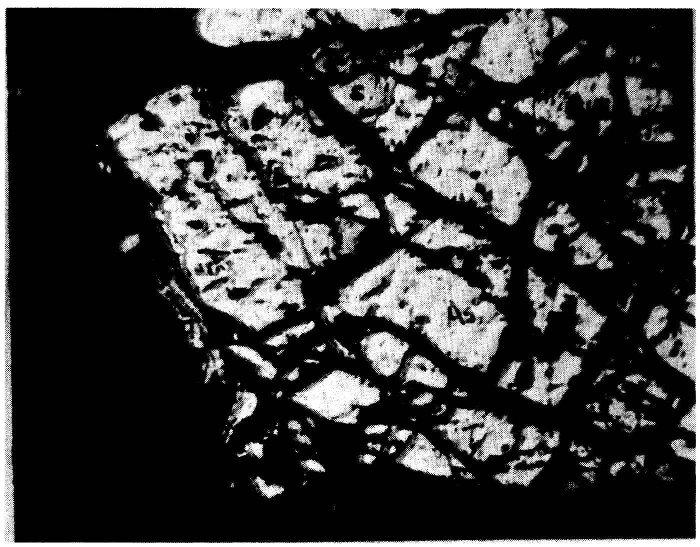

Fig. 3. Photomicrograph of ore from the Morris Basin mine. Brecciated arsenopyrite (As) with early sphalerite (S), cemented and penetrated by tetrahedrite (T). x 100.

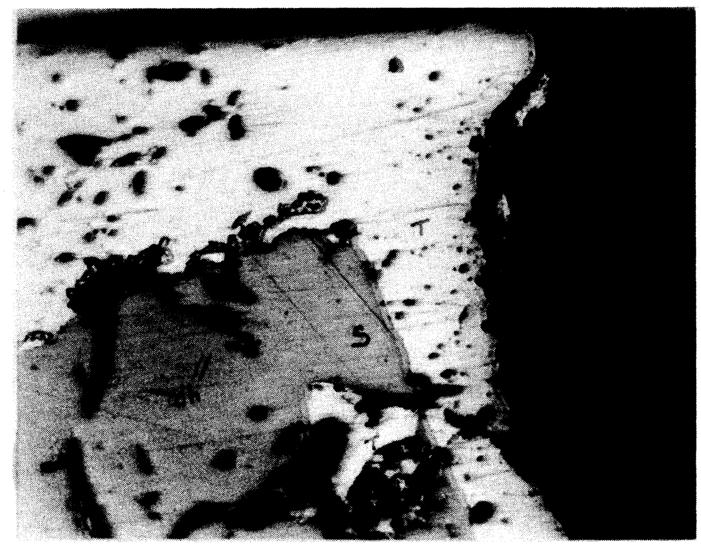

Fig. 4. Photomicrograph of ore from Morris Basin mine. Tetrahedrite (T) surrounding crystal of sphalerite (S) which contains minute blebs of chalcopyrite (Ch) x 100.

PLATE 8

Fig. 1. Photomicrograph of ore from the Tiger mine. Sphalerite (S) cutting and containing inclusions of arsenopyrite (As). Small tetrahedrite (T) veinlets irregularly penetrate sphalerite and arsenopyrite. x 100.

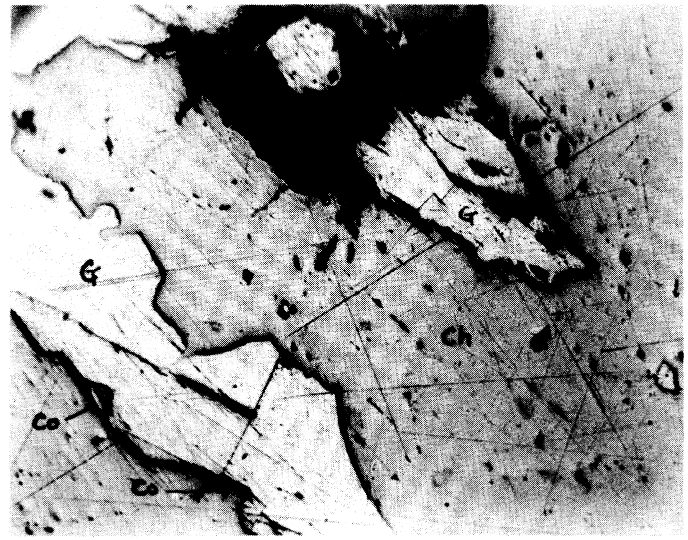

Fig. 2. Photomicrograph of ore from the Snow Creek mine. Veins of galena (G) irregularly penetrate chalcopyrite (Ch) along fractures. Supergene covellite (Co) between galena and chalcopyrite. x 100.

Fig. 3. Photomicrograph of ore from the Snow Creek mine. Remnants of pyrrhotite (P) in chalcopyrite (Ch) and with mantles of sphalerite (S). Galena (G) penetrates sphalerite. x 100.

Fig. 4. Photomicrograph of ore from Snow Creek mine. Chalcopyrite (Ch) irregularly penetrates pyrrhotite (P). Covellite (Co) is a supergene replacement of chalcopyrite. Galena (G) fills fractures in the gangue and mantles pyrrhotite. x 100.

PUBLICATIONS

State of Oregon

Department of Geology and Mineral Industries

702 Woodlark Building, Portland 5, Oregon

BULLETINS		Price postpaid
1.	Mining laws of Oregon, 1942, rev. ed., contains Federal placer mining regulations	$ 0.20
2.	Progress report on Coos Bay coal field, 1938: F. W. Libbey	0.10
3.	Geology of part of the Wallowa Mountains, 1938: C. P. Ross	0.50
4.	Quicksilver in Oregon, 1938: C. N. Schuette	0.50
5.	Geological report on part of the Clarno Basin, 1938: Donald K. MacKay	(out of print)
6.	Preliminary report on some of the refractory clays of western Oregon, 1938: Wilson & Treasher	(out of print)
7.	The gem minerals of Oregon, 1938: H. C. Dake	(out of print)
8.	Feasibility of steel plant in lower Columbia area, rev. ed., 1940: R. M. Miller	0.40
9.	Chromite deposits in Oregon, 1938: J. E. Allen	0.50
10.	Placer mining on Rogue River in relation to fish and fishing, 1938: H. B. Ward .	(out of print)
11.	Geology and mineral resources of Lane County, Oregon, 1938: W. D. Smith	0.50
12.	Geology and physiography of northern Wallowa Mountains, 1941: W. D. Smith, J. E. Allen, et al	0.65
13.	First biennial report of the Department, 1937-38	(out of print)
14.	Oregon metal mines handbook: by the staff	
	A. Baker, Union, and Wallowa counties, 1939	(out of print)
	B. Grant, Morrow, and Umatilla counties, 1941	(out of print)
	C. Vol. I, Coos, Curry, and Douglas counties, 1941	(out of print)
	Vol. II, Section 1, Josephine County, 1942	(out of print)
	Section 2, Jackson County, 1943	0.75
15.	Geology of Salem Hills and North Santiam River basin, Oregon, 1939: T. P. Thayer (map only)	0.25
16.	Field identification of minerals for Oregon prospectors and collectors, 2d ed., 1941: compiled by Ray C. Treasher	0.50
17.	Manganese in Oregon, 1942: by the staff	0.45
18.	First aid to fossils, or what to do before the paleontologist comes, 1939: J. E. Allen	0.20
19.	Dredging of farmland in Oregon, 1939: F. W. Libbey	(out of print)
20.	Analyses and other properties of Oregon coals, 1940: H. F. Yancey & M. R. Geer	(out of print)
21.	Second biennial report of the Department, 1939-40	Free
23.	Investigation of reported occurrence of tin at Juniper Ridge, Oregon, 1942: H. C. Harrison & J. E. Allen	0.40
24.	Origin of the black sands of the coast of southwestern Oregon, 1943: W. H. Twenhofel	0.30
25.	Third biennial report of the Department, 1941-42	(out of print)
26.	Soil: Its origin, destruction, and preservation, 1944: W. H. Twenhofel	0.45
27.	Geology & coal resources of Coos Bay quadrangle, 1944: J. E. Allen & E. M. Baldwin	1.00
28.	Fourth biennial report of the Department, 1943-44	Free
29.	Ferruginous bauxite deposits in northwestern Oregon, 1945: F. W. Libbey, W. D. Lowry, & R. S. Mason	1.00
30.	Mineralogical and physical composition of the sands of the Oregon coast from Coos Bay to the mouth of the Columbia River, 1945: W. H. Twenhofel . .	0.35
31.	Geology of the St. Helens quadrangle, 1946: Wilkinson, Lowry, & Baldwin	0.45
32.	Fifth biennial report of the Department, 1945-46	Free
33.	Bibliography (Supplement) of the geology and mineral resources of Oregon, 1947: J. E. Allen	1.00
34.	Mines and prospects of the Mt. Reuben mining district, Josephine County, Oregon, 1947: E. A. Youngberg	0.50
35.	Geology of the Dallas and Valsetz quadrangles, Oregon, 1947: E. M. Baldwin . . .	0.75
36.	Five papers on foraminifera from the Tertiary of Western Oregon, 1947: J. A. Cushman, R. E. Stewart, & K. C. Stewart	1.00

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1.	Preliminary report upon Oregon saline lakes, 1939: O. F. Stafford	(out of print)
2.	Industrial aluminum - a brief survey, 1940: Leslie L. Motz	$ 0.10
3.	Adv.rept. on some quicksilver prospects in Butte Falls quad., Oregon, 1940: W.D.Wilkinson .	(out of print)
4.	Flotation of Oregon limestone, 1940: J. B. Clemmer & B. H. Clemmons	0.10
5.	Survey of nonmetallic mineral production of Oregon for 1940-41: C. P. Holdredge	0.10
6.	Pumice and pumicite, 1941: James A. Adams	(out of print)
7.	Geologic history of the Portland area, 1942: Ray C. Treasher	0.15
8.	Strategic and critical minerals, a guide for Oregon prospectors, 1942: Lloyd W. Staples	(out of print)
9.	Some manganese deposits in the southern Oregon coastal region, 1942: Randall E. Brown .	0.10
10.	Investigation of Tyrrell manganese and other nearby deposits, 1943: W. D. Lowry	0.15
11.	Mineral deposits in region of Imnaha and Snake rivers, Oregon, 1943: F. W. Libbey . . .	(out of print)
12.	Prelim.rept. on high-alumina iron ores in Wash. County, Oregon, 1944: Libbey, Lowry, & Mason	0.15
13.	Antimony in Oregon, 1944: Norman S. Wagner	0.15
14.	Notes on building-block materials of eastern Oregon, 1946: Norman S. Wagner	0.10
15.	Reconn. geology of limestone deposits in the Willamette Valley, Oregon, 1946: J. E. Allen	0.15
16.	Perlite deposits near the Deschutes River, southern Wasco County, Oregon, 1946: J. E. Allen	0.15
17.	Sodium salts of Lake County, Oregon, 1947: Ira S. Allison & Ralph S. Mason	0.15

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2.	Geologic map of the Medford quadrangle, 1939: F. G. Wells & others	0.40
3.	Geologic map and geology of the Round Mountain quadrangle, 1940: W.D.Wilkinson & others .	0.25
4.	Geologic map of the Butte Falls quadrangle, 1941: W. D. Wilkinson & others	0.45
5.	Geologic map and geology of the Grants Pass quadrangle, 1940: F. G. Wells & others . . .	0.30
6.	Preliminary geologic map of the Sumpter quadrangle, 1941: J. T. Pardee & others	0.40
7.	Geologic map of the Portland area, 1942: Ray C. Treasher	0.25
8.	Geologic map of the Coos Bay quadrangle, 1944: J.E.Allen & E.M.Baldwin (sold with Bull. 27)	----
9.	Geologic map of the St. Helens quadrangle, 1945: W. D. Wilkinson, W. D. Lowry, & E. M. Baldwin (also in Bull. 31)	0.35
10.	Geologic maps of the Dallas and Valsetz quadrangles, Oregon, 1947: E. M. Baldwin (sold with Bull. 35)	----

MISCELLANEOUS PUBLICATIONS

THE ORE.-BIN: issued monthly by the staff as medium for news about the Department, mines, and minerals. Subscription price per year	0.25
Oregon mineral localities map (22 x 34 inches) 1946	0.10
Oregon quicksilver localities map (22 x 34 inches) 1946	0.25
Landforms of Oregon: a physiographic sketch, (17 x 22 inches) 1941	0.10
Index to topographic mapping in Oregon, 1945	Free
Index to geologic mapping in Oregon, 1946	Free

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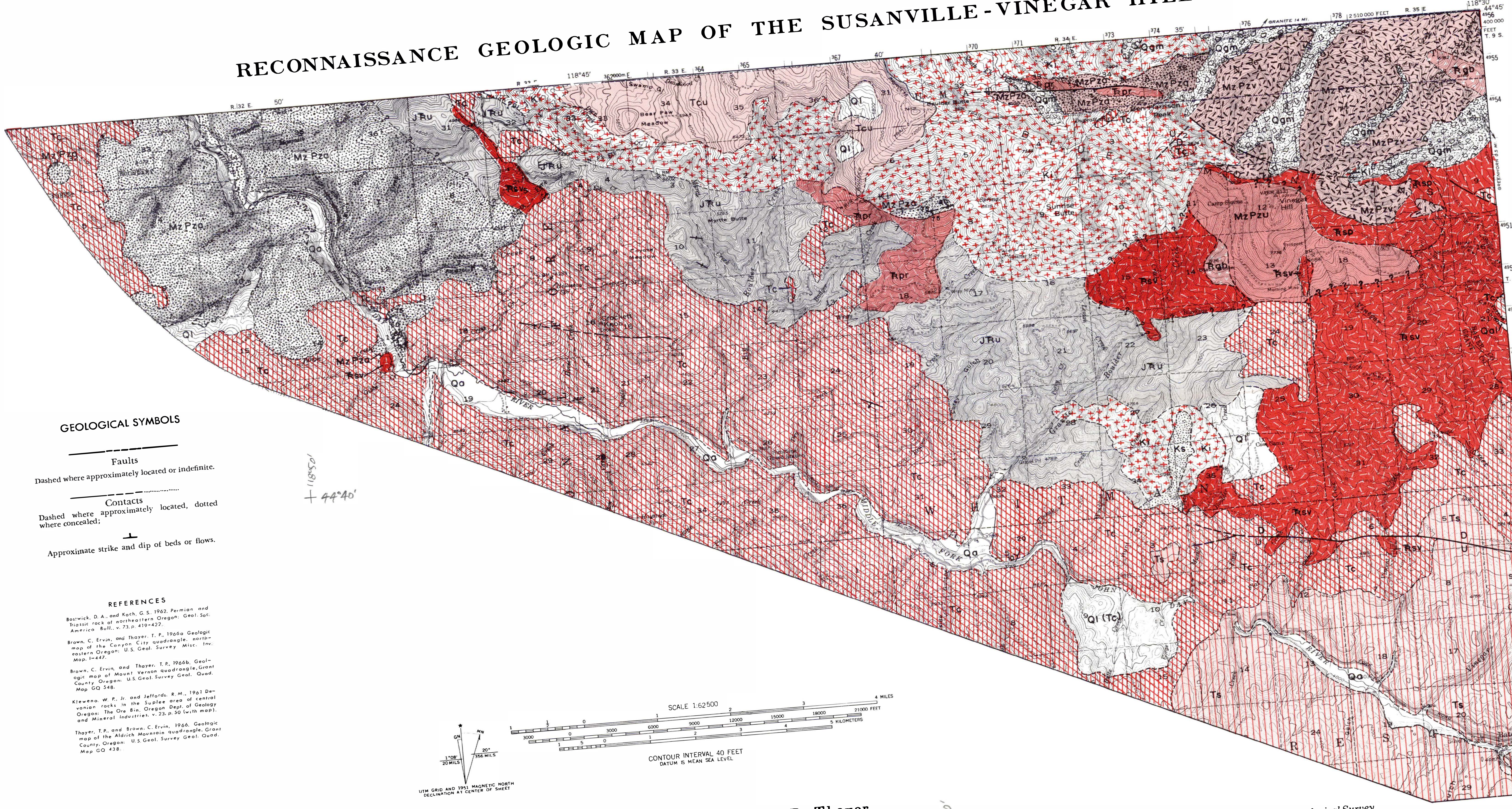
RECONNAISSANCE GEOLOGIC MAP OF THE SUSANVILLE-VINEGAR HILL AREA, GRANT COUNTY, OREGON



EXPLANATION

QUATERNARY — Holocene

Qa — Alluvium

Mainly valley fill consisting of silt, sand, and gravel. Dredged for gold along the Middle Fork of the John Day River below Granite Boulder Creek and Elk Creek.

Ql — Landslide debris

Where known, underlying formation is indicated by symbol in parentheses.

QUATERNARY — Pleistocene

Qgm — Glacial moraine

TERTIARY — Middle Miocene through Lower Pliocene

Ts — Strawberry volcanics

Mostly medium- to pale-gray basaltic andesite, platy or rudely jointed in columns. Includes leaf-bearing, water-laid ash beds interlayered with flows in the vicinity of Bates and Austin.

Tcu — Columbia River Group, undivided

Basalt flows, some containing olivine; range from pale gray, porous, and platy to dark gray and massive with columnar jointing.

UNCONFORMITY

TERTIARY — Eocene

Tc — Clarno Formation

Lava flows ranging from fresh olivine basalt to andesite and dacite; volcanic breccia and conglomerate with thin lenses of leaf-bearing, water-laid ash. Conglomeratic beds in lower parts, os in Bear Creek (secs. 10, 15, T. 10 S., R. 32 E.), contain placer gold.

UNCONFORMITY

CRETACEOUS — Upper Cretaceous

Ks — Sandstone and conglomerate

Yellow orkosic(?) sandstone and conglomerate comprising well-rounded pebbles of chert and volcanic rocks and lying on diorite.

CRETACEOUS — Lower Cretaceous

Ki — Dioritic intrusive rocks

Massive, medium- to coarse-grained diorite and quartz diorite.

TRIASSIC & JURASSIC — Upper Triassic through Middle Jurassic

JRu — Sedimentary rocks, undivided

Coarse- to medium-grained graywacke and shale, commonly showing graded bedding. Schistose and mica-bearing where metamorphosed near contacts with quartz diorite. Lithologically similar to Triassic and Jurassic rocks in the Aldrich Mountains (Brown and Thayer, 1966a, 1966b; Thayer and Brown, 1966).

UNCONFORMITY

TRIASSIC — Lower and Middle Triassic

Rpr | **Rgb** | **Rsv** — Igneous and metamorphic rocks

Rpr, partly to completely serpentinized peridotite, extensively altered to tremolite near quartz diorite.
Rgb, gabbro and metagabbro.
Rsv, serpentinite, metagabbro, metavolcanic rocks, and some argillite and chert, undivided.

PALEOZOIC?

MzPzu | **MzPza** | **MzPzv** — Sedimentary, volcanic, and intrusive rocks

MzPzu undivided sedimentary and volcanic rocks, and scattered small masses of serpentinite.
MzPza sedimentary rocks, mostly argillitic, with much chert in places; complexly folded and commonly slaty.
MzPzv metavolcanic rock, ranging from basalt to keratophyre or rhyolite, with some cherty interbeds.

May range in age from Devonian to Late Permian (Kleweno and Jeffords, 1961; Bostwick and Koch, 1962).

GEOLOGICAL SYMBOLS

Faults
Dashed where approximately located or indefinite.

Contacts
Dashed where approximately located, dotted where concealed;

Approximate strike and dip of beds or flows.

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SCALE 1:62500

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

UTM GRID AND 1951 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

By C. Ervin Brown and T. P. Thayer

Modified in 1970 from Geologic Map of the Canyon City Quadrangle, Map I-447

Base Map from U.S. Geological Survey

Map prepared by
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
R. E. CORCORAN, STATE GEOLOGIST