AN ABSTRACT OF THE THESIS OF

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GRANT COUNTY, OREGON

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The Quartzburg District is seven miles north of Prairie City in east-central Grant County, Oregon. The District is in a pre-Tertiary window of volcanic, plutonic, and sedimentary rocks ranging from Permo-Triassic to Eocene-Oligocene in age. The Permo-Triassic Dixie Butte volcanics consist of thick basalts and andesites with minor volcanic breccias and intercalated argillite, chert, and conglomerate. This unit was moderately to intensely fractured by closely spaced faults prior to the emplacement of plutons of Early or Middle Triassic age. These plutons include spinel peridotite, gabbro, and granodiorite. Serpentinite is found in and adjacent to the ultramafic plutons. A second episode of intrusion is represented by the Late Jurassic Dixie Creek granodiorite. The Dixie Creek granodiorite is a concentrically zoned pluton, which changes in composition gradationally from a thin (less than 30 meters in width) marginal diorite, through granodiorite, to a core of quartz monzonite. The granodiorite portions of the pluton fed north-striking dacite porphyry dikes. Magmatic segregations of

chalcopyrite and pyrite are present in the diorite phase. A potassium-argon age determination on biotite from this pluton yielded a 145 m.y. date (Thayer and Brown, 1964). Sedimentary rocks of mid-Cretaceous age are present in the northern and southwestern parts of the District. They include chert pebble conglomerate, sandstone (lithic arenite), and a single exposure of mudstone. Dikes of basaltic and andesitic breccia, rhyolite, and basalt of the Eocene-Oligocene Clarno Formation intruded the older pre-Tertiary terrain and fed flows that covered large portions of the Quartzburg District. Deposits of air-fall tuff breccia and minor siltstone and calcareous mudstone are intercalated with the flow rocks. During mid-Miocene time, the rocks of the District were covered by flows of the Strawberry volcanics and the Columbia River Group. Uplift of the Blue Mountains Anticline and subsequent erosion has exposed the pre-Tertiary rocks. Erosion of the mineral-bearing veins has produced rich placer deposits in Dixie Creek and the John Day River. Explosive eruption of Mt. Mazama during Recent time left deposits of volcanic ash along hill slopes and in topographic depressions.

Structural evidence suggests a post Eocene-Oligocene age for mineralization. The Clarno Formation is crosscut by west-northwest to northeast-trending faults. These are in turn crosscut by northeast to east-trending faults which, along with the permeable contact zones of the dacite porphyry dikes, guided the mineralizing fluids from a source at depth. These fluids formed rich mesothermal gold-quartz veins and hypothermal copper-tourmaline massive sulfide veins and replacement deposits.

Geology of the Quartzburg Mining District, Grant County, Oregon

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INTRODUCTION

The purpose of this investigation was to define and delimit the lithologies and mineralization of a twenty-four square mile area in a pre-Tertiary window of northeastern Oregon. Interest in the Quartzburg District was initiated while working as an assistant geologist for Norandex, Inc.. The wide variety of lithologies and mineral deposits provided both geologic challenge and economic interest. Norman Wagner of the Oregon Department of Geology and Mineral Industries, and T. P. Thayer of the U. S. Geological Survey pointed out numerous imperfections in the knowledge of the geology of this District. Partial financial support for the study was provided by Norandex, Inc., and the Oregon Department of Geology and Mineral Industries.

The Quartzburg District occupies approximately two-thirds of the largest exposure of Permo-Triassic volcanic rocks in the 1:250,000 Canyon City quadrangle (Brown and Thayer, 1966). The ore deposits are hypothermal copper-tourmaline replacement masses and massive sulfide veins, and smaller mesothermal gold-quartz veins. The District was productive from 1862 to 1916, with some activity persisting to the present day. Total production is estimated at between 2.5 and 4 million dollars.

Location and Accessibility

The Quartzburg Mining District is in the east-central part of Grant County, in northeastern Oregon (Figure 1). It is about four miles north of Prairie City, and it occupies the southwestern portion of the U. S. Geological Survey 15-minute Bates quadrangle. The District lies mainly on the south flank of a divide separating the watersheds of the Main and Middle Forks of the John Day River; part is on the northern flank. Detailed mapping covered secs. 23-26, 35, 36, T. 11 S., R. 33 E.; secs. 1, 2, 11-14, T. 12 S., R. 33 E.; secs. 28-33, T. 11 S., R. 34 E.; and secs 4-9, T. 12 S., R. 34 E. The area is roughly outlined by the prominent ridges surrounding the Standard and upper Dixie Creek drainages.

The District can be reached by automobile from the John Day Valley Highway (U. S. 26) via U. S. Forest Service roads at Prairie City or Dixie Summit. The road from Prairie City follows Dixie Creek and enters the Quartzburg District at the start of a steep narrow canyon. Numerous mining and logging roads branch from the main road, and they provide both exposures to bedrock and access to the more remote parts of the District. The road continues through the eastern half of the Quartzburg District and connects with the Lick Creek and Sulphur Creek roads of the Middle Fork Valley. The Dixie Summit road and associated branching roads provide access to the

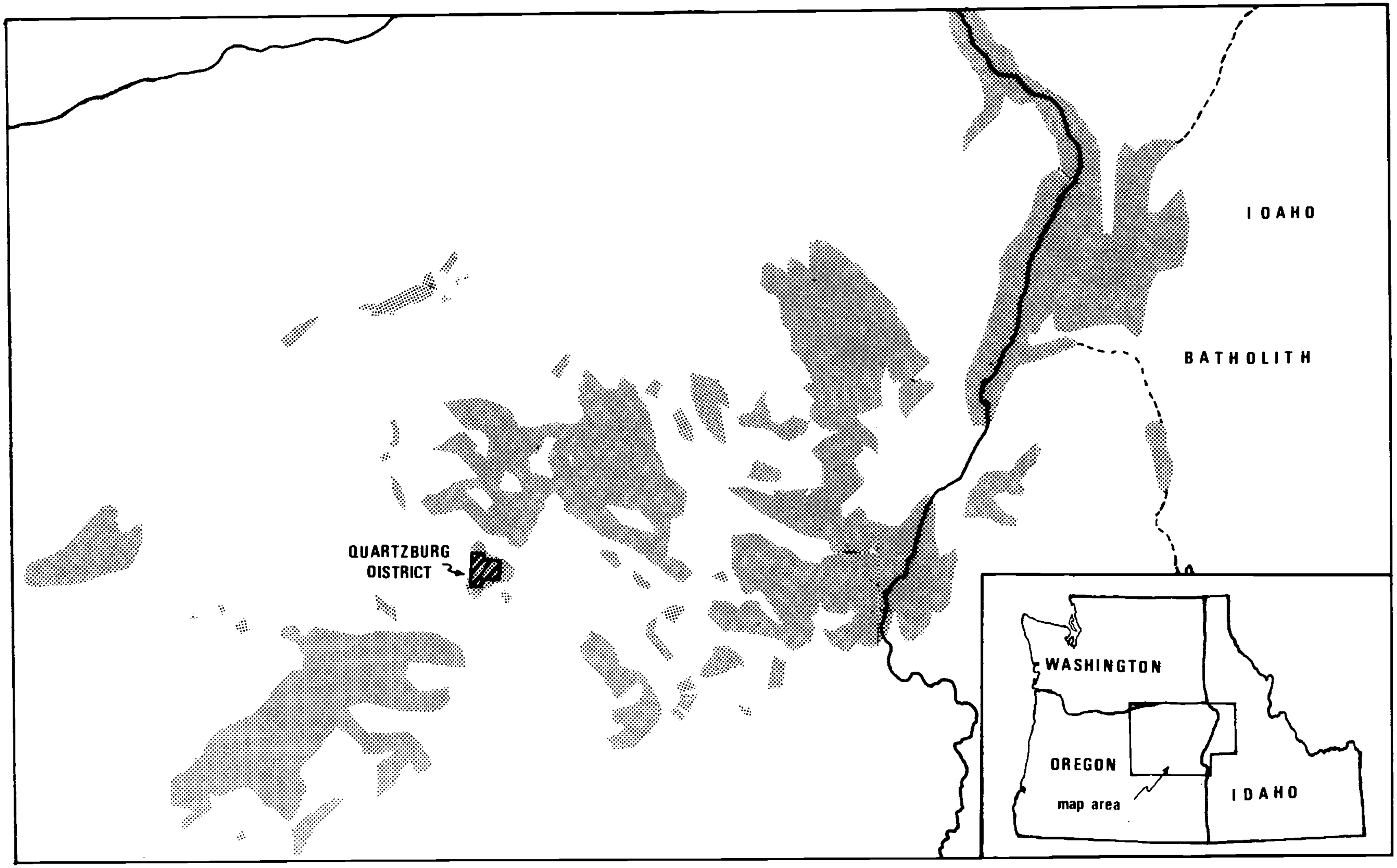

Figure 1. Index map showing pre-Tertiary exposures (shaded) other than Idaho Batholith.

southeastern portion of the District. This route continues to the lookout on Dixie Butte. A branch of this road continues along the divide and connects with the Dixie Creek road at Camp Tommy. This and several other roads have been abandoned by the Forest Service.

Topography and Vegetation

The Quartzburg District has about 3,600 feet of relief from the bottom of Dixie Creek in the southwest part of the District to the top of Dixie Butte at 7,600 feet. Dixie Butte was a pioneer landmark, rising abruptly 3,000 feet from the Middle Fork Valley. The topography and drainage systems are youthful, with small high mountain flats such as Dixie Meadows in the northwestern part of the District, and an undissected upland in the area surrounding Wickiup Springs. Stream valleys are generally steep-sided and V-shaped, stream piracy is evident in Ella Gulch, Reese Creek, and Upper Dads Creek, in the southwestern, northwestern, and southeastern portions of the District, respectively. Mechanical weathering is dominant.

All but six square miles are included in the Whitman National Forest. The vegetation consists primarily of ponderosa pine, Douglas fir, and tamarack, with patches of mountain mahogany and scrubby pines in the higher altitudes.

Previous Work

As with most old, productive mining districts, the Quartzburg District has been examined by a number of workers. Lindgren (1901) covered the area in his study of the mining camps of the Blue Mountains of Oregon, and included it in a generalized regional geologic map. Swartley (1914) examined the mines in a study of mining districts in northeastern Oregon, and reworked the area with Parks (1916). Gilluly and others (1933) presented more complete and detailed geologic data for the mines, which largely confirmed the previous work of Lindgren (1901). The Metal Mines Handbook for Northeastern Oregon (1941), compiled by the Staff of the Oregon Department of Geology and Mineral Industries, includes the District. Wagner (1956) noted the historical background of discovery and development of the Standard Mine, a massive sulfide copper-cobalt deposit. Mobley (1956) and Nelson (1956) included the District in their short-term reconnaissance mapping of sections of the Bates quadrangle. Vhay (1959) mapped one square mile around the Standard Mine in a study of the copper-cobalt deposits of the District. Brown and Thayer (1966) mapped the 1:250,000 Canyon City quadrangle, of which the Quartzburg District is a part. A selective mine summary is included in Gold and Silver in Oregon, by Brooks and Ramp (1968). In general, previous studies have been brief, with detailed geology restricted to mine workings and closely adjacent areas.

Methods of the Research

U. S. Forest Service and U. S. Geological Survey aerial photographs and topographic maps were utilized in the mapping of the present study. Field investigations were accomplished over a period of three and one-half months. In addition to detailed mapping at the scale 1:24,000, samples of the principle lithologies and hydrothermally altered and mineralized suites from several of the mines were examined in detail by geochemical, mineralogical, and petrographic methods. The chemical data are presented in weight percent. Modal estimates for chemically analysed samples were determined from an average of 2,000 points per thin section. The modal data are presented in volume percent. For reference purposes the individual plutons of the District are herein informally named for nearby drainages or topographic features.

These studies were undertaken to enhance existing knowledge concerning (1) character and distribution of lithologies, (2) lithologic similarity of the Permian and Triassic rocks to those of the same age in the Canyon Mountain Complex and the Baker Valley-Snake River Canyon areas, and (3) distribution, characteristics, and age of mineralization.

REGIONAL SETTING

The Quartzburg District is in the western part of the Blue Mountains region of the Columbia Plateau physiographic province. The Blue Mountains are a large northeast-trending asymmetrical anticline. The north flank rises steeply from the Columbia Plateau; the south flank merges gradually with high plateau country to the southeast. Plutons near the District are those of the Canyon Mountain Complex, 14 miles to the southwest, and the Bald Mountain Batholith, 20 miles to the northeast. A large satellite pluton of the latter is seven miles north of the District (Brown and Thayer, 1966).

Tectonic uplift and subsequent erosion of Tertiary volcanic rocks have exposed volcanic, plutonic, and sedimentary rocks ranging in age from Permian to Cretaceous. The oldest exposed rocks are a thick unit of Permo-Triassic mafic volcanics. Thick volcanic units of similar age are found in the Canyon Mountain Complex (Thayer, 1963), and the Baker Valley-Snake River Canyon areas of eastern Oregon and western Idaho (Gilluly, 1937). The volcanic rocks are intruded by Early Triassic plutons similar to the Canyon Mountain Magma Series, and a stock of Late Jurassic age related to the Bald Mountain Batholith (Brown and Thayer, 1966). Intrusions of similar ages are found in the Klamath Mountains of southwestern Oregon and northwestern California (Hotz, 1971), Sierra Nevada Batholith of eastern California (Evernden and others, 1970), Snake River Canyon of western Idaho (Field and others, 1974), and the Coast Range of western British Columbia and southeastern Alaska (Monger and others, 1972). Sedimentary rocks, correlative to those of mid-Cretaceous age of the Mitchell area in central Oregon, were deposited on the older plutonic and volcanic rocks of the Quartzburg District.

These basement rocks and overlying sedimentary rocks were covered by Tertiary volcanics of the Clarno and John Day Formations, Strawberry Volcanics, and the Columbia River Group. Unconsolidated deposits of volcanic ash in the Quartzburg District and elsewhere in central Oregon record more recent events of explosive volcanism in the Cascade Range, some 140 miles to the west.

ROCK UNITS

Introduction

The Dixie Butte volcanics, a thick unit of mafic volcanics with minor intercalated sedimentary rocks, are the oldest exposed rocks in the Quartzburg District. They were intruded by the Early or Middle Triassic Ruby and Dads Creeks peridotites, the Comer Creek, Cougar Ridge, and Dads Creek gabbros, and the Standard Creek and Dixie Meadows granodiorites. A second episode of intrusion is represented by the Late Jurassic Dixie Creek granodiorite. Cretaceous sedimentary rocks of the Hudspeth and Gable Creek Formations unconformably overly these older rocks, and are unconformably overlain by volcanic flow rocks and tuff of the Eocene-Oligocene Clarno Formation. Small pockets of unconsolidated volcanic ash are found along stream beds.

Dixie Butte Volcanics

The Dixie Butte volcanics are herein named from exposures along the flanks of Dixie Butte in secs. 28, 29, 33, T. 11 S., R. 34 E. They consist of weakly metamorphosed basalts and andesites with subordinate volcanic breccia, argillite, chert, phyllite, and conglomerate, in decreasing order of abundance. The Dixie Butte volcanics are widely distributed throughout the Quartzburg District. In areas of thick soil the exposures are limited to roadcuts and silicified masses which project from the land surface. The prominent jointing of the outcrops is discontinuous and has irregular orientations.

The basalts form massive, dark-colored, and dense outcrops. They are moderately resistant to erosion and underlie Dixie Butte and the prominent ridges that surround the Quartzburg District. Rock colors range from dark gray to black with faint greenish hues from chlorite alteration. The plagioclase feldspar phenocrysts are translucent and often obscured by the dark colored groundmass.

The andesites have a characteristic greenish-gray groundmass with either large phenocrysts (5-30 mm) or abundant amygdales. The amygdales comprise up to 45 percent of some specimens and exhibit unusual shades of red, green, and yellow as the mineral fillings weather. Outcrops of andesite are slightly less resistant to erosion than the basalts. Dikes of andesite are present in sec. 12, T. 12 S., R. 33 E., and sec. 4, T. 12 S., R. 34 E.

Outcrops of tuff-breccia are not resistant to erosion. The few exposures are in secs. 8 and 9, T. 12 S., R. 34 E., along roadcuts. Rock colors range from light grayish-brown to light brown, with slightly darker breccia fragments. The breccia fragments comprise between 15 and 30 percent of the tuff breccia.

Argillite is found in secs. 23 and 26, T. 11 S., R. 33 E.. Lindgren (1901) and Gilluly and others (1933) reported small masses of argillite in subsurface localities in other parts of the District. The rock is dark black with streaks of gray from sheared quartzose layers. The argillite forms low, rounded outcrops.

Scattered pods of chert are found in the southeastern part of the Quartzburg District. Both ribbon and massive types are present. The ribbon type consists of chert beds averaging 2.5 cm thick separated by layers of argillite up to 3 mm thick. A good exposure is in sec. 9, T. 12 S., R. 34 E., and is marked x-101 on the geologic map (Plate 1 in pocket). Outcrops of massive chert have a lensoidal form and average 15 meters in length and 3 meters in width. The chert beds have been tightly folded and compacted into a hard dense rock. The chert is translucent and has a greenish-black color.

Quartz-biotite phyllite is found in sec. 23, T. 11 S., R. 33 E., between the Dixie Meadows granodiorite and the Ruby Creek peridotite. The weathered outcrops of phyllite appear similar to those of argillite, but fresh surfaces reveal tightly folded layers of quartz with micaceous coatings. The rock is a slope former, and exposures consist mostly of float and a few rounded outcrops. Rock colors range from brownish-gray to medium-gray.

The two outcrops of conglomerate are found in the NE 1/4, sec. 2, and west center, sec. 1, T. 12 S., R. 33 E., marked x-102 and x-103, respectively, on the geologic map. Both exposures are in roadcuts. The rock is not resistant to erosion and is deeply weathered. Outcrops are dark blackish-brown. Jointing crosscuts some of the clasts and distinguishes the rock from conglomerates of Cretaceous age found in the Quartzburg District.

An exposure of limestone (tactite) is found in the SE 1/4, sec. 4, T. 12 S., R. 34 E. The elongate mass is a xenolith in the Dads Creek gabbro. Weathered surfaces are a distinctive white; fresh surfaces are greenish-gray.

The true thickness of the Dixie Butte volcanics cannot be determined from known exposures, since marker beds are absent, and neither the top nor bottom of the unit has been recognized in the District or surrounding region (Brown and Thayer, 1966).

Lithology and Petrography

Average modal analyses of the basalts and andesites are listed in Table 1. Samples were selected from the freshest appearing outcrops. The basalts are characterized by pilotaxitic and hyalopilitic textures. Phenocryst minerals are plagioclase feldspar and hornblende. The volcanic glass in the groundmass has been altered to varying proportions of clay, chlorite, calcite, chalcedony, actinolite-tremolite, sericite, and epidote. Apatite and zircon are common accessory minerals.

The phenocrysts of plagioclase feldspar form tabular crystals, which range from 0.5 to 4 mm in length and 0.3 to 0.8 mm in width.

Table 1. Average modal analyses of basalt, andesite, and a tuff breccia of the Dixie Butte volcanics.

	Basalt	Andesite	Tuff Breccia
plag	55.8 (An_{57})	49.0 (An_{39})	51.6 (An_{36})
hbl	1.0	1.4	4.8
magn	0.7	0.6	1.0
apa	0.1	0.1	0.1
chl	15.5	19.2	10.0
trem & act	10.5	3.2	0.3
qtz (sec)	5.5	6.1	3.9
calc	3.6	6.9	4.7
epid	3.5	7.1	0.2
clay	3.0	5.5	22.3
chal	0.2	0.5	0.1
seri	0.1	0.3	0.2
sulf	0.2	0.1	0.8
Total	100	100	100
Number of Samples	5	11	1

Normal zoning is omnipresent and is best displayed along the crystal margins. The anorthite content variation averages two to three percent. The phenocrysts are fractured and warped in most specimens. Offsets along the fractures vary from slight (0.1 mm) to more than one-half the width of the feldspar lath. Apatite and zircon, to a lesser extent, appear as inclusions in the margins of the feldspar crystals. Microlites of plagioclase are abundant in fresh samples of basalt. The common alteration minerals are calcite and clay, with minor amounts of chlorite, sericite, and chalcedony.

Hornblende appears as remnant slivers which occupy the sites of phenocrysts. These slivers are outlined by cleavage traces. Alteration minerals are green chlorite and clay with some calcite.

The andesites have well-developed trachytic textures. Amygdales show elongation parallel to the orientation of the plagioclase feldspar microlites. Plagioclase feldspar is the most abundant mineral. Hornblende, titanomagnetite, and quartz are also present.

Plagioclase feldspar in the andesites occurs chiefly as microlites with some phenocrysts. Phenocryst laths range from 2 mm to 2.5 cm in length and 0.5 to 6 mm in width. Normal zoning is best developed on the margins of the laths. The average composition is medium andesine (An_{39}). Most of the laths are slightly warped and fractured. Inclusions of apatite are occasionally found in the margins of the feldspar laths.

As in the basalts, hornblende occurs as relict slivers which occupy the sites of phenocrysts. The hornblende has been replaced by an alteration assemblage of chlorite and actinolite. Skeletal crystals of titanomagnetite and rounded crystals of quartz are present in a few specimens. Tiny quartz inclusions are also found in the titanomagnetite crystal framework.

Only one tuffaceous breccia specimen was suitable for petrographic study. The matrix modal analysis is presented in Table 1. The matrix consists of plagioclase feldspar microlites and phenocrysts set in a groundmass altered to green chlorite, clay, clacite, and lesser amounts of quartz, actinolite, and pyrite. The lithic fragments are basalt and andesite.

The argillite consists of silt sized grains of quartz and muscovite surrounded by thin margins of clay. Recrystallization of both the quartz and muscovite is evidenced by large irregularly shaped grains which cut across the bedding of the argillite. Fine-grained pyrite and a few grains of rutile are also present. Alteration minerals are conspicuously absent in the sedimentary rocks.

The cherts consist chiefly of cryptocrystalline chalcedony (76 percent). Casts of radiolaria and seams of organic material comprise 18 percent of the rock. The bedding is crosscut by numerous veins of fibrous and microcrystalline chalcedony and quartz.

The quartz-biotite phyllite is comprised chiefly of quartz (96 percent) with thin seams of biotite outlining quartz layers 1 to 4 mm thick. The quartz layers are very tightly folded and contain a few inclusions of chert. The folds have been crosscut by small scale shears.

The limestone (tactite) has a complex mineralogy consisting of a dense mass of antigorite, wollastonite, calcite, and garnet. Antigorite and wollastonite are equally common and together comprise 83 percent of the tactite. The antigorite may indicate a magnesium rich carbonate (dolomite?) or replacement of volcanic constituents in the original limestone.

Depositional Environment and Origin

The Permian and Triassic volcanic and sedimentary rocks of eastern Oregon and western Idaho have been interpreted by Hamilton (1963) to be indicative of a eugeosynclinal depositional environment. The wide areal extent and large apparent thickness of the Dixie Butte volcanics suggest a similar environment of deposition.

Age and Regional Correlation

Two major Permian units are recognized in eastern Oregon. They are the Elkhorn Ridge Argillite, a thick series of sedimentary rocks with minor intercalated volcanics, and the Clover Creek

Greenstone, a thick sequence of meta-volcanics with subordinate sedimentary rocks. Both units were originally described by Gilluly (1937) from exposures in the Baker quadrangle 35 miles northeast of the Quartzburg District. Although the Dixie Butte volcanics and the Clover Creek Greenstone are similar in gross lithology, the volcanics of the latter unit are mostly keratophyres (Gilluly, 1937), which contrast sharply with the Dixie Butte volcanics. Accordingly, Permian or Early Triassic rocks directly correlative to the Dixie Butte volcanics have not been recognized in eastern Oregon.

Nonetheless, the writer provisionally accepts the Permo-Triassic age for the Dixie Butte volcanics that was implied by Brown and Thayer (1966) from the similarities of this unit to Permian and Triassic volcanic rocks in the Canyon Mountain Complex and the Baker Valley-Snake River Canyon areas.

Intrusive Rocks

A plutonic complex of Early or Middle Triassic age is distributed throughout the Quartzburg District. The complex consists of three major rock types which include peridotite, gabbro, and granodiorite, with secondary serpentinite in the ultramafic plutons. The area of outcrop is roughly four square miles, most of which is the Standard Creek granodiorite. A later intrusion, the Dixie Creek granodiorite, is located in sec. 4, T. 12 S., R. 33 E. According to

Thayer and Brown (1964), a potassium-argon age of 145 m.y. (Late Jurassic), was obtained on biotite (Thayer, 1973, personal communication).

Peridotite

Mining operations and headward erosion of Ruby Creek provide good exposures of the Ruby Creek peridotite in secs. 23 and 24, T. 11 S., R. 33 E. The pluton is outlined by a break in slope and numerous serpentinite pods in an area of peridotite grus and float. Outcrops are massive, except where cut by serpentine veins. Individual minerals are not easily distinguished on fresh surfaces, but they are well defined by differential weathering. The rock is greenish-black when fresh, and varying shades of reddish-orange on weathered surfaces. The serpentine veins are more resistant to weathering and form linear ridges on the outcrop faces. Open cavity fillings of quartz and chalcedony are common, as are veins and bunches of asbestos.

The Dads Creek peridotite in sec. 9, T. 12 S., R. 34 E., is covered by a thick mantle of grus. Roadcuts along Dads Creek expose up to 5 meters of grus and serpentinite without revealing any fresh peridotite. Asbestos, which is associated exclusively with the peridotite, was used along with serpentinite and peridotite float to delineate the pluton.

Lithology and Petrography

The Ruby Creek peridotite exhibits an allotriomorphic-granular texture. The roughly equidimensional anhedral crystals average 3 mm in diameter. The major minerals are enstatite (81.3 percent) and olivine (15.6 percent). Both minerals have wavy or undulatory extinction. The enstatite crystal planes are gently warped in one or two directions. Spinel occurs as small (0.3 mm) rust-brown colored crystals. They comprise 1.2 percent of the rock. The crystals have irregular and occasionally angular outlines. These minerals are crosscut by several 0.5 to 1 mm wide crush zones, which consist of small comminuted mineral fragments. This assemblage is cut by numerous thin veins of serpentine, the only alteration mineral present. The larger serpentine veins have stringers of chromite in their cores.

Peridotite float from the Dads Creek locality was too weathered for petrographic examination. However, serpentinite from the Dads Creek peridotite lacks the spinel characteristic of serpentinites from the Ruby Creek peridotite.

Chemistry

Chemical analyses of sample 146-1 from the Ruby Creek peridotite and an olivine-rich peridotite from the Canyon Mountain Complex (Thayer and Himmelberg, 1968) are presented in Table 2. Silica,

Table 2. Chemical analyses of the Ruby Creek peridotite (146-1) of the Quartzburg District, and olivine-rich peridotite of the Canyon Mountain Magma Series (Thayer and Himmelberg, 1968, Table 1, sample 2).

	146-1	2*
SiO_2	43.2	43.6
TiO_2	0.0	0.03
Al_2O_3	0.7	1.8
FeO	9.8	9.2
MgO	43.8	43.1
CaO	1.3	1.4
Na_2O	0.1	0.02
K_2O	0.0	0.0
Total	98.9	99.2

*Recalculated to 100 percent on a water free basis, total iron as FeO.

total iron, and magnesia constitute 96.8 percent of the Ruby Creek peridotite; alumina, lime, and soda comprise only 2.1 percent. Potash and titania are not present in detectable concentrations. The ratio of total iron to magnesia suggests a high magnesia content in the enstatite and olivine. The presence of chromite in the specimen suggests that the total iron-magnesia ratio is even higher than 1:5. Substitution of calcium for magnesium in the enstatite crystal structure is evident by the lime content. The small alumina content is mostly attributable to spinel.

The whole-rock chemistry of the sample of Ruby Creek peridotite is similar to that of the olivine-rich peridotite from Canyon Mountain. Although the peridotite from the Quartzburg District may be depleted in alumina (by 1.1 percent), and enriched in soda (by 0.08 percent) relative to the olivine-rich peridotite from the Canyon Mountain Complex, the cause of these possible differences cannot be determined, as Thayer and Himmelberg (1968) do not present modal data with their chemical analyses.

Gabbro

Outcrops of gabbro are slope formers. The fresh rock is dark greenish-gray to olive-green. Weathered surfaces are light gray. The Comer Creek gabbro in secs. 1 and 2, T. 12 S., R. 33 E., is medium crystalline, and plagioclase crystals show distinct lineations on weathered surfaces. Xenoliths of Dixie Butte volcanics are abundant near the contacts. The Dads Creek gabbro in secs. 4 and 9, T. 12 S., R. 34 E., is coarsely crystalline, and the plagioclase phenocrysts often display a radial arrangement. Lensoidal pods of serpentinite are occasionally found along shear zones. The Cougar Ridge gabbro in sec. 12, T. 12 S., R. 33 E., is only 25 meters in diameter. The intrusive has phenocrysts of hornblende set in a gray-green groundmass of plagioclase. The pluton is zoned, with narrow prisms of hornblende in the margins, and short thick hornblende crystals in the core. The numerous dikes of basalt porphyry with fresh hornblende phenocrysts and dikes of hornblendite in the Quartzburg District are probably related to the gabbro plutons.

Lithology and Petrography

The Comer Creek gabbro has a hypidiomorphic-granular texture. The average grain size is 3 mm and ranges from 2 to 5 mm. Phenocrysts of plagioclase feldspar, found in several hand specimens, were not observed in the thin section. Plagioclase is the main constituent of the specimen (78 percent). Augite and hornblende have been extensively altered to chlorite and actinolite and comprise only 2 percent of the gabbro. These two alteration minerals comprise 18 percent of the sample. Accessory zircon is found in some pyroxene crystals.

Magnetite in the Comer Creek gabbro is relatively abundant (2 percent).

Plagioclase occurs as subhedral lath-shaped crystals. Fractured and warped laths are abundant, with offsets of more than one-half the width of the crystal commonplace. Both normal and oscillatory zoning are common. The core composition of the laths averages An_{71}; the margins average An_{59}. The more calcic zones have been selectively altered to calcite and clay with some chlorite. The pyroxenes are present as subhedral interstitial fillers between a tight mesh of plagioclase laths. Twins are evident in some of the less altered augite prisms. Hornblende crystals appear bleached, and the cores of some prisms contain tiny inclusions of quartz, presumably indicative of deuteric replacement of augite (Taubeneck, 1964).

The Dads Creek gabbro has a distinctive ophitic texture with crystals of plagioclase feldspar set among large plates of augite. The modal data, along with the chemical analysis, are presented in Table 3 of the chemistry section. The Dads Creek gabbro is comprised chiefly of plagioclase (76.6 percent), with augite (9.9 percent) and magnetite (0.8 percent). An alteration assemblage of calcite, chlorite, epidote, and tremolite comprises the remaining 13 percent of the specimen.

Plagioclase occurs as subhedral laths. Fractured and warped crystals are uncommon; offsets rarely exceed 0.3 mm. Compositional zoning of the laths is best developed on the margins. Both normal and oscillatory zoning are common. Compositions range from An_{76} in the core to An_{54} on the margins. The more calcic zones have been selectively altered to calcite and clay. Augite has been extensively altered to chlorite, actinolite, and some epidote. The abundance of chlorite and actinolite observed in the thin section suggests that augite originally comprised approximately 20 percent of the unaltered gabbro. The augite is interstitial to the mesh of feldspar crystals. Crystal plates of augite are optically continuous over small areas, but few are continuous when separated by feldspar laths. Irregularly shaped poikilitic inclusions of plagioclase feldspar and skeletal crystals of magnetite appear in the augite.

The Cougar Ridge gabbro has a porphyritic texture. The large phenocrysts of hornblende (up to 1.5 cm) comprise 32.8 percent of the specimen. The remainder of the gabbro consists of smaller crystals of plagioclase feldspar (54.5 percent), magnetite (3.2 percent), quartz (2.8 percent), augite (1.4 percent), and an alteration assemblage of chlorite, calcite, and clay (5.4 percent).

The hornblende crystals are euhedral in most cases. Many of the prisms are twinned. The hornblende is greenish-brown in color and slightly altered to chlorite. Plagioclase occurs as subhedral and euhedral laths that average 3mm in length. The subhedra are gently warped along their junctures with hornblende. Normal and oscillatory zoning are concentrated on the crystal margins. Compositions average

An_{72} in the cores and An_{51} at the margins. Calcite and clay alteration are common in the more calcic zones. Augite occurs in the cores of some hornblende prisms. The host hornblende is slightly bleached and has numerous tiny inclusions of quartz. Quartz also occurs as an interstitial filler. Magnetite is disseminated throughout the specimen as small (0.3 mm) irregularly shaped crystals.

Chemistry

Chemical analyses and modal estimates of samples from the Dads Creek (172-3) and Cougar Ridge (55-3) gabbros are presented in Table 3. Comparative chemical analyses of augite gabbro from the Canyon Mountain Magma Series (Thayer and Himmelberg, 1968), and an average hornblende gabbro (Nockolds, 1954) are also listed.

The whole-rock chemistry of the samples of the two gabbro plutons from the District is correlative to their respective mineralogies. The Dads Creek gabbro specimen contains considerably more calcic plagioclase feldspar than the sample from the Cougar Ridge gabbro, and it has correspondingly higher values for alumina (by 4.5 percent) and lime (by 3.4 percent). The higher magnetite content of the Cougar Ridge gabbro is reflected by higher values for total iron (by 2.8 percent) and titania (by 0.4 percent). The relatively large potash content (2.0 percent) of the sample of Cougar Ridge gabbro probably indicates substitution of potassium for sodium in the

Table 3. Chemical and modal analyses of the Dads Creek (172-3) and Cougar Ridge (55-3) gabbros, and chemical analyses of augite gabbro of the Canyon Mountain Magma Series (Thayer and Himmelberg, 1968, rock type 6), and average hornblende gabbro (Nockolds, 1954, Table 7, rock type 1).

	172-3	55-3	6*	1*
SiO_2	50.1	53.4	47.8	48.5
TiO_2	0.72	1.12	0.2	1.6
Al_2O_3	21.8	17.3	20.0	17.4
FeO	6.0	8.8	4.3	10.7
MgO	4.9	4.3	10.1	7.5
CaO	11.8	8.4	16.0	10.9
Na_2O	3.4	3.8	1.3	2.3
K_2O	0.18	2.0	0.1	0.5
Total	98.9	99.1	99.8	99.4
qtz	-0-	2.8		
plag	76.6	54.5		
hbl	-0-	32.8		
aug	9.9	1.4		
magn	0.8	3.2		
calc	0.5	4.0		
chal	-0-	0.7		
chl	6.2	0.7		
epid	0.9	-0-		
trem	5.3	-0-		

*Recalculated to 100 percent on a water free basis, total iron as FeO.

hornblende crystal lattice as described by Deer and others (1966).

The two samples of gabbro from the Quartzburg District are chemically dissimilar from those of the Canyon Mountain Magma Series. Those of the District are enriched in silica (by 2.3 and 5.6 percent), titania (by 0.52 and 0.92 percent), total iron (by 1.7 and 4.5 percent), soda (by 2.1 and 2.5 percent), and potash (by 0.08 and 1.9 percent), and depleted in magnesia (by 5.2 and 5.8 percent) and lime (by 4.2 and 7.6 percent), relative to those of the Canyon Mountain Magma Series.

Comparison of the two samples of gabbro from the District to those of the Canyon Mountain Magma Series (Thayer and Himmelberg, 1968) and the average hornblende gabbro (Nockolds, 1954) shows three consistent variations in the Quartzburg suite. Both the Dads Creek and Cougar Ridge gabbro samples are enriched in soda (average 1.8 percent) and silica (average 3.6 percent) and depleted in magnesia (average 4.2 percent).

Granodiorite

The granodiorite of Triassic age is one of the least erosion-resistant rocks in the Quartzburg District. Exposures are characterized by a few low-lying outcrops, abundant float, and grusy soil cover. On north-facing slopes only float is found. Outcrops are light gray in color, with traces of yellowish-orange limonite stain. The Standard Creek granodiorite in secs. 31 and 32, T. 11 S., R. 34 E., and secs.

5 and 6, T. 12 S., R. 34 E., is medium to coarsely crystalline. This pluton is distinguished from others of the Quartzburg District by chloritic alteration in and around the plagioclase feldspar crystals. The original minerals in portions of the pluton are obscured by alteration to clay and calcite. The Dixie Meadows granodiorite in sec. 23, T. 11 S., R. 33 E., is medium crystalline. Exposures on the north side of the divide are very poor, with sparse float and grus in the soil. Orange-brown colored grus is observed in roadcuts. A third locality of granodiorite is a 50 meter thick dike in sec. 35, T. 12 S., R. 33 E. Outcrops are moderately resistant to erosion, and float rock extends downslope from the exposures.

Lithology and Petrography

Granodiorites from the Standard Creek, Dixie Meadows, and sec. 35 localities all exhibit a hypidiomorphic-granular texture. The average grain size ranges from 3 mm in the Dixie Meadows pluton to 5 mm in the Standard Creek granodiorite. The major minerals are plagioclase feldspar, quartz, hornblende, and orthoclase. Accessory minerals are magnetite, zircon, apatite, and biotite. Augite and hypersthene are present in a contact phase of the Standard Creek granodiorite. Clay, chlorite, calcite, and sericite are common alteration minerals that normally comprise about 5 percent of the rock.

The granodiorites contain approximately 54 percent plagioclase feldspar. The crystals are subhedral laths. Both normal and oscillatory zoning are common. Compositions range from An_{47} to An_{24} from core to margin of the laths. Some crystals have calcic cores which are surrounded by markedly more sodic plagioclase. Laths are rarely fractured or warped. The fractures appear to have guided the calcite-clay-sericite alteration to the calcic cores.

The quartz content of the granodiorites averages 26 percent. It is present as rounded crystals and as an interstitial filler. The rounded crystals often display strained extinction.

The average content of hornblende in the granodiorites is 6 percent. However, it is conspicuously absent in portions of the granodiorite in sec. 35. Hornblende occurs as subhedral prisms and as poikilitic inclusions in the plagioclase feldspar. A few prisms are bleached and contain tiny inclusions of quartz that are indicative of deuteric replacement of augite (Taubeneck, 1964). Chlorite alteration of the hornblende is common.

The orthoclase content of the granodiorites averages 8 percent, as determined by petrographic methods and the staining of granodiorite slabs. Crystals of the potassium feldspar are anhedral and appear very similar to the interstitial variety of quartz. Clay and sericite alteration of the orthoclase is common.

Biotite comprises an average of 0.5 percent of the granodiorites. It occurs both as poikilitic inclusions in hornblende and as distinct crystals. The crystal plates average 1.8 mm in diameter. The biotite has been variably altered to chlorite.

Magnetite is the most common accessory mineral and comprises about 1.5 percent of the granodiorites. The tiny disseminated magnetite crystals are irregularly shaped. Apatite and zircon comprise an average of 0.3 percent of the granodiorites. The crystals form thin (0.2 mm) subhedral prisms.

Serpentinite

Serpentinite is the most resistant rock in the Quartzburg District. It is found as alteration masses within the mafic plutons, and as separate units. These units are present in the south center, sec. 23, T. 11 S., R. 33 E., the S 1/2 SE 1/4, sec. 9, T. 12 S., R. 34 E., and the SW corner, sec. 14, T. 12 S., R. 33 E. Fresh surfaces are olive-green and weather to greenish-black with yellow-brown limonite stain. Outcrops are crosscut by veins of chromite and magnetite that often contain small aggregates of asbestos.

Lithology and Petrography

Sieve, mesh, and bastite textures are evident among the randomly oriented serpentine fibers. Sieve texture is the most common, indicating a high olivine content in the host rock. Major minerals are antigorite, chrysotile, olivine, chromite, and magnetite. Serpentinite from the Ruby Creek peridotite contains spinel.

The relative proportion of antigorite to chrysotile approximates 20:1. The average content of antigorite in the serpentinites is 78 percent and ranges from 48 to 94 percent. It occurs as mineral replacements and, to a lesser extent, as a vein filler. Chrysotile is found only in the veins, and it is abundant around stringers of chromite.

Olivine constitutes up to 43 percent of the serpentinites. The olivine crystals are irregularly shaped, with angular outlines and are crosscut by numerous veinlets of antigorite and chrysotile. Some of the crystals have undulatory extinction and gently warped planes of parting.

Chromite and magnetite are equally common; the average content of each in the serpentinites is 3 percent. The chromite occurs as crystal aggregates in the cores of the larger serpentine veins. The subhedral cubes and octahedra of magnetite are disseminated throughout the serpentinite.

Dixie Creek Granodiorite

The Dixie Creek granodiorite is distinguished from granodiorites of Triassic age by its resistance to erosion and the unaltered appearance of freshly broken surfaces. This stock is zoned from diorite along the contacts to quartz monzonite in the vicinity of Bull Run Creek. The bulk of the pluton is granodiorite. Rock colors range from medium-gray along the contacts to light-gray or pale orange-gray in the quartz monzonite. Rounded inclusions of dark-colored and finely crystalline diorite are common. Crystals of hornblende and biotite have a linear alignment over most of the pluton. These lineations have an average trend of N. 12° W., 75°.

Dikes from the stock range in composition from dacite porphyry to quartz monzonite. Dikes of quartz monzonite are generally confined to the margins of the pluton, whereas those of dacite porphyry extend for more than a mile from the stock. Thin dikes of aplite and granophyre are occasionally found along the contacts of the pluton.

Lithology and Petrography

The Dixie Creek granodiorite exhibits a hypidiomorphic-granular texture. The component crystals average 4 mm in diameter. The major minerals are plagioclase feldspar, quartz, hornblende, biotite, and orthoclase. Accessory minerals are magnetite, apatite, zircon, and sphene. Modal estimates for an average of two diorite samples (01 & 02), a granodiorite sample (6A), and a quartz monzonite dike (6B) are listed in Table 4.

Quartz occurs both as an interstitial filler and as rounded crystals. The rounded crystals average 5 mm in diameter and have well

Table 4. Modal analyses of an average of two diorite samples (01+02), granodiorite (6A), and quartz monzonite dike (6B) from the Dixie Creek granodiorite.

				Net Change		
	01+02	6A	6B	1+2→6A	6A→6B	1+2→6B
qtz	5.9	16.4	22.4	+10.5	+ 6.0	+16.5
plag	68.6	62.4	44.8	- 6.2	-17.6	-23.8
orth	1.5	6.4	28.8	+ 4.9	+22.4	+27.3
hbl	19.1	8.2	0.4	-10.9	- 7.8	-18.7
bio	1.5	2.8	0.2	+ 1.3	- 2.6	- 1.3
magn	2.1	1.2	0.4	- 0.9	- 0.8	- 1.7
zir & apa	0.2	2.3	1.4	+ 2.1	- 0.9	+ 1.2
sph	0.8	0.1	0.2	- 0.7	+ 0.1	- 0.6
alt	0.3	0.2	1.4			

developed strained extinction. The interstitial variety displays slightly strained extinction and often contains irregularly shaped inclusions of plagioclase and hornblende.

Plagioclase feldspar occurs as subhedral laths that range in length from 3 to 8 mm. Normal and oscillatory zoning are common, and some laths exhibit limited reverse zoning. Laths have an average core to margin composition of An_{48} to An_{35} in the diorite and An_{36} to An_{21} in the quartz monzonite. Fractured and warped laths are more common in the diorite than in the more silicic phases of the pluton. The calcic cores are slightly altered to calcite and clay.

The hornblende crystals form subhedral prisms which average 1.5 mm in width and 6 mm in length. Many of the prisms have euhedral cross-sections. Some of the crystals have solution pits and embayments. The hornblende shows limited alteration to chlorite and clay.

Laths of orthoclase are only found in the granophyres and aplite dikes. It normally occurs as interstitial filler similar in appearance to the interstitial quartz. Determination of the orthoclase content was accomplished by staining of rock slabs and by petrographic analysis.

Biotite occurs as poikilitic inclusions in hornblende and as distinct crystals. These crystals average 0.3 mm in diameter. A few display gently warped cross sections. The biotite is slightly altered to chlorite and clay.

Zircon and apatite crystals are euhedral prisms which average 0.05 mm in width and 0.8 mm in length. Both magnetite and sphene occur as irregulary shaped crystals which average 0.2 mm in diameter. Sphene is commonly found along the edges of the magnetite crystals, and occasionally as inclusions in the magnetite. Sphene also shows a close association with the sulfide blebs found in the diorite. These pyrite and chalcopyrite blebs form small (0.1 mm) drop-like inclusions between the major minerals. The sulfides are restricted to the diorite and comprise less than 0.1 percent of the host.

Chemistry

Chemical analyses of an average of two samples of diorite (01 & 02), a granodiorite (6A), and a quartz monzonite dike (6B) are presented in Table 5. For purposes of comparison, analyses of the granodiorite phase of the Dixie Creek granodiorite, the Anthony Lake granodiorite of the Bald Mountain Batholith (Taubeneck, 1957), and an average hornblende-biotite granodiorite (Nockolds, 1954) are listed in Table 6.

Systematic variations in the chemistry of the three phases of the Dixie Creek granodiorite are evident from Table 5. With the exception of soda and potash, the chemical changes between the three phases of the pluton are nearly identical. The sharper depletion of alumina (by 2.3 percent) and soda (by 0.6 percent) between the granodiorite

Table 5. Chemical analyses of an average of two diorite samples (01+02), granodiorite (6A), and quartz monzonite dike (6B) from the Dixie Creek granodiorite.

	01+02	6A	6B	Net Change 1+2→6A	Net Change 6A→6B	Net Change 1+2→6B
SiO_2	59.0	67.1	75.0	+ 8.1	+ 7.9	+16.0
TiO_2	0.86	0.47	0.17	- 0.39	- 0.3	- 0.69
Al_2O_3	17.2	15.8	13.5	- 1.4	- 2.3	- 3.7
FeO	6.8	4.1	1.3	- 2.7	- 2.8	- 5.5
MgO	2.6	1.2	0.1	- 1.4	- 1.1	- 2.5
CaO	7.0	4.4	1.7	- 2.6	- 2.7	- 5.3
Na_2O	4.3	4.4	3.9	+ 0.1	- 0.5	- 0.4
K_2O	2.06	2.32	4.02	+ 0.26	+ 1.7	+ 1.96
Total	99.82	99.79	99.69			

Table 6. Chemical analyses of Dixie Creek granodiorite (6A), Anthony Lake granodiorite of Bald Mountain Batholith (Taubeneck, 1957, Table 20), and average hornblende-biotite granodiorite (Nockolds, 1954, Table 2, rock type 7).

	6A	Anthony Lake*	7*
SiO_2	67.1	67.6	66.0
TiO_2	0.47	0.47	0.62
Al_2O_3	15.8	15.9	15.8
FeO	4.1	3.8	4.4
MgO	1.2	2.2	1.9
CaO	4.4	3.9	4.1
Na_2O	4.4	3.6	3.9
K_2O	2.32	2.2	3.0
Total	99.79	99.67	99.72

*Recalculated to 100 percent on a water free basis, total iron as FeO.

and the quartz monzonite dike is mostly attributable to the depletion of plagioclase feldspar as noted in Table 4. The enrichment of potash (by 1.44 percent) between the granodiorite and the quartz monzonite dike reflects a marked enrichment in orthoclase.

Similarities in the whole-rock chemistry between the granodiorite from the Quartzburg District and those of the Anthony Lake granodiorite (Taubeneck, 1957) and the average hornblende-biotite granodiorite (Nockolds, 1954) may be noted in Table 6. However, the Dixie Creek granodiorite appears to be depleted in magnesia (by 1.0 and 0.7 percent) and enriched in lime (by 0.5 and 0.3 percent) and soda (by 0.8 and 0.5 percent) relative to the Anthony Lake and average hornblende-biotite granodiorites. Whether or not these differences are significant would require the analyses of many additional samples of the Dixie Creek granodiorite.

Mid-Cretaceous Sedimentary Rocks

Sedimentary rocks of mid-Cretaceous age are present in the southwestern and northern parts of the Quartzburg District. They include chert pebble conglomerate, sandstones (lithic arenite), and mudstone.

In the southwestern part of the District, conglomerates are found in sec. 13, T. 12 S., R. 33 E., and sec. 7, T. 12 S., R. 34 E.

Outcrops are massive and moderately resistant to erosion. Well-rounded, resistant chert pebbles and cobbles protrude from the general surface of the rock. Rock colors range from brownish-grays to blackish-brown and vary with the color of the chert clasts. The conglomerates contain a few particles of gold. The conglomerates in the center, N 1/2 SW 1/4, sec. 13, T. 12 S., R. 33 E., and sec. 7, T. 12 S., R. 34 E., differ only in having smaller sized clasts.

Two isolated exposures of conglomerate are found in the northern part of the Quartzburg District. The conglomerate in the northeast corner of sec. 24, T. 11 S., R. 33 E., is identical to those of the southwestern part of the District. The large exposure of conglomerate in sec. 29, T. 11 S., R. 34 E., is lithologically unique in comparison to the other conglomerates. The conglomerate has an apparent thickness of 350 feet. Outcrops of this conglomerate are not resistant to weathering and are characterized by abundant float pebbles of black and dull-white chert, and numerous rounded boulders of granodiorite protruding from the surface. One granodiorite clast is 4 meters in diameter.

Exposures of sandstone are found in secs. 11 and 13, T. 11 S., R 33 E. Outcrops are orangish-brown to light-brown in color. The sandstones are slightly more resistant to weathering than the surrounding volcanics. Exposures have a characteristic coarse, sandy, weathered texture. Pelecypod fossils are found in sec. 11, at the localities marked x-107 and x-108 on the geologic map (Plate 1 in pocket).

The mudstone in sec. 11, T. 11 S., R. 33 E., has been exposed by a bulldozed trench. The rock is bluish-black where fresh, with the bedding outlined by zones weathered light-gray in color. The mudstone is apparently not resistant to erosion, as much of the exposure has disintegrated to silt and clay that have washed to the bottom of the trench.

Lithology

Clasts in the conglomerates in sec. 13, sec. 7, and sec. 24 are mostly chert (85-95 percent), with some Dixie Butte volcanics (3-12 percent), and minor diorite, schist, and gneiss (2 percent). A matrix of chert, silt, and clay comprises an average of 24 percent of the conglomerates.

Clasts in the conglomerate in sec. 29 are chiefly granodiorite (76 percent). The remainder of the clasts are chert (13 percent) and Dixie Butte volcanics (11 percent). A matrix of sand and silt with grus from the granodiorite clasts comprises 28 percent of the conglomerate.

Many of the component grains in the sandstones have been destroyed by weathering. The remainder consists of angular fragments of chert and quartz. The matrix is comprised of clay that is bleached and slightly stained by limonite.

The mudstones are fine-grained, weathered, and poorly indurated, thus rendering them unsuitable for petrographic examination.

Origin and Depositional Environment

Chert clasts in the conglomerates in sec. 13, sec. 7, and sec. 24 are well-rounded, indicating long distance transport or remobilization from an older conglomerate. These chert clasts do not have counterparts within the District. In contrast, the granodiorite and chert clasts in the sec. 29 conglomerate appear to be compositionally and texturally similar to the Standard Creek granodiorite and to ribbon cherts found in the Dixie Butte volcanics, respectively.

The conglomerates, sandstones, and mudstone are indicative of fluvial, deltaic, and shallow marine (?) depositional environments, respectively. The conglomerates in sec. 13 are closely associated with sandstones which contain numerous wood fragments. This association suggests a fluvial or deltaic environment. The sandstones in sec. 11 contain fossil pelecypods and are closely associated with mudstone. This indicates a deltaic or shallow marine (?) depositional environment.

Age and Regional Correlation

The pelecypods found in the sec. 11 sandstones resemble faunas at Tunnel Creek, Bernard Ranch, and Antone; the Antone fauna have been identified by E. L. Packard as Cenomanian (mid-Cretaceous) according to K. F. Oles (1973, personal communication).

The sedimentary rocks in the southwestern part of the Quartzburg District have been correlated by K. F. Oles (1973, personal communication) to the Hudspeth and Gable Creek Formations of the Mitchell area in central Oregon described by Wilkinson and Oles (1968).

Clarno Formation

The Clarno Formation was named by Merriam (1901) from exposures in the vicinity of Clarno Ferry on the John Day River. In the Quartzburg District this unit consists of: flow-type andesitic and basaltic tuff breccias, 53 percent; rhyolite, 27 percent; air-fall tuff breccias, 14 percent; basalt and andesite, 5 percent; and ash-flow tuff and volcanic related sediments, 1 percent. It rims the Quartzburg District to the south, west, and part of the north. In addition, isolated down-faulted blocks of Clarno Formation rocks are preserved as structural remnants. Where orientations could be determined, the flows maintained a consistent west-northwest strike with shallow dips of 5 to 17 degrees to the south. Joints are local and discontinuous. Two volcanic necks have been recognized by Brown and Thayer (1966) a few miles northwest of the Quartzburg District. Dikes of the various flow rock types are common in the western half of the District.

Outcrops of the tuff breccia flows are massive and average 8 meters in thickness. They contain angular fragments of rhyolite, andesite, basalt, and other tuff breccias in a matrix of basalt or andesite. These fragments are generally more resistant to erosion than the enclosing matrix, and they litter the ground below outcrops. The breccias in the NW 1/4 SE 1/4, and center, SW 1/4, sec. 29, T. 11 S., R. 34 E., (marked x-105 and x-106 on the geologic map), contain boulders of granodiorite. Basaltic and andesitic tuff breccia dikes are found in the SW 1/4 SE 1/4, sec. 28, T. 11 S., R. 34 E., and the NE corner, and SW 1/4 NE 1/4, sec. 9, T. 12 S., R. 34 E.

There are two varieties of rhyolite. One is yellowish-brown with prominent liesegang rings. The other is reddish or grayish-brown with flow banding outlined by closely spaced parallel joints. The rhyolites are porphyritic, and some are vesicular. A small rhyolite plug is exposed in the north center of the NE 1/4 SE 1/4, sec. 23, T. 11 S., R. 33 E., and a dike extends from this plug to the thick rhyolite capping of the hill to the west. Other dikes are present in the W 1/2, sec. 36, T. 11 S., R. 33 E., secs. 1 and 2, and the SE 1/4, sec. 13, T. 12 S., R. 33 E., and the NE corner of sec. 9, T. 12 S., R. 34 E. They are strongly flow banded and slightly more resistant to erosion than the surrounding Dixie Butte volcanics.

The air-fall tuff breccias are poorly indurated. Outcrops are not resistant to erosion and are restricted to an undissected upland area in the E 1/2, sec. 25, T. 11 S., R. 33 E. Rock colors are normally very pale shades of red and green. In hand specimen, this unit exhibits a matrix of volcanic ash and lapilli of basalt or andesite, rhyolite, and tuff breccia. Greater than 80 meters of air-fall tuff breccia are exposed from the top of a small hill in the S 1/2 NE 1/4 SE 1/4, sec. 25, to an outcrop of basalt 1/4 mile to the southwest.

Outcrops of basalt and andesite are moderately resistant to erosion. The flows are only a meter thick in most cases and protrude from outcrop faces. Rock colors range from dark-black to medium-gray. In fresh specimens the groundmass has retained a glassy appearance. Basaltic dikes are found in the NW 1/4, sec. 12, and the SW 1/4 NE 1/4, sec. 14, T. 12 S., R. 33 E.

Ash flow tuff is found in the south center of sec. 9, T. 12 S., R. 34 E. The unit is nearly 70 meters in thickness and caps a cone-shaped hill, whose summit is just south of sec. 9. This tuff is well indurated and consists of volcanic ash with a few small inclusions of pumice and lithic material. Mineral fragments of quartz and plagioclase feldspar are also present.

Two localities of volcaniclastic sedimentary rocks were found. The largest occurs near the base of the Clarno Formation in the SW corner of the SE 1/4, sec. 11, T. 12 S., R. 33 E., and is marked x-109 on the geologic map (Plate 1 in pocket). The unit is seven meters in thickness and crops out intermittently over a distance of

100 meters. The bed is medium-brown in color and consists of calcareous silt and clay. The second locality is in the SE 1/4 SE 1/4, sec. 30, T. 11 S., R. 34 E., and is marked x-104 on the geologic map. The rock is a grayish siltstone which contains numerous fossil reeds. The unit is one meter in thickness and is not laterally continuous for more than 17 meters.

Lithology and Petrography

The flows of basaltic and andesitic tuff breccia have a predominantly glassy matrix that contains microlites and phenocrysts of plagioclase feldspar. The crystals show flow-induced orientations around the included material. The borders of some fragments are indistinct from the matrix.

The plagioclase feldspar crystals are subhedral laths and average 2 mm in length. Normal and oscillatory zoning are common. Average compositions of the zoned plagioclase range from An_{61} in the cores to An_{48} on the margins. The more calcic zones have been selectively altered to calcite and clay. The phenocrysts have been slightly fractured and warped along their junctures with the breccia fragments. Small (0.2 to 0.8 mm) hornblende crystals and a few rounded, strained quartz crystals are present in some specimens. The hornblende is brownish-green in color and is variably altered to chlorite. The quartz crystals average 0.7 mm in diameter. Apatite prisms are generally more abundant in the breccia fragments than in the matrix. The slender prisms average 0.2 mm in length. Apatite also occurs as inclusions in the margins of some plagioclase feldspar laths. The few amydales are filled with zeolites, chalcedony, and calcite.

The rhyolites contain phenocrysts of plagioclase feldspar, quartz, biotite, sanidine, and in one case garnet, set in a groundmass that has been extensively altered to clay. The accessory minerals are hornblende, zircon, magnetite, and apatite.

Plagioclase feldspar occurs as subhedral lath-shaped crystals. Normal and oscillatory zoning are common. The average composition from core to margin is An_{46} to An_{34}. The more calcic zones are selectively altered to clay, calcite, and occasionally sericite. The laths found in rhyolite dikes are commonly fractured and warped. Quartz occurs as rounded crystals which average 1.2 mm in diameter. Strain features are common in quartz from the dikes. A few crystals show effects of solution and regrowth. The solution damage is outlined by tiny inclusions and trails of clay in the crystal margins. Biotite phenocrysts are found in most of the specimens. They average 0.5 mm in diameter and often have a deep-brown stain on their margins. Inclusions of apatite and zircon are common in the biotite. The few sanidine phenocrysts appear as cloudy, lath-shaped crystals with irregular outlines. They average 0.8 mm in length and are altered to clay and sericite. Phenocrysts of garnet from a rhyolite in sec. 30, T. 11 S., R. 34 E., (marked x-104 on the geologic map), occur as dodecahedral euhedra. They average 1.5 mm in diameter and contain numerous inclusions of apatite. Using the data of Winchell (1956), the composition of the garnet is near almandite, with a deep-red color and an index of refraction greater than 1.8. Green hornblende occurs as small prisms which average 0.7 mm in length. They are weakly altered to chlorite and clay. Prisms of apatite and zircon and irregularly shaped crystals of magnetite are disseminated throughout the rhyolites.

The basalts and andesites contain phenocrysts of plagioclase feldspar, hypersthene, hornblende, biotite, and quartz. Accessory minerals are apatite, zircon, and magnetite. The plagioclase crystals form subhedral and euhedral laths which average 4 mm in length. Normal zoning is common. Compositions average An_{62} in the basalts and An_{48} in the andesites. Hypersthene is found in a few specimens and the average content approximates 2 percent. It is present as lath-shaped subhedra having rounded ends and an average length of 1 mm. The hornblende content of the basalts and andesites averages 3 percent, with a maximum of 15 percent. The crystals form subhedral prisms which average 0.8 mm in length. Crystals of biotite often have a dark-brown stain halo. They are rounded and average 1 mm in diameter. Biotite occasionally has inclusions of apatite and zircon.

Rounded quartz crystals, which range from 0.7 to 2 mm in diameter, appear in some flows. Where present, they comprise less than 1/2 of one percent of the rock. Quartz commonly exhibits strained extinction. Small (0.2 to 0.4 mm) prisms of apatite and zircon, and irregularly shaped crystals of magnetite are disseminated through the specimen.

The samples of ash-flow tuff, air-fall tuff, and the sedimentary rocks were either too extensively weathered or too poorly indurated for petrographic examination.

Chemistry of Two Basalts

The chemical analyses and modal estimates for two basalts of the Clarno Formation and the average chemical analysis for calc-alkaline andesite of continental margins (McBirney, 1969) are presented in Table 7.

The chemical analyses of the two Clarno Formation basalts are similar to that of the average calc-alkaline andesite. The two Clarno Formation basalts are enriched in titania (by 0.62 and 0.06 percent), soda (by 1.18 and 1.38 percent), and potash (by 0.23 and 0.87 percent), and depleted in alumina (by 0.83 and 0.43 percent), magnesia (by 1.28 and 2.38 percent), and lime (by 0.56 and 1.76 percent), relative to the average calc-alkaline andesite.

Table 7. Chemical and modal analyses of two Clarno Formation basalts, including chemical analysis of an average calc-alkaline andesite of continental margins (McBirney, 1969, Table 2).

	00-08	103-1	calc-alkaline andesite
SiO_2	57.5	61.5	58.65
TiO_2	1.41	0.85	0.79
Al_2O_3	16.6	17.0	17.43
FeO	9.2	6.6	6.69
MgO	2.0	0.9	3.28
CaO	5.7	4.5	6.26
Na_2O	5.0	5.2	3.82
K_2O	2.22	2.86	1.99
Total	99.63	99.41	98.91
plag	69.0 (An_{64})	66.9 (An_{62})	
hyp	-0-	4.7	
hbl	-0-	4.1	
magn	9.7	0.8	
glass	19.3	23.3	
alt	2.0	0.2	

Depositional Environment

The smooth but regionally irregular base of the Clarno Formation in the Quartzburg District implies an erosional surface of rounded hills and valleys. The sedimentary units that contain fossil reeds suggest that small lakes or ponds dotted the volcanic terrain.

Age and Regional Correlation

The Clarno Formation has been divided into two units separated by an angular unconformity in the Mitchell quadrangle of central Oregon (Oles and Enlows, 1973). This distinction is not feasible in the Quartzburg District on the basis of limited outcrops. Only the general Eocene-Oligocene age (Oles and Enlows, 1973) can be applied to the Clarno Formation of the District.

Correlation to the Clarno Formation of central Oregon was made by Brown and Thayer (1966) from the extensive exposures of this unit to the immediate west of the District.

Recent Volcanic Ash

Recent volcanic ash deposits are occasionally found along the sides of the major streams of the District. Deposits range from a few centimeters to 7 meters in thickness. They commonly exhibit a gray or tan weathered capping over white ash. The thicker deposits are located in the north center of sec. 36, T. 11 S., R. 33 E., the center of the NE 1/4, sec. 9, T. 12 S., R. 34 E., and the center of the NE 1/4 SE 1/4, sec. 2, T. 12 S., R. 33 E., and the northwest corner of the NE 1/4 NE 1/4, sec. 11, T. 12 S., R. 33 E., marked x-110, x-111, x-112, and x-113, respectively, on the geologic map (Plate 1 in pocket).

Lithology and Petrography

In thin section, angular grains of plagioclase feldspar and quartz are evident among the volcanic glass shards. Composition of the plagioclase feldspar averages medium oligoclase (An_{20}). Several of the quartz grains exhibit strained extinction. The size of the angular mineral fragments ranges from 0.1 to 0.8 mm in diameter, and averages 0.3 mm.

Age and Regional Correlation

The thick volcanic ash pockets found in northeastern Oregon and eastern Washington are attributed to the collapse of the summit of Mt. Mazama, 6,600 years b.p. (Higgins, 1973).

METAMORPHISM

The basement rocks of the Quartzburg District exhibit insipient regional metamorphism. Contact metamorphism of host rocks by plutons is common. The contact metamorphic zone ranges from about 100 meters in width adjacent to the Dixie Meadows granodiorite to less than 2 meters in width around other plutons.

Regional Metamorphism

Insipient greenschist metamorphism is evidenced by the presence of actinolite-tremolite, chlorite, calcite, epidote, and traces of albite in the groundmass and amygdales of the Dixie Butte volcanics. These metamorphic minerals comprise up to 68 percent of the basaltic and andesitic rocks. The most common are either actinolite-tremolite or chlorite and calcite. Epidote and albite are present in only a few specimens. Epidote may comprise up to 12 percent of some samples, whereas albite rarely exceeds 0.1 percent. In the amygdales these minerals occur in the same relative proportion as in the host.

Contact Metamorphism

Contact metamorphic effects are best developed where the plutons intrude sedimentary rocks intercalated in the Dixie Butte volcanics. Contact metamorphism has imposed only slight thermal effects on the basalts and andesites of the Dixie Butte volcanics.

The Dixie Meadows granodiorite has intruded argillite along part of the southern contact. As the contact is approached from the south, the argillite becomes increasingly dense and resistant to erosion. About 10 meters from the contact, the argillite is hornfelsic with macroscopic plates of mica and crystals of quartz. Small (0.1 mm) disseminated pyrite grains have recrystallized into large 3 mm grains and crystal aggregates. Stringers of pyrite are common along bedding planes. At the contact, mica and quartz grains comprise 85 percent of the hornfelsic argillite. The groundmass is a dense, medium-gray colored aggregate of clay.

Finely crystalline quartz-biotite phyllite is found along the northeastern contact of the Dixie Meadows granodiorite. The phyllite is characterized by layers of quartz (3 to 6 mm thick) that are separated by thinner layers of biotite (0.3 to 0.8 mm thick). Abundant quartz (96 percent) and the presence of inclusions of chert in the quartz layers suggest a chert-bearing parent rock. The quartz-biotite phyllite probably formed from contact metamorphism of a thin bedded ribbon chert, and biotite formed in the more argillaceous interbeds.

Contact metamorphism imposed by the plutons on basaltic and andesitic units of the Dixie Butte volcanics consists of strong chloritic alteration in hornblende, plagioclase feldspar, and the groundmass within 1 cm of the contact. From approximately 1 to 2.5 cm away from the contact, the strong chloritic alteration changes to moderate chlorite-calcite-clay alteration of the groundmass and, to a lesser extent, the phenocrysts. With increasing distance from the contact, the alteration is generally restricted to the groundmass and grades into the weak, pervasive, chlorite-calcite-clay alteration from regional greenschist metamorphism.

STRUCTURAL GEOLOGY

Tectonic Setting

The pre-Tertiary rocks of northeastern Oregon occupy a critical position in the establishment of a plate tectonic model for the Pacific Northwest. They are situated at the intersection of the trends of Mesozoic subduction zones postulated for British Columbia (Monger and others, 1972) and those of northwestern California and southwestern Oregon (Davis, 1968). Moreover, blueschist minerals associated with subduction zone metamorphism have been recognized in Permian metasedimentary rocks in the Mitchell area of central Oregon (Swanson, 1969). However, the sporadic distribution of pre-Tertiary windows in northeastern Oregon hinders development of a detailed tectonic model for the region.

Beaulieu (1972) has summarized possible correlations of major stratigraphic units in Oregon to specific tectonic settings. Permian rocks of northeastern Oregon (Elkhorn Ridge Argillite, Burnt River Schist, and the Permian part of the Clover Creek Greenstone) are interpreted from gross lithologic criteria to represent slabs of oceanic crust that have been rafted against the continent by sea floor spreading. Similarly, Ave'Lallemant (1973) interprets the Canyon Mountain Complex as an ophiolite. Beaulieu (1972) interprets the Late Triassic part of the Clover Creek Greenstone and the Eocene-Oligocene Clarno

Formation as continental-margin type island arc volcanism.

Regional Setting

The Quartzburg District is located in the center of the doubly plunging and northwest-trending Dixie Anticline. The folding is Late Tertiary age, and has involved the Columbia River Group of Miocene age. Fold axes parallel the Basin and Range faults a few miles south and southeast of the District as shown by Brown and Thayer (1966). These structures cut across the northeast-trending and regionally metamorphosed basement rocks of the Blue Mountains Anticline that have been intruded by stocks and batholiths of Early or Middle Triassic and Late Jurassic to Early Cretaceous age.

Folds

Periods of folding are indicated in the pre-Tertiary basement rocks by major Permo-Triassic to mid-Cretaceous and mid-Cretaceous to Eocene angular unconformities. The time and duration of these events cannot be evaluated from the available exposures. Interpretation of the Canyon Mountain Complex as an ophiolite (Ave' Lallemant, 1973) suggests strong diastrophism during Early or Middle Triassic time. Rocks that may have been deposited on such an unconformity in the Quartzburg District before mid-Cretaceous time have been removed by erosion. The mid-Cretaceous sedimentary rocks are not sufficiently wide-spread throughout the District to determine the character of diastrophism from mid-Cretaceous to Eocene-Oligocene time.

Faults

Rocks of the Quartzburg District have been crosscut by faults which range in age from Triassic to Late Tertiary. Faults of post Permo-Triassic and pre-Early or Middle Triassic age have moderately, and in some cases intensely, fractured the Dixie Butte volcanics. These randomly oriented structures are closely spaced and have dislocated the Dixie Butte volcanics such that individual lithologies rarely persist for more than 12 meters. In the western half of the Quartzburg District, dikes from the Early or Middle Triassic and Late Jurassic plutonic events are controlled by faults with northerly trends and near vertical dips. In the same area dikes of the Eocene-Oligocene Clarno Formation are controlled by faults with easterly trends and near vertical dips. This suggests that Early or Middle Triassic to Late Jurassic fault trends were crosscut by faults with easterly trends of post Late Jurassic to Eocene-Oligocene age. Faults younger than Eocene-Oligocene age which crosscut the Clarno Formation have trends that range from northeast to west-northwest and dip steeply to the southeast and northwest. The post Eocene-Oligocene faults are crosscut by several of the ore-bearing faults and fissures of the Quartzburg District (Gilluly and others, 1933). The mineralized structures trend north-northeast and dip steeply to the southeast and northwest. They are in turn crosscut by faults of limited displacement with northwest to north trends.

ECONOMIC GEOLOGY

Mining History

Production from the Quartzburg District was initiated in 1862 by the discovery of placer gold in the lower part of Dixie Creek. In the 1870's prospecting for the source of the placers led to the opening of lode deposits of gold-silver and copper-cobalt. Mining of the gold-rich, oxidized vein cappings flourished into the 1890's. By 1900 only the veins with ore-grade material below the oxidized zone were being mined. Several of the veins carried rich ore-shoots with values up to $500 (27 oz) per ton in gold and silver (Lindgren, 1901). Native gold can still be found in some of the old dumps and tailings. One of the more impressive mines, the Standard, contained massive chalcopyrite and bornite lenses up to 1 meter thick. The Standard mill offered a small smelter to operators of the other mines.

Mining has continued intermittently in both the lode and placer deposits to the present day, with the total production between 2.5 and 4 million dollars. Detailed descriptions of the mines are given in Appendix I, where their locations are shown on Figure 2.

Ores from the Quartzburg District presented several difficulties in processing. The gold-silver veins were plagued by "robber" clays, which trapped fine gold and carried it over the amalgam collecting plates. At the Dixie Meadows Mine, the gold was too fine-grained to be freed by ore crushing. In addition, the mercury alagamation process could not hold the gold on the extraction plates, thus causing loss of both gold and mercury. Metallurgical problems with the separation of gold and cobalt from the copper-cobalt veins resulted in a meager 33 percent recovery with respect to assayed ore values.

Classification of Mineral Deposits

The mineral deposits of the Quartzburg District occur as magmatic segregations and two hydrothermal subtypes according to the classification of Lindgren (1933).

Magmatic concentrations of chalcopyrite and pyrrhotite appear as bleb-shaped interstitial fillings (0.1 mm or less in diameter) in the contact zone of the Dixie Creek granodiorite. Their primary nature is suggested by (1) absence of associated alteration or replacement features, (2) absence of structural control, and (3) bleb-shaped form. Crystals of chalcopyrite also appear on some joint planes in the core of the stock.

On the basis of mineralogy and textures, Lindgren (1901) subdivided the hydrothermal deposits of the Quartzburg District into two types: gold-silver veins, similar to those of the California gold belt, and copper-tourmaline replacement deposits. These were later reclassified as mesothermal gold-quartz veins and hypothermal copper-tourmaline deposits, respectively, (Lindgren, 1933).

The mesothermal gold-quartz veins are not readily separable from epithermal varieties of the same vein type. In several cases the vein descriptions given by Gilluly and others (1933) strongly resemble epithermal veins as described by Lindgren (1933). A mesothermal classification is supported by the presence of pyrrhotite and arsenopyrite and by the lateral and vertical continuity of grade (Lindgren, 1933). Common associated sulfides in diminishing order of abundance are pyrite, pyrrhotite, arsenopyrite, chalcopyrite, sphalerite, marcasite, and galena (Gilluly and others, 1933). Sulfide deposition was accompanied by wall rock alteration to a quartz-sericite-clay assemblage that formed selvages several decimeters in thickness outward from the veins (Gilluly and others, 1933).

The hypothermal deposits are considered normal replacement veins by Lindgren (1901). The country rock has been strongly altered to an assemblage of sericite-quartz-schorlite. Sulfides occur as disseminated blebs up to 10 centimeters in diameter, small stringers, and massive vein fillings. The ores contain a few cavities that are lined with subhedral sulfides and prisms of schorlite and quartz. Ore minerals are chalcopyrite, bornite, cobaltite, pyrite, and pyrrhotite, with lesser amounts of tetrahedrite, galena, sphalerite, native bismuth, bismuthinite, smalltite, magnetite, and secondary marcasite (Gilluly and others, 1933).

Areas of disseminated pyrrhotite and pyrite are sporadically distributed in the Dixie Butte volcanics. The deposits are usually small, but one in Wickiup Creek Canyon is nearly 600 meters in length, 100 to 300 meters in width, and at least 150 meters in thickness. Sulfide content ranges from 0.5 to 6 percent and averages 3 percent. Sulfides occur as fracture coatings and disseminations. In porphyritic rocks, the plagioclase feldspars have been selectively replaced by a quartz-chlorite-sulfide assemblage which is surrounded by a halo of clay alteration. Weathered outcrops are leached and colored a distinctive yellowish-white. These leached rocks are comprised of clay, quartz, and chlorite, with sericite in the larger deposits. They are laced by fracture coatings of hematite and jarosite.

Hydrothermal Alteration

Suites of samples representing hydrothermal alteration from the mesothermal gold-quartz and hypothermal copper-tourmaline deposits were collected and studied by petrographic and whole-rock chemical methods of analysis. The data are tabulated separately in Tables 8 and 9 for mesothermal and hypothermal alteration suites, respectively.

The Wagonwheel Mine (number 26 in the Appendix) is representative of the mesothermal gold-quartz veins. The deposit is localized in a breccia zone at the contact between the Standard Creek granodiorite and Dixie Butte volcanics. The associated sulfides are pyrite, pyrrhotite, sphalerite, galena, and probably tetrahedrite. Alteration minerals include quartz, sericite, calcite, and clays. Samples were collected from an unaltered contact phase of the granodiorite (167-1) 200 meters from the deposit, and from an altered granodiorite breccia fragment (163-1) in the workings.

In thin section, the "fresh" granodiorite contains incipient chlorite-calcite-clay-sericite alteration of the plagioclase feldspar and ferromagnesian minerals. Hydrothermal alteration has produced significant mineralogical changes in the granodiorite, whereas only moderate variations in the whole-rock chemistry are evident from Table 8. The presence of calcite and sulfides has resulted in a low cumulative percentage for the chemical analysis of the altered specimen. Silica increased only 2.4 percent while the quartz content increased 54.2 percent. The quartz apparently formed from silica released by destruction of the major silicate minerals, such as plagioclase feldspar. The depletion of alumina, total iron, magnesia, lime, and soda is the result of the destruction of major silicate minerals.

Table 8. Comparison of unaltered granodiorite (167-1) to an altered granodiorite (163-1) from the Wagonwheel Mine mesothermal gold-quartz deposit, using chemical and modal analyses.

	167-1	163-1	
SiO_2	56.4	59.4	
TiO_2	1.1	0.98	
Al_2O_3	15.1	13.5	
FeO	7.5	5.7	
MgO	5.7	2.1	
CaO	8.5	5.3	
Na_2O	3.6	0.3	
K_2O	1.0	3.2	
Total	98.9	90.48	
			net change
qtz	0.4	54.6	+54.2
plag	67.2	0.1	-67.1
px	24.0	-0-	-all
orth	0.9	-0-	"
bio	1.8	-0-	"
magn	2.0	-0-	"
chl	3.4	0.1	- 3.3
calc	0.1	15.2	+15.1
clay	0.1	3.2	+ 3.1
seri	0.1	21.5	+21.4
sulf	-0-	5.3	+ 5.3

The introduction of sulfides has masked some of the total iron depletion. In the same way, the introduction of calcite has masked some of the depletion of lime. The introduction of sericite has produced a marked increase in potash.

The Blueberry Mine (number 1 in Appendix), also referred to as the Prindle or Black Prince in previous literature (Lindgren, 1901; Gilluly and others, 1933), is used as an example of hydrothermal alteration associated with the hypothermal copper-tourmaline deposits. The deposit is localized along a fault zone in the basaltic host rocks of the Dixie Butte volcanics. The fault zone trends westerly and dips steeply to the south. The common metallic minerals are chalcopyrite and pyrite. Smaller amounts of magnetite, arsenopyrite, sphalerite, covellite, and smalltite are also present (Gilluly and others, 1933). They occur as stringers and disseminations in the vein and adjacent wall rocks. Sulfide deposition was accompanied by wall rock alteration to a quartz-schorlite-sericite-calcite assemblage that formed selvages several decimeters in thickness outward from the veins. Calcite also is present as thin (0.1 mm) borders enveloping the sulfide veins.

The moderately altered basalt (see Table 9) consists largely of quartz which has replaced the groundmass of the basalt host. Sericite and calcite are scattered in and around the quartz and in association with microscopic sunbursts and prisms of schorlite. The phenocrysts of plagioclase feldspar are completely replaced by calcite, sericite, and clay. Actinolite was apparently unstable, as it was completely destroyed by alteration. In the strongly altered basalt, quartz and schorlite comprise 93 percent of the rock. Schorlite appears to have replaced the quartz along grain boundaries. The well-developed schorlite sunbursts average 3 mm in diameter and are generally larger than those found in the moderately altered basalt. Sericite is conspicuously absent in the strongly altered specimen.

Mineralization and alteration have produced appreciable chemical variations between the moderately altered basalt and the "fresh" basalt. Silica is enriched as a result of destruction of plagioclase feldspar and actinolite and the introduction of quartz, schorlite, and sericite. Titania is depleted by the destruction of magnetite. Alumina is depleted as a net result of the destruction of plagioclase feldspar and the introduction of sericite. The destruction of magnetite and actinolite and the introduction of schorlite have produced a net depletion in total iron. The depletion of magnesia is attributable to the destruction of actinolite. The destruction of plagioclase feldspar has resulted in the depletion of soda, and along with the increase in calcite

Table 9. Comparison of host basalt (00-33) to moderate (204-1) and strong (204-2) stages of alteration in the Blueberry Mine hypothermal copper-tourmaline deposit, using chemical and modal analyses.

	00-33	204-1	204-2			
SiO_2	57.2	66.9	72.8			
TiO_2	0.93	0.48	0.48			
Al_2O_3	17.0	13.4	10.7			
FeO	7.8	4.9	8.3			
MgO	3.6	0.8	0.7			
CaO	9.0	4.8	1.4			
Na_2O	3.4	0.6	0.7			
K_2O	0.6	1.9	-0-			
Total	99.53	93.78	95.08			
					Net Change	
				33→204-1	4-1→4-2	33→204-2
qtz	-0-	64.5	49.8	+64.5	-14.7	+49.8
plag	48.4	-0-	-0-	-all	-0-	-all
magn	1.8	-0-	-0-	"	-0-	"
act	48.9	-0-	-0-	"	-0-	"
tour	-0-	22.4	42.9	+22.4	+20.5	+42.9
calc	0.1	7.2	1.4	+ 7.1	- 5.8	+ 1.3
clay	0.7	1.3	1.8	+ 0.6	+ 0.5	+ 0.9
seri	0.1	4.6	-0-	+ 4.5	- 4.6	- 0.1
sulf	-0-	-0-	4.1	-0-	+ 4.1	+ 4.1

has produced a net depletion of lime. The introduction of sericite has produced an increase in potash.

Comparison of the strongly altered basalt to the moderately altered specimen shows additional chemical variation. Silica is enriched as a net result of enrichment in schorlite and depletion of quartz and sericite. Titania is unchanged. Alumina is depleted by the destruction of sericite. Total iron is enriched by the introduction of sulfides and an enrichment in schorlite. The very slight depletion of magnesia may be due to changes in the clay mineralogy or reflect differences in the host rocks. The depletion of lime is attributable to the near-absence of calcite. The slight enrichment of soda suggests incorporation of sodium in the schorlite crystal lattice. The total destruction of sericite has resulted in the elimination of potash from the specimen.

Sulfide Paragenesis of a Selected Deposit

Metallic mineral occurrences in the mesothermal and hypothermal deposits are substantially different. Sulfides from the hypothermal copper-tourmaline deposits are massive and occur as single crystals greater than 1 cm in diameter. Although there is a wider variety of sulfides in the hypothermal deposits, they are coarsely crystalline and thus are not satisfactory for study from a small number of polished sections. Sulfide veins in the mesothermal deposits are generally less than 1 cm in width, thus allowing a representative assemblage of sulfides to be studied in a single polished section. Accordingly, a sample from the Yankee Boy Vein (Appendix, number 27), a mesothermal gold-quartz deposit, was examined in polished section.

Sulfide paragenesis in the Yankee Boy Vein is in the order pyrrhotite, sphalerite, pyrite, and chalcopyrite. The veinlet is 8 mm in width and consists principally of pyrrhotite and sphalerite. The walls are lined with quartz prisms, and thin quartz veinlets extend into the adjacent host rock. Pyrrhotite occurs as thin coatings on the quartz prisms and as irregularly shaped masses in the bulk of the veinlet. The margins of pyrrhotite crystals have irregular boundaries with sphalerite, and pyrrhotite is occasionally embayed by sphalerite. Crystals of sphalerite are subhedral and have well developed cleavage. Several of the sphalerite crystals contain tiny (0.5 mm) bleb-shaped inclusions of pyrite, chalcopyrite, or both. Chalcopyrite also occurs as thin stringers in the central portion of the veinlet. Sphalerite often has subhedral crystal outlines that extend into the chalcopyrite stringers, whereas pyrrhotite has been replaced and embayed by the chalcopyrite.

Age and Source of Mineralization

Mineralization in the Quartzburg District appears to be of post Eocene-Oligocene age. This conclusion is supported by (1) two instances of mineralization in Clarno Formation rocks, and (2) mineralized structures that show very little offset by cross-faulting (Gilluly and others, 1933). In the north center of the NW 1/4 NW 1/4 NW 1/4, sec. 11, T. 12 S., R. 33 E., a basaltic flow breccia of the Clarno Formation is crosscut by several veinlets of pyrite 1 to 5 mm in width. The associated alteration halo of sericite, calcite, and clay is several centimeters in width. In the E 1/2 SE 1/4 NE 1/4, sec. 2, T. 12 S., R. 33 E., an adit exposes a mesothermal gold-quartz vein which is localized in and along the contacts of a rhyolite dike in the Clarno Formation.

A source of mineralization cannot be determined from the available exposures. The steep dips of the ore-bearing faults and fissures (from 70° to vertical) suggest a source at depth. Moreover, plutons dated at 33 m.y., that are genetically related to ore deposits, are found in the Paisley area of south central Oregon (Muntzert, 1969). Unexposed plutons of similar age may be the source of the mineral deposits of the Quartzburg District.

However, this interpretation is hindered by the paucity of Tertiary rocks and the possibility of remobilization or multiple stages of mineralization. Potassium-argon age determinations of sericite in the alteration selvages of the veins would provide a more reliable age of mineralization.

GEOLOGIC SUMMARY

During Permo-Triassic time, the Quartzburg District was situated along an active eugeosyncline. Extrusions of basalt and andesite accumulated into the thick Dixie Butte volcanics, the oldest unit in the District. Small amounts of argillite and chert were intercalated with the volcanic rocks. The Dixie Butte volcanics were moderately to intensely fractured by closely spaced faults before they were intruded by plutons of peridotite, gabbro, and granodiorite of Early or Middle Triassic age. Contact metamorphism of argillite and ribbon cherts in the Dixie Butte volcanics to hornfelsic argillite and quartz-biotite phyllite, respectively, occurred along the contacts of the Dixie Meadows granodiorite. Contact metamorphism of the basalts and andesites produced thin zones of pervasive chloritic alteration. After emplacement of the Comer Creek gabbro and before intrusion of the Standard Creek granodiorite, a north-trending fault system was established in the western part of the Quartzburg District. The faults provided structural control for the emplacement of dikes from the Early or Middle Triassic and the Late Jurassic granodiorite plutons. During mid-Cretaceous time, large streams dissected the region and deposited conglomerate in the northern part of the Quartzburg District. In the southwestern part of the District, these conglomerates are associated with deltaic sandstones and shallow marine (?) mudstones.

By Eocene-Oligocene time, erosion had removed all but a few lenses of the mid-Cretaceous sedimentary rocks. In the western part of the District, east-trending faults served as feeders for basaltic flow breccias, rhyolites, and basalts that eventually covered the region. Violent eruptions, possibly from two vents northwest of the District (Brown and Thayer, 1966), left deposits of airfall tuff interbedded with the volcanic flows. Small ponds or lakes in the volcanic terrain collected ash and silt. The volcanics were crosscut by faults with trends that range from northeast to west-northwest with steep southeast and northwest dips. They were crosscut by northeast to east-trending faults which dip steeply to the north and south. Hydrothermal fluids entered this latter set of faults, as well as the contacts of several dikes in the western portion of the area, and formed the rich mesothermal gold-silver and hypothermal copper-cobalt-bismuth bearing veins of the Quartzburg District. The mesothermal gold-silver veins occur in widths up to 1 meter with grades as high as 29 oz. gold per ton. The hypothermal copper, cobalt, and bismuth deposits occur as massive sulfide veins with associated breccias and disseminated mineralization. During Miocene time, flows of the Strawberry volcanics and later the Columbia River Group spread out and over rocks of the Clarno Formation and the underlying basement. Post mid-Miocene uplift along the Blue Mountains Anticline resulted in erosion of the Tertiary volcanic capping over the Quartzburg

District, and provided exposures of the pre-Tertiary lithologies.

Erosional concentration of gold from numerous veins of the District produced the rich placer deposits in Dixie Creek and the John Day River. The explosive eruption of Mt. Mazama during Recent time is recorded as small residual accumulations of volcanic ash along hill slopes and in topographic depressions.

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MINE AND PROSPECT DESCRIPTIONS

Introduction

The following brief descriptions largely summarize data from other studies (Lindgren, 1901, pp. 710-712; Gilluly and others, 1933, pp. 87-104; Oregon Department of Geology and Mineral Industries, 1941, pp. 148-153). For more complete information the reader is referred to the above original sources.

The lode mines are listed alphabetically. The unnamed workings are listed according to distribution over the District south to north. The localities are shown on Figure 2 by the number designations in this section. The mines are listed on Table 9 with their vein types. In review, the lode deposits are of two general types: mesothermal gold-quartz veins mined for gold and silver, and hypothermal copper-tourmaline replacement masses mined for gold, silver, copper, cobalt, and bismuth.

The placer mining operations are summarized at the last of the section. The deposits in lower Dixie Creek and in the John Day River immediately below Dixie Creek are included, since the source of these deposits was in the veins of the Quartzburg District.

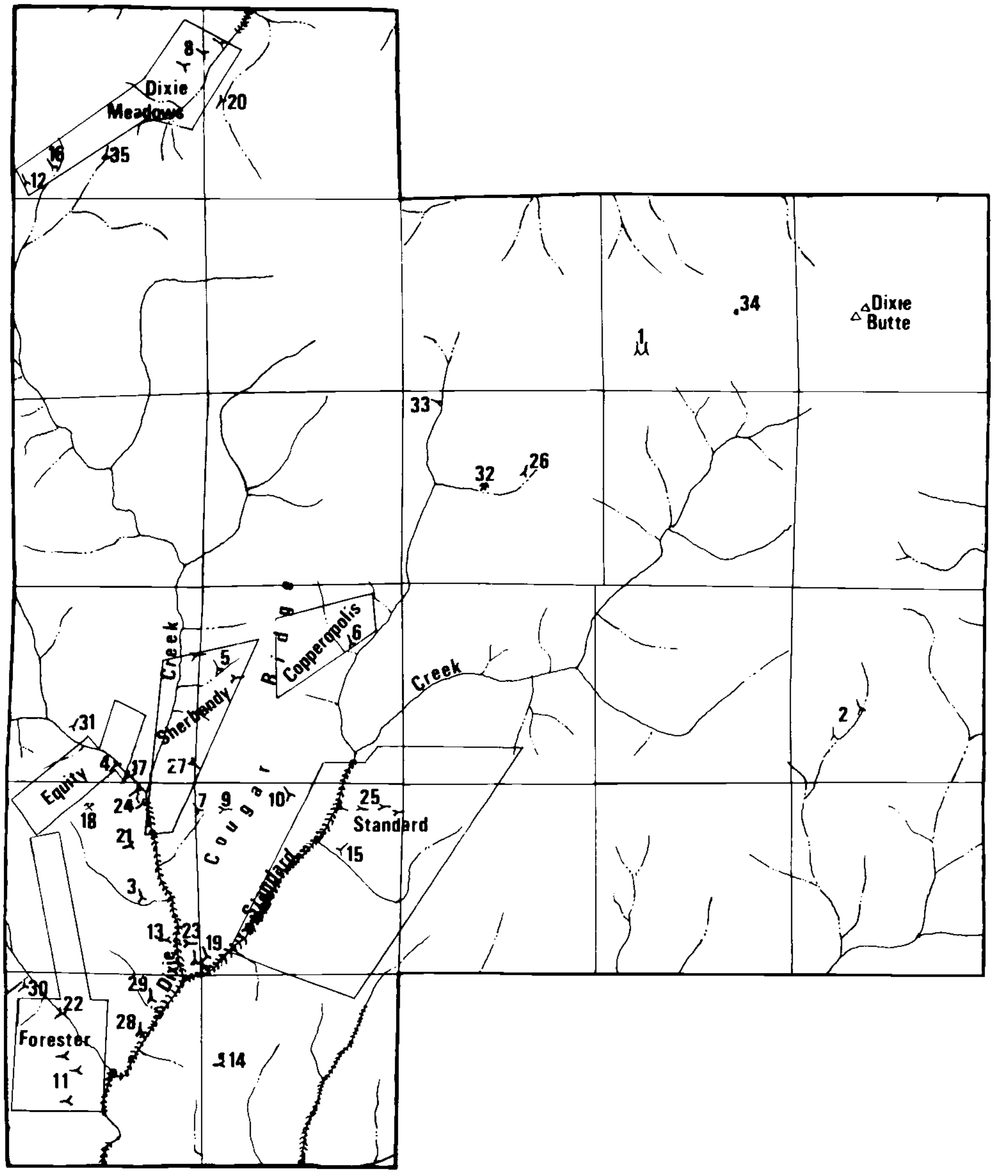

Figure 2. Mine location index map for mine descriptions in appendix, showing names and generalized outlines of patented claim blocks, and placer mines (hatchered drainage lines). See following page for mine names and deposit types.

Table 9. Mine list for Figure 2. Notation for vein types: A- mesothermal gold-quartz, B- hypothermal copper-tourmaline. For mine descriptions see appendix.

No.	Name	Type	No.	Name	Type
1.	Blueberry	B	19.	Klondike	A
2.	Boulder	A	20.	Last Chance	A
3.	Buck Gulch	A	21.	New Deal	A
4.	Colorado	A	22.	Ophir	A
5.	Copper Mountain	B	23.	Paul Tote	A
6.	Copperopolis	B	24.	Present Need	A
7.	Cougar	A	25.	Standard	B
8.	Dixie Meadows	B	26.	Wagonwheel	A
9.	Dixie Queen	A	27.	Yankee Boy	A
10.	Fitzsimmons	A	28.	unnamed	A
11.	Forester	A	29.	"	A
12.	Gladys	A	30.	"	A
13.	Haley	A	31.	"	A
14.	Howell and Haight	A	32.	"	A
15.	Juniper	B	33.	"	A
16.	Kayuse	A	34.	"	?
17.	Keystone	A	35.	"	?
18.	Keystone Extension	A			

Lode Mines

1. Blueberry (Prindle, Black Prince)

   Location: NE 1/4 SW 1/4 SW 1/4, sec. 29, T. 11 S., R. 34 E.

   Type: hypothermal copper-tourmaline

   Vein: Quartz-schorlite replacement mass in metavolcanics, trending east-west, dipping steeply south. Ore minerals are pyrite, with lesser amounts of magnetite, arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, covellite, and smalltite, with some sericite and calcite. Width in dump material indicates thin stringers of sulfides within a several foot wide alteration zone; sulfide pockets also occur.

   History: The small dumps indicate little activity other than the 750 feet of workings known in 1933. No production is recorded, but gold values ran as high as $10 (0.48 oz.) to the ton.

2. Boulder

   Location: Adits in center of the NE 1/4 SW 1/4, and center of the SW 1/4, sec. 4, T. 12 S., R. 34 E.

   Type: mesothermal gold-quartz

   Vein: Orientation N. 70 to S. 70° E., steep southerly dip. Vein follows fault and consists of silicified and mineralized metavolcanics. Thickness of sulfide veins varies from less than an inch to 4 inches. Ore minerals are pyrite, arsenopyrite, chalcopyrite, sphalerite, pyrrhotite, and smalltite, with quartz and some calcite.

History: About 1,000 feet of workings had been driven on the vein in 1933. No production is recorded. Picked ore ran 8 percent cobalt, 2 percent copper, and 0.1 ounce gold per ton.

3. Buck Gulch

Location: NE 1/4 NW 1/4 SE 1/4, sec. 11, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: East-west trending pocket deposits of leaf gold in metavolcanics. Pyrite is found in dumps, with calcite-quartz gangue.

History: Small pocket of leaf gold valued at $50 (1.43 oz.) was removed in 1937. Caved shaft and numerous pits along trend of vein on surface.

4. Colorado (Equity, Quartzburg)

Location: Center of the SW 1/4 SW 1/4 SE 1/4, sec. 2, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz, massive sulfide

Vein: Orientation N. 35-45° E., 75-80° S. Vein consists of one foot to less than one inch wide fault zone filled with quartz, dolomite, and sulfides. Ore minerals are pyrite, chalcopyrite, galena, and sphalerite. The host gabbro shows sericitic alteration close to the vein.

History: The deposit was discovered in 1878, and worked almost continuously until 1910. The mine has been developed on several levels to a depth of 275 feet. Total production is estimated between four and six ~~hundred~~ thousand dollars, the largest of any gold-silver mines in the District, and close to that of the Standard Mine. Gold ran up to $500 (24 oz.) per ton.

5. Copper Mountain

Location: E 1/2 SE 1/4 NE 1/4, sec. 2, and S 1/2 SW 1/4 NW 1/4, sec. 1, T. 12 S., R. 33 E.

Type: hypothermal copper-tourmaline; adit in sec. 2 follows mesothermal gold-quartz vein.

Vein: The deposit is a combination of fault veins with brecciation, silicification, sericitization, and sulfide impregnation from 2 to 6 feet into the wall rocks; and schorlite-quartz-chalcopyrite replacement bodies only slightly controlled by faulting. The vein deposits trend 30-45° E., dipping steeply south. Ore minerals include pyrite, chalcopyrite, bornite, and probably cobaltite, with quartz and tourmaline.

The country rocks are metavolcanics with dikes of diorite and gabbro. The sec. 2 adit is part of the group, but it follows a mid-Tertiary rhyolite dike. The vein consists of pyrite, with quartz and calcite, along the contacts of the dike. Disseminated sulfides appear in the dike and host metavolcanics.

History: The claims were located in 1896, and work since has been small in scale. About 500 feet of workings, and a few surface pits have been made. No production is known.

6. Copperopolis

Location: Center of the NE 1/4, sec. 1, T. 12 S., R. 33 E.

Type: hypothermal copper-tourmaline breccia pipe

Vein: The main deposit is a quartz-schorlite-sulfide breccia pipe 75 feet wide, and 1,000 feet long, in a N. 60° E. continuation of the Copper Mountain veins. Included fragments are slightly to completely replaced by quartz-schorlite. Ore minerals are pyrite, chalcopyrite, cobaltite, and bornite, with lesser amounts of tetrahedrite, galena, sphalerite, magnetite, and hematite. The ore body contains a 35 foot wide unreplaced horse of metavolcanic country rocks. The mineralized rock has sharp boundaries with the country rocks.

History: There are about 3,000 feet of workings. The ore is low grade, and about 250 tons have been milled. Values mainly in copper and gold.

7. Cougar

Location: West center of the NW 1/4 NW 1/4, sec. 12, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite, chalcopyrite, and galena-rich quartz, calcite, and gouge, along the east wall of the same dacite porphyry dike as the Klondike Vein. Vein strikes northerly, dipping steeply to the west and east; the width varies from 3 inches to one foot.

History: The area is dotted with small adits and pits along the dike and closely adjacent metavolcanics. By 1933, 270 feet of drifting had been done on the main ore vein. Picked ore ran $450 per ton (gold-silver).

8. Dixie Meadows

Location: NE 1/4 SE 1/4 NE 1/4, sec. 23, to SW 1/4 NW 1/4 NW 1/4, sec. 24, T. 11 S., R. 33 E.

Type: hypothermal copper-tourmaline (gold-silver-copper)

Vein: The country rock is a complex of metavolcanics, granodiorite, spinel peridotite, and argillite. The vein is locallized in argillite along a fault. Widths vary from

10 to 60 feet, and the vein has been traced to a depth of 600 feet. The ore minerals are pyrite, arsenopyrite, chalcopyrite, pyrrhotite, galena, sphalerite, and marcasite. The most common gangue is quartz, with lesser amounts of ferriferous dolomite. Replaced rock consists of quartz, schorlite, sericite, and hydrothermal(?) biotite. The biotite may have recrystallized from the argillite. The fault bounded vein is composed of mineralized zones in gouge and breccia 60 feet wide, with granodiorite on either side. The vein trends N. 30-35° E., 65-70° SE.

History: The deposit was discovered in 1901. The original samples from the surface exposures ran $100 (5.41 oz.) gold per ton. The deposit was opened on three levels by 1903 exposing a vertical continuation of 350 feet. Ore zones with gold values up to $480 (23 oz.) per ton were found. A tin-stamp mill was set up in 1905, but most of the gold was too fine-grained to be freed by crushing and the mine was closed. A second attempt to mine the deposit lasted from 1911 to 1914, eventually failing for the same reason as before. In the 1950's a fourth level was driven, showing vertical continuation of the vein for 600 feet. As of this writing, the mine is under lease and is being actively explored in preparation for mining. Chemical treatment of the ore, rather than amalgum extraction, is planned for removal of the fine gold.

9. Dixie Queen

Location: Center of the NW 1/4 NW 1/4, sec. 12, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite, chalcopyrite, and galena, with quartz and calcite, along the contacts of dacite porphyry dikes in metavolcanics. Orientations vary from N. 15° W. to N. 15° E., dipping steeply east. Veins in dumps average a few inches in width.

History: There was a total of 350 feet of workings in 1940. The surface vein is not known to have been intercepted, and no production is recorded. The dacite porphyry dike in the Cougar and Klondike workings is paralleled by the Dixie Queen dikes.

10. Fitzsimmons

Location: NE 1/4 NE 1/4 NW 1/4, sec. 12, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: The vein apparently lies along a diorite dike in metavolcanics. The vein trends N. 12° E., vertical, and consists of quartz and gouge with pyrite, galena, and free gold.

The width averages 2 1/2 feet, with pyrite disseminated in the metavolcanic wall rocks.

History: The volume of dump material suggests several hundred feet of workings. Ore values in 1940 varied from $25 (0.71 oz. gold) to $50 (1.4 oz. gold) per ton.

11. Forester

Location: SE 1/4 NW 1/4, sec. 14, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite and quartz, with free gold, in a 1 1/2 foot wide gouge and breccia zone along the footwall of a sericitic diorite porphyry dike in metavolcanics and granodiorite. Dike trends N. 5° E., dipping 80° E.

History: In 1933 there were 500 feet of accessible workings in the main adit.

12. Gladys

Location: SW 1/4 SW 1/4 SW 1/4, sec. 23, T. 11 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Widespread disseminations and stringers of gold-bearing pyrite and pyrrhotite in argillite. Trace amounts of chalcopyrite are present. The main ore carrying zone consists of 20 feet of sheared argillite with close spaced stringers of massive sulfides with quartz.

History: The Gladys is the southernmost extension of ore similar to that of the Dixie Meadows Mine. The deposit has been opened by about 100 feet of workings.

13. Haley

Location: Center of the SE 1/4 SE 1/4, sec. 11, T. 12 S., R. 33 E.

(Tentative: there is some discrepancy as to which workings were the Haley property, but the late owner's dwelling is very close to the described property.)

Type: mesothermal gold-quartz

Vein: Fracture trending N. 20° E., 85° SE, through complex assemblage of numerous dacite porphyry dikes in metavolcanics. Vein follows fracture and carries pyrite, pyrrhotite, and a little chalcopyrite with calcite and quartz; widths vary from 8 inches to two feet. Vein considered high grade.

History: Workings include a 35 foot shaft and 150 feet of crosscuts. Some ore was milled in 1940.

14. Howell and Haight

Location: Tentatively SW 1/4 NW 1/4, sec. 13, T. 12 S., R. 33 E., but geology does not fit mine description, and property could not be located.

Type: mesothermal gold-quartz

Vein: High grade streak along the hangingwall of a dacite porphyry dike trending N. 20° E., and dipping 45° E., through diorite. Ore is pyrite and free gold with quartz. The ore minerals also occur as disseminations in the dike.

History: In 1933, a 30 foot shaft was sunk on the dike, exposing \$4 to \$5 (0.21 oz.) to the ton gold ore. No production was known in 1940.

15. Juniper

Location: East center of the SW 1/4 NE 1/4, sec. 12, T. 12 S., R. 33 E.

Type: hypothermal copper-tourmaline

Vein: The Juniper is the southernmost of the four major copper-cobalt veins paralleling the Standard vein. The vein trends N. 75-80° E., 80° S., consisting of pyrite, chalcopyrite, and arsenopyrite, with quartz, schorlite, and calcite. Widths range from 3 inches to 3 feet. The metavolcanic wall rocks contain considerable schorlite and show hornfelsic-like texture.

History: The Juniper Vein has been mined and milled with the Standard Vein, and production records were not separated from those of the Standard Vein. The vein has been opened by 900 feet of drifts.

16. Kayuse

Location: NE 1/4 SW 1/4 SW 1/4, sec. 23, T. 11 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Same as the Gladys Mine

History: The Gladys adit and Kayuse shaft are developed on a possible extension of the Dixie Meadows Mine ore zone.

17. Keystone

Location: Center of the S 1/2 SW 1/4 SE 1/4, sec. 2, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite, pyrrhotite, chalcopyrite, sphalerite, and galena, along a northeast trending, steep southerly dipping fracture in gabbro. The vein is four feet wide, with mineralization along the walls; the gangue consists of calcite with a little quartz.

History: The mine was operated on seven levels in 1882. In 1883, $20,000 of gold-silver ore was removed. The mine has been inactive since 1900, except for short term exploration for ore shoots.

18. Keystone Extension

Location: NE 1/4 NW 1/4 NW 1/4, sec. 11, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Southerly continuation of workings in oxidized capping of Keystone Vein. Pyrite, chalcopyrite, malachite, and azurite, in intensely silicified metavolcanics. Vein trends N. 10° E., 75° E., consisting of gouge and breccia up to 4 feet wide, with mineralized widths from 1 to 3 feet.

History: The old workings are of unknown extent, but they attempted to remove the entire gold-rich oxidized capping of the Keystone Vein. Present exposures are provided by extensive trench cuts.

19. Klondike

Location: SW 1/4 SW 1/4 SW 1/4, sec. 12, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite, with a little quartz, in gouge and breccia along the east wall of a dacite porphyry dike, trending N. 5° E., dipping 85° E. Disseminated chalcopyrite also found in dike, and in host metavolcanics, along with pyrite.

History: Extent of workings is unknown. A high grade pocket yielded 33 tons of ore; the date is unknown.

20. Last Chance

Location: Center of the SW 1/4 NW 1/4, sec. 24, T. 11 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Orientation N. 60° E., 60° S. Widths vary from a few inches to 1 1/2 feet, with some disseminated ore minerals in the wall rocks. Ore minerals are pyrite, galena, sphalerite, pyrrhotite, and some chalcopyrite, with quartz and some ferriferous dolomite. The host metavolcanics and peridotite are sheared and silicified.

History: No production is recorded, but ore grades were considered high at $4 to $8 (0.29 oz.) to the ton gold. There are about 400 feet of workings.

21. New Deal

Location: SW 1/4 NW 1/4 NE 1/4, sec. 11, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite, chalcopyrite, and secondary marcasite, with calcite and a little quartz, in gouge and breccia along a N. 75° E., 80° N., trending fracture in metavolcanics. Vein averages 4 inches in width. There is some disseminated pyrite and pyrrhotite in the wall rocks.

History: The workings consist of one adit approximately 200 feet long. No production recorded, but there is considerable free gold in the concentrates. The oxidized vein capping ran 2.59 oz. gold and 0.56 oz. silver per ton, and 0.92 percent copper.

22. Ophir

Location: S 1/2 NE 1/4 NW 1/4, sec. 14, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Gougy shear zones in granodiorite. Wide areas are criss-crossed with limonite stringers. Shears trend north-south, dipping 50-70° E.

History: In 1940 there was a total of 1,500 feet of workings.

23. Paul Tote

Location: NE 1/4 SE 1/4 SE 1/4, sec. 11, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite and chalcopyrite with a little quartz and calcite along two intersecting veins in metavolcanics. The veins trend N 10° W., and N 10-25° E., both dipping 75° E. The widths vary from 3 inches to 2 feet in the NNE vein and from 6 inches to 8 feet in the NNW vein.

History: About 700 feet of total workings in 1933. The NNW vein carried $7 (0.34 oz.) gold per ton.

24. Present Need

Location: NE 1/4 NW 1/4 NE 1/4, sec. 11, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite, pyrrhotite, chalcopyrite, sphalerite, galena, and secondary marcasite, in two shoots dipping 65° S., in a N 20° E., 70° E., trending vein in metavolcanics and gabbro. The vein width is 2 to 3 feet, with 4 inches to 2 feet filled with quartz and ore.

History: The Present Need is the best silver vein known in the Quartzburg District. Ore values ranged from 6 to 25 oz. silver and 4 to 5 oz. gold per ton. There are 300 feet of workings.

25. Standard

Location: East center of the NW 1/4 NE 1/4, sec. 12, T. 12 S., R. 33 E.

Type: hypothermal copper-tourmaline

Vein: Three veins were developed by the Standard Mine: the Standard, the Smuggler, and the Grover Cleveland. These veins contain pyrite, chalcopyrite, bornite, covellite, cobaltite, smalltite, bismuthinite, native bismuth, safflorite, galena, arsenopyrite, and sphalerite, with quartz, ferriferous dolomite, calcite, and schorlite gangue. The veins are a group of persistent stringers along faults trending N 70-80° E., 60-80° S., through metavolcanics. Vein widths vary from a few inches to 5 feet. The Grover Cleveland Vein follows in part a granodiorite porphyry dike. The vein is a brecciated zone about 8 feet wide, filled with stringers of ore and gangue. The Smuggler Vein was described as a diorite dike (Gilluly and others, 1933), however, a quartz tourmaline replacement mass follows the projected trend of the Smuggler Vein on the surface.

History: The Standard Mine was the largest single producing mine of the Quartzburg District. Production has continued intermittently from 1880 to the present, with short term leasing after 1907. The total production record is unknown, but the extensive workings and stopes are suggestive of several thousand tons. In 1907 a shipment of 311 tons of concentrates averaged 0.03 oz. gold and 1 oz. silver to the ton, and 10 to 12 percent copper (cobalt was lost in favor of the gold).

26. Wagonwheel

Location: NE 1/4 SW 1/4 NE 1/4, sec. 31, T. 11 S., R. 34 E.

Type: mesothermal gold-quartz

Vein: Brecciated metavolcanics and granodiorite along the contact of the Standard Creek granodiorite. Vein follows contact in part, with several N. 20° E., trending stringers extending into the metavolcanics. Ore minerals are pyrite, and probably tetrahedrite, with lesser amounts of chalcopyrite, sphalerite, and galena, and quartz-calcite gangue. The average width of the mineralized breccia zone is 6 feet, but the ore occupies small portions of the breccia.

History: The deposit is developed on two levels, approximately 40 feet apart. The lower adit is old and caved, the upper one has been worked recently. The upper adit is 50 feet long and some silver ore has been mined in the last few years.

27. Yankee Boy

Location: East center of the SE 1/4 SE 1/4 SE 1/4, sec. 2, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Six shear zones trending N 5-20° E., 75-85° E., varying from 3 inches to 1 foot wide. The vein consists of gouge with pyrrhotite, sphalerite, chalcopyrite, pyrite, and galena, with quartz and calcite gangue. The host rocks are metavolcanics.

History: There are about 700 feet of workings on three levels. Production is not recorded, but the quantity and type of mine buildings suggests that the mine has been recently active.

28. unnamed

Location: Center of the NE 1/4, sec. 14, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Mineralized fault trending N 15° W., 85° NE., with some disseminated pyrite in the structure and the host metavolcanics. The strongly iron-stained, gougy vein averages 3 inches wide. Bleaching of the country rocks is evident over a width of two feet across the vein.

History: An adit has been driven along the vein, but it is caved at the portal. The dumps have been used in construction of the Dixie Creek road, preventing an accurage estimate of the extent of the workings.

29. unnamed

Location: East center of the NW 1/4 NE 1/4, sec. 14, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Strongly iron-stained fault gouge with some quartz and calcite gangue. The fault parallels that of No. 28 in orientation and dip. The country rocks are bleached and silicified over a five foot width, and less altered samples contain abundant disseminated pyrite.

History: An adit follows the vein, and was open for over 50 feet at the time of this study. No known production.

30. unnamed

Location: N 1/2 NW 1/4 NW 1/4, sec. 14, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Strongly iron-stained six inch wide shear zones in granodiorite. The shear zones occur over a width of 40 feet;

the intervening area is altered to moderately iron-stained grus. Shears trend N 10° E., to N 10° W., dipping from 60° E to 60° W. Some shears appear to follow jointing trends.

History: No known production. The deposit is opened by a large cat trench. Free gold can be panned from the shear zone gouge.

31. unnamed

Location: SW 1/4 NE 1/4 SW 1/4, sec. 2, T. 12 S., R. 33 E.

Type: mesothermal gold-quartz

Vein: Pyrite with quartz along the contact of Comer Creek gabbro and metavolcanics. Vein consists of gouge, breccia and ore; widths vary from a few inches to 1 foot in the dumps.

History: No known production. The sulfide content is very low, and the dumps are small. The condition of the dumps suggests that the workings are very old.

32. unnamed

Location: SE 1/4 SE 1/4 NW 1/4, sec. 31, T. 11 S., R. 34 E.

Type: mesothermal gold-quartz

Vein: Numerous exposures in shallow trenches of hematite-stained, silicified metavolcanics and granodiorite, along the contact of the granodiorite. Pyrite is the only sulfide, with quartz and calcite gangue. Deposit appears to be the same type as the Wagonwheel, but it is too far away to be an extension.

History: The excavations are new in most cases, and may represent exploration in mineralized ground by the owners of the Wagonwheel Mine.

33. unnamed

Location: Center of the N 1/2 NW 1/4 NW 1/4, sec. 31, T. 11 S., R. 34 E.

Type: mesothermal gold-quartz

Vein: Strongly disseminated pyrite with some chalcopyrite, in pervasively sericitized and silicified metavolcanics and granodiorite. Sulfides also occur as blebs and stringers along the main vein structure. Vein trends N. 70° E., 75° S. Widths vary from several to tens of feet for the disseminated zone, and average one foot for the main sulfide zone.

History: No production is known, and the small extent of the workings suggests that ore values were too low for mining. A short adit exposes the vein.

34. unnamed

Location: NE 1/4 NW 1/4 SE 1/4, and SE 1/4 SW 1/4 NE 1/4, sec. 29, T. 11 S., R. 34 E.

Type: unknown

Vein: No ore appears in any of the material surrounding the shaft.

History: A 35 foot deep shaft has been sunk on an unknown target. The workings may have been an attempt to test the underlying conglomerate for gold particles found in other localities of Cretaceous conglomerates.

35. unnamed

Location: NW corner of the SW 1/4 SE 1/4, sec. 23, T. 11 S., R. 33 E.

Type: Nickel in serpentinite (olivine)

Vein: The adit is in a serpentinite body, and the lack of quartz veins and sulfides suggests that it was an attempt to mine a nickel-rich rock, but the nickel was tied up in olivine.

History: The workings appear old. The adit is about 50 feet long.

Placer Mines

The Dixie Creek placers were the most extensive and productive of the Quartzburg District, yielding one nugget over three inches in diameter. Total gold production was estimated at $600,000 by Lindgren (1901). Dredging was conducted from 1930 to 1936, and 1938 to 1940, in lower Dixie Creek and in the John Day River below its confluence with Dixie Creek, adding 22,500 ounces of gold ($780,000) to the estimated total. Much smaller placer deposits in Ruby and Happy Camp Creeks were operated by Chinese in the late 1800's. The latter creek is located just east of the District. The Ruby Creek placer has been mined intermittently to the present day. An unusual placer gold deposit is found in Corral Creek in sec. 13, T. 12 S., R. 33 E. The deposit was accumulated by erosional concentration of gold particles from the nearby Cretaceous conglomerates.