AN ABSTRACT OF THE THESIS OF

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Title: THE GEOLOGY AND MINERAL DEPOSITS OF EDEN VALLEY-SADDLE PEAKS AND VICINITY, SOUTHEASTERN COOS AND NORTHEASTERN CURRY COUNTIES, OREGON

Abstract approved: Dr. Cyrus W. Field

The Eden Valley-Saddle Peaks area lies within the northern boundary of the Klamath Mountains, largely in southeastern Coos County, about 12 miles southeast of Powers, southwestern Oregon. The rocks of the area range in age from Late Jurassic to early Tertiary (Middle Eocene), but only the Mesozoic rocks were studied in detail.

The Mesozoic rocks were deformed by an intense period of folding and thrust faulting that was terminated by large displacement normal faulting (herein called the Camp Hope Fault) sometime between post-Early Cretaceous and Middle Eocene time. The Camp Hope Fault and the Powers-Agness Fault may be of the same age. Copper sulfide mineralization at the Bolivar Copper Mine near the center of the area also appears to have been emplaced during this period of folding and thrust faulting. The ore minerals consist of chalcopyrite, bornite, and chalcocite associated with quartz, barite, and alunite gangue minerals, all of which have been emplaced in volcanic host rocks of the Rogue Formation. The Rogue Formation has been hydrothermally altered largely to chlorite and clay minerals in the mine area. The emplacement of mineralization appears to

have been structurally controlled, largely by the Rogue-Riddle thrust fault contact. Both the mineralization and host rocks of the Bolivar Mine are closely similar to those of the Almeda Mine southeast of the area near Galice, which implies a genetic relationship.

The Mesozoic rocks consist of the Rogue, Dothan, Riddle, and Days Creek Formations, the latter two comprising the Myrtle Group. The three contacts among these four formations are southeast-dipping thrust faults (herein called the Rogue-Dothan, Rogue-Riddle, and Riddle-Days Creek thrusts). The Rogue-Dothan thrust appears to have been the most intense of the three, because it has a wide zone of associated cataclasis and recrystallization evident as a well-developed foliation near the thrust. An ultramafic intrusion (serpentinite) occupies the Rogue-Dothan thrust east of Mt. Bolivar. Thin section study revealed a zone of metasomatic alteration in the volcanic rocks of the Rogue Formation near the ultramafic intrusion. In this zone, calcium-bearing minerals and quartz have completely replaced the original minerals of the Rogue andesitic basalts.

Neither of the two remaining thrusts (Rogue-Riddle and Riddle-Days Creek) has an associated zone of cataclasis and recrystallization or an ultramafic intrusion. This contradicts the Geologic Map of Oregon West of the 121st Meridian, compiled by F. G. Wells and D. L. Peck and published in 1961, which shows an ultramafic intrusion along the contact between volcanic rocks of the Dothan Formation (more recently included with the Rogue Formation) and the Riddle Formation. This contact is the same as the Rogue-Riddle thrust.

The Geology and Mineral Deposits of Eden Valley-Saddle Peaks
and Vicinity,
Southeastern Coos and Northeastern Curry Counties, Oregon

by

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INTRODUCTION

Location, Size, and Accessibility

The area of study shown in Figure 1 is located along the northern boundary of the Klamath Mountain geomorphic province (Diller, 1902) in southwestern Oregon. The area is composed of 35 sections, principally in T. 32 S., R. 10 W., that are centrally located in the south one-third of the U. S. Geological Survey Bone Mountain quadrangle (15 Minute Series, Topographic). Prominent local geographic features include Eden Valley, Saddle Peaks, and Mt. Bolivar.

Improved all-weather roads provide access to the area except during brief periods of heavy snowfall in the winter months. The main all-weather road crosses the center of the area from east to west, joining a paved highway near Powers, 30 miles to the west, and joining U. S. Highway Interstate 5 at both Glendale and Wolf Creek, 45 miles to the east.

Local access to most of the area is provided to a limited extent by a few all-weather logging roads. These give way to temporary logging roads and jeep trails that are not maintained. As a result, nearly one-half of the area can be reached only on foot. Access is hindered further by dense vegetation throughout most of the area, and by extremely rugged topography in the east and southeast parts of the area.

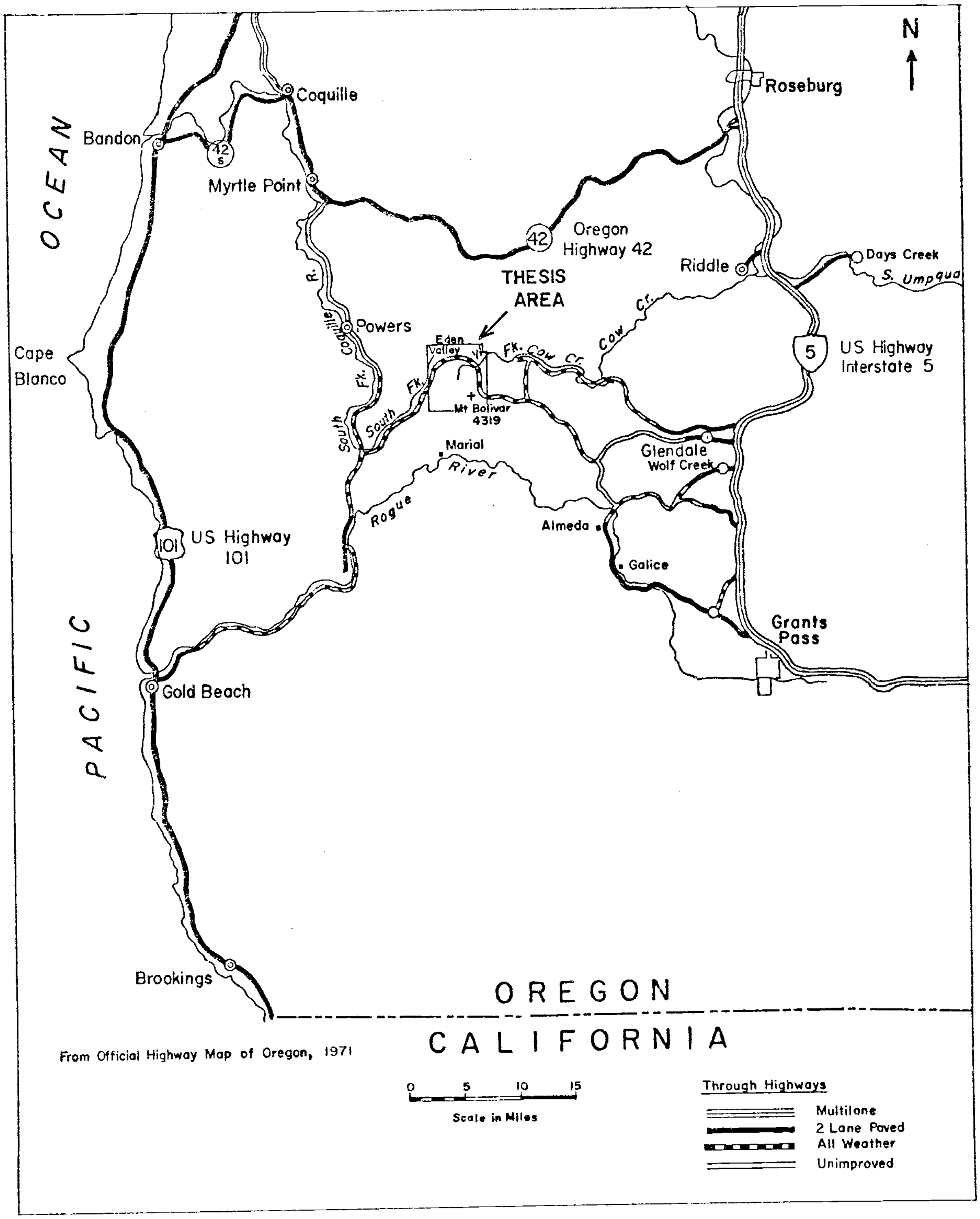

Figure 1. Index map of thesis area location in southwestern Oregon.

Plate 1. View looking southwest across Eden Valley from the NW¼NW¼ sec. 3, T. 32 S., R. 10 W. Eden Valley crosses the picture from the right foreground to the left center. Table Rock forms the skyline in the right background.

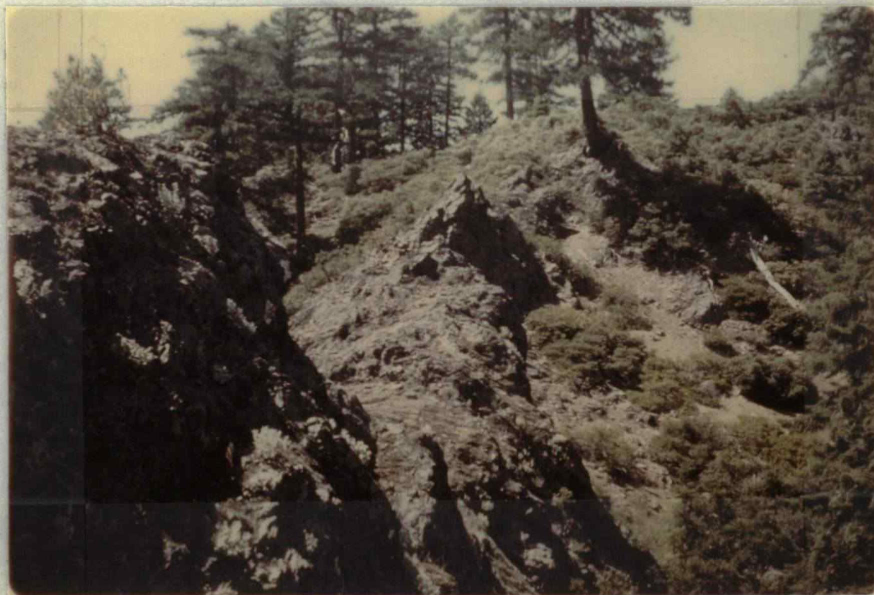

Plate 2. A typical south slope exposure of volcanic rocks of the Rogue Formation in the SE¼NW¼ sec. 22, T. 32 S., R. 10 W.

Topographic Relief, Rock Exposure, and Drainage

Within the belt of volcanic rocks that bends across the area from southwest to northeast, the terrain is extremely rugged and sometimes impassable. Maximum relief developed on these volcanic rocks is 3,500 feet. Sedimentary rocks underlie nearly all of the remaining area of study. Terrain developed on the sedimentary rocks is less rugged than that developed on the volcanic rocks. However, dense vegetation on the sedimentary rocks hinders travel nearly as much as the rugged volcanic rock terrain. Maximum relief of the sedimentary rock terrain is 1,000 feet in the northwest and 2,800 feet in the southeast. Elevation extremes in the area range from 800 feet in the canyon of Mule Creek to 4,319 feet at the summit of Mt. Bolivar.

Bedrock exposure in the volcanic rocks is best on south slopes of ridges where vegetation, talus, and colluvium are more limited compared to north slopes. On north slopes, vegetation is more dense, and the cover of talus and colluvium is deeper. In either case, most bedrock exposures are restricted to ridge crests and stream beds. This same general pattern applies to sedimentary rocks, except that they are usually more deeply weathered, and consequently, bedrock exposures are less common than in the volcanic rocks. Accordingly, most of the stratigraphic, structural, and lithologic information was obtained from systematic study of the cut banks of logging roads and jeep trails.

A major drainage divide crosses the area from both east to west and north to south. Tributaries of the Rogue River drain to the south. The South Fork of the Coquille River and its tributaries drain to the west. Tributaries of the South Umpqua River drain to the east and north. Runoff swells these streams to near flood stage during the winter and early spring months, and perennial springs sustain their flow during the dry summer months.

Climate and Vegetation

The local climate is temperate, typical of the Coast Ranges of southwestern Oregon and northwestern California. According to Highsmith (1962), the average January temperature is 34° F., and the average July temperature is 64° F. The average annual precipitation includes 50 to 80 inches of rain accompanied by 10 to 30 inches of snow during the winter months. The wettest months are December and January. The driest months are July and August.

Vegetation is typical of the Coast Range of southwestern Oregon. Most of the Eden Valley-Saddle Peaks area is covered with a dense, coniferous forest with a moderately to strongly developed undergrowth of shrubs such as salal, rhododendron, huckleberry, and sadler oak. On south slopes exposed to more direct sunlight, conifers are smaller and more scattered than they are on north slopes. The undergrowth of south slopes is a more sparse covering of mountain live oak, manzanita, madrona, and tan oak compared to north slope undergrowth. Thickets of thorny "buck brush" cover parts of the nearly bare ridges and the driest parts of the valleys developed on the Cretaceous sedimentary rocks.

Purpose and Method of Investigation

The purpose of this thesis work was to develop a clearer picture of the complex stratigraphic and structural relationships of the Mesozoic rocks of the Eden Valley-Saddle Peaks area than previous reconnaissance mapping portrayed. Detailed mapping of both formational and lithologic contacts was used as a means of revealing the nature of these complex relationships. In addition, an attempt was made to determine the age, extent, and controls of mineralization in the volcanic rocks of the Rogue Formation at the Bolivar Copper Mine. Hopefully, this information will be helpful to those who wish to begin a more detailed study of the economic potential of the Rogue volcanic rocks as hosts for copper mineralization.

Field work was begun in August of 1968 and completed in late September of 1969, involving a total of approximately 18 weeks. U. S. Forest Service 1:12,000 aerial photographs were used as a mapping base. Geologic information was transferred to a 1:12,000 topographic map constructed on Mylar from a photographic enlargement of the 1:62,500 U. S. Geological Survey Bone Mountain quadrangle. U. S. Geological Survey aerial photographs (1:60,000) were used to aid interpretation of large geologic features.

Laboratory work consisted of both macroscopic and microscopic examination of rock and mineral samples collected in the thesis area. Petrographic work included studies of thin sections and polished sections with the petrographic and ore microscopes. The Rock Color Chart published by the Geological Society of America was used as a reliable means of reporting reproducible comparative rock colors.

Previous Work

The thesis area was mapped in reconnaissance prior to 1968 by Wells and Peck (1961) for compilation of the Geologic Map of Oregon West of the 121st Meridian. Since 1968, small parts of the area of study have been mapped in detail by two Master of Science candidates.

One of the candidates, J. O. Rud, received his degree from the University of Oregon in 1970. The other candidate, Richard C. Kent, was expecting to complete his manuscript in June, 1972, at Portland State University.

ROCK UNITS

Introduction

General Statement

Much of the interpretation of local stratigraphic relationships is dependent upon detailed knowledge of the regional stratigraphy. The relative ages of the Rogue and Dothan Formations, which form the eastern part of the Eden Valley-Saddle Peaks area, are still unknown, largely because of complex, regional, structural and stratigraphic relationships. In the Klamath region, formations have large apparent thicknesses, generally moderate to steep southeast dips, numerous internal bedding slips, and many lithologic similarities. Contacts between different formations are commonly faults, which are often intruded by ultramafic rocks.

The stratigraphic section that is presented will begin with the Rogue Formation as the oldest unit in the area. The Dothan Formation is herein considered to be a lateral equivalent of the Galice Formation, as proposed by Baldwin (1969). The writer chooses to exclude from discussion all rock units older than the Late Jurassic Rogue Formation, although he is aware that these older rocks probably formed both the provenance area from which the Late Jurassic sediments were eroded, and the surface on which they were deposited.

The Rogue-Galice-Dothan Controversy

The relative ages of the Rogue, Galice, and Dothan Formations have long been controversial. The Galice Formation contains a Late Jurassic (Oxfordian and Kimmeridgian) faunal assemblage, and it is generally believed to be correlative with the Mariposa Formation of the

Sierra foothills of northern California because the two formations have identical fauna. The Rogue and Dothan Formations are unfossiliferous, but, in the type area, the Rogue conformably underlies the Galice and is considered to be older by Taliaferro (1942), Wells and Walker (1953), Baldwin (1969), and Hotz (1969), among others. However, the contact between the Rogue Formation and the underlying Dothan Formation is a thrust fault (Hotz, 1969).

Previous investigators apparently did not observe the thrust fault separating the Rogue and Dothan Formations and described the contact as gradational (Taliaferro, 1942; Wells and Walker, 1953). Diller (1907, 1914) saw evidence of thrusting and concluded that the type section was either overturned or the Galice had been thrust over the Dothan. He proposed that the Dothan Formation was therefore younger than the Galice Formation. Although they did not agree on the relative ages of the three formations, most of the earlier workers believed that these formations were parts of an uninterrupted Late Jurassic sequence of deposition.

Dott (1965) noted the overall similarity of the Dothan-Rogue-Galice sequence in southwestern Oregon to the Late Jurassic Cosumnes-Logtown Ridge-Mariposa sequence of formations that crop out in the Sierra foothills of northern California. He cited the lithologic similarities of the Dothan and Cosumnes Formations, the Rogue and Logtown Ridge Formations, and the Galice and Mariposa Formations. From oldest to youngest, the Sierra foothills sequence consists of the sandstone-rich Cosumnes Formation, the volcanic Logtown Ridge Formation, and the black slate-rich Mariposa Formation.

Irwin (1964) suggested a post-Nevadan age for the Dothan Formation based on evidence he observed in the Klamath Mountains and Coast Ranges of northern California. Later supporting field evidence was found in southwestern Oregon by Hotz (1969). Irwin proposed that the Rogue and Galice Formations were deposited before, and the Dothan Formation was deposited after the Nevadan orogeny. The entire sequence was thought to have been brought into juxtaposition later by thrusting from the southeast.

An apparent gradation of strata of the Dothan Formation into Colebrooke Schist was noted by Dott (1965). This led him to infer that the Colebrooke might be the metamorphic equivalent of the Dothan. However, Dott (1971) later altered his viewpoint when Coleman cited evidence of a thrust fault separating the Colebrooke and Dothan areas in 1969.

Baldwin (1969) proposed that the Galice and Dothan Formations were coeval facies laid down on the Rogue Formation in different parts of the same basin of deposition. Although he agrees that thrusting is probably responsible for the present juxtaposition of formations, he does not agree with Irwin's (1964) proposed post-Nevadan age for the Dothan Formation. The writer favors the proposal of Baldwin (1969) because he believes that it does not contradict the most recent evidence, and that it offers a more flexible foundation for future interpretation than does the earlier proposal of Irwin (1964). Nonetheless, the age of the Dothan Formation is still controversial and unresolved.

Table 1. Stratigraphic section of the Eden Valley-Saddle Peaks area.

Rock Name		Epoch	Period
Tyee Formation			
--unconformity--		Middle Eocene	
Umpqua Formation (upper member)			Tertiary
		Early Eocene	
--angular unconformity--			
		Paleocene	
? (serpentinite) ?		Late Cretaceous	
		Middle Cretaceous	Cretaceous
Days Creek Formation	Myrtle Group	Early Cretaceous	
--possible disconformity--	Myrtle Group		
Riddle Formation	Myrtle Group		
--angular unconformity--		Late Jurassic	
? (serpentinite) ?			Jurassic
? Dothan Formation ?			
Rogue Formation			

Rogue Formation

Distribution and Field Description

Altered volcanic rocks of the Rogue Formation crop out in a continuous belt which crosses the area from southwest to northeast. Steep slopes and rugged topography characterize the volcanic terrain. In many places these slopes are covered with thick accumulations of talus composed of sharp-edged rhombic and pyramidal blocks.

Flow units recognizable in outcrops include altered, greenish to brownish, andesitic varieties along with minor rhyolitic varieties. Intercalations of tuff and other pyroclastic materials are present but uncommon. Typical colors of fresh exposures are various shades of greenish-gray, usually dark greenish-gray (5G 3/1), due to moderate, chloritic alteration. Colors of weathered rocks range from grayish-orange (10YR 7/5) to pale orange (10YR 8/3).

Attitudes of outcrops are obscured by a confusing network of closely spaced fractures and low-angle, southeast-dipping faults. However, aerial photographs show uniformly steep, southeast dips.

The presence of many, small, low-angle, southeast-dipping thrust faults indicates that parts of the sequence of volcanic rocks may be both omitted and repeated. The outcrop width in the area varies from about 5,000 feet to nearly 20,000 feet. If one assumes that various parts of the sequence are omitted and repeated by faulting, the stratigraphic thickness along the southern boundary of the area may still be as much as 15,000 feet. Within the same belt of volcanic rocks exposed near Marial, a few miles south of the area, Baldwin (1969) estimated the thickness to be at least 10,000 feet.

The western contact of the Rogue Formation with sedimentary

Plate 3. A typical veined and sheared outcrop of the Rogue Formation exposed in a small quarry near the Rogue-Riddle thrust in the NW¼NE¼ sec. 16, T. 32 S., R. 10 W.

rocks of the post-Nevadan Myrtle Group (Riddle Formation) is a thrust fault. In contradiction to the map of Wells and Peck (1961), the writer found no trace of ultramafic intrusive rocks along this faulted contact.

The contact of the Rogue Formation with the overlying Dothan Formation is a thrust fault which dips toward the southeast at about 45°. It is exposed along the main road in the low saddle at the base of the east slope of Mt. Bolivar, where it has been intruded by a somewhat tabular, discontinuous mass of serpentinite. As the contact is approached from the east, slaty cleavage appears in the sedimentary rocks of the Dothan Formation, becoming more strongly developed nearer the fault contact. As the contact is approached from the west, a gneissic foliation appears in the volcanic rocks of the Rogue Formation. The texture of the volcanic rocks becomes pegmatitic near the serpentinite contact. Near their mutual contacts with the serpentinite, rocks of both formations are veined by abundant quartz. Hotz (1969) noted similar effects near a thrust fault separating the Rogue and Dothan Formations in the type section near Galice. He regarded them as evidence of cataclasis and recrystallization along the sole of the thrust fault.

<u>Lithology and Petrography</u>

In outcrop the volcanic units resemble andesite, basalt, dacite, and rhyolite, with minor intercalations of tuff and pyroclastic material. Fresh exposures are greenish-gray due to chloritic alteration, and locally the rocks are veined by quartz, quartz-epidote, calcite, and sulfide minerals.

In thin section, most of the rocks are hyalocrystalline andesitic basalts with pilotaxitic textures. In some sections the rocks are amygdaloidal, with amygdale fillings of chalcedony, chlorite-group minerals, and calcite. The Michel-Levy method shows the average composition of plagioclase feldspar phenocrysts to be labradorite (An_{55} to An_{60}). A typical andesitic basalt flow unit is composed of phenocrysts of labradorite, augite, enstatite-hypersthene, and actinolite set in a felty groundmass. If biotite and/or hornblende were present, they have been completely altered to actinolite and chlorite-group minerals. Calcite and epidote are sometimes present, but usually only in small amounts. The felsic groundmass commonly makes up 35 to 45 percent of the total volume of constituents, with tiny laths of plagioclase feldspar often being the only groundmass constituents that are not completely altered to chlorite minerals.

Minerals of the chlorite group compose about 30 percent by volume of the average host rock. Enstatite-hypersthene is much more susceptible to chloritic alteration than is augite. Plagioclase shows incipient to weak argillic alteration, incipient alteration to white mica, and in some sections, moderate to complete alteration to calcite and chlorite minerals. Magnetite and reddish-brown, translucent, hydroxides of iron are usually present.

Origin and Depositional Environment

According to Baldwin (1969), the Rogue Formation consists mostly of submarine flows, breccias, and tuffs. He considers it to be the initial stage of the Late Jurassic sequence of deposition in southwestern Oregon, where it was laid down in a subsiding, eugeosynclinal trough. There is no evidence in the area of the source of these flow units.

Age and Regional Correlation

A northeast-trending belt of similar volcanic rocks, which is continuous through the Eden Valley-Saddle Peaks area, crops out along the Rogue River near Marial, about 18 miles west of the type section near Galice. Baldwin (1969) included this western belt of volcanic rocks with the Rogue Formation on the basis of lithologic and petrographic similarities. He also noted that it seemed to conformably underlie the Dothan Formation at Marial and the Galice Formation at Galice with the same general relationships. He considers the Rogue Formation to represent the initial stage of Late Jurassic deposition in southwestern Oregon on which the Galice and Dothan Formations were deposited as coeval facies.

The writer has included the altered volcanic rocks of the Eden Valley-Saddle Peaks area with the Rogue Formation because they are laterally continuous these similar volcanic rocks near Marial, which Baldwin (1969) assigned to the Rogue Formation. They are herein considered to be the oldest rocks exposed in the area and of probable Late Jurassic age.

Dothan Formation

Distribution and Field Description

The Dothan Formation was not studied in detail because it, along with the serpentinite intrusion, was discovered outside the original map area during a reconnaissance traverse, which was made after field studies had been essentially completed. As a consequence of this find, the map area was extended a short distance to the east to better define geologic relationships.

Sedimentary rocks of the Dothan Formation crop out in the southeast corner of the thesis area. The rocks form a large, northeast-trending, homoclinal ridge, which has an associated system of tributary ridges that trend northwest. Ridge slopes near the major summit are gentle, but along the deeply incised tributary streams the slopes are much steeper. Almost impenetrable thickets of underbrush cover most of this area.

Where the strata are exposed in road cuts in the area, they consist of thin- to thick-bedded, light yellowish-brown, well indurated, medium- to fine-grained, graywacke sandstone beds with dark gray to black interbeds of siltstone and mudstone.

Slaty cleavage appears in rocks of the Dothan Formation near the fault contact with the underlying Rogue Formation. Surfaces of cleavage plates have a phyllitic appearance, and, near the contact with the intrusion of serpentinite, the sedimentary rocks are strongly veined by quartz.

The contact of the Dothan Formation with the Rogue Formation appears to be a high-angle thrust fault. Near it, both formations strike northeast and dip southeast at about 45°. Although the contact is poorly exposed, one can still see an abrupt change from sedimentary to volcanic rocks. There are no intercalated sedimentary and volcanic rocks in either formation near the contact as one would expect if the sequence of deposition had been continuous. Continuous deposition should have produced a gradational contact.

An intrusion of serpentinite occupies the Rogue-Dothan thrust fault contact, which suggests that it is a deep-seated fault zone that may penetrate to the mantle (Dott, 1965). Hotz (1969) observed a similar thrust fault contact between the Rogue and Dothan Formations in the type section area about 20 miles to the southeast. He associated slaty cleavage in the Dothan Formation near the thrust fault with cataclasis and recrystallization resulting from movement along the sole of the thrust. In the type section area, the Rogue overlies the Dothan, whereas, in the Eden Valley-Saddle Peaks area, the Dothan overlies the Rogue. In both areas, the two formations dip moderately to steeply southeast and strike northeast.

Lithology and Petrography

Strata of the Dothan Formation consist of an alternating sequence of sandstones, siltstones, and minor intercalated mudstones. In other exposures east of the area mapped, the sequence also includes submarine basalt flows and flow breccias. Bedded chert is abundant in some outcrops of the sedimentary sequence, according to Wells and Peck (1961).

Origin and Depositional Environment

Baldwin (1969) described the Dothan Formation as a sandstone facies (coeval with the Galice Formation) deposited on the Rogue Formation near the western side of the basin of deposition, and derived from a source on that side. Clastic components of the Dothan Formation, described by Dott (1965), consist of abundant chert, sedimentary and lithic volcanic fragments, plagioclase feldspar, and quartz, with no potassium feldspar. The source of these rocks could have been a sequence of volcanic rocks compositionally similar to the Rogue units.

Age and Regional Correlation

Baldwin (1969) proposed that the Dothan and Galice Formations were originally deposited conformably on the Rogue Formation as coeval facies, and that their present relative positions are the result of thrusting to the northwest. He disagrees with the suggestion of Irwin (1964) that the Dothan was deposited after the Nevadan orogeny, which deformed the Rogue and Galice Formations in Late Jurassic time. In view of more recent evidence, such as that reported by Hotz (1969), Dott (1971) seems inclined to agree with Irwin (1964). However, he also points out that the age of the Dothan Formation is still unresolved.

Irwin (1964) suggested that the Dothan Formation is equivalent to part of the Franciscan of northwestern California, largely on the basis of lithologic similarities. The fact that the Franciscan is an assemblage of eugeosynclinal rocks of Late Jurassic to Late Cretaceous age indicates that, in conformance to the stratigraphic code, it should be termed the Franciscan complex (Dott, 1965). According to Dott (1965), the Franciscan complex and the Dothan Formation were structurally juxtaposed by Cenozoic shearing where the California Coast Ranges abut against the Klamath Mountain province. However, Dott (1971) stated that there is increasing evidence that the Dothan is coextensive with known Franciscan rocks, and may also be equivalent in age to the Otter Point Formation (which is equivalent in age to the Riddle Formation as given by Koch, 1966). Ages ranging from pre-Nevadan, Late Jurassic (Baldwin, 1969) to post-Nevadan, Late Jurassic (Irwin, 1964) have been proposed, but the evidence is conflicting and neither proposal can yet be proved.

There is no evidence in the area mapped by the writer to support a post-Nevadan age for the Dothan Formation. However, the presence of a serpentinite intrusion within the Rogue-Dothan thrust fault contact, and the complete absence of ultramafic intrusions from the other thrust faults involving younger (post-Nevadan) rocks in the area, imply that the Rogue-Dothan thrust may be related to a separate, and probably older, tectonic event. This event may have been related to the Nevadan orogeny, which would make the Dothan Formation pre-Nevadan in age.

Serpentinite

Distribution and Field Description

In the Eden Valley-Saddle Peaks area, only a single ultramafic intrusion was found. It is, as mentioned in previous sections, a body of serpentinite, which may have formed from complete serpentinization of a peridotite. It occupies the thrust fault between the Rogue and Dothan Formations in the low saddle at the foot of the east slope of Mt. Bolivar. In outcrop, the intrusion is a tabular-shaped, discontinuous body of serpentinite, which contains several, large, tectonic inclusions of volcanic rocks of the Rogue Formation. The serpentinite strikes northeast, nearly parallel to the strike of strata of the Dothan Formation, and it dips steeply southeast within the Rogue-Dothan thrust fault contact. The body thins and pinches out in both directions along its strike.

Near the serpentinite contact, sedimentary rocks of the Dothan Formation and volcanic rocks of the Rogue Formation are veined by quartz. The Rogue volcanics have a foliated appearance and are recrystallized to the extent that they are pegmatitic at the contact. The serpentinite is strongly sheared, and is composed of numerous, small, black-white-and-green pods of slickensided serpentine.

Lithology and Petrography

The serpentinite is light colored, with shades of white, light gray, and light green more common than shades of dark gray and black. The rocks appear to be pure serpentine, are somewhat translucent, and contain disseminated crystals of chromite and magnetite.

In thin section, the rocks are composed of antigorite and chrysotile with about 15 percent disseminated grains of chromite and magnetite. The writer suspects that systematic sampling might have produced specimens of incompletely serpentinized peridotite, but the three thin sections examined were completely serpentinized.

Beginning in the Rogue Formation about 1,000 feet northwest of the Rogue-serpentinite contact, thin sections of the volcanic rocks reveal vein quartz, myrmekite, actinolite, quartz, epidote, and various minerals of the chlorite group. Minor amounts of relict partial grains of the original plagioclase and augite phenocrysts are still present and recognizable. Within 300 feet of the contact, all traces of the original texture and constituents have disappeared from thin sections. Nearly 70 percent of the rock is now a turbid, brownish-red, translucent, mostly isotropic mineral aggregate that may be hydrogarnet (Coleman, 1967). The remainder is composed of about 28 percent actinolite, veined by about 2 percent non-ferrian zoisite. Thin sections of the recrystallized and foliated volcanic rocks next to the serpentinite contact contain 20 to 30 percent non-ferrian zoisite, 50 percent quartz, 5 percent actinolite, and minor amounts of sphene, ferrian zoisite, and zircon. Quartz and calcium-bearing minerals appear to be concentrated near the contact.

Origin and Conditions of Intrusion

Coleman (1967) attributed a similar alteration assemblage to metasomatism related to the processes of serpentinization and tectonic emplacement of alpine type ultramafic intrusions. The metasomatic alteration caused enrichment of calcium and magnesium in the reaction zone of the country rock, which was accompanied by a concomitant loss of silica to the serpentinite. Moreover, he suggested that

> "the reaction zones develop at the time when large portions of ultramafic mantle are tectonically emplaced into the base of the crust or are moved tectonically higher into the crust. Serpentinization of the ultramafic material is contemporaneous with alteration and tectonism. Thus the alteration represents a tectonic contact metamorphism and is not related to igneous activity."

According to this interpretation, an ultramafic body of peridotite emplaced in a fault at the base of the crust may be remobilized during periods of tectonism and move higher into the crust. Each period of remobilization is accompanied by renewed serpentinization, so that the original peridotite may eventually become pure serpentinite.

The ultramafic intrusion that occupies the Rogue-Dothan thrust fault contact appears to be a nearly pure serpentinite. A very detailed study of this intrusion would be required to prove that its history of intrusion corresponded with that outlined in Coleman's (1967) hypothesis for complete serpentinization of peridotite. If the serpentinite is nearly pure, then it may have undergone multiple periods of tectonic remobilization and serpentinization while within the structural confines of the Rogue-Dothan thrust.

Coleman (1967) has suggested that the ultramafic rocks of the

Pacific Coast were probably emplaced during deformational events that resulted in folding, faulting, and metamorphism of the surrounding eugeosynclinal sedimentary rocks. According to Dott (1965), the close association of ultramafic rocks with shear zones implies deep faults penetrating to the mantle.

Age and Regional Correlation

Irwin (1964), Koch (1966), and Lanphere and others (1968) have reported ultramafic intrusions that range in age from possibly Paleozoic to Late Cretaceous or early Tertiary. Most of these are believed to have been emplaced during the Nevadan orogeny.

Lanphere and others (1968) set the approximate absolute age of the end of the Nevadan orogeny in northern California at 132 m. y. ago, during the Tithonian stage of the Upper Jurassic. The most probable absolute age of the Nevadan orogeny in southwestern Oregon seems to be somewhere between 135 and 145 m. y. (Dott, 1965).

The serpentinite within the Rogue-Dothan contact in the Eden Valley-Saddle Peaks area may be related to the Nevadan orogeny. The age of the Dothan Formation is still in question, but the Rogue Formation is of probable Late Jurassic (and pre-Nevadan) age because it is in conformable and gradational contact with the Galice Formation of known Late Jurassic, pre-Nevadan age. As previously stated in the introduction of this section, the Rogue Formation underlies the Galice Formation in the type section area with a conformable relationship.

From the evidence presented in the foregoing paragraph, it is reasonably clear that the serpentinite intrusion is post-Rogue Formation, post-Dothan Formation, and younger than the thrust fault which separates the two formations.

Farther west in the area mapped, the Rogue Formation has been thrust to the northwest over the Riddle Formation of the Myrtle Group. The writer found no evidence of an intrusion along this Rogue-Riddle thrust. Because the Rogue-Riddle thrust contains no ultramafic intrusion, and because it is near the Rogue-Dothan thrust that contains an ultramafic intrusion, the writer suggests that these two major thrust faults may be related to separate tectonic events. He considers the Rogue-Dothan thrust to be related to an older tectonic event, which may have taken place during the Nevadan orogeny.

Riddle Formation

Distribution and Field Description

The Riddle Formation in the area of study consists of two members that make up a folded and faulted belt of sandstones, siltstones, and conglomerates. This belt trends northeasterly across the center of the area, marked by a series of hogbacks and homoclinal ridges developed on the resistant conglomerate units.

The lower member of the Riddle Formation is an alternating sequence of thin-bedded sandstones and siltstones that crops out along the eastern boundary of the upper member. Compared to the upper member, its strata are thicker and less distinct in outcrop. Colors of fresh sandstone and siltstone units are generally the same as those listed for the upper member, but colors of weathered rocks are usually either dark yellowish-orange (10YR 6/5) or light brown (5YR 5/5). The lower member contains abundant calcareous concretions along with localized concentrations of limestone lentils and lenses of metavolcanic pebble conglomerate. Some of the concretions contain fossil molds and casts of the pelecypod Buchia piochii. One exposure, in a small excavation pit in sec. 16, contains abundant calcareous fossils of a species of belemnite that resembles Pachyteuthis. Fossils, limestone lentils, and calcareous concretions are comparatively uncommon in the upper member. The metavolcanic pebble conglomerate lenses appear to be restricted to the lower member.

The upper member is composed of siltstone with sandy lenses, and subordinate, thin-bedded, fine- to medium-grained sandstone. The siltstone is usually very thin-bedded, and ranges from thin-bedded to occasionally laminated (McKee and Weir, 1953). Fresh exposures of siltstone are olive-gray (5Y 4/1), olive-black (5Y 2/1), and black (N3). Weathered siltstones are light olive-brown (5Y 5/6), light olive-gray (5Y 5/2), and light gray (N7). The thin-bedded sandstones and the sandy lenses in siltstone are light olive-gray (5Y 5/2) to dusky yellow (5Y 6/4) when fresh, and they range from grayish-orange (10YR 7/4) and very pale orange (10YR 8/2) to yellowish-orange (10YR 8/1) when weathered. Less common, but frequently observed, weathered sandstone and siltstone colors include dark yellowish-orange (10YR 6/5), light brown (5YR 5/5), and yellowish-gray (5Y 7/2). Sedimentary structures are abundant in some exposures. Scour-and-fill channels and graded bedding indicate that strata of limbs of anticlines are upright.

Three, ridge-forming, very thick-bedded, pebble conglomerate units make up the remainder of the upper member of the Riddle Formation. The pebbles average slightly less than two inches in size, are very well-rounded, and consist predominantly of dark and light colored chert,

Plate 4. A southeast-dipping sandstone and siltstone sequence of the upper member of the Riddle Formation exposed in a road cut near the Riddle-Days Creek thrust in the NW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 16, T. 32 S., R. 10 W.

veined by white and black chalcedonic quartz. Outcrops of these conglomerate units usually have a very uniform weathered color of grayish-orange (10YR 7/4), when observed from a distance.

Cross sections of limbs of anticlines reveal a minimum average thickness of both members of the Riddle Formation that totals about 5,000 feet of apparently unrepeated section. Of this, about 4,000 feet belong to the upper member and about 1,000 feet to the lower member. The siltstones and sandstones of the upper member make up about 1,500 feet of the total section in the south part of the area and about 2,000 feet in the north part. The conglomerate units of the upper member compose about 2,500 feet of the Riddle Formation section in the south part of the area and about 1,500 feet in the north part. The thickness of the lower member is highly variable throughout the area; probably because it has been disrupted by thrust faulting.

The upper member is exposed as a series of fault-bound parts of what originally may have been an anticline, which extended across the area from southwest to northeast. The present distribution of the anticlinal limbs is apparently the result of deformation of the folded strata by normal and reverse (thrust) faulting. The southeast limbs of the anticline dip more steeply in the south part of the area (50° to 70°) than in the north part (30° to 40°).

The relative position of the lower member with respect to the upper member indicates that the two have probably been juxtaposed by a southeast-dipping thrust fault. In the southern part of the area, beds of the lower member dip northwest and adjacent beds of the upper member dip southeast. To the north, in contrast, both members dip southeast at nearly the same angle near their mutual contact. The contact is covered by talus and colluvium for most of its length, but it is exposed in a road cut west of Saddle Peaks. The thrust fault has been disrupted by a zone of shearing, which is apparently related to a nearly vertical normal fault nearby. The attitude of this thrust fault is not clear, but it appears to dip steeply to the southeast.

The western contact of the Riddle Formation with the Days Creek Formation is a thrust fault. Although it is covered by talus and colluvium along most of its length, two good exposures have been uncovered in road cuts. The best exposure is in the south part of the area in a small quarry on the west side of Foggy Creek, about 1,600 feet due south from the northwest corner of sec. 16. The fault dips about 35° to the southeast beneath an overthrust plate of conglomeratic units of the Riddle Formation. The plate has been thrust northwest over a sequence of sandstones of the younger Days Creek Formation. The other exposure of the thrust fault is in a logging road cut, located in the northeast part of the area near the center of sec. 35. Here, the fault is marked by a deeply weathered zone of shearing that dips toward the southeast at about 40°. The contacts of recognizable Riddle and Days Creek rocks with the fault zone are concealed by talus and weathered colluvium.

Near the southern boundary of the area, the outcrop belt of the Riddle Formation is onlapped by a sedimentary sequence of Tertiary rocks.

Lithology and Petrography

Sedimentary rocks of the Riddle Formation exposed in the Eden

Valley-Saddle Peaks area are composed of sandstone, siltstone, mudstone, and conglomerate. They do not show the evidence of hydrothermal alteration that characterizes the Rogue Formation. Additionally, they show little evidence of cataclasis and recrystallization along thrust faults in marked contrast to the Rogue-Dothan thrust as previously described.

The Riddle and Days Creek Formations compose the Myrtle Group as revised and defined by Imlay and others (1959). The two formations have similar rock types, but several characteristics distinguish the rocks of the Riddle Formation from those of the Days Creek Fromation. The strata of the Riddle Formation are generally well-bedded and thin-bedded compared to the massive, often thick-bedded strata of the Days Creek Formation. Fresh surfaces of Days Creek sandstones are often an unusual greenish or bluish color, and weathered surfaces are often darker brown, compared to typical Riddle sandstones and siltstones.

A limited petrographic study of 12 thin sections of sedimentary rocks of the Myrtle Group revealed some general lithologic differences between the Riddle and Days Creek units. Rocks of the Riddle Formation tend to be less calcareous and micaceous than those of the Days Creek Formation. In addition, the Riddle Formation rocks contain more lithic fragments, more argillic alteration of feldspars, and more chloritic alteration of ferromagnesian minerals than do similar rocks of the Days Creek Formation.

Origin and Depositional Environment

The sedimentary rocks of the Riddle Formation were derived from erosion of older Mesozoic rocks of the region that were folded, faulted, and uplifted during the Nevadan Orogeny. The Riddle Formation formed the basal portion of the post-Nevadan, Myrtle Group deposited in small marine basins on the truncated, pre-Nevadan surface. The Myrtle Group rocks are now infolded and infaulted in synclines and fault blocks in the Klamath Mountains, according to Baldwin (1964a).

Irwin (1964) included the Riddle Formation (and the entire Myrtle Group) with what he called "superjacent" (equivalent to post-Nevadan) rocks. The superjacent deposits are represented by both eugeosynclinal and noneugeosynclinal rocks that he believes are coeval facies deposited in different parts of the same basin. He included the Riddle Formation among the noneugeosynclinal shelf deposits that were laid down on the "subjacent" (equivalent to pre-Nevadan) rocks which formed the continental shelf and slope.

Age and Regional Correlation

The Riddle Formation contains a faunal assemblage of fossils that are Portlandian and middle to late Tithonian (latest Jurassic) in age, and the same age as a similar faunal assemblage found in the upper part of the Knoxville Formation in California (Imlay and others, 1959). Koch (1966) considers the eugeosynclinal Otter Point Formation in the Port Orford-Gold Beach area to be equivalent to the Riddle Formation in age.

Days Creek Formation

Distribution and Field Description

In the thesis area, the Days Creek Formation is poorly exposed. It is a valley-former and thus is largely buried under the alluvium that covers most of Eden Valley and the valley of Clear Creek. Rock exposures are restricted to road cuts, stream gullies, and a few, low, hummocky hills. The upper and lower members of the Days Creek Formation form a northeast-trending belt of sandstones and sandy siltstones. It crosses the central part of the area west of its contact with the northeast-trending outcrop belt of the Riddle Formation. Most of the Days Creek Formation is covered by a coniferous forest and dense underbrush. Limited exposure, combined with the thick-bedded and poorly bedded character of most units, makes the contacts between units and members virtually impossible to trace.

The lower member is composed of alternating thick-bedded units of fine-grained sandstone and sandy siltstone that crop out in secs. 4, 5, 8, 34, and 35. The siltstone sometimes contains calcareous concretions, and thin beds of chert pebble conglomerate are sparingly present. Weathered surfaces of outcrops are often medium gray (N5) in color. Fossil molds and casts of the plump pelecypod *Buchia crassicollis* are fairly abundant, especially in units containing lenses of limestone.

The upper member consists of very thick-bedded to massive units of medium- to fine-grained sandstone with thinner interbeds of sandy siltstone. The units are often spheroidally weathered and colored dark yellowish-brown (10YR 4/2). Fresh colors are different shades of bluish- and greenish-gray. The upper member crops out in secs. 9, 17, and 18, where it contains abundant fossil molds and casts of pelecypods, ammonites, and belemnites.

Where bedding is exposed, the rocks usually strike northeast and dip northwest at moderate angles. High-angle dips prevail near the

Riddle-Days Creek thrust fault contact.

About 5,000 feet of Days Creek section is exposed in the area, but thickness of individual members is not determinable. There is probably some stratigraphic repetition caused by thrusting and normal faulting.

In the type locality near the town of Days Creek, the Days Creek Formation overlies the Riddle Formation with apparent conformity. Imlay and others (1959) suggested that the contact may be a disconformity. In the Eden Valley-Saddle Peaks area, the Riddle-Days Creek contact appears to be a southeast-dipping thrust fault. The thrust is concealed beneath talus and colluvium along most of its length, but it is well exposed in a small quarry in sec. 17 on the west side of Foggy Creek. A description of this contact is given in the Distribution and Field Description section under Riddle Formation.

The contact of the Days Creek Formation with the Tertiary (Eocene) upper member of the Umpqua Formation (Baldwin, 1965) is a west-dipping angular unconformity. The contact is poorly exposed throughout its length within the area. Near this contact, Days Creek units dip 45° to 60° to the northwest, and upper Umpqua units dip about 20° to the west. At the south end of the Days Creek belt of outcrop, the upper Umpqua rocks completely overlap the Days Creek Formation and extend onto the adjacent Riddle Formation farther east.

Lithology and Petrography

The Days Creek Formation is composed of a poorly-bedded sequence of sandstone, sandy siltstone, and siltstone units. The rocks are unmetamorphosed, and appear to be less altered than the rocks of the older Riddle Formation. A lithologic and petrographic comparison to the Riddle Formation was made in the previous section. Compared to similar units of the Riddle Formation, units of the Days Creek Formation are more thick-bedded and often massive. Fresh surfaces are an unusual greenish or bluish color, and weathered surfaces are darker brown than those of the Riddle Formation.

Origin and Depositional Environment

The units of the Days Creek Formation (Myrtle Group upper member) were deposited on the Riddle Formation (Myrtle Group lower member) in a similar environment of deposition. Lithologic similarities of the two formations indicate that they were probably derived from the same provenance area. The Days Creek units were deposited disconformably (Imlay and others, 1959) on the Riddle Formation in small marine basins that are now infolded and infaulted in synclines and fault blocks in the Klamath Mountains of southwestern Oregon (Baldwin, 1964a).

Age and Regional Correlation

The Days Creek Formation was named by Imlay and others (1959) for the village of Days Creek near the type locality along the South Umpqua River. At the type section, the Days Creek Formation is more than 800 feet thick and is separable into two members where well exposed. According to Imlay and others (1959), the lower member is distinguished from the upper member by its limestone lenses, its medium gray instead of greenish-gray siltstone units, its less massive sandstone units, and its fossils of the pelecypod *Buchia crassicollis*. Where fossiliferous, the Days Creek units are distinguished from similar units of the Riddle Formation by the presence of specimens of the plump pelecypod *Buchia crassicollis*. A distinctly different, slender pelecypod, *Buchia piochii*, occurs only in the Riddle section.

The age of the Days Creek Formation is Early Cretaceous, based on its Valanginian to Barremian fauna (Imlay and others, 1959). Koch (1966) considered the Days Creek to be equivalent in age to parts of the Rocky Point Formation and the Humbug Mountain Conglomerate in the Port Orford-Gold Beach area.

Tertiary Rocks

The writer made no detailed study of the Tertairy section in the Eden Valley-Saddle Peaks area because he was primarily concerned with the pre-Tertiary rocks. However, certain general features were noted.

The Tertiary rocks in the area consist of the upper member of the Umpqua Formation (Baldwin, 1965) and the overlying Tyee Formation. They form a north- to northeast-trending belt that crosses the west and northwest parts of the area. The resistant conglomeratic sandstones of the Tyee Formation form the summit and northwest dip slope of Table Rock. Both formations are covered by a dense coniferous forest, and most exposures are thus limited to road cuts and stream beds.

The upper member of the Umpqua Formation is composed of an alternating sequence of medium- to coarse-grained, sometimes pebbly, flaggy, micaceous sandstones and thin-bedded, fine-grained to silty sandstones that are often poorly indurated. The Tyee Formation is a sequence of cliff-forming, well indurated, often conglomeratic, medium- to coarse-grained sandstones. The two formations strike generally north to northeast and dip west and northwest at about 20°. The Table

Rock section is about 2,500 feet thick.

The upper member of the Umpqua Formation laps onto the Riddle and Days Creek Formations with apparent angular unconformity. At the contact, the Myrtle Group beds dip steeply and the Tertiary beds dip gently to the west and northwest.

The Umpqua-Tyee contact was interpreted in part from aerial photographs by using as an arbitrary contact the break in slope that occurs at the base of the Tyee.

There is no evidence that the Tertiary rocks have been affected by the thrusting which deformed the Mesozoic rocks in the area.

The two formations contain rocks with similar compositions and lithologic characteristics, which implies that they were derived from the same provenance region and were deposited in similar environments. The presence of coal lenses (Baldwin, 1964a), in addition to conglomerates, suggests that the sediments were deposited in a shallow, estuarine-marine environment, probably near the margin of the basin, as suggested by Baldwin (1965).

According to Baldwin (1965), the upper member of the Umpqua Formation is probably of middle Eocene age, and it was partly removed by erosion prior to deposition of the Tyee. The Tyee Formation was laid down in late middle Eocene time following a period of crustal warping, and hence the upper Umpqua-Tyee contact is a mild angular unconformity.

STRUCTURAL GEOLOGY

Tectonic Setting

The Klamath geologic province occupies the continental margin along the western edge of the Cordilleran mobile belt and encompasses nearly equal areas in southwestern Oregon and northwestern California, according to Dott (1971). The Klamath structural pattern is a large, convex westwardly arc of lithologic and formational belts called the Mendocino orocline (Dott, 1971, p. 6), a feature very evident in geologic maps of the Klamath region. Diller (1907), Taliaferro (1942), Irwin (1964), and others noted a younger-westward trend among these arcuate belts of Klamath rocks, a trend similar to that found in lithologic belts of the Sierra Nevadas (Dott, 1971).

The origin of the Mendocino orocline has been variously interpreted. According to Dott (1971), it may have been formed by northward movement of western California relative to the continental interior, or by westward thrusting of Klamath rocks at a lower angle than the Sierra Nevada rocks. He cites overwhelming evidence that rocks formed in different tectonic environments have been structurally juxtaposed by thrusting. The vast, sheared and chaotic Franciscan and Otter Point terranes were probably formed in late Mesozoic time as oceanic crust was thrust beneath continental crust along the western margin of the Klamath block, as suggested by Dott (1971). He further states that near the southwestern Oregon coast the major thrusting took place in mid-Cretaceous and possibly early Tertiary time, culminating a Jurassic and Early Cretaceous period of intense structural deformation. Northwest-trending vertical faults, presumably related to the San

TECTONIC MAP

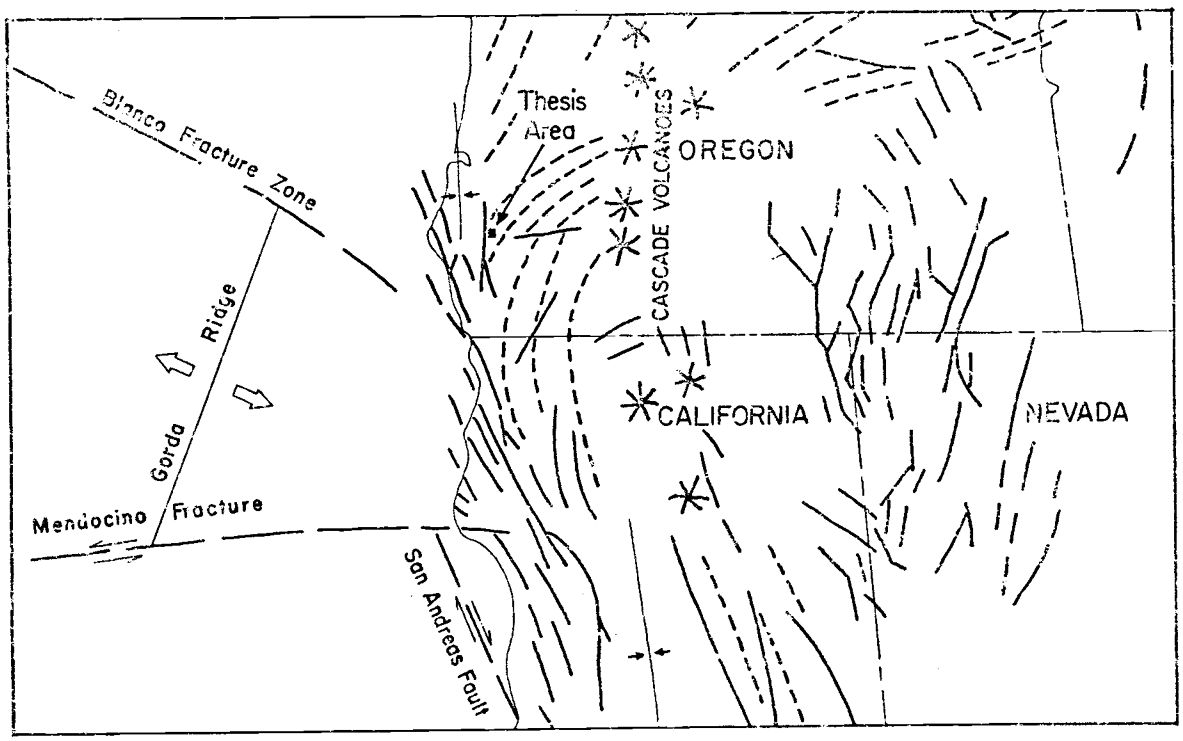

Figure 2. Tectonic setting of southwestern Oregon and adjacent oceanic crust. Note the discordance between the Mesozoic to early Cenozoic arcuate structural pattern (dashed lines) and the superimposed, late Cenozoic Cascade volcanic arc and faulting (heavy lines). This map was modified from the tectonic map of Dott (1971, p. 8).

Andreas system, were later superimposed on the older structural features in late Cenozoic time (Dott, 1965).

In the Eden Valley-Saddle Peaks area, the major structures and the outcrop belts of formations of late Mesozoic rocks show the same arcuate pattern as the regional Klamath structure. Locally, thrusting appears to have begun as high-angle faulting with associated cataclasis, recrystallization, and ultramafic intrusion. This was followed by a period of low-angle thrusting of apparently less intensity. Sometime in post-Early Cretaceous, pre-Middle Eocene time, normal faulting of large displacement (Camp Hope Fault) marked the end of compressional stresses and resultant thrusting in the area.

Much of the Klamath Mountain structure has been attributed by various workers to the Nevadan orogeny. Dott (1965) suggested that in southwestern Oregon the Nevadan orogeny probably took place between 135 and 145 m. y. ago during the Late Jurassic. In the Eden Valley-Saddle Peaks area, structural deformation (folding and thrust faulting) similar to that of the Nevadan continued until post-Early Cretaceous, pre-Middle Eocene time.

Irwin (1964) proposed to subdivide the rocks of the Klamath Mountains based on their involvement in the Late Jurassic, Nevadan orogeny. Rocks involved in the Nevadan were called "subjacent", whereas younger strata deposited unconformably on them in post-Nevadan time were called "superjacent". The writer believes that the terms "pre-Nevadan" and post-Nevadan are more meaningful for the purposes of this discussion. They are used when applicable throughout the text of this report, with the end of the Nevadan orogeny considered to be pre-Myrtle

Group in age.

Folding

Rogue and Dothan Formations

Folding of the Rogue and Dothan Formations may have been the oldest structural event in the study area. Both formations are exposed in the eastern part of the area, where they strike northeast and dip southeast at about the same angle. Although the Rogue-Dothan thrust has brought the two formations into juxtaposition, they may be parts of southeast-dipping limbs of formerly continuous, overturned, isoclinal folds. Kays (1968) summarized the data of earlier workers and noted that the pre-Nevadan, Mesozoic units dipped steeply and uniformly southeast. This implies that the rocks were regionally isoclinally folded and overturned to the northwest prior to thrusting. However, no evidence of isoclinal folding and overturning could be found in the poorly exposed Rogue-Dothan sequence in the area mapped.

Myrtle Group

A later period of folding took place in post-Early Cretaceous time following deposition of the upper member of the Myrtle Group (Days Creek Formation). The strata of the Myrtle Group were deformed into somewhat asymmetrical, open folds with northwest trends. Continued compressional stresses seem to have caused failure by rupture in forelimbs, after which the folded strata were thrust to the northwest. The folds are best preserved in the lower member of the Myrtle Group (Riddle Formation), as illustrated in the geologic map which accompanies this report.

Plate 5. View looking north from a ridge crest in the SE¼SW¼ sec. 9, T. 32 S., R. 10 W. The ridge extends from the left foreground to the right background, formed on the southeast-dipping limb of a Riddle Formation fold. The ridge is capped by a resistant unit of conglomerate. West-dipping Tertiary strata form the skylined ridge in the left background.

Tertiary Warping

Two periods of warping are recorded in the Tertiary rocks in the northwestern part of the area. A short period of mild warping took place in Middle Eocene time (Baldwin, 1965) following deposition of the upper member of the Umpqua Formation and preceding deposition of the Tyee Formation. Strata of both formations dip to the west at low angles where they crop out along the west and northwest boundaries of the area. This relationship indicates that additional mild crustal warping occurred after deposition of the Tyee Formation in Middle Eocene time.

Faulting

Faulting in the area consists of an earlier, more intense period of thrust faulting accompanied by minor normal faulting in folded strata of the Myrtle Group. Superimposed discordantly on these thrust faults is a later period of normal faulting marked by a large normal fault (Camp Hope Fault) with more than 1,600 feet of displacement.

Thrust Faults

Thrust faulting has had a more dynamic effect on the local structural history. It is represented from east to west by three major structures which include the Rogue-Dothan, Rogue-Riddle, and Riddle-Days Creek thrusts.

The Rogue-Dothan thrust shows evidence of the most intense structural deformation by compressional stresses. This consists of a serpentinite intrusion, metasomatic alteration of both formations near the intrusive contact, and the abrupt appearance of foliation in rocks of both formations near the thrust. The foliation is regarded as due to cataclasis and recrystallization resulting from shearing stresses acting along the sole of the thrust fault. Based on the attitude of the foliation, the surface trace of the thrust in relation to topography, and the dip of the fault seen in two road cuts, the Rogue-Dothan thrust strikes northeast and appears to dip southeast at about 45°. Its attitude is essentially parallel to that of the surrounding strata.

Although the other two major thrusts also post-date the Rogue and Dothan Formations, they involve the post-Nevadan Myrtle Group and have no associated ultramafic intrusions or zones of cataclasis and recrystallization. However, ultramafic intrusions emplaced during a Middle to Late Cretaceous period of orogeny have been noted elsewhere in the Klamath region by Irwin (1964) and Koch (1966).

From the foregoing evidence, the writer infers that the Rogue-Dothan thrust was involved in a more intense stage of compressional deformation that may have preceded the less intense deformational stage that produced the Rogue-Riddle and Riddle-Days Creek thrusts. There is no evidence in the area to prove that the Rogue-Dothan thrust is related to the Late Jurassic, Nevadan orogeny or to the post-Early Cretaceous period of thrusting which involved the Rogue Formation and the post-Nevadan Myrtle Group. However, the writer believes that the evidence points to a Nevadan age, or at least to formation during the initial and more intense stage of the post-Early Cretaceous thrusting, for the Rogue-Dothan thrust.

The presence of exclusively southeast dips among the pre-Nevadan, Late Jurassic rocks of the region (Kays, 1968) implies that the sequence was first isoclinally folded and then overturned to the northwest by horizontal compressional stresses. Continuation of these compressive stresses caused forelimb rupture in the tightly folded strata, and some of the resultant faults may have continued downward into bedding plane thrusts. The Rogue-Dothan thrust appears to have formed in this manner, although there is no evidence of isoclinal folding exposed in the area. The Rogue-Dothan section here may represent structurally dislocated parts of limbs of formerly continuous, isoclinally folded strata that were overturned to the northwest. Erosion has further modified the section to form the relationship as it appears today.

Farther west in the area, the pre-Nevadan Rogue Formation has been thrust northwest over the post-Nevadan Riddle Formation. This Rogue-Riddle thrust strikes north to northeast and dips moderately to steeply east and southeast. Near the thrust, strata of the Riddle Formation are strongly disrupted by numerous small faults and bedding plane thrusts. A number of small, discontinuous, southeast-dipping, low-angle thrust faults occur in the sedimentary and volcanic rocks along the main fault zone. These small thrust faults are prevalent in the thick Riddle conglomerate units as far as 1,000 feet west of the Rogue-Riddle thrust. Where exposed, the thrust fault is a deeply weathered zone of iron stained sandy gouge and rock fragments, which varies from less than 5 to more than 15 feet in width.

The age of the Rogue-Riddle thrust is post-Myrtle Group (post-Early Cretaceous). The fault appears to have formed after most of the Days Creek Formation had been removed by erosion from the underlying Riddle Formation, because no Days Creek strata were found anywhere along the thrust in the area mapped. This implies that folding and thrust faulting of the Myrtle Group rocks may pre-date the Rogue-Riddle thrust in this area.

Near the center of the thesis area, the Late Jurassic Riddle Formation has been thrust to the northwest over the Early Cretaceous Days Creek Formation. This Riddle-Days Creek thrust is exposed in a small quarry in sec. 17, where it strikes northeast and dips southeast at about 35°. Near the thrust across most of the area, the Riddle Formation dips moderately southeast and the Days Creek Formation dips steeply northwest. However, in the southwestern part of the area, both formations dip steeply northwest in the vicinity of the thrust. The thrust fault zone is a dark yellowish-brown to dark reddish-brown zone of intensely sheared and brecciated rock fragments and sandy gouge.

Although the relative ages of the Rogue-Riddle and Riddle-Days Creek thrusts cannot be resolved from the available evidence, the evidence suggests that the Riddle-Days Creek thrust may be the older. The only exposures of the Days Creek Formation in the Eden Valley-Saddle Peaks area occur west of the Riddle-Days Creek thrust. Because the younger Days Creek Formation was deposited disconformably on the older Riddle Formation, one would expect the Days Creek to overlie the Riddle throughout the area. The evidence indicates that folding of the Myrtle Group culminated in forelimb rupture and thrusting. Plates of folded Myrtle Group rocks were thrust over one another so that, in this area, the crest of an anticline was directly over the northwest-dipping limb of a syncline. The Days Creek Formation was removed from the anticline by erosion, but it was preserved in the syncline where it was more deeply buried. The Rogue-Riddle thrust was formed after erosion had completely removed the Days Creek and exposed the Riddle on the crest and flanks of the anticline.

The Days Creek Formation is Early Cretaceous in age; hence, the Riddle-Days Creek thrust is post-Early Cretaceous and post-dates folding of the Myrtle Group in this area.

Late Early Eocene thrust faulting, involving the lower member of the Umpqua Formation near Roseburg, was described by Baldwin (1964b). This indicates that thrusting in the thesis area may have continued until the early Eocene. Along the west side of Eden Valley and in the valley of Clear Creek, the Middle Eocene, upper member of the Umpqua Formation (Baldwin, 1965) onlaps the Early Cretaceous Days Creek Formation with angular unconformity. Because the Days Creek is the youngest formation in the area to be involved in thrusting, the thrusting must have ended sometime between Early Cretaceous and Middle Eocene time. It may be related to the same period of deformation that caused the post-early Late Cretaceous thrusting in northern California which Irwin (1964) attributed to the "Coast Range Orogeny".

Normal Faults

During the time the Rogue plate was being overthrust, a series of normal faults were formed in the folded strata of the Myrtle Group. These faults may have formed before the Myrtle Group was involved in thrusting, but there is no evidence to either confirm or refute this inference. The faults developed generally perpendicular to the strike of the folded strata. They show more offset in the Myrtle beds than in the Rogue volcanic units where the faults cross the Rogue-Riddle thrust. This difference in apparent offset may indicate that displacement on the faults took place in the Myrtle Group prior to the arrival of the overthrust Rogue plate. In view of the northwest-southeast direction of the compressive stresses, strike-slip movement on these normal faults could have extended them laterally across the Rogue-Riddle thrust into the Rogue Formation after the Rogue plate had arrived. However, there is insufficient evidence to confirm this displacement. The normal faults post-date folding of the Myrtle Group and, at least in part, post-date the Rogue-Riddle thrust. They are therefore younger than the Early Cretaceous Days Creek Formation. They do not appear to cut the Tertiary section in the area, so they are probably older than Middle Eocene. They may be related to the Camp Hope Fault period of normal faulting.

The Camp Hope Fault is a large normal fault which crosses the extreme southern part of the map area in an east-west direction, and passes near to and south of Camp Hope. The trace of this fault relative to local topography indicates that it dips steeply to the south. The Rogue and Riddle Formations are juxtaposed along the western half of the fault, and no rocks of the Myrtle Group were found south of it. In several places along the fault, the writer found rubble zones of pebble to boulder sized, angular to subrounded, fault breccia fragments in a matrix of sandy gouge. The apparent width of the fault varies from less than 10 to more than 100 feet. It offsets the Rogue-Dothan thrust approximately 1,000 feet horizontally. If the dip of the Rogue-Dothan thrust is assumed to be 45° southeast, the calculated minimum slip is more than 1,600 feet. The offset of the Rogue-Dothan thrust indicates that the displacement is south side up relative to the north side. The relationship of the sedimentary rocks of the Riddle Formation to the

Camp Hope Fault and to volcanic rocks of the Rogue Formation implies that the Riddle Formation (and the entire Myrtle Group) overlies the Rogue Formation throughout the area mapped.

The age of the Camp Hope Fault can be closely bracketed. Because it cuts both the Rogue-Dothan and the Rogue-Riddle thrusts, it is therefore younger than the post-Early Cretaceous period of thrusting. The fault does not appear to offset the Middle Eocene, upper member of the Umpqua Formation, so it is older than Middle Eocene. It was probably formed during the same period of large-scale normal faulting that produced the Powers-Agness fault a few miles west of the area, which Baldwin (1965) described. He related the Powers-Agness fault to deformation that involved the middle member of the Umpqua Formation and older rocks a few miles southwest of the Eden Valley-Saddle Peaks area.

Compressional deformation that culminated in thrusting appears to have ceased in the region during late Early Eocene time, and it was followed by a period of regional dilation and resultant normal faulting, according to Baldwin (1965). He suggested that normal faulting decreased in intensity from late Early Eocene to Middle Eocene time. In the Klamath region, uplift and normal faulting and shearing has continued throughout the late Cenozoic until the present, as noted by Dott (1965; 1971) and Koch (1966). There is no evidence of this later faulting and shearing in the thesis area.

GEOMORPHOLOGY

Regional Geomorphology

Most of the thesis area lies within the Klamath Mountain Geomorphic Province, the boundary of which is the Mesozoic-Cenozoic contact, as defined by Diller (1902).

Probably since early Mesozoic time, the Klamath Mountain block has been subjected to episodes of spasmodic uplift and subsidence, accompanied by intervals of stability and erosion, which has continued throughout the Mesozoic and Cenozoic to the present. These processes have modified the Klamath surface to form the present, rugged, mountainous terrain. Many of the major river valleys show evidence of multiple rejuvenation and planation. Diller (1902) noted remnants of at least three major peneplains, the most widespread of which he named the Klamath peneplain. He proposed a late Miocene age for the Klamath peneplain based on evidence of dislocation and subsequent planation of Miocene rocks in the Coast Range of northwestern California within the Klamath Mountain province.

Uplift of the Klamath block is continuing, as indicated by regional stream degradation and the existence of several, prominent, late Cenozoic, marine terraces along the southern Oregon coast. The highest of these terraces is approximately 2,000 feet above sea level. Throughout most of the Klamath Mountain region, the topography fits the criteria of Thornbury (1958) for the early youth stage of the fluvial cycle of erosion.

Local Geomorphology

The Mesozoic-Cenozoic contact, which separates the Klamath

Mountain and Oregon Coast Range geomorphic provinces, crosses the Eden Valley-Saddle Peaks area from the southwest corner to the approximate center of the northern boundary.

In general, major drainages in the area parallel the strike of strata and major structures, so the valleys are subsequent and longitudinal (Thornbury, 1958). They do not conform to the typical drainage pattern of the Klamath Mountains described by Diller (1902). Instead, they match his description of the Northern Coast Range of California, where the drainage commonly parallels the strike of the strata.

The low-angle dips of strata of the Tertiary section produce distinctively different topography and drainage patterns, which make them easy to distinguish from the more steeply dipping Mesozoic strata in the area. Strata of the Riddle Formation in the southwest part of the area have steeper dips and form hogback ridges. Low, hummocky, northwest-trending hills are developed on parts of the Days Creek Formation. The Rogue Formation forms steep-sided, narrow, somewhat serrate, hogback ridges. Homoclinal ridges prevail on the Dothan Formation in the southeast part of the area.

In strata of the Myrtle Group, Riddle Formation conglomerate units are ridge-formers, whereas Days Creek Formation sandstone units and Riddle Formation siltstone units are valley- and slope-formers.

Degradation by nearly all streams in the area indicates renewed uplift. In some places they have eroded as much as 20 feet of valley alluvial and colluvial fill, exposing bedrock in many places where it was formerly covered.

ECONOMIC GEOLOGY

Location

In the Eden Valley-Saddle Peaks area, mineralization of possible economic importance occurs only in the altered volcanic rocks of the Rogue Formation. Diller (1914) reported the presence of pyrite, chalcopyrite, and bornite, along with numerous veins of quartz and calcite, in the "greenstones" (Rogue volcanics) of the area. Brooks and Ramp (1968) described the mineralization as sulfides of copper, lead, and iron contained in small quartz veins.

The only deposit of potential significance found in the area is the high grade copper sulfides of the Bolivar Copper Mine (NE$\frac{1}{4}$ sec. 10, T. 32 S., R. 10 W.).

History and Mine Development

The first mining activity in the area was directed to gold placers, and this was soon followed by a search for lode deposits. Most of the claims were staked during the 1890's and early 1900's. Placer mining was significantly productive for a very short period. The lode deposits were typically of low grade, and were usually found to have been offset by faults of unknown displacement.

When the first lode claims were being staked in the area, Joseph M. Thompson of Douglas County, Oregon located a promising copper prospect. The deposit was found on the south side of the West Fork of Cow Creek in the NE$\frac{1}{4}$ sec. 10, T. 32 S., R. 10 W. Diller (1914) later visited the area and reported the Thompson Mine to be the most important copper prospect in the surrounding region. He noted its condition as "currently idle", but estimated its past production to have been "at least 50 tons" of high grade copper ore.

During 1942 and 1943, the property was examined by Rosenberg (1943), who called it the Fuller Copper Mine. He estimated the total developed reserves to be at least 1,000 tons of ore averaging four percent copper, and described the ore as dense, hypogene sulfides rather uniformly distributed throughout a silicified gangue. The deposit was developed on three levels by adits that provided access to 1,056 feet of drifts, crosscuts, and winzes. The workings explored the deposit for 560 feet horizontally and 193 feet vertically. The best ore was found on the upper level, a few small pods and lenses were found on the intermediate level, and no ore was located on the lower level (Rosenberg, 1943).

When the writer examined the property in 1968 and 1969, it was being developed by a group of stockholders from Douglas County, Oregon. The principal stockholder, Mr. Raymond F. Carr, had restaked the lapsed original claims in 1956 under the new name of Bolivar Copper Company. The stockholders had recently incorporated a pilot milling operation, called "Omex", to test the feasibility of concentrating the copper sulfides for direct shipment to a smelter from the mine site. Their evaluation of 20 exploratory core and rotary diamond drill holes appeared to confirm Rosenberg's earlier conclusion about the nature and distribution of copper sulfides in the deposit. However, the average grade was determined to be about two percent copper instead of the four percent figure that had been estimated in 1943. As defined by by exploratory drill holes, mineralization occurs as remnant pods and lenses of high grade copper sulfide ore surrounded by oxidized material of lower and more variable copper content.

Plate 6. The recent surface excavation above the old underground workings at the Bolivar Copper Mine in the SW¼NE¼ sec. 10, T. 32 S., R. 10 W.

A series of exploratory trenches were excavated along the ridge crest that trends southwest from the mine site. In the mine area, most of these trenches exposed intensely weathered, friable, volcanic host rocks of the Rogue Formation, that contained no visible traces of copper mineralization. However, one trench outside the mine area (SE¼SW¼ sec. 10, T. 32 S., R. 10 W.) intersected more competent and less intensely weathered Rogue volcanic rocks that were veined by chalcocite, bornite, covellite, and minor malachite.

The writer observed three additional occurrences of sulfide mineralization nearby, but essentially outside the mine area. These are all near the thrust fault that separates volcanic rocks of the Rogue Formation from the underlying sedimentary rocks of the Riddle Formation. Bornite and chalcopyrite occur in two places in the volcanic rocks along the fault in sec. 16, and pyrite is abundant in both sedimentary and volcanic rocks at the fault contact in sec. 9 (T. 32 S., R. 10 W.).

Geology

Current development indicates that sulfide mineralization at the Bolivar Mine occurs exclusively within volcanic host rocks of the Rogue Formation. Detailed mapping of the area by the writer shows that the Rogue volcanics have been thrust northwest over sedimentary rocks of the Riddle Formation. The thrust fault contact lies about 1,000 feet north of the approximate center of the old subsurface workings. The fault plane is very irregular along most of its length in the thesis area, but it appears to be more uniform in the mine area. On the basis of topographic relationships of the fault trace, it may be inferred that the thrust fault dips approximately 50° south in the vicinity of the

Bolivar Mine; hence, it is actually a reverse fault.

A prominent normal fault was traced southeast from where it offsets the Riddle Formation and across the thrust fault into volcanic rocks of the Rogue Formation where the amount of offset appears to be substantially less. The fault trace of the normal fault is marked by several old prospect pits and caved adits, and it is mappable to within about 400 feet of the Bolivar mine site.

The volcanic rocks in the mine area are intensely weathered and almost completely decomposed at the surface. Here, the Rogue Formation consists of closely fractured flows and flow breccias of hydrothermally altered basaltic andesite and minor rhyolite porphyries. There is no biotite or hornblende, and most of the orthopyroxenes are completely altered to chlorite-group minerals. The principal ferromagnesian mineral, augite, shows significantly less chloritic alteration. The feldspar is plagioclase, compositionally near the labradorite-andesine boundary (An_{55}). Fracture surfaces near the sulfide mineralization are heavily stained by iron oxides. If the host rocks did not originally contain biotite and/or hornblende prior to hydrothermal alteration, they would be classified as basaltic andesites.

Immediately south of the thrust fault is an outcrop of strongly bleached and apparently recrystallized porphyry that may have been either rhyolite or dacite prior to alteration.

Sulfide and Gangue Minerals

The opaque ore minerals and transparent gangue minerals from the Bolivar Mine were identified using ore and petrographic microscopes. The main ore minerals are bornite, chalcopyrite, chalcocite, and minor covellite. Other opaque minerals include relict pyrite, marcasite,

Plate 7. A high-grade, bornite-chalcocite vein about four inches wide, exposed in the surface excavation shown in Plate 6.

Plate 8. A close-up view of the bornite-chalcocite vein shown in Plate 7. Note the network of closely spaced fractures filled by malachite that cuts the high-grade copper sulfide vein.

magnetite, sphalerite, and galena. In order of their relative abundance, the gangue minerals are barite, quartz, alunite, calcite, malachite, azurite, and epidote.

Polished sections of the ore minerals exhibit both primary and secondary textural relationships. The only ore mineral that appears to be distinctly hypogene is chalcopyrite. One section shows a complex intergrowth of bornite and chalcopyrite that can be interpreted as being either a primary eutectic unmixing or a replacement texture, according to Edwards (1965). Most of the chalcocite occurs as rim replacements around cores of bornite. Commonly, an outer zone of white chalcocite grades inward to a narrower zone of "blue" chalcocite that encircles the bornite core. The "blue" chalcocite may be a mixture of covellite and white chalcocite.

Specimens of nearly pure chalcopyrite, showing incipient replacement by irregularly shaped bodies of bornite, grade laterally into areas of almost pure bornite that contain small bodies of chalcopyrite. As the proportion of bornite to chalcopyrite increases, the amount of replacement of bornite by chalcocite also increases. Relict, rounded and shattered grains of pyrite were seen in all specimens, except those composed exclusively of chalcopyrite and quartz. Covellite is locally abundant, often replacing chalcocite. It also occurs as fracture fillings in bornite-chalcocite and as small replacement bodies in chalcopyrite-bornite.

Small bodies of bornite disseminated in barite gangue overlie one of the large pods of high grade copper sulfides near the surface. The bornite has been partly replaced by rims of chalcocite, and the sulfides and barite gangue are veined by malachite.

An unusual form of magnetite occurs in the chalcopyrite-quartz samples. The magnetite crystals resemble sheaves of grain with terminal ends like the tuft of an artist's brush. The writer has seen goethite crystals of similar habit and suggests that these crystals may be magnetite pseudomorphs after goethite.

Small barite-quartz veins cut the altered volcanic host rocks near the sulfide mineralization. These veins also contain marcasite, sphalerite, and galena in order of decreasing abundance. The marcasite is strongly anisotropic, paler brass yellow than pyrite, and it occurs as rectangular, prismatic crystals. The sphalerite grains are subhedral, and they are enclosed within and cut by marcasite in places. Galena is a rare constituent and was not found to cross-cut either marcasite or sphalerite. The writer believes that galena was the last of these three sulfides to crystallize for two reasons. First, its concentration in the vein is much lower than the concentration of the other sulfides. If this is a reliable indication of its original concentration in the fluid, then it should have crystallized last. Second, in most hydrothermal base metal deposits galena is among the last minerals to crystallize and is generally later than marcasite and sphalerite (Edwards, 1965). Hence, the paragenetic sequence appears to be sphalerite followed by marcasite with galena last.

The paragenetic sequence for the copper sulfides appears to be chalcopyrite followed by pyrite. Some bornite may have accompanied the chalcopyrite. Next came supergene replacement of chalcopyrite by bornite and chalcocite with concomitant destruction of much pyrite by acidic fluids in the zone of oxidation. The supergene bornite was then replaced by chalcocite and minor covellite. Some of the covellite may also replace chalcocite. No evidence was found to indicate the relative ages of the copper sulfide and the barite-quartz-sulfide vein mineralization. Because the magnetite pseudomorphs after goethite seem to have been contemporaneous with the chalcopyrite-quartz assemblage, all three are considered to be of hypogene origin.

With the exception of chalcopyrite, textural relationships among the copper sulfides are indicative of a supergene origin. However, Edwards (1965) does not regard such evidence as conclusive. The presence of relict grains of pyrite and the general absence of unmixing eutectic textures, combined with the clear relationship of chalcocite replacing bornite, leads the writer to believe that most of the copper sulfides are supergene. All of the chalcopyrite, and perhaps some of the bornite, is of hypogene origin.

According to Edwards (1965), the presence of galena indicates a temperature of deposition below 500° C., and the presence of marcasite indicates that deposition took place below 300° C., if these sulfides are of hydrothermal origin. There is no evidence relating these sulfides to the copper mineralization.

According to Lindgren's depth zone classification of 1933, as listed by Krauskopf (1967), chalcopyrite and pyrite can be either epithermal or mesothermal. Barite and bornite are listed as mesothermal, and alunite and calcite are listed as epithermal.

From these mineralogical criteria, it is evident that both epithermal and mesothermal minerals are present at the Bolivar Mine. The chalcopyrite-quartz-bornite-pyrite-barite assemblage may have been mesothermal. The marcasite, alunite, and calcite may have been epithermal. The Bolivar copper deposit is considered by the writer to be of mesothermal to epithermal origin in terms of temperature-pressure conditions of hydrothermal processes.

Of the gangue minerals, barite and alunite are unusually abundant. They both occur as two generations in association with the sulfide minerals.

In the veins containing marcasite, sphalerite, and galena, both barite and alunite occur as somewhat translucent grains with numerous inclusions and imperfections. The alunite has a peculiar, granular, abraded appearance and commonly has no distinct crystal boundaries.

In the upper part of the mineralized zone, barite is the only gangue mineral of significance. It forms the matrix surrounding irregularly shaped bodies of bornite which have been partly replaced by chalcocite. This generation of barite is usually colorless in thin section, contains few inclusions, and is cut by veins of malachite. Barite crystals that fill cavities in the oxidized wall rock are locally abundant.

Directly beneath this upper barite-rich zone, both the wall rock and the copper sulfides are cut by many, small, white veins of alunite, calcite, and barite. The alunite consists of two generations: an older type of cloudy, granular, indistinct anhedra, and a younger type of clear, euhedral, slender, prismatic crystal that grows both into and away from the margins of the older type.

Schwartz (1953) reported finding barite in a quartz-sulfide vein in highly sericitized rock at the San Manuel copper mine in Arizona. The vein was intercepted by a drill hole at a depth of 1,135 feet. This barite was introduced at a late stage in the sequence of mineralization. Shenon (1935) observed the close association of barite with galena at the Flathead Mine, northwestern Montana, and he considered both to be of hypogene origin. Barite generally appears during the lead and silver sulpho-salt stage of hydrothermal mineralization, according to Edwards (1965). It is preferentially concentrated in potassium minerals, particularly the potassium micas, as explained by Goldschmidt (1954). The average andesite has a very low concentration of barium (600 ppm) compared to that of the average rhyolite (2,300 ppm), as listed by Krauskopf (1967).

The source of the abundant barite in the Bolivar deposit may have been an intrusion of intermediate composition that was somewhat deficient in potassium. The association of barite with supergene copper sulfides indicates that it may also have formed from the combination of barium and sulfate ions liberated during the oxidation of sulfides (source of sulfate ions) and the concomitant chemical weathering of feldspars (source of barium ions). A rhyolite would provide about four times as much barium from weathering of feldspars than would andesite (Krauskopf, 1967). A basaltic andesite would be even more barium deficient. A rhyolite would seem to be a more plausible source for the barium ions than a basaltic andesite.

Alunite appears to be the only potassium-bearing mineral associated with the Bolivar mineralization. Kerr (1959) has described it as a prominent vein mineral that commonly occurs as a hydrothermal alteration product of rhyolite, dacite, and andesite. The source of potassium is hydrothermally altered feldspars.

Schwartz (1953) noted abundant hydrothermal alunite in part of the San Manuel copper deposit of southeastern Arizona. Although he was impressed by its close association with the copper mineralization, he found no evidence of a direct genetic relationship. At the Flathead Mine in northwestern Montana, Shenon (1935) observed that near the ore bodies, in highly altered porphyritic latite, sanidine and plagioclase were commonly either silicified or altered to clay minerals and alunite. The associated sulfides were galena, argentite, antimonial matildite, pyrite, enargite, marcasite, and small amounts of covellite. Quartz, barite, and clay minerals, along with alunite and some jarosite, were listed as the associated gangue minerals. Shenon considered barite to be later than quartz.

Occurrences of alunite as cited in the literature are most commonly associated with base metal deposits that are found in altered Tertiary volcanic rocks of the western United States and elsewhere. According to Shenon (1935), it is apparently a product derived either directly or indirectly from the oxidation of sulfides. Hot solutions containing sulfuric acid react with the wall rock to form alunite. The potassium and sodium of the alunite is derived from hydrothermally altered feldspars.

The Almeda Mine in Josephine County, Oregon, about 20 miles to the southeast of the Bolivar Mine and near Galice, contains abundant quartz and barite gangue associated with copper sulfides. The two deposits are similar in many respects. Treasher (1942) described the Almeda ore as being composed of fine-grained quartz, barite, and massive sulfides in varying proportions. The paragenesis was considered to be quartz followed by barite, with copper sulfides last. The deposit lies within volcanic rocks of the Rogue Formation adjacent to the contact with sedimentary rocks of the Galice Formation. It is associated with a porphyritic dacite intrusion, according to Treasher (1942).

Alteration

Thin sections of the volcanic flow rocks of the Rogue Formation reveal variable phenocryst to groundmass ratios. Textures are porphyritic, pilotaxitic, and consist of phenocrysts of calcic to intermediate plagioclase, augite, and enstatite-hypersthene set in a felty groundmass composed chiefly of tiny laths of plagioclase. Nearly all of the smaller enstatite-hypersthene phenocrysts are completely altered to chlorite-group minerals. If these volcanic rocks originally contained biotite and/or hornblende, they too have been completely altered to chlorite-group minerals. The plagioclase phenocrysts are incipiently to moderately altered to clay minerals, white mica, calcite, and chlorite minerals. Although augite was not as susceptible to chloritic alteration as enstatite-hypersthene, both pyroxene minerals are commonly and variably altered to chlorite-group minerals and calcite.

The groundmass in the various volcanic flow units is a dense assemblage of chlorite-group minerals in which tiny plagioclase laths represent the only recognizable original constituent. A few grains of unaltered, possibly secondary, epidote occur in some specimens.

Point count analyses of several thin sections of altered volcanic rocks averaged 30 percent plagioclase, 15 percent augite, 5 percent enstatite-hypersthene, 5 percent opaque minerals (chiefly magnetite), 5 percent vein minerals (chiefly barite, quartz, and alunite), and 35 percent chlorite-group minerals which are mostly confined to the groundmass.

Compositions of a number of polysynthetically twinned plagioclase phenocrysts were estimated from the maximum extinction angle of albite twins by the Michel-Lévy method. The range of values was from An_{45} to An_{68}, with most indicating a labradorite composition. These values suggest that the Rogue volcanics in the Bolivar mine area are basaltic andesites.

The chlorite-group mineral assemblage is composed of about equal amounts of chamosite and pennine, with subordinate amounts of prochlorite, as determined from criteria given by Kerr (1959). The clay minerals are too fine-grained for positive identification, but they appear to include both kaolinite and montmorillonite.

Similar volcanic rocks of the Rogue Formation at the Almeda Mine near Galice contain hornblende that has been largely altered to chlorite, epidote, and zoisite near zones of copper sulfide mineralization (Treasher, 1942). The feldspar has been mostly altered to masses of saussurite, calcite, zoisite, and epidote. Treasher (1942) also noted zones of intensely silicified volcanic host rocks. Similarly, Rosenberg (1943) observed that the copper sulfide minerals in the Bolivar Mine were rather uniformly distributed in a silicified gangue. Thus, copper mineralization at both mines is associated with abundant silicification.

North of the Bolivar Mine, near the thrust fault contact of the Rogue volcanics, is the only outcrop of a strongly bleached and altered porphyry that perhaps was originally a rhyolite or a dacite. Its groundmass is a mosaic of apparently recrystallized quartz and feldspar, and it contains only trace amounts of chlorite and ferromagnesian minerals. It may have been the source of the barium, and possibly most of the potassium and sodium, that formed the barite and alunite in the Bolivar copper deposit nearby.

Thrust fault breccia is exposed in an exploratory road cut across a small tributary stream and about 300 feet west of the outcrop of bleached and altered porphyry. The breccia is silicified and heavily stained by medium yellowish-brown iron oxides. In thin section, the breccia fragments are mostly identifiable as volcanic rocks of the Rogue Formation. The fragments are intensely argillized and altered to minerals of the chlorite group. The plagioclase phenocrysts are moderately to strongly altered to white mica. Presumably because of surficial oxidation, sulfides were not seen in the silicified fault breccia.

The presence of such intense alteration and silicification in the thrust fault breccia suggests that the copper mineralization in the nearby Bolivar Mine may be the surface expression of a larger copper deposit localized by the thrust fault beneath the mine. Deep exploratory drilling would be required to prove this inference.

Structural Controls

The copper sulfides of the Bolivar Mine occur as irregular bodies and lenses that were deposited in and along fractures in the wall rock, according to Rosenberg (1943). In the lower workings, he noted a prominent network of structural joints that dipped west at 30° to 40°.

At the surface, deposition of sulfides, which occur as irregular bodies and discontinuous lenses, appears to have been controlled by faults, joints, and related fractures. These massive sulfide bodies are broken by a network of fractures spaced less than one inch apart. The frequency of joints in the host rock averages four per foot. As the sulfide bodies and the host rocks have similarly trending joints and fractures, the evidence supporting structural control of mineralization is strong.

A normal fault that offsets strata of the Riddle Formation northwest of the mine area was traced across the thrust fault and into volcanics of the Rogue Formation. The fault appears to have offset the Rogue Formation less than it has offset the Riddle Formation. It can be easily traced on the surface to within about 400 feet of the Bolivar Mine by following a line of old prospect pits and caved adits that were excavated to explore the fault for mineralization. The relation of the trace of the normal fault to topography indicates a nearly vertical, steep dip (60° to 70°) to the southwest.

The greater amount of apparent offset on the normal fault in strata of the Riddle Formation, compared to the apparent offset of units of the Rogue Formation, indicates that the displacement may have been partly strike-slip. The normal fault formed in an anticlinal structure of the Riddle Formation by a process similar to that described by Badgley (1965), who pointed out that transverse faults which develop approximately normal to anticlinal axes are probably the most common type of normal fault. The process is characterized by inward collapse of the anticline toward the center of the uplift.

The normal fault near the Bolivar Mine may have formed in the anticline as a result of the same episode of compression that caused overthrusting of the Rogue Formation. Continued stress produced later strike-slip movement along the fault, extending it laterally across the thrust and into the volcanic Rogue Formation.

At the Bolivar Mine, this normal fault and associated fractures and joints appears to have controlled the emplacement of the copper sulfides. The closely fractured nature of the pods and lenses of massive sulfides indicates that structural movement followed solidification of the sulfides. The writer was unable to determine whether the post-sulfide movement was related to movement on the normal fault or the thrust fault. Nonetheless, fracturing of the host rock, both before and after the emplacement of copper sulfides, appears to have been related to overthrusting of the Rogue plate.

The youngest rocks involved in thrusting in the Eden Valley-Saddle Peaks area belong to the Early Cretaceous Days Creek Formation. The Days Creek Formation is overlain unconformably by the Middle Eocene upper member of the Umpqua Formation which was not involved in thrusting. Therefore, the probable age of emplacement of the copper sulfides in the Bolivar Mine is between 50 and 130 m. y. If this interpretive age for the mineralized normal fault is correct, it is reasonable to expect additional copper mineralization to occur within the fractured zone of the thrust fault beneath the overthrust plate of Rogue volcanic rocks. Hydrothermal alteration and copper and iron sulfides which are evident in rocks of the Riddle and Rogue Formations along the thrust fault provide further support for this inference. Accordingly, there should be additional copper mineralization along the normal fault beneath the Bolivar Mine, both down dip and laterally along the strike of the fault.

Hypotheses of Origin

The assemblage of hydrothermal minerals points to a probable nearby intrusive source, although no intrusions are exposed in the mine area. Barite, quartz, and alunite form the bulk of the mineralization at the Bolivar Mine. Their unusual abundance must be related to the mechanism of mineralization here. Pressure-temperature requirements for the sequence of ore and gangue minerals at the Bolivar Mine indicate a probable igneous intrusive source.

If one assumes that the source of heat and mineralizing fluids was an intrusion, what composition might it be expected to have? Most of the intrusions in the Klamath Mountain region are diorites and quartz diorites. The intrusive body associated with copper sulfides at the Almeda Mine is a porphyritic dacite, which is compositionally equivalent to a quartz diorite. Because mineral assemblages, alteration, and host rocks are practically identical in the Bolivar and Almeda Mines, the writer proposes that the source intrusion at the Bolivar Mine may also have been a porphyritic dacite or quartz diorite.

A literature search was made to check the possibility of the existence in the area of an intrusion of the appropriate age and composition. The most permissive evidence was obtained from work done by Lanphere and others (1968), who isotopically dated a number of plutons in the Klamath Mountains of northern California. Their results showed decreasing absolute ages of diorites and quartz diorites along a directional trend toward the northwest. The youngest plutons were nearest the Oregon border, and their absolute ages were 127 to 146 m. y. If this "younger northwest" trend continues into Oregon, it is reasonable to assume that plutons younger than 130 million years might occur at depth in the Bolivar Mine area. Of possible importance is an undated quartz monzonite that intrudes the Vesa Bluffs pluton (146 million years old) northwest of Yreka, California (Lanphere and others, 1968).

The mineralization of the Bolivar Mine is mesothermal to epithermal in terms of pressure-temperature conditions that controlled its emplacement. There are several possible mechanisms by which it may have been concentrated and emplaced. Additionally, the alternative interpretations depend upon whether the barite and alunite are of hypogene or supergene origin.

If alunite and barite are considered to be hypogene, at least two mechanisms of origin are possible. First, the intrusion may have been deficient in potassium so that, as the melt crystallized, no potassium minerals formed to incorporate barium ions in their crystal lattices (Goldschmidt, 1954). As a second alternative, an upward migrating crystal mush may have contacted barite-rich sedimentary rocks after most of its potassium minerals had crystallized, and some of the barite was assimilated. For either mechanism, barium, along with some potassium, became concentrated in the residual fluids of the intrusion. These fluids accompanied the emplacement of sulfide minerals in the form of hydrothermal fluids, and barite and alunite were deposited as hypogene minerals.

Nonetheless, these two mechanisms for a possible hypogene origin contradict the evidence given in previous sections. A third mechanism, which involves a supergene origin for the barite and alunite, seems to be more compatible with the evidence. According to this mechanism, the hydrothermal fluids that accompanied the copper sulfides altered the feldspars of the volcanic host to clay minerals. Some of the units of the volcanic host are rhyolites that presumably are relatively enriched in barium, potassium, and sodium, compared to basaltic andesites. Circulating meteoric waters carrying ions of barium, potassium, and sodium derived from weathering of the hydrothermally altered feldspars encountered sulfate-bearing, acidic waters at depth, which were derived from oxidation of sulfides. The result was immediate supergene precipitation of insoluble barite at the site, and later precipitation of the more soluble alunite in more widespread parts of the system. This hypothesis is supported by the occurrence of at least two generations of barite and alunite, the zone of almost pure barite capping the deposit, and the relict pyrite replaced by chalcocite and bornite of assumed supergene origin. The quartz-chalcopyrite assemblage along with the pyrite are considered to be hypogene minerals emplaced during the period of hydrothermal alteration. As previously stated, the intrusive source of these hypogene minerals was probably a porphyritic dacite or quartz diorite.

GEOLOGIC SUMMARY

The sequence of geologic events in the Eden Valley-Saddle Peaks area began with deposition of the Late Jurassic rocks of the Rogue and Dothan Formations. According to the interpretation of Baldwin (1969) and other workers, the Rogue volcanic sequence was the first to be laid down. It was deposited on the emergent and eroded pre-Late Jurassic surface as a series of extrusive flows, flow breccias, and tuffs. As volcanism continued and the succession of flows thickened, the area was gradually submerged beneath an eastward transgressing sea. While marine deposition continued, submarine flows became intercalated with clastic sediments brought in from emergent areas then being eroded. In one part of the basin, this sequence of clastic sediments and associated flows formed the Dothan Formation. As the Dothan sequence accumulated, the frequency of volcanism and associated flows decreased until volcanic rocks were no longer an important lithology.

At some point in Late Jurassic time, possibly when the total thickness of sediments and volcanics had reached 30,000 feet, forces of horizontal compression folded, faulted, and uplifted the section and exposed it to erosion. Intrusive rocks of intermediate and ultramafic composition were emplaced regionally, and the latter chiefly along faults. These compressional forces and intrusions characterize the beginning of the Nevadan orogeny. The compression continued until the rocks were tightly folded. They may have been isoclinally folded and overturned to the northwest. Continued compression culminated in rupture, and the rocks were thrust northwestward as a series of imbricate plates. During this phase of the Nevadan orogeny, the Rogue-

Dothan thrust fault was probably formed, accompanied by the emplacement of the serpentinite intrusion.

The compressional forces gradually subsided during the last stage of Nevadan orogenesis in Late Jurassic time. Nonetheless, the land remained emergent and erosion degraded the exposed rock units until a transgressing sea encroached upon the land surface. At this time, deposition of the post-Nevadan, Late Jurassic Riddle Formation of the Myrtle Group took place, probably on the submerged, eroded surface of the Rogue Formation and in a shallow, shelf environment. After a brief depositional hiatus, probably because of either nondeposition or emergence, the younger Days Creek Formation of the Myrtle Group was deposited disconformably on the Riddle Formation in Early Cretaceous time.

Shortly after the Myrtle Group was deposited, another orogenic pulse of horizontal compression folded and uplifted the sequence. The folds in the strata of the Myrtle Group were open and nearly symmetrical when failure by rupture occurred, and the strata were thrust over one another to the northwest. Erosion of the emergent rocks, perhaps accompanied by relaxation of horizontal compressional forces, removed nearly all of the younger Days Creek Formation from the underlying and older Riddle Formation in the Eden Valley-Saddle Peaks area.

Somewhat later, the horizontal compression resumed, and the pre-Nevadan, Late Jurassic Rogue Formation was thrust to the northwest over the post-Nevadan, Late Jurassic Riddle Formation of the Myrtle Group. At essentially the time of arrival of the overthrust Rogue plate, the Myrtle Group folded sequence was disrupted by a series of normal faults of small displacement. These faults developed generally normal to the strike of the Myrtle Group rocks. The faults later extended across the thrust fault and into the overthrust Rogue plate. The age of this period of thrusting and associated normal faulting is somewhere between Early Cretaceous and Middle Eocene. It is probably correlative with thrusting in late Early Eocene rocks near Roseburg, which has been described by Baldwin (1964b). Copper mineralization and associated hydrothermal alteration from a probable igneous intrusive source at depth appear to have been emplaced during this episode of thrusting.

After horizontal compression and the related thrusting ceased, a normal fault of large displacement, the Camp Hope fault, formed along the southern margin of the area. It involved rocks of the Rogue and Dothan Formations and the Myrtle Group. The south side has moved up at least 1,600 feet relative to the north side, as calculated from offset of the Rogue-Dothan thrust. The Camp Hope fault appears to be the same age as the Powers-Agness fault (Baldwin, 1965; Baldwin and Hess, 1971), which Dott (1971) listed as the Coquille River Fault Zone.

A period of emergence and erosion accompanied and followed this last episode of faulting. During this time, rocks of the Myrtle Group were completely eroded from the underlying Rogue Formation on the south side of the Camp Hope fault along the southern margin of the area mapped. The middle member of the Umpqua Formation may have been eroded from the underlying Myrtle Group, if the middle Umpqua member reached this far toward the east. With eastward transgression of the Middle Eocene sea, the upper member of the Umpqua Formation was deposited unconformably on the eroded surface of the Myrtle Group. Once again the area was briefly emergent and exposed to erosion, but submergence soon followed. The Tyee Formation was then deposited with slight angular unconformity on the eroded surface of the upper member of the Umpqua Formation.

Following deposition of the Tyee Formation, emergence and mild regional warping formed a shallow syncline in the Middle Eocene strata west of the Eden Valley-Saddle Peaks area. If younger rocks were ever present in the area, they have since been removed by erosion. It is reasonable to assume that the area has been emergent and exposed to erosion since Oligocene or possibly Miocene time. There is no clear evidence of post-Eocene faulting in the area, although minor late Cenozoic faulting may have taken place.

Table 2. Summary of geologic events of the Eden Valley-Saddle Peaks area.

Epoch	Event
post-Late Eocene	Probable continuous emergence with possible minor normal faulting and shearing.
Late Eocene	Mild regional warping, resulting in uplift and emergence. Submergence and deposition of Tyee Formation unconformably on Umpqua Formation.
Middle Eocene	Regional warping, resulting in uplift and emergence. Submergence and deposition of Umpqua Formation, with upper member onlapping Myrtle Group with angular unconformity.
Early Eocene Paleocene	Regional dilation and resultant, large displacement normal faulting (Camp Hope Fault). Possible time of formation of small displacement normal faults in Myrtle Group.
Late Cretaceous	Regional compression and thrusting of Rogue Formation over Riddle Formation. Possible time of thrusting of Riddle Formation over Days Creek Formation. Probable time of emplacement of copper sulfide mineralization at Bolivar Copper Mine. Possible time of thrusting of Dothan Formation over Rogue Formation and emplacement of serpentinite. Period of uplift and erosion. Most of Days Creek Formation removed from underlying Riddle Formation. Probable time of thrusting of Riddle Formation over Days Creek Formation due to regional compression. Regional compression causing folding and uplift of Myrtle Group. Probable time of formation of small displacement normal faults in Myrtle Group.
Early Cretaceous	Submergence and deposition of Days Creek Formation of Myrtle Group disconformably on Riddle Formation. Fossil hiatus.
Late Jurassic	Submergence and deposition of Riddle Formation of Myrtle Group on truncated surface of Rogue Formation. End of Nevadan orogeny.

Table 2. (Contd.)

Epoch	Event
Late Jurassic	Regional compression and possible thrusting of Dothan Formation over Rogue Formation. Possible time of emplacement of serpentinite.
	Nevadan orogeny begins. Regional compression causes uplift and folding of Rogue and Dothan Formations.
	Gradual submergence and deposition of Dothan Formation.
	Emergence and deposition of volcanics of Rogue Formation, followed by gradual submergence as deposition continues.

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