AN ABSTRACT OF THE THESIS OF

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Title: GEOLOGY AND MINERAL DEPOSITS OF THE BRATTAIN DISTRICT, LAKE COUNTY, OREGON

Abstract approved: Redacted for privacy
Cyrus W. Field

The Brattain district is in the Paisley Mountains about four miles south of Paisley in central Lake County, Oregon.

Rocks in the area mapped range from pre-early Oligocene to Pleistocene in age. Lithologies include primarily volcanic flows with minor sedimentary and pryoclastic rocks and a small plutonic complex.

The oldest unit in the area is a sequence of dacite flows 2000 to 2600 feet thick, that is pre-early Oligocene in age. Unconformably overlying the dacite flows are 2500 feet of andesitic sedimentary and pyroclastic rocks with intercalated andesite flows of the Cedarville Series of early Oligocene age. The Cedarville Series is the most extensively exposed unit in the area. Dacite flows and andesites of the Cedarville Series have been intruded by a plutonic complex composed of diorite, granodiorite and quartz monzonite. In the western

part of the district younger andesite flows overlie older rocks with angular unconformity. The unit is 400 to 500 feet thick and is believed to be middle to late Miocene in age. Silicic flows that range from rhyolite to dacite in composition overlie the andesite flows. The silicic flows are approximately 300 feet thick and are late Miocene or early Pliocene in age. High alumina basalt flows and dikes of Pliocene age overlie and intrude all older rocks. The flows are approximately 200 feet thick and some dikes exceed 50 feet in width. Two rhyolite plugs and a series of secondarily silicified rhyolite flows of Pliocene to Pleistocene age overlie and intrude the older rocks. The youngest rocks in the area are 100 to 200 feet of vesicular, glassy basalt flows of Pleistocene age. The eastern margin of the area contains Pleistocene lacustrine deposits and local landslide deposits.

The Paisley Mountains are a small range in the Basin and Range Province. The main mass of the Paisley Mountains is a horst bounded by two approximately parallel northwesterly striking faults. The dacite flows and Cedarville Series have been domed by the intrusion of the plutonic complex. Fracture controlled veins in the Cedarville Series display an imperfect radial distribution and are believed to be associated with formation of the dome.

Mineralization and associated hydrothermal alteration are chiefly limited to narrow veins and small disseminated deposits. Pyrite is the most common sulfide. The ore minerals are imperfectly zoned with respect to the plutonic complex. Chalcopyrite is locally abundant in and adjacent to the plutonic complex. Sphalerite and minor galena were found only in volcanic host rocks that enclose the complex. Quartz, sericite and kaolinite are the most abundant alteration products. An imperfect zonation of the less common alteration minerals also exists. Tourmaline is found in and adjacent to the plutonic complex. Epidote and calcite occupy an intermediate zone between tourmaline and zeolites that are restricted to volcanic rocks on the periphyry of the district. The mineralizing fluids are believed to have been derived from a source at depth within the plutonic complex.

Geology and Mineral Deposits of the
Brattain District, Lake County, Oregon

by

James Kay Muntzert

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

GEOLOGY AND MINERAL DEPOSITS OF THE BRATTAIN DISTRICT, LAKE COUNTY, OREGON

INTRODUCTION

Location and Accessibility

The thesis area is approximately four miles south of Paisley in central Lake County, Oregon (Fig. 1). The area consists of approximately 20 square miles in T. 33 S., R. 18 E., and T. 34 S., R. 19 E.

Principal access is via State Highway 31, which passes through the eastern edge of the area. Several unimproved dirt roads extend into the area and these are generally passable only with four wheel-drive vehicles.

Purposes and Method of Investigation

The purpose of this thesis is to provide a general study of the stratigraphy, structure, and the extent, type and controls of mineralization and alteration and a detailed study of small quartz monzonite and diorite stocks and associated dikes in a small area south of Paisley, Oregon.

Field work was conducted during the summer of 1967, from June 20 to September 24. An enlarged portion (scale 1:12,000) of of the U. S Geological Survey preliminary topographic sheets of Summer Lake No. 4 N. E. and Summer Lake No. 4 S. E. quadrangles

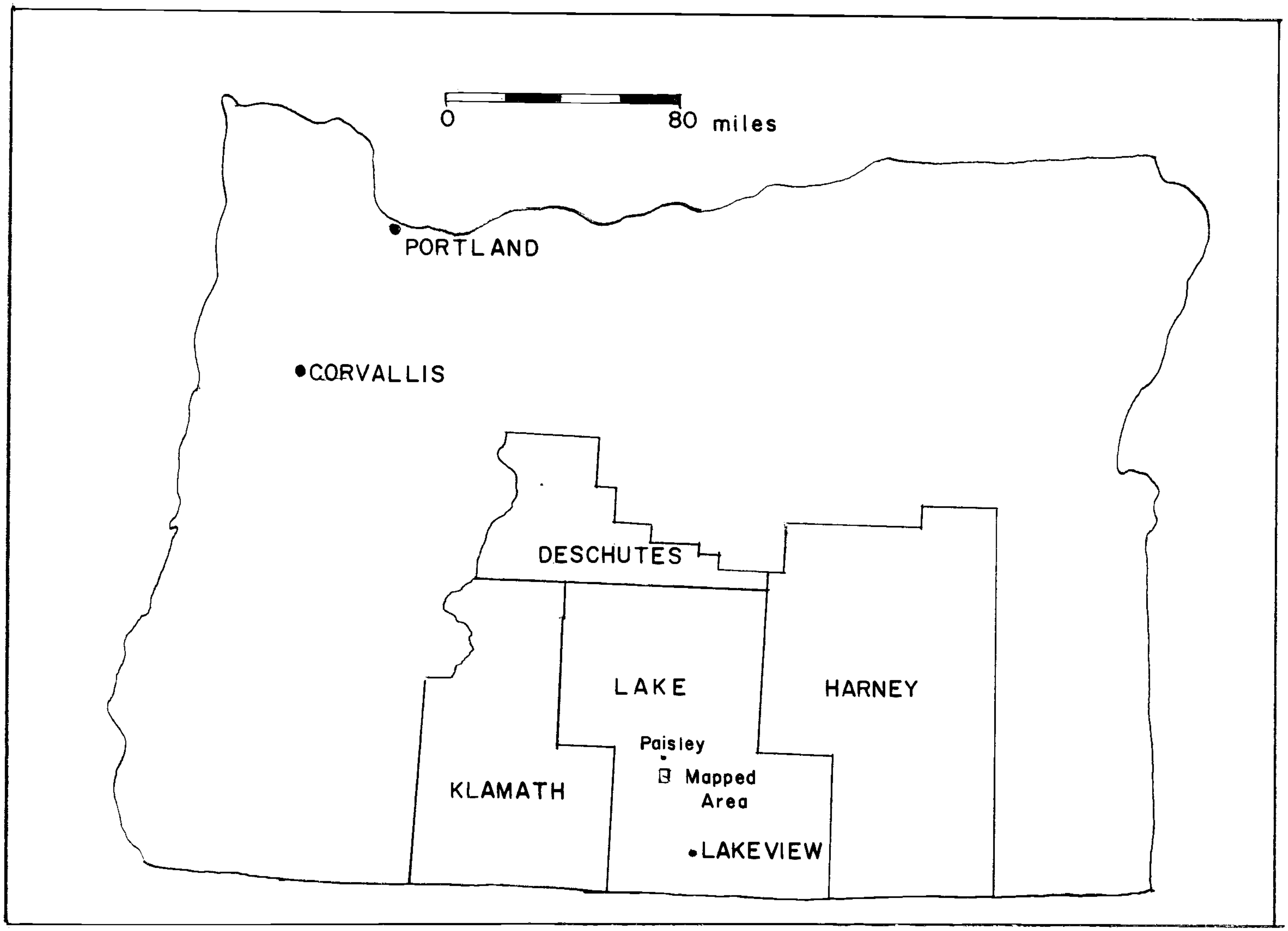

Figure 1. Index map of the Brattain district, Oregon.

was used as a base map.

Laboratory investigations involved studies of 61 thin sections and three polished ore sections. Modal analyses were made of selected representative rock types. Clay minerals and other alteration products were identified by X-ray diffraction methods.

Climate and Drainage

The climate at Paisley, the nearest U. S. Weather Bureau recording station, is semi-arid. The average minimum annual temperature of 30.1° F. occurs in January and the average maximum annual temperature of 68.2° F. occurs in July. Annual average precipitation is 11.89 inches. The thesis area is somewhat cooler and more moist because of its higher altitude.

The area is drained by several intermittent streams. All streams drain into the Chewaucan River which flows north along the western side of the area and then turns south along the eastern side of the area and eventually flows into Lake Abert.

Relief

Maximum relief of 2555 feet is in the east central portion of the area. Here, the Paisley Mountains rise abruptly from the Chewaucan Marsh to a maximum altitude of 6861 feet.

Vegetation

Sagebrush and juniper trees are the most common plants in the area. Mountain mahogany, quaking aspen and several species of pine and fir are common at higher altitudes. Alder, willow, chokecherry and other shrubs and bushes are found along stream beds and near springs.

Previous Work

Previous work in the immediate area is mainly limited to that of Appling (1950). Appling studies the Gaylord mine in the central part of the area and is responsible for naming this area the Brattain mining area.

Three general rock types in south-central Oregon were recognozed by Waring (1908)--older acidic effusives, older basaltic effusives, and recent erruptives. He concluded that the older basaltic effusives were roughly contemporaneous with the Columbia River basalt. However, later work proved these to be Pliocene in age.

Waring (1908, p. 23) also mentions a thick tuff unit in the mountains south of Paisley.

> This tuff, which is colored various shades of red and blue, has been mineralized to some extent by quartz and calcite. Towards its southern end considerable prospecting for gold has been done, and good values are reported to have been found in places.

Faults bounding the east and west sides of the Chewaucan Marsh were recognized by Russell (1883). The elongate depression formed by Summer Lake, Chewaucan Marsh, and Goose Lake Valley is a graben (Fuller and Waters, 1929). They believed this type of structure to be more common in southern Oregon than tilted fault blocks.

Donath (1962) found that the faults in the Summer Lake basin form a rhombic pattern. He postulated that this pattern resulted from a conjugate stike-slip shear. Later normal faults were controlled by these structues. He concluded that the major normal faulting commenced in pre-late Pliocene time.

Other geologists have worked in the Summer Lake-Chewaucan Marsh area. Shrock and Hunzicker (1935) studies the lake sediments in the basin and concluded that over 800 feet are present. Water wells drilled in the area have penetrated 200 feet of lake sediments. Allison (1945) studies pumice beds in Chewaucan Marsh and postulated their derivation from Mount Mazama. Quicksilver deposits on the western edge of Summer Lake were examined by Ross (1941). Lastly, Walker published a reconnaissance geologic map of the eastern half of the Klamath Falls (AMS) quadrangle.

GENERAL GEOLOGY

Stratigraphy

The rocks exposed in the thesis area range from pre-early Oligocene to Pleistocene in age. They consist of dacite flows, andesitic sedimentary, pyroclastic, and flow rocks, a small quartz monzonite diorite intrusive complex, andesite flows, rhyolite and dacite flows and plugs, and basalt flows and intrusives. In addition, there are Pleistocene lacustrine sediments and recent landslide deposits on the eastern border of the area.

Unconformities exist between almost all units. A major erosional unconformity exists between the dacite flows and overlying andesitic sedimentary, pyroclastic, and flow rocks. Relief on the old erosion surface is low to moderate. Younger andesite flows lie with angular unconformity on the older andesitic sedimentary, pyroclastic, and flow rocks. This unconformity is probably related to tilting and uplift caused by intrusion of the plutonic complex. Other minor unconformities exist, especially at the base of the youngest basalt flow.

Correlation of the local units with regional formations is difficult. The thick sequence of andesitic sedimentary, pyroclastic, and flow rocks probably correlates with part of the Oligocene-Miocene Cedarville Series exposed near Lakeview, Oregon, and will be referred to as the Cedarville Series. Walker (1963) suggests that this formation is a time equivalent of the John Day and Mascall Formations of central Oregon.

Dacite Flows

Definition, Distribution, and General Character

The dacite is composed of a thick sequence of flows. Appling (1950) divided this unit into a basal soda dacite member and an upper dacite member, but the writer did not make this distinction.

These flows are exposed along the eastern flank of the Paisley Mountains from approximately 1000 feet south of Jones Canyon to approximately one mile south of Johnson Canyon. Exposures are generally poor except along either side of Brattain Canyon and in several isolated hoodoo-like mounds that stand approximately 50 feet above the surrounding land surface. Basalt dikes that cut these mounds may have partly silicified the host rocks and made them more resistant to erosion.

The dacite flows usually form slopes of moderate relief. However, along the extreme eastern flank of the range the slopes are steeper because of faulting.

Jointing, partially flow jointing is well developed throughout the unit, and brecciation is extensive near the top. Combination of jointing and brecciation caused the rock to weather into small fragments that from long talus slopes at the base of many outcrops.

Stratigraphic Relation and Thickness

The dacite flows are only exposed in the northeastern part of the thesis area, but similar flows crop out in Clover Flat about three miles south of the area (Appling, 1950).

Attitudes are difficult to obtain because of poor exposures and jointing. The thickness is unknown because the base is not exposed. Exposures indicate that the unit is at least 2,000 to 2,600 feet thick. Appling (1950) indicated a combined thickness of 3000 feet for the soda dacite and dacite flows.

Lithology and Petrography

This unit is a thick sequence of dacite flows. Fresh surfaces are medium gray (N5) to light gray (N7) in color but weather to a yellowish-gray (5Y 8/1) or dark yellowish-brown (10YR 6/2).

Most of the flows are aphyric or only sparingly porphyritic, with a few phenocrysts of plagioclase over one millimeter in length. In thin section these rocks exhibit a hyalopilitic texture.

These rocks have been extensively altered. Plagioclase is the dominant mineral but no composition could be determined because of alteration. About 15 percent is present but some of this may be secondary. Chlorite and sericite are the major alteration minerals. According to Appling (1950, p. 19-24) all of the plagioclase is oligoclase or andesine, and both the soda dacite and dacite contain 20 percent quartz.

Age

The dacite flows are of unknown Tertiary age. They are believed to be pre-early Oligocene. No evidence of metamorphism is present to suggest a Mesozoic age.

Cedarville Series

Definition, Distribution, and General Character

This unit is a thick sequence of andesitic sedimentary and pyroclastic rocks with intercalated andesite flows. Walker (1963) correlated this unit in the Paisley Mountains with the lower part of the Cedarville Series exposed in the Warner Range in northeastern California.

This is the most extensively exposed unit in the thesis area. It forms the main mass of the Paisley Mountains but is not exposed in the western part of the thesis area because it is overlain by younger rocks. It typically forms gentle slopes and is not well exposed except in canyon and valley walls. The best exposures are in

Ennis, Jones and the upper part of Johnson Canyons.

The Cedarville Series consists mainly of andesitic graywackes, tuffaceous sandstones, mudstones, conglomerates, and breccias. A few andesite flows occur in the middle of the section and become increasingly more abundant toward the top. The Cedarville Series is characterized by variations in color which range from pale green (10G 6/2), greenish-gray (5G 6/1), grayish-purple (5P 4/2) to grayish-blue (5PB 5/2) with both sedimentary and tuffaceous units displaying considerable vertical and horizontal color variations. Grain size of the sedimentary rocks ranges from silt to large pebbles and occasionally boulders. The flows are dark gray to greenish-gray (5GY 4/1) in color and range from equigranular to porphyritic. The greenish coloration of many flows is caused by chlorite alteration.

Stratigraphic Relation and Thickness

The Cedarville Series is exposed throughout the entire eastern half of the thesis area. It unconformably overlies the dacite flows and is overlain with angular unconformity by younger andesite flows. The base of this unit is poorly exposed. The best exposure of the base is in the upper part of Johnson Canyon.

The thickness is variable but probably averages about 2500 feet. However, faulting may have cut out a part of the section. These rocks are in fault contact with the younger andesite flows along the western side of the Paisley Mountains. Relative movement along the fault has raised the Cedarville Series with respect to the andesite flows.

Lithology and Petrography

The Cedarville Series consists of a basal breccia, which grades upward into graywackes, sandstones and mudstones with interbedded conglomerates. Intercalated andesite flows are present in the middle and upper parts of the unit. In the uppermost part of the unit flows are the dominant rock type.

The basal breccia contains abundant fragments of the underlying dacite flows. The fragments are subangular in shape and range in size up to 12 inches in diameter. This unit grades upward into a greenish-gray graywacke that is typical of the lower part of the Cedarville Series. In Ennis Canyon the lowermost unit is a mudstone containing moderately abundant carbonized wood fragments. Above this fossiliferous zone are well exposed beds which are alternately greenish-gray and grayish-purple. Many of these beds display graded bedding containing very coarse sand-to silt-sized particles. Thin beds of conglomerate containing andesite clasts up to one and one half inches in diameter are interbedded with the finer-grained rocks. Andesite flows first appear in the lower middle part of the unit and become increasingly more abundant toward the top. These flows are usually less than 20 feet thick and range from non-porphyritic to almost porphyries.

In thin section the sedimentary rocks are composed mainly of subangular to rounded andesite fragments up to 2 mm in diameter set in a matrix of clay. A few samples contain abundant devitrified glass. These rocks are classified as graywackes and tuffaceous sandstones.

The flows exhibit a pilotaxitic texture with phenocrysts up to 1.5 mm. The dominant mineral is plagioclase (An_{42-54}) with andesine (An_{45}) most common. Orthoclase, possibly of secondary origin was found in some flows. Hornblende phenocrysts are present, most of which have been altered to clinochlore, penninite, and minor calcite. Several of the lowermost flows contain clots of penninite up to 5 mm long. Most of the flows have a greenish color because of abundant chlorite. Sample JM-124 (15,600E, 15,000N) contains about 35 percent chlorite.

Part of the sedimentary rocks have been extensively altered and bleached over large areas, especially on the north side of Ennis Canyon (17,000E, 5300N). This alteration is primarily quartz and sericite. There may have been minor sulfide minerals present because there is extensive limonite staining on these rocks.

Epidote is abundant in the lower part of this unit where replacement nodules up to four inches in diameter are found. Near

Johnson Canyon tourmaline is found on fracture surfaces. In the lowermost flows large irregular clots of chlorite attain a length of 2 cm. Toward the top of the unit quartz and calcite become abundant as fracture fillings and replacements. Both of these are euhedral crystals in cavities. At the head of Jones Canyon, the rock contains large euhedral crystals of natrolitie-pectolite up to 1.5 inches long.

Locally the Cedarville Series has been extensively mineralized along fractures. Lead, zinc and copper are the major metals, whereas gold and silver are minor. Their distribution and occurance will be discussed in detail later.

Age

Walker (1963) correlated this unit with the Cedarville Series of northeastern California. Similar rocks have been described by Peterson (1959) northwest of Lakeview and by Larson (1965) in the Drake Peak area. These rocks were assigned an early Miocene (Arikareean) age by Peterson (1959) on the basis of a rhinoceros tooth and plant fossils from the Warner Range.

In the thesis area, these rocks are older than an early Oligocene quartz monzonite (33.1 ± 1 m.y. by K-Ar) that has intruded the unit.

Although these rocks are older than the Cedarville Series elsewhere they have been assigned to this unit because of similar lithologies. Axelrod (1949) described a flora from the lower Cedarville as pre-Bridge Creek flora of the John Day Formation. The Bridge Creek flora has been dated at 31.1 to 31.5 m.y. (Baldwin, 1964).

Andesite Flows

Definition, Distribution, and General Character

A sequence of gray to brownish-gray andesite flows and breccias unconformably overlies rocks of the Cedarville Series in the western half of the thesis area. These rocks are usually poorly exposed and form gentle to moderate slopes. The best exposures occur along ridge crests and valley walls. Contacts between individual flows are very poorly exposed. The lithology varys horizontally and vertically. Many flows are extensive whereas others appear to be very local. These may represent either local outpourings of lava or erosional remnants. The breccias are thought to be locally derived.

Stratigraphic Relation and Thickness

The andesite flows lie with angular unconformity on the Cedarville Series. This angular unconformity probably reflects uplift and tilting related to intrusion of the plutonic complex. Part of the contact along the western side of the Paisley Mountains may be a fault.

The thickness of this unit is estimated to be 300 to 400 feet. The youngest lahar deposit is about 50 to 75 feet thick.

Lithology and Petrography

The andesite flows are variable in form, composition and color. The lower part of this unit is composed entirely of aphyric to porphyritic flows where as the upper part consists chiefly of laharic breccias. The flows range from basaltic andesite to hornblende andesite. On fresh surfaces the color is medium dark gray (N4), medium gray (N5), and brownish-gray (5YR 4/1) and light brownish-gray (5YR 6/1), pale yellowish-brown (10YR 6/2) and moderate reddish-brown (10R 4/6) on weathered surfaces.

In thin section these rocks exhibit pilotaxitic and less commonly hyalopilitic textures. The dominant mineral is plagioclase (An_{33-60}) with andesine (An_{45}) being the average composition. Many phenocrysts of plagioclase are zoned and are charged with glass blebs. Hornblende, olivine, biotite and augite comprise the mafic minerals and usually occur as phenocrysts. In most samples the mafic minerals have been partically to completely altered to chlorite, montmorillonite, magnetite, and iddingsite. Montmorillonite is abundant in many samples (Table 1). Sample JM-6 is an olivine-bearing andesite in which all olivine phenocrysts have been altered to saponite and iddingsite.

Many flows have been mineralized by calcite and quartz. These minerals generally occur as cavity fillings with calcite having been deposited prior to quartz. Many samples, especially chalcedony exhibit rhombic cavities from which calcite has been dissolved.

Table 1. Modal analyses of three andesites.

Mineral	JM-4[1]	JM-6[2]	JM 187[3]
Plagioclase	68.1	72.7	76.6
Hornblende	4.0	2.1	4.1
Augite	-	-	-
Olivine	-	5.0	-
Montmorillonite	18.4	11.6	8.3
Chlorite	-	0.6	4.2
Fe Oxides	7.5	8.0	5.1
	100.0	100.0	100.0

[1] Andesite (100E, 24,100N).

[2] Olivine-bearing andesite (1700E, 23,300N).

[3] Hornblende andesite (1200E, 2700N).

Age

The age of this unit is unknown but is assumed to be middle to late Miocene. Larson (1967, personal communication) described andesite flows in Coglan Buttes east of Chewaucan Marsh that appear to be similar to those in the Paisley Mountains. The flows in Coglan Buttes are overlain by the Steens Basalt of late Miocene age (14.6 m.y.) Moreover, Larson (1967, personal communication) has indicated that the Steens Basalt terminates against the Paisley Mountains and is not exposed on the western side of Chewaucan Marsh. Its absence suggests that the Paisley Mountains were high in late Miocene time.

Silicic Flows

Definition, Distribution, and General Character

This unit is composed of silicic flows and plugs of rhyolitic to dacitic composition and one thin welded tuff.

The silicic flows are exposed in the western half of the thesis area and also in the northeastern and southeastern parts of the Paisley Mountains. With the exception of plugs the outcrops are generally poor. Flows typically display gentle slopes whereas the plugs exhibit steeper slopes.

Most flows exhibit flow banding. Locally the jointing may be concentric or radial, similar to the jointing pattern of silicic domes and plugs. This jointing is best developed in the plug in the extreme north central part of the area (8800E, 24,000N). On the western side of this plug the jointing is almost vertical and approximately concentric with the outer margin. However, the attitude of joints become more horizontal to the east and suggests that the eastern part is possibly a flow.

The only locality where welded tuff crops out is in the extreme north-central part of the area (6200E, 25,000N). This tuff occupies the uppermost unit of the silicic flows. The outcrop measures approximately 2000 feet along strike and forms a ridge with steep slopes. The source vent for the welded tuff is thought to be north or west beyond the area mapped.

A silicic flow that has been altered and locally extensively brecciated is located in the southern part of the area (14,300E, 1600N). Traces of copper mineralization were found in an abandoned adit (14,300E, 1000N).

Stratigraphic Relation and Thickness

The silicic flows unconformably overlie the andesite flows and locally the Cedarville Series. This formation is believed to be local in origin because many outcrops display platy concentric and radial jointing that is common to silicic plugs and domes.

Thickness is variable and usually difficult to determine because of poor exposures. However, the unit is believed to be less than

300 feet thick. The uppermost welded tuff is about 75 feet thick.

Glassy basalt unconformably overlies the welded tuff. Elsewhere, the silicic flows are unconformably overlain either by basalt flows or by silicified rhyolite.

Lithology and Petrography

The silicic flows vary from rhyolite to dacite in composition with dacite the most common.

Color of fresh surfaces is pale grayish-red (5R 5/2) and pale red (5R 6/2). On weathered surfaces it is light brownish-gray (5YR 6/1) and pale red (10R 6/2).

Most samples exhibit flow banding that is poorly developed or indistinct. Weathering products also form liesegang rings that are commonly at angles to flow banding. The rings are well developed in many outcrops of the silicic plugs. They are usually moderate yellowish-brown suggestive of limonite staining. Excellent examples of this banding are displayed by the northernmost plug.

In thin section, many samples exhibit hyalopilitic and occasionally sub-pilotaxitic textures. Plagioclase is the dominant mineral with oligoclase, as phenocrysts most abundant. Some specimens contain subparallel plagioclase microlites that are usually more indicative of less silicic flows. Quartz is common in the groundmass, but rarely forms phenocrysts. Many samples are slightly altered and contain chlorite and clays.

The welded tuff is light gray (N7) on fresh surfaces and medium light gray (N6) on weathered surfaces. It is poorly welded with pumice fragments up to six inches in diameter. The pumice fragments are only slightly flattened.

Age

The age of the silicic flows is uncertain but is assumed to be late Miocene or early Pliocene based on stratagraphic position.

Basalt Flows and Intrusives

Definition, Distribution, and General Character

This unit is mainly composed of basalt flows and a few basalt plugs and dikes. All basalts with the exception of the youngest glassy flows were included in this unit regardless of composition, character, and possible differences in age.

These rocks are sporadically exposed throughout the Paisley Mountains, but the main masses crop out in the central and western parts of the thesis area. Individual flows could not be differentiated or traced laterally for any distance because of poor exposures. Their topographic expression varies: generally the larger flows form gentle to moderate slopes and smaller flows and dikes form ridges and hills.

The basalts range from non-porphyritic to porphyritic--in some instances almost porphyries. Dikes are generally more porphyritic than flows or plugs. A few flows are vesicular.

Stratigraphic Relation and Thickness

The basalts unconformably overlie and intrude all older units. The unconformities are generally indistinct and have little relief. The glassy basalt is the only unit that clearly overlies the basalt. However, the silicified rhyolite may overlie this basalt, but contact relations could not be determined from available exposures.

The thickness is variable and probably does not exceed 200 feet. Dikes attain a maximum thickness in excess of 50 feet but the majority are less than ten feet thick.

Lithology and Petrography

The color of these basalts on fresh surfaces is dark gray (N3), grayish-black (N2) and olive black (5Y 2/1), and grayish-red (10R 4/2) or pale yellowish-brown (10YR 6/2) on weathered surfaces.

Most of the basalt flows are non-vesicular and vary from non-porphyritic to nearly porphyries. Some phenocrysts of plagioclase are 1 cm long, but the average size is about 0.7 mm.

In thin section most rocks exhibit an intergranular porphyritic texture, but some approach a pliotaxitic texture. The dominant mineral is plagioclase (An_{35-65}) with labradorite (An_{55}) being most abundant. Many of the large phenocrysts of plagioclase have been partially resorbed and are charged with glass particles (Fig. 2). Clinopyroxenes are abundant as anhedral grains in the groundmass and as rare phenocrysts. Olivine is also present both as phenocrysts and in the groundmass. Much of the olivine has been altered to montmorillonite, iddingsite, and mangetite. Chlorophaeite is common in a few samples as vesicle fillings and as interstitial grains in the groundmass. Secondary magnetite is moderately abundant in most samples. Minor calcite is found as an alteration product of mafic minerals (Table 2).

In sample JM-34 saponite forms euhedral pseudomorphs after olivine (Fig. 3). These pseudomorphs show embayed boundaries which indicate that the olivine was not in equilibrium during the cooling stages. In samples JM-51 and JM-77 nontronite is also present and in JM-77 it is the dominant clay.

Chemically, these basalts are high alumina basalts characteristic of the Oregon Plateaus (Table 3).

Age

The ages of basalt dikes and flows are unknown and probably cover a moderate range in time. The bulk of the flows are believed

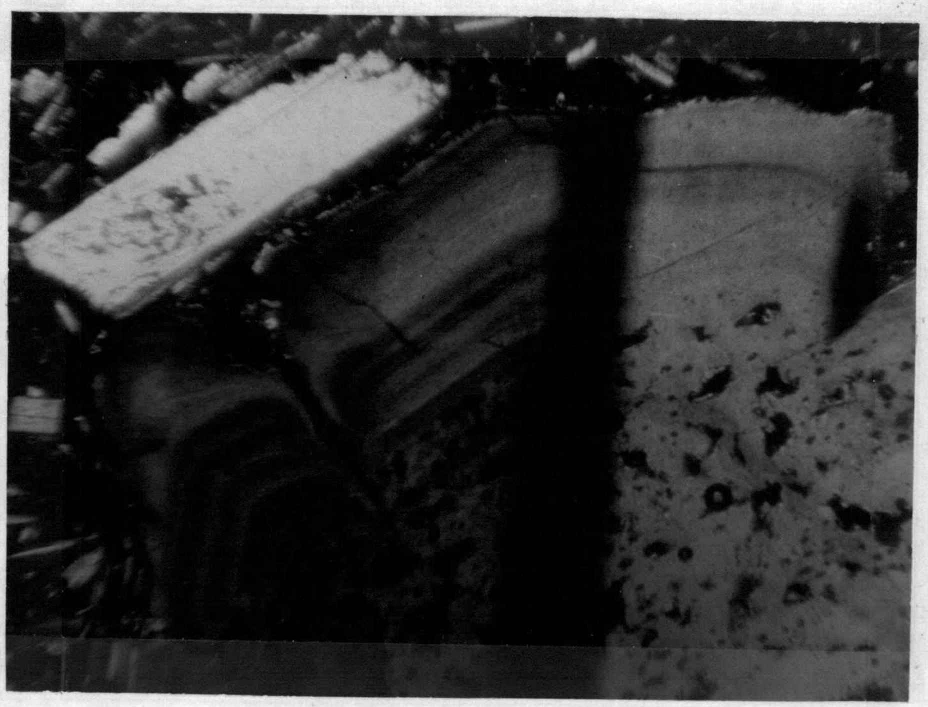

Figure 2. Photomicrograph of a zoned plagioclase phenocryst which has been embayed. (Crossed Nicols, x120).

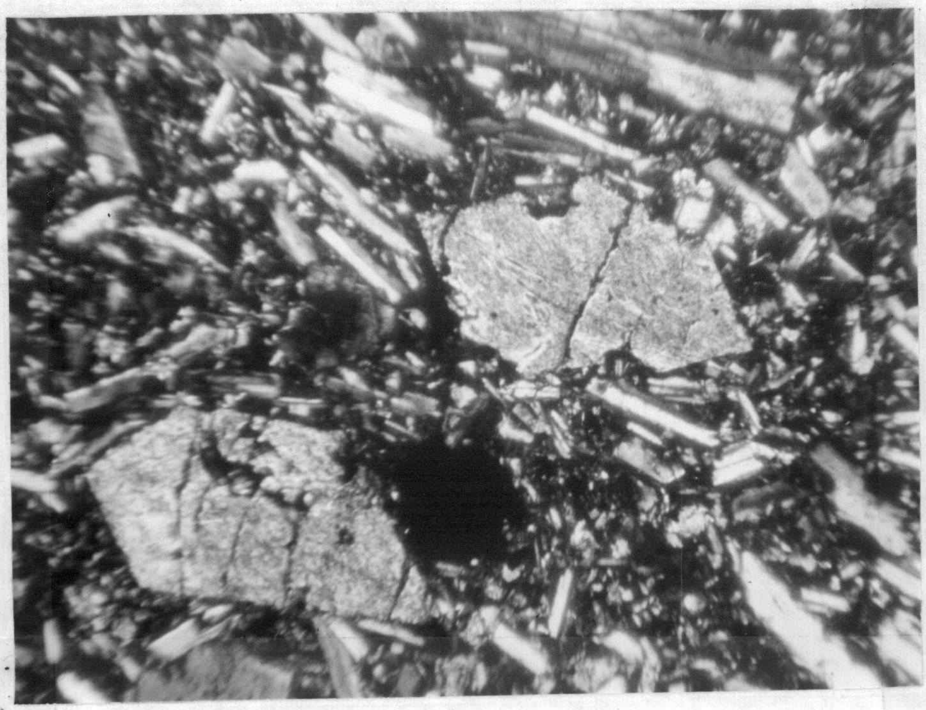

Figure 3. Photomicrograph of saponite pseudomorphs after olivine. Note embayment of boundaries. (Crossed Nicols, x120).

Table 2. Modal analyses of three basalts.

Mineral	JM-34[1]	JM-51[2]	JM-77[3]
Plagioclase	67.4	64.9	62.1
Clinopyroxene	9.0	9.3	12.6
Olivine	6.6	11.8	7.1
Magnetite	5.0	3.0	7.5
Montmorillonite	7.6	11.0	10.7
Chlorophaeite	4.4	-	-
	100.0	100.0	100.0

[1] (1500E, 24,300N).

[2] (12,200E, 22,600N).

[3] (9200E, 12,900N).

Table 3. Chemical and trace element analyses of sample JM-34[1] (analyst, K. Aoki, Tohoku University and Rocky Mountain Geochemical Corporation).

Compound	Percent	Element	ppm
SiO_2	52.81	Copper	130
TiO_2	1.42	Zinc	105
Al_2O_3	18.71	Lead	20
Fe_2O_3	4.30	Molybdenum	4
FeO	3.54		
MnO	0.17		
MgO	2.55		
CaO	7.58		
Na_2O	3.76		
K_2O	1.93		
H_2O+	1.15		
H_2O-	1.43		
P_2O_5	0.51		
	99.86		

[1] (1500E, 24,300N).

to be Pliocene in age whereas a few dikes may be older.

Rhyolite Plugs

Definition, Distribution, and General Character

Two separate rhyolite plugs, similar in composition and appearance, comprise this unit. They are considered to be partly intrusive and partly extrusive.

The plugs crop out in the south-central part of the thesis area. The main body of the southernmost plug lies beyond the area mapped. They form conical shaped hills that are characterized by steep slopes. Slopes are covered with scree and outcrops are infrequent.

The rhyolite plugs are platy and flow banding is well developed. Platyness is caused in part by jointing and separation along flow bands. Obsidian is present in large quantities. Usually it occurs as alternate layers in flow banded rhyolite.

Joint and flow banding patterns are usually vertical and concentric. The attitudes are similar to that typically displayed by most silicic domes and plugs. Locally flow banding is more or less horizontal. Such attitudes are common to flows or the interior of domes.

Country rocks adjacent to the southern plug have undergone mild contact metamorphism. Andesite flows have been discolored or bleached near the contacts. Outcrops (6800E, 300N) colored medium gray prior to metamorphism, are grayish-red (5R 4/2) to dusky red (5R 3/4). This change in color is probably caused by alteration of mafic minerals.

Stratigraphic Relation

The rhyolite plugs are intruded into the older rocks including the silicic flows. The exact nature of the contacts is unknown because of poor exposures. The silicified rhyolite may unconformably overlie the northern plug, but contact relations could not be determined. No other rocks overlie the rhyolite plugs.

Lithology and Petrography

On fresh surfaces this unit is uniformly light brownish-gray (5YR 6/1) whereas on weathered surfaces it is pale red (5R 6/2).

Most samples exhibit flow banding and laminae may be one-eighth inch or less in thickness. Obsidian commonly alternates with crystalline material in the flow bands. Many samples also show numerous small spherulites, up to one-fourth inch in diameter, that interrupt the flow banding.

In thin section this rhyolite exhibits a hyalopilitic texture. Phenocrysts of oligoclase are sparingly present. The groundmass contains many small euhedral crystals of feldspar. Their composition could not be determined because few are twinned. However, it is believed that sanadine, with possibly minor albite, is the principle constituent. Quartz is abundant both in the groundmass and as aperulites up to one millimeter in diameter.

Age

The age of this unit is unknown but is probably late Pliocene.

Silicified Rhyolite

Definition, Distribution, and General Character

The silicified rhyolite unit is a flow, probably originally rhyolite, that has undergone extensive secondary silicification. At many localities this unit has been totally replaced by silica.

This unit is only exposed in the west-central part of the area. It commonly forms ridge caps or gentle slopes that may represent original dips. Outcrops are generally good. Locally the presence of silicified rhyolite as prominent ridges in relatively flat terrain suggests feeder dikes for the flow or silicifying fluids.

Stratigraphic Relation and Thickness

In most places the silicified rhyolite unconformably overlies the silicic and andesite flows. The relief on this unconformity is gentle and slopes to the west. No rocks overlie this unit.

Silicified rhyolite dikes are intruded into the andesite flows and along the contact between the andesite flows and the Cedarville Series (6300E, 16,600N).

The maximum thickness of the flow is probably about 150 feet at (6700E, 11,200N) which is believed to be the main source area for the flow. The unit thins rapidly from this location and elsewhere its thickness averages less than 50 feet.

Lithology and Petrography

This unit is a very dense secondarily silicified flow that ranges in color from dark gray (N3) and medium gray (N5) to white (N9) on fresh surfaces. The usual weathered surfaces are light brown (5YR 5/6), dark yellowish-orange (10YR 6/6), and dark reddish-brown (10R 3/4) in color.

The range in color in the fresh samples is thought to be a result of weathering or possibly deuteric alteration of finely disseminated pyrite that is found only in the dark samples. Many of the dark samples have rims of white at the surface and white on either side of fractures. Much of the yellow-brown and red color is probably caused by limonite and hematite staining. Some samples have iridescent red and blue staining which is believed to be an iron product. Locally malachite staining is present. Weathering often causes this unit to appear quite clayey and soft.

In most samples replacement by silica is complete. Many samples show outlines of plagioclase phenocrysts that have been preserved. In one outcrop very thinly laminated flow banding is preserved with small veinlets of quartz cutting the sample.

Drusy quartz, containing some crystals up to one-fourth inch in diameter are found in cavities and along fractures. Finely disseminated pyrite is found in many dark samples.

In thin section the texture is aplitic, with quartz being the major mineral. Axiolitic structures are present in some of the samples. The quartz replaces all feldspars, in some cases leaving outlines of plagioclase phenocrysts. Pyrite and magnetite are also present. Much of the pyrite occurs along plagioclase ghost boundaries. There may be some clay minerals, but they were not differentiated. All fractures are filled with small anhedral quartz grains with the exception of a few larger ones in which euhedral quartz crystals have formed perpendicular to the fracture walls. Study of the very thinly laminated, flow banded sample revealed that pyrite and magnetite are concentrated in the laminae. Some chalcopyrite must be present as indicated by the malachite staining on some samples.

Age

The age of this unit is unknown. Since it is not clearly overlain by any rocks, it may be the youngest rock in the area. However, contacts are too poorly exposed to determine if any of the basalt flows overlie this unit. A Pliocene or Pleistocene age is assumed for this unit.

Glassy Basalt

Definition, Distribution, and General Character

This unit is composed of several flows, most of which are glassy and almost all are vesicular. The glassy basalt is only exposed in the northwestern part of the area but it extends to the north beyond the area mapped an unknown distance.

The best exposures are on isolated hills and along ridge crests. Outcrops generally consist of large blocks as much as 20 feet in diameter. Most of the gentler slopes are covered with a pavement of cobbles and boulders.

In a few places, the basalt is grayish-red (5R 4/2) to moderate red (5R 5/4) breccia. Fragment are rounded and vesicular with cavities filled with calcite and probably zeolites. These breccias are interpreted to be either vents, usually small and none over 200 feet in diameter, or the breccia zone at the base of a flow. The best example of this breccia crops out on the southwestern flank of a small hill (5300E, 21,900N) that is almost surrounded by older basalt. The breccia grades downslope into a more massive flow rock.

This unit is characterized by the breccias which are grayish to moderate red in color and flows that are medium gray (N5) to dark gray (N3) in color. All are markedly vesicular. The flows are thin and conformable to the old topographic surface and typically contain visible glass.

Stratigraphic Relation and Thickness

The glassy basalt flows unconformably overlie older units. This unconformity is distinct and has appreciable relief.

The unit ranges from 100 to 200 feet in thickness. Individual flows do not exceed 30 feet in thickness and probably flowed only short distances from their source.

Lithology and Petrography

The flows are typically vesicular and porphyritic. Vesicles may be as large as 25 mm in diameter but their average size is less than 5 mm. Phenocrysts may comprise up to 25 percent of the basalt. The flows may also contain blebs of glass up to 2 mm in diameter.

In thin section the rock exhibits an intergranular porphyritic texture with phenocrysts of plagioclase feldspar and olivine up to 2 mm in diameter. The plagioclase composition ranges from An_{45} to An_{60} with labradorite (An_{56}) the dominant composition. Clinopyroxene is present as anhedral grains in the groundmass. Iron oxide is abundant and occurs both in the groundmass and rimming mafic minerals. Although glass is nearly absent in the sample studied (Table 4), Appling (1950, p. 35) states that, "Examination of thin sections of this rock prove of little value because of the vitreous texture".

Chemically this rock is a high alumina basalt characteristic of the Oregon Plateaus (Table 4).

Age

The glassy basalt is probably the youngest rock in the thesis area. Although no definite age can be assigned to these flows they are believed to be Pleistocene in age.

Unconsolidated Quaternary Deposits

Quaternary deposits are limited to the eastern margin of the thesis area and major stream valleys. Most of those along the eastern margin are Pleistocene lacustrine deposits which merge with alluvial fan deposits at the base of the Paisley Mountains. Landslide deposits are locally present along the eastern flank of the range.

Pleistocene Lacustrine Deposits

Pleistocene lacustrine deposits occupy most of the eastern margin of the thesis area. They were not studied in detail. Shrock

Table 4. Modal and chemical analyses of glassy basalt sample JM-7[1] (Chemical analyses by K. Aoki, Tohoku University and Rocky Mountain Geochemical Corporation).

Modal Analysis		Chemical Analyses	
Mineral	Percent	Compound	Percent
Plagioclase	67.5	SiO_2	49.12
Clinopyroxene	12.9	TiO_2	1.70
Olivine	6.5	Al_2O_3	17.37
Magnetite	5.1	Fe_2O_3	6.28
Vesicles	7.4	FeO	4.15
Glass	0.6	MnO	0.28
	100.0	MgO	6.15
		CaO	8.93
		Na_2O	3.36
		K_2O	0.97
		H_2O+	1.04
		H_2O-	0.27
		P_2O_5	0.50
			100.12

Trace Element Analysis	
Element	ppm
Copper	70
Zinc	85
Lead	20
Molybdenum	2

[1] (1000E, 21,700N).

and Hunzicker (1935) estimated their thickness to be about 800 feet in this area. However, Appling (1950) states that a water well was drilled to a depth of 2000 feet before bedrock was encountered.

Landslide Deposits

Locally extensive landslide deposits are found along the eastern flank of the Paisley Mountains. The largest of these is one-half mile south of Johnson Canyon. Smaller deposits occur both to the north and south. Many rocks exposed near Johnson Canyon show anomalous dips indicative of landslide but physical features could not be found to corroborate this movement. Many veins in this area are nearly horizontal because of either creep or drag during landslide.

Stream Alluvium

All major stream valleys including Jones, Brattain, Johnson, and Ennis Creeks contain alluvium. Alluvial fans are common along the eastern base of the Paisley Mountains.

Plutonic Rocks

Introduction

Plutonic rocks in the thesis area were found only recently and have not been described previously. Lithologies include diorite, grandoiorite and quartz monzonite as stocks and dikes. Part of the granodiorite is quartz deficient and part is orthoclase rich.

These plutonic rocks intrude both the dacite flows and the Cedarville Series. A K-Ar age determination of the quartz monzonite provides an average age of 33.1 $\pm$1 m.y. that is late early Oligocene (Funnell, 1964).

The plutonic complex occurs near the interpolated quartz diorite line of Moore (1959).

Definition, Distribution, and General Character

The plutonic rocks are sporadically exposed along the eastern flank of the Paisley Mountains from just south of Brattain Canyon (15,300E, 20,300N) to the mountain south of Ennis Butte (15,300E, 1400N). The largest stock is about 1500 feet by 2500 feet. Plutonic rocks rarely form bold outcrops but exposures are generally good. In most areas color contrast is not great and from a distance the plutonic rocks appear to be similar to the surrounding dacites and andesites.

Plutonic rocks that comprise the stocks are medium grained, largely equigranular, and have an average grain size of 1.0 mm. Rocks from dikes and smaller bodies are finer grained and porphyritic with phenocrysts of plagioclase up to 5 mm long.

Contacts are sharp, but chilled borders are usually narrow or absent. The diorite stock has a chilled border of fine-grained granodiorite and minor quartz monzonite (Table 6). Quartz and potassium feldspar are greatly increased in the marginal phase of this stock. This more silicic margin is tenatively attributed to fluids rich in silica and potash that migrated to the cooler contacts because of a thermal gradient. At the contact, the host rock contains abundant anhedral quartz and orthoclase crystals characterized by numerous inclusions. The quartz monzonite stock has a diorite chilled margin. Country rocks are rarely strongly deformed at the contact.

Petrography

Major rock types of the plutonic complex, in order of decreasing abundance are diorite, granodiorite, and quartz monzonite. The diorite is the oldest phase of the complex and quartz monzonite is the youngest.

Diorite. Most of the diorite occurs as dikes and small bodies. However, the largest outcrop of diorite forms the core of the largest stack (16,200E, 19,400N) (Table 6).

Color, texture, and grain size vary considerably and appear to be dependent on the size of the outcrop. The color on fresh surfaces is greenish-gray (5G 6/1), grayish-green (5G 5/2) and pale yellowish-green (100GY 7/2), with darker samples found in dikes. The green color is caused by chlorite which has altered from mafic minerals.

Many diorite dikes are porphyritic, with phenocrysts comprising as much as 25 percent in a few samples. Plagioclase phenocrysts may be up to 5 mm long.

In thin section, the diorite commonly displays porphyritic textures, but hypidiomorphic granular textures are also present. Plagioclase (An_{34-50}) is the most abundant mineral with andesine (An_{43}) being the average composition. Many plagioclase grains are intensely fractured and sheared which suggest that the magma was a crystal mush when emplaced (Fig. 4). Plagioclase grains are often zoned and many have an outer rim clouded with clay minerals and glass blebs. Orthoclase is present part of which is microperthite. Hornblende is the most abundant primary mafic mineral. In the southernmost stock biotite is more abundant than hornblende. Iron oxides, mainly magnetite, occurs in varying amounts up to 6.5 percent, part of which is secondary after mafic minerals. Trace amounts of zircon and apatite comprise the minor accessory minerals (Table 5).

The mafic minerals have been deuterically altered to clinochlore, penninite, magnetite, and minor calcite. Clinochlore and penninite are the most abundant alteration minerals, and commonly are present in sub-equal amounts. Sericite and calcite are alteration products of plagioclase. Minor amounts of epidote and montmorillonite are also present.

Figure 4. Photomicrograph of plagioclase phenocryst exhibiting fracturing caused during intrusion (Crossed Nicols, x100).

Table 5. Modal analyses of four diorite samples.

Mineral	JM-126[1]	JM-147[2]	JM-217[3]	JM-257a[4]
Plagioclase	63.0	54.1	55.7	69.8
Orthoclase	7.4	14.4	4.4	3.0
Quartz	4.5	4.2	4.9	4.3
Hornblende	6.1	2.4	-	3.5
Biotite	-	-	-	5.8
Clinochlore	8.9	3.8	-	5.3
Penninite	6.6	10.5	11.3	-
Magnetite	1.1	3.0	3.4	6.5
Calcite	-	1.1	9.0	-
Sericite	1.8	2.2	11.3	3.5
Epidote	-	4.3	-	-
Accessory	0.7	T	T	0.3
	100.0	100.0	100.0	100.0

[1] (16, 100E, 15, 400N).

[2] (14, 300E, 8800N).

[3] (18, 200E, 2800N).

[4] (15, 000E, 1400N).

Table 6. Modal analyses of three samples from the large diorite stock (16, 200E, 19, 400N).

Mineral	JM-63e[1]	JM-63a[2]	JM-63b[3]
Plagioclase	50.9	52.9	30.3
Orthoclase	11.0	17.7	32.3
Quartz	7.1	18.1	31.9
Hornblende	6.5	0.6	2.0
Biotite	-	0.8	-
Clinochlore	11.6	6.9	2.0
Penninite	5.5	1.5	-
Magnetite	4.5	1.5	1.5
Sericite	2.9	-	-
Accessory	T	T	T
	100.0	100.0	100.0

[1] Quartz-bearing diorite from center of stock (16, 200E, 19, 000N).

[2] Granodiorite from contact with dacite flow (15, 400E, 20, 100N).

[3] Quartz monzonite from near contact (15, 400E, 20, 100N).

Table 7. Chemical analyses of sample JM-63e[1] (analyst K. Aoki, Tohoku University and Rocky Mountain Geochemical Corporation).

Compound	Percent	Element	ppm
SiO_2	57.12	Copper	40
TiO_2	1.00	Lead	10
Al_2O_3	17.99	Zinc	65
Fe_2O_3	3.61	Molybdenum	1
FeO	3.49		
MnO	0.16		
MgO	3.02		
CaO	5.23		
Na_2O	3.94		
K_2O	1.97		
H_2O+	1.78		
H_2O-	0.10		
P_2O_5	0.32		
	99.73		

[1] Quartz-bearing diorite (16,200E, 19,400N).

Granodiorite. Granodiorite usually occurs in stocks and less commonly in smaller bodies and in dikes.

On fresh surfaces the granodiorite is light greenish-gray (5GY 8/1), medium greenish-gray (5G 5/1) and pale yellow green (10GY 7/2). Most samples are sparingly porphyritic, although equigranular textures are present. Average grain size is 0.8 - 1.0 mm with phenocrysts up to 5 mm long. Most of the mafic minerals have been deuterically altered to chlorite. Epidote is locally present.

In thin section the samples are sparingly porphyritic with a hypidiomorphic granular groundmass. Plagioclase (An_{31-55}) is the dominant mineral with andesine (An_{39}) the most common composition. Many plagioclase grains are fractured and sheared indicating that they were crystalline when intruded. Grain boundaries are embayed which suggest that plagioclase was not in equilibrium during cooling. Orthoclase is present both interstitially and partly replacing plagioclase. Quartz is mainly interstitial but also may occur as micrographic intergrowths with orthoclase. Hornblende and biotite comprise the mafic minerals. They have been altered to clinochlore, penninite, magnetite, and minor calcite. Sericite is a common alteration product after plagioclase. Part of the iron oxide present is a deuteric alteration product of mafic minerals. Minor accessory minerals include apatite and zircon. Minor epidote is present both as replacements of plagioclase and mafics and as veinlets.

Table 8. Modal analyses of two granodiorite samples.

Mineral	JM-151[1]	JM-276[2]
Plagioclase	53.5	57.1
Orthoclase	10.6	17.5
Quartz	12.0	10.1
Hornblende	2.6	5.2
Chlorite	8.2	7.5
Magnetite	3.8	-
Sericite	3.8	-
Calcite	3.2	-
Epidote	2.3	-
Accessory	T	T
	100.0	100.0

[1] (16,100E, 8600N).

[2] (16,100E, 11,600N).

Quartz monzonite. The quartz monzonite is the youngest plutonic rock and comprises two stocks in the central part of the complex. The larger stock forms part of the south wall of Johnson Canyon. A quartz monzonite phase was found along the chilled margin of the diorite stock south of Brattain Canyon (Table 6).

Color on fresh surfaces is light greenish-gray (5G 8/1) and pinkish-gray (5YR 8/1). Quartz monzonite of the large stock is medium grained with average grain size of 1.5 mm and some grains up to 4 mm long. A chilled margin of diorite exists around one small stock of quartz monzonite (16, 800E, 12, 100N) with an average grain size of 0.5 mm. Biotite and hornblende have been partially altered to chlorite. Tourmaline is present near zones of hydrothermal alteration and in a breccia dike.

In thin section the quartz monzonite exhibits a hypidiomorphic granular texture. Plagioclase (An_{27-43}) is the most abundant mineral with andesine (An_{33}) being most common. Many of the grains are fractured which suggests that the magma was a crystal mush when emplaced. The orthoclase content is usually approximately equal to that of plagioclase. Much orthoclase is microperthitic and it commonly replaces plagioclase. Crystals of plagioclase and orthoclase are commonly rimmed with micrographic intergrowths of orthoclase and quartz. Quartz occurs as interstitial fillings and as micrographic intergrowths. Hornblende and biotite are the mafic minerals. The mafics are typically altered to clinochlore and magnetite, and plagioclase is slightly altered to sericite. Minor accessory minerals include apatite and zircon (Table 9).

Origin and Mode of Emplacement

The plutonic complex in the Paisley Mountains is thought to be of local origin. The nearest Tertiary plutonic intrusion is 120 miles to the west in the Cascade Range.

Table 9. Modal and chemical analyses of JM-291[1] (analyst K. Aoki, Tohoku University and Rocky Mountain Geochemical Corporation).

Mineral	Percent	Compound	Percent
Plagioclase	37.8	SiO_2-	60.40
Orthoclase	22.0	TiO_2	0.79
Quartz	8.5	Al_2O_3	17.19
Micrographic Intergrowths	10.0	Fe_2O_3	2.88
Hornblende	4.0	FeO	2.38
Biotite	2.9	MnO	0.15
Chlorite	11.5	MgO	2.48
Magnetite	2.3	CaO	4.29
Sericite	1.0	Na_2O	4.20
Accessory	T	K_2O	3.08
	100.0	H_2O+	1.51
		H_2O-	0.19
		P_2O_5	0.20
			99.74

Trace Element Analysis

Element	ppm
Copper	85
Lead	20
Zinc	70
Molybdenum	1

[1] (15,900E, 13,200N).

The ages of the intrusive rocks in the western Cascade Range are 35 ±10 m. y. and 25 ±10 m. y. respectively for the Nimrod quartz monzonite and the granodiorite stock near Detroit, Oregon. These dates are based on lead-alpha determinations of zircon (Peck, et. al., 1964).

Chemical compositions of the Paisley Mountains complex and the western Cascade Range rocks are slightly different (Table 10). The Paisley Mountains rocks are generally higher in Al_2O_3 and K_2O and lower in FeO, MgO, CaO, and Na_2O. If the Paisley Mountains complex and the plutonic rocks of the western Cascade Range are of similar age, the chemical differences are best explained as a consequence of separate magmas or sources.

The Paisley Mountains are believed to be a volcanic center (Larson, 1967, personal communication). If this is the case, the plutonic complex may be related to volcanism. Both Bouguer and free air gravity anomaly maps (Berg and Thiruvathukal, 1967) show a closed positive anomaly of about 15 milligals in the general area. Assuming a density contrast of 0.1 gm/cc between the plutonic and host rocks, this gravity anomaly suggests that the plutonic mass extends to a depth of three to four kilometers (Heinrichs and Couch, 1968, personal communication).

The plutonic complex is wholly discordant and was emplaced by moderately forceful intrusion in the epizone (Buddington, 1959).

Table 10. Comparison of chemical analyses of plutonic samples from the Paisley Mountains and the Western Cascade Range.[1]

Compound	JM-63e	JM-291	3
SiO_2	57.12	60.40	52.67
TiO_2	1.00	0.79	1.13
Al_2O_3	17.99	17.19	17.36
Fe_2O_3	3.61	2.88	3.37
FeO	3.49	2.38	5.14
MnO	0.16	0.15	0.17
MgO	3.02	2.48	5.06
CaO	5.23	4.29	8.80
Na_2O	3.94	4.20	3.06
K_2O	1.97	3.08	0.73
H_2O+	1.78	1.51	2.15
H_2O-	0.10	0.19	0.18
P_2O_5	0.32	0.20	0.29
	99.73	99.74	100.11

[1] Data obtained from (Peck, et. al., 1964, p. 44-46).

JM-63e Quartz-bearing diorite (16,200E, 19,400N) K. Aoki, analyst.

JM-291 Quartz monzonite (15,900E, 13,200N) K. Aoki, analyst.

3 Augite diorite; collected from small plug 1/2 mile west of the Peakaboo mine, in sec. 14, T. 23 S., R. 1 E., Bohemia District (Buddington and Callaghan, 1936, p. 427-428, col. 1).

Table 10 continued.

Compound	4	5	6
SiO_2	59.70	65.71	71.57
TiO_2	1.13	0.81	-
Al_2O_3	15.53	14.29	13.55
Fe_2O_3	3.57	2.44	1.55
FeO	4.07	2.85	2.28
MnO	0.18	0.18	0.03
MgO	3.16	2.15	0.53
CaO	6.17	4.13	1.52
Na_2O	3.65	3.55	4.75
K_2O	1.34	2.42	4.09
H_2O+	0.98	0.82	0.13
H_2O-	0.03	0.11	0.20
P_2O_5	0.25	0.20	0.03
	99.75	99.66	100.05

4 Augite quartz diorite; collected from porphyritic border facies of small stock on the Champion Trail 1600 feet north of Golden Curry Creek, in sec. 1, T. 23 S., R. 1 E., Bohemia District (Buddington and Callaghan, 1936, p. 427-428: col. 2).

5 Augite granodiorite; collected from small stock on Champion Creek road at first creek crossing of Golden Curry Creek in sec. 36, T. 22 S., R. 1 E., Bohemia District (ibid., col. 6).

6 Granite; collected from stock at Nimrod, McKenzie River (ibid., col. 8).

The Cedarville Series has been domed, and veins are radically distributed within this unit suggesting that the doming was caused by intrusion of the plutonic complex. These structural considerations will be discussed in detail later. A few xenoliths of country rocks and early plutonic rocks are found near contacts of the stock.

Characteristics of plutons of the epizone are: 1) composite character caused by a series of magma emplacements of diverse composition, 2) homophanous without lineation or foliation, 3) relatively unmetamorphosed country rocks, 4) zoning of associated mineral veins on a regional scale, and 5) earlier members of complex plutons show chill zones against country rocks. All of these criteria apply to the complex in the Paisley Mountains. Lack of contact metamorphism and structural deformation of the rocks at the contact indicate that many plutons of the epizone have been emplaced as highly viscous magmas at relatively low temperatures ($<600^{\circ}$ C) (Buddington, 1959).

Age

The age of the larger quartz monzonite stock was radiometrically determined by Prof. R. L. Armstrong of Yale University. Ages of 32.6 $\pm$0.7 m.y. and 33.6 $\pm$1.5 m.y., were obtained for the biotite and hornblende concentrates respectively (Table 11). These concordant ages place intrusion of the quartz monzonite in late early Oligocene (Funnell, 1964).

Table 11. Age determination data for biotite and hornblende from sample JM-291[1] (Analyst, R. L. Armstrong, Yale University).

	%K	Ar x 10^{-6}cc	%Air	Age
Biotite	5.54	7.23	50	32.6 ±0.7 m.y.
	5.45	7.23	43	
Hornblende	1.27	1.71	71	33.6 ±1.5 m.y.

[1] Quartz monzonite (15,900E, 13,200N).

STRUCTURE

The Paisley Mountains comprise a small range in the Basin and Range Province. The main mass of these mountains is a horst bounded by two approximately parallel faults. The eastern fault strikes approximately N 20°W and forms the boundary to the range. The western fault of the horst is in the west-central part of the thesis area and strikes approximately N 25°W and dips approximately 30°W. Part of the western fault forms a structural contact between the Cedarville Series and younger rocks.

Chewaucan Marsh occupies a graben to the east of the Paisley Mountains. Fuller and Waters (1929) were the first to recognize this depression as a graben. Appling (1950) considers this graben to have originated as a result of keystone faulting during upfolding.

Faults are the predominant structural feature of the thesis area. Most have a northwesterly strike, with only one northeasterly striking fault recognized in the area. Northeasterly striking faults are found both north and south of the area (Walker, 1963). Additional faults may have been overlooked because of poor exposures, lack of distinct marker beds and limited displacements.

Landslides caused by oversteepening of slopes as a consequence of faulting occur along the eastern flank of the range. Their presence was inferred from aerial photographs, hummocky terrain and locally anomalous dips.

Folds are a minor structural feature in the area. An asymmetrical structural dome exists in the dacite flows and Cedarville Series. Dips along the margins of the dome are variable: up to 50° on the north side, up to 35° on the west side, but only 5° to 15° on the south side. This dome has been modified by later Basin and Range faulting and tilting which with subsequent erosion is responsible for its exposure at the surface. Small drag folds are found associated with some faults.

Veins in the Cedarville Series are fracture controlled. They display an imperfect radial distribution (Fig. 5) that suggest that these fractures are related to the doming. Wisser (1960) states that mineral deposits commonly occur in domes that may be related to intrusion of plutonic masses. Tension fractures are produced by uplift and continue to form until uplift or expansion of the crust ceases. At this stage graben and antithetic faulting may occur. Mineralizing fluids generally enter the deformed structure after emplacement of the last intrusive phase. The fluids may also be responsible for additional limited expansion.

Thus, doming and related mineral deposits appear to have formed by intrusion of the plutonic complex into the dacite flows and Cedarville Series.

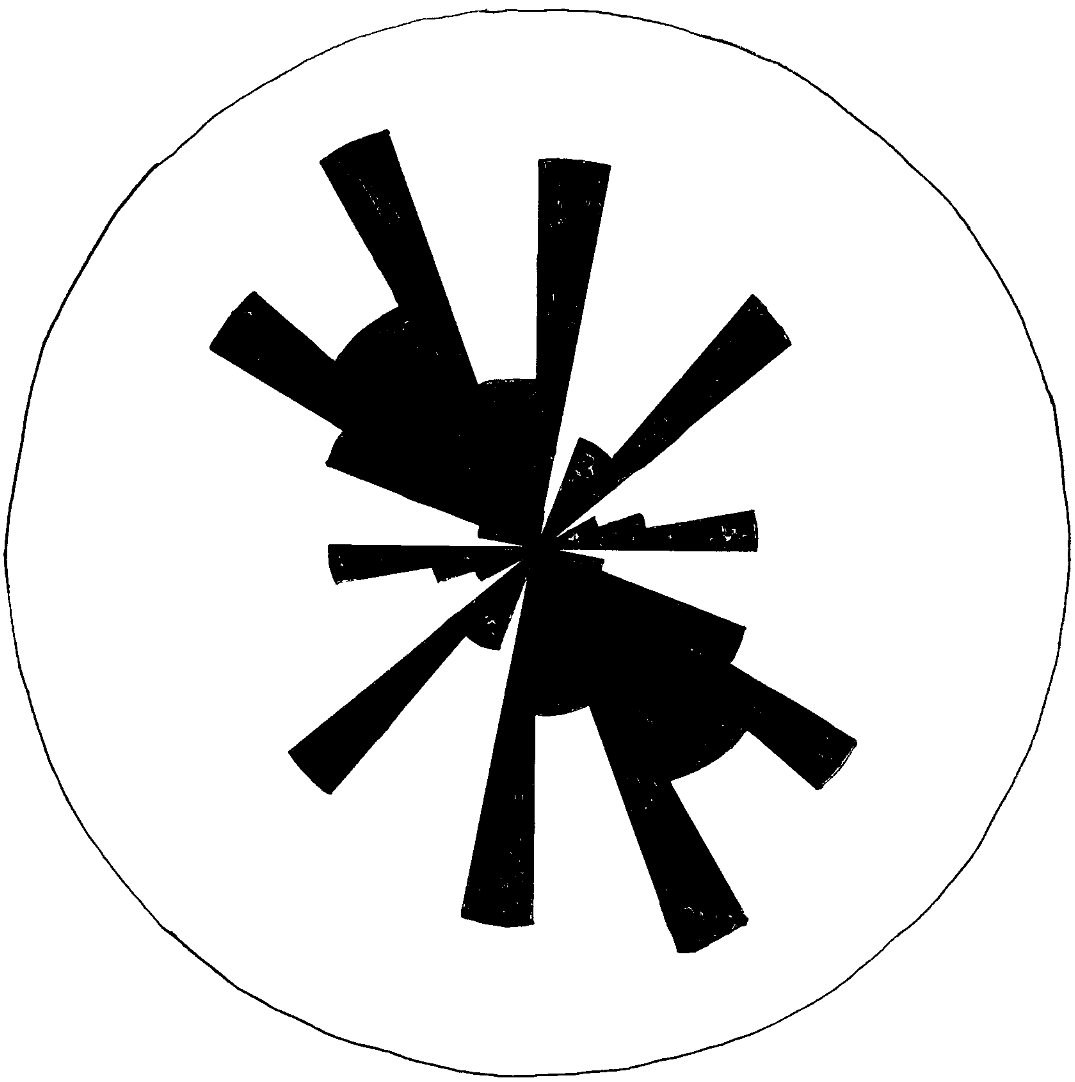

Figure 5. Diagram showing orientation of veins in the Cedarville Series (based on 58 attitudes).

MINERAL DEPOSITS

History and Development

Mineralization in the Paisley Mountains was first reported in 1875 by a member of an army patrol who found traces of gold in stream gravels on the eastern side of the mountains. This report brought prospectors in search of gold to the area. Several shafts, most of which are now caved were dug. Lead and zinc were not mined until later when a Rev. Gaylord excavated the tunnel that bears his name. He also dug three or four shafts in search of gold.

Location and accessment work constitute the only development in this area since Rev. Gaylord ceased operations. However, lode claims were recently optioned to The Hanna Mining Company but results of their exploration program have not been released.

Description

Both disseminated and cavity filling deposits occur in the Brattain District. The latter are by far most common.

Disseminated mineralization is restricted to the plutonic rocks and is best developed in the large quartz monzonite stock along the south side of Johnson Canyon. The only recognizable mineral in this deposit is pyrite and it is sparingly present.

A breccia dike is localized in the quartz monzonite stock at

(16, 800E, 13, 200N). It attains a maximum width of 50 feet but the average width is nearer 20 feet. This dike strikes N 53°E for about 200 feet and then changes to N 78°E for the remaining 600 feet of its exposed length. The dike is composed of altered quartz monzonite fragments up to ten inches in diameter. The breccia is porous and characterized by cavities filled with drysy quartz and small crystals of green tourmaline. Tourmaline also occurs as sunbursts in the altered fragments with quartz and small flakes of muscovite. Pyrite is inferred to have been abundant but has weathered to limonite. The limonite occurs both as stains adjacent to square cavities and as residual pseudomorphs after pyrite. Copper minerals were not recognized in the dike.

Veins that represent cavity filling of fissures are widespread. They are localized principally in the Cedarville Series, to a lesser extent in quartz monzonite and granodiorite, and, rarely, in dacite flows. The diorite stock is apparently barren.

The veins exhibit an imperfect radial distribution (Fig. 5). They are narrow and usually less than three feet wide. Alteration zones or selvages in wall rock may exceed 100 feet in width, but are usually less than 30 feet in width. A number of veins show secondary movement characterized by mineralized breccia fragments and unmineralized matrix. The Gaylord vein is an excellent example of this post-mineralization movement. At the southeast end of the

Gaylord drift the vein has been faulted and contains up to six inches of gouge. This fault parallels the vein for about 20 feet before it veers into the country rock.

Classification

According to Bateman (1950, p. 363), these deposits would be classified as simple fissure veins of the cavity filling variety.

However, difficulties arise when using Lindgren's (1933) classification of hydrothermal deposits. The ore minerals are typical of mesothermal deposits. Lindgren (1933, p. 530) states that neither tourmaline nor kaolinite are present in mesothermal deposits. Tourmaline is a high temperature mineral whereas kaolinite is considered to be a low temperature mineral. However, both minerals occur in a single sample together with abundant sericite which is typically mesothermal.

McKinstry (1948, p. 380) lists tourmaline as occasionally occurring in mesothermal deposits. Park and McDiarmid (1964, p. 290) state that although clay minerals are more characteristic of epithermal deposits they are also common along the periphery of mesothermal deposits. Regardless of these discrepancies, the mineral deposits of the Brattain district are probably mesothermal.

Mineralogy and Paragenesis

Pyrite is the most abundant metallic constituent in the veins. Chalcopyrite and sphalerite are found in many of the larger veins. Galena is locally present in a few veins around the periphery of the district: especially near the Gaylord tunnel. Other minerals of minor abundance are tetrahedrite (?), supergene chalcocite, covellite, and malachite. Gangue minerals are predominantly quartz and calcite. Siderite is locally abundant in the Gaylord tunnel area and other viens to the northwest. Barite, associated with quartz was found in a single vein in the southwestern part of the district (13, 200E, 7400N).

Study of three polished sections of sulfides revealed that the ores exhibit a brecciated texture. Pyrite exhibits this texture most distinctly. The pyrite was deposited in two generations: during an early main phase of mineralization, and later after movement had occurred. Much of the pyrite is anisotropic. According to Short (1940, p. 162),

> More than 99 percent of pyrite specimens are isotropic; rarely, however, polished sections show pyritohedrons with the color of pyrite rather than marcasite, each pyritohedron being a mosaic of grains of weak anisotropism and diverse orientation.

Pyrite in the specimens studied resembles this description. A few grains are moderately anisotrophic but they do not display the polarization colors of marcasite. Much of the pyrite has been weathered to hematite and limonite. All samples of sphalerite contain small blebs of exsolved chalcopyrite. The blebs are usually randomly distributed and are rarely exsolved along cleavage planes. Much of the sphalerite is banded. Chalcopyrite is commonly rimmed with supergene chalcocite and covellite. The rims are rarely over 1/20 mm wide. Malachite, presumably derived from chalcopyrite, locally stains gangue minerals. Tetrahedrite, tentatively identified, is present in trace amounts with galena from the Gaylord tunnel.

The paragenetic sequence of ore deposition was established from the study of polished sections. The general sequence is pyrite, chalcopyrite, and sphalerite, galena and pyrite. Sphalerite and chalcopyrite were deposited nearly simultaneously as shown by exsolution blebs of chalcopyrite in sphalerite. Quartz and calcite, the dominant gangue minerals, were deposited both prior to and after sulfide mineralization.

Zonation

The Brattain district displays an imperfect zonation of ore minerals. Chalcopyrite, although found in most samples studied, is more abundant in the veins adjacent to the plutonic complex. Sphalerite is most abundant in the Gaylord tunnel area. Galena is found only in the Gaylord tunnel. The distribution of these sulfides agrees reasonably well with the classical zonation sequence described by Emmons (1936).

Genesis of Ore Forming Fluids

The ore forming fluids are believed to have emanated from the plutonic complex. This interpretation is substantiated by: 1) the occurance of veins only in rocks intruded by the plutonic complex; 2) the zonation of ore and gangue minerals with respect to the plutonic complex; 3) the radial distribution of the veins around a dome believed to have formed by intrusion of the plutonic complex; and 4) the presence of disseminated ore and higher temperature gangue minerals within the plutonic complex.

HYDROTHERMAL ALTERATION

Description

The most extensively hydrothermally altered rocks in the Paisley Mountains include parts of the dacite flows, Cedarville Series and plutonic rocks. Rocks overlying the Cedarville Series have been little affected by hydrothermal alteration, however, they do show variable effects of deuteric alteration as previously described in the sections on pertography.

Hydrothermal alteration is confined to narrow zones adjacent to veins, dikes and the larger stocks. The most pronounced alteration effects are associated with veins. The width of wall rock alteration is rarely over 30 feet but adjacent to larger veins it may exceed 100 feet.

Characteristic alteration minerals are tourmaline, epidote, quartz, sericite, kaolinite, calcite, siderite, zeolites, magnetite, and pyrite. Quartz is the most abundant. Kaolinite and sericite have completely replaced plagioclase directly adjacent to the veins, and partially replaced the plagioclase in the country rocks. Epidote is found as a replacement mineral in the country rocks but not in veins. Epidote nodules up to four inches in diameter are found in the lower Cedarville Series. Chlorite is mainly a product of deuteric alteration, but also replaces country rocks adjacent to veins. Tourmaline is most abundant in the breccia dike that cuts the quartz monzonite. Elsewhere, it was observed in one vein (15,600E, 14,200N) and on joint surfaces of dacite flows near the stocks. Two types of tourmaline are present; green tourmaline found in the breccia dike and adjacent quartz monzonite, and a black tourmaline found in the vein and on joint surfaces. No studies were undertaken to determine the composition of these tourmalines, as they require refined chemical, instrumental and optical methods of analysis. Calcite is present in most veins and particularly near the Gaylord tunnel. Here, euhedral crystals of calcite up to one-fourth inch long are present in veins. Siderite occurs in some veins but is difficult to identify because of limonite staining and poor crystal form. Zeolites were found in the Cedarville Series at the head of Jones Canyon as large euhedral crystals of natrolite-pectolite up to one and one-half inches long. Pyrite, largely weathered to limonite, is ubiquiteous in veins.

The quartz monzonite adjacent to one vein (16,600E, 13,100N) has been altered to a quartz-sericite assemblage. Chemical analyses of fresh (JM-291) and altered (JM-P-5b) quartz monzonite suggest that SiO_2, Al_2O_3, TiO_2, and H_2O have been added as a consequence of hydrothermal alteration. This effect may be more apparent than real because of intense leaching of FeO, CaO, and Na_2O with the complete destruction of biotite, chlorite, hornblende, and feldspars to form the more stable quartz-sericite-kaolinite assemblage.

Table 12. Comparison of modal and chemical analyses of fresh quartz monzonite JM-291[1] and its altered phase JM-P-5b[2] (Chemical analysts, K. Aoki, Tohoku University and Rocky Mountain Geochemical Corporation).

Modal			Chemical		
Mineral	JM-291	JM-P-5b	Compound	JM-291	JM-P-5b
Plagioclase	37.8	---	SiO_2	60.40	70.74
Orthoclase	22.0	---	TiO_2	0.79	1.04
Quartz	8.5	35.3	Al_2O_3	17.19	17.70
Micrographic Intergrowths	10.0	---	Fe_2O_3	2.88	0.83
			FeO	2.38	0.25
Hornblende	4.0	---	MnO	0.15	0.02
Biotite	2.9	---	MgO	2.48	0.72
Chlorite	11.5	---	CaO	4.29	0.10
Fe Oxides	2.3	4.2	Na_2O	4.20	0.16
Sericite	1.0	31.7	K_2O	3.08	2.59
Kaolinite	---	17.6	H_2O+	1.51	5.19
Tourmaline	---	1.5	H_2O-	0.19	0.31
Voids	---	9.7	P_2O_5	0.20	0.05
Accessory	T	T		99.74	99.70
	100.0	100.0	Element	ppm	
			Cu	85	10
			Zn	70	20
			Pb	20	850
			Mo	1	3

[1] (15,900E, 13,200N).

[2] (16,600E, 13,100N).

Zonation

A definite zonation of alteration minerals exists in the Brattain district. This is readily recognized by the presence of tourmaline, epidote, calcite, and zeolites. Tourmaline is near the center of the district and associated with the plutonic complex; epidote is intermediate; calcite occurs beyond the epidote zone, and zeolites are only found on the periphery of the mineralized area.

Sericite and Kaolinite are imperfectly zoned. Samples collected from the plutonic complex show larger sericite: kaolinite ratios than other samples nearer the periphery of the district. This rough quantitative estimate is based on the comparison of relative strengths of X-ray diffraction peaks for sericite and kaolinite. Montmorillonite may be present farther from the veins but it was not detected with in the more intensely altered zones.

This zonation of sericite and kaolinite indicates that temperature, pH, potassium ion concentration gradients, or combinations thereof, decreased outward from the central part of the district (Meyer and Hemley, 1967).

GEOLOGIC HISTORY

The character and distribution of the rocks in the Paisley Mountains area are indicative of a continental environment.

The earliest recognizable event was the pre-early Oligocene eruption of dacite flows. This was followed by erosion and deposition of early Oligocene Cedarville Series rocks. Episodic uplift of the source area of this unit is indicated by graded bedding and interbedded conglomerates. Andesitic pyroclastic rocks and flows were erupted during deposition of the upper part of the Cedarville Series.

Intrusion of diorite, granodiorite and quartz monzonite into the dacite flows and Cedarville Series occurred during early Oligocene time (33.1 $\pm$1 m.y. by K-Ar) and caused local doming of the older rocks. Hydrothermal fluids were injected into the older rocks from a source within the plutonic complex.

Uplift associated with plutonism was followed by erosion, and during middle or late Miocene time andesite flows were erupted. Lahar deposits were locally formed. The late Miocene Steens Basalt (14.6 m.y.) terminates against the Paisley Mountains which suggests that the range was a topographic high at this time.

During the early Pliocene silicic plugs and flows were erupted. These in turn were overlain by basalt flows, also of Pliocene age.

Basin and Range faulting is believed to have commenced during

Miocene time, but the oldest recognizable faults are Pliocene.

After eruption and faulting of these basalt flows rhyolite plugs were intruded in the late Pliocene. This event was followed by extrusion of the silicified rhyolite of Pliocene-Pleistocene age. The glassy basalt is believed to be the youngest rock in the Paisley Mountains and is Pleistocene in age.

Continued Basin and Range faulting during Pleistocene time accentuated the horst and graben structures that now characterize the Paisley Mountains and adjoining Chewaucan Marsh. Sediments were shed into a large lake occupying the graben. This uplift and erosion is responsible for the present topography. Alluvial fans and landslides have formed along the eastern flank of the Paisley Mountains in Recent time.

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