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Title: Geology of the Fly Creek Quadrangle and the North Half of Round Butte Dam Quadrangle, Oregon

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Paul T. Robinson

A thick sequence of intercalated andesite and basalt flows, tuffs, and volcanic sediments crop out in the Fly Creek Quadrangle and the north half of the Round Butte Dam Quadrangle. This sequence was deposited in the ancestral Deschutes River Valley along the east flank of the Cascade Range during the Pliocene and the Recent. These rocks are relative flat lying and appear to have been undisturbed since the time of their implacement.

An older (pre-Pliocene) andesite characterized by phenocrysts of basaltic hornblende crops out in the northeast corner of the area and serves as a basement rock. Younger basaltic andesites which are mineralogically similar to the hypersthene andesites exposed in the High Cascade Range to the west interfinger with the olivine basalt flows, tuffs, and sediments of the Madras Formation along the western edge of the Fly Creek Quadrangle. Olivine basalt flows similar to those intercalated in the Madras Formation overlie this

sequence with no apparent unconformity in the eastern two-thirds of the area. Younger olivine basalts characterized by a diktytaxtic texture are intracanyon to the Madras Formation in the Deschutes, Crooked, and Metolius River canyons.

Geology of the Fly Creek Quadrangle and the North Half of Round Butte Dam Quadrangle, Oregon

by

Samuel Loyd Hewitt

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Dean of Graduate School

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GEOLOGY OF THE FLY CREEK QUADRANGLE AND THE NORTH HALF OF THE ROUND BUTTE DAM QUADRANGLE, OREGON

I. INTRODUCTION

Location and Geologic Setting

The Fly Creek Quadrangle and the northern half of the Round Butte Dam Quadrangle are in central Oregon (Plate I). The Cove State Park is located in the northeast corner of the area. Logging roads, the Çove State Park road, and the Round Butte Reservoir provide access to the area.

Rocks exposed in the area include the Pliocene Madras Formation, Pleistocene to Recent basalts, and Recent intracanyon flows. Cascade andesites interfinger with the Madras Formation along the western edge of the area and pre-Pliocene hornblende andesites crop out in the northwest corner of the Fly Creek Quadrangle.

The lower part of the Madras Formation is covered by water of the Round Butte Reservoir. The normal pool elevation is 1,945 feet, forming a convenient base level for mapping purposes.

Topography

The basalt flows capping the Madras Formation form a large, flat plain in the eastern two-thirds of the area. This plain is cut by

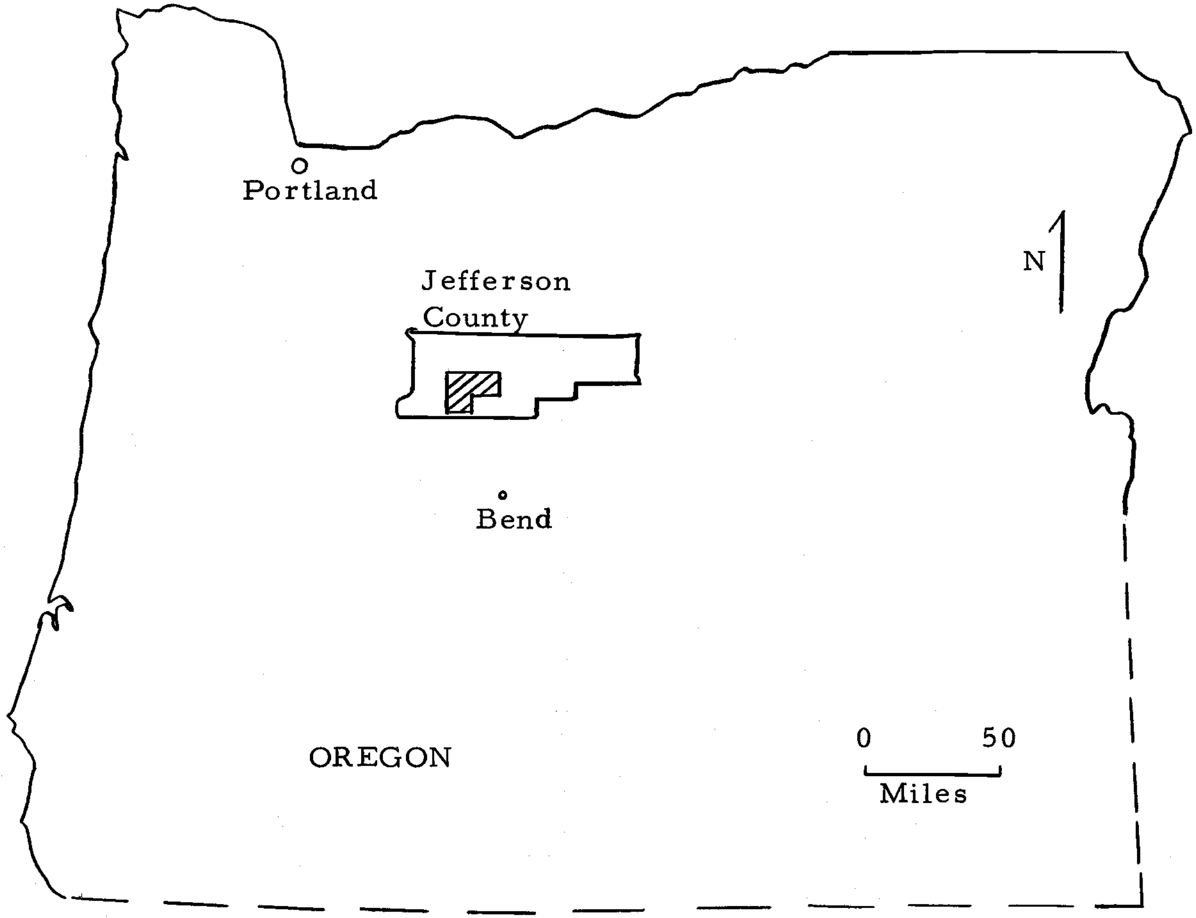

Plate I. Index map showing location of the thesis area. Mapped area is hashed portion of Jefferson County.

the deep, steep-walled canyons of the Metolius, Deschutes, and Crooked Rivers. The Metolius River canyon was approximately 1,000 feet deep before it flooded; it is now 500 to 600 feet deep (Figures 1 and 2).

Squaw Back Ridge, in the southwest corner of the area, and Round Butte, in the northeast corner, are shield volcanoes. Green Ridge, a fault block, extends north-south along the western edge of the area.

Elevations range from 1,580 feet in the Deschutes canyon below Round Butte Dam to 3,920 feet on Squaw Back Ridge.

Climate and Vegetation

Metolius, Oregon, six miles east of the area, has an average annual precipitation of 11.3 inches, and an average temperature of 47.6° F. Summers are hot, with temperatures reaching 115° F in the canyons; most of the precipitation falls during the winter months.

The area is sparsely vegetated with sagebrush (*Artemisia arbuscula*), juniper (*Juniperus occidentalis*) and grasses. Clumps of alder (*Alnus tenuifolia*) mark springs at the base of lava flows in the Madras Formation. On the higher slopes of Squaw Back Ridge and Green Ridge yellow pine (*Pinus ponderosa*), and manzanita (*Arctostaphylos obtusifolia*) are dominant.

Figure 1. View west from the mouth of the Metolius up the Metolius River canyon before construction of the Round Butte Dam. The Pelton Basalt flows are exposed above the river.

Figure 2. A view east across the mouth of the Metolius River after construction of the Round Butte Dam.

Previous Work

Russel (1905) and Stearns (1930) described rock units in the area while studying water resources for the United States Geological Survey. Hodge mapped the Madras Quadrangle in 1940. The southern and western edges of the area are included on Williams' map of the central Cascades (1957). Portland General Electric drilled 107 exploration holes prior to the construction of the Round Butte Dam in 1962 and compiled an unpublished geologic report on the dam area.

Purpose and Scope of Study

The purpose of this study is to determine the stratigraphy of the area, describe the lithology and thickness of the rock units, and to determine the source of the rock units. The relationship of the Cascade andesites and Madras Formation is given special attention. Other problems considered are the areal extent of ash flow tuffs in the Madras Formation and the relationship of the intracanyon basalts to the old topographic surface on which they rest.

Methods of Study and Procedures Followed

The geology was plotted on seven and one-half minute United States Geological Survey quadrangle sheets (Plate II). Stratigraphic sections were measured with a chain and Brunton compass.

Specimens were studied in thin section and the modal composition determined by the point count method described by Chayes (1949). The composition of the plagioclase was determined by the Michel-Levey method described by Kerr (1959). The composition of the glass in the tuffs was estimated on the basis of their indices of refraction. Photomicrographs were taken with a Leitz Orthomat camera.

II. STRATIGRAPHY

Introduction

A thick sequence of intercalated andesite and basalt flows, tuffs, and volcanic-rich sediments crop out in the mapped area. The oldest rocks are pre-Pliocene andesites exposed in the northwest corner of the area (Williams, 1957). These are overlain by basaltic andesites (Upper Pliocene-Lower Pleistocene) which slope off the east flank of the Cascade Range and interfinger with the Madras Formation of approximately the same age.

In the Deschutes Plateau the Madras Formation is capped by extensive flows of olivine basalt. During recent times olivine basalt has entered the area from the southeast and southwest partially filling the Metolius and Deschutes canyons. These flows have been reduced to wedge shaped remnants by the rivers.

Recent slides of rock debris occur along the canyon walls throughout the area, and in the Cove area have almost filled the old Deschutes and Crooked River channels.

Pre-Pliocene Volcanic Rocks

Distribution and Topographic Expression

Hornblende-rich andesite crops out in the Metolius River canyon in the northwest corner of the area. Williams (1957) mapped this unit in the Metolius canyon, and found it exposed in the Green Ridge fault scarp west of the area. A similar volcanic sequence of the same age was mapped by Williams (1957) along a fault block southeast of Newberry Caldera.

Lithology and Petrography

The andesite is light gray to white, weathering to a whitish gray or light brown, and has elongated phenocrysts of hornblende visible in the hand specimen.

In thin section the rock displays a porphyritic texture with phenocrysts of labradorite and basaltic hornblende in a felted groundmass of microcrystalline plagioclase laths and minor amounts of disseminated iron oxide. Basaltic hornblende crystals (1-3 mm in diameter) are euhedral to anhedral, occasionally twinned or zoned, and are fractured and resorbed (Figures 3, 4, and 5). They are pleochroic from red-brown to orange. The labradorite phenocrysts (0.125-1 mm in length) have a composition of An 57. The labradorite crystals are euhedral, zoned, and in places, broken (Figure 6). Titaniferous magnetite occurs as very fine, subhedral crystals scattered throughout the groundmass. The magnetite has altered to leucoxene.

Figure 3. Photomicrograph of pre-Pliocene andesite (Sample 1); resorbed phenocryst of basaltic hornblende cut normal to the c-axis in a matrix of stubby andesine laths (plain light); note iron oxide forming around the edges of the hornblende.

1 mm

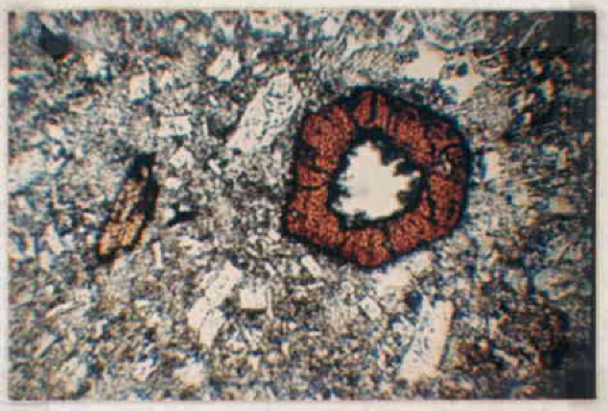

Figure 4. Photomicrograph of pre-Pliocene andesite (Sample 1); same view as Figure 3 with crossed nicols.

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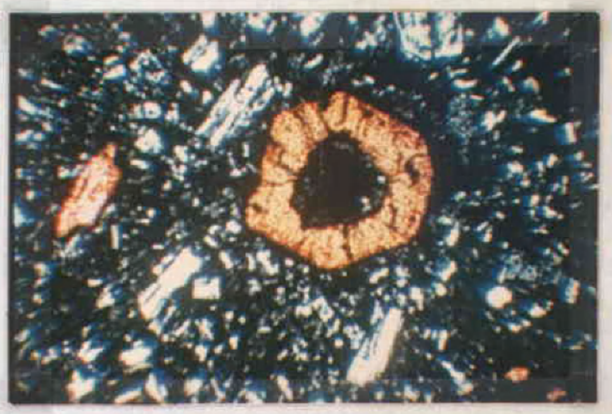

Figure 5. Photomicrograph of pre-Pliocene andesite (Sample 1); fractured prism of basaltic hornblende; note high interference color (crossed nicols).

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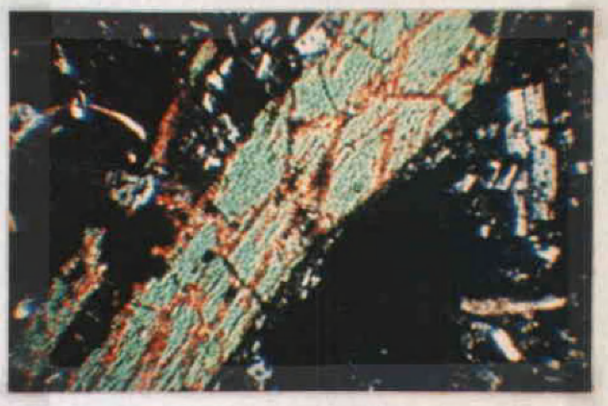
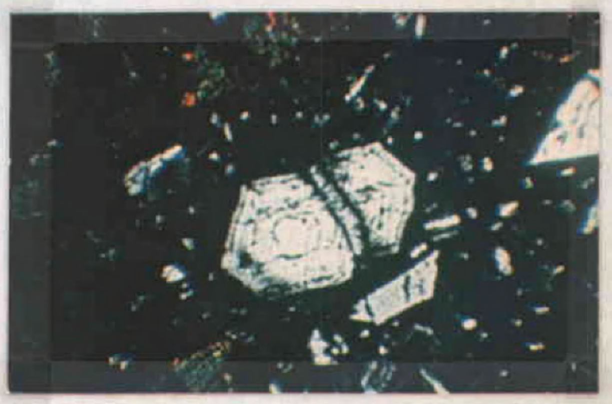


Figure 6. Photomicrograph of pre-Pliocene andesite (Sample 1); broken, zoned, plagioclase phenocryst (crossed nicols).

1 mm



Stratigraphic Relationship and Geologic Age

The exact age of this andesite is uncertain, but it lies beneath the Pliocene-Pleistocene Cascade andesites and the Madras Formation, making it pre-Pliocene. Williams (1957) states that it is correlative with part of a series of Eocene-Miocene volcanic rocks exposed in the western Cascades, which he believed interfinger with equivalents of the Clarno, John Day, Columbia River, and Mascall Formations.

Cascade Basaltic Andesites

Distribution and Topographic Expression

Basaltic andesite flows interfinger with the Madras Formation in the western part of the thesis area. These are mineralogically similar to the hypersthene andesites exposed in the High Cascade Range to the west.

The flows crop out on the east slope of Green Ridge, in Fly Creek, Spring Creek, and Street Creek canyons, and in the Metolius River canyon west of its junction with Fly Creek (Plate II). Williams (1957) has shown that these andesites extend as much as 15 miles east and west of the crest of the present Cascade Range.

These andesites form resistant layers, 20 to 120 feet thick, in the Madras sediments and tuffs imparting a stair-step effect to the northeast-trending ridges along the east slope of Green Ridge. The layers consist of one or more flows with multiple flows generally separated by flow breccia.

The flows are characterized by well developed platy jointing. Several joint patterns occur, the most common being horizontal with plates 3 to 6 inches thick (Figures 7 and 8). A platy rubble has accumulated along the base of the flows as a result of the jointing. Large (15-20 feet in diameter) columnar joints occur in the flow capping a ridge in sec. 36, T. 11 S., R. 10 E. (Figure 9).

Two types of flow breccia are associated with the andesite flows. The flow capping the ridge in sec. 31, T. 11 S., R. 11 E., has 3 to 4 feet of flow breccia composed of 1 to 3 inch angular fragments of fine crystalline andesite in a matrix of the same material on its upper surface. In contrast the flow breccias associated with flows in sec. 13, T. 12 S., R. 10 E., and the NW 1/4 sec. 13, T. 11 S., R. 10 E., are made up of blocky, crusty fragments of andesite in a frothy matrix. The breccia at the latter location is 30 to 40 feet think and contains blocky fragments up to 3 feet in diameter. This type of breccia occurs as both lower and upper flow breccias.

In places (NW 1/4, sec. 13, T. 11 S., R. 10 E.) the andesites appear to have been intracanyon to the Madras Formation at the time of deposition. This is suggested by an abrupt thickening of the flows

Figure 7. Platy jointing displayed by the Cascade andesites.

Figure 8. Very fine, scaly jointing at 45° to flow surface in Cascade andesite flow.

Figure 9. Poorly developed columnar jointing in a Cascade andesite flow in sec. 36, T. 11 S., R. 10 E.

(up to 200 feet) and narrowing towards the bottom.

The contacts between the flows and the Madras sediments and the tuffs are sharp, with a thin (6 inches to 2 feet) baked zone beneath the flows. Rarely the baked zone extends as much as 15 feet into the underlying beds.

Lithology and Petrography

The andesites are medium gray rocks that weather gray-brown to red-brown. These andesites are porphyritic to microporphyritic with phenocrysts of olivine, hypersthene, and plagioclase (An 52 to An 66) set in a pilotaxitic groundmass of andesine microlites (An 45 to An 50) and interstitial pigeonite (Figure 10 and Table I). One flow

(NE 1/4 NE 1/4 sec. 23, T. 11 S., R. 10 E.) has an orthophyric groundmass composed of short, rectangular plagioclase microlites (Figure 11). The phenocrysts are for the most part anhedral, ranging in size from 0.1 mm to 2.0 mm. These are often embayed (Figure 12). The hypersthene is pleochroic from red to yellow with a gray interference color (Figure 12). Fine, granular crystals of iron oxide (titanomagnetite?) are scattered throughout the groundmass.

Alteration is not common. The olivine has altered to iddingsite. Rims of augite have formed around the hypersthene phenocrysts in sample 5 (Table I). The plagioclase has altered slightly to sericite along fractures.

TABLE I. Modes for pre-Pliocene and Cascade andesites.

Sample	1	2	3	4	5
Plagioclase	89.3%	79.4%	70.7%	70.2%	66.8%
Pigeonite		1.2	20.7	26.6	23.0
Hypersthene			1.0	trace	1.3
Hornblende	7.7				
Olivine				1.0	2.6
Iron oxide	3.0	19.4	7.3	2.4	6.3
Augite					trace

1. Pre-Pliocene andesite: NW 1/4 NE 1/4 sec. 14, T. 11 S., R. 10 E., Fly Creek Quadrangle.
2. Cascade andesite: NE 1/4 SW 1/4 sec. 36, T. 11 S., R. 10 E., Fly Creek Quadrangle.
3. Cascade andesite: NE 1/4 SW 1/4 sec. 13, T. 12 S., R. 10 E., Fly Creek Quadrangle.
4. Cascade andesite: NE 1/4 NE 1/4 sec. 23, T. 11 S., R. 10 E., Fly Creek Quadrangle.
5. Cascade andesite: NW 1/4 NW 1/4 sec. 20, T. 11 S., R. 11 E., Fly Creek Quadrangle.

Figure 10. Photomicrograph of Cascade andesite (Sample 3); pilotaxitic groundmass with microcrystalline pigeonite interstitial to subparallel andesine laths (crossed nicols).

0. 1 mm

Figure 11. Photomicrograph of Cascade andesite (Sample 4); orthophyric groundmass with pigeonite interstitial to short, stumpy andesine laths (crossed nicols).

0. 1 mm

Figure 12. Photomicrograph of Cascade andesite (Sample 3); phenocryst of hypersthene in lower right corner; deeply embayed plagioclase phenocryst in lower right corner (crossed nicols).

0. 1 mm

Stratigraphic Relationship and Geologic Age

There is some controversy concerning the stratigraphic position and geographic extent of the Cascade andesites. Hodge (1940) named the Cascade andesites the Cascan Formation and indicated that the andesite flows overlie and interfinger with the Madras Formation (Figure 13).

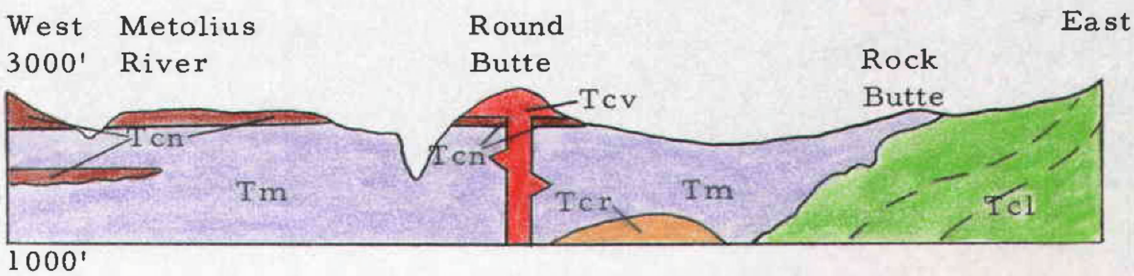


Figure 13. Structural cross section after Hodge (1940) showing the Cascade andesites interfingering with, and overlying the Madras Formation. Tcl - Clarno Formation, Tcr - Columbia River Basalt, Tm - Madras Formation, Tcn - Cascan Formation, Tcv - Cascan volcano.

Williams (1957) places the Cascade andesite flows below the Madras Formation. He differentiated between these flows and the basaltic andesites capping the Madras Formation which he considers a product of post-Madras volcanism.

The present work revealed that the andesites interfinger with the Madras Formation of the western edge of the central Oregon plateau. This relationship is well exhibited along the walls of Fly Creek Canyon where the andesite flows are intercalated in a sequence of Madras sediments and tuffs.

The basaltic andesites capping the Madras Formation are texturally and lithologically different from the Cascade andesite flows. In the southwest quarter of the Fly Creek Quadrangle the basaltic andesites lap onto the low dipping Cascade andesites (Plate II). This supports Williams' conclusion that the basaltic andesites are post-Madras and not part of the High Cascade andesite flows. The Cascade andesite flows were extruded during the Pliocene and Pleistocene while the Madras Formation was being deposited.

Madras Formation

Distribution and Expression

A sequence of intercalated fluvial sediments, ash-flow tuffs, and basalt flows crop out in the eastern two-thirds of the area. These rocks were described by Russel in 1905, who named them the Deschutes Sands. Because of flows in the sequence, I. A. Williams changed the name to the Deschutes Formation in 1924, and called the lower basalt flows the Pelton Basalt Member. In 1928, Hodge described the same sequence near Madras, Oregon using the name Madras Formation. He later suggested that these beds were equivalent to Condon's (1869) Dalles Formation (Hodge, 1940), and in 1942 stated that the Dalles Formation had priority over the Madras

Formation. Although all of these names except Deschutes Sands are still in use, the name Madras Formation is used here to correspond with the more recent work done by Williams (1957).

The Madras Formation was deposited along the eastern front of the Cascades in an erosional and structural low during Pliocene and Pleistocene time. It forms a broad, flat plateau capped by younger basalts. The plateau is cut by deep, V-shaped canyons. Steep cliffs occur on the canyon walls where the basalt flows and ash-flow tuffs crop out. Talus slides and slumps are common along the canyon walls. Buttes occur where the basalt cap has been isolated by erosion.

Pelton Basalt Member

The Pelton Basalt Member of the Madras Formation crops out below Round Butte Dam, forming a bench on either side of the river. It extends south along the Deschutes River as far as T. 13 S., R. 12 E. (Stearns, 1930), and north of the thesis area for several miles (Hodge, 1940). It could be traced four miles west along the Metolius River prior to flooding of the Round Butte Reservoir. Core holes drilled by Portland General Electric in 1958 and 1961 prior to construction of the dam show 80 to 140 feet of olivine basalt in three to five separate flows. The flows range from 10 to 30 feet thick, separated by flow breccia of a baked soil zone. Crude columnar jointing is common, with columns up to 8 feet in diameter (Figure 14). The flows become vesicular approaching the upper flow surfaces.

The flow surfaces and joints in the upper part of the flows are coated or filled with white to cream colored montmorillonite clay (Portland General Electric Unpublished Core Hole Descriptions).

Figure 14. Crude columnar jointing in the Pelton basalts.

Lithology and Petrography. The Pelton basalts are steel gray, porous rocks that weather dark gray to red-brown.

Two textures are displayed by these basalts. Sample 6 (Table II) has an intergranular texture, with pyroxene interstitial to fine and euhedral plagioclase laths (0.3-1.0 mm). Sample 7 (Table II) has a subophitic matrix with anhedral to subhedral pyroxene partially enclosing euhedral plagioclase laths (Figure 15). The plagioclase has a range in composition from An 62 to An 67. The pyroxene (augite) has a 2V of approximately 60. It is pale brown to neutral with a

TABLE II. Modes for the Pelton, Madras, and Quaternary rim-forming basalts.

Sample	6	7	8	9	10	11
Plagioclase	40.6%	47.4%	55.5%	43.5%	53.5%	67.5%
Augite	38.8	35.2	23.9	29.6	30.2	17.9
Olivine	14.2	10.0	19.6	12.8	14.2	13.2
Iron Oxide	6.4	7.0	1.0	14.1	2.2	1.4
Glass		trace				

6.	Pelton basalt:	SE 1/4 SE 1/4 sec. 15, T. 11 S., R. 12 E., Round Butte Dam Quadrangle.
7.	Pelton basalt:	SE 1/4 SE 1/4 sec. 15, T. 11 S., R. 12 E., Round Butte Dam Quadrangle.
8.	Madras basalt:	SE 1/4 NE 1/4 sec. 34, T. 11 S., R. 12 E., Round Butte Dam Quadrangle.
9.	Madras basalt:	SW 1/4 SE 1/4 sec. 27, T. 11 S., R. 12 E., Round Butte Dam Quadrangle.
10.	Quaternary Rim-Forming basalt:	SE 1/4 NE 1/4 sec. 34, T. 11 S., R. 12 E., Round Butte Dam Quadrangle.
11.	Quaternary Rim-Forming basalt:	SE 1/4 SE 1/4 sec. 8, T. 12 S., R. 11 E., Fly Creek Quadrangle.

maximum interference color in the upper first order. It displays characteristic cleavage in two directions parallel to (110).

Other minerals occurring in the basalts are olivine, iron oxide, and trace amounts of volcanic glass (Sample 6). The olivine is anhedral to subhedral with grains averaging 0.5 mm in diameter in Sample 7. Two generations of olivine occur in Sample 6, an early generation characterized by large (up to 6.0 mm), resorbed, glomerophyric phenocrysts (Figure 16), and a later generation of small (0.25-0.5 mm) crystals scattered throughout the rock. Rims of iddingsite have formed around the olivine (Figure 15). Fine,

Figure 15. Photomicrograph of Pelton basalt (Sample 7); subophitic texture with augite partially enclosing plagioclase laths. Note olivine phenocryst rimmed with iddingsite in upper left corner (crossed nicols).

2. 0 mm

Figure 16. Photomicrograph of Pelton basalt (Sample 6); large, deeply embayed olivine phenocryst in upper part of photo (crossed nicols).

2. 0 mm

disseminated crystals of titaniferous magnetite scattered throughout the rock alters to leucoxene and hematite.

Madras Basalts

The olivine basalts in the Madras Formation occur in massive flows separated by thin (2 to 5 foot) scoriaceous flow breccias. The individual flows range from 10 to 40 feet thick, display crude columnar jointing, and are vesicular near the upper and lower flow surfaces.

Lithology and Petrography. The medium gray to black Madras basalts (weathering to dark gray or red-brown) have a diktytaxitic texture with 3 to 5 percent void space. The texture ranges from subophitic (Figures 17 and 18) to intergranular, with augite either interstitial to, or partially enclosing the plagioclase laths. The plagioclase ranges from An 62 to An 67 in composition (labradorite), occurring as elongate euhedral to subhedral laths (0.5-0.75 mm in length). Olivine occurs as scattered subhedral crystals partly replaced iddingsite (average diameter 1.0 mm). Titaniferous magnetite occurs as fine, granular crystals and in Sample 9 (Table II) forms rims around the olivine. It alters to leucoxene and occasionally to hematite around the edges of the crystals.

Figure 17. Photomicrograph of Madras basalt (Sample 9); augite partially enclosing the plagioclase laths (crossed nicols).

1.0 mm

Figure 18. Photomicrograph of Madras basalt (Sample 9); same view as Figure 17 (plain light).

1.0 mm

Ash-Flow Tuffs of the Madras Formation

The basal ash-flow tuff (Unit I) crops out at water level in the Cove area. This pink to grayish-pink tuff thickens from 20 feet along the Deschutes canyon to approximately 70 feet in the western part of the mapped area. It consists of approximately 50 percent white to gray pumice fragments (5 to 10 mm in diameter), 35 to 40 percent gray ash, and minor amounts of basaltic rock fragments, plagioclase, magnetite, and a trace of olivine. In the Cove area scattered basalt cobbles (3 to 12 inches in diameter) have been incorporated in the base of the flow.

In the Fly Creek Quadrangle (sec. 22, T. 11 S., R. 11 E.), the basal ash-flow is overlain by a 20 to 30 foot pumiceous layer (Unit 2) consisting of 60 percent white angular pumice fragments (5 mm to 15 cm in diameter) in a matrix of pink ash. The contact between the two units is sharp and the pumice shows no deformation, suggesting a possible pumice-flow origin for the upper unit. The pumice unit also thickens to the west. The ash-flow tuff weathers to a flesh color and forms narrow ledges (at places only 1 to 2 feet wide) where the softer overlying beds have eroded away.

A thin ash-flow tuff (Unit 3, Sample 13, Table III) crops out approximately 30 feet below the lower Madras basalt in sec. 34, T. 11 S., R. 12 E. This tuff is only 5 to 10 feet thick and is exposed in the gullies for approximately 500 feet north and 1,000 feet south of Measured Section I. It consists of 20 to 30 percent of multicolored pumice fragments (5 to 20 mm in diameter) in a matrix of light gray ash. Minor amounts of rock fragments, iron oxide, hypersthene, and a trace of hornblende occur in the tuff. A slight eutaxitic texture is visible in hand specimen as well as in thin section (see Figure 21). This tuff is not exposed elsewhere in the area.

The ash-flow tuff cropping out directly below the upper Madras basalt (Unit 4) extends from the SE 1/4 sec. 27, T. 11 S., R. 11 E. to the SW 1/4 sec. 28, T. 11 S., R. 11 E. on the south side of the canyon. The tuff is 10 to 30 feet thick, light gray in color and weathers to a gray brown. It is made up of approximately 40 to 50 percent white to gray pumice fragments (range up to 25 cm in diameter), 30 to 40 percent gray ash, and minor basaltic lithic fragments. Scattered plagioclase phenocrysts are visible in hand specimen. Where exposed, the upper 5 to 6 feet of the tuff appears to have been baked by the overlying basalt flow and is a brick red color.

The ash-flow tuff cropping out 40 feet above the upper olivine basalt flow (Unit 5) also extends throughout the mapped area. It thickens from 30 feet in the Cove to 220 feet in the Fly Creek Quadrangle. This tuff grades in color from a lavender-gray at its base to a pinkish-tan near the top due to change in color of the ash-sized material. White to tan pumice fragments range from 5 to 35 mm in diameter with the larger sized fragments concentrated near the top of the flow and in places make up to 80 percent of the flow. In the Box Canyon area (sec. 21 and 22, T. 11 S., R. 11 E., Fly Creek Quadrangle) large blocks of pumice up to 18 inches in diameter occur in the upper part of the flow. Scattered, black scoriaceous lapilli and blocks are present in the base of the flow in this area.

There is a densely welded portion in the upper part of Unit 5 in the Fly Creek Quadrangle. A lower, tightly welded zone (3 to 10 feet thick) resembles obsidian in the hand specimen. The pumice fragments have been completely flattened and cannot be distinguished with the unaided eye. The rock is black and contains approximately 18 percent plagioclase phenocrysts. Above this is a 10 to 20 foot zone of orange-brown, less compacted welded tuff. The pumice fragments are disc shaped (5 by 50 mm), appear gray in color, and are aligned horizontally giving a streaked appearance to the rock. The upper, less welded zone extends four to five miles further to the northeast than does the lower obsidian-like zone, which dies out in sec. 27, T. 11 S., R. 11 E. The welded zone displays crude columnar jointing and weathers in large blocks (3 to 5 feet). Hoodoos form where the more resistant welded tuff blocks slide down and cap the softer non-welded tuff (Figures 19 and 20). In places the overlying non-welded tuff has been eroded away leaving the welded tuff capping the remainder of the ash-flow and forming low buttes (sec. 30, T. 11 S., R. 11 E.). Elsewhere it forms a sharp cliff where it crops out in the softer ash-flow material.

The increase in intensity of welding and the thickening of the ash-flow to the southwest suggest a source in that direction. Williams (1957) briefly describes an ash-flow tuff which flowed from a vent on Broken Top in the Cascade Range that somewhat resembles the one discussed above and is located approximately the same distance below the rim-forming basalts. If these flows are the same, the material deposited in the thesis area would have had to travel over 60 miles northeast from its source.

The ash-flow tuff (Unit 6) cropping out just below the

Figure 19. Hoodoos of ash-flow tuff capped by blocks of black, glassy, welded tuff.

Figure 20. A hoodoo of ash-flow tuff capped by a platy fragment of welded tuff.

rim-forming basalt (sec. 34, T. 11 S., R. 12 E., and sec. 3, T. 12 S., R. 12 E. Round Butte Dam Quadrangle) is from 8 to 15 feet thick, gray in color (weathering red-brown) and exposed intermittently for 6,000 feet along the west wall of the Deschutes canyon. This tuff consists of 30 percent dirty white pumice fragments, 40 percent gray ash and about 25 percent angular basaltic or andesitic rock fragments (average 1 mm in diameter). In thin section minor iron oxide and a trace of hypersthene can be observed. The minor eutaxitic structure displayed by this tuff is discernible in hand specimen. The tuff forms a narrow cliff where it is exposed in the gullies and is easily recognized by its red-brown weathered color.

Lithology and Petrography. In general, the ash-flow tuffs in the Madras Formation are characterized by a high content of lapilli sized pumice fragments, 7 to 24 percent angular lithic fragments (andesitic or basaltic), and from 3 to 18 percent euhedral to subhedral plagioclase phenocrysts (Table III). Other phenocrysts present in minor amounts include magnetite, hypersthene, olivine, and augite. Most of the phenocrysts are embayed and range from 0.5 to 2.0 mm. Lithic fragments are andesitic or basaltic with minor tuffaceous xenoliths.

Rocks range from vesicular, very slightly welded tuffs with Y and U shaped shards, to welded tuffs with flattened, eutaxitic glass shards (Figures 21 to 25).

TABLE III. Modes for Madras ash-flow tuffs.

Ash-Flow Units	1	3	5	5	5	5	5	6
Sample	12	13	14	15	16	17	18	19
Glass	73.0%	88.7%	85.4%	85.8%	70.6%	74.4%	87.3%	70.4%
Lithic fragments	21.6	7.0	8.2	2.0	10.1	10.6	6.7	24.2
Plagioclase	4.4	2.7	5.0	9.2	18.1	13.0	4.0	3.4
Iron oxide	1.0	1.3	0.8	2.0	2.8	1.6	1.0	1.6
Hypersthene		0.3		1.0			1.0	0.4
Augite					0.6	0.4		
Olivine			0.6	trace				

12. Ash-flow tuff: SW 1/4 SW 1/4 sec. 26, T. 11 S., R. 12 E., Round Butte Dam Quadrangle.

13. Ash-flow tuff: SE 1/4 NE 1/4 sec. 34, T. 11 S., R. 12 E., Round Butte Dam Quadrangle (Measured Section I, 183.5 feet from base).

14. Ash-flow tuff: SE 1/4 NE 1/4 sec. 34, T. 11 S., R. 12 E., Round Butte Dam Quadrangle (Measured Section I, 352.5 feet from base).

15. Ash-flow tuff: SW 1/4 NE 1/4 sec. 27, T. 11 S., R. 12 E., Round Butte Dam Quadrangle.

16. Welded tuff: NW 1/4 NE 1/4 sec. 31, T. 11 S., R. 11 E., Fly Creek Quadrangle.

17. Welded tuff: NE 1/4 SW 1/4 sec. 27, T. 11 S., R. 11 E., Fly Creek Quadrangle.

18. Ash-flow tuff: NE 1/4 SW 1/4 sec. 21, T. 11 S., R. 11 E., Fly Creek Quadrangle.

19. Ash-flow tuff: SE 1/4 NE 1/4 sec. 34, T. 11 S., R. 12 E., Round Butte Dam Quadrangle (Measured Section I, 404 feet from base).

Figure 21. Photomicrograph of ash-flow tuff (Sample 13); curved and Y-shaped glass shards around a phenocryst of hypersthene (plain light).

0. 5 mm

Figure 22. Photomicrograph of ash-flow tuff (Sample 15); slightly eutaxitic with Y-shaped glass shards (plain light).

0. 5 mm

Figure 23. Photomicrograph of welded tuff (Sample 16); densely welded with extreme flattening and stretching of the pumice fragments (plain light).

1. 0 mm

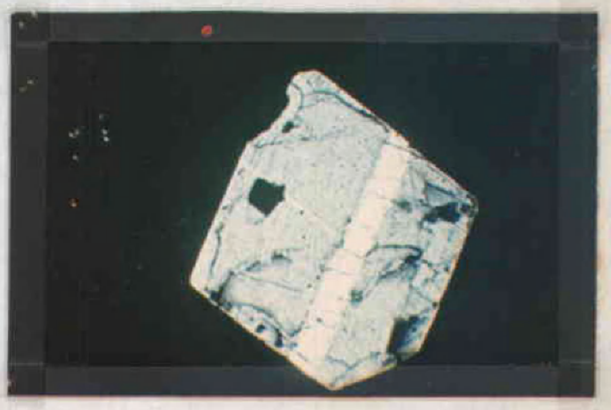


Figure 24. Photomicrograph of welded tuff (Sample 16); same view as Figure 23 with crossed nicols; note lack of devitrification.

1. 0 mm

Figure 25. Photomicrograph of welded tuff (Sample 17); moderately welded with eutaxitic texture; pumice fragments are collapsed; plagioclase phenocryst is embayed (plain light).

1.0 mm

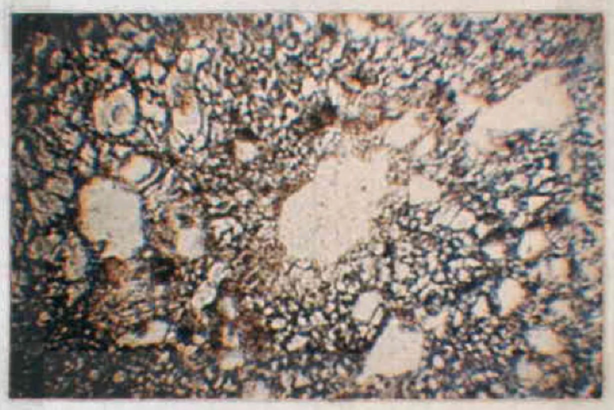


Figure 26. Photomicrograph of ash-flow tuff (Sample 18); vesicular texture displayed by non-welded zone of ash-flow tuff (plain light).

1.0 mm

The change in the degree of welding exhibited by the welded tuff in Unit 5 in the southwest part of the area is shown in Figures 23 through 26. The black glassy basal portion of the tuff (Sample 16, Table III) displays extreme flattening and stretching of the pumice fragments. Above this a less compacted zone with flattened and aligned shards (Sample 17, Table III) grades upward into a non-welded undeformed pumice flow (Sample 18, Table III). The percentage of plagioclase phenocrysts increases as the degree of welding and compaction increases. This appears to be due to decreased volume in the welded zone. The difference in concentration of the plagioclase can be seen in outcrop where the black lower zone and the less compacted zone are exposed together.

The approximate silica content of the glass in the ash-flow and welded tuffs was determined (Table IV) using the method described by George (1924). All of the tuffs examined were intermediate (Sample 19, Table IV) or higher in silica content. Samples 14 through 18 are from the extensive ash-flow which contains the welded tuff in the western part of the area (Unit 5). The range from 64 to 69 percent silica would suggest a possible dacitic composition for this tuff. The presence of minerals characteristic of andesites (augite, olivine, and hypersthene) and the andesitic or basaltic rock fragments in a more acid glass is the normal occurrence rather than an exception (Ross and Smith, 1961). The composition of the plagioclase phenocrysts could not be determined and no devitrification of the glass was observed in any of the tuffs examined.

TABLE IV. Approximate silica content of Madras ash-flow tuffs (Samples 12-19, Table III) determined from the indices of refraction of the glass (n) as described by George (1924).

Ash-flow Unit	1	3	5	5	5	5	5	6
Sample	12	13	14	15	16	17	18	19
n	1.518	1.502	1.510	1.511	1.507	1.517	1.517	1.529
% SiO_2	64.5	72.5	67.0	67.0	69.0	64.0	64.0	59.5

Sedimentary Rocks of the Madras Formation

Fluvial sands, silts, and gravels deposited along the east front of the Cascade Range during upper Pliocene and Pleistocene time make up the bulk of the Madras Formation. These sediments thicken away from the Cascade Range, and have a slight (1/2 to 2°) initial dip in that direction. The sediments were apparently deposited by high energy, glacial-fed streams draining the Cascades. Increased volcanic activity resulting in melting of winter snows and glaciers could have produced torrential floods, which in turn deposited the very coarse, unsorted gravel and mud-flow units.

Silts are rich in reworked water-laid volcanic ash. Thin air-borne and water-laid pumice beds occur throughout the section (Figure 27).

The sandstones are cross-bedded (Figure 28), poorly consolidated, and poorly sorted. They consist chiefly of subangular to sub-rounded basalt, andesite, and pumiceous lithic fragments, with minor olivine and plagioclase grains. An occasional olivine-rich sand occurs, as do sands rich in material derived from an under-lying ash-flow tuff. The matrix is composed of silt-sized lithic material, volcanic ash, and clay (see appendix for measured sections).

Semi-consolidated gravels form layers 1 to 90 feet thick (Figure 29). These gravels are composed of subangular to round

Figure 27. Cross-bedded volcanic sand in the Madras Formation. Note tan pumice fragments in the sand.

Figure 28. Interbedded pumice fragments and volcanic ash in the Madras Formation. Note apparent quiet water depositional environment.

Figure 29. Semi-consolidated gravel beds in the Madras Formation.

basalt and andesite pebbles, cobbles, and boulders set in a matrix of lithic sand, ash, pumice fragments, and clay.

What appears to be a mud flow deposit (lahar) crops out in sec. 20, T. 11 S., R. 11 E. It consists of unsorted basalt cobbles and boulders in a matrix composed of ash, clay, and sand.

Stratigraphic Relationship and Geologic Age

Stearns (1930) and Hodge (1928, 1940) state that the Madras Formation rests unconformably on the older Columbia River Basalt, John Day, and Clarno Formations. The lower Pelton basalt flows underlie the Madras sediments, appearing to be conformable with them, and Hodge (1928) states that these flows are not part of the

Columbia River Basalts. In core holes drilled by Portland General Electric the Columbia River flows are separated from the Pelton basalts by only 2 to 10 feet of Madras-type sediments suggesting that stratigraphic position is a poor criterion for excluding this series of flows from the Middle Miocene Columbia River Basalts. Work by Waters (1961) pointing out lithologic and textural differences between the Columbia River and the younger Pliocene to Quaternary flows supports Hodge's (1928) conclusion that the Pelton basalts are not part of the Columbia River flows. The younger basalts have a diktytaxitic texture, higher content of plagioclase and olivine, less pyroxene, rare chlorophaeite, and tend to be lighter in color (Table V).

TABLE V. Average modes after Waters (1961) for Columbia River Basalts and Pliocene-Quaternary Basalts compared to the average mode for the Pelton Basalts in the thesis area.

Sample	A	B	C
Plagioclase	37.0%	46.6%	44.0%
Pyroxene	32.2	22.6	37.0
Olivine	3.0	19.1	12.2
Chlorophaeite	3.4	Trace	None

A. Average mode for 70 samples of the Picture Gorge, Imnaha, and Yakima flows (Columbia River Basalt).
B. Average mode for 31 samples of Pliocene-Quaternary basalts in eastern Oregon and Washington.
C. Average mode for Samples 6 and 7 (Table II) Pelton Basalt in thesis area.

In contrast, the Columbia River flows have no intercrystalline voids, a lower content of plagioclase and olivine, more pyroxene, contain up to 5 percent chlorophaeite, and are darker in color.

The geologic age of the Madras Formation is based on floral remains found in sediment and tuffaceous beds. Chaney (1938) described fossil plant debris found in the Madras sediments nine miles northwest of Madras, Oregon. This flora, dominated by *Populus pliotremuloides*, was assigned to lower or middle Pliocene by Chaney. He felt that the Madras was correlative with the Dalles and Rattlesnake Formations. In 1939 Chaney, after studying flora from the Dalles Formation, concluded that the Dalles was older than the Madras, and assigned the Madras to the middle Pliocene. Williams (1957) believed the Madras to be late Pliocene in the Bend Quadrangle. The middle Pliocene conglomerates in the Arlington area (Shotwell, 1956) appear to be equivalent to the Madras Formation (Baldwin, 1964). Thus it appears that the Madras Formation was deposited during the middle to upper Pliocene and the Pleistocene.

Quaternary Basalts (Rim Former)

Distribution and Topographic Expression

Quaternary basalt flows cap the Madras Formation in the eastern two-thirds of the mapped area, lapping up onto the east dipping Cascade andesites in the western part of the area. Stearns (1930) states that these flows cover the Madras for about one-half of its extent, having been removed by erosion elsewhere. The flat-lying flows form rims along the canyons. The upper surface of these flows is either bare with scattered, circular mounds of soil, or is covered with a thin ash-rich eolian soil (Figure 30).

Squaw Back and Little Squaw Back Ridges, low shield volcanoes directly southwest of the mapped area, appear to be sources for these basalt flows. Round Butte (secs. 13 and 24, T. 11 S., R. 12 E.), a low shield capped by a cinder cone, is also a local source for the flows (Figure 31).

Physical Characteristics

Two to four flows ranging from 20 to 70 feet thick are separated by thin (1 to 5 foot) scoriaceous zones of flow breccia. Columnar jointing is common with columns ranging from 5 to 10 feet in diameter. In sec. 15, T. 11 S., R. 12 E. fine columnar jointing is exhibited by the lower flow. This jointing resembles that characteristic of andesites, with columns averaging 1 foot in diameter and jointed horizontally (forms 1 to 2 inch plates).

Lithology and Petrography

The basalt flows capping the Madras Formation closely

Figure 30. View of bare surface of the rim-forming basalt flows. Mount Jefferson in the background.

Figure 31. View looking east at Round Butte, a low shield volcano that is an apparent source of the Quaternary rim-forming flows.

resemble those intercalated with the sediments. These basalts are light gray, weathering dull gray or a gray-brown. They are diktytaxitic (less than 5 percent intercrystalline void space) and range in texture from intergranular to subophitic. The labradorite laths in the groundmass (An 66 to An 67) average 0. 5 mm in length and enclose the augite in angular interstices or are partially enclosed themselves by larger crystals of augite. Phenocrysts of plagioclase (up to 1. 5 mm) are zoned and have altered to white mica (very minor). Olivine occurring as phenocrysts (up to 1. 5 mm in diameter) has altered to iddingsite (Figures 32 and 33). The scattered granules of titaniferous magnetite have altered to leucoxene. The

Figure 32. Photomicrograph of Quaternary rim-forming basalt (Sample 11); olivine phenocryst almost completely replaced by iddingsite (crossed nicols).

1. 0 mm

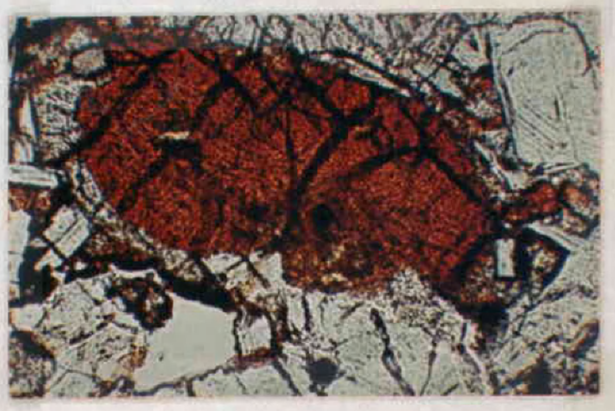


Figure 33. Photomicrograph of Quaternary rim-forming basalt (Sample 11); same view as Figure 32 (plain light).

1. 0 mm

flows whose apparent source was Squaw Back Ridge have a higher content of plagioclase and less augite than those in the Madras sediments and the rim-forming flows near Round Butte (Table II).

Stratigraphic Relationship and Geologic Age

The Quaternary rim-forming flows directly overlie the Madras Formation with no apparent unconformity. Williams (1957) distinguished between these flows and the older, glaciated basaltic andesite flows of the High Cascades, while Hodge (1940) concluded that the flows capping the Madras were a continuation of the Cascade andesites (Figure 13). The textural and lithological differences between the rim-forming flows and the Cascade andesites, and the lapping of these flows onto the low dipping Cascade andesites in the southwest quarter of the Fly Creek Quadrangle indicate that they are younger (late Pleistocene to Recent) as suggested by Williams (1957).

Youngest Basaltic Lavas (Intracanyon)

Distribution and Topographic Expression

The Quaternary basalt which partially filled the Crooked, Deschutes, and Metolius canyons in the eastern part of the area flowed from vents near the Tetherow Buttes (Williams, 1957). Stearns (1930) believed that the lavas entered the Crooked River near the

Smith Rocks, flowed downstream for 36 miles, and backed up the Deschutes and Metolius Rivers for three or four miles. He felt that flows from the same source flowing down the Deschutes never reached its junction with the Crooked River in the Cove State Park area. The farthest remnant of these flows is eight miles downstream from the Cove area. Hodge (1940) believed that Round Butte was the source for the intracanyon flows, but they can be traced south to where they enter the Crooked River.

The intracanyon flows cropping out along the Metolius canyon from sec. 27, T. 12 S., R. 11 E. westward appear to have a source in that direction. These flows have a slight eastward dip (1/2°) and differ appreciably in composition from the intracanyon flows in the Cove area (Table VI), suggesting separate sources for the flows.

The flows, once filling the canyons to within a few hundred feet of their tops, have been reduced to wedge-shaped remnants by fluvial erosion (Figures 34, 35, and 36). South of the mapped area the Crooked River channel is cut in the intracanyon flows. The "Island" is a large triangular remnant of the flows left between the Deschutes and Crooked Rivers.

Physical Characteristics

The sequence of intracanyon flows in the eastern part of the area ranges from 40 to 540 feet thick with as many as 23 flows

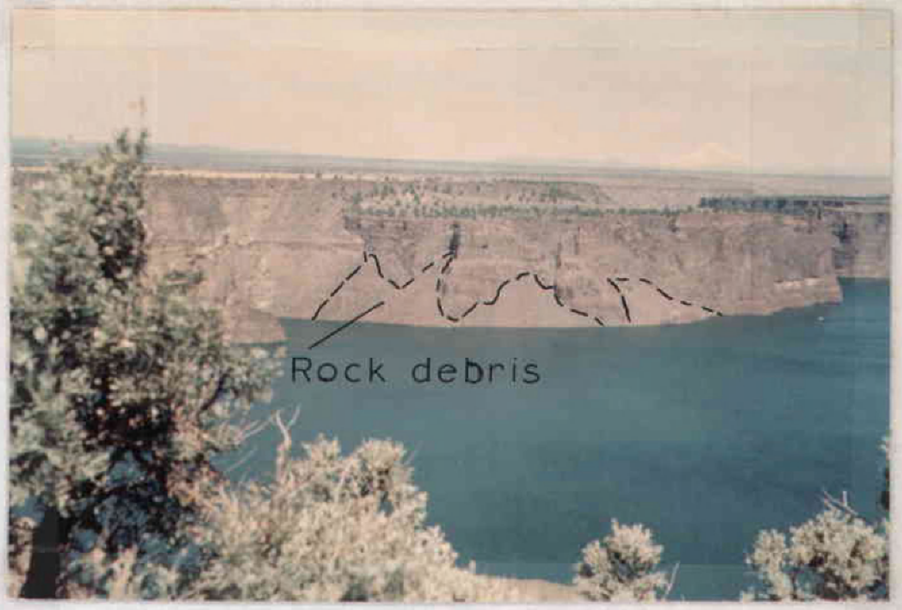


Figure 34. Large remnant of the intracanyon basalts on the west wall of the Deschutes canyon. Note large talus slopes of basalt debris. Mount Hood in the background.

Figure 35. Wedge-shaped remnant of the intracanyon basalts in sec. 15, T. 12 S., R. 12 E. Note very sharp contact with underlying Madras sediments, and the lack of a baked soil zone between the two units.

TABLE VI. Modes for Youngest Basaltic Lavas (Intracanyon).

Sample	20	21	22	23
Plagioclase	48.6%	56.6%	51.3%	50.0%
Augite	26.0	16.8	23.2	25.0
Olivine	1.0	19.3	18.0	18.0
Iron Oxide	12.2	7.5	7.4	7.0
Glass	12.2			

20.	Youngest basaltic lava: (Intracanyon):	NE 1/4 SW 1/4 sec. 28, T. 11 S., R. 11 E., Fly Creek Quadrangle.
21.	Youngest basaltic lava (Intracanyon):	NE 1/4 SE 1/4 sec. 27, T. 11 S., R. 12 E., Round Butte Dam Quadrangle (taken from lowest exposed flow in sequence)
22.	Youngest basaltic lava (Intracanyon):	NE 1/4 SE 1/4 sec. 27, T. 11 S., R. 12 E., Round Butte Dam Quadrangle (taken from upper flow in sequence)
23.	Youngest basaltic lava (Intracanyon):	NE 1/4 SE 1/4 sec. 34, T. 11 S., R. 12 E., Round Butte Dam Quadrangle (taken 4 feet above water level of Lake Chinook)

present. These flows are 10 to 60 feet thick, and are separated by thin (3 to 10 feet) zones of scoriaceous flow breccia. The flow surfaces are undulating and the upper surfaces characterized by a thin (1/2 to 1 inch) scoriaceous glassy layer. The flows are vesicular near their upper surface with elongate vesicles averaging 10 to 20 mm in length. These vesicles are filled with white opaline material. The intracanyon flows along the Metolius canyon in the Fly Creek Quadrangle are similar in physical appearance further east, but lack the opaline material in the vesicles.

Columnar jointing is characteristic of these flows, with columns ranging from 10 inches to 6 feet in diameter and up to 30 feet long. The upper 4 to 5 feet of the columns are platy, with the plates ranging from 2 to 10 inches thick. Jointing patterns range from vertical to radial (Figure 37), with the vertical columns dominant throughout the flows. Possible causes for the radial arrangement of columns include the formation of pressure ridges prior to being covered by a succeeding flow (Figure 38), or the cooling of the lava in submarine tubes formed beneath the hardened crust of a flow. Stearns (1930) in describing columnar jointing associated with the intracanyon basalts suggested that the radial jointing occurred where large, vertical, shrinkage cracks extended down from the surface into the flow during cooling. Columns are generally formed perpendicular to a cooling surface, and contact with the canyon walls could cause the irregular arrangement of columns.

Contacts between the intracanyon flows and the walls of the canyons cut in the Madras Formation are steep (24 to 30°) and planar (Figures 35 and 36). The contact zone is relatively narrow, generally consisting of 1 to 3 feet of scoriaceous flow breccia in contact with an underlying 6 inch to 2 foot baked zone. Material from the canyon walls has been incorporated into the base of the flows along the contacts. For example, cobbles and boulders up to 1 1/2 feet in diameter have been picked up from a gravel bed and enclosed in the

Figure 36. Wedge-shaped remnant of the intracanyon basalts about three miles up the Metolius River from its mouth. The contact with the underlying ash-flow tuff is planar.

Figure 37. Radial joint pattern displayed by the intracanyon basalts. Undulating flow structure in upper right of picture may represent pressure ridges.

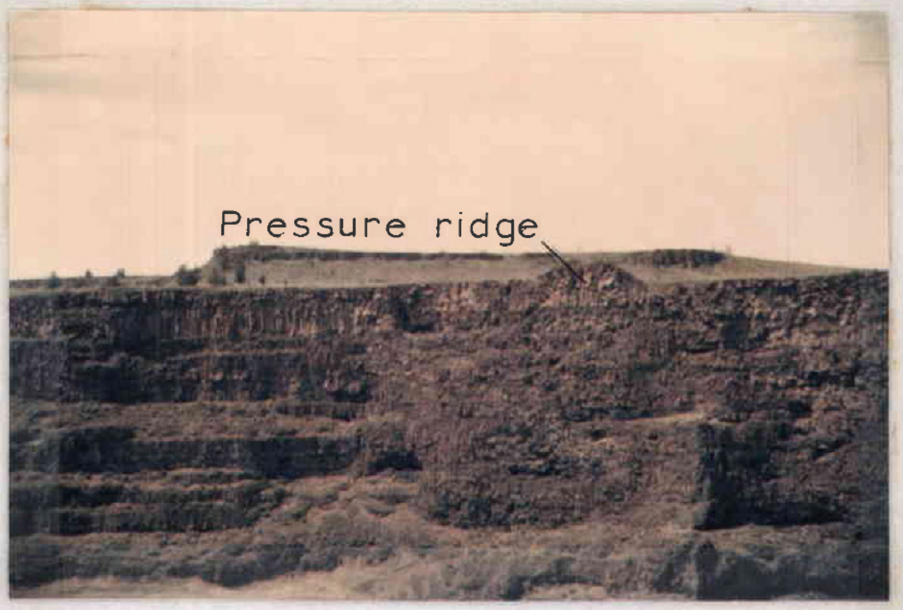


Figure 38. Radial jointing displayed by a pressure ridge in the uppermost intracanyon flow (sec. 22, T. 11 S., R. 12 E.)

flow breccia in the center of sec. 11, T. 12 S., R. 12 E. The lack of a residual soil along the contacts is probably due to sheet erosion along the steep canyon walls prior to the eruption of the intracanyon flows.

South of the area under discussion where the intracanyon flows overlie the Quaternary (rim-forming) basalts, these flows are characterized by long, low pressure ridges and lava tubes.

Lithology and Petrography

In hand specimen the intracanyon basalts are medium to steel gray and weather to a dark brown or black. Their pronounced diktytaxitic texture with up to 15 percent intercrystalline void space is readily apparent and can be used to distinguish these rocks from older basalts in the field. Small yellow to green phenocrysts of olivine can be seen with the unaided eye.

The intracanyon basalts in the Cove area have an intergranular texture with brown augite interstitial to the plagioclase laths (Figure 39). Ophitic and subophitic textures were not observed in these basalts as is common in the Pelton, Madras, and Quaternary (rim-forming) flows. The plagioclase laths average 0. 5 mm in length and range in composition from An 63 to An 69. No evidence was found to support Hodge's conclusion (1940) that the plagioclase in these basalts ranged up to An 90 in composition. Olivine crystals average 0. 25 mm in diameter and tend to be cumulophyric (Figure 40). The

Figure 39. Photomicrograph of intracanyon basalt (Sample 21); brown augite interstitial to the plagioclase laths; note high relief of augite (plain light).

1. 0 mm

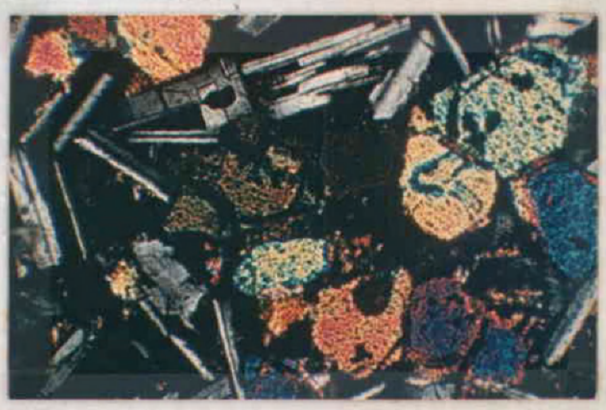


Figure 40. Photomicrograph of intracanyon basalt (Sample 23); olivine crystals clustered together in right side of photo (crossed nicols).

1. 0 mm

olivine is altered to iddingsite, and in Samples 21 and 22 (Table VI) several crystals of olivine have double rims of iddingsite and titaniferous magnetite around them. Scattered granules of titaniferous magnetite alter to leucoxene. In Sample 23 (Table VI) minor amounts of red clay occur in narrow bands.

The intracanyon basalts cropping out in the Fly Creek Quadrangle also have an intergranular texture but differ in that they contain approximately 49 percent plagioclase (average 0. 5 mm in length) with an average composition of An 60. Approximately 12 percent volcanic glass with fine magnetite dust disseminated throughout it is present in the groundmass of these rocks (Sample 20, Table VI). As discussed earlier the mineralogical differences suggest a different source for these flows than those in the Cove area.

Stratigraphic Relationship and Geologic Age

The Youngest Basaltic Lavas (intracanyon) overlie the rim-forming flows south of the mapped area, becoming intracanyon to the Madras beds in sec. 13, T. 13 S., R. 13 E. (Williams, 1957). Stearns (1930) felt the flows were Pleistocene to Recent in age and attributed the rapid canyon cutting through the flows to the extensive columnar jointing in them. Williams (1957), in keeping with the late Pleistocene to Recent age he assigned to the rim-forming basalts, placed these flows in the Recent.

Landslide

Rock and debris slides are common along the canyons in the area. Large talus slopes of broken basalt columns flank the wedge-shaped remnants of the intracanyon flows (Figures 34 and 37). Occasionally, as along the west side of the "Island," large blocks of the intracanyon flows have slumped and rotated backwards as they moved down the canyon wall. Long, narrow rockslides occur below the rim-forming and Madras basalts. These slides usually fill small gullies, fanning out toward the base of the slope. Unsorted Madras sediments and flow material have slumped into the canyons in the Cove area and in secs. 25 and 26, T. 11 S., R. 11 E. These slides display the typical hummocky surface associated with landslides (Figure 41).

Figure 41. View of hummocky landslide area in the Cove State Park.

III. STRUCTURE

The upper Miocene to Recent rocks cropping out in the mapped area are undeformed. The Cascade andesites along the western edge of the area have 1/2 to 3° east dips, and the low, Quaternary shield volcanoes (Round Butte and Squaw Back Ridge) have quaquaversal dips up to 6°.

Baldwin (1964) believes that the topographic low into which the Madras Formation was deposited was formed by downwarping of the older John Day Formation and Columbia River Basalts, which were deformed during late Miocene time. These rocks are structurally high north (Mutton Mountains) and east (Hay Creek uplift) of the basin of deposition (Hodge, 1940).

A north-south trending fault along the front of Green Ridge ten miles west of the area exposes pre-Pliocene volcanic rocks (Williams, 1957). Williams (1962) also mentions an east-facing, north-trending fault scarp in the Mount Jefferson area. Although the nature of the faulting has not been determined, it is possible that the two faults are related, with the area between them being a down-dropped block.

IV. GEOMORPHOLOGY

The eastern two-thirds of the mapped area is a broad, relatively flat surface cut by deep V-shaped canyons. These canyons form a dendritic drainage pattern controlled by the Deschutes River, which in turn flows north into the Columbia. The basalt flows forming the flat surface overlie a sequence of alluvial and volcanic deposits (Madras Formation) derived for the most part from the Cascade Range to the west. These flows and certain of the ash-flow tuff units intercalated in the series of alluvial sediments form near vertical cliffs along the canyon walls. The upper surface of the rim-forming flows is relatively bare with only minor scattered, eolian soil.

Wedge-shaped remnants of intracanyon basalt flows occur along the Crooked, Deschutes, and Metolius canyons, forming a series of flat topped benches whose upper surfaces form a slightly north dipping plane. Intracanyon flows form benches similar to those in the Cove area along the Metolius River in the western part of the area. Their upper surfaces dip gently to the east.

Two low shield volcanoes, Round Butte and Squaw Back Ridge occur in the mapped area, and a third (Little Squaw Back) is located just southwest of the area. The shields are characterized by low, quaquaversal dips, and Round Butte is capped by a steep sided cinder cone (Figure 31).

Along the western edge of the area the more resistant Cascade andesites cap the Madras tuffs and sediments giving a stair-step effect to the ridges as they break from Green Ridge onto the level central Oregon plateau. These ridges trend east to northeast, and are controlled by the drainage from Green Ridge into the Metolius River.

Landslide in the area includes talus slopes beneath the intracanyon flows, hummocky Madras debris, and rockslides occurring under the Madras and rim-forming flows.

V. GEOLOGIC HISTORY

The ancestral Cascades began to form during the early Eocene and by mid-Oligocene time 10,000 feet of volcanics had accumulated along a north-south belt in approximately the same location as the present day High Cascades. These ancestral mountains were never over a few hundred feet high due to subsidence of the underlying material (Williams, 1962).

During late Miocene time the Cascades were uplifted and during the Pliocene the shield volcanoes of the present High Cascade Range began to form (Turner and Verhoogen, 1960; Williams, 1962). The Miocene John Day Formation and Columbia River Basalts were also deformed, forming several separate topographical lows along the east front of the Cascades, the ancestral Deschutes River Valley being one of these (Hodge, 1940). Alluvium from the east flank of the Cascades was washed into the Deschutes River basin. These volcanic rich sediments were intercalated with ash-flow tuffs and basalt flows (Madras Formation). Andesite flows from the Cascades interfingered with the Madras beds along the western edge of the basin. The drainage, cut off to the west by the Cascades, flowed to the southeast for a time, eventually changing to the north as the basin filled (Hodge, 1940).

At the close of the Pliocene glaciers shrouded the High

Cascades, deeply dissecting them (Ice Age). Torrential deposits of mud and gravel, triggered by sudden melting of the glaciers due to increased volcanism or regional warming, were swept off the Cascades into the basin. During this time composite cones such as the South Sister and Mount Jefferson were built up (Williams, 1962).

Deposition into the ancestral Deschutes River Valley was continuous into late Pleistocene time, forming a large pediment fan east of the Cascades (Williams, 1957). At the close of the Pleistocene, lavas flowed from low shield volcanoes covering this pediment fan with a sheet of olivine basalt. Streams cut down through this thick accumulation of sediments and flows forming canyons 1,000 feet deep. The down cutting was initiated by regional uplift, or by the filling of the basin causing the rivers to find an outlet to the north (Stearns, 1930).

In Recent time olivine basalt flows entered the canyons from the south and the west, partially filling them, only to be cut through again by the rivers draining the area. A thin, scattered, ash-rich soil has formed on top of the flows covering the Madras Formation and the remnants of the intracanyon flows. Rock and landslides have occurred along the canyon walls.

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APPENDIX

APPENDIX

Measured Section I: Located in SE 1/4 NE 1/4, sec. 34, T. 11 S., R. 12 E., Round Butte Dam Quadrangle. (Base of section water level of Lake Chinook).

Unit thickness in feet	Total thickness in feet	
13.9	13.7	Ash-flow tuff (Unit 1); gray, weathers flesh; 50% white to gray pumice fragments (5-10 mm), 35-40% gray ash, 5 to 7% small angular basalt fragments (1/2-1 mm), 5% basalt cobbles 3 to 12 inches).
9.8	26.4	Interbedded- Volcanic sand: black; poorly cemented, very friable; fine- to coarse-grained, poorly sorted; 90% subangular basalt lithic fragments, 5-10% olivine, 1-2% pumice fragments (up to 5 mm). Tuffaceous silt: dull purple at base, grades to pink at top; poorly indurated; contains volcanic ash.
0.2	26.6	Pumice: white to gray; subangular; fragments average 1 mm in diameter.
3.2	29.8	Water laid tuff: white to pink, weathers gray, 25% white pumice shards (10 mm in diameter), 70-75% white ash, 1-2% angular basalt fragments (0.1 mm); upper contact displays cut and fill.
4.6	34.4	Pumiceous sand: light brown to white; 70% pumice (1/2 mm), 30% basalt lithic fragments (up to 1/2 mm in diameter) and volcanic ash; upper 2 inches composed of white pumice fragments (20 mm in diameter).

Unit thickness in feet	Total thickness in feet	
8.0	42.4	Volcanic sand: gray med- very coarse grained; poorly consolidated; 50% gray pumice fragments, 20-30% black basaltic lith fragments, matrix clay with minor ash; crossbedded with cut and fill structures.
6.9	49.3	Interbedded- Volcanic gravel: black; subrounded basaltic pebbles (5-40 mm in diameter); matrix contains ash material. Pumice: white; fragments average 20 mm in diameter.
12.0	61.3	Volcanic sand: dark gray, weathers tan to reddish brown; coarse grained; subangular; 85-90% basaltic lith fragments, matrix clay with volcanic ash.
8.0	77.9	Covered: brown reddish brown soil.
1.5	79.4	Volcanic sand: black, weathers with a red tint; med-coarse grained; subangular; 85-90% basaltic lith fragments; very friable with a clay matrix.
3.4	82.8	Volcanic gravel: gray to red basalt and andesite pebbles (20-100 mm); subangular-subrounded; poorly sorted with matrix of sand sized pumice and lithic fragments; displays normal graded bedding.
6.3	89.1	Pebbly, volcanic sand: gray; coarse grained, subangular-subrounded; 50% basaltic lith fragments, 10% olivine and plagioclase grains, semi-consolidated with white ash matrix.

Unit thickness in feet	Total thickness in feet	
1.7	90.8	Pumice: red, yellow, gray and white waterlaid pumice fragments (3-20 mm); 10% subangular coarse grained, lith fragments.
12.1	112.7	Covered
5.2	117.9	Volcanic sand: gray, weathers brown; medium-very coarse; subangular-subrounded; 50% basaltic lith fragments, 30% pumice fragments (up to 20 mm); matrix ashy, poorly consolidated; upper 2 feet baked, contact with overlying flow sharp, displays cut and fill structure; sand grains included in bottom of flow.
22.0	139.9	Olivine basalt: dark gray, weathers red-brown; subophitic to intergranular groundmass, with intercrystalline voids (diktytaxitic); displays crude columnar jointing (columns 5 feet in diameter); lower 1/2 inch and upper 2 feet vesicular (vesicles average 20-40 mm in diameter).
25.8	165.7	Covered
7.5	173.2	Interbedded-
		Pumaceous volcanic sand: gray; medium to very coarse; subangular to rounded; 60-65% basaltic lith fragments, 20-25% pumic fragments (up to 10 mm), matrix ashy; in 1 to 12 inch beds.
		Ash: pink

Unit thickness in feet	Total thickness in feet	
10.3	183.5	Ash-flow tuff (Unit 3): 20-30% orange, pink, gray, and white pumice fragments (5-20 mm in diameter); 60% gray-white ash, 5% zoned plagioclase crystals, 5-8% lithic fragments (0.2 mm in diameter); minor eutaxitic structure with Y-shaped glass fragments; upper contact covered.
28.7	212.2	Interbedded- Volcanic sand: steel gray; medium grained; 60% basaltic lith fragments, 20% ash matrix; in 1-3 feet beds. Gravel: basalt cobbles averaging 3 inches in diameter, range up to 12 inches; has matrix rich in sand size lithic and pumice fragments; bedded in 8-12 inch beds; displays normal graded bedding; poorly consolidated.
1.7	213.9	Pumice: white, weathers tan to orange; fragments 2-20 mm, average 10 mm; no sorting or rounding; apparently air fall.
5.2	219.1	Gravel: gray to black, weathers with reddish tint; 80% basaltic pebbles, matrix lithic sand with minor clay; poorly consolidated; upper 2 feet baked bright brick red; contact with overlying flow sharp.
64.0	283.1	Olivine basalt: gray, weathers dark gray to brown; subophitic groundmass with intercrystalline voids (diktytaxitic); crude columnar joints (10 feet in diameter); lower 6 inches and upper 20 feet of flow vesicular; upper 20 feet platy.

Unit thickness in feet	Total thickness in feet	
2.0	285.1	Gravel: dark gray; basalt pebbles and cobbles ranging up to 16 inches in diameter; subangular-subrounded; very poorly sorted.
31.0	316.1	Pebbly volcanic sand: dark gray; medium grained; with 10% pebble sized materials, 50% basaltic lith fragments, 15-20% olivine and feldspar grains, ash matrix; contains cross bedded olivine rich (60-70%) lenses.
6.2	322.3	Pumice: white, weathers tan; angular fragments average about 30 mm in diameter.
30.2	352.5	Ash-flow tuff (Unit 5): lavender-gray, changing to pink up slope; 45% tan pumice fragments (5-15 mm in diameter), 40% lavender-gray to pink ash, 5-10% lithic fragments (basaltic), 3-5% plagioclase crystals; pumice fragments are flattened and aligned giving a eutaxitic structure to the rock.
2.5	355.0	Volcanic sand: gray with pink tint; medium-coarse grained; composed of subangular-subrounded fragments of underlying ash flow tuff.
3.1	358.1	Pumice: white; angular fragments averaging 15 mm.
9.2	367.3	Interbedded-
		Volcanic sand: gray; medium-very coarse grained; basaltic lith fragments with ash matrix; (poorly consolidated some pebbles; in 2-3 inch beds displaying normal graded bedding.)

Unit thickness in feet	Total thickness in feet	
		Volcanic ash: gray to purple; very fine, no bedding structure. (5-10 inch layers).
29.0	396.3	Interbedded-
		Volcanic sand: dark gray; coarse grained; subangular-subrounded; 60% basaltic lith fragments, 15% feldspar grains, 10% olivine grains; poorly consolidated with white ash matrix; in 3-4 foot beds.
		Ash: white, fine in 1-foot beds.
		Pebble conglomerate: basalt pebbles and boulders up to 10 inches in diameter in sandy matrix; no grading; bedded in 1-2 foot beds.
7.7	404.0	Ash-flow tuff (Unit 6): gray, weathers reddish brown; 30% pumice fragments, 20-30% basaltic lith fragments (up to 20 mm), 40% gray ash; displays minor eutaxitic structure.
3.4	407.4	Interbedded-
		Volcanic sand: dark gray; medium-coarse grained; 70-80% basaltic lithic fragments with minor feldspar and olivine grains, clay matrix with minor ash.
		Pumice: white; angular fragments (10-15 mm); unconsolidated.
56.1	463.5	Covered

Unit thickness in feet	Total thickness in feet	
88.0	551.5	Olivine basalt: gray, weathers dark gray to light brown; groundmass subophitic with intergranular voids (diktytaxitic); olivine phenocrysts up to 2 mm; 2 flows with 1-2 feet of scoriaceous flow breccia at the base of each flow; lower flow 21 feet thick, upper flow 67 feet thick.

Measured Section II: Located in the SE 1/4, sec. 22, T. 11 S., R. 11 E., Fly Creek Quadrangle (Base of section water level of Lake Chinook).

Unit thickness in feet	Total thickness in feet	
34	34	Covered; cobble and boulder till.
8	42	Volcanic sand: gray with a yellow tint, weathers gray; medium grained; subangular; 10% lithic basalt fragments in a yellow, ash matrix bedded in 1-inch to 1-foot beds; lower contact covered, upper contact sharp, undulating.
83	125	Ash-flow tuff (Unit 1): medium gray to pinkish gray, weathers flesh to gray-brown; 30-40% white to gray pumice fragments (average 5 mm), 30-40% gray ash, 20% basaltic lithic fragments (average 10 mm), trace plagioclase crystals; upper contact sharp.
22	147	Ash-flow tuff (Unit 2): 60% white angular pumice fragments, show no flattening; range from 5-150 mm; about 40% pink ash matrix.
29	176	Volcanic sand: alternation 1-5 foot dark gray to gray-green olivine rich sand, lithic sand, and pumice rich sand, medium to very coarse grained; subangular-subrounded; poorly sorted.
40	216	Gravel: dark gray; basalt and andesite pebbles to boulders; subrounded, poorly sorted; in matrix of sand size lithic and pumice fragments; poorly consolidated.
31	247	Interbedded-

Unit thickness in feet	Total thickness in feet	
		Volcanic sand: medium gray; 60-70% basaltic lith fragments in matrix of yellow-gray clay; bedded in 2-5 foot beds; poorly to non-consolidated.
		Tuffaceous silts: yellow to pink, 50-60% volcanic ash.
11	258	Gravel: medium gray to black basalt cobbles (8-9 inches), grades upward medium to coarse grained sandy matrix with minor ash; poorly consolidated; upper contact poorly defined.
52	310	Pumice and Ash (water-laid): alternating 2-3 foot layers of rounded pumice fragments (off white-yellow) and gray ash; pebbles from underlying gravel picked up in lower part of unit; upper contact displays small scale cut and fill structure.
48	358	Interbedded-
		Volcanic sand: medium-dark gray, as at 247 feet, bedded in 3-10 foot beds.
		Tuffaceous silt: yellow brown-light brown silt beds with 50-60% volcanic ash; rare 1-6 inch white ash units; bedded in 1-3 foot beds; upper contact covered.
54	412	Ash-flow tuff (Unit 5): light lavender, weathers with a gray tint; 50% lavender ash, 40% white pumice fragments (up to 10 mm in diameter), 10% black glass shards, minor angular basaltic lith fragments; grades upwards to -

Unit thickness in feet	Total thickness in feet	
45	457	60% tan ash, 30% pumice fragments (average 10 mm), 10% basaltic lith fragments, 3-5% plagioclase crystals; upper contact is gradiational to -
119	576	50-60% tan to pink pumice lapilli (average 35 mm) in pink ash; some pumice blocks near top up to 18 inches in diameter; minor black, scoriaceous blocks near base.
132	708	Covered
76	784	Olivine basalt: medium gray, weathers gray brown; intergranular groundmass with intercrystalline voids (diktytaxitic); contains phenocrysts of olivine; in 2 flows separated by 3-10 feet of flow breccia; displays columnar jointing.

Measured Section III: Located in sec. 13 and 14, T. 12 S., R. 10 E., Fly Creek Quadrangle (Base of section bottom of Fly Creek Canyon).

Unit thickness in feet	Total thickness in feet	
114	114	Covered
58	172	Ash-flow tuff (Unit 5): pink; 50% tan to pink pumice fragments (average 1/2 inch in diameter, range up to 8 inches); 40% pink ash, 10% lithic fragments (basalt or andesite), range up to 1/2 inch.
16	188	Covered
63	251	Ash-flow tuff (Unit 5): pink, 30-40% smoky gray to pink pumice fragments (average 2 mm), 30% pink ash, 10-15% black glass shards (average 10 inches, range up to 18 inches in diameter), minor lith fragments (basalt or andesite) ranging up to 1 mm in diameter; upper 15 feet of unit baked brick red; upper contact is sharp.
72.5	323.5	Andesite: medium to dark gray, weathers dark brown to red brown; microporphyritic with a pilotaxic groundmass; minor hypersthene; in 2 flows displaying platy jointing and separated by flow breccia; lower flow has 9 feet of scoriaceous basal flow breccia; lower flow 53 feet thick, upper flow 19.5 feet thick.

Off set 1500 feet north 78° west.

Unit thickness in feet	Total thickness in feet	
33	356.5	Volcanic sand: gray to yellow-brown; medium-coarse grained, friable, very loosely consolidated; 50-60% lithic andesite fragments, 30% pink and yellow pumice fragments up to 10 mm in diameter, matrix of brown clay; bedded in 1-2 foot beds separated by 1/4 inch layers of caliche.
148	404.5	Covered: light yellow brown soil.
10	414.5	Andesite: medium to steel gray, weathers dark gray to brown with red iron streaks on joint planes; microporphyritic; displays horizontal platy joints (plates 1 to 6 inches).