# Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 5 drill hole, Clackamas County, Oregon

by

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## INTRODUCTION

EWEB 5 was the fifth of six geothermal gradient holes drilled by U.S. Department of Energy, Eugene Water and Electric Board, Sunoco Energy Development Company and Southland Royalty Company under U.S. Department of Energy, Region X, Grant No. DE-FG51-79ET 2743. Eugene Water and Electric Board (EWEB) was the contracting organization. Walter Youngquist, consulting geologist for EWEB, supervised the drilling and supplied splits of the cuttings and drilling information for this study.

EWEB 5 was sited at lat 44°58'59", long 121°57'03" (T. 7 S., R. 7 E., SESE 4), in the Mount Hood National Forest, Clackamas County, Oregon (fig. 1). Drilling commenced on October 9, 1979, at an elevation of 1280.5 m (4,200 feet) above sea level, and reached a depth of 222.6 m (730 feet).

Drilling information and cuttings were logged in feet; therefore, English units will be used, rather than metric, throughout this report. Cuttings were taken from EWEB 5 hole every 10 feet during drilling except at 190, 220, 290, 530, and 570 feet where there was no recovery.

In the laboratory, splits of the cuttings were washed through a 200-mesh screen, and both the coarse and fine fractions were saved. The coarse cuttings were studied with a binocular microscope and typical lithologies, as well as unusual and altered material, were selected for X-ray diffraction to determine the mineral components. X-ray diffraction was done using a Norelco unit with Cu radiation and

a focusing monochrometer with a graphite crystal. Goniometer speed was $1^{o}$ per minute, and recording chart speed was one-half inch per minute. Each sample was hand ground in an agate mortar and pestle and run as a smear made from a water slurry on a glass slide. Samples in which clay minerals were identified or suspected were glycolated at $60^{o}C$ for at least one-half hour and then X-rayed again to determine structural expansion, if any.

A summary of volcanic stratigraphy and effects of alteration are reported here using the data obtained from the laboratory studies and the drill log. No chemistry is available on the cuttings, and no temperature data or geophysical logs from the drill hole are available at this time.

## GEOLOGIC SETTING

The area of the EWEB 5 drill site is near the boundary between the Miocene volcanic rocks of the Western Cascade Range and the younger Pliocene to Recent volcanic rocks of the High Cascade Range (Wells and Peck, 1961; Peck and others, 1964). More detailed mapping of the area by Hammond and others (1980) show that in the vicinity of the EWEB 5 drill hole the boundary between the two provinces consists of several north-northwest-trending major faults downdropped to the east.

The outcrop nearest the EWEB 5 drill hole is about 1/2 km to the west where flows of medium- to light-gray olivine andesite of the High Cascade Range are exposed in a quarry. About 1/2 km further to the west of the quarry, rocks of the upper Miocene Rhododendron Formation outcrop along the road. Between the two outcrops is a

north-northwest-trending fault, dipping steeply east and downdropped about 100 m to the east according to the mapping of Hammond and others (1980).

The Rhododendron Formation rocks consist of interstratified gray, coarsely porphyritic pyroxene andesite flows and multicolored (pink, brick-red, purple) lithic and pumice breccia and tuff which have been faulted and thus are repeated in the section (Hammond and others, 1980). The breccia and tuff of the Rhododendron Formation usually has a brick-red groundmass which is oxidized and partly altered to montmorillonite and hematite. Primary mineralogy of the groundmass consists of plagioclase, clinopyroxene, tridymite, and α-cristobalite. Glass may have been a major constituent and is now altered completely to montmorillonite. Phenocrysts of plagioclase and titanaugite are moderately abundant.

The thin flows of the Rhododendron Formation are andesite with phenocrysts of olivine partly altered to iddingsite. Plagioclase and clinopyroxene are present as phenocrysts, and the groundmass consists of plagioclase, clinopyroxene, and magnetite. In a few places a zeolite, heulandite, fills intergranular spaces and microfractures in andesite flows.

EWEB 5 drill hole is sited in the vicinity of the andesite of the High Cascade Range and penetrates the Miocene Rhododendron Formation at depth, probably about 150 feet, although the drilling log suggests it may be as deep as 190 feet. The nature of the contact in the drill hole is probably an unconformable normal flow contact (fig. 3).

Trace-element chemistry or other information is needed to determine just which flows belong to what age units.

## VOLCANIC STRATIGRAPHY

### General

The EWEB 5 drill hole penetrated eleven flows and eight interlayered volcanic debris[1] units (fig. 2). The upper 150 feet consists of andesite flows and volcanic debris units probably of the High Cascade Range volcanic rocks; below 150 feet the flows and volcanic debris units are probably of upper Miocene Rhododendron Formation. Most of the flows are andesites; however, flows 8 and 11 are probably dacites (although no confirmation has been done by chemistry.) Vapor-phase minerals, including pyroxene, ilmenite, and hematite, are prominent in flows 4 through 10.

Plagioclase phenocryst composition was determined by the X-ray diffraction method of Smith and Yoder (1956) as follows: 90 feet, $An_{41}$; 140 feet, $An_{40}$; 460 feet, $An_{36}$; 550 feet, $An_{35}$; 640 feet, $An_{39}$; 730 feet, $An_{36}$.

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[1]The term "volcanic debris" is used very generally in this report to describe any interval that is not a lava flow but consists entirely of volcanic material such as a mudflow, debris flow, or block and ash flows.

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Fracture zones, lost circulation zones, and intervals of no recovery as obtained from the drill log are indicated in figure 2. The fracture zones have abundant pink oxidized andesite fragments indicating some circulation of fluids. There is nothing in the cuttings to indicate the nature of, or reason for, the lost circulation zones and intervals of no recovery.

0-40 feet Overburden

Consists of weathered oxidized andesitic volcanic rock fragments. Andesite has abundant small plagioclase phenocrysts, and scattered mafic phenocrysts.

40-80 feet Flow 1 Andesite

Flow 1 is a very fresh, dense andesite with abundant small plagioclase phenocrysts in a fine-grained gray groundmass. Clinopyroxene and olivine phenocrysts are moderately abundant.

80-120 feet Volcanic debris

Three lithologies are prominent in the cuttings from this interval: (1) chips from overlying andesite flow 1 which occur in the interval from 40 to 80 feet; (2) tan, fine-grained fragments with clear plagioclase and clinopyroxene phenocrysts and with groundmass of plagioclase, pyroxene, hematite, and montmorillonite; and (3) black, vesicular andesite with phenocrysts of plagioclase, clinopyroxene, and orthopyroxene and with hematite in the groundmass. Oxidation of the andesites is slight and increases slightly downward in this interval.

120-130 feet Flow 2 Andesite

This flow is fresh, fine-grained, medium-gray andesite with phenocrysts of plagioclase, clinopyroxene, and olivine.

130-140 feet Volcanic debris

Dark-gray andesite with abundant white plagioclase phenocrysts is the dominant rock type. Vapor-phase cavities are lined with a pink oxidized rim, and hematite occurs in the groundmass. About one-third of the cuttings are orange grains of oxidized and altered volcanic rock, consisting mostly of montmorillonite. The orange fragments may be a flow top which was exposed to surface weathering.

140-150 feet Flow 3 Andesite

This flow is a dark-gray, massive, fine-grained andesite with sporadic phenocrysts of olivine, plagioclase, orthopyroxene, and possibly scarce clinopyroxene. The groundmass contains plagioclase and hematite. This flow is very different in appearance from the overlying flows.

150-170 feet Volcanic debris

Mixed lithologies similar to interval 130-140 feet make up this unit. Medium-gray andesite with abundant plagioclase phenocrysts is most abundant.

170-300 feet Flow 4 Andesite

Probably more than one flow makes up this interval, but the cuttings do not change significantly, except for minor oxidation and vapor-phase cavities increasing downward. Vapor-phase cavities contain pyroxene and euhedral hematite crystals. Scattered phenocrysts of plagioclase, olivine, orthopyroxene and

scarce clinopyroxene are set in a dark-gray, fine-grained groundmass. Oxidation increases downward and is prominent from 260-300 feet. A fracture zone with circulation loss at 267 feet is reported in the drill log and is probably responsible for the oxidation.

300-310 feet Flow 5 Andesite

This flow is dense, fine-grained, medium-gray andesite with scattered phenocrysts of plagioclase, olivine, and clinopyroxene. Hematite and α-cristobalite are present in the groundmass. A few vapor-phase cavities are present and contain pyroxene and hematite. This flow is readily distinguished from overlying andesite flow 4.

310-425 feet Volcanic debris

A mixture of volcanic fragments in varying proportions is present in this interval, indicating that it may either consist of several thin flows between volcanic debris layers, or that several large volcanic boulders were encountered during drilling. The dominant rock types are: (1) somewhat vesicular, dark-gray to black andesite with red oxidized fracture surfaces; (2) medium-gray to pinkish-gray, fine-grained andesite with few phenocrysts; and (3) completely oxidized brick-red andesite. Vapor-phase cavities containing hematite, ilmenite, and pyroxene are especially prominent from 330 to 425 feet. A yellow smectite clay coats many pyroxene crystals in vapor-phase cavities throughout this interval.

425-450 feet Flow 6 Andesite

Flow 6 consists of mottled gray and pinkish, partly oxidized andesite with few phenocrysts of plagioclase, olivine, and clinopyroxene. The groundmass contains plagioclase, clinopyroxene, hematite, and α-cristobalite. Vapor-phase cavities contain euhedral hematite and tridymite(μ). Andesite between flows is oxidized.

450-500 feet Flow 7 Andesite

This flow is very similar to overlying andesite flow 6, but the two are separated by an oxidized layer at 450 feet.

500-530 feet Volcanic debris

A mixed lot of fragments consist of the following:

(1) gray, fine-grained andesite with abundant plagioclase and subordinate olivine and clinopyroxene phenocrysts;

(2) very dark gray, fine-grained andesite with red oxidized edges;

(3) red oxidized andesite; and

(4) buff-tan, fine-grained, rounded volcaniclastic fragments.

540-550 feet Flow 8 Dacite

Fresh, light-gray, medium-, fine-grained dacite with scarce phenocrysts of plagioclase and clinopyroxene comprise this flow. Groundmass consists of plagioclase, α-cristobalite, clinopyroxene, and hematite.

550-580 feet Volcanic debris

The dominant rock type is dark gray, partly oxidized andesite with some vapor-phase cavities. Phenocrysts are scarce, and the groundmass contains plagioclase, clinopyroxene, and minor hematite, α-cristobalite, and K-feldspar. The andesite is quite oxidized at the base of this interval. A few fragments of the overlying dacite flow occur at 560 feet.

580-600 feet Flow 9 Andesite

Flow 9 is a medium-gray to mottled pink porphyritic andesite with sporadic phenocrysts of plagioclase, clinopyroxene, orthopyroxene, and olivine. Vapor-phase hematite and tridymite occur in cavities.

600-660 feet Volcanic debris

A variety of fragments consist dominantly of the following types: (1) dark-gray andesite with scarce phenocrysts, occasional vapor-phase cavities, and pink oxidized fracture surfaces; (2) brick-red, completely oxidized andesite; (3) light-pink equigranular andesite; (4) scarce brownish to yellowish volcaniclastic rock; and (5) at 640 feet is abundant gray andesite with many white plagioclase phenocrysts. Gibbsite and chlorite and a 10Å clay were identified from this interval.

660-670 feet Flow 10 Andesite

This thin flow consists of medium-gray, dense, fine-grained andesite with few phenocrysts.

670-720 feet Volcanic debris

Same lithologies as interval 600 to 660 feet.

720-730 feet (bottom) Flow 11 Dacite

Light-gray, fine-grained, equigranular dacite makes up flow 11, which is very similar to flow 8. Groundmass consists of plagioclase, clinopyroxene, α-cristobalite, K-feldspar, and hematite.

## ALTERATION MINERALOGY

Much of EWEB 5 drill hole is probably in the upper Miocene Rhododendron Formation which is hydrothermally altered nearly everywhere it crops out.

Alteration in the EWEB 5 drill hole consists of two types:

(1) Fe oxidation which changes the color of the rock from gray to pink or reddish by staining, and often results in dissemination of hematite and (or) goethite in the groundmass. This process can occur during cooling of the flows and probably accounts for most of the oxidation described for these rocks. However, low-temperature hydrothermal alteration can also cause iron oxidation in the rocks.

(2) Alteration by circulating low-temperature thermal waters. The brick-red groundmass alteration of the surface outcrops and volcanic debris units in the drill hole is probably due to low-temperature hydrothermal alteration reacting to cause iron oxidation as the mafic phenocrysts break down and feldspars alter to montmorillonite. Montmorillonite that is not drilling material occurs in very minor amounts at several intervals (80-120 ft, 130-140 ft, 330-425 ft, and 600-660 ft). Chlorite, a 10Å clay and gibbsite ($Al(OH)_3$) occur in the 600-660 foot interval.

Montmorillonite is most commonly an alteration product of feldspar but may also be formed by alteration of fine-grained to glassy groundmass. Montmorillonite in the interval 330-425 feet is a thin, soft, yellow-green deposit on vapor-phase pyroxene crystals in cavities. The pyroxene crystals are partly altered and may be partly replaced by montmorillonite.

Alteration minerals in the 600 to 660 foot volcanic debris unit interval indicates unusual chemistry. The chlorite may easily have formed from mafic phenocrysts. The 10Å clay has an illite structure and could be an alteration product of plagioclase. Gibbsite is not found in low-temperature hydrothermal environments. Gibbsite occurs in several places northwest of Portland and near the city of Salem, Oregon, as a weathering product of Miocene basalts (Libbey and others, 1945). Quite possibly the EWEB 5 volcanic debris interval from 600-660 feet was affected by surface weathering prior to or during deposition.

Calcite was identified at 320 and 560 feet and must be contamination from mud and cement used during drilling (Taylor, 1964). Samples of mud and cement were obtained from the drilling area and X-ray diffraction traces showed that the mud consists of montmorillonite, the cement consists largely of calcite, and a mud-cement mixture consists mostly of calcite, montmorillonite, and thaumasite.

## SUMMARY

The EWEB 5 drill hole penetrates the andesite of the High Cascade Range near the surface and goes into upper Miocene Rhododendron Formation. The contact may be at 150 feet, but trace-element chemistry will be necessary to determine exactly which flows are Rhododendron Formation and which are High Cascades volcanic rocks.

The deposition of vapor-phase hematite, ilmenite, pyroxene, and tridymite is high-temperature from crystallization which occurred during emplacement and cooling of the lava flows.

The occurrence of montmorillonite and heulandite, and abundant Fe oxidation are indicative of widespread low-temperature hydrothermal alteration in the Rhododendron Formation. There is no indication of hydrothermal alteration in the andesites of the High Cascades volcanic rocks. There is no obvious mineralogical indication of present-day hydrothermal alteration taking place along the north-northwest-trending fault(s) in the vicinity of EWEB 5.

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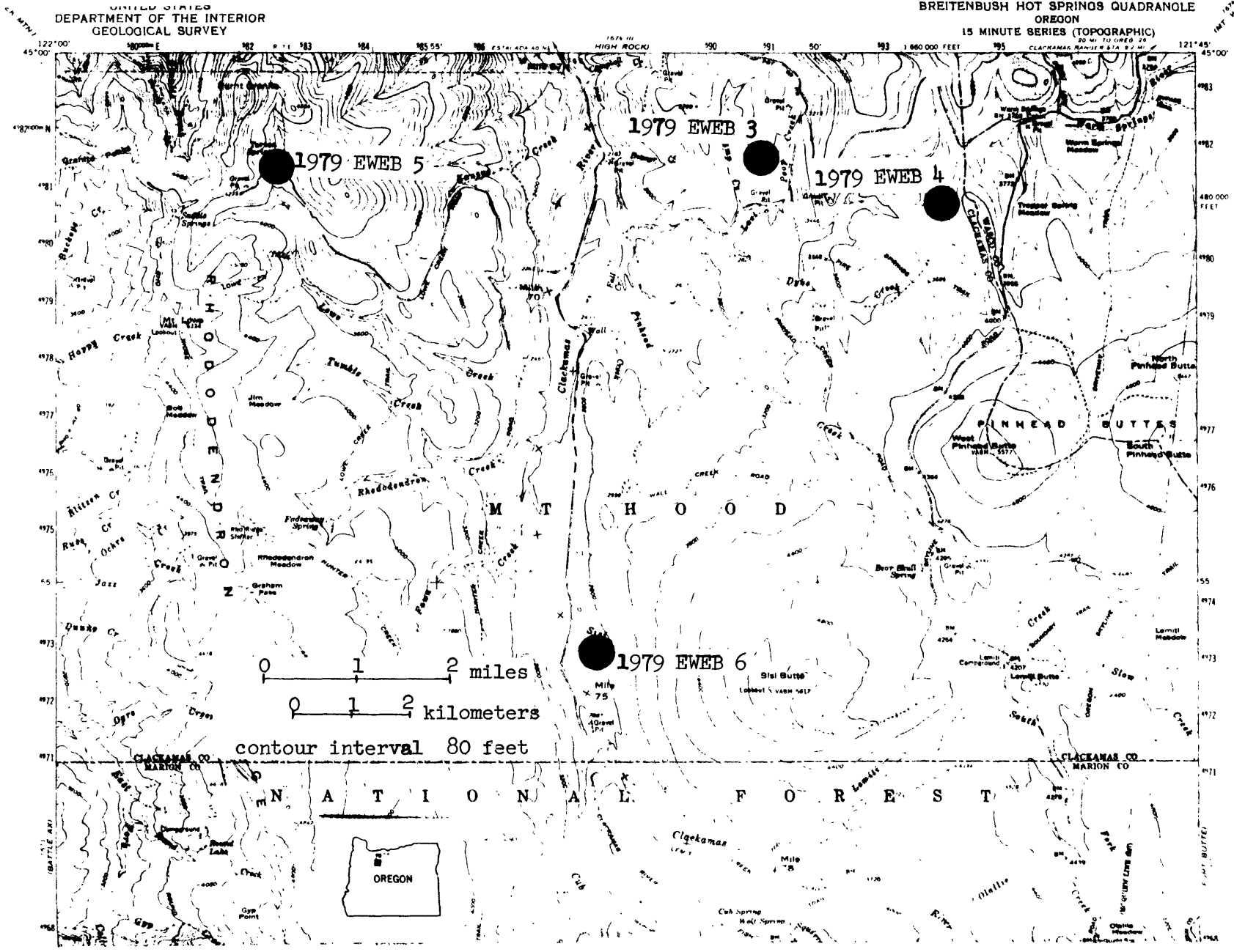


Figure 1. Location of EWEB 5 drill hole.

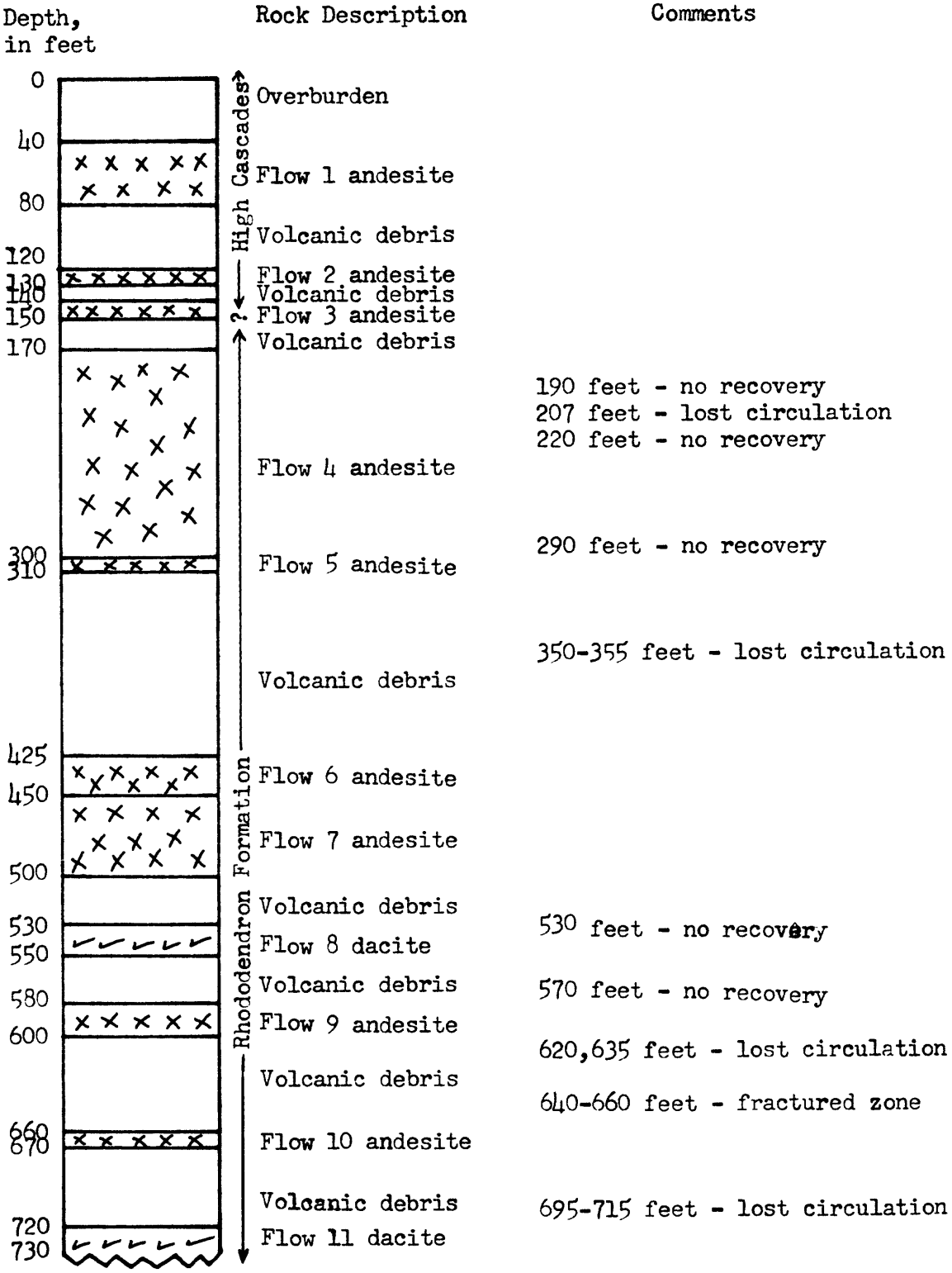


Figure 2. Volcanic stratigraphy of EWEB 5 drill hole.

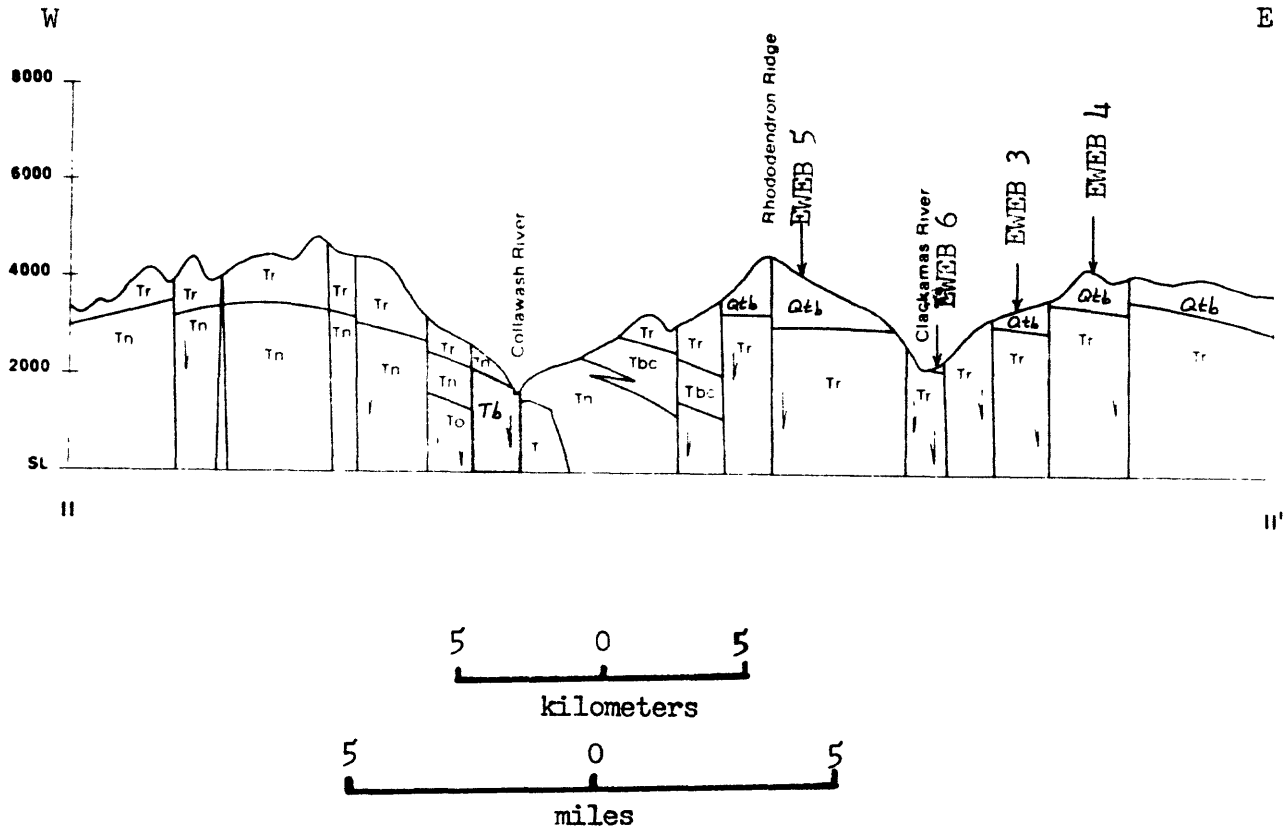


Figure 3. Cross section showing the generalized geologic relationships (after Hammond and others, 1980) and relative locations of EWEB drill holes 3, 4, 5, and 6.

Qtb - Older High Cascade basalt
Tr - Rhododendron Formation
Tbc - Beds of Bull Creek
Tn - Nohorn Andesite
Tb - Breitenbush Formation