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Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 6 drill hole, Clackamas County, Oregon

by

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INTRODUCTION

EWEB 6 was the last 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 6 was sited at lat 44°54'9", long 121°52'52" (T. 8 S., R. 8 F., NWSW 6), in the Mount Hood National Forest, Clackamas County, Oregon (fig. 1). Drilling commenced on October 17, 1979, at an elevation of 2800 feet (853.7 m) above sea level, and reached a depth of 1510 feet (460.4 m) on November 6, 1979.

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 6 drill hole every 10 feet during drilling except at 70, 140, 150, 190, 380, 440, 470 to 540, 980, 1090, 1340, and 1510 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 determination of 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 laboratory studies and the drill log (fig. 2). Temperatures measured during drilling are shown on figure 2.

GEOLOGIC SETTING

The location of the EWEB 6 drill site is on the west side of the High Cascade Range where Pliocene to Recent basalt flows have flowed over Miocene volcanic rocks (Rhododendron Formation) of the Western Cascade Range (Wells and Peck, 1961; Peck and others, 1964). Sisi Butte is a conspicuous young basalt cone about 3 km east of the drill site. Detailed mapping of the area by Hammond and others (1980) defined several northwest trending, nearly vertical faults with the east side displaced downward (fig. 3).

VOLCANIC STRATIGRAPHY

General

The EWEB 6 drill hole penetrated twelve distinctive units (fig. 2). Some of these are simply one flow with very little variation in lithology of the rock making up the flow. Others, designated as flow units, may consist of more than one flow, but the flows are thin and impossible to differentiate with cuttings. Volcanic debris units are indicated where there is a variety of textures and colors in cuttings which may have come from a volcanic mud flow, volcaniclastic layer, or even water deposited material made up entirely of volcanic boulders and cobbles. Any of these units could be encountered in the drill hole as they are exposed in road cuts and stream valleys in various parts of the Cascade Range.

Andesite is the most common rock type encountered in the drill hole. The uppermost unit may actually be basalt or basaltic andesite. Deeper in the drill hole, some rock fragments have a few mafic phenocrysts and no mafic minerals in the groundmass so these have been designated as dacites. No chemistry has been done or thin sections made on any of the cuttings so all the rock types in this report are hand specimen identifications.

Plagioclase compositions were determined on representative samples from several units by the X-ray diffraction method of Smith and Yoder (1956) as follows: 530 ft, An_{40}; 660 ft, An_{46}; 1330 ft, An_{42}; 1440, An_{43}.

A possible contact at the EWEB 6 site for the High Cascades lavas overlying the upper Miocene Rhododendron Formation is at 330 feet depth; however, because of the lack of trace element chemistry and lack of flow correlation in either type of lava, the contact is speculative. According to the studies of Hammond and others (1980), the contact in the area of EWEB 6 is probably an unconformable flow contact rather than a fault contact (fig. 3).

Fracture zones, lost circulation zones, and intervals of no recovery are indicated in figure 2 as obtained from the drill log. There is no rock material to indicate the nature of, or reason for, the lost circulation zones and intervals of no recovery. A fault may have been intersected by EWEB 6 drill hole from 470 to 550 feet. This is an interval of lost circulation and no recovery until a soft, pink material, judged to be hydrothermally altered material was recovered at 550 feet. However the material could be a fine-grained volcaniclastic unit, a lake deposit, or fault gouge.

0-70 feet, Unit 1, Glacial debris.

The uppermost 70 feet of cuttings consist of very dark gray microporphyritic olivine basalt of High Cascades lava. Most of the basalt is dense; some is vesicular. Clear to white, stubby to lath-shaped plagioclase phenocrysts are abundant. Mafic phenocrysts are mostly olivine and scarce clinopyroxene. Groundmass consists mainly of plagioclase, clinopyroxene, and magnetite.

70-90 feet, Flow 2, Olivine basalt.

Dense, microporphyritic, medium gray olivine basalt makes up this flow. Conspicuous olivine phenocrysts are ± 1 mm in diameter; plagioclase phenocrysts are small, but moderately abundant. Groundmass consists mainly of plagioclase, clinopyroxene, and magnetite.

90-150 feet, Flow 3, Olivine basalt.

Most of the flow consists of dense, medium to dark gray microporphyritic basalt. The upper 20 feet of the flow is somewhat vesicular as is typical of a flow. Small phenocrysts of clear to white plagioclase are abundant. Olivine phenocrysts are relatively large (±1 mm) but not abundant. Groundmass consists dominantly of plagioclase, clinopyroxene, and magnetite.

150-290 feet, Flow 4, Basalt.

Nearly equigranular fine-grained, orthopyroxene, plagioclase, and minor olivine make up the typical basalt of this flow. However, abundant medium gray, dense, fine-grained olivine basalt also occurs throughout the unit.

290-330 feet, Flow 5, Interlayered black glass, andesite.

Thin flows of black olivine basaltic or andesitic glass and crystalline andesite are probably interlayered in this interval. The drill log notes "very hard" layers at 290 and 310 feet which are interpreted to be the layers of black olivine basaltic or andesitic glass. Microphenocrysts of plagioclase and olivine occur in the glass. Most of the rock in the interval 290-330 feet consists of dark gray fine-grained microporphyritic andesite with relatively large olivine phenocrysts. The andesite groundmass consists mainly of plagioclase, clinopyroxene, and olivine.

330-470 feet, Unit 6, Volcanic debris.

The dominant rock types of this unit are dense, dark and medium gray andesites. The medium gray andesite is orthopyoxene-rich and the dark gray andesite has moderately abundant olivine phenocrysts. Groundmass of both types consists largely of plagioclase. Minor amounts of black glass persist from 330 to 370 feet and at 410 feet.

A greenish to tan, slightly coarser-grained rock occurs in minor amounts throughout the interval; X-ray diffraction traces show it to consist of plagioclase (andesine) and a trace of orthopyroxene. A buff to white deposit in dark gray vesicular andesite fragments at 330 feet is plagioclase (andesine), minor clinopyroxene, and hematite. Unit 6 probably consists of thin andesite flows interlayered with volcanic mud flows (cold or hot) with large volcanic boulders and cobbles typical of the Western Cascades volcanic rocks. The drill log has a note of red clay at 440 feet. None of the red clay was recovered, but this type of material occurs as oxidized surface weathering layers within outcropping volcanic debris units in the Western Cascade Range.

470-570 feet, Unit 7, Interval of hydrothermal alteration.

No recovery was obtained throughout most of this interval, however, a small amount of material at 500 to 560 feet consists of fine-grained, soft, pink to buff, hydrothermally-altered volcanic rock, probably dacite. Some plagioclase phenocrysts remain as do dark reddish black, partly oxidized hornblende phenocrysts.

570-1310 feet, Unit 8, Dacite.

The only change in cuttings from this long interval is slight darkening of the pink and gray colors from top to bottom.

The rock is fine-grained dacite with phenocrysts of plagioclase and partly oxidized reddish black, altered hornblende. Groundmass consists mainly of plagioclase, α-cristobalite, hematite, montmorillonite-illite, and traces of clinopyroxene, quartz, and K-feldspar. The rock is mostly light gray, but half the fragments are pink from partial oxidation along fractures.

At 840 and 940 feet are samples dominantly of a medium gray olivine, orthopyroxene andesite which may be a thin flow or a zone protected from alteration. Minor amounts of reddish, tan and gray andesitic to dacitic fragments are also mixed in these intervals.

Red to orange hydrothermal iron staining on fracture surfaces occurs from 760 to 800 feet.

<u>1310-1360 feet</u>, Unit 9, Volcanic debris.

Multicolored fragments of volcanic material comprise this unit. Listed in order of decreasing abundance:

1. Dark to light gray, moderately fine-grained andesite with phenocrysts of clear plagioclase, quartz, orthopyroxene, and some montmorillonite alteration. Plagioclase and α-cristobalite are in the groundmass.
2. Light to medium gray, fine-grained andesite with plagioclase, α-cristobalite, and quartz in the groundmass.
3. Minor fine-grained orange, yellow, red, purplish oxidized fragments.
4. Light tan, poorly cemented volcaniclastic rock with sand-sized grains.

<u>1360-1410 feet</u>, Flow 10, Andesite.

Light to dark gray, dense microporphyritic fine-grained andesite makes up this flow. Phenocrysts consist of clear plagioclase and small hornblende phenocrysts. Groundmass consists dominantly of plagioclase and montmorillonite. Some of the rock is pink due to iron oxidation of mafic phenocrysts.

1410-1440 feet, Flow 11, Andesite.

Dark gray, fine-grained andesite with scattered clear plagioclase phenocrysts. Groundmass consists of plagioclase, orthopyroxene, and a trace of α-cristobalite.

1440-1500 feet, Flow 12, Dacite.

Two slightly different volcanic rock types make up this flow unit. The dominant phase is light gray, or pink where oxidized, microporphyritic dacite with clear plagioclase, and a few elongate black hornblende phenocrysts. The groundmass consists of plagioclase, α-cristobalite, hematite, and montmorillonite.

The second rock type is dark gray, fine-grained dacite composed of plagioclase, clinopyroxene, α-cristobalite and vapor phase tridymite. Hydrothermal montmorillonite is also in the groundmass.

HYDROTHERMAL ALTERATION

Geothermal alteration in EWEB 6 is significant in two intervals:

1. 470-560 feet where recovery consists of a few pieces of light pink altered dacite which has been extensively altered to montmorillonite, and
2. 760-800 feet where there are red to orange iron-stained fracture surfaces. The drill log at 800 feet mentions red clay, but nothing other than iron hydroxide occurs in the cuttings.

Partial alteration of groundmass to montmorillonite has occurred at 1360-1400 and 1440-1500 feet.

The significance of the alteration in the 470 to 560 feet interval is difficult to determine because of lack of material. The factors to be considered are (1) the lithology of the interval, and (2) the extent of alteration. Without recovery, there is obviously no data on either factor. Based on the two samples at 550 and 560 feet--which are soft, light pink, altered dacite consisting of partly altered plagioclase and montmorillonite--and the drill log notes of lost circulation and no recovery, we can imply two possibilities as to the nature of the material: (1) the material existed as small unconsolidated particles which may have been a tuff of some kind, perhaps deposited here in a former topographic low to account for a thickness of 100 feet; (2) the material could have been the upper part of the dacite unit which extends from 570 to 1310 feet and was thoroughly hydrothermally altered. The possibility exists that, regardless of the nature of the material, the 100-foot interval may be a fault zone which fractured and brecciated the rock and provided a channel for hydrothermal solutions. No evidence of any hydrothermally deposited minerals exist in the available samples other than montmorillonite.

The iron hydroxide coating and staining on fracture surfaces from 760 to 800 feet could have been deposited by hydrothermal fluids circulating in a fractured interval or by late cooling (deuteric) fluids during emplacement of the flow. The "red clay" recorded in the drill log could have been soft massive iron hydroxide. If it was indeed clay, it must have been iron stained and probably deposited in association with the iron hydroxide coating the fractures. Additional indications of low-temperature hydrothermal alteration are the montmorillonite in the groundmass of flow units 10 (1360–1410 feet) and 12 (1440-1500 feet)(fig. 2).

Cuttings from the fractured zone, noted in the drilling log from 1086 to 1154 feet, show no evidence of hydrothermal alteration. The alteration is all in the older rocks of the Western Cascade Group (Rhododendron Formation). None of the overlying rocks of the High Cascades Group flows are altered.

SUMMARY

EWEB 6 drill hole penetrates basalt and andesite of the High Cascade lavas for approximately 330 feet and then is probably in Upper Miocene Rhododendron Formation which consists of interlayered andesite flows, and volcanic debris. The contact cannot be assigned with certainty without further data, including trace element chemistry.

Two significant intervals of low-temperature hydrothermal alteration occur in the Rhododendron Formation at 470–560 feet and 760–800 feet. Temperatures measured during drilling indicate that any hydrothermal fluids in the present system are low temperature. An important consideration is that possibly the 470–560 foot interval was a fault zone that served as a channel for low-temperature hydrothermal fluid.

REFERENCES

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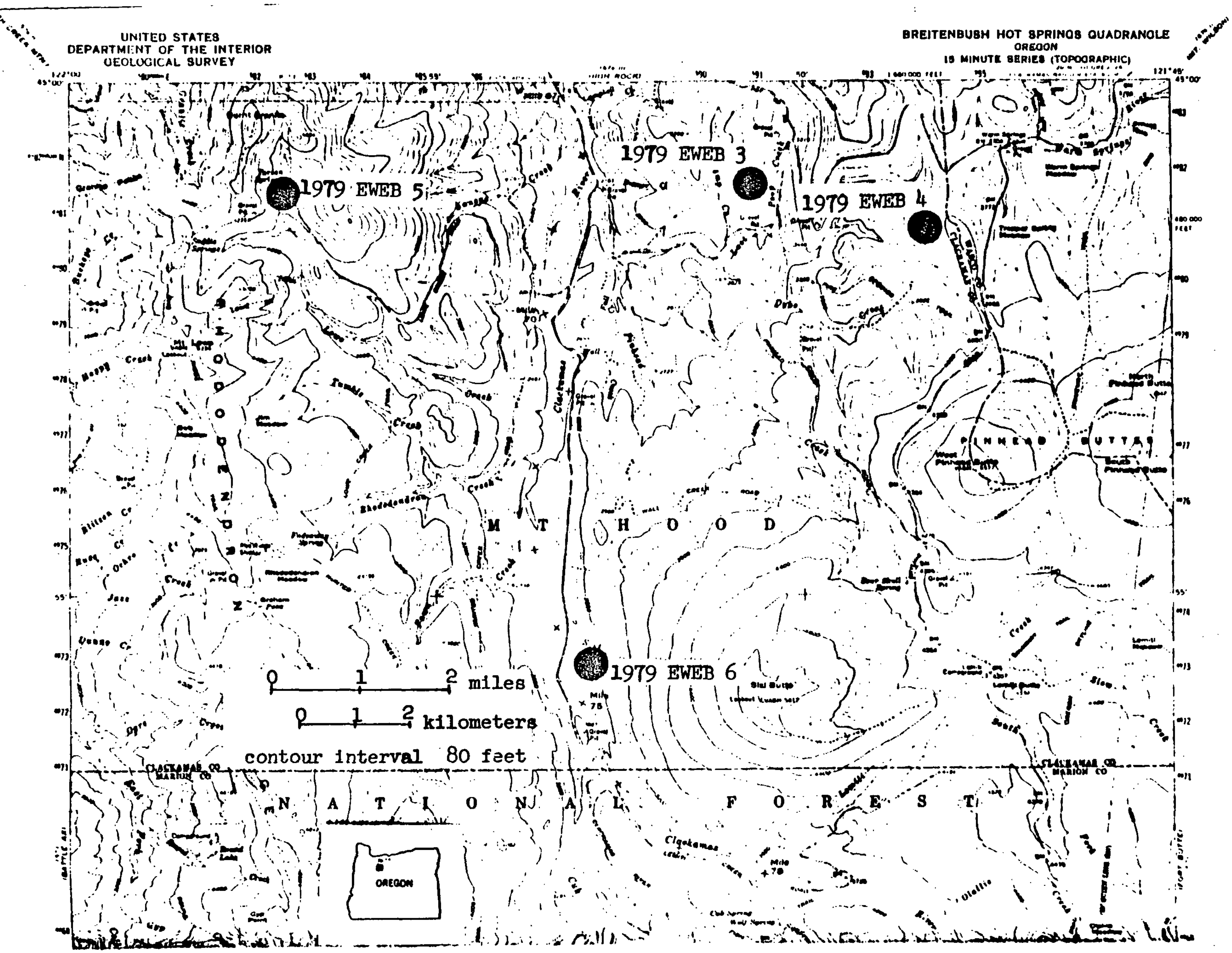

Figure 1. Location of EWEB 6 drill hole.

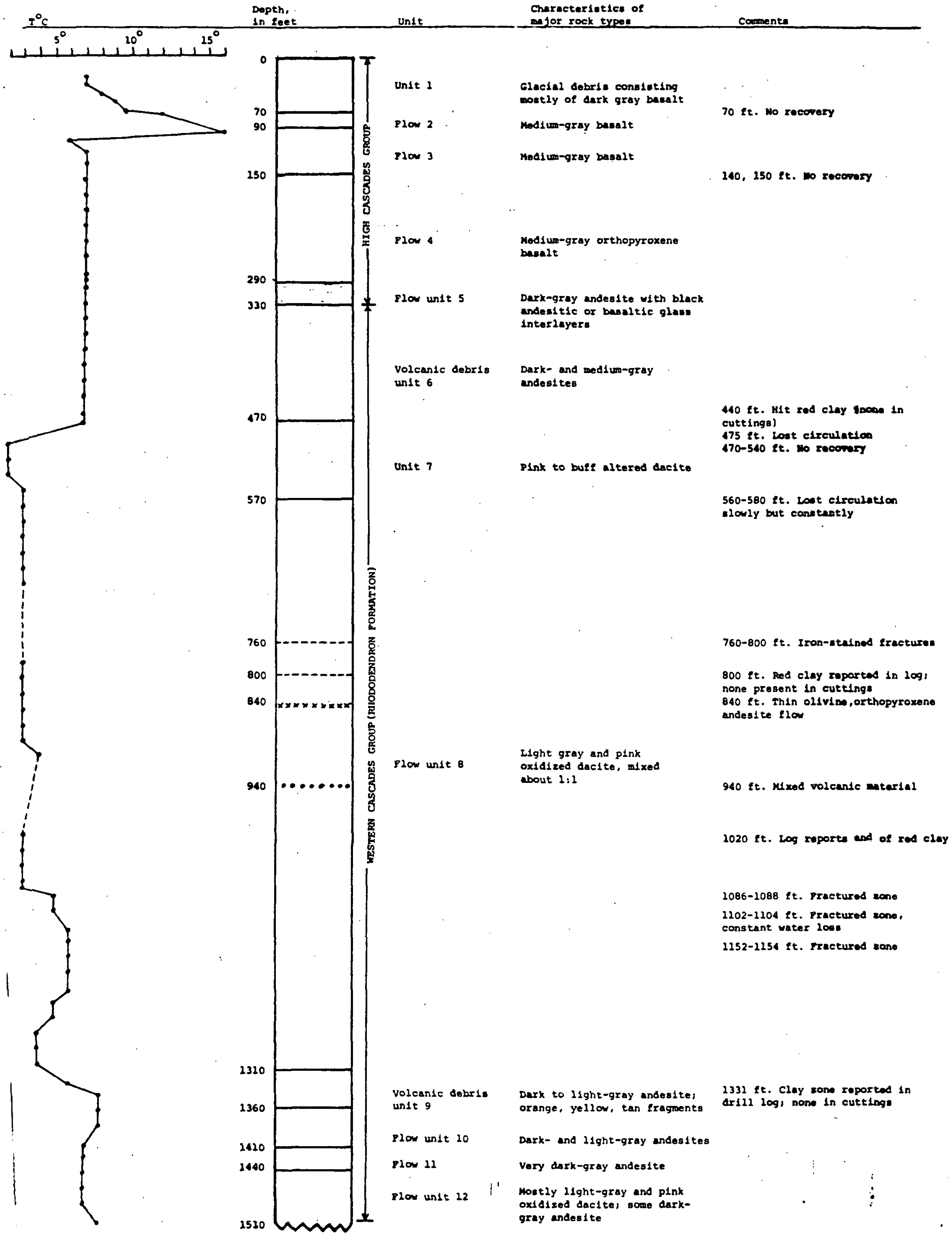

Figure 2. Stratigraphic section of EWEB 6 drill hole.
Temperatures measured during drilling are shown at left.

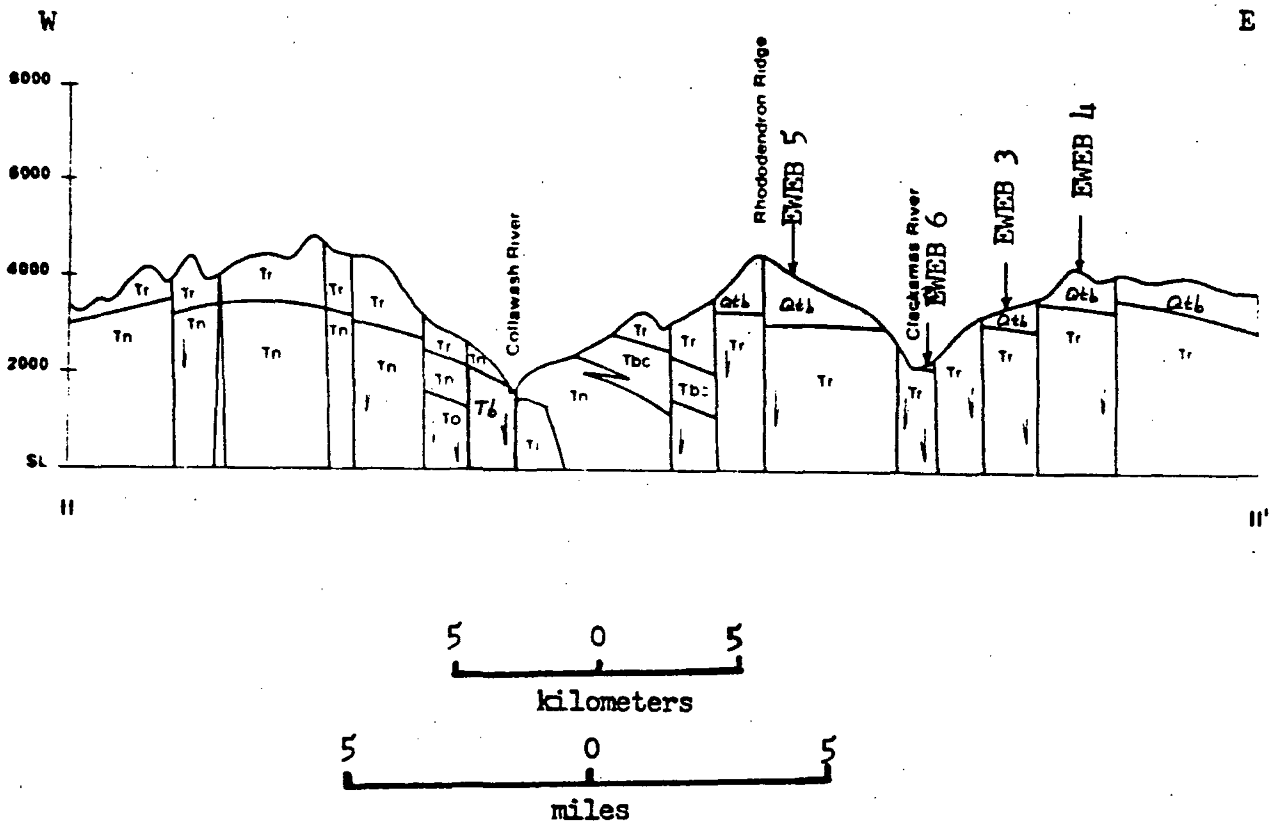

Figure 3. Cross section showing the generalized geologic relationships (after Hammond and others, 1980) and relative locations of EWEB drill holes 3, 4, 5, and 6.

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