Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 2 drill hole, Linn County, Oregon

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INTRODUCTION

EWEB 2 was the second 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 2 was sited at lat 44°32'20", long 121°58'28" (T. 12 S., R. 7 E., NWSE 9), in the Willamette National Forest, Linn County, Oregon (fig. 1). Drilling commenced on August 14, 1979, at an elevation of 3,760 feet (1145.1 m) above sea level, and reached a depth of 1,965 feet (599.1 m) on September 11, 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 2 drill hole every 10 feet during drilling except at 10, 40, 70, 180, 200, 340, 540, 820, 990, 1,070, 1,110, 1,570, 1,630, 1,640, 1,790, 1,890, 1,910, and 1,960 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.

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Goniometer speed was 1° 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°C for at least one-half hour and then X-rayed again to determine structural expansion, if any. Plagioclase compositions, where indicated, were determined using the X-ray diffraction method of Smith and Yoder (1956).

A summary of volcanic stratigraphy and effects of alteration are reported here using the data obtained from the laboratory studies and the drill log. Temperatures measured during drilling are shown on figure 2. No chemistry is available on the cuttings and no geophysical logs from the drill hole are available at this time.

GEOLOGIC SETTING

The area of the EWEB 2 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). In the area of EWEB 2, basalt and andesite flows of the High Cascades Range having eruptive vents to the east, unconformably overlie a thick section of andesitic to basaltic rocks of the Western Cascade Range. The older volcanic material consists of volcanic mud flows, breccias, tuffs of various kinds, and thin lava flows. Old weathered surfaces and oxidized flow tops can be seen in outcrops. Much fracturing and faulting undoubtedly has been superimposed upon an already complex volcanic pile.

VOLCANIC STRATIGRAPHY

EWEB 2 drill hole penetrates basalt and andesite flows of the High Cascades Group to a depth of 550 feet. These rocks unconformably overlie a thick section of interlayered flows, tuffs, volcanic debris and volcaniclastic rocks of the Western Cascade Group extending from 550 feet through the bottom of the drill hole (fig. 2). The unconformable flow contact between Western and High Cascade Groups may be adjusted with more detailed studies, including trace element chemistry, but on the basis of the present study it appears to occur at about 550 feet.

0-60 feet, Overburden, glacial deposit.

The overburden consists dominantly of black vesicular basalt which has been reworked and deposited by glacial activity.

60-120 feet, Flow 1, olivine basalt.

This flow consists of black microporphyritic basalt with phenocrysts of plagioclase and olivine. The groundmass consists dominantly of plagioclase (An_{47}), clinopyroxene, and magnetite. Iron oxidation has resulted in red coatings along fractures and on grain surfaces of olivine. The basalt is very vesicular from 70-90 feet and massive from 100-120 feet.

120-410 feet, Flow 2, olivine andesite.

Flow 2 is a massive, light gray andesite with phenocrysts of plagioclase, olivine, and, rarely, quartz and groundmass of plagioclase, clinopyroxene, and magnetite. There are few mafic minerals in the groundmass in contrast to the overlying flow. Near the top of the flow, fractured olivine phenocrysts are coated by reddish iron oxide on fracture and grain surfaces.

410-550 feet, Flow 3, olivine basalt.

Interlayered vesicular basalt, dense crystalline olivine basalt, and basalt glass make up this flow. Olivine and plagioclase occur as phenocrysts in all the basalt types and orthopyroxene phenocrysts are present in the dense crystalline basalt. Black basalt glass occurs in both the massive and vesicular flows. From 510-550 feet there is dark brown "frothy" basalt glass mixed with the other basalt types.

550-640 feet, Volcanic debris unit.

Cuttings in this interval consist of a variety of lithologies:

1. Fine-grained, tan volcaniclastic siltstone and fine sandstone composed mostly of plagioclase and montmorillonite and minor hematite.
2. Black vesicular basalt glass.
3. Medium gray dense olivine andesite.
4. Fine-grained, blue-gray fragments with relatively large orthopyroxene and plagioclase phenocrysts.

Much, if not all, of this interval probably consists of silt to boulder size andesite and basalt fragments which were deposited very rapidly, either warm or cold, possibly as a volcanic mud flow or as a water-mud transported flood deposit. The andesite and basalt could be large boulders within the volcanic debris deposit or they may represent thin flows.

The siltstone and sandstone fragments were crushed and examined in oils under a petrographic microscope to look for evidence of glass shards, but none were seen. Most of the grains were plagioclase. Glass shards may have originally been present, but have been altered to montmorillonite. There is a curious lack of mafic fragments considering the basaltic to andesitic, or possibly dacitic, origin of the volcanic debris. Thin layering, which is probably bedding, was observed in some fragments indicating that perhaps these are water-laid sediments from a shallow lake environment.

640-770 feet, Volcanic debris unit.

In contrast to the overlying volcanic debris unit, this interval consists mainly of medium gray, fine-grained olivine andesite. The olivine andesite has large rounded phenocrysts of olivine, clear phenocrysts of plagioclase (An_{47}), and groundmass composed of plagioclase, clinopyroxene, tridymite, α-cristobalite, and traces of K-feldspar and quartz. Hornblende phenocrysts are present in the olivine andesite at 770 feet. There is a significant amount of varied andesitic lithologies mixed with the olivine andesite to suggest that much of this unit is volcanic debris, although it may represent thin flows of olivine andesite interlayered with volcanic debris.

Slight oxidation of iron in the mafic minerals occurs sporadically through the interval. Minor chlorite has formed from mafic phenocrysts at 710 feet.

770-780 feet, Flow 4, olivine andesite.

Light gray, dense andesite with phenocrysts of olivine, plagioclase, and hornblende and groundmass composed of plagioclase, clinopyroxene, tridymite, α-cristobalite, and magnetite make up this flow. The flow is distinctive in the cuttings, but may be just a thin flow within a volcanic debris unit extending from 650-830 feet.

780-830 feet, Volcanic debris unit.

This unit is very similar to the interval from 640-770 feet. The dominant lithology is medium gray, dense andesite with olivine and plagioclase phenocrysts. Volcaniclastic buff siltstone and fine sandstone occurs at the base of this interval. Fine bedding is evident in the larger fragments.

830-840 feet, Flow 5, olivine andesite.

Dark gray andesite with small vesicles makes up this flow. Phenocrysts are plagioclase and olivine; groundmass consists of plagioclase, clinopyroxene, and magnetite. A thin layer of green montmorillonite lines most of the small vesicles. Tan to white, very fine-grained chalcedony and montmorillonite (mixed or finely layered) partly fill some of the vesicles.

840-890 feet, Flow 6, olivine andesite.

Flow 6 is composed of light gray, dense, medium fine-grained andesite with scarce phenocrysts of olivine and plagioclase. The groundmass consists of plagioclase, clinopyroxene, and magnetite.

890-980 feet, Volcaniclastic unit.

Tan fragments of siltstone to fine sandstone are probably volcaniclastic rather than volcanic ash (see interval 550-640). Fine layering can be seen in the larger fragments. Subordinate amount of fragments of dark gray, slightly vesicular andesite, blue-gray orthopyroxene andesite, and reddish oxidized andesite are present in the cuttings.

980-1,260 feet, Flow 7, olivine andesite.

Flow 7 is a quite fresh appearing flow of dark gray, dense to moderately vesicular porphyritic andesite; most is crystalline, but some is glassy. Phenocrysts are olivine, plagioclase, and orthopyroxene; groundmass consists of plagioclase, clinopyroxene, and magnetite.

Tan volcaniclastic material persists from 990-1,020 feet. The upper part of Flow 7 may be interbedded thin flows and volcaniclastic material. Fine bedding is present in the fragments and fresh water diatoms (identified by John Barron, written communication, 1981) are evidence of a lake deposit between lava flows. An ash layer consisting of white pumice with plagioclase phenocrysts occurs from 1,180-1,220 feet. Note the drop in temperature measured during drilling at the ash layer (fig. 2), indicating high permeability of the layer and an influx of cold groundwater.

1,260-1,740 feet, Volcaniclastic unit.

This interval is dominantly tan siltstone to fine sandstone similar to that at 900-980 feet, but there are thin andesite flows and a pumice (or ash) layer within the unit. The volcaniclastic material consists mostly of plagioclase and montmorillonite with minor clinopyroxene. Bedding is conspicuous in many fragments. From 1,260-1,430 feet, light gray equigranular andesite composed of plagioclase, clinopyroxene, olivine, and magnetite represents interlayered flows. Black andesitic (?) glass and dark gray andesite are also present. A minor amount of white pumiceous ash is mixed with the gray andesite at 1,430-1,460 feet. From 1,460 to 1,520 feet, the medium-grained sandstone fragments contain rounded volcanic rock fragments and phenocrysts that are probably fluvial. Fine sandstone and siltstone fragments remain abundant. Dense, fine-grained, dark gray andesite gradually becomes the dominant lithology at 1,520 feet and makes up several flows, interlayered with volcaniclastic material, from 1,520-1,580 feet. The andesite has phenocrysts of plagioclase, olivine, and clinopyroxene and groundmass of plagioclase, clinopyroxene, and magnetite. From 1,580-1,670 feet, flows of equigranular andesite consisting of plagioclase, clinopyroxene, and magnetite occur. Volcaniclastic material is again prominent from 1,670-1,700 feet. Siltstone and fine sandstone are more common than medium-grained sandstone. Bedding of thickness ranging from 1/4 to 1/2 mm is exhibited by laminations with sharp contacts. The base of the unit from 1,700-1,740 feet is a flow, or flows, of light gray, dense, equigranular andesite composed of plagioclase, olivine, clinopyroxene, and magnetite.

1,740-1,750 feet, Flow 8, olivine andesitic or basaltic glass.

Flow 8 is a thin, distinctive, finely crystalline flow of dark gray to black glassy andesite or basalt. Phenocrysts are olivine and plagioclase.

1,750-1,840 feet, Volcanic debris unit.

A variety of volcanic lithologies is present in this interval suggesting that the material was deposited as a mudflow, flood water, or by some other chaotic mechanism. The dominant lithologies in the upper part of the unit are dark gray andesite and white pumice. Subordinate lithologies are tan, volcaniclastic siltstone and fine-grained sandstone, red oxidized andesite, fine-grained, greenish andesite with magnetite octahedra, and equigranular, light gray olivine andesite with minor black hornblende phenocrysts.

1,810 feet marks the last occurrence of white pumice, and from this level the proportion of volcaniclastic material begins to increase downward relative to andesite flow fragments.

Hydrothermal alteration at 1,800 feet is indicated by euhedral, clear, tiny quartz crystals cementing several volcanic fragments. There is some evidence of veins and vesicle filling or lining. Fine-grained chlorite and hematite occur as alteration of mafic phenocrysts and groundmass in andesitic fragments.

1,840-1,950 feet, Volcaniclastic unit.

Tan, brown, and olive-green volcaniclastic siltstone and fine- to medium-grained sandstone mixed with minor amounts of dark gray andesite fragments comprises this interval. The volcaniclastic material consists mainly of plagioclase and montmorillonite with minor hematite and chlorite in places. The medium-grained sandstone contains grains of mafic and plagioclase (An_{47}) phenocrysts, and of black andesite or basalt fragments. The volcaniclastic fragments are well cemented in this interval. Thin bedding is conspicuous in many fragments.

The color change of the volcaniclastic material from tan to brown and olive-green, the better cementation, and the occurrence of minor chlorite and hematite suggest that the rocks have been altered by low-temperature hydrothermal activity or by slightly elevated temperatures and pressures due to burial, or both.

HYDROTHERMAL ALTERATION

Mineralogical evidence of hydrothermal alteration is found in several intervals of EWEB 2. At 840 feet, the olivine andesite flow contains minor amounts of silica (chalcedony) and medium green montmorillonite deposited as coatings and, sometimes, filling vesicles. At 1,800 feet in the volcanic debris unit (fig. 2), clear euhedral quartz, chlorite, and hematite occur as deposits on tiny fractures and filling vesicles. Although the volcanic debris unit extends from a depth of 1,750 to 1,840 feet (fig. 2), the only evidence of hydrothermal alteration is at 1,800 feet. The quartz, chlorite, hematite assemblage could be indicative of moderate temperature, propylitic alteration conditions. In the volcaniclastic unit from 1,840 to 1,950 feet, mafic minerals are partly altered to chlorite, and hematite is disseminated throughout the groundmass. These minerals are probably a result of the same temperature effect as the hematite-chlorite assemblage at 1,800 feet, although no quartz has been identified from 1,840 to 1,950 feet.

Montmorillonite is present in all the volcaniclastic intervals and is probably of moderately low temperature hydrothermal origin . Some montmorillonite might be contamination from drilling. A few unaltered black glass fragments coexist with glass fragments partly altered to montmorillonite. No shard structure was observed in crushed fragments of the glass under the petrographic microscope; nevertheless, the montmorillonite probably formed from the alteration of volcanic glass shards by thermal water circulating along fractures. Thin andesitic lava flows interbedded with the volcaniclastic layers indicate that sources of heat were available during periods of volcanic activity. Burial pressure built up somewhat as later lava flows and volcanic debris covered the volcaniclastic layers. Heat from lava flows and burial pressure is certainly enough to cause the formation of montmorillonite from glass, but neither temperature and pressure conditions nor permeability allowing fluid circulation were sufficient to cause formation of zeolites and other hydrothermal minerals, except locally at 1,800 feet, and depths below 1,840 feet where chlorite and hematite formed.

SUMMARY

No hydrothermal alteration was found in the High Cascades Range lavas in the upper 550 feet penetrated by the drill hole. The only alteration observed occurs in rocks of the older Western Cascade Range lavas.

Mineralogical evidence of hydrothermal alteration is found at (1) 840 feet in the olivine andesite flow; (2) 1,800 feet in the volcanic debris unit; and (3) 1,840 to 1,950 feet in the volcaniclastic unit. The montmorillonite in the volcaniclastic units penetrated is mostly, if not all, hydrothermal. The chlorite, hematite, and $\pm$ quartz at (2) and (3) above is indicative of possible moderate temperatures, about 200° to 300°C, during the period of hydrothermal activity.

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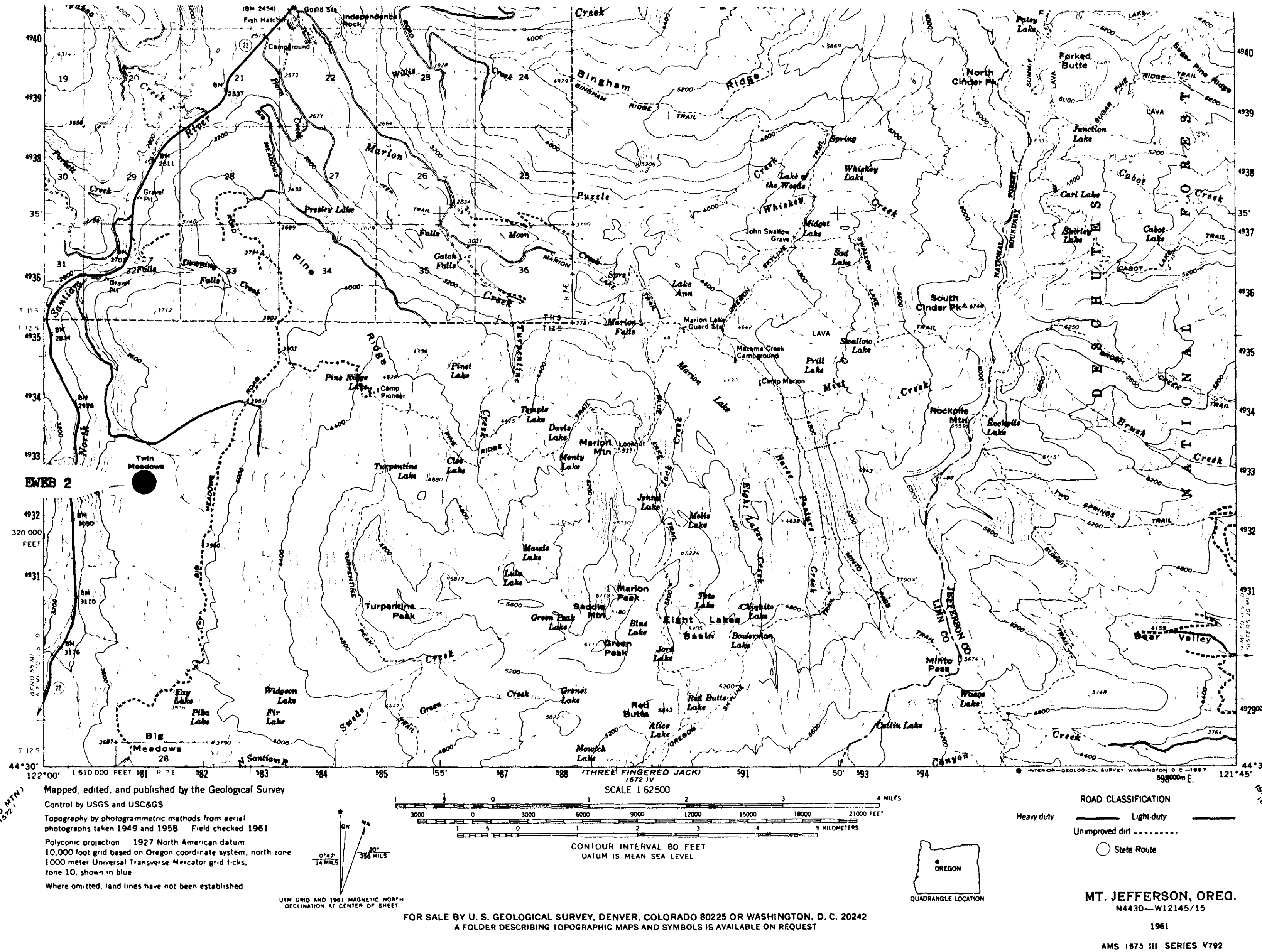

Figure 1. Location of EWEB 2 drill hole

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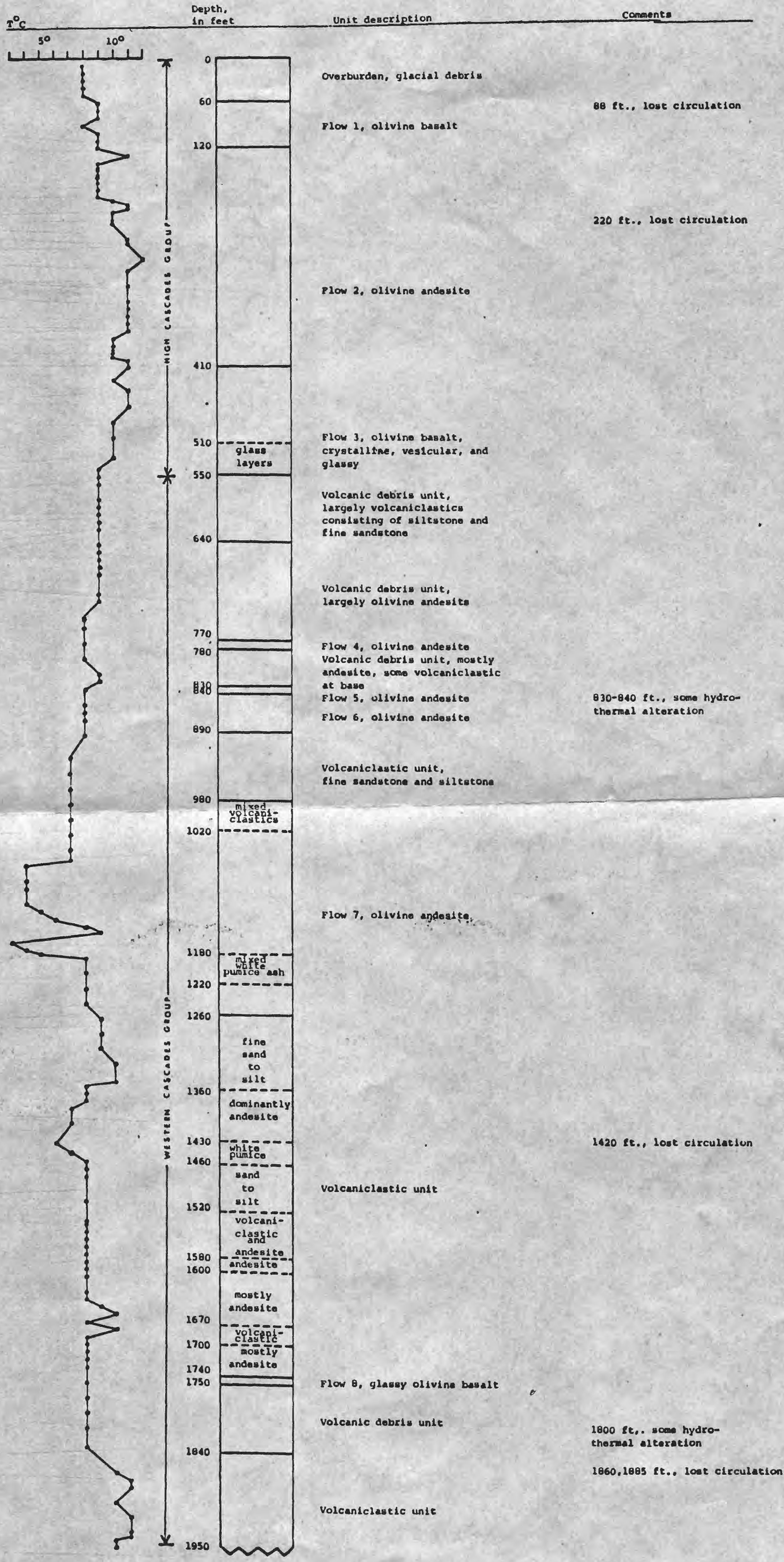

Figure 2. Stratigraphic section for EWEB 2 drill hole. Temperatures measured during drilling are shown at left.