Volcanic stratigraphy and alteration mineralogy of drill cuttings from EWEB 3 drill hole, Clackamas County, Oregon

by

Terry E. C. Keith and James R. Boden

U.S. Geological Survey, Menlo Park, California 94025

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INTRODUCTION

EWEB 3 was the third 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 3 was sited at lat 44°59'04", long 121°50'45" (T. 7 S., R. 8 E., SESE 5), in the Mount Hood National Forest, Clackamas County, Oregon (fig. 1). Drilling commenced on August 24, 1979, at an elevation of 3,200 feet (975.6 m) above sea level, and reached a depth of 960 feet (292.7 m). After numerous drilling problems were encountered, a second hole, EWEB 3A, was drilled about 100 feet (30.5 m) from the first hole. The second hole fared no better than the first, and attempts to drill deeper were finally abandoned on September 23, 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 3 hole every 10 feet during drilling except at 160, 690, 770, 840, 870, 910, and 930 feet where there was no recovery. No samples were taken from EWEB 3A except from the bottom of the hole.

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[1] unit with Cu radiation

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[1]The use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

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and a graphite focusing monochrometer. 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 $60^{\circ}C$ 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 rocks in the vicinity of the drill hole (the nearest outcrop is about 1 mile away) are andesitic lavas of the High Cascade Range although the area is near the boundary between the volcanic rocks of the High Cascade Range and those of the Western Cascade Range (Peck and others, 1964; Wells and Peck, 1961).

VOLCANIC STRATIGRAPHY

General

At least six major units can be distinguished from EWEB 3 cuttings (fig. 2): (a) 50 to 140 feet--andesite flow unit 1, (b) 170 to 500 feet--andesite flow unit 2, (c) 510 to 670 feet--andesite flow unit 3 with minor amounts of vesicular andesite, (d) 680 to 690 feet--andesite flow unit 4, (e) 700 to 820 feet--andesite flow unit 5 with minor amounts of gray obsidian from 740 to 800 feet, and (f) 830 to 960 feet (bottom)--dacite with abundant vapor phase crystallization. The "hard" intervals of the drill log from 680 to 690 feet, 745 to 749 feet, and 762 to 768 feet may also be thin flow units. A major circulation loss is recorded in the drill log at 600 feet. Another loss of circulation occurred at 660 feet, which is just above the dense andesite flow from 680 to 690 feet. Other intervals of significant circulation loss were at 940 and 960 feet; both are within the dacite unit at the bottom of the hole which has a zone of vapor-phase crystallization.

Surface to 40 feet--overburden

The overburden consists of gray, tan, and reddish to orange aphanitic volcanic rock fragments. Composition of the darker fragments is andesite; the reddish to orange fragments are oxidized basalt from cinder cones. A few fragments of chalcedony are in the overburden, but none was found deeper in the drill hole.

50 to 140 feet--andesite flow unit 1

The andesite is medium-gray, microporphyritic with groundmass of plagioclase (An_{30-40}, by X-ray diffraction method of Smith and Yoder, 1956) and α-cristobalite, and phenocrysts mainly of plagioclase and orthopyroxene (hypersthene). Some rock fragments are pinkish because of Fe oxidation in the groundmass. Pink, yellowish, and some brown amorphous Fe and Mn oxides coat fractures and are probably vapor-phase products formed during cooling of the flow.

140 to 160 feet--porous layer of ash(?)

The drill log notes a silty zone beginning at 130 feet, and cuttings recovered from 150 feet are mostly light gray, slightly bleached, fine-grained porous andesitic ash(?). An X-ray trace shows that the ash consists of primary plagioclase, α-cristobalite, and orthopyroxene, and secondary(?) hematite. Even though the mineralogy remains unchanged, the change in texture and color of the cuttings suggests a break between andesitic flows.

170 to 500 feet--andesite flow unit 2

This andesite flow unit is medium-gray microporphyritic with groundmass of plagioclase and α-cristobalite and phenocrysts of plagioclase, olivine, orthopyroxene, and clinopyroxene. Fragments of reddish oxidized andesite are moderately abundant in the upper part of the andesite flow from 170 to 200 feet, suggesting some flow top oxidation. However, most of the andesite is not altered or oxidized, indicating low permeability to fluids.

A more careful study may show that this unit actually consists of several flows, but there appears to be little variability and no indication of permeable or altered zones upon which the interval could be subdivided.

510 to 670 feet - Andesite flow unit 3

Cuttings recovered from this interval are dark-gray and brown vesicular andesite fragments mixed with microporphyritic andesite (similar to the overlying flow unit 2) and tan slightly oxidized volcanic fragments. The groundmass of the vesicular andesite fragments consists of plagioclase, clinopyroxene, and α-cristobalite, and the phenocrysts are mostly plagioclase and clinopyroxene. The iron oxide stained tan fragments have the same mineralogy.

A major blowout during drilling occurred at 600 feet, resulting in water flow of 120 gallons per minute, and a major circulation loss occurred at 660 feet. The cuttings do not reveal any significant difference in the character of the flow unit; however, the mixed vesicular andesite fragments suggest occasional zones of higher porosity. There may have been a porous, vesicular zone, possibly an aquifer at 600 feet. A potential aquifer also exists at 660 feet which overlies a "hard" zone or thin andesite flow extending from about 680 to 690 feet.

680 to 690 feet--andesite flow unit 4

A medium-gray, microporphyritic, fresh-appearing andesite flow, described as a "hard" zone in the drill log, has a groundmass composed of plagioclase, clinopyroxene, and α-cristobalite; plagioclase and orthopyroxene phenocrysts are not abundant. A very minor amount of pink oxidation color in the andesite suggests that the flow unit has little microfracturing and a low permeability. This may be significant since alteration and vapor-phase minerals, and significant alteration or bleaching of some of the andesite first appears in the cuttings below flow unit 4.

700 to 820 feet--andesite flow unit 5

Flow unit 5 consists of medium-gray microporphyritic andesite mixed with reddish to tan aphanitic altered andesite chips. The andesite is similar to flow unit 4 and has a groundmass composed of plagioclase, α-cristobalite, and clinopyroxene, and phenocrysts of plagioclase (An_{30}) and orthopyroxene. The reddish to tan chips consist of plagioclase, α-cristobalite, and minor clinopyroxene and appear to be leached and slightly altered (oxidized). The number of reddish to tan leached fragments increases downward, and the gray andesite becomes lighter gray and appears to be more leached downward. From 740 to 800 feet a subordinate amount of gray amorphous obsidian chips are mixed with the crystalline andesite chips. Two "hard" zones, noted in the drill log between 745 to 749 feet and 762 to 768 feet, may also be explained by thin obsidian flows.

830 to 960 feet (bottom)--dacite (vapor-phase crystallization)

This interval is significantly different from the overlying units. The rock fragments are light gray and tan, aphanitic to microporphyritic with a groundmass composed of plagioclase (An_{30}), sanidine, tridymite, and α-cristobalite and phenocrysts of plagioclase, orthopyroxene, and clinopyroxene. Vapor-phase tridymite is very abundant, and vapor-phase hematite is moderately abundant although some of the hematite crystals have broken down, as evidenced by the pink staining of the rock fragments. Cuttings from this interval contain a little pyrite and chalcopyrite. Traces of green staining and disseminated blue (azurite?) patches in a few rock fragments from 950 feet suggest copper mineralization.

Circulation losses occurred at 940 feet and 960 feet, and drilling finally was stopped after multitudinous problems were encountered at 960 feet. There is no indication in the cuttings as to why the circulation losses might have occurred.

One sample, recovered from an unknown depth near the bottom of EWEB 3A, is a light-gray crumbly rock consisting of α-cristobalite, sanidine, plagioclase, and minor tridymite. The mineralogy indicates vapor-phase crystallization similar to that at the bottom of EWEB 3. X-ray diffraction peak positions and intensities indicate that the K-feldspar is primary or vapor-phase sanidine and is not of hydrothermal origin (adularia).

HYDROTHERMAL ALTERATION MINERALOGY

There is very little material that can be ascribed to hydrothermal alteration in the EWEB 3 drill hole. Reddish-oxidized fragments and yellow and tan leached fragments are present in several intervals, but the only change in mineralogy is partial breakdown of mafic minerals and permeation of Fe in fluids. Hematite is present as tiny grains in much of the andesite, and upon breaking down, red Fe coloration has spread through the rocks.

From 170 to 680 feet the cuttings consist mostly of unaltered gray andesite; however, scattered fragments of reddish, yellow, pink, and white material are mixed with the gray andesite and increases slightly in abundance downward relative to the gray andesite. The mineralogy of the multicolored fragments and the gray andesite are similar and differ basically in the amount of Fe migration and oxidation. The gray andesite is not altered or leached but is mixed with altered or leached material.

Between 700 and 820 feet the proportion of yellowish-altered material to medium-gray unaltered andesite increases with depth. Near the bottom of the interval gray andesite begins to appear slightly leached; however, the mineralogy of unaltered and leached fragments is quite similar. As in the above interval, the main alteration is due to leaching and Fe migration, and there are no hydrothermal minerals present.

The interval from 830 feet to the bottom of the drill hole at 960 feet consists of light gray, light pink, and some white fragments of rhyodacite or dacite in contrast to the overlying units. Tridymite first appears in relative abundance at 820 feet and the euhedral clear to white crystals are abundant throughout the remainder of the drill cuttings. Hematite and magnetite occur as tiny grains disseminated in the groundmass. Red Fe stain from oxidation causes pink coloration in places. Pyrite and chalcopyrite are present throughout the interval but are not abundant; azurite is present at 950 feet.

The abundance of tridymite and hematite indicate that the 830- to 960-foot interval is a zone of high-temperature vapor-phase crystallization. Oxidation of the hematite may have occurred during cooling after the vapor-phase activity. The sulfides and azurite must be a result of minor low-temperature deposition, but the small amounts and local occurrence preclude their significance.

Kaolinite, smectite, and mixed layer smectite-illite were detected in many samples by X-ray diffraction. The fine particles from washing the samples had identical clays, and these are presumed to be from drilling mud. Calcite was identified by X-ray diffraction in white material from several samples and is probably drilling material. Minor amounts of ettringite and thaumasite occur with some of the calcite and are without doubt a product of synthetic cementing materials used during drilling (Taylor, 1964). No calcite fragments suggestive of natural material were observed with the binocular microscope.

SUMMARY

Most of the cuttings down to 670 feet consist of medium gray unaltered andesite. Various amounts of yellow, pink, and tan leached and oxidized fragments are mixed with the unaltered fragments and are likely to be a result of slumping during drilling or undifferentiated flow tops. Vesicular, oxidized, and leached flow tops are not uncommon in the volcanic rocks of the Cascade Range.

From 680 to 690 feet there appears to be a hard unaltered gray andesite flow. This layer may form a permeability barrier, at least locally. From 700 to 820 feet the gray andesite becomes lighter gray with depth indicating slight leaching effects. Leached and oxidized fragments similar to those above 670 feet are also mixed with the gray andesite.

The volcanic unit below 830 feet may be dacite or rhyodacite and has abundant tridymite and hematite due to high temperature vapor-phase crystallization. In fact, this unit is completely permeated with vapor-phase minerals and its permeability must have been great.

There are no vein or cavity deposits throughout the drill hole. Fractures with a thin coating of Fe oxide or hydroxide are present in some flow units, and Fe oxidation of rock adjacent to fracture surfaces is common and probably is a result of cooling of the lava.

The only possible hydrothermal deposition is very minor sulfides and azurite below 820 feet. The significant secondary crystallization is high temperature vapor phase from 820 to 960 feet. Minor alteration activity causing Fe migration, oxidation, and leaching may be due to cooling of the lava flow, groundwater circulation, or low-temperature hydrothermal alteration.

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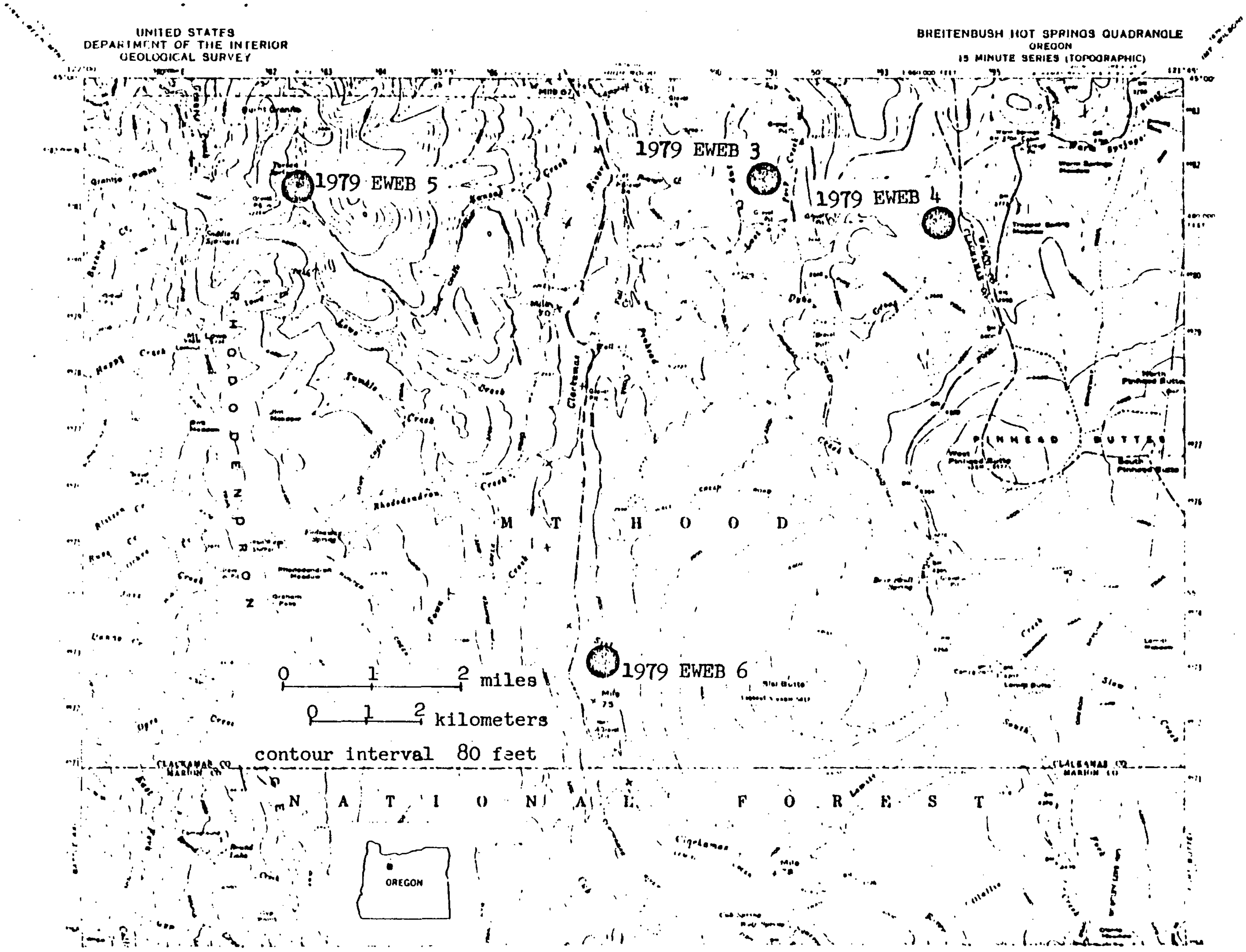

Figure 1. Location of EWEB 3 drill hole.

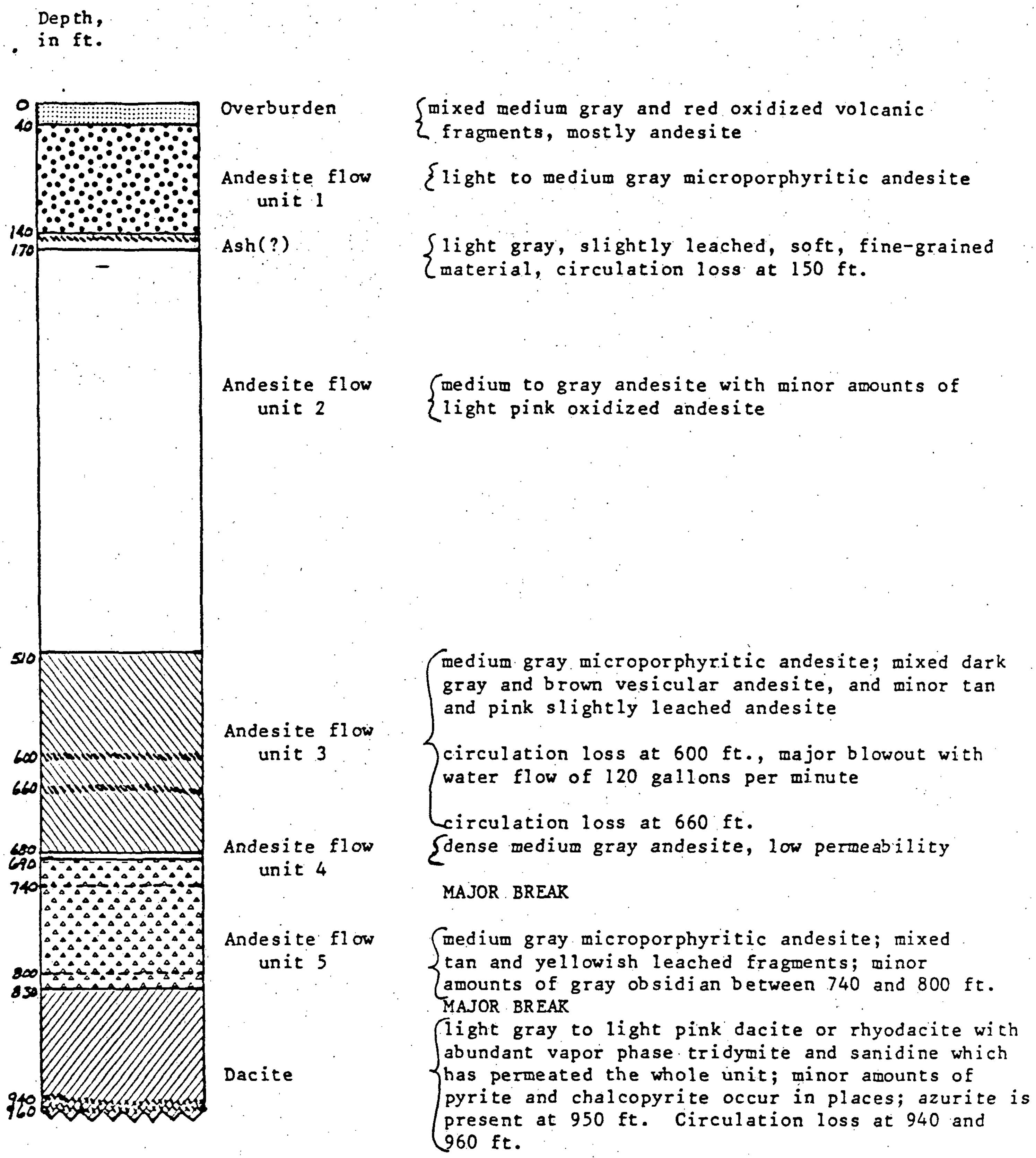

Figure 2. Stratigraphic column for drill hole EWEB 3.