Geothermal Resources Council, TRANSACTIONS, Vol. 8, August 1984

MINERALOGICAL STUDIES OF THE HYDROTHERMAL SYSTEM IN NEWBERRY VOLCANO DRILL HOLE 2, OREGON

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ABSTRACT

Studies of secondary mineral distribution, whole-rock chemical compositions, isotopes, and fluid inclusions are being conducted on the core from Newberry Volcano drill hole 2. Rocks from the drill core are divided into 3 major intervals on the basis of their alteration pattern, which is controlled by rock permeabilities, primary lithologies, and temperatures. Incomplete alteration of pumice-rich lithic tuff layers in the upper part of the altered section and lack of self-sealing in fractures of most lava flows suggest that the hydrothermal system is young. Most of the secondary minerals could have been formed at temperatures near those present today; maximum measured temperature was 265°C at the bottom of the hole. Fluid inclusions indicate that past temperatures in the deeper part of the drill hole may have been as much as 100°C hotter than presently measured temperatures.

INTRODUCTION

Newberry 2 is an exploratory hole in the caldera of Newberry Volcano, Oregon. The hole was sited in the central part of the caldera near the locus of vents for rhyolitic rocks less than 6,900 ^{14}C years old, and near the toe of Big Obsidian Flow (fig. 1). Drilling was done in several stages beginning in the summer of 1978 and ending in late summer 1981 (Sammel, 1981). The maximum measured temperature in the drill hole was 265°C at the bottom, 932 m below the ground surface.

Newberry Volcano is one of the largest Quaternary volcanoes in the Cascade Range and lies approximately 60 km east of the main N-S-trending crest of the range. Several periods of caldera collapse have resulted in the present 6- to 8-km-wide caldera. The oldest caldera probably formed about 150,000 years ago; the age of the youngest caldera is poorly known but may be many tens of thousands of years (MacLeod and Sammel, 1982). Several rhyolite obsidian flows and pumice cones within the caldera are younger than 6,900 years B.P.; the most recent recognized activity is Big Obsidian Flow, 1350 years old (MacLeod and Sammel, 1982). Because of the relatively recent activity, parts of the magma chamber may still be hot (MacLeod and Sammel, 1982).

The drill hole penetrated caldera fill and then older volcanic rocks but relations of these rocks to flank outcrops are uncertain (MacLeod and Sammel, 1982). Core recovery in the upper 300 m was about 45% and below 300 m was over 90%. The upper 300 m of the drill hole penetrated pumiceous tuffs, an obsidian flow, and glassy basaltic volcaniclastic sediments. Pumice-rich lithic tuffs predominate between 300 and 500 m depth, and a rhyodacite sill intrudes these tuffs at 460-470 m. The section between 500 and 700 m consists of several brecciated dacite flows and interflow breccias. Below 700 m are subhorizontal andesite to basalt lava flows and interflow breccias. Significantly, no cross-cutting dikes or major throughgoing fractures were observed in the drill core.

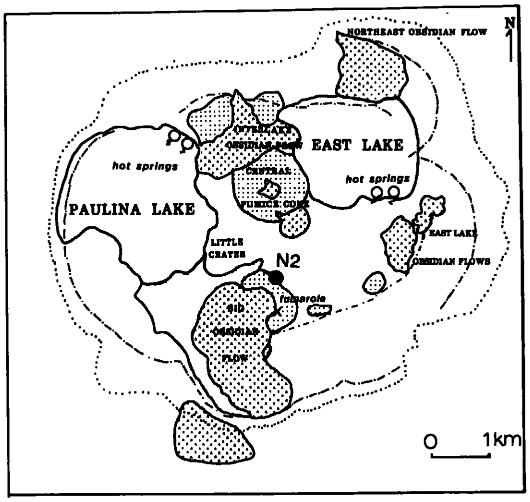

Figure 1. Generalized geologic map of Newberry caldera (after MacLeod et al., 1982), showing location of drill hole Newberry 2 (N2), hot springs, fumarole, caldera ring fractures (dot-dashed line), caldera rim (dotted line), and some of the younger volcanic deposits--obsidian flows (inverted "v" pattern), ash flow of Paulina Lake (wavy pattern), and pumice rings and cones (dotted pattern).

HYDROTHERMAL ALTERATION STUDIES

Binocular and petrographic microscope studies show that hydrothermal minerals in Newberry 2 were mostly deposited in open spaces such as fractures, vesicles, and cavities resulting from brecciation of flows and poor sorting of tuffs. Zeolites and smectite also occur replacing glass in pumiceous tuffs. In the deeper part of the core below 833.6 m, plagioclase phenocrysts were partly replaced by calcite and below 911 m by calcite, epidote, and illite.

Hydrothermal alteration is controlled by rock permeability, temperature, the composition of hydrothermal fluids, and the crystallinity and composition of the host rocks. Alteration is pervasive in permeable layers of interflow breccias and highly brecciated lava flows, but no self-sealing by secondary minerals has occurred. The dense, aphanitic lava flows show few effects of alteration except in fractured zones, and there alteration is only immediately adjacent to fractures.

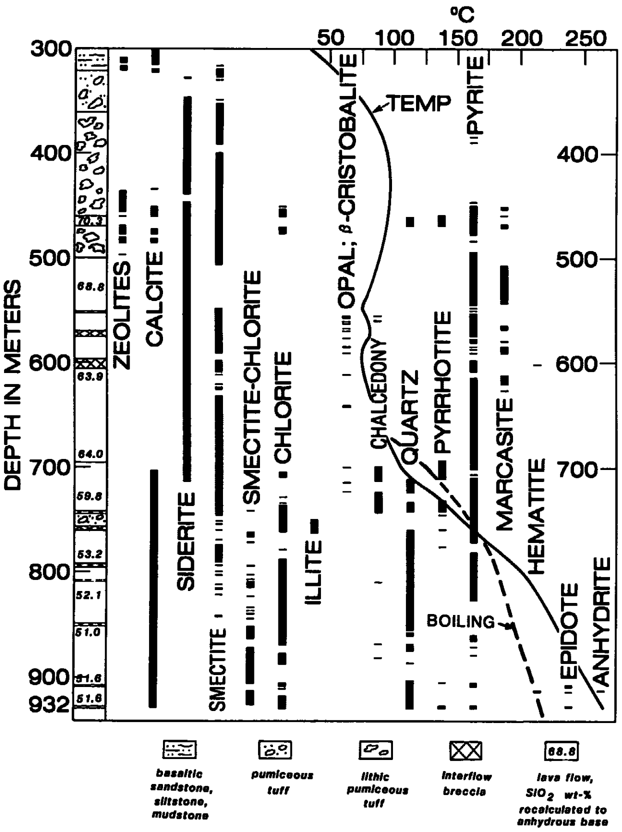

Figure 2. Distribution of secondary minerals between 300 and 932 m depth in Newberry 2 drill hole. Solid line represents temperatures measured during drilling; dashed line is the reference boiling-point curve for pure water assuming the regional water table at 1274 m (680 m depth).

Hydrothermal mineralogy and the significance of hydrothermal mineral distribution is discussed in Bargar and Keith (1984) and in Keith et al. (1984). Figure 2 shows the distribution of major secondary minerals, temperatures measured during drilling, and a reference boiling-point curve for pure water assuming the regional water table at approximately 1274 m altitude (Priest et al., 1983) (680 m depth in the drill hole). The interval from 0-300 m is not shown because it has no significant alteration, only hydration of the glass. The interval between 300 and approximately 700 m is affected by cooling meteoric waters in a shallow convection system extending from the surface to approximately 700 m depth. Temperatures were not very hot throughout the upper 300- to 500-m section because much of the glassy pumice is unaltered or only partly altered to smectite. However, significantly higher temperatures in the past are indicated by the mineralogy associated with the rhyodacitic sill at 460-470 m (fig. 2). Temperatures in the fractured and brecciated dacite flows and interflow breccias between 500 and 700 m were initially somewhat higher than present, but cooling and oxidation are indicated by alteration and replacement of early-formed pyrrhotite and by deposition of abundant siderite. The mineral assemblages and the temperature curve change at about 700 m (fig. 2). Below 700 m the heat flow is mainly conductive because the convective system from the surface has not penetrated the nearly impermeable subhorizontal massive lava flows. The mineral assemblage below 700 m reflects initial temperatures close to presently measured temperatures. However, homogenization temperatures from fluid inclusions in quartz crystals indicate higher temperatures occurred in the past.

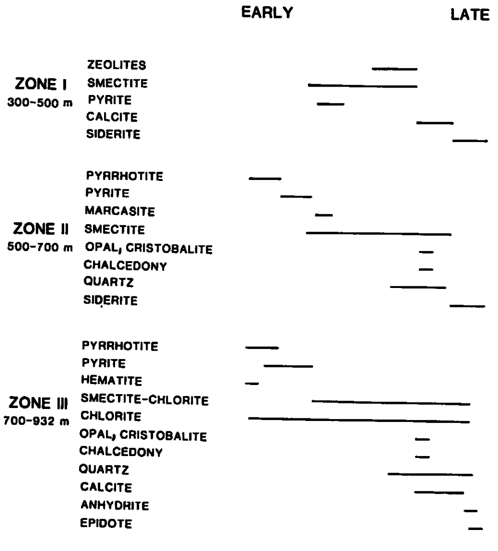

Figure 3. Generalized paragenetic sequence of major secondary minerals in Newberry 2 drill core; length of line does not indicate duration of depositional period.

Fluid inclusions in hydrothermal quartz crystals below 750 m usually occur in clusters too small to study (less than 3 μm diameter). However, homogenization temperatures were obtained on 95 secondary inclusions (Bargar and Keith, 1984). Temperatures ranged from 370° to 170°C indicating higher fluid temperatures in the past; however, none showed evidence of boiling fluids. Fluid salinities were very low.

The general paragenetic sequences for major secondary minerals in Newberry 2 are divided into the three zones shown in figure 3. Minerals associated with the rhyodacite sill between 460 and 470 m, which superimposed local higher temperature alteration on the adjacent pumiceous tuff, are not shown. In each of the zones clay minerals are interspersed throughout the depositional sequence. Sulfides crystallized early, followed by silica minerals (mostly quartz; opal and cristobalite are scarce), and carbonates last. Near the bottom of the hole are anhydrite and epidote, the last minerals to have formed.

Figure 4 shows major-oxide analyses on rocks selected to represent the least altered and the altered equivalent representative units in the drill core. The analyses of least altered rocks show that from 300 m to the bottom of the hole the lava flows change gradationally from rhyodacite to basalt. The analyses of unaltered (or least altered) and equivalent altered rocks in several selected intervals below 650 m show consistent leaching of SiO_2, CaO, K_2O, and usually Na_2O, and enrichment in Al_2O_3, Fe_2O_3, and usually MgO.

Whole-rock samples were analyzed for oxygen isotopes (fig. 5). The two samples of frothy glass above 300 m show no alteration mineralogically, and the $\delta^{18}O$ values are close to that expected for fresh glass. The sample from 311.4 m is a slightly altered siltstone composed of basaltic glass which has been partly replaced by tiny zeolite crystals. The +10.8 °/oo $\delta^{18}O$ value is a result of low-temperature zeolitic alteration of glass

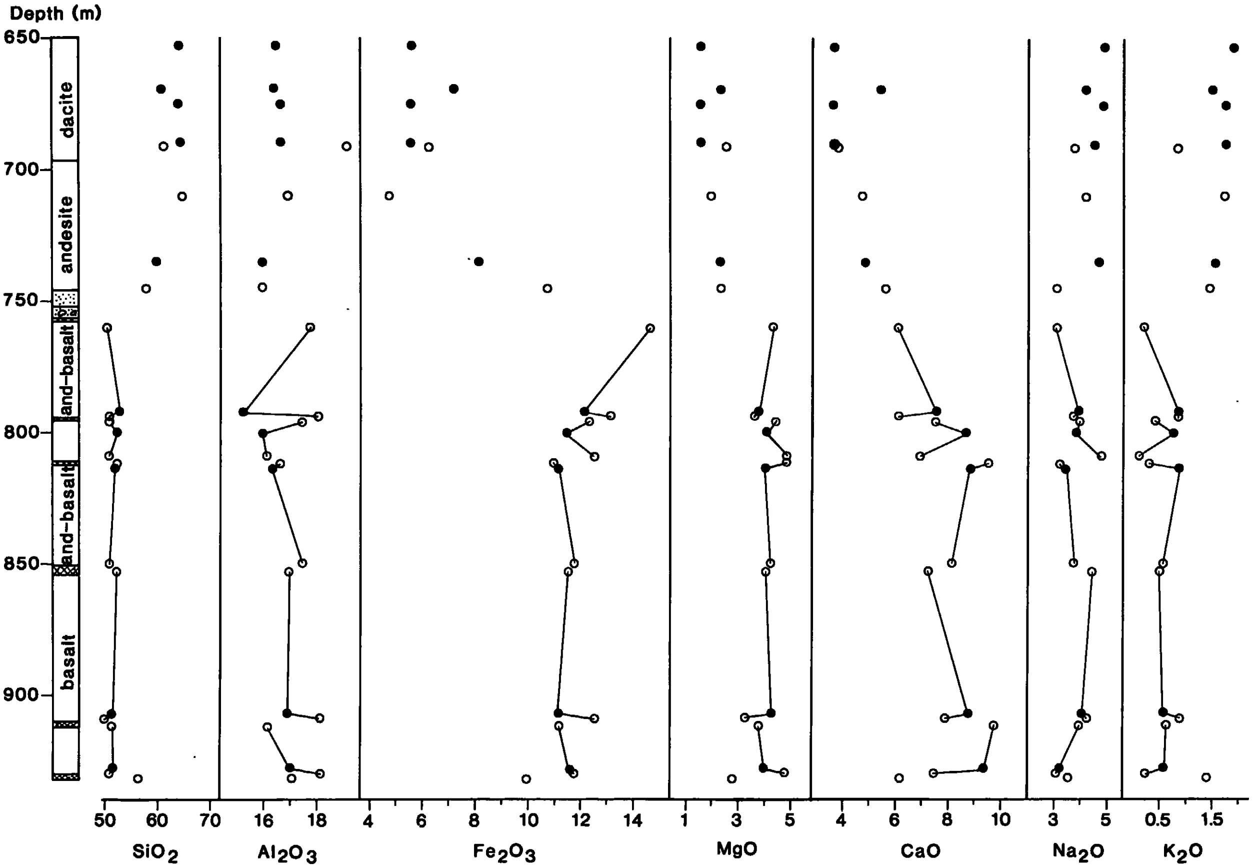

Figure 4. Selected whole rock major oxides (wt. %) calculated to anhydrous base versus depth below 650 m in Newberry 2 drill core. Total Fe represented as Fe_2O_3; open circles are altered rocks, closed circles are unaltered (or least altered) rocks; tie lines connect altered and least altered rock equivalents.

which is probably taking place at the present temperatures, 55°-65°C. The whole-rock isotopic composition of both the unaltered and altered rocks becomes increasingly depleted in ^{18}O as temperature (and depth) increases. As expected, the unaltered (or least altered) rocks are not as depleted in ^{18}O as the altered rocks; extent of alteration in the altered rocks varies as reflected in the whole-rock $\delta^{18}O$ values and the mineralogy. The only altered rock that deviates from this pattern is at the bottom of the drill hole, 931 m, where the thoroughly altered rock is less depleted in ^{18}O than the least altered rocks.

Selected mangano-siderites were analyzed for stable carbon and oxygen isotopes from throughout the drill hole. Siderite is the last hydrothermal mineral to have been deposited in the interval from 300-500 m. Preliminary $\delta^{18}O$ values for samples above 500 m indicate siderite-water equilibration temperatures of approximately 100°C, which is very close to the present temperatures.

The sulfur-isotopic compositions of two sulfide mineral samples, one pyrite and one pyrrhotite, were measured to place constraints on the source of sulfur in the hydrothermal system. The $\delta^{34}S$ value for the pyrite (from a depth of 930 m) is +1.6 $^{o}/oo$, and that for the pyrrhotite (from a depth of 713 m) is +1.7 $^{o}/oo$. Although sparse, the data suggest that sulfur in the hydrothermal system was initially from a magmatic source.

CONCLUSIONS

1. Newberry 2 drill hole penetrates a young hydrothermal system, as indicated by low-temperature mineral assemblages and lack of complete alteration of glassy pumiceous lithic tuff layers at temperatures presently between 50° and 100°C. Self-sealing and refracturing of secondary mineral deposits is absent in most breccias and fracture zones.
2. The upper part of the hydrothermal system above 700 m was never much hotter than at present. An exception is the local zone associated with the rhyodacite sill at 460-470 m.
3. Secondary homogenization temperatures of fluid-inclusions in quartz indicate that the lower part of the hydrothermal system has been as hot as 370°C in the past.
4. Isotopic and petrographic studies indicate that the later-formed minerals in the system were deposited by the present hydrothermal fluids.

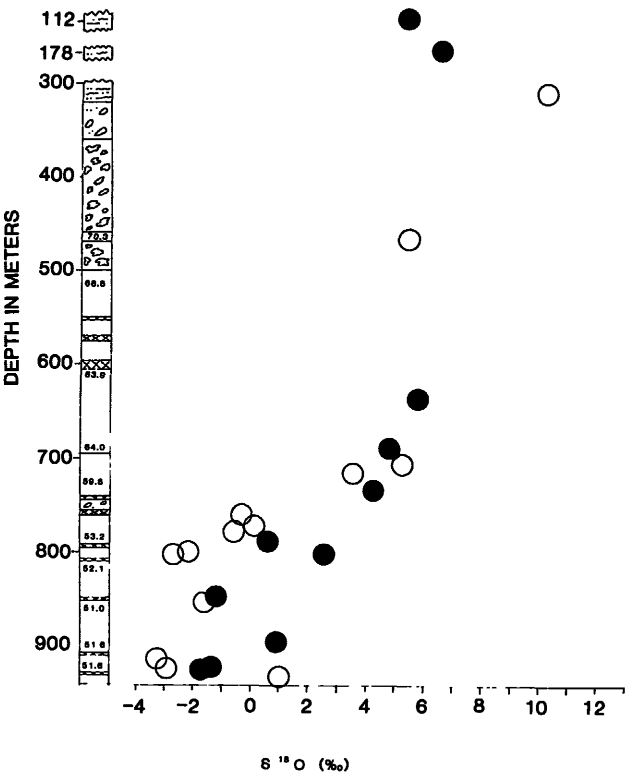

Figure 5. Whole-rock $\delta^{18}O$ (in $^{o}/oo$ relative to SMOW) versus depth. Open circles are altered rocks, closed circles are least altered rocks. Stratigraphic explanation is the same as for figure 2.

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