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FRACTIONATION AND CONTAMINATION PROCESSES, CRATERS OF THE MOON LAVA FIELD, IDAHO, 2000-2500 YEARS BP

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The Craters of the Moon lava field, Idaho, was the site for eruption of approximately 4 km³ of basaltic lava flows in the late Holocene (2000-2500 yr BP). On the basis of 52 whole-rock analyses, the flows fall into two distinct compositional groups: basalts with 44-52% SiO₂ and trachyandesites with 55-64% SiO₂. The two groups can also be distinguished with Si/K ratios: basalts have a range of 17-21 and trachyandesites have a range of 9-15. None of the available analyses have SiO₂ contents or Si/K values between the ranges cited.

The basalts contain olivine (Fo50), plagioclase (An45), rare augite, and minor ulvöspinel (Usp65) phenocrysts in a groundmass of olivine (Fo30), plagioclase (An30), augite, and Fe-Ti oxides. The trachyandesites contain microphenocrysts of olivine (Fo35-10), plagioclase (An30), Fe-Ti oxides (Usp70), rare augite, and alkali feldspar (Or45-20) in a groundmass of olivine (Fo10), plagioclase (An15), augite, minor alkali feldspar, and Fe-Ti oxides (Usp55); in addition, zircon and apatite occur as minor phases in the groundmass and as larger crystals in glomerocrysts with olivine and Fe-Ti oxides.

Xenocrysts of olivine, plagioclase, rare augite, and alkali feldspar and xenoliths consisting of olivine (Fo30-7), plagioclase (An38-10), hypersthene, Fe-Ti oxides, zircon, apatite, and baddeleyite in a pumiceous matrix occur in trachyandesite flows. Inclusions of pumiceous rhyolite, ranging from meter- to microscopic-size, are present in several cinder cone vents for the trachyandesite flows. Microscopic pumice inclusions are present in trachyandesite flows, but meter-size pumice inclusions have not been recognized in these flows. Geophysical evidence suggests that the inclusions represent Tertiary rhyolitic rocks that form the upper crust through which basaltic magmas rose to the surface.

Derivation of trachyandesite from basalt by crystal fractionation, overprinted by contamination of basalt by pumiceous rhyolite, is suggested by coherent trends and nonzero intercepts on Pearce element ratio plots. The chemical variations cannot be explained by fractionation of olivine and plagioclase alone but must include augite and Fe-Ti oxide accumulation/fractionation as well.

Thermodynamic modelling suggests that olivine and plagioclase phenocrysts and microphenocrysts were not in equilibrium with the enclosing melts at surface pressures. In order to have cotectic crystallization of olivine and plagioclase, pressures in excess of 0.5 GPa are required. A high pressure fractionation/accumulation stage is consistent with indications from the chemical data that augite and Fe-Ti oxide phases participated in the derivation of trachyandesite from basalt. The modelling also shows that augite would appear on the liquidus with olivine and plagioclase at high pressures.

GEOHERMAL SYSTEM GEOCHRONOLOGY BY U-SERIES METHODS: PROGRESS AND PROSPECTS

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The U-series dating methods have been exploited widely in Quaternary geochronology (e.g., for corals, tufas, travertines, speleothems, sediments, magmas). However, relatively little attention has been given to the geochronology of geothermal systems. The practical application of these dating methods has recently been investigated using α -counting techniques for a variety of materials from active geothermal systems at Yellowstone (Wyoming), Long Valley (California), Valles (New Mexico), and other sites. The results of these studies indicate that some valid generalizations may now be made regarding the utility and limitations of U-series methods for geothermal system geochronology.

The ratio of ²³⁰Th ($t_{1/2}=75,200$ yr) to its parent ²³⁴U ($t_{1/2}=248,000$ yr) provides the most useful and direct dating tool for the range ~1000 to ~350,000 yr. The ²³⁰Th/²³⁴U ratio has been used for dating hot spring deposits of travertine and sinter, and vein deposits of calcite and silica. The principal limitations of this method are: the low U/Th ratios in hot spring deposits and vein minerals (mostly <1.5) require multiple analyses and the use of ²³⁰Th/²³²Th vs. ²³⁴U/²³²Th isochron plots for dating; many samples may not be dated unless an initial value for ²³⁰Th/²³²Th is assumed; secondary deposition or mobilization of U may occur in porous or fractured material, obscuring its age; and amounts of available material in veins or vugs may be very small (<1g), requiring mass spectrometry techniques for analysis. Best results are derived from relatively pure, unfractured, nonporous material; replicate analyses should always be performed for verification. Ages obtained should either satisfy the constraints of field relations or be rejected.

Changes in whole rock U/Th caused by geothermal fluid-rock interaction may be dated in favorable situations (e.g., U accumulations on aquifer surfaces produced where low-Eh geothermal waters mix with high-Eh shallow groundwaters, or U depletions in acid-altered rocks), using whole rock drill core analyses plotted on a ²³⁰Th/²³²Th vs. ²³⁴U/²³²Th isochron diagram. This method has been used to date the initiation of post-glacial thermal water discharge through rhyolite at a site in Biscuit Basin (Yellowstone). Similar applications may be found in aquifers having initially high permeability and homogeneous U/Th (e.g., unzoned flow breccias or unwelded tuffs) where significant changes in U/Th have been imposed by geothermal processes on a time scale that is short relative to the $t_{1/2}$ of ²³⁰Th.

The ²³⁴U/²³⁸U ratio can, in principle, be used to date material up to ~1 Ma using an assumed value for the initial ratio. However, at several of the investigated localities, initial ²³⁴U/²³⁸U has varied considerably with time. Therefore, this method should not be considered accurate unless the initial ratio can be verified independently.

The excess ²²⁶Ra method can be used to date travertine ≤10,000 yr old, if the initial activity of ²²⁶Ra ($t_{1/2}=1602$ yr) is known. Modern travertine at Mammoth Hot Springs (Yellowstone) has excess ²²⁶Ra activity that ranges from 6 to 15 pCi/g. The accuracy of this method is limited by the uncertainty of the initial ²²⁶Ra activity, but travertine deposition rates may be obtained from a plot of excess ²²⁶Ra vs. stratigraphic position.

Further efforts in the application of U-series methods (especially ²³⁰Th/²³⁴U) to the geochronology of geothermal systems are encouraged. Mass spectrometry techniques are preferable when sample quantities are limited and/or when maximum precision is required.