Argon isotopic composition of historical lavas of Hawaii

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The aim of this study

To clarify whether the mass fractionation of argon occurs in hot spot volcanoes and to find out how the effect of excess argon can be avoided in K-Ar or $^{40}Ar/^{39}Ar$ dating, we collected and analyzed about thirty samples of historical lavas from Kilauea, Mauna Loa and Hualalai volcanoes on the island of Hawaii (the Big Island).

Mass fractionation

Although initial isotopic composition of argon is assumed to be the same as the atmospheric value in conventional K-Ar dating, mass fractionation has been found in some of the historical (virtually zero age) volcanic rocks (Krummenacher, 1970; Kaneoka, 1980). Matsumoto et al. (1989) revealed that mass fractionation occurs in many of the historical lavas in Japan, and Matsumoto and Kobayashi (1995) showed that the K-Ar ages of young lavas can be dated successfully by the “mass fractionation correction procedure”, in which initial $^{40}Ar/^{36}Ar$ ratio is calculated from $^{38}Ar/^{36}Ar$. However, it is not clear whether this procedure can be applied to other tectonic settings such as hot spot. Our preliminary results suggest that mass fractionation also occurs in the hot spot setting, and that the correction is necessary for dating young samples.

Excess ^{40}Ar

Excess argon has been found in a historical lava flow of Hualalai (Dalrymple, 1969), which yielded apparent K-Ar ages of 1.19 and 1.05 Ma. Dalrymple (1969) attributed the excess argon to the xenolith contained abundantly in the flow. We collected samples from the same flow as those reported in Dalrymple (1969), and analyzed groundmass. Preliminary results suggest that the amount of excess argon can be sufficiently removed by this procedure.

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Melt-peridotite reaction in the upper mantle: Constraints from major exchange components

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The general mass balance model [1] is applied to exchange major components (Mg-Fe^{2+} and Cr-Al) and compatible trace elements (e.g., Ni) in order to constrain open magmatic processes in a peridotite system under the spinel stability field. A set of mass balance equations for the open-system reaction model, is combined with equilibrium relationships among minerals and melt and appropriate reaction stoichiometry. Equilibrium constants for exchange reactions (e.g., exchange partition coefficients) with or without composition dependence were determined to reproduce melt and mineral compositions of peridotite melting experiments.

The modeling results for melting without material influx shows that variation of the major exchange components for fractional or critical melting is not significantly different from that of batch melting before clinopyroxene is melted out, but they notably differ at higher degree of melting after the complete consumption of clinopyroxene, even if the effect of melt separation on reaction stoichiometry is taken into consideration.

Variation trends of the exchange components in open reaction with material influx are generally very nonlinear irrespective of the net mass transfer between solid peridotite and melt. They are controlled mostly by the modal abundance of reacting solid, reaction stoichiometry, influxing melt composition, and trapped melt fraction. If some of these parameters are constrained, other factors may be estimated. For example, if net mass transfer between melt and solid can be regarded as negligible, the amount of melt involved in the reaction and the melt composition may be estimated.

The worldwide correlation between Fo in olivine and Cr# of spinel (olivine-spinel mantle array [2]) shows a large variance, which may be explained by innevitable reactions between partial melt and residues of variable degree of melting during melt segregation and transporation in the upper mantle. The negative correlation between Fo and Cr# of spinel and the concomitant positive correlation between Fo and NiO wt% in olivine observed in harzburgite of the Hayachine-Miyamori ophiolite [3], northeastern Japan, are attributable to reactive transport of an evolved melt, which is consistent with the observed variation of incompatible trace elements.

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