Extension of the Afar Plume Material: He isotope Constraints

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Afar plume triggered the activities of Oligocene to recent Afro-Arabian volcanism. We have investigated $^{3}He/^{4}He$ and revealed a contribution of plume component in Ethiopian lavas. Ebinger and Sleep (1998) recently suggested that volcanisms in northern and central Africa during this epoch were results of single large heat source, Afar Plume. Herein we report helium isotopic compositions of olivine phenocrysts in lavas and xenoliths of Yemen and Saudi Arabia on north east , and Hogger and Kivu west and southward respectively to investigate the extension of the plume component.

Results and Implications

$^{3}He/^{4}He$ ratio of olivine phenocrysts from Kivu, Saudi Arabia, Hogger lavas varies between 2.3 Ra with evidence of radiogenic ^{4}He addition, and 8.9 Ra. Thus it is unlikely to account an inheritance of primitive deep signature. Another important feature is the relative depletion of magmatic He in these lavas comparing to those showing high $^{3}He/^{4}He$ in Ethiopia. This implies that the lower $^{3}He/^{4}He$ observed in distant localities were not a result of dilution by additional radiogenic ^{4}He of originally Afar-type component.

In Yemen we observed clear plume signature in olivine phenocryst of one sample (16.2 Ra). Diopside from metasomatic vein in the composite xenolith showed higher $^{3}He/^{4}He$ ratio comparing to non-metasomatic olivine. The metasomatic agent was reported to have trace element characteristics identical to Afar plume. Our results indicate that the metasomatic agent was in fact of plume-origin. Therefore, it is evident that plume originated metasomatism affected the lithospheric mantle beneath Yemen. Revealing to what lateral extent the metasomatism occurred will be another clue to whether or not an enormous plume exists. It is then noteworthy that mantle xenoliths from Sidamo, Ethiopia, are anhydrous and show no evidence of metasomatism.

Distant localities show no evidence for the contribution of plume component, thus limited extension of Afar plume component is suggested.

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Mantle metasomatism and rapid ascent of slab components beneath Miyakejima volcano, Izu arc, Japan

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^{238}U-^{230}Th-^{226}Ra systematics of Miyakejima volcano is shown together with major and trace element compositions as well as their Sr-Nd-Pb isotopes to estimate the timescale of magmatic processes beneath island arc. Based on previous geological works, we divided the volcanic history of Miyakejima into four stages. Strong enrichment of LILE compared to HFSE, and Sr-Nd-Pb isotopic systematics observed imply metasomatism of depleted mantle by fluid related processes with little contribution from a sedimentary component. The variations of some trace element ratios (e.g. U/Th, B/Nb, and Ba/Th) are made by this process.

^{238}U-^{230}Th disequilibrium observed in Miyakejima lavas ($(^{238}U/^{230}Th)$=1.2-1.5) also implies metasomatism of depleted mantle by fluid related processes occurred within the last 350 kyr. In the equiline diagram, trends of Stage 1 and 2 are regarded as two different isochrones that have common initial ($^{230}Th/^{232}Th$) ratio. Our model regarding slab dehydration suggests that the fluid released from the slab can contain a certain amount of Th, resulting in that apparent ^{238}U-^{230}Th age calculated does not represent absolute time of material transport in the mantle wedge. However, the differences of the age between each stage, 15 kyr between Stage 1-2, and 3 kyr between Stage 2-3, are valid and they should be the interval of individual fluid-release.

Very large ^{226}Ra-^{230}Th disequilibrium ($(^{226}Ra/^{230}Th)>2$) observed in some lavas suggests actual transport time of slab component in the mantle wedge as short as a few kyr, corresponding to ~50-100 m/yr of the ascending rate of slab materials to the surface. Such a rapid rate can be achieved by material transport via crack system in the mantle wedge explained by hydrofracture model and channel-flow model, rather than permeable-flow model.

From the ^{226}Ra-^{230}Th disequilibrium in Stage 3 lavas, the minimum interval of the fluid-release is calculated as ~1 kyr. Therefore, the fluid-release and subsequent melt generation in the mantle wedge are episodic events that intermittently occur with 1~15-kyr scale, indicating that subduction zone volcanism is generally controlled by the timing of the fluid-release from the slab occurring within several-kyr scale.

In contrast, Stage 3 and 4 samples depict a mixing trend in the equiline diagram between old andesitic magma and newly injected less-differentiated magma. The involvement of less-differentiated magma generally decreases from Stage 3 towards present. Stage 1 magma is a primary end-component of the andesitic magma which differentiated >7 kyr in the magma chamber that is isolated in the crust after active eruptions of Stage 1.