

Across-arc Variation of Li Isotope in the Izu Arc: Implications for Crust-Mantle Recycling at Subduction Zones

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Water has played an important role in material recycling between the crust and mantle, via plate tectonic processes at subduction zones. The Earth's surface materials, consisting of oceanic sediment and basalt, undergo water/rock interaction underneath the ocean floor and subsequent dehydration and/or partial melting during subduction. The dehydration of the subducting oceanic crust causes a preferential release of water-soluble elements to metasomatize the overlying mantle wedge resulting in the generation of island-arc magmas. The chemical composition of the slab is undoubtedly changed as a result of the subduction process. The slab is finally introduced into the mantle where it may form a chemical anomaly, which may eventually become the source region for mantle plumes expressed at the Earth's surface as ocean island basalt magma (OIB).

Such large scale crust-mantle recycling has been extensively investigated in relation to the geochemical evolution of the mantle and crust mainly by applying radiogenic isotopes systematics, such as Sr, Nd and Pb isotopes, in OIB. It is, however, difficult to assess the residence time of the subducted oceanic crust in the mantle and consequently to identify the Earth's surface material involved in the crust-mantle recycling because parent/daughter ratios in these isotope systems cannot be easily constrained due to the change of the ratios before and during subduction (e.g. Shibata & Nakamura, 1997, Chauvel et al., 1992).

Unlike radiogenic isotopes, stable isotope composition is independent of time and parent/daughter ratio. Therefore, stable isotope systematics overcome such difficulties, so long as isotopic fractionation does not occur during subduction. In particular, Li isotopes have a great potential as a geochemical tracer for understanding crust-mantle recycling because of the following unique physicochemical characteristics of Li: (i) Li commonly exists as a trace element in rocks and minerals. Furthermore, it is a moderately incompatible element in magmatic processes such as partial melting and fractional crystallization. The solid/melt bulk distribution coefficient of Li is similar to those of Y and Yb (Ryan & Langmuir, 1987). Therefore, Li can be concentrated in crustal materials compared to mantle materials. (ii) Li is highly mobile in fluid-related processes such as weathering and alteration at sea floor and metamorphism in subduction zone (e.g. Seyfried et al, 1984). Therefore, it is expected that Li is strongly enriched by seawater weathering and alteration, and then released at subduction zone. (iii) Li possesses two stable isotopes, ^6Li and ^7Li , with an extremely large mass difference, and thereby suffers large isotopic fractionation in the $^7\text{Li}/^6\text{Li}$ ratio of natural samples,

exceeding 30 per mil (e.g. Chan et al, 1992). The large isotopic fractionation of Li develops during low-temperature reactions associated with water at the Earth's surface. In contrast, Li isotopic fractionation is extremely small when the temperature exceeds 350°C (Chan et al, 1994), and thus, Li isotope fractionation is expected to be insignificant in magmatic processes. This suggests that Li isotopic compositions in mantle-derived magmas may directly indicate the composition of source materials in the Earth's interior. Hence, the Li isotope variation in igneous rocks, especially those derived from the mantle, may indicate the involvement of surface material subducted into the source regions, preserving the variable Li isotopic compositions imprinted by water/rock interaction under near-surface conditions.

In this study, Li isotope systematics were applied to Izu arc volcanics, Japan, in order to establish the usefulness of Li isotope as a geochemical tracer, together with B and Pb isotopes for understanding crust/mantle recycling at subduction zones.

Li isotope ratios ($\delta^7\text{Li}$) and Li/Y of the arc lavas show clear across-arc variations, decreasing ($\delta^7\text{Li}$: +7.6 to +1.1 per mil, Li/Y: 0.36 to 0.25) with increasing depth to the Wadati-Benioff zone (150 to 210 km). This suggests that the amount of subduction component as a fluid added to the source region decreases with depth. $\delta^7\text{Li}$ -Y/Li systematics of the arc lavas clearly indicate a simple mixing between two distinctive chemically homogenous end-members, a slab-derived fluid and the mantle wedge. Furthermore, Li-B-Pb isotope systematics allow clear discrimination between the relative contribution of altered oceanic crust (AOC), oceanic sediment and mantle wedge to arc lavas, and suggests that AOC is the dominant subduction component, whereas the contribution of oceanic sediment is extremely small (AOC/oceanic sediment = 97/3).

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