Hf-Nd isotopic constraints on the role of sediments in mantle wedge metasomatism beneath the North Luzon Arc

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Abstract

Subduction zone is the major tectonic setting where surface materials were recycled back to the interior of the Earth. The subducted materials thus chemically modify mantle compositions, a process referred to as “mantle metasomatism”. The metasomatic agents include subducted altered oceanic crust (AOC), pelagic sediments and associated hydrous fluids and siliceous melts. Mass and chemical fluxes from these materials play a major role in chemical evolutions of local arc magmatisms as well as bulk silicate earth. Although the involvement of recycled materials can be unambiguously detected by radiogenic ^{10}Be (e.g., Morris et al., 1990), the use of ^{10}Be is limited by its short half-life. Moreover, the contributions from subducted AOC and sediments cannot be distinguished by ^{10}Be. In contrast, $^{176}Hf/^{177}Hf$ is a potent pelagic sediment tracer because zircon, the major host of Hf, is mostly deposited offshore rather than transported to ocean basin. Thus, pelagic sediments are expected to be zircon-free with high Lu/Hf ratios leading to more radiogenic Hf isotopic ratios (e.g. Blichert-Toft et al., 1999). As an example, we use Hf isotope to verify the involvement of subducted sediments in the mantle wedge beneath the North Luzon Arc (NLA).

The NLA islands were formed by eastward subduction of the South China Sea (SCS) plate beneath the Philippine Sea plate. In the $^{176}Hf/^{177}Hf$-$^{143}Nd/^{144}Nd$ space, the NLA lavas deviate from the terrestrial array to higher $^{176}Hf/^{177}Hf$ ratios at a given $^{143}Nd/^{144}Nd$ ratio implying the involvement of pelagic sediments (Marini et al., 2005). If the tectonic setting is considered, the SCS plate and overlying sediments are the most possible sources of the metasomatic agents. The Hf-Nd isotopic systematics of SCS sediments core by ODP site 1148 therefore can provide constraints on the relative contributions of subducted sediments and/or AOC to the mantle wedge beneath the NLA. We calculate the $^{176}Hf/^{177}Hf$ and $^{143}Nd/^{144}Nd$ ratios of the depleted mantle that metasomatized by introducing (1) solid sediments, (2) sediment-derived melt, and (3) mixtures of melts derived from sediments and AOC.

The $^{176}Hf/^{177}Hf$ ratios of sediments from ODP site 1148 vary in the range of 0.28265–0.28276 with higher values for samples below 455 mcd (ca. ~23 Ma) (Fig. 1). This variation range is smaller than that for the NLA lavas. The Nd-Hf isotopic

systematics of the southern island lavas can be explained by deriving from mantle metasomatized by introducing of solid sediments and/or sediment-derived melts, while sources of the northern island lavas required additional contribution from AOC-derived melts (Fig.2). Note that the Benioff zone beneath the northern islands extends to greater depths than that beneath the southern islands (Fig.2), consistent with AOC-melting in addition to sediment-melting. Alternatively, the southern and northern island lavas can be explained by mixing AOC-derived and sediment-derived melts with variable amounts of residual zircon in the sources of metasomatic agents (Fig.3). Only < 0.001% of residual zircon in subducted sediments can increase the Nd/Hf of the associated melts by six fold (Fig.3). In such a scenario, HFSE cycling in subduction zone and even global-scale mantle convection is dominated by trace amounts of zircon in subducted sediments.

References

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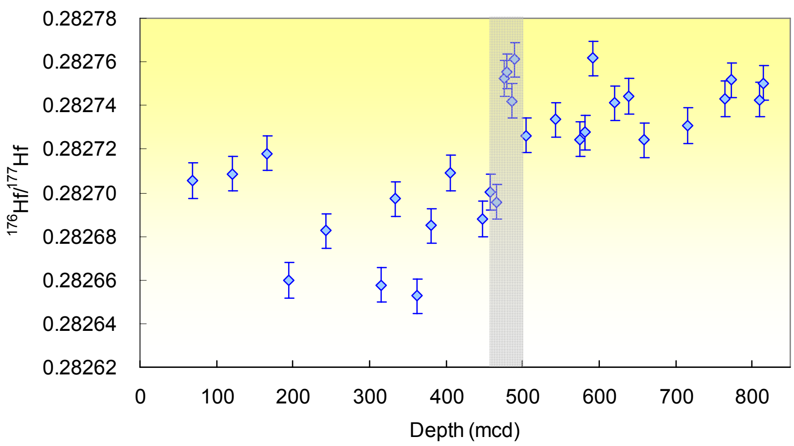

Figure 1. Temporal variation of Hf isotopic ratio. Grey zone shows a remarkable jump at 477~455 mcd (ca. 23~27 Ma).

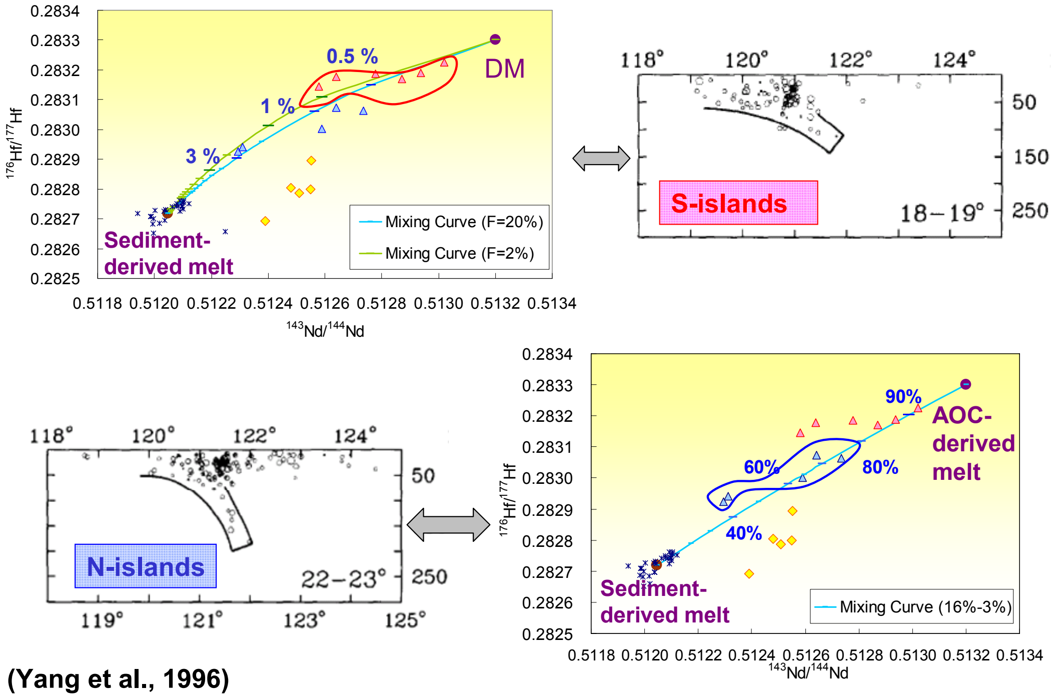

Figure 2. The southern island lavas were derived from mantle chemically modified by solid sediments and/or associated melts, while the sources of the northern island lavas required additional contribution from AOC-derived melts. The requirement of melting AOC beneath the northern islands is consistent with the deeper Benioff zone.

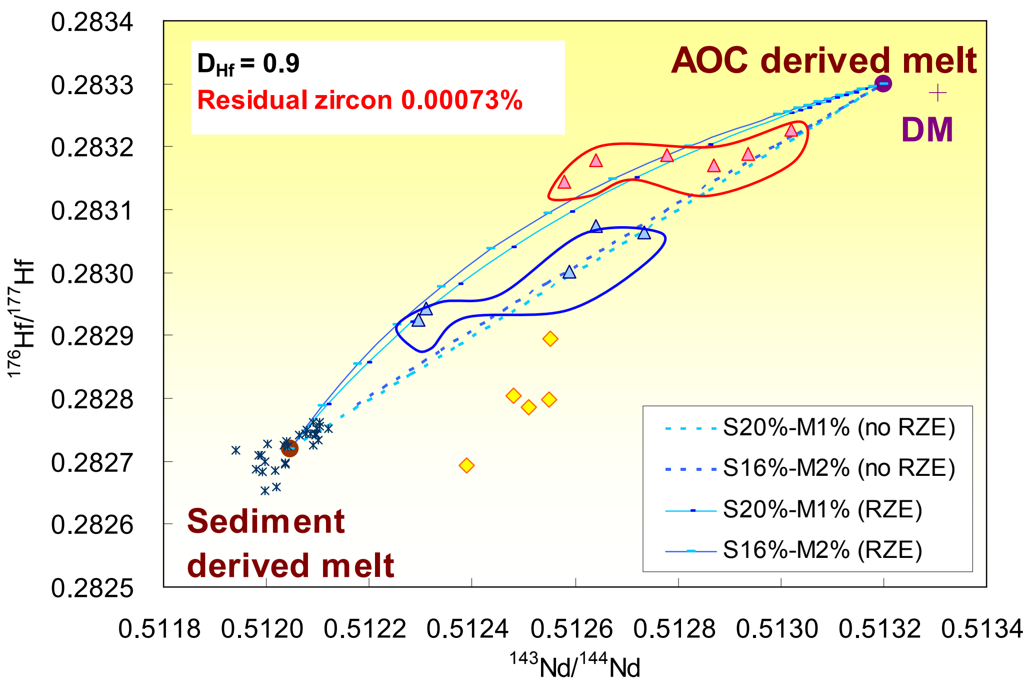

Figure 3. The southern and northern island lavas can be explained by mixing AOC-derived and sediment-derived melts with variable amounts (< 0.001%) of residual zircon (RZE) in the sources of metasomatic agents.