Small-scale variations in abyssal peridotites from Atlantis Bank of the slow-spreading Southwest Indian Ridge

Tomoaki MORISHITA *(Kanazawa University, moripta@kenroku.kanazawa-u.ac.jp),* Takeshi MATSUMOTO *(University of the Ryukyus)*, Henry J. B. DICK *(WHOI)*, Shoji ARAI *(Kanazawa University)* and Yoshito ISHIDA *(Kanazawa University)*

Oceanic crust represents solidified partial melts formed by partial melting of adiabatically decompressing mantle peridotite. Understanding of the formation processes of oceanic lithosphere is therefore a major issue in the Earth Sciences. Peridotites tectonically exposed on ocean floors are called as abyssal peridotites and occur in a variety of tectonic settings such as mid-ocean ridges, back-arc, fore-arc and amagmatic passive continental margins. Petrology and geochemistry of abyssal peridotites provide direct information on mantle melting, melt extraction and post-melting processes beneath ocean floors in diverse tectonic settings. Furthermore, characterization of abyssal peridotites should be essential to know origin of ophiolites. Since many studies on abyssal peridotites were conducted based on local averages, less attentions have been paid to local variations in modal and chemical compositions in peridotites. Field-work like close-spaced observation and sampling on a wall of the Atlantis II Fracture Zone in the slow-spreading Southwest Indian ridge (14 mm/year full spreading rate) were conducted by submersible SHINKAI 6500 of the Japan Marine Science Technology Center. The Hole 735 B of Ocean Drilling Program (Legs 118 & 176), a vertical interval ~ 1.5 km thick through a complex assemblage of gabbroic rocks (Dick et al., 1991, 2000), is located at the top of Atlantis Bank located 100-km south of the SWIR rift valley on the crest of the eastern traverse ridge of the Atlantis II Fracture Zone. We present local variations in peridotites collected from two dives traversed a southwestern facing slope of Atlantis Bank with interval of 1000 m water depth.

We succeeded a cross-sectional observation of an outcrop where layered gabbros are directly underlain by granular peridotites (gabbro/peridotite boundary hereafter). Nineteen of 20 samples are plagioclase-free spinel lherzolite with Cr# of spinel 0.2-0.35, mainly concentrated around 0.2. Chondrite-normalized REE patterns of clinopyroxene in these peridotites have LREE-depleted signatures and systematically decrease in LREE with increasing of the Cr# of spinel, and are compatible with mantle residue of a low-degree of partial melting predicted for slow-spreading ridges (Dick and Bullen, 1989; Arai, 1994). Clinopyroxenes compositions are not equilibrium with mid-ocean ridge basalt in terms of REE concentrations as suggested by Johnson et al. (1990). Strong LREE depleted signatures in residual clinopyroxene were interpreted mantle residues after nearly fractional (Johnson et al., 1990).

On the other hand, based on phase equilibria and field evidence from mantle-hosted dunite commonly found in many ophiolitic peridotites, dunites were thought to be acting as conduits for focused melt flow due to melt-mantle interactions (e.g., Kelemen et al., 1995). The dunite sample (6K643R15) was at the first time recovered from outcrop at about 40 m below the gabbro/peridotite boundary. It occurs as a dike (~ 20cm in thickness) highly oblique to the gabbro/peridotite boundary. The dunite is accompanied with dunitic lherzolite (olivine-rich rock with high cpx/opx ratio) at the edge of the sample and is intruded by gabbro vein (< 2cm in thickness) (Morishita et al., 2004). A chromian spinel-rich veinlet (1 cm in thickness) occurs in the dunite parallel to the lithological boundary between the dunite and the dunitic lherzolite. The lithological relationships between the chromian spinel-rich vein and the host peridotites are the same as those for podiform chromitite in ophiolites/orogenic peridotites irrespective of the differences in size. The Cr# of chromian spinel is, however, apparently lower in the chromian spinel-rich vein (0.3) than in typical podiform chromtites in ophiolites/orogenic peridotites (> 0.6) (e.g., Arai, 1997) as well as oceanic chromitites (0.5-0.6) (Arai & Matsukage 1998; Abe et al., 2003) from a first-spreading ridge. This study combined with previous work from ocean floor chromitites suggests that magmatism beneath ocean ridge is generally not suitable for the formation of high-Cr chromitites (Arai, 1997). The Cr# of spinel in the dunite (0.3) is, however, similar to those in the SWIR MORB far from hot spots (Le Roex et al., 1983). REE concentrations of calculated melt equilibrated with dunite clinopyroxene show a flat to weak LREE-enriched patterns, which are similar to those in the SWIR MORB formed by low-degree of partial melting. These data indicate that the dunite acts as melt conduit even in a slow-spreading ridge. Dunites are minor but were collected from mid-ocean ridge, back-arc and fore-arc settings. This means that dunites may act important role as melt conduit beneath ocean floor in diverse tectonic settings.

Clinopyroxene in the dunitic lherzolite occurs as porphyroclast, interstitial grain between olivine matrix and rarely rimming of orthopyroxene. Chondrite-normalized REE patterns of clinopyroxene in the dunitic lherzolite are variable corresponding to the occurrences above, LREE-depleted, LREE-enriched and high-concentrations of REEs with negative Eu anomaly, respectively. These suggest that some clinopyroxene might be formed from interstitial melts. The dunitic lherzolite is therefore interpreted to be residue of high-degree of partial melting, even in a slow-spreading ridge. Since the computed bulk compositions of the Hole 735B is too evolved to be in equilibrium with mantle peridotites, there must be a significant mass of "missing primitive cumulates (such as high-Mg# dunite and trocotlite)" in the lower crust or in the mantle section around the studied area (Dick et al., 2000; 2002; Niu et al., 2002). Our results suggest that large quantities of melt were trapped in the upper mantle rather than bleeding upward to solidify in the crust if magmatic activity is low.

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