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"21st Century MoHole —Researches on Magmatic Processes of the Moho Transition Zone beneath the fast-spreading ridges"

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The main objective of the 21st century MoHole is to understand the Moho below the ocean floor. It is of prime interest not only to know the constituents of the Moho but also to understand the formation processes of the Moho. I propose to drill through fast-spread oceanic crust and the Moho Transition Zone (MTZ) into the upper mantle by Chikyu in order to understand the critical role of the Moho transition zone in the magma plumbing system at fast-spreading ridges, with special reference to the genetic link between the off-ridge volcanism and the MTZ.

Mid-ocean ridge system, the world largest volcanic zone, produces approximately 80% of the magma on the whole Earth that forms oceanic plates covering the 70% of the Earth's surface. Fast-spreading (>8 cm/yr) ridges yield 50% of the entire oceanic plates and are critical in understanding the mechanisms of plate construction and the magma plumbing system at plate divergent boundaries. Furthermore, the oceanic lithosphere formed at fast-spreading ridges subducts deeply into the Earth, which plays the major role in evolution of the Earth through material transfers between the interior and the surface of Earth. Therefore, it is very important to understand the accretionary processes at fast-spreading ridges and to know the bulk compositions of entire oceanic crust and the uppermost mantle as an input to subduction zones. The primary target of the 21st century MoHole is to penetrate the entire oceanic crust formed at a fast-spreading rate through the Moho to the uppermost mantle.

Lithospheric minerals obtained from the ocean floors show progressive depletion of incompatible elements with increasing spreading rate, indicative of higher melting degrees of uprising asthenospheric materials beneath faster-spreading ridges (Niu and Hekinian, 1997). However, the degree of melting estimated from inversions of rare earth element contents in mid-ocean ridge basalts (MORBs) show a positive correlation with the spreading rate only for slow-spreading (3-4 cm/yr) ridges, but is almost constant for faster-spreading ridges (Brown and White, 1994). This discrepancy may arise from the interaction of the uprising magma with the surrounding mantle peridotite through the crust/mantle boundary that determines the final primary magma compositions supplied to the crust.

Uprising magma through the uppermost mantle reacts with the surrounding peridotite and changes its chemical composition toward silica-enriched, olivine-saturated melts that leaves dunite after peridotite (Arai, 1999; Kelemen et al., 2000; Ozawa, 2001, 2005, 2008). Magma trapped within the dunite differentiates to form gabbroic veins and pods enriched in volatile and incompatible elements, comprising the Moho Transition Zone (MTZ) with the host dunite. The MTZ tends to be thicker beneath fast-spreading than slow-spreading ridges. The primary MORB composition that forms the crust is more likely to be controlled by the MTZ reaction, which obscured the spreading-rate dependence of the MORB composition for faster-spreading ridges. However, the axial lava compositions were modified from the primary MORB compositions through the crystallization differentiation and magma mixing in the lower crust and do not retain their primitive signatures obtained by the MTZ reaction.

Meanwhile, a number of young seamounts and lava flows are known to have erupted >4 km off the southern East Pacific Rise (Figure 1; Geshi et al., 2007; Kishimoto and Hilde, 2003; Macdonald et al., 1989; Perfit et al., 1994; Umino et al., 2008; White et al., 1998, 2002). ODP Holes 1256C and D drilled into superfast-spread oceanic crust and penetrated through a 100-m thick ponded lava, which is considered to be a part of a single large lava field that erupted and were emplaced >10 km off the ridge axis (Crispini et al., 2006; Umino et al., 2008). These off-ridge volcanoes are distributed symmetrically on the both sides of the ridge axis, suggesting that they comprise the magma plumbing system of the East Pacific Rise. Large Lava Fields (LLFs) are specifically important because they possess a volume of 7-30 km^3, which amounts to several times of the global average annual magma production of 4-5 km^3 (Crisp, 1984), and potentially have a large influence on the Earth's environment. LLFs are also known from slow-spreading ridges (Umino, 1994). Thus, LLFs are the manifest of common fluctuation of magma production rates which are involved in the magma plumbing system at plate divergent boundaries. The off-ridge magmas have much wider spectrum of compositions than the axial magmas, and span from depleted Normal through Transitional to enriched MORB compositions. Furthermore, erupted volumes of LLFs largely exceed the volumes of the axial magma chambers (< 2 km^3; Hooft et al. [1997]). Both the large volumes and variable magma compositions of the off-ridge volcanoes strongly suggest the existence of independent off-ridge magma conduits other than the axial magma plumbing system, which erupt without interacting with the evolved magmas in the axial magma chambers (Figure 2; Umino et al., 2008). Therefore, the variable off-ridge magmas are more likely to retain the primary chemical signatures obtained through the MTZ magma processes than the axial magmas.

The knowledge of the primitive pre-MORB compositions that pass through the MTZ to become the primary MORB forming the crust is critical to understand the processes of magma production within the uprising mantle asthenosphere. The fast-spread crust, the prime target of the 21-century MoHole, is overlain by the off-ridge volcanoes, and will consequently drill through the off-ridge eruptive products and their genetically related MTZ materials. With the knowledge of the both products of the MTZ reaction (the MTZ dunite and the primary MORBs represented by the off-ridge products) and one of the reactants (host mantle peridotite), we are able to determine the rest of the reactants, pre-MORB magma compositions that form within the upwelling asthenosphere beneath the spreading ridge.

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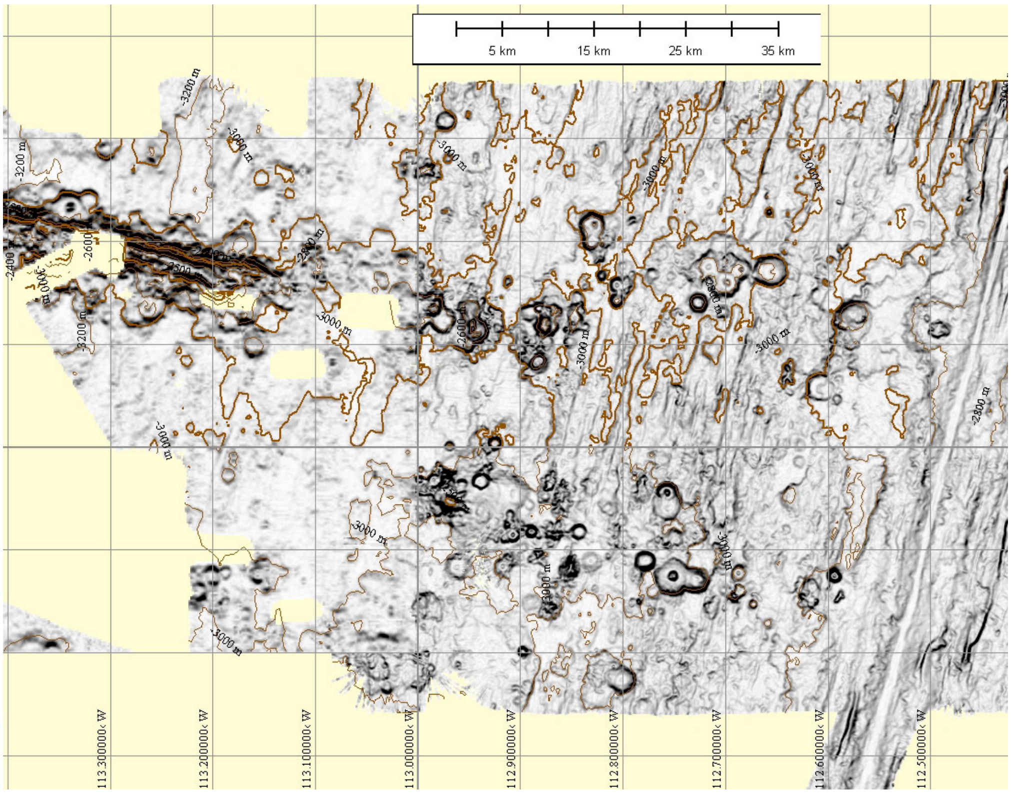

Figure 1. Off-ridge volcanoes at southern East Pacific Rise at 14°S (Umino et al., 2008).

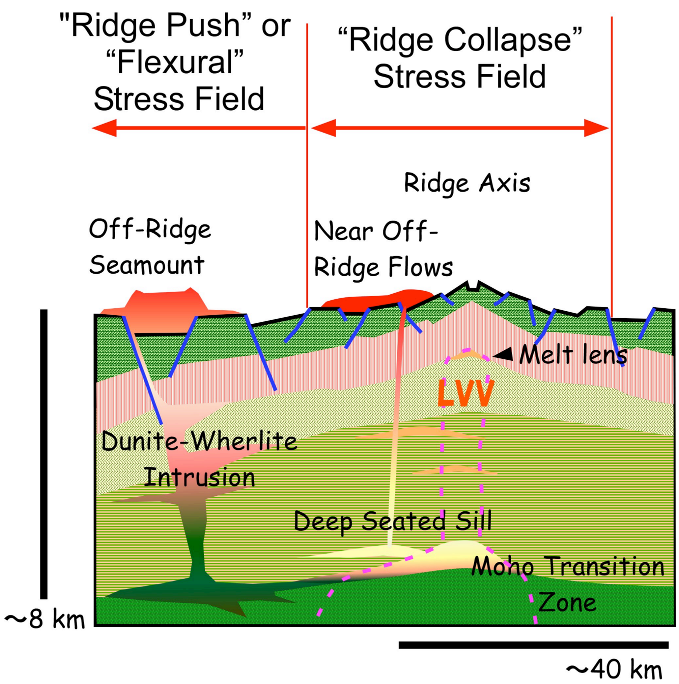

Figure 2. Schematic section across the southern EPR at 14°S. Off-ridge flows and volcanoes are most likely fed from the deeply seated magma chambers in the Moho Transition zone.