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SIT05-P01 Room:Convention Hall Time:May 26 18:15-19:30

Origin of geochemical variations of primary boninite magmas of the Ogasawara (Bonin) Archipelago

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Stratigraphy and ages of volcanic rocks of the Ogasawara Archipelago indicate secular variations of magmas generated during the early Izu-Ogasawara-Marina Arc with the progress of subduction of the Pacific Plate. The onset of subduction of the Pacific Plate beneath the Philippine Sea Plate at 52 Ma forced upwelling of depleted mid-ocean ridge basalt mantle (DMM; Workman and Hart, 2005), which was adiabatically melted to yield proto-arc basalt (PAB). With the rise of DMM, refractory harzburgite ascended without melting, and hence retained its high temperature. At 48-46 Ma, introduction of slab fluids caused remelting of the PAB residue and high-T harzburgite, resulted in the low-Si and high-Si boninites, respectively. Meanwhile, convection within the mantle wedge brought the less depleted residue of PAB and DMM into the region fluxed by slab fluids, which melted at 45 Ma to yield less depleted low-Si boninite and fertile arc basalts, respectively. By 40 Ma boninite magmatism was replaced by arc tholeiite and calc-alkaline magmatism (Ishizuka et al., 2006, 2011; Umino and Nakano, 2007; Kanayama et al., 2012; Umino et al., 2015). Here, we discuss the origin of the geochemical variations of primary boninite magmas on the basis of melt inclusions in chrome spinel from the Ogasawara Archipelago.

48-46Ma ultra-depleted high-silica boninitic melt inclusions (SiO_2 >54.7 wt%, MgO <23.3 wt%) exhibit V-shaped and dish-shaped rare earth element (REE) patterns. The former inclusions have higher LILEs/La ratios than the latters. V-shaped REE patterns are unique to melt inclusions and have never been found among the bulk boninites. On the other hand, all 48-46Ma low-silica boninitic inclusions (SiO_2 >54.6 wt%, MgO <17.7 wt%) show dish-shaped REE patterns, which are common to bulk boninites. On the contrary, 45Ma less-depleted boninitic melt inclusions have the lowest SiO2 (SiO_2 >53.5 wt%, MgO <18.9 wt%) and flat REE patterns.

We have modeled the geochemical variations of primary boninite magmas, which are assumed to be the highest MgO melt inclusions of each geochemical type, by using the Arc Basalt Simulator (Kimura et al, 2010). Ultra-depleted boninite magmas were generated by partial melting of residue of 10% to 20% fractional melting of DMM, with the introduction of fluid liberated from eclogitic slab. LILEs/La variations of the ultra-depleted melts could be explained by the varying degrees of dehydration of the mantle just above the subducting slab, depending on the thermal status of the mantle wedge. The 45-Ma less-depleted boninite magma requires less depleted source mantle which experienced 4 to 8% fractional melt from DMM with relatively high contribution of sediment fluid.

Major and trace element variations of boninitic melt inclusions can be explained by the mixing of primitive boninite magmas with felsic melts during ascent in the upper mantle. Mixed magmas entered into the stability field of chrome spinel, resulted in rapid crystallization of chrome spinel which trapped melt with a broad compositional range (Arai and Yurimoto, 1994).

Different compositional variations of the bulk boninites from the melt inclusions were formed by crystallization of spinel, olivine and pyroxenes from primitive magmas enhanced by degassing at shallow depths, combined with mixing with evolved magmas.

Keywords: boninite, melt inclusion, trace element composition, subduction zone, island arc, primary magma

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IODP Expedition 351 Izu-Bonin-Mariana Arc Origins: Summary of lithostratigraphy and geophysical data

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Introduction: International Ocean Discovery Program (IODP) Expedition 351 (June-July 2014) cored 1611-m-long cores composed of 1461-m-long sediments and 150-m-long igneous basement rocks from Site U1438 in the Amami Sankaku Basin (ASB), west of the Kyushu-Palau ridge (KPR) which represents a remnant part of the now active Izu-Bonin-Mariana (IBM) arc. Here we provide a summary of the lithostratigraphic and geophysical data of recovered cores which provide a high-resolution record of subduction initiation and the subsequent evolution of the IBM arc.

Lithostratigraphy of the site U1438: Cores recovered from the site U1438 are composed of hemi-pelagic sediments, turbidites and igneous basement rocks. Based on lithostratigraphy, the recovered cores are divided into five units. The uppermost Unit I (160.3-m long) is composed of hemi-pelagic sediments with interspersed discrete ash layers probably derived from explosive volcanism from the Ryukyu and Kyushu arcs. Both Units II (139.4-m long) and III (1046.4-m long) are composed of turbidites, which record the magmatic history of the IBM arc. The estimated ages of Units II and III are Oligocene and Oligocene to Eocene, respectively, based on biostratigraphic and paleomagnetic studies. As a whole, Unit III sediments are coarser grained than those of Unit II and comprise five intervals of coarser clastic sedimentary rocks. Unit IV (99.7-m long) is composed of siliceous pelagic sediments interbedded by tuffaceous sandstones. Age of Unit IV would be early Eocene ($\sim$50 Ma). The igneous basement (Unit 1, 150.0-m long) occurs at 1461 mbsf. The radiometric age of the basement rocks has not been determined yet, but it should be equivalent to or older than $\sim$50 Ma based on biostratigraphy. Unit 1 is composed of basaltic lava flows, the majority of which are high-MgO (mostly $\geq$8 wt%), low-TiO_2 (0.6-1.1 wt%) tholeiitic basalts. Most of the igneous rocks are aphyric, but some contain phenocrysts of Cr-spinel, olivine, plagioclase and clinopyroxene. Their groundmass textures are variable from holocrystalline to microcrystalline and glassy.

Geophysical properties of the site U1438: The geophysical properties of recovered cores, such as P-wave velocity, density, porosity, thermal conductivity and magnetic susceptibility, were measured to help characterize the lithostratigraphic units and provide the basis for linking the lithostratigraphy to seismic imaging of the subseafloor geological structure. There is an overall reduction in porosity and consequent increase in P-wave velocity through sedimentary Units I to IV, reflecting the compaction of sediments. There are significant jumps in sonic velocity, grain density, and magnetic susceptibility at the Unit I/II, II/III and IV/1 boundaries. Oscillations in P-wave velocity and magnetic susceptibility within the top portion of Unit III correspond to changes in the proportion of sands and conglomerates to muds. Higher velocities are correlated to mudstones with dense clasts, and lower velocities are found in mudstones without clasts. There is also a prominent spike in the level of natural gamma radiation within Unit IV, most likely due to elevated concentrations of U, Th and K.

Downhole temperature measurements were made at seven depths using the advanced piston corer temperature tool (APCT-3) from the seafloor to 83.2 mbsf, and these give a linear geothermal gradient without any substantial deviation from 77.6 K/km. With nearly constant values of thermal conductivity (0.952 W/mK), the geotherm is undisturbed by local processes, such as sediment compaction and fluid flow within the porous sediments. The calculated heat flow is 73.7 mW/m^2, implying a thermal age for the underlying lithosphere of 40-60 Ma. This is consistent with an age constrained based on biostratigraphic and paleomagnetic studies ($\sim$50 Ma or older), as mentioned above.

Keywords: IODP, IBM arc, Kyushu-Palau ridge, Amami Sankaku Basin, evolution of island arc

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Serpentinization in the oceanic lithosphere along the outer-rise faults

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Hydration of oceanic lithosphere can occur along outer-rise faults that relate to the plate bending at close to the trench (Faccenda et al. 2009). This contributes an additional source of water into the Earth interior, which might have larger water flux than that transported by hydrated oceanic crust. Recent seismic reflection survey has shown that seismic velocity in the oceanic lithosphere decreases at where bending-related faults are observed (e.g., Ranero et al. 2003; Fujie et al. 2013). Although these seismic data is not enough to image what extent of hydration occurs along the outer-rise faults, we modeled the thickness of serpentinization based on fluid percolation. When the reaction kinetics is much faster than the fluid access to the reaction front, the reaction rate is controlled by permeability through the hydrated layer (Macdonald and Fyfe 1985). Using laboratory measured permeability, the reaction thickness of serpentinization is estimated as thick as 10 km for a period from the initiation of outer-rise fault to the trench axis assuming a plate velocity of 10 cm/year. If outer-rise faults occur 100 km interval, subduction water flux is estimated to be 4.8 x 10^{12} kg/year by hydrated oceanic lithosphere, which is approximately 4 times larger than that carried by oceanic crust. More detail discussion and implication will be prepared for the meeting.

Keywords: outer-rise fault, oceanic lithosphere, serpentinite

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Origin of peridotites outcroppted in the westernmost margin of the southern Mariana Trench

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The Izu-Bonin-Marina (IBM) arc is a typical intra-oceanic arc system. The forearc is non-accretionary convergent margin, where Mafic crustal rocks occurred along the inner trench slope with mantle peridotites. Mariana arc system is the southern part of the IBM arc system and forms arcuately. The trench axis of the southern Mariana trench runs across Mariana volcanic arc and backarc basin (Mariana trough) and is connected to Parece Vela Basin at the westernmost area. There have been no geological studies on the westernmost Marianas trench since Hawkins and Batiza(1977). Recently, investigations for the junction area between Mariana trench and Parece Vela Basin have been conducted using the submersible Shinkai6500 (Dive 6K1397 and 6K1398) as a part of YK14-13 cruise by the R/V Yokosuka in 2014. Shinkai6500 recovered plagioclase-bearing lherzolites and harzbergites from the tectonic ridge along the inner trench slope of the westernmost Mariana Trench. The samples show coarse grained textures (>1mm), heterogeneous intermediate textures, and fine grained textures (<0.6mm). The peridotites with the coarse grained texture were sampled from the shallowest part (3705-4042m) in the dive area, whereas the peridotites with the fine grained textures were sampled from the deepest part (5996m). Olivine fabrics vary associate with texture. : (010)[100]pattern for the coarse grained textures, {0kl}[100]pattern for the fine grained textures, and various indistinct patterns for the heterogeneous textures. The variations of both olivine textures and crystallographic fabrics with depth suggest variations of deformation processes with depth. Olivine-Spinel compositions are in a range of the Olivine-Spinel Mantle Array, indicating that the peridotites are depleted residues after partial melting of the upper mantle. Spinel compositions is bimodal between moderately high Cr# spinels (up to 0.54 in 6K1398R16) and relatively low Cr# spinels (as low as 0.30 in 6K1397R18). The increase of Cr# appears to be correlated with Ti contents (0.03-0.49), indicating that melt-rock interaction under shallow lithospheric mantle conditions. Furthermore, chemical compositions of Spinel Mg# and Cr# are almost identical to those of Parece Vela Basin peridotites, suggesting that Parece Vela Basin Mantle may be exposed on the inner trench slope in the westernmost Mariana trench.

Keywords: peridotite, Mariana Trench, Parece Vela Basin, olivine, CPO

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Preliminary isotope results from the deeper part of Hole U1437, IODP Exp. 350: rear-arc or volcanic-front sources?

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The Izu-Bonin-Mariana arc (IBM) is an intra-oceanic arc that formed ~50 million years ago (Ma). Understanding the magmatic evolution of this arc is fundamental in understanding the initiation and evolution of other intra-oceanic arcs and the genesis of continental crust. Previous drilling and dredging at the volcanic front and dredging in the rear-arc of the IBM has provided a record of the magmatic evolution of the volcanic front since the arc's formation, and revealed a geochemical asymmetry between the volcanic front and rear-arc. Determining the causes of this geochemical asymmetry and when it became established is important to understand the magmatic process of the entire IBM arc.

One of the scientific objectives of IODP Exp. 350 is to clarify the geochemical characteristics of the Paleogene basement underlying the Izu rear-arc region, which has not be accessed by dredging (Tamura et al., 2013). Site U1437 is located in the Izu rear-arc, ~330 km west of the axis of the Izu-Bonin Trench and ~90 km of the arc-front volcanoes Myojinsho and Myojin Knoll, at 2117 mbsl. Site U1437 consists of three coherent holes (U1437B, D, and E), reaches 1806.5 mbsf, and is divided into seven lithostratigraphic units (Unit I-VII). Units VI and VII, below 1320 mbsf, are volcaniclastics with coarser material, while Units I to V are tuffaceous mud and mudstone with intercalated volcaniclastic layers. It is worth noting that Unit VI is intruded at ~1390 mbsl by a single rhyolitic intrusion (igneous Unit 1) (Tamura et al., 2015).

Although the available age constraints are 10.97-11.85 Ma, inferred from a nanofossil assemblage at ~1403 mbsf and a preliminary U-Pb zircon concordia intercept age of 13.6 +1.6/-1.7 Ma on the rhyolite at ~1390 mbsl (Tamura et al., 2015), the geochemical characteristics of units VI and VII are expected to approach the geochemical characteristics of the older basement. Moreover, the volcaniclastics of units VI and VII include a greater proportion of coarser material, indicating they are more proximal to their sources.

Therefore, initially we have focused on Hole U1437E (Units V to VII) in order to obtain as much information on the older basement as possible. The shipboard geochemical analyses, using Zr and Y elements that are resistant to alteration, showed that the proximal volcaniclastics of units VI and VII have a wide signature, including arc-front and rear-arc sources, and the geochemical variation in Units I-V generally reflect relative proportions of distal arc-front and proximal rear-arc volcanic sources (Tamura et al., 2015). Our onshore major and trace elements analyses also show arc-front and rear-arc signatures in units VI and VII (Sato et al., 2015).

The rear-arc volcanos in the Izu-Bonin arc are known to have lower $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$, and $^{206}Pb/^{204}Pb$ ratios than arc-front volcanos (Tamura et al., 2007). Therefore, in addition to the major and trace element compositions, isotope ratios such as Sr, Nd, Pb, and Hf also provide important constraints to identify the source characteristics of the volcaniclastics. We are now analyzing the Sr, Nd, Pb, and Hf isotope ratios of selected samples from Hole U1437E. Although acid leaching is necessary to eliminate the alteration effect, it is expected that the Nd and Hf isotopes will preserve their original characteristics because of their high resistance to alteration, even though the samples are severely altered. We will present the preliminary isotope results, with constraints, to elucidate the source characteristics of the volcaniclastics and intrusion of site U1437.

Keywords: Sr-Nd-Pb-Hf isotopes, Volcanic front, Rear arc, Izu-Bonin-Mariana (IBM), Exp 350, U1437