SIT41-P01 Room:Poster Time:April 28 18:15-19:30

Mafic and ultramafic rocks along the southern Central Indian Ridge close to the Kairei Hydrothermal Field

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The central Indian Ridge (CIR) is situated at the north of the Rodrigues Triple Junction (RTJ) and is a slow- to intermediate-spreading mid-ocean ridge with a spreading rate increasing from 30 mm/year in full rate near the Equator to 49 mm/year in full rate at the RTJ. In the southern CIR near RTJ, the Kairei Hydrothermal Field (KHF) was discovered in August 2000 as the first directly observed hydrothermal vent site in the Indian Ocean. Recently, KH-10-06 cruise aboard R/V Hakuho-maru was organized for understanding the hydrothermal system and geological feature around KHF. In this study, we present the petrography of mafic and ultramafic rocks dredged from the vicinity of the KHF during KH-10-06 cruise. A total of 76 samples have been studied from 9 sites, including 24 ultramafic rocks and 38 mafic rocks and 14 other rocks. Most of them are remarkably altered and hydrated. We classified them into sub-groups based on their textures and mineral assemblies. The ultramafic rocks were classified into 5 sub-groups: 1 peridotite, 2 pyroxenites, 3 serpentinized peridotites, 9 olivine-bearing serpentinites and 9 serpentinites. The mafic rocks were classified into 8 sub-groups: 21 Fe-Ti oxide gabbros, 4 gabbros including 2 mylonites, 3 olivine gabbros, 7 gabbroic rocks with various textures and 8 amphibole-rich gabbros. The other rocks consist of 5 aragonites and 9 hydrothermally altered rocks.

Keywords: mafic rock, ultramafic rock, Central Indian Ridge, Kairei Hydrothermal Field

SIT41-P02 Room:Poster Time:April 28 18:15-19:30

Upper mantle electrical resistivity structure at the continental margin of East Antarctica

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The breakup of the Gondwana supercontinent is one of targets of the study on the plate tectonics and related mantle dynamics. The crust and the upper mantle structure under the western Cosmonauts Sea at the continental margin of East Antarctica, where a rifting of Gondwana and a subsequent seafloor spreading occurred, are anticipated to reflect the breakup process of Gondwana. We carried out a marine electromagnetic experiment to reveal an electrical resistivity structure at depth of the crust and the upper mantle under the western Cosmonauts Sea. Time variations of the electromagnetic field were acquired at two seafloor sites in the experiment. The time variations data were processed on the basis of the magnetotelluric (MT) method. The MT response function was obtained after considering influence of non-plane magnetic field sources at high geomagnetic co-latitude. The obtained MT response functions and polar diagrams imply that the MT responses involve topographic distortion and/or reflect a higher dimensional resistivity structure under the observational sites. Three dimensional forward modeling was conducted to examine influence on the observed MT responses from the topographic variation around the observational sites and a conductive layer just under the sites, which is mostly regarded as sediment. The results of the forward modeling clearly show that the topographic variation and the surface conductive layer have severe influence on the observed MT responses. A series of 3-D forward modeling with the topographic variation and the surface conductive layer was implemented to examine a resistivity structure at depth of the crust and the upper mantle. The results indicate that the resistivity structure is explained by a two-layer resistivity structure, in which the upper layer is resistive and the lower layer is conductive. The upper resistive and the lower conductive layers likely represent dry and water/melt rich oceanic upper mantle, respectively. The thickness of the upper resistive layer is thinner than that expected for a typical oceanic upper mantle of the seafloor age of the study area. The thin upper resistive layer may require high temperature and high water/melt anomalies that were generated through mantle convection, which was related to the breakup process of Gondwana at the continental margin of East Antarctica.

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Geochemical characteristics of the peridotites from the southern Mariana forearc

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Dehydration of a subducting oceanic plate and infiltration of the fluid/melt released from the oceanic plate are thought to be the key processes to invoke melting of the wedge mantle. Although a number of studies on volcanic rocks in arcs have been conducted to reveal a material recycling process at subduction zone, understanding of geochemical development process within the wedge mantle is still not as far advanced. The southern Mariana forearc is one of the best locations on the Earth to investigate issues above, since serpentinized peridotites are widely exposed on the inner slope of the Mariana Trench. We have collected peridotite samples obtained by dredging and Shinkai diving from 3000 − 7000 mbsl at the southern Mariana Trench. The dredge and dive points are geographically grouped into three sites: site 1 (KH98-1-D1, KH98-1-D2, and 6K-973), 2 (KH03-3, KH98-1-D3, and 6K-1094), and 3 (6K-1095, 6K-1232, 6K-1233, and 6K-1234) from the east to the west. We conducted EPMA and LA-ICP-MS analyses on minerals in the recovered samples to reveal geochemical development process of the wedge mantle.

Peridotites from the easternmost site 1 consist of olivine (Fo# = 90 − 91), orthopyroxene (Mg# = 90 − 91), spinel (Cr# = 40 − 50), clinopyroxene (Mg# = 89 − 93), tremolite (TiO_2 = 0 − 0.4 wt%), pargasite (TiO_2 = 2.0 − 2.5 wt%), plagioclase, and serpentine. Clinopyroxene and pargasite exhibit LREE-depleted (type C1 and A1, respectively) and orthopyroxene LREE- and MREE-depleted patterns (type O1) in a chondrite-normalized diagram.

Peridotites from the westernmost site 3 consist of olivine (Fo# = 91 − 92.5), orthopyroxene (Mg# = 91 − 93.5), spinel (Cr# = 45 − 75), clinopyroxene (Mg# = 94 − 96), tremolite (TiO_2 = 0 − 0.2 wt%) and serpentine. Some clinopyroxene exhibits LREE-enriched convex upward pattern (type C2), others strong LREE- and MREE-enriched REE pattern (type C3). Tremolite and orthopyroxene exhibit LREE-enriched convex upward (type A3) and weakly LREE-enriched convex upward REE patterns (type O2), respectively. HREE, Ti, and Y abundances of type C3 clinopyroxene are higher and their LREE and Sr abundances lower than those of type C1 clinopyroxene.

Peridotites from the middle site 2 show intermediate characteristics between site 1 and 3. They consist of olivine (Fo# = 90 − 92), orthopyroxene (Mg# = 91 − 92.5), spinel (Cr# = 45 − 52), clinopyroxene (Mg# = ˜95), pargasite (TiO_2 = 0.8 − 1.7 wt%), tremolite (TiO_2 = 0 − 0.2 wt%), plagioclase and serpentine. Some clinopyroxene exhibits C1-type REE pattern and coexists with A1-type pargasite, while other clinopyroxene exhibits LREE- and MREE-depleted patterns (type C2) coexisting with LREE- and MREE-depleted tremolite with weak enrichment in LREE (type A2).

Compared to results of high-pressure melting experiments on peridotite, monotonous increase of Mg# of olivine, clinopyroxene, and orthopyroxene as well as Cr# of spinel from site 1 to 3 suggests increase of melting degree of the mantle peridotite from site 1 to 3. Monotonous decrease of HREEs, Ti, Y, Zr, and Hf abundance from C1- to C3-type clinopyroxene, from A1- to A3-type amphibole, and from O1- to O2-type orthopyroxene, is consistent with major element variations above. However, in contrast to the observation above, LREE and LILE abundance increase from C1- to C3-type clinopyroxene, from A1- to A3-type amphibole, and from O1- to O2-type orthopyroxene, suggesting involvement of melt/fluid enriched in such elements.

LREE-enriched clinopyroxene and amphibole have been found from mantle xenoliths and subaerial peridotite complex. Those clinopyroxene and amphibole have been interpreted as a product of melting and melt separation involving infiltration of LREE-enriched melt/fluid into the melting system. Similarity of geochemical characteristics of type C3 clinopyroxene and A3 amphibole to those in xenoliths or peridotite complexes may suggest involvement of LREE-enriched melt/fluid to the mantle beneath the southern Mariana forearc.

Keywords: Mariana Trench, peridotite, pyroxene, amphibole, trace element

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Petrological features of the peridotite xenoliths in the 1991 Pinatubo dacite and mantle metasomatism by subducted ocean

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We observed peridotite xenoliths in the dacite of the 1991 pyroclastic flow deposit of Pinatubo volcano, which is located at the volcanic front of the Luzon (Bataan) arc, Luzon island, the Philippines. The Luzon arc is associated with eastward subduction of the South China Sea plate along the Manila Trench. We also found olivine xenocrysts and xenoliths of amphibolite and granitic rocks in the dacitic deposits. The largest xenolith was up to 14 cm across among about 200 collected samples. Selvage of hornblendite, up to 5 mm width, is common between the peridotite and the dacite host.

Arai et al. (1996) classified peridotite xenoliths from Iraya volcano, Batan Island, the Philippines, into coarse grained (C) and fine grained (F) types depend in terms of olivine grain size. The C-type xenoliths are equivalent to ordinary mantle xenoliths from various localities and the F-type xenoliths are quite different in texture, its individual grains being hardly visible by the naked eye and the fine-grained ($\leq$ 0.1 mm) part occupying $>$10 % by volume (Arai and Kida, 2000). They interpreted that the F-type peridotite was possibly formed from the C-type one by recrystallization assisted by SiO_2-rich fluid or melt originated from subducting slab. Such peculiar F-type xenoliths can be observed in the peridotite xenoliths from Avacha volcano on the volcanic front of the Kamchatka arc, Russia (Ishimaru et al., 2007) and at Tubaf and Edison volcanos, Tabar-Lihir-Tang-Feni island arc, which occur in the fore-arc region of the New Ireland intra-oceanic island arc, Papua New Guinea (McInnes et al., 2001). According to their definition, the F-type peridotites occupy about 50 % of 40 Pinatubo samples. Almost all of the Pinatubo C-type xenoliths are spinel harzburgites (olivine + orthopyroxene + amphibole + spinel $\pm$ clinopyroxene $\pm$ phlogopite) except a wehrlite and a dunite samles. CO_2-bearing saline fluid inclusions were observed in all samples (Kawamoto et al., 2013).

The Sr-Nd isotopic compositions of amphibole from the primary C-type xenolith containing least amounts of fine-grained part are consistent with the most depleted values of the range of andesite and dacite ($^{87}Sr/^{86}Sr$ = 0.70419 - 0.70425, $^{143}Nd/^{144}Nd$ = 0.512863 - 0.512924; Castillo et al, 1991; Bernard et al, 1991). Their compositional variation is within a range of South China Sea oceanic basalt (Tu et al., 1992). Multi-element chondrite-normalized patterns of the amphiboles show depleted signatures with enrichment of Ba, Rb, U, in Pb. These enriching elements are considered as fluid mobile during dehydration of subducting mantle, oceanic crust and sediment (e.g. Tatsumi et al., 1986; McColloch & Gamble, 1991). The present Sr-Nd isotopic and geochemical signatures of the amphibole suggest that the Pinatubo C-type mantle xenoliths have also been metasomatized by aqueous fluids released from subducted oceanic crust beneath the volcanic front.

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Keywords: amphibole-bearing peridotite xenolith, Pinatubo, mantle metasomatism, mantle wedge

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Petrology of mafic-ultramafic rocks in the East Taiwan Ophiolite, in the Lichi melange, Taiwan

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Taiwan is located on the border between the Philippine Sea Plate and the Eurasia Plate. The blocks of cherts, volcanic rocks, plutonic rocks (mafic-ultramafic rocks) are widely distributed as exotic blocks in the Lichi melange, southeastern Taiwan (Liou et al., 1977). These ophiolite-like rocks (cherts, volcanic rocks, plutonic rocks) are defined as the East Taiwan Ophiolite (Liou, 1977). The origin of the East Taiwan Ophiolite is still in debate. Three possible candidates are (1) Philippine Sea Plate (Liou, 1974), (2) the north extension of the Luzon volcanic arc (Ota and Kaneko, 2010), and (3) the South China Sea (Suppe et al., 1981). In this study, we focus on petrological characteristics of gabbros and peridotites in the East Taiwan Ophiolite.

In this research, we collected mafic-ultramafic rocks to cover a wide range of variations in terms of mineral variations at each outcrop. The gabbros are classified into troctolite, olivine gabbro, hornblende gabbro, and gabbronorite. Most of ultramafic rocks are extensively serpentinized, but have equigranular textures based on shape of relic and pseudomorph minerals except for a few serpentine mylonites. The serpentinized peridotites are classified into clinopyroxene-bearing harzburgite and dunite. The Cr# (Cr/(Cr+Al) atomic ratio) and Mg# (Mg/(Mg+Fe) atomic ratio) of spinels in the serpentinized peridotites are 0.3-0.6 and 0.3-0.5, respectively. It is well characterized that the high-Cr# spinel ($>$0.6) coupled with the formation of secondary orthopyroxene are commonly observed in ultramafic xenoliths in Luzon arcs (Arai et al., 2004). We conclude that the East Taiwan Ophiolite is similar with abyssal peridotites and gabbros collected from mid-ocean ridges or back arc basins.

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Petrological evidence for arc-metasomatized peridotites beneath mid-ocean ridges

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Here we report for the first time petrological evidence of recycled subduction-modified mantle materials beneath the Mid-Ocean Ridge. We conducted several cruises with submersible SHINKAI 6500 dives and dredges in the south end of the Central Indian Ridges (Phenix knoll). We recovered orthopyroxene-rich lithologies coupled with peridotites and gabbros from a small knoll along the present mid-ocean ridge. The orthopyroxene-rich lithologies can be formed by magmatic processes beneath the present mid-ocean ridges by crystallization from ultra-depleted primary melts (Sobolev and Shimizu, 1993, Nature) in the Mid-Ocean ridge system. Orthopyroxene-rich peridotites are also commonly observed in peridotite bodies of suprasubduction ophiolites (e.g., Morishita et al., 2011 Lithos) as well as in several sub-arc xenoliths (McInnes et al., 2001 EPSL; Arai and Kida, 2000 Island Arc; Arai et al., 2004 J. Petrol; Shimizu et al., 2004 Trans. Royal Soc. London; Ishimaru et al., 2007 J. Petrol). It is also well known that 30% of continental upper mantle samples are enriched in OPX/olivine relative to residual peridotite from partial melting of the primitive mantle (e.g., Boyd, 1989 EPSL; Kelemen et al., 1998 EPSL). Silica-enrichment in the uppermost mantle section under island-arcs is explained by infiltration of silica-rich hydrous fluids/melts derived from subducting slabs. The Re-Os system also supports subduction-metasomatized peridotite origins for orthopyroxene-rich lithologies. The Re-Os isotope system is used for a tracer of recycled crustal materials because oceanic/continental crust possess high Re/Os (parent/daughter) ratios, and develop radiogenic Os isotope compositions over time, which can be readily traced as recycled material if mixed back into the convective mantle. We examined the Os-isotopic compositions of the representative samples: dunite, one harzburgite and one olivine-orthopyroxenite, without signs of petrological and chemical modifications caused by the formation of gabbroic veins. The orthopyroxenite is characterized by a distinctively high in radiogenic Os (187Os/188Os) isotope signatures (0.1475-0.1499) with relatively high in Re contents (382-402 ppt) whereas the Os isotope of the harzburgite is slightly lower than the present-day depleted MORB mantle (0.123-0.126). High 187Os/188Os ratio coupled with high Os and Re contents of the olivine-orthopyroxenite cannot be accounted for by in situ 187Re decay after interaction between MORBs and peridotites for a million years. Radiogenic Os isotope compositions have been reported for MORB glass, and attributed to the presence of recycled oceanic crust in the upper mantle. Mixing of depleted mantle with exotic component that have an isotopic component with high 187Os/188Os ratios, i.e., radiogenic Os components, are required for the sample. We evaluate the effect of metasomatism of mantle by slab-derived fluids or melts on Os systematics observed in the samples. We conclude that ancient subduction-modified mantle domains, probably formed at continental margin of the Gondwanaland, now exists beneath the Central Indian Ridge.

Keywords: Mid-Ocean Ridge, Mantle, Peridotite, arc, recycling