Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT41-01 Room:314 Time:April 28 10:00-10:15

Microstructural and fabric characteristics of the uppermost mantle peridotites in the Taitao ophiolite, South America

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The <6Ma young Taitao ophiolite, exposed at the westernmost promontory of the Taitao Peninsula, is located approximately 40 km southeast of the Chile triple junction and consists of a complete sequence of oceanic lithosphere, including ultramafic rocks, gabbros, a dyke complex and volcaniclastic rocks. The ophiolite is surrounded by several contemporaneous granite plutons intruded in between the ophiolite and the Pre-Jurassic metamorphic basement. Several studies have been carried out on the Taitao ophiolite and surrounding granites. Whereas they have focused mostly on petrology and geochemistry, we investigated microstructures and crystal-fabrics of the ultramafic rocks, aiming to understand the origin of the ophiolite. 6 out of 16 ultramafic rocks preserved peridotite textures despite of intense serpentinization and show mostly porphyroclastic textures consisting of pyroxene porphyroclasts with a fine-grained olivine-pyroxene matrix. Their olivine crystal-fabrics shows [100]{0kl} and [100](001) patterns. These indicate that the uppermost mantle section have remarkably been deformed before and/or during the obduction process after their formation beneath the mid-ocean ridge.

Keywords: Taitao ophiolite, mantle section, peridotite, microstructure, olivine fabrics

SIT41-02 Room:314 Time:April 28 10:15-10:30

Gabbroic petrology of oceanic lithosphere: comparison between Godzilla Megamullion and megamullions in mid-ocean ridges

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Godzilla Megamullion is the largest oceanic core complex on the Earth, with the dimension 125 km (along axis) and 55 km (across axis) (Ohara et al., 2001). Our study has revealed systematic petrological characteristics of the gabbroic rocks from the Godzilla Megamullion. In this contribution, we will report these characteristics and compare the results with those of gabbroic rocks from mid-ocean ridges.

Low modal abundance of olivine and high abundances of amphibole and iron oxide minerals are the prominent feature of the majority of the gabbroic rocks recovered from the Godzilla Megamullion. The studied gabbroic rocks are classified into troctolite, olivine gabbro, gabbro, hornblende pyroxene gabbro, pyroxene hornblende gabbro, hornblende gabbro on the basis of the classification by Streckeisen (1976). The chemical compositions of constituent minerals show systematic variations that are indicative of magmatic differentiation. Anorthite content in plagioclase, XMg (Mg/ (Mg + Fe) value in olivine and clinopyroxene decrease from less differentiated to highly siliceous evolved rocks. The mineral compositions indicate that troctolite is the most primitive variety and that trondhjemite is the most differentiated variety in the Godzilla Megamullion.

Troctolite, olivine gabbro and gabbro were recovered only from the distal parts of the Godzilla Megamullion. An age of ~13 Ma has been reported from this region (Tani *et al*., 2011). On the other hand, trondhjemite was recovered from the medial and proximal parts of the megamullion, with ages of 11 and 8.7 Ma (Tani *et al*., 2011), respectively. Gabbroic rocks with relatively primitive composition were recovered from the Neck Peak region (age of 8.4 Ma; Tani *et al*., 2011). The spatial and temporal distribution of gabbroic rocks in the Godzilla Megamullion suggests the following magmatic model: a robust magmatic activity was predominant in the distal part, a declined magmatic activity in the medial to proximal parts, and a resurgent magmatic activity in the Neck Peak region. This model is consistent to the results obtained independently from petrological analysis on the peridotites from the Godzilla Megamullion (Snow *et al*., in preparation).

The lithological proportions of the gabbroic rocks in the Godzilla Megamullion are characterized by lower primitive gabbro (troctolite and olivine gabbro) ratio than in the Kane Megamullion in the Mid-Atlantic Ridge and in the Atlantis Bank in the Southwest Indian Ridge.

Keywords: Parece Vela Basin, Godzilla Megamullion, gabbro, Oceanic core complex

SIT41-03 Room:314 Time:April 28 10:30-10:45

The Po/So waves propagating in the Philippine Sea

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The Po/So waves which have high-frequency content, large amplitude, and long-duration propagate for large distance (up to 3000 km) across the oceanic lithosphere. In our previous study, we analyzed Po/So waves from deep-focus earthquakes occurring in the subducting slab beneath Japan, recorded by broadband ocean bottom seismometers (BBOBSs) at northwestern Pacific [Shito et al., 2013]. We demonstrated that the Po/So waves are developed by multiple forward scattering of P and S waves due to laterally elongated heterogeneities in both the subducting and laterally extending oceanic lithosphere. Following this study, the question when and where do the small-scale heterogeneities form in the oceanic lithosphere comes about. In order to answer this question, the Po/So waves in younger oceanic lithosphere need to be analyzed. Therefore in this study, we investigate the Po/So waves in the Philippine Sea plate (15-60 Ma), which is much younger than the Pacific Plate (130 Ma).

The Philippine Sea is one of the marginal seas of the Pacific Ocean. It is fundamentally divided into two regions bounded by the Kyushu-Palau Ridge. It is thought that these two regions were formed in different episodes of back-arc spreading and that western part (45-60 Ma) is older than eastern part (15-30 Ma) [e.g., Seno and Maruyama, 1984]. The comparison of Po/So waves propagation in the different ages of the oceanic lithosphere is expected to reveal the origin of the small-scale heterogeneities.

Seismological observations using BBOBSs was conducted in the Philippine Sea from 2005 to 2008, and high-quality Po/So waves from earthquakes in subducting Philippine Sea plate were recorded very clearly. The findings from the observed Po/So waves in the Philippine Sea plate are summarized as follows. (1) The Po/So waves propagate much effectively in western part than eastern part of the Philippine Sea. (2) The Po/So waves propagate even in youngest oceanic lithosphere (15 Ma) near the past spreading center of the Shikoku Basin.

In order to reveal the structure of the oceanic lithosphere and propagation efficiency in the Po/So waves, we performed numerical FDM simulations of 2-D seismic wave propagation in a realistic oceanic lithosphere model. The model is developed in the same procedure as the case of the Pacific plate [Shito et al., 2013]. In the oceanic lithosphere, we introduce laterally elongated small-scale heterogeneities, which are described by von Karman type stochastic random distribution function. Because the thickness of the oceanic lithosphere is considered to correlate with the age [e.g., Kawakatsu, et al. 2009], we vary the thickness of the oceanic lithosphere from 80 km to 20 km. To evaluate the fit of the computed waveforms to the data, we use the spatial attenuation of the seismic wave energy along the record section (up to 1500 km). The seismic wave energy is defined as integrated squares of amplitudes in a certain tine window (25 s from the Po/So wave onset). The model with the thickness of the oceanic lithosphere of 60 km and 30 km successfully explain the spatial attenuation of the Po/So waves record section observed at western and eastern parts of the Philippine Sea, respectively. The thicknesses are consistent with those obtained by previous studies [Kawakatsu et al., 2009]

This result suggests that the oceanic lithosphere including small-scale heterogeneities grow as it ages and develop large-amplitude and long-duration of high-frequency Po/So waves. The small-scale heterogeneities may form at the bottom of the lithosphere as it cools. They suggest that small-scale melts in the asthenosphere are frozen and attached at the bottom of the lithosphere, which remain even after the lithosphere is subducted into the mantle.

Keywords: Po/So waves, Philippine Sea plate, oceanic lithosphere

Japan Geoscience Union Meeting 2014
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SIT41-04 Room:314 Time:April 28 11:00-11:15

Multi-scale heterogeneity of abyssal peridotite

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Petrological studies of peridotite have increasingly revealed the origin of magma as well as materials and processes of Earth interior. Although we now only access to the interior indirectly, we can obtain the mantle-derived material brought by magma transporter or by large tectonic reconstruction of the earth surface. At the ocean floor near the mid-ocean ridge spreading center, where the deep seated rock is exposed along spreading axis or fracture zone, abyssal peridotite is collected. The abyssal peridotite studies significantly contribute not only to understanding of the formation of oceanic lithosphere but also to development of analytical way for the mantle material. In mineralogical and geochemical approaches, chromian spinel is a good indicator for the origin; for example, the spinel Cr# reflects a partial melting degree of the upper mantle material (e.g., Dick and Bullen, 1984; Arai, 1987). Trace-element compositions of clinopyroxene allow us to discuss the melting process quantitatively (e.g., Johnson et al., 1990). Recently, further discussions can be available by using ultra-trace elements and PGE isotopes (e.g., Harvey et al., 2006; Ishikawa, 2012).

Several petrological studies of abyssal peridotite samples have demonstrated "regional-scale" heterogeneity of the upper mantle along Mid-Atlantic Ridge based on their spinel Cr# (e.g., Dick et al, 1984; Michael and Bonatti, 1985). In "Global-scopic" differences between Atlantic, Indian and Pacific oceans, Niu and Hekinian (1997) proposed that the spinel Cr# of abyssal peridotite is dependent on spreading rate. Contrasting to such a heterogeneity, Ghose et al. (1996) and Dick et al. (2010) showed that the compositional variation of the abyssal peridotite is controlled by local structures at the mid-ocean ridge: for example, spreading axis, fracture zone, abyssal plane and oceanic core complex. Geochemical heterogeneity of each abyssal peridotite sample is recently discussed in aspects of magmatic event during or after partial melting stage (Tamura et al., 2008; Warren and Shimizu, 2010).

In our presentation, to review petrological characteristics of abyssal peridotite, we will demonstrate our compiling data set focused on relationship between their spinel Cr# and sample localities, such as ocean floor structures at the mid-ocean ridge. The example of abyssal peridotite sample heterogeneity are also discussed. Then, we would like to discuss the factor and significance of compositional variation of abyssal peridotite.

Keywords: abyssal peridotite, spinel, ocean floor

SIT41-05 Room:314 Time:April 28 11:15-11:30

Heterogeneity from mantle to crust at the central Southwest Indian Ridge (1) -Upper mantle-

MATSUNO, Tetsuo[1*] ; SEAMA, Nobukazu[2] ; SATO, Hiroshi[3] ; SATO, Taichi[4] ; SENDA, Ryoko[5] ; MACHIDA, Shiki[6] ; NAKAMURA, Kentaro[5] ; MORISHITA, Tomoaki[7] ; MIZUMA, Keiko[2] ; NOGI, Yoshifumi[1] ; OKINO, Kyoko[8]

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Mantle is heterogeneous in terms of geophysical (e.g., bathymetry, geomagnetics, and gravity) and geological (e.g., petrology and geochemistry) aspects. Because heterogeneity is enhanced at slow spreading ridge, the ultra-slow spreading Southwest Indian Ridge (SWIR) is suitable for understanding the heterogeneity. We conducted geophysical and geological investigations since 2007 at the segment along the central SWIR between 35^{o}E and 40^{o}E, where the ridge segment is close to the Marion hotspot.

Serpentinised mantle peridotites occurring as clasts in the conglomerate were dredged from a topographic high within the Prince Edward fracture zone at 35^{o}E. A marine electromagnetic experiment was conducted along a 110 km transect across a subsegment at 37^{o}E to reveal an electrical resistivity structure of the upper mantle.

The peditotites are considered to have originally been lherzolite based on petrographic and mineral chemical composition analyses. Chemical compositions of spinel (Cr# and Mg#) in the peridotites suggest that the peridotites have undergone moderate partial melting without enhancement of melting by the hotspot regardless of proximity of the dredge site to the Marion hotspot. Light rare earth elements of clinopyroxene are more depleted than were previously reported for SWIR peridotites, suggesting that the peridotites have undergone little to no metasomatism of a melt-mantle interaction. Osmium isotope ratios are highly depleted, resulting in that a model age of rhenium depletion (T$_{RD}$) is 1 billion years. These results suggest that the dredged peridotites have not been enriched after the last melt extraction event 1 billion years ago, preserve their initial depleted compositions without hotspot effects, and show the presence of a refractory mantle domain under the central SWIR.

A preliminary 2-D electrical resistivity structure of the upper mantle down to 200 km depth does not show a remarkable conductive melting region beneath the ridge axis and a more conductive asthenospheric mantle than those observed at other mid-ocean ridges. The resistivity model suggests that the presence of the Marion hotspot does not result in enhancement of melt production beneath the ridge and enrichment of conductors like water in the upper mantle at present.

The result of this study suggests that the source mantle contain ancient, refractory, and depleted portion. This mantle may be a part of the depleted mantle prevailed under the Marion Rise, which was proposed by Zhou and Dick (2013) and may be supported by the absence of slow velocity anomalies around the Marion hotspot in upper mantle seismic tomography images (e.g., Zhao, 2007).

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT41-06 Room:314 Time:April 28 11:30-11:45

Heterogeneity from mantle to crust at the central Southwest Indian Ridge (2) -Crust-

SATO, Hiroshi[1*] ; SATO, Taichi[2] ; MACHIDA, Shiki[3] ; SENDA, Ryoko[4] ; MATSUNO, Tetsuo[8] ; SEAMA, Nobukazu[5] ; NAKAMURA, Kentaro[6] ; MORISHITA, Tomoaki[7] ; NOGI, Yoshifumi[8] ; OKINO, Kyoko[9]

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Mantle is heterogeneous in terms of geophysical (e.g., bathymetry, geomagnetics, and gravity) and geological (e.g., petrology and geochemistry) aspects. Because heterogeneity is enhanced at slow spreading ridge, the ultra-slow spreading Southwest Indian ridge is suitable for understanding the heterogeneity. We conducted geophysical and geological investigations since 2007 at the segment along the central Southwest Indian Ridge (SWIR) between 35E and 40E, where the ridge segment is close to the Marion hotspot.

Recent investigations of topography and geophysics along the central Southwest Indian ridge between 35E and 40E (Sato, T. et al., 2013) classify the segment between the Prince Edward and Eric Simpson fracture zones as four subsegments: PE-1, PE-2, PE-3, and PE-4 from west to east. A long oblique axial valley (NTD-1) is recognized between PE-1 and PE-2. Geochemical and isotopic compositions of MORB samples from these subsegments consist with previously reported MORB and/or SWIR basalts. However, small scale geochemical and isotopic heterogeneity are recognized in these samples. Sato, T. et al. (2013) considered that strong melt-focusing could be principle process to produce volcanic and low volcanic subsegment rather than the effect of proximity to the Marion hotspot. Continuous seafloor morphology and isochrons over off-axis areas of segment PE-1 and NTD-1 suggest that PE-1 shortened after the C2An chron, indicating the magmatic process has changed for several million years.

Among MORB from the subsegments, PE-1 and NTD-1, geochemically enriched sample (e.g. those with La/Sm>1) are enriched in isotope (higher Sr and lower Nd), suggesting that enrichment is due to source enrichment rather than smaller degree of melting of the homogeneous source mantle. Although geochemical and isotopic compositions could be explained by the mixture of depleted MORB source and the Marion components, contribution of the Marion component is limited only in the eastern part of PE-1 and NTD-1 subsegments. Therefore, it is reasonable to consider that source mantle beneath eastern part of PE-1 segment contains the enriched Marion components rather than direct contribution from Marion hotspot. Degree of enrichment (i.e. amount of enriched component) is higher beneath the present eastern part of PE-1 subsegment.

Sato, T. et al. (2013) pointed out that the melt supply center (tip of V-shaped bathymetric structure) between segment PE-1 and NTD-1 has migrated westward. It means that the enriched portion in the source mantle beneath PE-1 and NTD-1 subsegments has migrated westward. Melting of enriched, probably preferentially melting, components induced the strong melt-focusing process to form the V-shape bathymetric structure between PE-1 and NTD-1. This constraints the spatial scale and type of enriched component in depleted mantle.

References

Sato, T., K. Okino, H. Sato, M. Mizuno, T. Hanyu, and N. Seama (2013), Magmatic activities on the Southwest Indian Ridge between 35E and 40E, the closest segment to the Marion hotspot, Geochem. Geophys. Geosyst., 14, 5286?5307, doi:10.1002/2013GC004814.

Keywords: heterogeneity, mantle, crust, MORB, Southwest Indian Ridge

SIT41-07 Room:314 Time:April 28 11:45-12:00

Origin of Magnetization High at the Yokoniwa Hydrothermal Vent Fields, the Central Indian Ridge

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Measurement of near bottom magnetic anomalies is an effective method to reveal the spatial extent of hydrothermal alteration zone and to find buried hydrothermal vent fields because hydrothermal alteration processes can change crustal magnetization by destruction and creation of magnetic minerals. In the Yokoniwa vent field (YVF), which is located at the top of the non-transform offset massif, called the Yokoniwa Rise, in the southernmost part of the Central Indian Ridge, a high magnetization zone was discovered by AUV r2D4 in 2009. Basalts and ultramafic rocks were found around the YVF, however the origin of positive magnetization and the relationships between high magnetization and hydrothermal activity are remains to be investigated.

In order to constrain the origin of magnetic source near the YVF, we conducted deep-sea geological observation and magnetic measurements using submersible Shinkai 6500 during the R/V Yokosuka cruises, YK09-13 and YK13-03. Vector geomagnetic field were successfully obtained along the all dive tracks at an altitude of ~10 m. The distribution of crustal magnetization is estimated by vertical and horizontal components of magnetic anomalies using the 2-dimesional forward modeling technique and frequency analysis.

In the southern slope of the Yokoniwa Rise, serpentinized-peridotites were discovered and absolute magnetization shows entirely low (~6 A/m). On the other hand, just around the YVF, hydrothermal sulfide deposits, tiny dead chimneys, shimmering and talc were observed and absolute magnetization shows relatively high (9 A/m). This magnetization contrast between the YVF and the surrounding area may be attributed to the difference in amount of magnetite, controlled by the degree and the temperature of serpentinization. One of the serpentinized-peridotite recovered during the cruises showed large amount of magnetite and high natural remanent magnetization. However, the highest absolute magnetization (20 A/m) was discovered at pillow basalt area with thin sediment just ~700 m away from the YVF, implying recent off-axis volcanic activity. Therefore basaltic intrusion beneath the YVF is also possible for the origin of high magnetization. In addition, magnetic iron sulfide (pyrrhotite) grown during hydrothermal circulation, which is proposed at the Rainbow hydrothermal vent field, is also possible.

Consequently, we proposed three possibilities for the origin of high magnetization at the YVF; serpentinized peridotites with high temperature hydrothermal alteration, basaltic intrusion bodies, and pyrrhotites concentration. All of these hypotheses are related to hydrothermal activity. For the further inspection, recovering subseafloor rocks and inspection of rock magnetic properties are absolutely necessary.

Keywords: Seafloor hydrothermal activity, Mid-ocean ridge, Ultramafic rock, Deepsea magnetic anomaly, Off-axis volcanism, Oceani lithosphere

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT41-08 Room:314 Time:April 28 12:00-12:15

Three-dimensional seismic structure of the Rainbow area, Mid-Atlantic Ridge 36 degree N

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Oceanic lithosphere formed along slow-spreading mid-ocean ridges is structurally and compositionally heterogeneous due to spatial and temporal variations in tectonic extension, magmatic accretion, and mantle temperature and composition. While mid-ocean ridges with greater magma supply host a greater abundance of hydrothermal systems, the relative roles of magmatic input, heat advection and faulting in controlling ridge structures are still poorly understood. These are particularly important to understanding formation and evolution of oceanic core complexes where ultramafic-hosted lithologies are exhumed at the seafloor by long-lived detachment faulting. The MARINER (Mid-Atlantic Ridge INtegrated Experiments at Rainbow) seismic and geophysical mapping experiment was designed to examine the relationship between tectonic rifting, heat/melt supply, and oceanic core complex formation at a non-transform offset of the Mid-Atlantic Ridge, 36 º 14 ' N, the site of the ultramafic-hosted Rainbow hydrothermal system. Using the seismic refraction data from this experiment, we constructed three-dimensional tomographic images of the crust and upper mantle around the Rainbow area. The seismic velocity images reveal undulations in crustal thickness across the ultramafic Rainbow massif, indicating temporal variations in melt supply, magmatic processes, and crustal construction. Previous studies suggest that a current heat source for the vents, which probably arises from a magmatic body, is required just beneath the hydrothermal vent, but the tomography does not detect a low-velocity anomaly indicating a significant magmatic system or high-temperature region beneath the Rainbow vent site. The only candidate region for high-temperatures and perhaps melt at shallow levels is much further to the south, and located roughly beneath the central valley of the spreading center. At the Rainbow massif, where mantle rocks have been recovered by direct sampling, mantle velocities near the seafloor are significantly reduced to ~ 5 km/s. This velocity reduction implies that an active hydrothermal circulation system altered the mantle via recharge and discharge of seawater.

Keywords: Slow-spreading ridge, Oceanic core complex, Rainbow hydrothermal field, Mantle alteration, Hydrothermal circulation, Seismic tomography

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT41-09 Room:314 Time:April 28 12:15-12:45

Thermal structure of old oceanic upper mantle: Constraints from electrical conductivity imaging in the NW Pacific

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Northwestern part of Pacific plate is very old as the crustal age is over 100 Ma. Seafloor subsidence and heat flow change with age for such old ocean have been explained by cooling of a plate with constant thickness (e.g., Parsons & Sclater, 1977; Stein & Stein, 1992). Electrical conductivity of the upper oceanic mantle typically has resistive layer over a conductive zone reflecting the thermal structure. However, our recent results on the electrical conductivity of the upper mantle beneath northwestern Pacific suggest that a simple plate cooling model can not explain the observations.

We have run marine electromagnetic observation in two areas (Areas A and B) of the northwestern Pacific since 2010. Areas A and B locate northwest and southeast of Shatsky Rise, respectively. Although a part of the observation is still going on, we analyzed the data collected by the last year to obtain magnetotelluric responses and one-dimensional (1-D) electrical conductivity structure beneath the observation areas. Here, we compare the results together with a model obtained for the mantle beneath the Pacific ocean off the Bonin Trench (Area C) by a past project. The mean lithospheric ages of Area A, B, and C are about 130, 140, and 147 Ma, respectively. Based on a plate cooling model, the age differences for the thermal structure among the areas are very small. However, the obtained electrical conductivity models show significant difference in the thickness of the resistive layer. The depth the mantle become more conductive than 0.01 S/m are about 80 km for Area A, about 110 km for Area B, and about 200 km for Area C. These differences can not be reconstructed from the age difference of a single plate cooling model.

Our observations revealed that there is large scale lateral heterogeneity in electrical conductivity. We need to consider another factors rather than age difference of the thermal structure to explain such the lateral heterogeneity.

Keywords: oceanic upper mantle, northwestern Pacific, magnetotellurics, electrical conductivity structure, thermal structure

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT41-10 Room:314 Time:April 28 14:15-14:30

PGE abundances and Os isotope ratios of troctolites from pacific oceanic lithosphere

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The structure of oceanic lithosphere becomes much clear in these days. Troctolite is a kind of gabbro, mainly consisting of olivine and calcic plagioclase with minor pyroxene, found in oceanic lithosphere. Melt-rock interactions at mantle-crust transition zone are believed to play a main role for troctolite formation. Troctolites are locally found at Atlantis Massif oceanic core complex, Mid Atlantic Ridge 30 iii N (Blackman et al., 2006), at Kane Megamullion, Mid Atlantic Ridge 23N (Dick et al., 2008; 2010), at Uraniwa Hills, Central Indidan Ridge (Nakamura et al., 2009), and at Godzilla Megamullion, Parece Vela Basin of the Philippine Sea (Sanfilippo et al., 2013). They also occurred as sections of the oceanic lithosphere in ophiolites and show similarity to lower crust sections from slow and ultra-slow spreading ridges (e.g., Herbert et al., 1989; Sanfilippo and Tribuzio, 2013). The formation process of the troctolites is in debate. From the ophiolite studies, troctolites were formed as cumulates from primitive basalts in a closed system (Bezzi and Piccardo, 1970; 1971; Borghini and Rampone, 2007). Alternatively, troctolites were the results of a substantial amount of mantle olivine incorporated into the lower oceanic crust (Suhr et al., 2008; Drouin et al., 2009; 2010) based on the studies of oceanic core complex.

Troctolites were also found in the drilled core at site 895 of ODP Leg 147 in Hess Deep, located at a triple junction between EPR and Cocos-Nazca plate boundary. Hess Deep is a small rift with intra-rift ridges, where deep-seated rocks probably formed at EPR are exposed (Francheteau et al., 1990; 1992). Ultramafic and related rocks were expected to be found at the site in fast-spreading ridge system and sequences of dunite, harzburgite, troctolite, and gabbro were actually drilled (Allan and Dick, 1996; Dick and Natland, 1996; Arai and Matsukage, 1996). Troctolite appears to be transitional from dunite to olivine gabbro (Arai and Matsukage, 1998).

Major, trace and platinum group element (PGE) abundances and Os isotope ratios of troctolites from Holes 895C, 895D and 895E were newly measured using XRF, ICP-MS, and TIMS. The samples are clearly divided in two groups by Al_2O_3, MgO and NiO. Prichard et al. (1996) reported the PGE and trace element abundances of the ultramafic rocks from Holes 895. Their PGE concentrations of the troctolites were in a similar range to hartzburgites and dunites from the same sites and Pt and Pd are enriched in some troctolites. They also found platinum-group alloys and base metals in troctolites. New data set with Os isotope ratios possibly make constraints on the forming process of troctolites under the oceanic ridge.

Keywords: troctolite, Os isotope ratio, PGE abundance, oceanic lithosphere

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT41-11 Room:314 Time:April 28 14:30-14:45

The origin for the olivine-rich troctolites from the oceanic lithosphere: remnants of a reactive MOHO

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Olivine-rich troctolites are documented since the early 1970s in the lower crust and mantle sections of the Jurassic oceanic lithosphere exposed along the Alpine-Apennine belt (Italy). These rocks were first interpreted to be cumulates formed by precipitation of olivine and accessory spinel from primitive basalts (Bezzi A. and Piccardo G.B., 1971. Mem. Soc. Geol. It.). The founding of olivine-rich troctolites bodies within the gabbroic sections of the Hess Deep (East Pacific Rise) and Atlantis Massif and Kane Megamullion (Mid Atlantic Ridge) called into question this idea, suggesting that they may represent portion of the crust-mantle transition entrapped during the growth of the lower crust (Arai and Matsukage, 1996, Lithos; Suhr et al., 2008, G-cubed). Recently, Japanese scientific cruises found olivine-rich troctolites associated with mantle harzburgites at the Godzilla Megamullion (Philippine Sea) [3] and at the Uraniwa Hills (Central Indian Ridge) (Nakamura et al., 2009, EPSL; Sanfilippo et al., 2013, J. Petrol.). We show that the olivine-rich troctolites from all these occurrences show peculiar structural and compositional features: i) highly variable forsterite, Ni and Co contents of olivine; ii) high Mg/(Mg+Fe), high Cr_2O_3 contents, and fractionated incompatible element compositions (i.e. Ti/REE and Zr/REE) of clinopyroxene; iii) the occurrence hydrous silicate mineral inclusions in spinels anomalously enriched in TiO_2. These features agree with the idea that olivine-rich troctolites formed through reactions between a pre-existing olivine-matrix and migrating melts [see also Renna and Tribuzio, 2011, J. Petrol.). In particular, we suggest that these chemical features were acquired at the crust-mantle transition, through interactions between mantle peridotites and melt stagnating at the base of the igneous crust. The occurrence of olivine-rich troctolites both at slow- to intermediate spreading ridges and at back-arc settings suggests that melt-peridotites reaction processes constrain the Moho under the totality of the oceanic plates.

Keywords: Ocean floor, Peridotite, Troctolite, Melt-Mantle reaction, Moho

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SIT41-12 Room:314 Time:April 28 14:45-15:15

Experimental study of anelasticity of a polycrystalline material for seismological application

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Rock anelasticity causes dispersion and attenuation of seismic waves. Therefore, for the quantitative interpretation of seismic low velocity and/or low Q regions in the upper mantle, understanding of rock anelasticity is necessary. However, due to the difficulty of forced-oscillation experiment under high-temperature ($>1000^oC$) and small strain (<10ˆ-6) conditions, systematic data on rock anaelasticity, needed for the understanding of underlying mechanisms, have not been obtained adequately. To address this lack of data, data from rock analogue (polycrystalline organic borneol) will be of merit. Our recent result published in McCarthy et al (2001) has shown that anelasticity of polycrystalline materials is subject to the Maxwell frequency scaling: Q = Q(f/fm). However, the applicability of this scaling to the seismic dispersion and attenuation has not been guaranteed because experimentally testing frequencies normalized to the Maxwell frequency fm of the laboratory samples are usually much lower than the seismic range in the upper mantle ($10^6 <$f/fm $<10^9$). In this study, by using borneol as an analogue to mantle rock, we measured anelasticity up to higher normalized frequencies (0.1 <f/fm $<10^8$), and examined the applicability of the Maxwell frequency scaling to these new data. The obtained data show that the Maxwell frequency scaling is no more applicable to higher normalized frequencies than f/fm = 10^4, where attenuation spectra plotted as functions of f/fm scatter significantly by temperature, grain size, and impurity. Especially, a small amount of impurity (diphenylamine) significantly enhanced the anelastic relaxation. The addition of dyphenylamine to borneol significantly lowers the melting temperature from Tm=477 K to Tm=316 K. From these results, we have speculated that the enhancement of anelasticity with impurity and/or temperature might be scaled by T/Tm. If this speculation is true and can be generalized to the other polycrystalline materials, it will give a crucial insight for the underlying mechanism. Because T/Tm is close to one in the upper mantle and it is important to investigate the detailed behavior of anelasticity near T/Tm=1.

Keywords: anelasticity, polycrystalline material

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SIT41-13 Room:314 Time:April 28 15:15-15:30

Seismic structural changes in the incoming oceanic plate beneath the well-developed horst and grabens

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Recent seismic, electromagnetic, and thermal structure studies in the trench-outer rise region have revealed the structural changes of the incoming plate in the trench-outer rise region. These structural changes are considered to be caused by the plate bending-related faulting and water penetration. However, there are many unresolved questions such as the maximum depth of the structural changes, the mechanisms of the water penetration, and the source of the water.

The northwestern Pacific margin, where extremely old (more than 120Ma) oceanic plate is subducting, is a good place to study structural changes in the incoming plate prior to subduction, because the horst and graben structure, which is caused by the bending-related faulting, is well developed in this region. However, the former seismic survey could not revealed the seismic structure around the trench axis, where seismic structure is expected to be significantly changed, because of the large water depth in the vicinity of the trench axis.

In 2013, we conducted extensive wide-angle seismic reflection and refraction surveys across the Japan trench with use of ultra-deep Ocean Bottom Seismometers (OBSs). Our obtained data enabled us to reveal the seismic structure in the vicinity of the trench axis, and we confirmed that the bending-related structural changes reach to the top of the oceanic crust. In addition, in the record sections obtained at the deep grabens, we observed seismic waves that laterally propagate within the sedimentary layer as well as the phases vertically propagate within the sedimentary layer. These two phases provided us new insights to the sedimentary structure, which implies that the bottom of the sedimentary layer can be the water source to the oceanic crust in the trench-outer rise region.

Keywords: oceanic plate, trench-outer rise region, bending-related faults, seismic structure, water contents, ocean bottom seismometer

SIT41-14 Room:314 Time:April 28 15:30-15:45

Mafic minerals within a sediment core sampled by ABISMO in Mariana Trench

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Mariana Trench is one of the deepest oceans in the world more than 10,000 m depth. Although the mantle section outcrops along the land-side slope of the southern Mariana Trench, the studied depth so far is approximately shallower than 7,000 m and therefore few geological information is available for the mantle section deeper than 7,000 m. In 2008, a sediment core has been sampled at 10,350 m in Challenger Deep of Mariana Trench by ABISMO (Automatic Bottom Inspection and Sediment Mobile) during KR08-05 cruise. The sediment core is 161.5 cm in length and contains mafic sandy grains such as olivine and spinel. In this study, we sampled the mafic minerals from the sediment core and analyzed their major element compositions. As a result, the chemical compositions of the mafic sandy grains were compatible with those of mafic minerals within the peridotites along the land-side slope of Mariana Trench shallower than 7,000 m. We will discuss the origin of these sandy grains.

Keywords: ABISMO, Mariana Trench, Challenger Deep, sediment core, spinel, olivine

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SIT41-15 Room:314 Time:April 28 15:45-16:00

High Ni and Mg olivine as a time recorder of chromitite P-T history

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High Ni and Mg olivines were found in dunites enveloping podiform chromitites from Oman, Ray-Iz and Luobusa ophiolites. These high Ni and Mg olivines occur only in dunite adjacent to chromitite. This characteristic suggests subsolidus Ni and Mg diffusion from the chromites of the chromitite. In the case of dunite enveloping concordant chromitite from Oman ophiolite, olivines show high NiO (up to 0.5 wt %) and Fo (around 92 mol %) contents. This is not the case, however, for the dunite envelope around the discordant chromitite in the Oman ophiolite. On the other hand, olivines in dunite enveloping UHP chromitites from Ray-Iz and Luobusa ophiolites are extraordinarily high in Fo value (94 - 96) and NiO (around 0.5 wt %). Silicate exsolution lamellae in spinel from UHP chromitites and concordant chromitite suggest that these chromitites have experienced substantial cooling, and probably decompression, for a longer priod than the discordant chromitite from Oman. According to the well-known Ni and Mg diffusion coefficients in olivine, the high-Ni and -Mg olivine in the dunite envelope may constrain the cooling duration of the chromitite and the history of ophiolite. Podiform chromitites are enigmatic in origin, and their origins should be systematically classified to understand concerning mantle processes. Their temporal relationship is a clue to solve this problem.

Keywords: Olivine, Ni and Mg diffusion, Podiform chromitite, Low pressure chromitite, Ultra-high pressure chromitite, P-T history

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SIT41-16 Room:314 Time:April 28 16:15-16:30

Geochemistry and genetic conditions of primary boninites from the Ogasawara Island Group and Oman ophiolite

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Subduction initiation and arc crust evolution along oceanic plate boundaries are fundamental processes that modify oceanic lithosphere and promotes the material evolution of the Earth. How subduction of oceanic plates initiates and develops largely depend on the thermochemical structure and mechanical strength of the colliding two plates. The resulting conditions of the wedge mantle can be best represented by the varying geochemistry of primary magmas produced through the subduction initiation. For example, the subduction zone in the Izu-Bonin (Ogasawara)-Mariana (IBM) arc started with an intense high-Si to low-Si boninite magmatism during 48-45 Ma (Ishizuka et al., 2006; Kanayama et al., 2012). By contrast, the subduction stage of the Oman Ophiolite lacked typical boninite and is characterized by the low-Si boninite magmatism (Ishikawa et al., 2002; Kusano et al., 2014). Because of its high Mg#s and andesitic chemistry, boninite is generally considered to be a candidate of a primary magma derived from the hydrous upper mantle, and therefore, its compositional variations reflect various thermochemical conditions of the source mantle. The geochemical and petrological studies on boninite magma genesis can provide crucial information on the evolution of arc and the formation of continental crust. Boninites are distinct from ordinary arc magmas in highly depleted U-shaped and depleted spoon-shaped chondrite-normalized rare earth elements (REE) patterns.

We have investigated melt (glass) inclusions enclosed by boninite-derived chrome spinel grains in beach sand, called " uguisu-zuna " from Ogasawara islands, and in wadi sand from the Oman Ophiolite. We analyzed major- and trace-element compositions of the boninitic melt inclusions by EPMA and LA-ICP-MS (Kanazawa Univ.) and H2O by SIMS (Hokkaido Univ. Creative Research Institution). Glass inclusions in spinel have more Mg-rich compositions than aphyric whole rocks, indicating their primitive nature since derivation from the source mantle, which experienced least modification by the processes such as crystal fractionation, and assimilation and contamination by the crust. Volatile measurements of melt inclusions confirmed that they were only slightly degassed and retain primitive contents. Five geochemical types (BIC-1~5) are identified among boninites from the Ogasawara Islands and a single geochemical type from the Oman Ophiolite. Both Ogasawara and Oman low-Si boninites show lower H2O contents than high-Si boninites. Assuming that the most magnesium-rich melts of each geochemical type in Ogasawara and Oman boninites coexisted with olivine and orthopyroxene, the P-T conditions of these primary boninite magmas were estimated by using the geothermobarometers of Putirka et al. (2007) and Putirka (2008). High-Si boninites erupted on the Ogasawara Islands during 48-46 Ma were generated at 1400-1440 ℃ and 0.7-0.9 GPa, whereas the subsequent low-Si boninite at 45 Ma formed at 1380-1400 ℃ and 0.8-0.95 GPa. This suggest that the geothermal gradient descended from 48 Ma to 45 Ma. On the other hand, low-Si boninite from the Oman Ophiolite was generated at 1320 ℃ and 0.5 GPa. Hence, it is apparent that the wedge mantle beneath the proto-IBM arc was significantly hotter than that in the Oman paleoarc.

Keywords: subduction initiation, IBM forearc, Oman Ophiolite, high-Si boninite, low-Si boninite, melt inclusion

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SIT41-17 Room:314 Time:April 28 16:30-16:45

Thermo-chemical evolution of mantle wedge during the incipient stage of the Izu-Ogasawara-Mariana subduction zone

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It is essential to understand the processes of subduction zone initiation and evolution of oceanic arcs which promote the development of Earth's structure and composition. We present the genetic conditions of the Eocene magmas from the Ogasawara (Bonin) Ridge and discuss the thermo-chemical structure of the mantle wedge beneath the Ogasawara region during the incipient stages of the IBM arc. On the Ogasawara Ridge, MORB-like basalt (forearc basalt: FAB) is generated just after the beginning of subduction of the Pacific Plate at 52 Ma, followed by ultra-depleted high-Si boninite activities began at 48Ma. This high-Si boninite magmatism gradually changed through less-depleted low-Si boninite at 45 Ma to arc tholeiite and calc-alkaline magmatism [1, 2].

Major element compositions of high- and low-Si boninites are similar to those of experimentally produced melts of harzburgite [3] and lherzolite [e.g. 4], respectively. Ultra low concentrations in rare earth elements (Yb$>$0.3 ppm) of high-Si boninite also indicate a depleted harzburgite source. On the other hand, characteristically high Zr/Ti ratio ($<$0.04) of boninites from the Ogasawara Islands reflects high contributions of slab melt [2]. FAB is produced by less than 10 % fractional melting of MORB source mantle, leaving residue of moderately depleted lherzolite. This suggests that the residue of FAB cannot be the highly depleted source of high-Si boninite.

P-T conditions at which the most primitive boninitic melts can coexist with harzburgite are 1430 ℃ and 0.83-0.96 GPa for high-Si boninite (MgO=23, H_2O=3.2 wt%) and 1380 ℃ and 0.86 GPa for low-Si boninite (MgO=19, H_2O=2.6 wt%) [5]. Genetic conditions of magmas other than boninite are dry, ˜1350 ℃ and 1.3-1.7 GPa for FAB and water-undersaturated (0-0.5 wt%), 1300-1350 ℃ and 1-1.2 GPa for arc tholeiitic and calc-alkaline magmas, which were estimated by comparing calculated primitive liquid compositions with experimentally produced liquid compositions of lherzolite melting [e.g.4].

Mantle potential temperatures (T_p) calculated based on MgO content of primary magmas are 1500 ℃ for high-Si boninite and 1450 ℃ for low-Si boninite, which are higher than the ambient mantle (T_p=1300-1400). Especially Tp for high-Si boninite is comparable to T_ps of mantle plumes [6]. This result is consistent with plume-related magmatism (51-45Ma) in the West Philippine Basin simultaneously with the high-Si boninite magmatism in the Ogasawara Ridge [7]. The ultra-depleted source of high-Si boninite is possibly the residue of the plume-related magmatism. T_p of FAB and arc tholeiitic and calc-alkaline magmas is 1400 ℃, equivalent to the ordinary oceanic mantle.

From the above, the thermo-chemical history of the mantle wedge beneath the Ogasawara Ridge during the incipient stage of the IBM subduction zone is advocated as follows; Spontaneous sinking of old, dense Pacific Plate induced upwelling of asthenosphere which melted to produce FAB in eastern margin of the Philippine Sea Plate at 52 Ma. At 48 Ma, depleted residual harzburgite of plume-related magmatism upwelled from deeper (˜3.5 GPa ?) asthenosphere to 1 GPa, suffering flux melting incorporating slab melt to generate the high-Si boninite magma. By 45 Ma, shallow mantle wedge was cooled by the subducted slab and asthenosphere began circulating in the wedge. As a result, magma composition changed from high-Si boninite through low-Si boninite to arc tholeiite and calc-alkaline magmas more fertile than the Quaternary frontal lava. Subsequently the IBM subduction zone changed to a stable arc-trench system.

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Keywords: Ogasawara (Bonin) Islands, boninite, mantle wedge, IBM arc, mantle potential tempareture, subduction zone

SIT41-18 Room:314 Time:April 28 16:45-17:00

Hot and ephemeral subduction zone magmatisms in the Oman Ophiolite

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Subduction zone is initiated by descending oceanic plate at the plate boundary and a counter flow of the mantle advances growth of the wedge mantle in the Izu-Ogasawara-Mariana arc (e.g. Stern, 2004). But it is questioned that do initial arc always develop a long-survived subduction zone? We present detailed volcanostratigraphy, petrology and geochemistry of short-lived juvenile arc tholeiite and subsequent boninite magmatism from the northern Oman ophiolite.

The Oman ophiolite belonging to the Tethys ophiolite belt is one of the best places to investigate magmatic and volcanic developing processes of an infant arc. The Ophiolite had formed on a spreading axis and followed by subduction stage magmatism at approximately 100 Ma. The V2 sequence was constructed by initial arc magmatism begun $<$2 m.y. after the spreading ridge stage (e.g. Hacker et al., 1996). Based on the radiolarian fossil age, the V2 volcanism ceased 2-3 m.y. after the ridge stage (Kurihara and Hara, 2012), therefore, it seems to record short-spanned island arc magmatism.

An 1110 m thick V2 sequence is divided into the lower 970 m (LV2) and upper 140 m (UV2) thick subsequences by a 1.0 m thick sedimentary layer in Wadi Bidi. Pahoehoe flows dominate in the lower part of the LV2, while the upper part consists mainly of sheet flows with intervened few pelagic sediments, a fissure vent and a cylindrical plug. In addition to the presence of feeder conduits, the flow-dominant lithofacies with a few thin sedimentary interbeds in the LV2 indicates that the study area was the center of a monogenetic volcano grown in a short period. The LV2 consist of arc tholeiite with orthopyroxene phenocrysts increasing in amount upward. The UV2 is composed of sheet flows overlain by a 2.0 m thick subaqueous pyroclastic fall deposit. They are boninite containing olivine and two-pyroxene phenocrysts with plagioclase in the groundmass. Successive orthopyroxene-bearing arc tholeiitic volcanism in the LV2 followed by a relatively small amount of boninite lavas in the UV2 overlain by thick pelagic sediments suggests that the infant arc volcanism was short lived and terminated long before the ophiolite obduction.

Keywords: High-T subduction zone, Initial arc magmatism, Boninite, Oman Ophiolite

SIT41-19 Room:314 Time:April 28 17:00-17:15

Fate of high-T subduction zone and the obduction of the Oman Ophiolite

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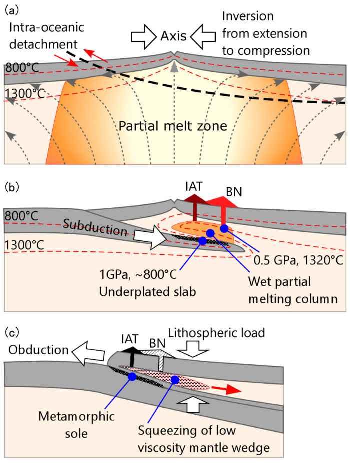
Obduction of ophiolitic bodies onto continental crust inevitably follows a tectonic event of conversion from divergence to convergence of plates. This is commonly accomplished by the formation of intraoceanic subduction zone near the ridge axis, where lithospheric lid is thinnest and weakest, and accompanies the boninite volcanism [3]. The upper part of the subducted slab is metamorphosed and later thrust over onto a continent with the overlying mantle to become ″ the metamorphic sole ″ . Known examples of metamorphic soles record peak T-P of 600˜840 ℃ and ˜1 GPa, whereas the thickness of overlying ophiolite sheets are only 10-20 km, yielding too small lithospheric load compared to the metamorphic pressure of the sole [4]. This discrepancy has been explained that the ophiolite sheet and the metamorphic sole formed at discrete places were emplaced and superposed at the same place during the obduction process [3].

However, we have demonstrated by examining the trace element geochemistry of the arc magmas and metamorphic sole of the Oman Ophiolite that fluid liberated from the metamorphic sole triggered flux melting of the overlying depleted mantle peridotite and produced arc tholeiitic basalt magma first, and subsequently low-Si boninite magma. Therefore, the ophiolite and the underlying metamorphic sole did not form independently at distant places, but were formed and transported together as an intact body with the present structural relationship. Genetic conditions estimated for a primitive boninite melt with 16 wt% MgO enclosed by Cr spinel indicate the segregation pressure of 0.5 GPa and 1320 ℃ from the mantle with the potential T of 1400 ℃ [1, Kusano et al., this session]. Thus, the boninite magma should have segregated from the mantle at a depth $>$17 km. Nevertheless, the present ophiolite body has the maximum thickness $<$15 km.

The above lines of evidence urged us to propose the following model; Conversion from spreading to closure of the Tethys resulted in the subduction of young and hot oceanic lithosphere beneath the Tethyan ridge axis. The oceanic crust of the subducted slab was metamorphosed to cpx-bearing amphibolite at a depth of ˜35 km and 800 ℃. Trace elements and Nd-isotopic evidence indicate fluids and partial melt of subducted sediments liberated from the dehydrated slab migrated upward and formed a partially melted column in the wedge mantle [6, 7]. Primary boninite magmas segregated from the residual harzburgite on the top of the melting column at a depth of ˜17 km and at 1320 ℃ and ascended to form dunite channels and depleted zones through the uppermost lithospheric mantle [8]. Because serpentine and chlorite are unstable $>$800 ℃, the subducted crustal rocks are metamorphosed to amphibolite and the overlying mantle peridotite becomes amphibolite-bearing lherzolite. The lack of mineral phases which could act as lubricant caused large friction and eventual cohesion of the metamorphic slab and hanging wall of the mantle peridotite. Because of the large mechanical strength of the upper crustal and the lower mantle section of the slab, the lower slab of lithospheric mantle are decoupled from the crustal upper slab and continued to subduct without dehydration because the lower slab was virtually anhydrous. This terminated the Oman arc volcanism in a few million years with the production of boninite magma. The strongly coupled upper slab with the overlying wedge mantle obducted together onto the Arabian Peninsula as the metamorphic sole. During the course of thrusting toward the continent, the hot and partially molten asthenospheric mantle in the wedge was squeezed and flattened by the load of the overlying lithosphere, resulted in the present structure of the thin ($<$15 km) ophiolite sheets underlain by the metamorphic sole formed at a high pressure ˜1 GPa.

Keywords: Oman Ophiolite, boninite, high-T subduction zone, metamorphic sole, subduction initiation, obduction

SIT41-19 Room:314 Time:April 28 17:00-17:15



Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT41-20 Room:314 Time:April 28 17:15-17:30

Magmatic diversity of the ultramafic rock in the oceanic crustal sequence, Oman ophiolite

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Although all the wehrlitic intrusions in the Oman Ophiolite are regarded as a single group (e.g. Koepke et al. 2009), there are two different types of wehrlitic intrusions. The first are ordinary wehrlitic intrusions that have similar features to the crustal sequence of V1 (MOR basalt). The second are a depleted type characterized by the appearance of true wehrlite and depleted mineral compositions (Adachi & Miyashita 2003; Yamasaki et al. 2006; Goodenough et al. 2010). The former and latter groups are linked to V1 and V2 magmatism, respectively.

We report the discovery of a new occurrence of the ultramafic rock in the oceanic crustal sequence from the Oman ophiolite, which does not intrude into the crustal sequence. This ultramafic rock is referred to as the Lasail-South complex, and the oldest rock in the study area because of being intruded by sheeted dyke complex. TiO2 and Na2O contents of clinopyroxene from the complex range 0.06-0.59 and 0.09-0.42 wt%, respectively, and are similar to the fractional crystallization trend of oceanic gabbro. Co-variation of Mg values of clinopyroxene and An contents of plagioclase show that most of samples plot in the Oman layered gabbro field. Although mineral compositions of the Lasail-South complex show characteristic of mid-ocean ridge magmatism, the complex mainly comprises plagioclase?hornblende lherzolite, olivine clinopyroxenite and clinopyroxenite. Such rock assemblage of is different from the assemblage of the oceanic crust of the Oman ophiolite. The Lasail-South complex shows intermediate characteristic of mid-ocean ridge and island arc magmatisms, and we attempt to discuss the origin of the complex.

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Keywords: Oman ophiolite, ultramafic rock, mid-ocean ridge magmatism, island arc magmatism

SIT41-21 Room:314 Time:April 28 17:30-17:45

Compositionally and genetically distinct domains found in the southernmost Salahi mantle section in the Oman ophiolite

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We investigate spatial variability in mineral compositions in the southernmost part of the Salahi mantle section and discuss genetic relationship between highly refractory peridotites and less refractory plagioclase-bearing peridotites in this region. The study separates the study area into two domains based on spinel Cr# such as high Cr# domain in the eastern part that is closer to Moho and low Cr# domain in the central part. Concordant dunites commonly occur in the low Cr# domain whereas discordant dunites are common in the high Cr# domain. Plagioclase-bearing peridotites and wehrlite also occur in the low Cr# region.

Highly refractory dunite with spinel Cr# $>$0.7 frequently occurs in the high Cr# domain. In the low Cr# domain, spinel Cr# is low and ranges from 0.47 to 0.57. We analyzed clinopyroxene (cpx) in dunites and harzburgite from both domains for REE abundances by LA-ICP-MS. The results show that harzburgite cpxs in the high Cr# domain and low Cr# domain are highly depleted in LREE ([Ce]CH =0.01~0.02) with [Yb]CH=2~3. Dunite cpxs in the low Cr# domain have REE abundances similar to the harzburgites in the same outcrop whereas those in the high Cr# domain are enriched in LREE relative to the harzburgite cpxs in the same outcrop. This implies that dunite cpxs in the high Cr# domain were reacted with LREE-enriched fluid infiltrated from the base of the ophiolite.

In the low Cr# domain, plagioclase-bearing dunite, plagioclase-bearing lherzolite vein occur and phlogopite-bearing wehrlite discordantly cuts them. The spinel Cr# of these dunites are in a range from 0.46 to 0.56. Abundances of REE in a melt in equilibrium with cpx in plagioclase-bearing peridotites and associated dunites are similar to those of N-MORB. On other hand, a melt in equilibrium with wehrlite cpx resembles to those of boninitic dikes from the Fizh block in the northern Oman ophiolite (Yamazaki, 2013). From the field occurrence, plagioclase-bearing dunite and plagioclase-bearing lherzolite formed by a reaction with MORB melt beneath spreading ridge whereas cumulative wehrlite was crystalized from a boninitic melt.

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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.

SIT41-P03 Room:Poster Time:April 28 18:15-19:30

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.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

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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