

The Ocean Floor was Expanded by Increasing Seawater

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Introduction

I wrote this paper in order to present the negation of a hypothesis which supports the plate tectonics. The hypothesis is 'Spreading Oceanic Floor Hypothesis'. This negation is based upon a new fact that has been revealed recently. I concluded the negation by such facts and my original reasoning. I already presented another fact negating the hypothesis of 'Spreading Oceanic Floor'. The abstract titled 'it was not switching global geo-magnetic fields that created the alternating anomalies over oceanic ridges' was presented at the Japan Geoscience Union Meeting 2013. Therefore, one of reasons that support the hypothesis of spreading oceanic floor was already denied. In this paper I will deny another reason of the hypothesis, which says that the plates of the oceanic floors are spreading.

What is the question

The Hypothesis of Plate tectonics was evolved from Wegener's 'Continental Drift Hypothesis' and based upon 'The Hypothesis of Spreading Oceanic Floor'. However, the hypothesis of spreading oceanic floor is denied as far as it means the spreading plate of oceanic floor. It is denied by the fact that the oceanic floors spread not because the oceanic plates themselves spread but merely because the seawater increased. Therefore, the hypothesis of plate tectonics lost one of its evidences.

The Expanding Oceanic Floor

The hypothesis of plate tectonics is supported by the hypothesis of spreading oceanic floor. The rapidity of the movement of the plate was estimated by the switching pattern of geo-magnetic anomaly near the ridges. The farther and farther it comes from the ridges, the older and older the dates of the basalts and fossils become. The estimated dates fit well the dates estimated from the pattern of geo-magnetic anomalies. It was proved that the rapidity was estimated 2cm per one year for the Pacific Ocean^{[1],[2]}.

Rising Sea Level Caused by Increasing Seawater

However, the hypothesis of spreading oceanic floor neglected the fact that the sea level increased greatly. The sea level increased more than 6000m after the creation of oceanic plates. That fact was revealed by the remaining river valleys on the oceanic floors. For instance the Kushiro River reaches more than 6000m in depth^[Fig1-B]. The Itoi River reaches about 3500m in depth^[Fig1-A].

These facts revealed that the seawater increased greatly after the creation of the oceanic plates. It takes very long time to raise sea level to recent level. Gradually the amount of seawater is increasing even now.

Probably the increase of seawater is caused by crustal movements squeezing water from the rocks of the crust. The squeezed water becomes hot springs.

The date of the fossils near the ridges are newer because those places are higher and newly became under the sea level.

Conclusion

The oceanic floors spread not because the oceanic plates spread but because the seawater increased largely after the creation of the oceanic floor plates.

Therefore, it has no relation between the dates of the oceanic plates and the date of fossils contained in upper layers. Therefore, one of evidences of plate tectonics was lost.

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Keywords: Dating the Ocean Floor, Rise in the Sea Level, Increase of Seawater, Expansion of the Ocean Floor

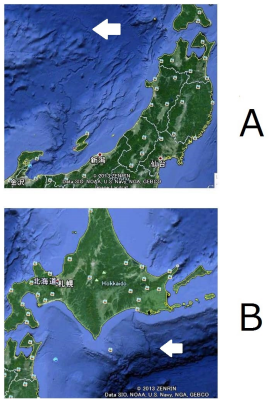


Fig 1

Noble gas evidence of deep plume origin of the Louisville hotspot

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Louisville seamount chain has been considered to be one of the long-lived hotspot tracks on the Pacific plate, but its magmatic source has not been well understood. I report noble gas compositions of the drill cores from four of the five seamounts drilled during IODP Expedition 330. Because the samples are aged (50-74 Ma), a stepwise crushing test for noble gas extraction from olivine phenocrysts and submarine glasses was made to assess contamination of post-eruption radiogenic nuclides. This test confirmed extraction of magmatic noble gases with minimal release of post-eruption radiogenic nuclides from the olivine samples; however, this was not always the case for the glass samples. The $^3\text{He}/^4\text{He}$ ratios in the olivine phenocrysts range from a value similar to those of mid-ocean ridge basalts (MORB) to slightly elevated ratios up to 10.6 Ra. Although these ratios are not as high as those observed in other ocean island basalts, two Louisville seamount basalts exhibit a primordial Ne isotopic signature that can be clearly discriminated from MORB Ne. The He and Ne isotopic compositions of the Louisville seamount basalts can be explained by the mixing of less degassed mantle and depleted upper mantle with different He/Ne ratios. The presence of the less degassed mantle component in the source of the Louisville seamounts documents the deep origin of the mantle plume.

One of the major objectives of the IODP Expedition 330 was to test the geodynamic model that predicts lateral advection of mantle plumes in the convecting mantle [Koppers et al., G-cubed, 2004; Steinberger and Antretter, G-cubed, 2006]. This model assumes a primary mantle plume that is rooted deep in the mantle, and the trajectory of a plume conduit is influenced by the overall mantle flow, which can be monitored by the hotspot drift on the Earth's surface [Tarduno et al., Science, 2009]. The paleomagnetic and dating results from IODP Expedition 330 verified the geodynamic modeling predictions for the Louisville seamount chain together with the Hawaiian-Emperor seamount chain [Koppers et al., Nat. Geosci., 2012]. The present noble gas data gives a guarantee for the deep-rooted Louisville plume assumed in the geodynamic model.

Keywords: Louisville seamount, mantle plume, deep mantle, noble gases, IODP

Preliminary result of the oceanic mantle structure revealed by "Normal Oceanic Mantle Project"

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The oceanic mantle is an important region to understand the Earth system, because more than 2/3 of the surface is covered by oceanic area. Since 1990s, we have operated several seafloor observations by using newly developed long-term broadband ocean bottom seismometers (BBOBSs) in the northwest and central part of the Pacific Ocean. These observations have revealed the structures in and around the subduction zone in the Pacific Ocean and in the Pacific superswells, respectively. However, we have no observation and result in the normal oceanic regions. To reveal the normal oceanic mantle structure from observational approach, we conduct a long-term observation called "Normal Oceanic Mantle Project" (NOMan project) from 2010, deploying ocean bottom geophysical (seismic and electromagnetic) instruments in the northwestern Pacific Ocean. We conduct two arrays in that region. One is northwest side of the Shatsky Rise (Area A) and the other is southeast side of the Shatsky Rise (Area B). Sea floor age of Area A is 125 - 135 Ma, that of Area B is 135 - 145 Ma, so that the shear wave structures of those area should be similar.

By using seismograms of the NOMan project, other BBOBS observations, and permanent broadband seismic stations on land, we have determined the three-dimensional shear wave velocity structure of the upper mantle in the northwestern Pacific Ocean to reveal this area to be really normal. We used a surface wave tomography technique in which multimode phase speed of the surface wave are measured and inverted for a 3-D shear wave velocity structure by incorporating the effects of finite frequency and ray bending.

Our obtained model shows that lateral heterogeneity of each area is not strong and that average structures are different in two areas. Area A is consistent with previous models, whereas Area B is faster than previous models. We think for the present that Area A seems to be normal oceanic mantle, though Area B is not. We will recover all BBOBSs in this year. These BBOBS's data enable us to obtain more reliable mantle structures.

Keywords: upper mantle, BBOBS, surface wave, tomography

Seismic anisotropy in the oceanic lithosphere/asthenosphere system estimated by the broadband ocean bottom seismology

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The uppermost mantle structure beneath the oceanic basins is essential to discuss the oceanic lithosphere/asthenosphere system, the most simple and representative system of the theory of plate tectonics. Seismic anisotropy within the oceanic lithosphere and asthenosphere is especially important, as it reflects the flow and deformation in the uppermost mantle. Previous structural studies have been, however, limited in terms of the depth range: the top of lithosphere at depths of ~10-20 km by refraction surveys, and the structure deeper than ~30 km by surface-wave tomography studies. There has been no discussion from the top of the lithosphere continuously to the asthenosphere, which needs the broadband analysis of surface waves at periods of 3-100 s. In addition, there has been limited discussion about the intensity of seismic anisotropy because of the difficulty of estimating the absolute value of seismic anisotropy by surface-wave tomography studies.

We have developed a new multi-band method to analyze surface waves in broadband array records of ocean bottom seismometers for determining seismic anisotropy structure at depths of ~10-100 km quantitatively (Takeo et al 2013 JGR, submitted to GJI). The method uses the ambient noise cross-correlation method for analyzing surface waves at periods of 3-30 s and to determine structure at depths shallower than ~50 km, as well as the array analysis method of teleseismic waveforms at longer periods for determining deeper structures.

In previous studies, we have applied the multi-band method to records obtained in three oceanic regions: the Shikoku Basin region (Takeo et al. 2013 JGR), the southwestern region of the Shatsky Rise (Takeo et al. submitted to GJI) and the French Polynesia region (Takeo et al. 2012 SSJ Fall Meeting). In this study, we applied the same method to the records of broadband ocean bottom seismometers obtained by the normal oceanic mantle (NOMan) project at two oceanic regions (northwestern and southeastern regions of the Shatsky Rise) from 2010 to 2013. By combining the results for five oceanic regions with different seafloor ages between 20 and 155 Ma, we can discuss the seismic structure and its anisotropy in the oceanic lithosphere and asthenosphere, and the deformation of mantle related to plate motions.

The results for five oceanic regions can be summarized into five points: (i) the high-velocity lid and the low velocity zone corresponds to the oceanic lithosphere and asthenosphere, (ii) the transition from the lithosphere to the asthenosphere occurs at depths of 40-90 km, (iii) the average intensity of S-wave radial anisotropy is 3-6 % at depths of 10-150 km with the velocity of horizontally propagating and vertically polarized S-wave slower than the horizontally polarized S-wave, (iv) the intensity of S-wave azimuthal anisotropy at depths of 10-100 km is weaker than that of S-wave radial anisotropy and weakens with depths, and (v) the azimuth of maximum S-wave velocity is not perpendicular to ancient spreading axis in general. These results indicate complex deformation system in the present and ancient oceanic asthenosphere related to the presence of partial melting, the unusual fabric of olivine and so on. We will summarize these results and discussions, and will also present the potential of the broadband ocean bottom seismology to elucidate structure and deformation in the oceanic lithosphere/asthenosphere system and in other oceanic systems such as hotspots, mid-ocean ridges and subduction zones.

Keywords: surface wave, ambient noise, anisotropy, plate tectonics

Locality and cause of the characteristics of high-frequency Po/So wave propagating in heterogeneous oceanic lithosphere

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In our previous study (Kennett & Furumura 2013; *Geophys. J. Int.*) we described the characteristics of the propagation of the high-frequency mantle phases Po and So. These oceanic Pn and Sn phases can be observed after propagation over many thousands of kilometres from the source, retaining high frequencies but acquiring a long and complex coda. This study concentrated on the way in which these characteristics can be sustained by fine-scale heterogeneity in the oceanic lithosphere that reinforces the influence of multiple P reverberations in the ocean and sediments as recognized by Sereno & Orcutt (1985; 1987). A form of quasi-laminar heterogeneity with horizontal correlation lengths around 10 km and vertical correlation lengths of about 0.5 km provides a good representation of the Po and So wavefield as also noted by Shito et al. (2013). This class of heterogeneity creates a strong scattering environment within the lithosphere that helps to sustain the Po and So phases over long distances. Propagation of So is most effective in thick old lithosphere, e.g., in the northwest Pacific Plate. Amplitudes of So are reduced significantly by propagation through thinner lithosphere in the Philippine Plate.

In this study we look at the entire Pacific basin and map out the propagation patterns for Po and So, which have the general characteristic of much more efficient propagation in the western sector than in the east that is much less well sampled. There are stronger changes in the nature of So than Po. For the same frequency S waves have a shorter wavelength than P waves, and so the So phase is more sensitive to the effects of both lateral variations in lithospheric structure and seismic attenuation.

We explore the relation of the nature of the observations of Po and So and the age of the lithosphere, based on 2-D FDM simulation seismic wave propagation for examining the influence of changes in lithospheric structure across fracture zones and similar features. The strong diffuse scattering field created in the oceanic lithosphere is hard to destroy and it is quite difficult to explain situations where So is very much weaker than Po, except by introducing enhanced seismic attenuation for younger lithosphere and the warmer asthenosphere in the neighborhood of spreading centers.

Distribution of petit-spot volcanoes in relation to deformation and structures on a subducting plate

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Tiny submarine volcanoes, known as petit-spots, occur in regions of plate flexure prior to subduction and seamount-loading (Hirano *et al.*, 2006, 2013). The surface morphology and distribution of petit-spot monogenetic volcanoes are influenced by the stress field in the lithosphere. The magmas produced by the accumulation of melt originating from asthenosphere just below the site of plate-flexure, are able to rapidly ascend to the surface from the base of the lithosphere (Hirano *et al.*, 2006; 2011; Valentine & Hirano, 2011). As monogenetic petit-spot volcanoes are too small to be detected by satellite altimetry, their study requires a research vessel equipped for shipboard acoustic multibeam surveys. Although previously surveyed areas are limited to the regions off the Japan Trench, the eruption ages of petit-spot volcanoes in this region represent monogenetic eruptions over a period of >9 Myr over a large area, and the eruptions are related to the outer rise bathymetry. Such tiny volcanoes are ubiquitous in regions of plate flexure worldwide, and have been recently reported from the Tonga Trench (Hirano *et al.*, 2008), the Basin and Range province (Valentine & Hirano, 2010), south of Greenland (Uenzelmann-Neben *et al.*, 2012), the Chile Trench (Hirano *et al.*, 2013), an accretionary complex in Costa Rica (Buchs *et al.*, 2013), and submarine French Polynesia (Hirano *et al.*, submitted).

The spatial distribution of submarine petit-spot volcanoes remains poorly constrained because shipboard bathymetry has not covered the entire northwestern Pacific Plate. If petit-spot volcanoes occur only in regions of plate flexure, then tiny submarine volcanoes should appear homogeneously on the submarine surface of outer rises. However, areas devoid of volcanoes and lava have been found surrounding areas of petit-spot volcanoes (i.e., sites A?C in Hirano *et al.*, 2006), indicating that the local characteristics of the lithosphere, in addition to plate flexure, control the occurrence of petit-spot volcanoes. Here we report that the distribution of petit-spot volcanoes is controlled by the tectonic structure of the seafloor. We conducted submersible dives along the linearly distributed petit-spot knolls by JAMSTEC *Shinkai6500* in April 2014. Areas with tectonic fabrics appear on the subducting Pacific Plate off the Japan Trench, including a ridge-perpendicular fabric zone (RPPFZ), ridge-parallel abyssal hills (RPRAH), and subducting 'horst and graven' structures (HAGS) (Nakanishi *et al.*, 2011). At Site C, which is a trench-oceanward slope offshore from Soma City, Fukushima Prefecture, the trend of the Japan Trench changes from N?S in the north to NE?SW in the south, where two areas of trench-parallel HAGSs are intersecting in a complex manner (Nakanishi *et al.*, 2011). The distribution of young volcanic cones of more than 80 petit-spots, reported from Site C by Hirano *et al.* (2008), seems to be controlled by the fabrics of RPPFZ and RPRAH, the trends of which are continuous with the HAGS to the north and south along the trench-oceanward slope, respectively. Although the RPPFZ is not recognized as a fracture zone, its trend is sub-parallel to that of the neighboring Nosappu and Kashima fracture zones (Nakanishi, 1993). As the RPPFZ and RPRAH that control the petit-spot distribution are clearly original structures of the lithosphere (in contrast to HAGS), the occurrence of petit-spot eruptions is possibly related to lithospheric structures.

Keywords: petit-spot, alkali-basalt, Pacific plate, outer rise, lithosphere

Magnetic Anomalies in the Southern Indian Ocean Revisited

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Magnetic anomalies in the Southern Indian Ocean are vital to understanding initial breakup process of Gondwana. However, seafloor age estimated from magnetic anomalies still remain less well-defined because of the sparse observations in this area. To understand the seafloor spreading history related to the initial breakup process of Gondwana, vector magnetic anomaly data as well as total intensity magnetic anomaly data obtained in the Enderby Basin, Southern Indian Ocean, are used. The strikes of magnetic structures are deduced from the vector magnetic anomalies.

Magnetic anomaly signals, most likely indicating Mesozoic magnetic anomaly sequence, are obtained almost parallel to WNW-ESE trending lineaments just to the south of Conrad Rise inferred from satellite gravity anomalies. Most of the strikes of magnetic structures indicate NNE-SSW trends, and are almost perpendicular to the WNW-ESE trending lineaments. Mesozoic sequence magnetic anomalies with mostly WNW-ESE strikes are also observed along the NNE-SSW trending lineaments between the south of the Conrad Rise and Gunnerus Ridge. Magnetic anomalies originated from Cretaceous normal polarity superchron are found in these profiles, although magnetic anomaly C34 has been identified just to the north of the Conrad Rise. However, Mesozoic sequence magnetic anomalies are only observed in the west side of the WNW-ESE trending lineaments just to the south of Conrad Rise and not detected to the east of Cretaceous normal superchron signals. These results show that counter part of Mesozoic sequence magnetic anomalies in the south of Conrad Rise would be found in the East Enderby Basin, off East Antarctica. NNE-SSW trending magnetic structures, which are similar to those obtained just to the south of Conrad Rise, are found off East Antarctica in the East Enderby Basin. However, some of the strikes show almost E-W orientations.

Moreover, the thickness of the crust increase just to the north of the Conrad Rise and clear magnetic anomaly signals considered to be magnetic anomaly C34 in this region may indicate continental-ocean boundaries while taking dredged continental origin rock samples at the Ob seamount into account. Therefore, magnetic anomaly C34 identified in the Indian Ocean must be reconsidered. These suggest complicated ridge reorganization occurred during initial breakup of Gondwana in the Indian Ocean.

Keywords: magnetic anomaly, Indian Ocean, Gondwana, continental crust

Origin of the Palau Basin and a revised spreading model of the West Philippine Basin deduced from three-component magnet

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The western part of the Philippine Sea (PHS) plate was occupied by the West Philippine Basin (WPB) in the north and the Palau Basin (PB) in the south. The WPB is generally considered to have opened from about 50 to 30 Ma, but the details are still unclear; in particular the origin and age of the PB was unknown. Studying the history of the WPB is important for understanding better the initiation and evolution of the IBM Arc. Here we discuss the spreading history of the WPB using new data on three-component magnetic anomaly and swath bathymetry acquired in the PB as well as those obtained previously by JAMSTEC fleets in the southern WPB. NS-trending magnetic boundaries and seafloor fabrics occur in the PB, indicating the formation by EW seafloor spreading. With a constraint from a ⁴⁰Ar/³⁹Ar age of 40.4 Ma obtained from the northernmost part of the PB, we interpret that the observed magnetic anomalies correspond to polarity reversals from C16n1r to C18n/C18r (35.6 to 38/39 Ma). Previous models of WPB spreading incorporated a spreading-rate decrease around 40 Ma from about 4.4 to 1.8 cm/year. Our study in the southern WPB, however, suggests that the decrease is unnecessary for correlating observed three-component anomalies to the GPTS. A typical profile along 130E corresponds to C16r to C21 (36.3 to 45.3 Ma). The cessation age of the spreading in our interpretation, about 35 to 37 Ma, is older than the previous estimation (about 30 to 33 Ma). It was difficult to constrain rotation of the PHS plate from the magnetic anomaly skewness.

Keywords: Philippine Sea plate, West Philippine Basin, Palau Basin, magnetic anomaly, seafloor spreading

The composition of back-arc basin basalts in the West Philippine Basin and association with mantle dynamics

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The Philippine Sea Plate was expanded by multiple extensions of backarc basins. Ishizuka et al. (2011) and Haraguchi et al. (2012) pointed out that the enriched mantle was flowed from backarc side during the spreading of the Shikoku Basin from 25 to 15 Ma (Okino et al., 1994, 1999). Haraguchi et al. (Meeting of the Volcanological Society of Japan, 2013) considered that the process of flowing of the enriched mantle estimated by the composition of the backarc basin basalts (BABB) recovered by the drilling of the Deep Sea Drilling Project (DSDP), Ocean Drilling Program (ODP) and Integrated Ocean Drilling Program (IODP). In this study, we attend the BABB of the West Philippine Basin, precede backarc spreading of the Shikoku Basin, and consider mantle dynamics by geochemical characteristics of BABB.

The first drillings in the West Philippine Basin by the Deep Sea Drilling Project are the Leg 31 same as the Shikoku Basin, and following operations are Leg 59 and the Ocean Drilling Program (ODP) Leg 195. And the diving of the R/V *Shinkai 6500* during the Y9611 cruise by R/V *Yokosuka* and dredges during the KR9801 cruise by R/V *Kairei* at the spreading axis (e.g. Fujioka et al., 1999). In this study, we discuss the new analyzed data of the basements of DSDP Leg 58 Site 446 and ODP Leg 195 Site 1201, and compare the data of the former studies.

Site 1201 is located in the west of the West Philippine basin, about 500km north from the Central Basin fault, axis of the spreading center. The main purpose of this site is the set up of the borehole site WP-1. Thickness of covered sediments at this site is more than 500m. The chemical characteristics of basements at this site are the typical BABB, not find the island arc characteristics. SiO₂ and MgO contents of these basalts are 49-53 and 5-8 wt%, respectively, and are similar to the basalts from the DSDP Leg 58 Site 442~444 in the Shikoku Basin. The TiO₂ contents of these basalts are 0.9~1.0 wt%, lower than those of the Shikoku Basin. The alkali elements are 1.5-2.8 wt% of Na₂O and 0.1-1.6 wt% of K₂O, similar K₂O and lower Na₂O contents to Shikoku Basin BABB. The trace elements are 320-420 ppm of Cr, higher than Shikoku Basin BABB, and lower Sr, Y and Zr. The Zr/Y and Nb/Zr ratio are also lower than Shikoku Basin BABB. We consider that these characteristics are the existence of the depleted parent mantle before the spreading of the Shikoku Basin pointed by Ishizuka et al. (2011) and Haraguchi et al. (2012).

Site 446 ate located in the Minami Daito Basin between the Daito and the Oki Daito Ridges. Thickness of covered sediments is about 350m. These volcanic rocks are considered to the intrusion in the sediment layer, different from the basement. The chemical characteristics of this volcanics are classified into alkali basalts, and prominent enrichment of TiO₂, more than 4 to 5 wt%. This extremely enrichment of TiO₂ is not found from other inner plate volcanism in the Philippine Sea Plate. Therefore, we assume that the different inner plate volcanism from the mantle plume in the West Philippine Basin about 40 Ma (Deschamps and Lallemand 2002) were more active in the other Philippine Sea region.

We discuss these analyzed data and former data of the basements in the Philippine Sea Region, and consider parental material composition and magma dynamics before 30 Ma.

Keywords: Backarc basin basalts, Incompatible element ratio, Parent material of magma, Mantle dynamics

Long-distance magma transport from oceanic island arc volcanoes

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Long-distance lateral magma transport away from volcanic centers is emerging as a common phenomenon where the regional stress regime is favorable. It should also be recognized as an important factor in the construction and growth of island arcs, and a potential trigger for devastating eruptions. In this contribution, we report on recent investigations into the magma dynamics of Izu-Oshima volcano: an active basaltic volcano with an extensive fissure system.

Geophysical observations in the Izu-Bonin intra-oceanic island arc indicate that magma periodically is moved away from the main basaltic composite volcanoes. When Miyakejima erupted in 2000, seismic activity migrated about 30km northwestward from the volcanic centre (Geshi et al., 2002). This event is interpreted to reflect magma injection and dike propagation at a depth range between 12 and 20km (Kodaira et al., 2002). Long-distance lateral magma transport has also been identified at the Nishiyama volcano on Hachijojima Island using petrological, geochemical and structural studies of satellite vents (Ishizuka et al., 2008). Nishiyama has provided evidence for two types of magma transport: Primitive magma moving laterally for >20km in the middle to lower crust (10-20km deep) and short distance transport (<5km) from shallow, differentiated magma reservoirs. Of these the long-distance transport seems to be controlled by a regional extensional stress regime, while short distance transport may be controlled by the local stress regime resulting from the load of the main volcanic edifice.

Izu-Oshima is flanked by numerous, subparallel NW-SE trending submarine ridges extending up to 22 km to the NW and SE from the center of the volcano. During a recent diving survey we have identified that these ridges are fissures which erupted basaltic spatter and lava flows. Furthermore, lavas are petrographically similar along each ridge, while there are noticeable differences between ridges. The subparallel ridges are observed to transect a series of knolls, the Izu-Tobu monogenetic volcanoes (ITMV), which are dispersed across this area of the rear-arc. However, there is a consistent petrographic difference between these seamounts and the ridges.

We have found similar, and in some cases a matching, geochemistry between the submarine ridges and subaerial ridges of eruptions found ascending the flanks of Izu-Oshima. This implies that the subaerial ridges and submarine ridges together represent the track of a magma transport episode away from the storage system beneath the central volcano.

ITMV and the transecting ridges are found to have quite distinct geochemical characteristics, indicative of different magma sources. Yet, they are essentially found interspersed in outcrop. The most appropriate scenario for their development is one where ITMV are fed by an "in-situ" underlying source, while the NW-SE ridges are fed by lateral magma transport from Izu-Oshima. Unlike Nishiyama volcano, Izu-Oshima does not show a compositional variation along the length of the ridges, and has no evidence of primitive magmas. Hence, the magma transport is likely to be derived from a crustal chamber where crystal fractionation and plagioclase accumulation has taken place.

Seafloor geodetic observation along the Nankai Trough - Progress report after the 2011 Tohoku-oki earthquake -

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We have been carrying out GPS/acoustic seafloor geodetic observation on the landward slope of the major trenches around Japan, such as the Japan Trench and the Nankai Trough. From the past observations, we detected intraplate deformation caused by the subduction of oceanic plates and coseismic displacements associated with large earthquakes.

Along the Nankai Trough, we deployed six seafloor reference points in the sea area from off-Omae-zaki through off-Muroto in 2002-2004 and had been carrying out campaign observations. From the observations conducted before the 2011 Tohoku-oki earthquake, we obtained the intraplate velocities of 2-5 cm/year toward WNW, which were generally consistent with those detected by on-land GPS measurements. A closer look gives us the differences of the velocities by sea areas.

Furthermore, to monitor seafloor movement spatially in the whole expected focal regions along the Nankai Trough, we deployed nine new seafloor reference points mainly off Shikoku in January 2012. If we obtain crustal velocities at all the site, it is expected that a spatial variation of interplate coupling will be revealed in the sea area along the Nankai Trough. It has been two years after the expansion of seafloor reference points and seafloor movements westward and northward are being observed at most of the sites.

In this report, we present a progress report on seafloor geodetic observation along the Nankai Trough after the 2011 Tohoku-oki earthquake.

Keywords: Seafloor geodetic observation, Seafloor geodesy, Nankai Trough

Postseismic seafloor movements following the 2011 Tohoku-oki earthquake detected by GPS/acoustic positioning

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The Hydrographic and Oceanographic Department, Japan Coast Guard, have been developing precise seafloor positioning systems using the GPS/acoustic combination technique and carrying out campaign observations along the major trenches in the Pacific Ocean, such as the Japan Trench and the Nankai Trough. For example, after the 2011 Tohoku-oki earthquake (Mw = 9.0), we detected a huge coseismic displacement of 24 m toward ESE at MYGI which is located above the epicenter. We have been continued the geodetic observations along the Japan Trench in order to detect postseismic deformation.

The results of the observations show that the displacements vary with the sites even in the directions. MYGI and KAMS had moved toward west-northwest at constant rate. MYGW had moved toward south-southeast. KAMN had moved toward northwest. FUKU and CHOS had moved toward east-southeast. In addition, the displacements at FUKU and CHOS decay with time. For vertical component, significant subsidence was detected at all sites except CHOS where no vertical displacement was detected within the accuracy range.

In this presentation, we will report and discuss the latest results of the seafloor geodetic observation along the Japan Trench.

Keywords: seafloor geodetic observation, the 2011 Tohoku Earthquake

A summary of the achievement in the project for advanced GPS/acoustic survey

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GPS/acoustic survey is known as a most probable way to measure the crustal deformation of seafloor far from the coasts, where dense GPS network is not available. We, Tohoku University, together with Nagoya University and Japan Coast Guard dedicated in GPS/acoustic survey for more than decade. MEXT has been strongly promotes our activities though financially support as governmental project. We summarize individual topics in the project.

For the moored buoy, collaborating with JAMSTEC and JAXA, we have started long-term continuous and realtime seafloor geodetic survey at Kumano-nada. At the early stage of the project, we employed a small buoy, which can be also used as towing survey, at off-Miyagi site. Because the size of battery is limited, sea-trials was lasting only for two days. However, using this platform, we developed an automatic ranging system and simple on-demand operation technique via UHF communication. In 2012, we have started developing a automatic ranging system in a realistic working condition using a time-proven platform, m-TRITON buoy, operated by JAMSTEC. Together with JAMSTEC and JAXA, satellite communication part and GPS positioning part have been shared for multi-purpose. Tohoku University group concentrate acoustic ranging part and onsite data processing to compute precise traveltimes. Using a limited onsite resource in the buoy, we have eliminated unnecessary and redundant procedure and data as possible. The first sea-trial took place in 2013 for four months and the ongoing second trial has started in 2014 for six months. In the second trial, acoustic ranging data has been successfully transmitted to onshore station every week and we can monitor it from our laboratory.

For the Autonomous Surface Vehicle (ASV) system, we aimed to develop an automatic survey system, which can also be used simultaneous measurements from other platform, such as a research vessel, for improve the ranging accuracy with multi-acoustic-paths. In our system, vehicle is like an unmanned boat (2.4m long and 400kg in weight), whose propulsion system is driven by electric power from onboard diesel generator lasting for a week. As the ASV system demonstrates sufficient performance for our use in GPS/acoustic survey, it can be a candidate of multi surface platform for simultaneous ranging to achieve high accuracy GPS/acoustic measurement taking the spatial sound speed variation into account.

After the Tohoku-Oki earthquake in 2011, the project has an extra mission that significantly enhance the survey framework, especially in deep seafloor (>5000m) near the trench axis. In this extra mission, we have developed a new type of seafloor transponder that works at over 5000m depth and its acoustic communication range is greater than 15km. We made 86 transponders in total and constructed 20 new GPS/acoustic station along the Japan Trench in 2012. In addition, we chartered a research ship for about 50 days per year to construct and observe the new stations. At present we have carried out four times of campaign surveys during 2012-2013. At these new stations, we conducted both moving and stationary surveys, the former generally took several hours and the latter 12 hours for each station. We found a problem in acoustic property in the new transponders, which can be corrected with post-processing shown in Azuma et al. (2014, JpGU). Campaign surveys ranges only about one year, but we have observed post-seismic movement at selected stations. These results are reported in Tomita et al. (2014, JpGU). The new transponders are hybrid type so that Japan Coast Guard has started to make measurements with their own system at several stations above.

This work has been supported by MEXT project for advanced GPS/acoustic survey. Staffs in RCPEV and IRIDeS, Tohoku University gave dedicated support and collaborative operation in the onboard and GPS surveys. The construction and surveys in the new stations were collaboration with Nagoya University.

Keywords: GPS/acoustic, moored buoy, autonomous surface vehicle, Japan trench

Detection of post-seismic movement after Tohoku-oki Earthquake using GPS/Acoustic technique

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Using GPS/Acoustic seafloor geodetic observation (GPS/A observation), we can directly measure seafloor movements, which cannot be obtained from on-land geodetic observation. For example, Kido et al. (2011) and Sato et al. (2011) detected huge co-seismic displacements associated with 2011 off Pacific coast of Tohoku Earthquake near the Japan Trench, 150km distant from the coast.

After the occurrence of the Tohoku-oki Earthquake, we deployed new seafloor benchmarks at 20 sites along the Japan Trench from Ibaraki-oki to Sanriku-oki. Including three sites installed before 2011, we totally have 23 sites to monitor the post-seismic movement for the Tohoku-oki Earthquake. We have conducted four GPS/Acoustic surveys at present (09/2012, 11/2012, 07/2013, 10/2013) at these sites.

The surveys consists of two types of observations; they are moving survey to locate the position of individual seafloor transponders that make up each geodetic site and point survey to determine the precise location of the center of the transponder array. The displacement at each site is estimated from the temporal change of the array center position. However, we identified two dominant factors that influence the precision of the array center positioning in our observation.

The first factor is the instability in the waveforms of acoustic signals. In GPS/A analysis, we calculate cross-correlation waveform between received and transmitted signals, and determine the timing of maximum peak as round trip travel time. However, multiple peaks separated by 0.3-0.5ms each other are found in a cross correlation waveform, whose relative amplitudes are influenced by the relative position between the hydrophone on the research ship and the seafloor transponder. We have developed an algorithm that can automatically picks up the first peak from the multiples and reduces the error in determining round trip travel time. The detail of this problem and the algorithm will be reported by Azuma et al. (2014, JpGU).

The second factor is uncertainty in the position of the hydrophone equipped on the research ship with respect to three GPS antennas at the top of the ship for attitude determination. In our observations, it is difficult to directly measure the relative position of the three GPS antennas and the hydrophone attached at the end of the pole mounted on the ship's side; the provisional position based on the drawing has about 1m offset. The horizontal component of the offset causes systematic deviation in the apparent position of the transponders depend on ship's heading. Taking this behavior into account, we can correct for the horizontal offset with about 5cm in accuracy. The vertical offset is thought to have less influence on the estimation of the array center position because the sound speed correction intrinsically includes the vertical offset. However, accuracy of offset estimation is still insufficient, hence the estimation technique must be refined further.

After these correction, we have succeeded to obtain preliminary movements at 10 sites using the data in two of the four surveys (09/2012 and 07/2013) at present. These preliminary results generally indicate eastward seafloor movements at the northern Sanriku-oki sites and westward movements at off-Miyagi sites. In this talk, we introduce outline of the analysis and up-to-date results of evaluation of the post-seismic movement incorporating the data in 11/2012 and 10/2013.

Keywords: seafloor geodesy, Tohoku-oki Earthquake, Japan Trench, post-seismic movement

Understanding recoupling process using a seafloor geodesy in megathrust earthquake zone

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The 11 March 2011 Tohoku-Oki earthquake ruptured the interplate boundary off the eastern shore Honshu, generated a devastating tsunami that swept the coastal area along the northeastern Japan. The seafloor geodesy brought important results that show that the large slip was near the Japan Trench and suggested the heterogeneity of the coseismic slip distribution in the plate interface. The maximum displacement region for interplate earthquake is mainly located offshore region. Therefore it is important to monitor the postseismic displacement and the stress accumulation process using seafloor geodesy. And if we can observe the postseismic displacement near the Japan Trench, we contribute to understand the coupling condition of plate boundary. There is a seafloor acoustic ranging system for direct observation of horizontal displacement on seafloor. We improve this system that adapted for the axis of Japan Trench. The system is designed to measure distances of up to 3 km and to adapt the pressure vessel of 9000m water-depth. We deployed the seafloor acoustic ranging system between 2013 May and 2013 Sep. We observed across the Trench baseline (about 7km), baseline between the bottom of Trench to the seaward side of Japan Trench (about 3.6km). We get data both baseline results for 4 month. We report this results on this presentation.

Keywords: seafloor crustal movement, Japan Trench

Sea trial of tsunami and crustal movement observation buoy system in real-time under environment with high speed sea cur

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Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Tohoku University and Japan Aerospace Exploration Agency (JAXA) have developed real-time observation system for tsunami and crustal movement using a buoy since 2011. Although observation interval of crustal movement is generally sparse, because the timing depends on availability of observation ship, we aim to construct to observe tsunami in real-time and crustal movement when it is necessary. Because Japan is surrounded by seismogenic zones with large earthquakes and such large event brought huge damages on coastal region people, early detection is needed to reduce the severe damage. Although online cable system is best for it, the cost for the construction and implementation is huge. Therefore, we point use of the buoy as the removable temporal early detection system. The system is composed of a pressure seafloor unit with pressure sensor and acoustic transmission unit, six seafloor transponders and buoy station incorporating some loggers, transducers to communicate with seafloor systems and data transmission system to land. The seismogenic zones, however, are under the environment of high speed sea current like the Kuroshio. Therefore, we use the slack mooring on our system, but the some technical development is needed for adoption of the mooring. For example, low consumption electricity due to high power acoustic signals for the data transmission and We tried sea trial for three months in last year, and confirmed to fully resistance for high speed sea current over 5.3 knots. On the other hand, the issued to be resolved are clarified, which are on acoustic transmission between the pressure seafloor unit and the buoy, the resistance for the fishery activities and so on. We took measures for above issues and deploy the revised system at off the Kumano Basin. The observation period of the second sea trial is six months. In addition to the measures, we implement tsunami mode. In normal case, we obtain tsunami data with an interval of 15 minutes, but, it is switched to be 15 seconds in tsunami mode. The tsunami mode is triggered when a ratio of average for short period of time (STA) and that of long one (LTA) exceed the threshold level. And, we move the timing of the STA and LTA and try to detect the first arrivals of tsunami. Now, we obtain real-time tsunami and crustal movement data via iridium transmission and introduce it in this presentation.

Study for improving efficiency in seafloor geodetic observation by means of multi acoustic ranging

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Japan Hydrographic and Oceanographic Department (JHOD) and the Institute of Industrial Science, University of Tokyo, have been developing a system for precise seafloor geodetic observation with the GPS/Acoustic combination technique. In this observation, the movements of the seafloor reference points are measured with 2 - 3 centimeters precision. JHOD has been carrying out seafloor geodetic observations 2 - 4 times a year for each station and reported the inter-seismic deformation before and after the 2005 Miyagi-oki earthquake and the co- and post-seismic deformations of the 2005 Miyagi-oki earthquake and the 2011 Tohoku-oki earthquake and so on.

After the 2011 Tohoku-oki earthquake, this observation is expected to be broadened and densely-arranged with the objective of large-scale earthquake disaster prevention. In order to expand further seafloor geodetic observation, shortening of observation time, which is about one day for one campaign, is required. Therefore, we are considering a new acoustic ranging method. In this new method, we conduct the acoustic ranging for multi seafloor transponders not individually but sequentially. We report the details of this new multi acoustic ranging method and discuss how much efficiency will be improved by the introduction of the new method.

Keywords: seafloor geodetic observation, acoustic ranging

Hydrothermal heat mining due to the aquifer thickening toward the trench axis: A model for the Japan Trench

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Observation: At the Japan Trench, a 135-Myr-old Pacific plate is subducting beneath the Japan Island. Heat flow on such an old oceanic plate is expected to be 50 mW/m^2 by a thermal model of the oceanic plate. However, observed heat flow values range from 50 to 120 mW/m^2 and the averaged value is 70 mW/m^2 (Yamano et al., 2008, Int. J. Earth Sci.). In the area of high heat-flow anomalies, a high V_p/V_s layer (highly porous, and probably highly permeable) is observed within the uppermost part of the oceanic plate (Fujie et al., 2013, JpGU Meeting). The layer thickness is observed to increase toward the trench axis.

Hypothesis: Permeability within the uppermost several hundred meters of oceanic plate is measured to be high for fluid to convect; this layer is called an aquifer. We assume that thickening of the observed high V_p/V_s layer is a consequence of thickening of this highly permeable layer. Accordingly, we construct a numerical model including hydrothermal circulation within an aquifer being thickened with time, and calculate the resulted heat flow anomalies.

Results: Calculations show that heat flow is increased as the aquifer thickness begins to increase. With typical parameter values for the Japan Trench, the result accounts for the observed high heat-flow anomaly of 20 mW/m^2 . This high heat-flow arises due to the mining of heat from the base of the thickening aquifer. Downward thickening of the aquifer invades the high-temperature region, and incorporates the heat into convection. As a result, this heat is transported upwards through sediments above the aquifer, and heat flow is increased.

Keywords: hydrothermal circulation, heat flow, the Japan Trench, seismogenic zone

Seismic structure and seismicity survey at the Kairei hydrothermal vent field in the Indian Ocean

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1. Introduction

In the first segment of the central Indian Ridge from the Rodriguez triple junction, the Kairei hydrothermal vent field exists and extrudes hydrothermal fluid with richer hydrogen content compared to other hydrothermal vents in the world. Around the Kairei hydrothermal field, serpentinized peridotite and troctolites, and gabbroic rocks were discovered. These deep-seated rocks exposed around the Kairei field may cause the enrichment of H₂ in the Kairei fluids. At the Kairei field, a hydrogen-based subsurface microbial ecosystem and various hydrothermal vent macrofauna were found. In the TAIGA Project (Trans-crustal Advection and In situ reaction of Global sub-seafloor Aquifer), this area is a representative field of TAIGA of hydrogen. To investigate how the deep-seated rocks (originally situated at several kilometers below seafloor) are uplifted and exposed onto seafloor, and the hydrothermal fluids circulate in subsurface, we conducted a seismic refraction/reflection survey and seismicity observation with ocean bottom seismometers (OBSs).

2. Observation

We conducted a seismic survey around the Kairei hydrothermal field from January 27 to March 19 in 2013 using S/V Yokosuka of Jamstec. We used 21 OBSs, an air gun (GI gun) and a single channel streamer cable. Deployed intervals of OBSs are about 7.5 km, and 2 km near the Kairei field. Survey lines are 5 lines NNW-SSE direction parallel to the ridge axis, 5 lines E-W direction, and 5 lines NNE-SSW direction. Line lengths are from 7 km to 30 km. In addition, we conducted other 5 lines pass around the point just above the Kairei hydrothermal field and the Yokoniwa Rise. The air gun was a GI gun with 355 cu. in. (5.5 l), and the shot interval was 40 s (about 100 m).

3. Results

From seismicity observation, we found many micro earthquakes in this area. A swarm of micro earthquakes exists at a location about 1 km northwest of the Kairei field. The swarm has a NNW-SSE strike, parallel to the ridge axis. The depth of the swarm is very shallow (~4 km from seafloor). This swarm may be related to the hydrothermal activities of the Kairei field. At the first segment of the central Indian Ridge, many micro earthquakes occurred. The depth of these events is deeper than that of the swarm near the Kairei field.

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Keywords: TAIGA, hydrothermal area, seismicity, Triple junction in the Indian Ocean

Origin of boron in Okinawa Trough hydrothermal fluids using B isotope as a tracer

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The Okinawa Trough is a back-arc basin located around the Ryukyu Arc, where several hydrothermal systems have been discovered. The Okinawa Trough has a very thick sedimentary cover, and the chemistry of the hydrothermal fluids appeared to be influenced by interaction with the sediment. However, the temperature environments below the seafloor have not been clarified yet in detail. In this study, we investigated B isotope ratios ($\delta^{11}\text{B}$) in hydrothermal fluids from Okinawa Trough, and discussed the origin of the boron and the reaction temperature.

The hydrothermal fluid samples were collected by WHATS with Hyper Dolphin and *Shinkai 6500* from Iheya North Knoll, Izena Caldron, Hatoma Knoll, and Yonaguni Knoll IV. The sample was filtered and acidified by HNO_3 . B was isolated by micro-sublimation, and $\delta^{11}\text{B}$ measurement was carried out using a MC-ICP-MS (Neptune plus). The precision was within 0.3%. All values reported in this study are presented in delta notation relative to NBS SRM 951.

The concentrations of B in the hydrothermal fluids from Okinawa Trough were higher than those from sediment-starved MOR, and the $\delta^{11}\text{B}$ showed ^{10}B enrichments. A difference of $\delta^{11}\text{B}$ among Okinawa Trough hydrothermal fields was found; Yonaguni IV < Izena Caldron < Iheya North < Hatoma Knoll. The $\delta^{11}\text{B}$ in the hydrothermal fluids showed the strong correlation with the carbon isotopic ratios of methane ($\delta^{13}\text{C}\text{-CH}_4$) in the hydrothermal fluids, suggesting the factor controlling the variation of $\delta^{11}\text{B}$ in the hydrothermal fluids is identical with the one controlling the variation of $\delta^{13}\text{C}\text{-CH}_4$ in the hydrothermal fluids. The controlling factor for the variation of $\delta^{13}\text{C}\text{-CH}_4$ in the hydrothermal fluids is a mixing ratio between thermogenic methane and microbial methane, implying the controlling factor for the variation of $\delta^{11}\text{B}$ would be a mixing ratio between B derived from sediment at higher temperature and lower temperature.

We calculated the reaction temperature based on the correlated equation of reaction temperature with $\delta^{11}\text{B}$ fractionation between solid phase and aqueous phase. For $\delta^{11}\text{B}$ of the solid phase, reported $\delta^{11}\text{B}$ of surface sediment from Okinawa Trough (-5.4 and -2.2 ‰) was used. However, all observed $\delta^{11}\text{B}$ in the hydrothermal fluids could not be explained. Instead, $\delta^{11}\text{B}$ of solid phase was estimated between 50 and 400 °C; the lowest temperature of leaching B from sediment is 50 °C and the highest temperature of sub-critical water is 400 °C. $\delta^{11}\text{B}$ of sediment involved in B leaching was estimated to be from -20 to -10 ‰, which are lower than the $\delta^{11}\text{B}$ in surface sediment from Okinawa Trough. Hydrothermal alteration lowered $\delta^{11}\text{B}$ in sediment, suggesting the origin of the B in Okinawa Trough hydrothermal fluids would be altered sediment. For the reaction temperature, the lowest value among Okinawa Trough hydrothermal fluids was obtained in Hatoma hydrothermal fluids, following Iheya North, Izena, and Yonaguni IV, suggesting a large amount of sediment is distributed in recharge zone in Hatoma Knoll, and the B would be derived from the sediment at relatively low temperature. On the other hand, sediment is distributed in reaction zone beneath Yonaguni IV, and the B would be derived from the sediment at relatively high temperature.

Keywords: hydrothermal fluid, Okinawa Trough, boron isotope

The structure of iron- and silica-rich mounds at hydrothermal environment in shallow marine, Satsuma Iwo-Jima

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Satsuma Iwo-Jima Island, located 38km south of Kyusyu, Japan, is a volcanic island in the northwestern rim of Kikai caldera. Iron- and silica-rich mounds develop with hydrothermal activity (pH=5.5, 50-60 degree Celsius) in Nagahama bay located south-western part of the island. The brownish seawater at the bay is due to mixing of the hot spring water with seawater (Shikaura and Tazaki, 2001). Very high deposition rate (33 cm per year) of iron-rich sediments was observed in the bay (Kiyokawa et al., 2012). In this study, we analyzed samples (20-30 cm long) recovered from mounds at the seafloor of Nagahama bay by the observation with X-ray CT scan, FE-SEM, and the thin-sectioned sample, and the chemical analysis with EDS, XRF, XRD and DNA, and found that the structure of mounds has unique information.

Visual observation indicated that the samples were made from two layer: black high-density hard layer and brownish low-density soft layer. X-ray CT scan observation shows that the inside of samples is constructed from the aggregation of convex structure (3-4 cm). Soft layer is covered by a hard layer as a rim. The soft layer has many pipe-like structures (typical radius: 1 mm). Petrographic observations indicate that soft and hard layers have filament-like forms, and the form in soft layer is perpendicular to that in the hard layer. The number of small particles (about 20 μm) observed on filament-like forms in soft layer increases toward hard layer. FE-SEM observation shows that filament-like form in hard layer consists of aggregation of bacillus-like form as the chain of particle (about 2 μm). At soft layer, on the other hand, bacteria-like form with smaller particles (<0.5 μm) is observed. Bacteria-like form could be classified into 3 types (helix, ribbon-like, twisted). Furthermore, the result of XRD and XRF show that hard layer consists of ferrihydrite and opal-A (Si: 26.8%, Fe: 56.0%) and soft one is composed by ferrihydrite, opal-A, quartz, cristobalite and tridimite (Si: 36.5%, Fe: 43.5%). DNA analysis indicated predominance of *Mariiprofundus ferrooxydans* that is known as iron-oxidizing bacteria belonging to Zeta-proteobacteria.

The forming process of the mounds at Nagahama bay is that firstly chemical and biological reaction made soft layer. During occurrence of the reaction, volcanic ash originating from Iwo-dake was contained as silica in the soft layer. Bacteria-like form in soft layer is considered to be the stalk made by iron-oxidizing bacteria according to the result of DNA analysis. Such neutrophilic iron-oxidizing bacteria prefers an environment of redox interface between hydrothermal water and seawater (Chan et al., 2011), and their activity made hard rim at outer soft layer. Inside of hard rim, the keeping of both reaction resulted in relative iron-rich layer and layering at hard rim. Because such process occurred repeatedly, the mounds at Nagahama bay had the aggregation of convex structure with many pipes as the hydrothermal vent. The high depositional rate of iron hydroxides is likely to be influenced by the activity of bacteria.

Keywords: hydrothermal activity, iron-hydroxide, iron-oxidizing bacteria, shallow marine

GPS/acoustic measurement using a multi-purpose moored buoy system

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For monitoring crustal deformation and tsunami occurrence in the source region of the upcoming Nankai and Tonankai earthquake, JAMSTEC, JAXA, and Tohoku University have jointly developed a realtime continuous observation system using a moored buoy, called m-TRITON, and have started its sea-trial. The system consists of a seafloor pressure sensor for monitoring tsunamis and vertical crustal deformation, a GPS system for monitoring sea-level and position/attitude of the buoy, and a GPS/acoustic system for monitoring horizontal crustal deformation. Measured data are transmitted to onshore station via satellite communication so that they can be monitored in realtime. The first sea-trial was carried out in Kumano-nada in 2013, and the second trial has been started in 2014 after improvement of the system. In this presentation, we focus on the issues particular to acoustic ranging of GPS/acoustic measurement for the purpose to remedy the system based on the data acquired in 2013, and report new data being acquired in the ongoing second trial in 2014.

The GPS/acoustic system measures horizontal movement of a seafloor benchmark, which consists of six transponders by combining GPS analysis of the buoy and acoustic ranging between the buoy and seafloor transponders. Considering bit-rate of the satellite communication, it is not realistic to send full acoustic waveform. So, it is required to send only the result processed on the buoy. In order to proceed acoustic wave with a low-powered device on the buoy, it is necessary (1) to cut out recorded waveform to the minimum requirement and (2) to send the processed data containing minimum but sufficient information. As for (1), in the current system recorded acoustic waveform is cut out by a window of ± 20 ms centered at synthetic traveltime calculated from provisional position of the buoy and each seafloor transponder. After that, cross-correlation waveform between the transmitted signal and the received signal is calculated to obtain an accurate observed traveltime. Then (2) send the correlogram only a 1 ms window centered at the maximum correlation peak, which is sufficient to include the sidelobe. Since correlation wave is represented in 8 bit and the sampling rate is in 100 kHz, the size-per-single wave to be transmitted can be reduced only to 101 byte.

As a result of considering the fluctuating range for the uncertainty of provisional position obtained by the NMEA output of the GPS (~ 10 m at most) and the average sound speed variation (~ 2 m/s) that affect the synthetic traveltime, the window width of ± 20 ms employed in (1) is a minimum requirement. In order to certainly cut out maximum correlation peak for all acoustic ranging, it is desirable to set the width to ± 30 ms. As for correlogram to be sent to onshore station, since the envelope of the correlation peak is within the 1 ms, current width is reasonable. However, apparent maximum correlation peak often known to appears due to multiples at sea surface. In that case, it is not possible to achieve proper adjustment only by the width. Therefore the development of an algorithm to detect the true correlation peak is required. We verified based on actual data about the condition that the multiple occurs, and found that it is explained by the incident angle of the sound wave and the directivity of transducer. We are developing an algorithm that automatically detects the true correlation peak based on this hypothesis.

Keywords: crustal deformation, moored buoy

Inversion analysis for slip deficit rate along the Nankai Trough using on- and offshore crustal velocities

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Along the Nankai Trough, megathrust earthquakes occur every 100-150 years. A nationwide continuous GPS observation network in Japan has measured precise crustal deformation in this area for the past decade. However, the sources of these earthquakes are located offshore where slip resolution is generally poor. Since the early 2000s, seafloor geodetic observations using GPS/Acoustic techniques have been conducted against such a background in Japan. Today, seafloor geodetic observations are recognized as an effective and essential procedure for understanding the source process of earthquakes that occur in offshore areas. In this study, we show the result of seafloor geodetic observations using GPS/Acoustic techniques from 2004 to 2012 and estimate slip deficit rates along the Nankai Trough using both onshore GPS velocities and offshore crustal velocities derived from seafloor geodetic observations. We conducted inversion analysis with a priori information, and then, a high slip deficit rate of more than 50 mm/yr was detected off the Shikoku district. This decreases to approximately 30-50 mm/yr off the Kii Peninsula, and then it falls to approximately 10-30 mm/yr around the Suruga Trough relative to the Amurian plate, except for slip deficit rate of nearly 40 mm/yr which was detected at a fault segment beside the seafloor benchmark at the Suruga Bay. In addition, we investigated slip resolution by adding new established seafloor benchmarks off Shikoku district. As a result, we found that slip resolution was still poorer in offshore areas such as off the Ashizuri Cape, the Muroto Cape, and the Kii Peninsula near the trench axis than in onshore areas. Thus, it is important to conduct seafloor geodetic observations in areas with poor slip resolution.

Keywords: GPS/Acoustic, Nankai Trough, crustal deformation, slip deficit rate, slip resolution

Development and examination of new methods for traveltine detection in GPS/A geodetic data to high-precise and automatic

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The development of a technique for GPS-acoustic (GPS/A) geodetic observations has enabled us to understand the slip distribution of the 2011 Tohoku-oki earthquake. However, there remains an issue with the precision of GPS/A measurement is still lower by two orders of magnitude than that of on-land GPS measurement due to problems in observations and data processing methods. In this study, we focus on the problem for determination of traveltimes of acoustic signals obtained from GPS/A measurement.

The conventional approach for determining the two-way traveltine of observed acoustic signals is to determine the maximum peak of the cross-correlation waveforms between the transmitted and returned signals. However, the maximum peak often differs from the true peak due to the distortion in the correlation waveform which depends on the relative spatial geometry of the ship and station. These misread traveltimes have been re-read manually so far. Such procedure is no longer applicable for processing vast array of data obtained at newly installed over 20 GPS/A stations after the 2011 Tohoku-oki earthquake. The aim of this study is to develop fully automated algorithms for analyzing GPS/A data with high precision. We introduce here two algorithms.

1) We read the maximum peak in the observed correlogram and then deconvolve it by the synthetic correlogram. Then, we apply the same operation to the deconvolved waveform. This procedure is iterated until the correlation coefficient decreases lower than a pre-defined threshold. A true traveltine is defined as the fastest traveltine during the iterations.

2) We classify the observed correlograms into several groups based on their similarity through cluster analyses and choose a master waveform in each group. Then evaluate the traveltine residual between the maximum peak and the true peak in the observed correlogram. Thus obtained residual is applied as the correction value of each clustered group.

We also use a seismic data analysis tool to visually inspect whether above algorithms work properly. We confirmed that the both new methods properly correct for misreadings in the current method, which sometimes amount to several hundred microseconds. This corresponds roughly to a 0.3-m difference in the slant range. Therefore, with the new algorithms, significant improvement in the estimation of the station location is expected. However, both methods have to be assigned an arbitrary value as a threshold. Further analyses are needed to determine arbitrary threshold values and to construct fully automated algorithms.

Keywords: ocean bottom geodetic observation

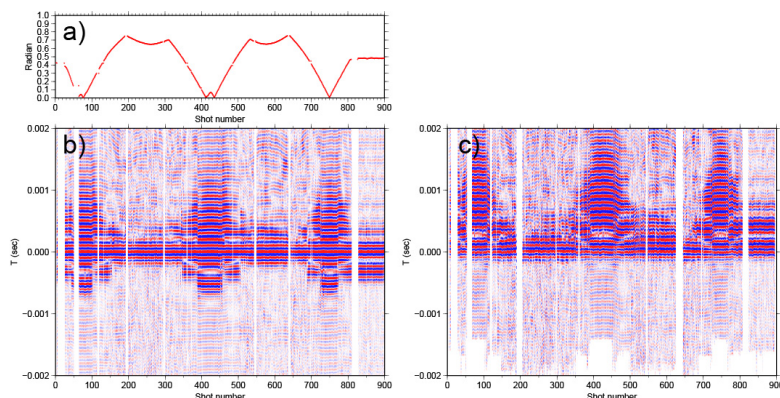


Fig. Incident angle of transmitted signals (a). Pasted correlation waveforms analyzed by reading maximum peak (b) and reading iteratively-deconvolved peak (c). Each trace was moved out by the observed traveltine.

A NaI spectrometer for long-term radon measurement at the sea floor

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In the Japanese Islands, the Tokai, Tonankai and Nankai earthquakes are expected within a few decades. It is a very important scientific issue to understand the physicochemical process occurring in the earthquake occurrence belt and the mechanism of earthquakes near the oceanic trench for damage mitigation of human lives and social basis. Increases of the radon concentration in atmosphere and in groundwater before earthquake are reported in the Southern Hyogo Prefecture Earthquake in 1995. In this research, gamma rays from radon daughter radionuclides at the sea floor will be continuously measured on the Kumanonada offing, where is the epicentral area of the expected Tonankai earthquake. The correlation between micro earthquakes and radon concentrations is also investigated to contribute the fundamental research on the response of the fluid in the crust corresponding to change of the crust.

Investigation on the gamma ray at the sea floor has been made only in a certain limited duration up to several hours while the submersible stays at the site for measurement. This time, a time variation of the gamma ray for several months is planned in order to investigate correlation between earthquakes and radon concentration. A battery drive type NaI spectrometer, which will be set on sea floor and can automatically record gamma ray, was designed. In this January it is almost constructed. A preliminary measurement is scheduled in February. After improvements of software and hardware, it will be set on spring water area of the Kumanonada offing from April to September, and will measure for more than about 4.6 months.

Specification of the NaI spectrometer for long-term radon measurement at the sea floor is as follows;

Name: Low consumed power type gamma-ray spectrometer for deep sea

PMT High-voltage : programmable (+1000V max)

Amplifier: Charge sensitive Memory Capacity: 1Gbit (NOR Flash)

Connection: RS-232C 921,600 bps Current: 110mA (on), 10mA (off)

Operation:

1. After initial setting with PC, measurement starts automatically, and records gamma-ray spectra.
2. It has the intermittent mode for electric power saving.
3. Battery Power Supply 30 AA alkaline batteries, 6 series, 9V
4. When the battery power supply voltage falls to 6V or spectral data is over memory capacity, measurement is suspended automatically and the battery power supply is disconnected.
5. It can connect with PC after measurement, and transfer the recorded spectra to PC.

Keywords: Radon, sea floor, long-term measurement, NaI

Time stamp experiment of MEMS-gyro for the observation of seafloor crustal deformation using multi-buoy system

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We are developing a new method for the observation of seafloor crustal deformation using multi-buoy system. The system measures seafloor crustal deformation by determining position of benchmarks on the seafloor using multi-buoy which link-up GPS and acoustic signals. Acoustic ranging is used to measure distance between the buoys and seafloor benchmarks. And kinematic GPS is used to locate the multi-buoy every 0.2 seconds. Now we have deployed 4 seafloor benchmark units at Suruga Bay and 4 units at Kumano Basin. At each survey site, three seafloor transponders are settled to define a benchmark unit. In November 2012, first observation of seafloor crustal deformation using the buoys was held in Suruga Bay. Analyzing observed data, errors of traveltime 's residual were about 0.2ms(Mukaiyama et al 2012JPGU). These errors were too large. From approximate calculation, it is predicted that these errors of 0.16ms at maximum can be removed by introduction of a gyro compass. So, we introduced MEMS-gyro to multi-buoy observation to monitor the attitude of the buoys at Suruga Bay at November 2013. The MEMS-gyro was NAV440CA by Crossbow Co.. For the attitude monitoring of the observation of seafloor crustal deformation, time stamp is important. Although the gyro introduces time stamp provided by its GPS processor, its accuracy was not evaluated. In this study, we conducted rotation experiments to evaluate the accuracy of its time stamp. In the experiment, we used another GPS antenna system as a time reference. The GPS antenna and the gyro were deployed on a rotation table to synchronize their motions and the time stamp of the rotated gyro was checked with reference to the GPS time. Timing between their motions was evaluated by cross correlation between GPS circular trajectory and the rotation angle of the gyro. Specifically, we rotated the table for 3 min every 1 hour. This subset was repeated 3 times. As a result, delay times in first two sets were about -38ms. But third set was -58ms. The delay became lager. Offset of the average angle between GPS and gyro was also deferent from first two sets to third set. This deference might be caused by that of rotation speed between three subsets. We tried additional experiment with different parameter settings of MEMS-gyro under controlled rotation speed. We will also report the result of this additional experiment.

Keywords: Seafloor crustal deformation, buoy, GPS, MEMS-gyro, Time stamp, Rotation experiment

Three year observations of ocean infragravity waves by broadband seismometers and pressure gauges of Japanese seafloor network

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Ocean infragravity (IG) waves are sea-surface gravity waves with periods of several minutes and wavelengths up to tens of kilometers. We used a slant-stack technique to detect IG waves from the three-year period records (2011-2013) of the vertical component broadband seismograms and pressure gauges of the seafloor network deployed in the Nankai Trough region (DONET). IG signals show good match in waveform between the seafloor displacement and pressure with propagation speeds consistent with the seafloor depths of 2000 m. The signal intensities are strongly azimuth-dependent. Except for the days with extreme weather, waves incoming from the SE direction (from the deep ocean to the coast across the Nankai Trough) are by far dominant. The incoming direction sharply splits into two, SSE and ESE. Waves from the deeper ocean in the SSE direction are more dominated in longer-period components than those from the shallower ocean in the ESE direction. Amplitudes of these waves clearly show a seasonal variation, high in winter and low in summer. The effect of typhoon is to generate IG waves incoming from the source direction and those incoming from the NE-ESE direction through the corridor between the coast and the Nankai trough. The latter is often stronger than the former.

Keywords: Infragravity wave, Nankai Trough, DONET

Evaluation of resolution and estimation error of vessel-based seafloor displacement observation using AUV bathymetry

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Bathymetry is basic information for any kind of seafloor observation, and therefore vessel-based multi-narrow beam bathymetric surveys are conducted quite often. In recent years, previous bathymetric data exist in most scientifically-important areas. A repeated bathymetric survey reveals seafloor displacement related to geodynamics [e.g. Fujiwara et al., Science 2011]. However, the spatial resolution and estimation error of the seafloor displacement observation from the vessel-based bathymetric survey are not exactly known. Because the observation compares a pair of limited-resolution bathymetric data. Water depth (distance from the vessel's echo sounder to the seafloor) degrades the spatial resolution and precision of depth measurement from the vessel-based survey. While on the other hand, a near-seafloor Autonomous Underwater Vehicle (AUV)-based survey enables us to obtain high-resolution bathymetric data. In this paper, we evaluated the spatial resolution and estimation error of the seafloor displacement observation from vessel-based bathymetric survey. In this evaluation, bathymetric data from vessel-based and AUV-based surveys in the Iheya-North knoll of the Okinawa Trough were used.

AUV Urashima bathymetric survey was conducted in YK07-07 cruise aboard the R/V Yokosuka in May 2007 [Yamamoto et al., 21st Mtg, Japan Society for Marine Surveys and Technology 2009]. The applied multi-narrow beam echo sounder was a SEABAT 7125. R/V Yokosuka bathymetric survey was performed using a SeaBeam 2112 echo sounder in YK06-09 cruise from 18 to 24 July 2006 [Masaki et al., JAMSTEC R&D 2011]. The vessel passed over the survey area six times with each constant speeds and obtained bathymetric data. One survey track was treated as one's independent survey in this evaluation. The beam angle (angle formed by the vertical line and a narrow sounding beam) was within 40° in the survey area.

AUV bathymetry shows hills (the shallowest depth ~870 m) in the western side and basins (the deepest ~1070 m) in the eastern side. The average/median depth is 1010 m. Hydrothermal chimney mounds ~30 m in diameter and ~10-20 m in height were found on the hillside in the high-resolution bathymetry. Vessel-based bathymetry is spatially-smoothed as a function of the footprint (area of the narrow sounding beam projected onto the seafloor) size. The footprint size of the Yokosuka survey at a depth of 1000 m is ~35×35 m-43×55 m (~5% of water depth). In the vessel bathymetry, geographical features smaller than the footprint size, such as the hydrothermal chimney mounds, cannot be recognized. And seafloor morphology is slightly different from each other track surveys due to distribution of sounding points and measuring error. Standard deviations of depth differences between the AUV- and the vessel-based data were 2.67-3.08 m. The AUV bathymetry are assumed to be the "true" bathymetry, and therefore the precision of the vessel-based depth measurement (standard deviation of measuring error) is considered to be ~0.2-0.3 % of water depth.

Simulated vessel-based bathymetric data "before and after" the seafloor displacement were made using AUV-based bathymetric data. The displacement was verified by comparing these simulated data using the analysis conditions that neither depth accuracy variation within the area nor locational errors of beam sounding points are allowed. We used the method of Fujiwara et al. [2011] to estimate horizontal displacement. As a result, we found that estimation error of the seafloor horizontal displacement depends on the precision of the depth measurement and is ~0.2-0.3 % of water depth. As for the seafloor vertical displacement, the smallest displacement that can be detected occurs when the horizontal extent of the deformation is larger than several times the size of the footprint, and in the situation that the amplitude of the depth difference is greater than the precision of depth measurement.

Keywords: Multi-narrow beam bathymetry, seafloor displacement, Iheya-North knoll, AUV Urashima, R/V Yokosuka

Bathymetric survey and discovery of hydrothermal plume in the Daiichi-Amami Knoll using autonomous underwater vehicle

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Many submarine volcanoes exist along the volcanic front in the Ryuku Arc. The Daiichi-Amami Knoll, which is located about 70 km off Amami Oshima Island, is one of those submarine volcanoes. Detailed bathymetric survey of this knoll has not been done before, therefore its shape and size have not been known. Japan Coast Guard conducted a high resolution bathymetric mapping of the knoll using survey vessel and autonomous underwater vehicle (AUV) and discovered hydrothermal plumes which are rising from the seafloor, indicating that the presence of hydrothermal activities in the Daiichi-Amami Knoll.

1. Method

The survey was conducted in August and September, 2013 using survey vessel Takuyo and AUV Gondo. The knoll was surveyed with multibeam echo sounder (MBES) installed on S/V Takuyo. Then the detailed survey was done with MBES on AUV Gondo.

2. Bathymetry

The bathymetry of the Daiichi-Amami Knoll indicates that the knoll is a volcanic high. The knoll has flat areas, a caldera with a diameter of 1.6 km and some volcanic cones at its summit. The knoll also has two small depressions near to the volcanic cones and they are deeper about 40 m than the surrounding areas. The relative high of the knoll is about 500 to 700 m and the shallowest depth of the knoll is 245 m.

3. Hydrothermal plume

Water column data acquired by MBES on S/V Takuyo detected the clear hydrothermal plumes in the two depressions. The plumes were especially clear at the rim of the depression. Some plumes were observed to rise from the seafloor of 350 m depth to near sea surface (although no discolored water was visually observed on the sea surface). Plumes were also detected at the slope areas of the volcanic cones. AUV Gondo dived to the depressions at the altitude 40-50 m above seafloor and conducted a detailed survey. The high resolution bathymetric map shows a presence of a numerous small depressions near the plume points. The side scan image by AUV Gondo also shows the plumes acoustically at its nadir.

4. Water temperature

AUV Gondo observed the water temperature at the altitude 40-50 m in the depressions, but distinguished temperature increases were not observed. Temperature profile observation, which was conducted using expendable bathythermograph launched from S/V Takuyo, showed over 2 degrees temperature increase near the seafloor in the depression. This observation along with the presence of plumes indicate the presence of hydrothermal activity in the Daiichi-Amami Knoll.

5. Importance of this survey result

The detailed bathymetry and the presence of plumes in the Daiichi-Amami Knoll were revealed by the survey using survey vessel and AUV. The discovery of plumes suggests the presence of hydrothermal deposits and chemosynthetic community, therefore being important in terms of seafloor resources. The high resolution bathymetric map acquired by AUV is fundamental information which is useful for scientific research and mineral exploration. This result is a first step for further survey to understand the geological history of the knoll and to secure new seafloor resources.

Keywords: Daiichi-Amami Knoll, submarine volcano, plume, AUV, bathymetry

Topography, geology, tectonics and ore deposit of the Bayonnaise knoll caldera, Izu-Ogasawara arc

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Several hydrothermal sites have been discovered in the volcanic front of the Izu-Ogasawara arc: Myojin knoll caldera, Myojinsho caldera, Smith caldera, Suiyo seamount, and Kaikata seamount. The Hakurei hydrothermal site in the Bayonnaise knoll caldera is the only hydrothermal site discovered in the rift zone of the arc. We analyzed deep-sea multibeam and side scan sonar data obtained using autonomous underwater vehicle Urashima in the caldera and discussed the topography, geology, tectonics, and ore deposit of the caldera.

The survey area ~3 km x ~2 km wide covers the southern half circle of the caldera. Major geomorphic elements are, from the outside to the inside, the knoll slope, the steep caldera wall, the flat caldera floor, the central cone with three peaks, and the central depression surrounded by the peaks. The high-resolution bathymetric map shows that large slope failures occurred in the southeastern caldera wall and that the Hakurei deposit is distributed over the failure area. Slope failure is also going on in the southwestern wall and a large collapse may shortly occur. The eastern hill, the main part of the central cone, seems to be a lava dome: it has a small flat surface on the top, convex slopes in the upper part, and rectilinear to concave slopes near the base. The northeastern slope of the dome is relatively flat from top to bottom, indicating that a slope failure occurred there. A series of depressions lying in a NW-SE direction in the western caldera floor would be a crater row, seeing that the terrain gently slopes down from the rim of the depressions. The direction of the crater row suggests that the caldera is under the extension stress in a NE-SW direction.

Morphological and textural characteristics of the Hakurei site were determined by three kinds of analyses. The gray-level co-occurrence matrix was used to describe the texture of the side scan sonar image and to classify the seafloor using cluster analysis. The Hakurei area was distinctly classified to a group that was characterized by high entropy and low homogeneity, and a broad area from the top to the northeast slope of the eastern lava dome was also classified to the group. Some areas belonging to the group were distributed around the top of the southern central cone, in the eastern caldera wall northeast of the Hakurei site, in the southwestern caldera wall, and around the crater row. A band-pass filtered topography was used to determine areas where short-wavelength topographic features like chimneys and mounds observed in the Hakurei site dominate. The band-pass filtering was also performed on the multibeam backscattering intensity data to detect similar patterns to numerous spots of strong backscattering from chimneys observed in the Hakurei area. These results commonly show that areas of similar characteristics to the Hakurei site are distributed in a zone crossing the caldera in a NW-SE direction, from the Hakurei site to the crater row through the central cone.

The Izu-Ogasawara rift zone is separated to many segments ranging in a N-S direction. The Bayonnaise knoll caldera is located on the northeastern margin of an oval depression called the North Myojin rift, which has a longer N-S axis of ~20 km. It appears that the direction of the crater row, the distributions of hydrothermal or volcanic features, and the distribution of slope failures are along the rim of the North Myojin rift going through the caldera. The North Myojin rift is surrounded by seven knolls including the Bayonnaise knoll. Although hydrothermal activity has been discovered only in the Bayonnaise knoll so far, the geological settings that volcanoes of acidic rocks lying along a circular fault of a depression host ore deposits closely resembles that of the Hokuroku Kuroko region in northern Akita. It is suggested that the Hakurei site is the present field of the Kuroko ore formation.

Keywords: hydrothermal deposit, Izu-Ogasawara rift, multibeam sonar, side scan sonar, GLCM, Kuroko deposit

Electrical resistivity structure of the Snail site at the Southern Mariana Trough spreading center

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The electrical resistivity of the oceanic crust is sensitive to the porosity of the crust and the fluid temperature within crustal fractures and pores. The spatial variation of the crustal porosity and the fluid temperature that is related to a hydrothermal circulation can be deduced by revealing an electrical resistivity structure of the oceanic crust involving a hydrothermal site. We carried out a magnetometric resistivity experiment using an active source to reveal an electrical resistivity structure of the oceanic crust at the Snail site on the ridge crest of the Southern Mariana Trough. Active source electric currents were transmitted along and across the ridge axis in a 4000 m² area including the Snail site. Five ocean bottom magnetometers were deployed around the Snail site as receivers to measure the magnetic field induced by the transmission of the active source electric currents. The amplitude of the induced magnetic field was calculated by maximizing data density and the signal to error ratio in the data, and locations of the transmissions were determined using several types of calibration data. An optimal 1-D resistivity structure of the oceanic crust, averaged over the experimental area, was deduced by least squares from the data of the amplitude of the magnetic field and the location of the transmission. After calculating magnetic field anomalies, which are deviations of the observed amplitude from the prediction of the optimal 1-D resistivity model, an optimal 3-D resistivity structure was deduced from the magnetic field anomalies through trial and error 3-D forward modeling. The optimal 1-D resistivity structure is a two-layer model, which consists of a 5.6 Ω-m upper layer having a 1500 m thickness and a 0.1 Ω-m underlying half-space. Using Archie's law and porosity profiles of the oceanic crust, the resistivity of 5.6 Ω-m at depths ranging from 800 to 1500 m suggests the presence of high-temperature fluid related to the hydrothermal circulation. The resistivity of 0.1 Ω-m below 1500 m depth may represent a magma mush that is a heat source for the hydrothermal circulation. The optimal 3-D resistivity structure includes a conductive anomaly (0.56 Ω-m in approximately 300 m² area down to 400 m depth) just below the Snail site, two resistive anomalies (56 Ω-m with slightly larger volumes than the conductive anomaly) adjacent to the conductive anomaly on the across-ridge side, and three conductive anomalies away from the Snail site. The conductive anomaly just below the Snail site suggests hydrothermal fluid, and the adjacent resistive anomalies suggest areas of low porosity. The size and distribution of the conductive and resistive anomalies near the Snail site constrains the size and style of the hydrothermal circulation.

Keywords: electrical resistivity structure, temperature and porosity, oceanic crust, hydrothermal circulation, magnetometric resistivity method

Crustal Imaging of initial structure in Izu-Ogasawara forearc region obtained by seismic reflection survey

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The Izu-Bonin (Ogasawara)-Mariana (IBM) arc is known to be the typical oceanic island arc, and it is the most suitable area to understand the growth process of island arc. The existence of two paleo arcs which consist of Oligocene and Eocene paleo arcs is known in the IBM forearc region by geological and geophysical studies. The Ogasawara ridge is also known to be the initial structure of arc evolution from geologic sampling of research submersible. In this region, IODP drilling site: IBM-2 is proposed in order to understand the temporal and spatial change in arc crust composition from 50 to 40 Ma magmatism. Site IBM-2 consists of two offset drilling holes (BON-1, BON-2). BON-1 is designed to first encounter forearc basalt and will reach the sheeted dykes. BON-2 will start in boninites and finish in fore arc basalts. The purpose of these drillings is sampling the full volcanic stratigraphy from gabbro to boninite. This drilling project is already scheduled in 2014. The survey lines along the proposed sites, however, there are no existing seismic data around BON-1 and BON-2. Therefore, it is necessary to conduct the MCS survey until 2013 for the evaluation of proposed site.

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) newly carried out multi-channel seismic reflection (MCS) survey using 7,800 cu.in. air gun, 5 km streamer with 444 ch hydrophones in April, 2013. We obtained two seismic reflection profiles of lines IBr11n and IBr11 across from Shikoku Basin and current volcanic front to the paleo arc. The preliminary results show the distribution of volcanic sediments and basement. We also identified the block type structure associated with the uplift in northern side of Kinyo seamount. We will discuss about the characteristics between backarc and forearc from north to south.

Keywords: MCS survey, IBM forearc, initial arc structure

Across-arc geochemical variation of Quaternary Basalts dredged from central part of Izu-arc

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The Izu-Bonin arc located western margin of the Philippine sea plate extend to ca. 1200 km south from central Honshu of Japan with ca. 400 km width. The Izu-Bonin arc is a match for NE Honshu arc (Nishimura and Yuasa, 1991). Although volcano lying on the volcanic front (VF) of northern part of this arc expose above the sea level (e.g. Izu Oshima, Miyakejima), almost this arc sink down to sea surface. Active rifts (AR) exist just behind VF with 20-30 km width. These are parallel to the VF and Izu-Bonin Trench and enclosed with escarpment. Ishizuka et al. (2003b) reported Ar-Ar age of igneous rocks dredged from central part of Izu-Bonin arc. According to these age data, recent volcanism (<1Ma) occurred only VF and AR. In this study, we report geochemical data of basalt dredged from Myojin volcano, Myojin rift and Aogashima rift. Basalts exhibit evident across-arc variations. Ba/La ratio, Sr, Nd and Hf isotopic ratios decrease correspondingly distance from Izu-Bonin trench toward rear-arc. Whereas (La/Sm)_N increase correspondingly distance from Izu-Bonin trench. Based on ratios of trace elements and each isotopic feature, we conclude that VF basalts generated from flux melting of mantle due to adding aqueous fluid to wedge mantle from subducting slab. On the other hand, genesis of AR basalt is to supply supercritical melt (e.g. Kessel et al. 2005) of slab to wedge mantle. Chromian spinel composition, Cr# of inferred chromian spine equilibrated with mantle is 0.75, held in olivine of VF basalt suggest that residual mantle equilibrated with VF primary magma is dunite. Degree of partial melt of AR basalt decrease correspondingly distance from Izu-Bonin trench toward rear-arc. Tollstrup et al. (2010) interpreted magma genesis of basalt after cessation of Shikoku back-arc basin. They proposed that basalts of western seamount chain (WS) and back-arc knolls (BAK) derived from partial melting of mantle due to adding supercritical melt to mantle wedge from subducting slab, whereas aqueous fluid contributed to partial melting of mantle beneath AR and VF. In their discussion, activity age and activity region are not considered. According to their conclusions, supercritical melt related to genesis of basalts from WS and BAK is not contribute to partial melting of mantle wedge recent volcanism (<1Ma). Bryant et al. (2003) revealed that VF basalt volcanism has continued since 15Ma. Moreover, Ishizuka et al. (2003b) reported volcanism has traveled eastward with time in the central Izu-Bonin arc. It means Izu-Bonin arc volcanism has become narrow range with time. Distinct slab flux between VF and AR in this study suggest that occurrence of supercritical melt is traveling with time toward VF side due to change subducting angle of slab into more steep angle since 15Ma to 3Ma (Honda et al., 2007). Therefore supercritical melt related to genesis of basalt from WS and BAK at predate volcanism contribute to AR recent volcanism.

Keywords: basalt, Izu-Bonin arc, geochemical across-arc variation, Myojin seamount, Aogashima rift, Myojin rift

The variety of silicic rocks around the Myojin volcano, central Izu-Bonin arc

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The Izu-Bonin arc located western margin of the Philippine sea plate (PSP) extend to ca. 1200 km south from central Honshu of Japan with ca. 400 km width. The Izu-Bonin arc is a match for NE Honshu arc (Nishimura and Yuasa, 1991). Active rifts (AR) exist just behind volcanic front (VF) with 20-30 km width. These are parallel to the VF and Izu-Bonin Trench and enclosed with escarpment. Generally primitive basalts possibly erupted at oceanic arc volcano without any process in the oceanic crust due to be thinner than continental crust. Although it is well known that Izu-Oshima and Miyakejima, located on VF, erupted basalts, Kouzushima, Niijima and Myojin reef are represented volcanoes which provide mostly felsic products exist on the Izu-Bonin arc VF (Tamura et al., 2009). Nowadays extensive seismic experiments in the Izu-Bonin arc have documented the occurrence of middle crust with P-wave velocity of 6.0-7.0km/s (e.g. Suyehiro et al., 1996). Because of the rock, with P-wave velocity of 6.0-7.0km/s, correspond to tonalite exposed Tanzawa complex Izu collision zone and tonalitic xenoliths in the volcanic rocks sampled VF, inferred middle crust of Izu-Bonin arc composed of tonalitic igneous rocks (Suyehiro et al., 1996). In this study, our aim is to understand mechanism of felsic volcanism contribute to making continental crust. Therefore we consider about felsic rocks dredged from Myojin volcano, Myojin rift and Aogashima rift.

Felsic rocks in this study are divided into three suites (type 1, type 2, type 3) on the basis of Zr/Y versus Zr diagram. Type 1 is lowest Zr/Y ratio trend, type 3 exhibit highest Zr/Y ratio and type 2 have intermediate Zr/Y ratio. Type 1 occur mainly VF, and small amount of type 1 appear AR. Type 2 collected overall from VF to AR. Type 3 occurs only AR.

Although Sr and Nd isotopic compositions of type 1 is similar to the basalt from the VF, Hf isotopic compositions of type 1 differ from VF basalt, and Hf isotopic compositions of type 1 is same as mafic xenoliths in VF lava rather than VF basalt. Isotopic features of type 2 are distinguished from lavas erupted normal-arc magmatism after cessation of Shikoku basin. And isotopic features of type 2 dredged from more AR-side have higher Nd, Hf isotope ratios. Although Sr and Nd isotopic compositions of type 3 is similar to the basalt from the AR, Hf isotopic compositions of type 3 differ from AR basalt, and isotopic compositions of type 3 is different from lavas erupted normal-arc magmatism after cessation of Shikoku basin and tephra data from ODP boring (Straub et al., 2010).

On the basis of Na₂O vs ASI diagram, three type felsic rocks in this study agree with compositions of experimental liquids which derived from basaltic source materials (e.g. Sission et al., 2005). There is possibility that felsic rocks derived from associated basalt. But because of Hf isotope ratio, all felsic rocks are not derived from associated basalt. Therefore all felsic rocks, provided by recent volcanism, are rejuvenated products of old arc crust.

Because of isotopic compositions of type 1 are similar to mafic xenoliths in VF lava, type 1 derived from remelting of arc crust which have postdate VF basalt composition (Bryant et al., 2003). Although There is possibility that type 2 derived from remelting of Oligocene mafic arc crust, type 2 dredged from more AR-side have higher Nd, Hf isotope ratios. It suggests that AR-side type 2 is possibly affected by PSP. Geochemical data which is similar to type 3 have been found out in previous ODP boring data, and it is possible exist crustal material which is peculiar to AR. We long for IODP projects which start at this year to accumulate new AR crustal material data to consider source of type 3. We propose heterogeneous crust model. It have made by underplating or intrusion of mafic magma derived from mantle into PSP for 50Ma.

Keywords: acidic rock, Izu-Bonin arc, Myojin volcano, Myojin rift, Aogashima rift

General remarks of velocity structures of the Ogasawara Plateau, revealed by the Continental Shelf Survey of Japan

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Japan Coast Guard conducted seismic refraction surveys with OBSs and multi-channel seismic surveys over more than 10 survey lines on the Ogasawara Plateau which is located on the Pacific Plate, close to a plate boundary to the Philippine Sea Plate. Analysis of these seismic data in 2006-2007 revealed that 1)the Ogasawara Plateau collide and partly accreted with the Philippine Sea Plate, 2)crustal thickness of the Ogasawara Plateau is approximately 25 km, close to that of the Izu-Ogasawara Arc, and 3)low velocity structure in lower crust extends below flat seafloor to the south-east to the plateau.

Recently, re-analyzing of the data by utilizing various later phases and MCS profiles revealed more detailed velocity structure of 1')plate boundary between the Pacific Plate and the Philippine Sea Plate, 2')under plating below the Ogasawara Plateau and 3')low velocity structure distributing around the plateau.

Keywords: velocity structure, Ogasawara Plateau, seismic experiment

Acoustic characterization of abyssal plain, northwestern Pacific region

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The old seafloor covered by pelagic sediment has not attracted large scientific attention and remained untouched for many years, however, the recent studies on intra-plate volcanism as well as the increasing interest in deep-sea natural resources focus spotlight on the abyssal plains. We analyzed the multi-beam bathymetry, beam intensity, and side-scan images of abyssal plain in the northwestern Pacific, around the Minami-Torishima (Marcus) Island. The data were collected by Japan Coast Guard as part of Japanese EEZ survey and by R/V Yokosuka for decades. The beam intensity data from multi-beam echo sounder were processed to create a backscatter mosaic without geometric distortion. The mosaic shows a large variation of acoustic characteristics in whole study area. The high backscattering areas at the foot of large seamounts likely reflect the distribution of volcanoclastic sediments and debris. We can also recognize another type of high backscattering areas in flat seafloor, where neither remarkable seamounts nor knolls exist. The latter type partly corresponds to the area where the high concentration of rare-earth elements were reported and may suggest a thin cover of uppermost soft sediment layer. We try to integrate the backscattering mosaics and the statistic analysis of bathymetry and to establish a new method of acoustic characterization of abyssal plain. We also plan to compare our results with piston core samples as ground references and to discuss the sedimentation process and the relationship with intra-plate volcanism on old seafloor.

Keywords: marine acoustics, muti-beam echo sounder, backscattering intensity, abyssal plain

Spreading stability at the mid-ocean ridges derived from 3D magnetic survey

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The Shipboard Three Component Magnetometer (STCM) has provided vector data of the geomagnetic field provided detailed information more than total magnetic force measurement. Previous study shows the results about relationship with ocean floor topography and standard deviation of magnetic boundary strike (MBS) calculated from Intensity of the Differential Vectors (ISDV) in Southeast Indian Ridge (SEIR) classified intermediate spreading rate. In this study, the standard deviation of MBS and half spreading rate were analyzed from STCM data in East Pacific Rise (EPR) of fast spreading ridge, Explorer Ridge (ER) and Southeast Indian Ridge (SEIR) classified intermediate spreading ridge and Mid Atlantic Ridge (MAR) categorized as slow spreading ridge. In EPR existing axial high, the results shows that standard deviation and half spreading rate are stable in west of EPR whereas standard deviation and half spreading rate are variability in east of EPR. However standard deviation is low and spreading rate is stable on both sides in MAR developed axial valley. Thus there is no relationship with topographic features and spreading of stability. Additionally, standard deviation of MBS is the low although half spreading rate has variability in ER. The results show differential MBS at the same position in SEIR. As a result, dispersion of MBS is caused by inaccurate measurements of magnetic anomaly. In addition, there is no clear relationship though the simulation was run about plate reconstruction. Therefore spreading stability is controlled by the balance among plate reconstruction, slab pull and magma provided from mantle.

Keywords: mid-ocean ridge, spreading rate, 3D magnetometry

Detailed bathymetry and magnetic anomaly in Central Ryukyu: Implications on westward shift of volcanic front after 2.1Ma

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Detailed bathymetry and magnetic anomaly were obtained by GH12 cruise in 2012 using R/V Hakurei, in the southern part of Central Ryukyu. Volcanic structures such as caldera were observed on the southwestward extension of the present-day volcanic front, implying recent volcanic front of the Ryukyu arc. Furthermore, bathymetric highs which are sub-parallel to the recent volcanic front were observed and is located ~20 km east. These are accompanied by spotted magnetic anomalies, which continue to Kume-jima via Aguni-jima Islands to the south, suggesting an existence of an ancient volcanic front. The ages of volcanic rocks from these Islands suggest that the magmatic activity along the ancient volcanic front had been active at least until ~2.1 Ma. The magmatic anomalies connecting two volcanic fronts suggest that a volcanic front have moved gradually westward. This shift would be explained by the termination of asthenospheric upwelling and/or rapid retreat of Ryukyu Trench.

Keywords: Ryukyu arc, Volcanic front, Okinawa Trough, magnetic anomaly, seafloor bathymetry

Evolution of depositional basin accompanied by recurring caldera collapses in Kikai caldera, southern-off Kyushu, Japan

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Kikai caldera (Matsumoto, 1943) is a mostly submerged highly active caldera volcano located in 40 km off Kyushu Island. The caldera is recognized as the product of 7300 cal. BP super-colossal eruption with Akahoya tephra (Machida and Arai, 1978; Fukuzawa, 1995) which is widely distributed along the western part of Japan. Previous studies for near-vent onshore geology strongly suggests such a large eruption was not occurred only once, but multiple times in the Kikai caldera (Ono et al., 1982).

In Kikai caldera, 24 lines of multi-channeled seismic reflection surveys were held in two survey cruises (KT-10-18 and KT-11-11) in 2010 and 2011 using R/V Tansai-maru of JAMSTEC (Japan Agency for Marine-Earth Science and Technology). The acquired seismic data for subseafloor structures spotted thick sedimentary basin at the eastern margin of the caldera. The basin covers 70 square km of the 20 km-wide caldera and is next to caldera rim fault. The infill of the basin is characterized by the group of onlapping stratified deposits named B which maximum thickness is more than 600 m. The B-sequence has two major depositional discontinuities in the middle and the top. The lower one is paraconformity and the upper one is disconformity though, the both of them are associated with similar deformation of the basin itself. The deformation is characterized by 1. Dragged-up reflectors along the caldera rim fault, and 2. Slight outward rotation of the deposits. Both characteristics intensify along the depth, which means lower deposits were experienced much more deformation.

The both two types of the deformation suggest the basin was experienced at least two major subsidence event. The former dragged-up structure is interpreted as the incomplete slip of the caldera rim fault for the relief of the subsidence, while the latter rotation shows the slippages were slightly listric. The displacements of the subsidence events could be estimated from the top and bottom of the dragged-up structures, as more than 100 m in the lower-older event and more than 50 m in the upper-newer event. The subsidence would be an abrupt event, as the paraconformity was formed in the lower-older event. The most likely candidate for such a significant subsidence is caldera collapse. As therefore, the basin might be the one of the pre-caldera structure, and it has been experienced multiple caldera collapse events in the past.

Keywords: caldera, seismic reflection survey, Kikai caldera, Akahoya

Estimates on fluid migration and material recycling via offshore mud volcanoes

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About 300-400 offshore mud volcanoes are currently confirmed and the double is inferred. Mud volcanism can be viewed as a tectonic window to understand geological frameworks at much greater depth, since mud volcanoes bring up deep substances and fluids to seafloor and are consequently good tools to explore their migration mechanism. Herein we present a global catalog of offshore mud volcanoes and estimate their contributions to subsurface fluid migration and material recycling.

Keywords: Submarine mud volcanoes, fluid migration, material recycling, overpressure

New Marine Sediment Core Database "COEDO"

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Japan Agency for Marine-Earth Science and Technology (JAMSTEC) established basic policies on the handling of data and samples (http://www.jamstec.go.jp/e/database/data_policy.html). On the basis of the policies, JAMSTEC provides data and samples in an easily accessible manner. Data and sample information of geological sediment core has been published at "JAMSTEC Core Data Site" since 2008. In order to improve quality and usability, we reconstructed and released new database in January 2014.

Details of the new database are shown below:

<Name>

COre Electronic Database of Ocean floor (COEDO)

<URL>

<http://www.godac.jamstec.go.jp/coedo/e/>

<Search Method>

Multiple-filter search using interactive map and basic information filters (Cruise ID, date, location etc.)

In the previous version of the database, users have to take longer steps to reach sample information, because only one of two methods (map search for general users and Cruise ID list menu for science parties) were available. In COEDO, all users can search samples by multiple filters in a single step on a single window.

<On-line accessible data>

Basic information of sediment core (Cruise ID, date of collect, chief scientist, ship name, position, depth), core photo, scanned image, visual core description, X-ray photo, X-ray scanned image, physical property data, literature, link for geochemical data.

We are planning further updates to improve the usability, as follows:

1. Acquiring information of sedimentary ages of core, and making them easily accessible on the database as numerically searchable information.
2. Integration with sample inventory information of JAMSTEC core sample collection, which is currently available at the Kochi Institute for Core Sample Research.
3. Publishing other data, which have not been incorporated into the database yet.

We aim not only improving services to current users, but also making effort to propagate the user community. JpGU and Yokohama city government have a special geological training course for junior/senior high school students at Keio University High School in Yokohama city on April 13. JAMSTEC cooperates with the training course, and provides lecture and practices using actual database and real core samples. In the training course, trainers give lectures on how to obtain marine sediment core onboard and how to study core sample data in COEDO, then trainees observe the actual core samples for which they have just pick up the associated data on the database. The course stimulates trainees' interest and curiosity on the geological study, and we can nurture the new generation. As a result of this cooperation, we can hopefully increase educational users of JAMSTEC core samples.

Keywords: JAMSTEC, marine sediment core, database, ocean floor, piston corer, geology

Geological Annotation for the Deep-Sea Images

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The Global Oceanographic Data Center (GODAC) of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been collecting, archiving and disseminating videos and photos acquired by deep-sea research programs using submersibles and remotely operated vehicles owned by JAMSTEC. We register those videos and photos to our database with annotations (keywords), which are names of geological features or organisms, and enable users to search for images of their interest. Those videos and photos with annotations are distributed from the data site called, " JAMSTEC E-library of Deep-sea Images (J-EDI)*1 " on the Internet.

Researchers of deep-sea can use the videos and photos distributed by J-EDI as materials for their research or lecture, and also for planning of research cruises or dives, etc. Through the database for marine biodiversity, " Biological Information System for Marine Life (BISMaL)*2 " , biological annotations are used to visualize the distribution of organisms or to accumulate the observation record of them, since those videos and photos of deep-sea organisms are not only valuable data, but also indicate the proof of existence of organisms at those points.

We put annotations which can be recognized from the images itself by clicking icons from the prefixed palette or selecting classification name from hierarchical tree. The videos and photos with annotations concerning to the ocean floor geoscience are 41,000 with 95 different kinds of terms out of approximately total 120,000 videos.

To promote the use of deep-sea videos and photos especially in the solid earth science we tried to register more detailed annotations by using scientific papers, reports or documents about research dives and we found that registration of precise annotations takes considerable time. In order to progress the annotating work efficiently we think it necessary to select contents of annotations that lead to an efficient expansion of its use.

In this presentation, we introduce the current status of annotating work for the geological features of the deep-sea and we also show our approach to expand its use.

*1 <http://www.godac.jamstec.go.jp/jedi/>

*2 <http://www.godac.jamstec.go.jp/bismal/>

Keywords: deep-sea video and photo, geological environments, annotation