Uncertainty of vertical positioning of seafloor geodetic observation

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The Hydrographic and Oceanographic Department of Japan Coast Guard has been developing a system for precise seafloor geodetic positioning with the GPS-Acoustic combination technique and deploying seafloor observation sites on the landward slope of the major trenches around Japan, such as the Japan Trench and the Nankai Trough.

For the precise GPS-Acoustic seafloor positioning, we are developing analysis software, which combines a kinematic GPS result and an observed acoustic travel time to get a precise position of an array of seafloor stations. In this analysis, vertical coordinates of seafloor stations and the sound velocity are not completely independent. Therefore vertical coordinates are influenced by the error of sound velocity and in consequence their accuracy is more deteriorated than that of horizontal coordinates.

In this presentation, we present a new analysis strategy for precision improvement.

Keywords: Seafloor geodetic observation, GPS-Acoustic combination technique

Accuracy of GPS-Acoustic seafloor geodetic observation evaluated by numerical simulation

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Hydrographic and Oceanographic Department, Japan Coast Guard (JHOD), has been carrying out seafloor geodetic observations with the GPS-Acoustic combination technique (GPS-A), in order to detect a displacesment of a focal area of the interplate earthquake. For example, we detected coseismic displacements, long-term interseismic and postsesmic deformations [e.g., Sato et al., 2011]. However, insufficient frequency of the observation (a few times per year) prevents us from detecting the short-term deformation due to slow slip events and time-dependent postseismic effects. Therefore, it is necessary to improve the accuracy and/or frequency of the observation under the condition of limited ship-time. For the purpose of improving the frequency, we tested the alternative survey lines to optimize the accuracy and geometrical simplicity simultaneously, using pseudo GPS-A data generated by the GPS-A simulator [Yokota et al., 2016]. This simulator can generate the pseudo observation data sets with any errors and obtain the pseudo positions of seafloor transponder by inversion analysis.
In this presentation, we report the results of the accuracy of the alternative survey line, comparing the results using actual observation data.

Keywords: seafloor geodetic observation, GPS-Acoustic combination technique

Analytical method of seafloor crustal deformation corresponding to the large-scale ocean current region

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We monitor seafloor crustal deformation at two observation points (north and south of Nankai Trough (TCA and TOA)) across the Nankai Trough, Japan, from 2013 to 2015. A warm ocean current flows frequently above our points called the Kuroshio current that has temperature difference perpendicular to the flow axis down to 1000 m in depths. Sound speed in the water depends on temperature [Del Grosso, 1974]. Determination of seafloor benchmark position has a bias when the sound speed structure includes a horizontal inhomogeneity in large-scale ocean current area. This bias is caused by trade-off between estimated spatial-temporal variation of sound speed structure and seafloor benchmark position. In this study, we propose a new analytical method adopted a horizontal inhomogeneity of sound speed structure.
We use the following equation to adopt the horizontal inhomogeneity model: $S(X,x,z)=S_0(z)+dS(A(z)\times \tan(q(X,x)-R(X))$, $S(X,x,z)$ where is the spatial variation of slowness but spatial variation is the uniform during the observation period, $S_0(z)$ is the reference sound speed structure from CTD observation, dS is the rasio of slowness variation of horizontal direction, $A(z)$ is the vertical distance between seafloor benchmark and z, $q(X,x)$ is angle of incidence from each benchmark, $R(X)$ is the horizontal distance of the seafloor benchmark position from gradient axis, x is the ship position, and X is the benchmark position, z is the depth of the horizontal inhomogeneity. The gradient axis and magnitude (parameter dS) can be estimated by the travel time residual derived from Ikuta et al. [2008] analysis method (Yasuda et al., 2015 in SSJ fall meeting). The characteristic of the horizontal inhomogeneity appears as the sine curve in three benchmarks in the travel time residual. The gradient axis and magnitude can be estimated by the initial phase and amplitude of three sine curves, respectively. The gradient parameters derived from the travel time residual are low precision. Therefore, we decide gradient parameters when the residual sum of squares becomes minimum by performing a grid search in the range of an error.
We observed four times at TCA and TOA stations, respectively. Kuroshio current flowed above observation point at all epoch. We carried out this new analysis at all epoch of TCA and TOA. As a result, the direction of the fastest speed of sound is south -southeast direction all observation. This direction is consistent with flow direction of the Kuroshio current. RMS of the travel time residual decreases at most 0.027 ms at TCA station on May 2015. RMS of the seafloor benchmark position in conventional analysis and this analysis decreased 40.1 cm in NS component and increased 0.9 cm EW component at TCA station. In TOA station, RMS decreased 38.3 cm and 16.7 cm in NS and EW component, respectively. The bias was largely improved by the analysis of this study.

Keywords: Seafloor crustal deformation, Kuroshio, Nankai Trough

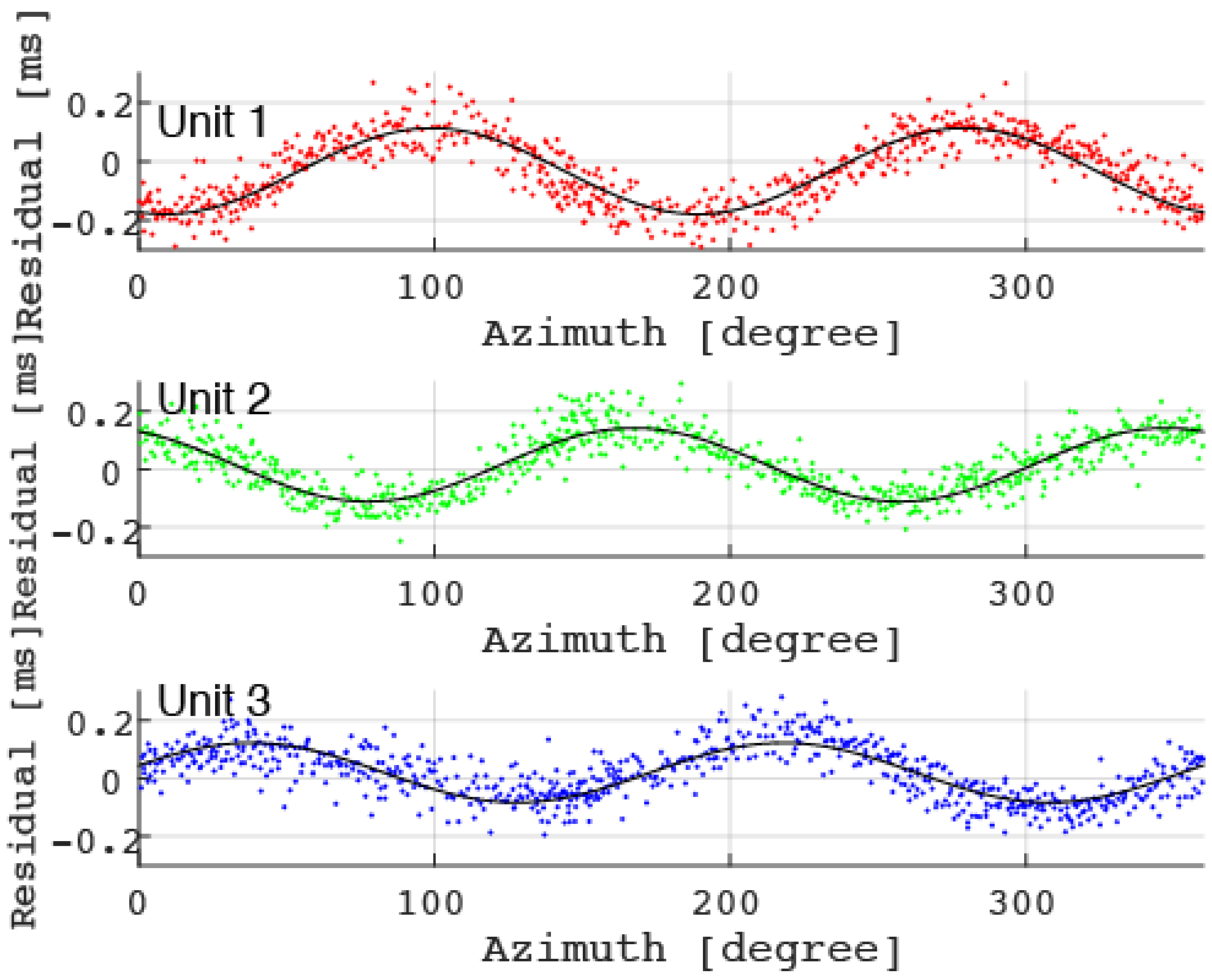

Figure 1. Travel time residual of TCA observation at May 1 2015. Solid line is the curve fitting by Yasuda et al. (2015) in SSJ fall meeting.

Seafloor Crustal Deformation Measurement at the Nanseisyoto Trench

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The occurrence potential of subduction-zone earthquakes has never been evaluated for the Nanseisyoto Trench because characteristics of earthquake occurrence remain obscure. In addition, Nakamura [2009] pointed out that the 1771 Yaeyama Tsunami, Southern Ryukyu Islands, Japan, was caused by subduction earthquake along the Nanseisyoto Trench; and it is necessary to understand the interplate coupling along the Nanseisyoto Trench. Although geodetic data are useful to grasp interplate coupling, it is difficult to deduce interplate coupling along the Nanseisyoto Trench only from the GPS network data on the Ryukyu islands because the trenchward motion of the Ryukyu Arc that is associated with the active backarc spreading along the Okinawa Trough. Nakamura [2011] measured seafloor crustal deformation at site RKA to the southeast of the Okinawa Island; and reported a full-coupling region beneath RKA with widths of about 50 km. In this study, we installed a new site RKB, in 2011. The site RKB is located about 70 km northeast of RKA and 53 km from the Nanseisyoto Trench axis. The water depth at RKB is about 2200 m. We performed seafloor crustal deformation observation four times in 2001, 2012, 2014, and 2015, using R/V Tonanmaru of Okinawa Prefectural Fisheries Research and Extension Center.
The four-years measurement revealed a site velocity at RKB, 6+/-22 mm/yr to the south and 2+/-26 mm/yr to the east with respect to GEONET Kamitsushima station on the Amurian Plate. The velocity is significantly different from that at RKA, 35+/-23 mm/yr to the north and 30+/-19 mm/yr to the west Nakamura [2011], indicating difference in interplate coupling beneath the two sites. The crustal deformation field along the Ryukyu Arc is affected by the backarc spreading along the Okinawa Trough [Nishimura et al., 2004], slow-slip events [Nishimura, 2014], and back-slip caused by the interplate coupling. The back-slip rate at RKB is calculated at 24+/-25 mm/yr in a northwest direction relative to stable Amurian Plate, resulting 0-20 % of interplate coupling rate beneath RKB from a forward modeling. The low coupling rate is consistent to an active strain release events, such as slow-slip events, very low frequency earthquakes [Tu et al., 2010], and trust-type earthquakes, around RKB. Our observation demonstrates less strain accumulation caused by plate convergence, in the hanging wall side at RKB. We plan to install a new site on the seafloor about 90 km southwest of RKA site in 2016.
Acknowledgement: This work was partly supported by Council for Science, Technology and Innovation (CSTI), Cross-ministerial Strategic Innovation Promotion Program (SIP), "Enhancement of societal resiliency against natural disasters" (Funding agency:JST).

Keywords: Nanseisyoto Trench, Seafloor Crustal Deformation, Interplate Coupling

GNSS/Acoustic measurement conducted on “Source region” of the 1771 Yaeyama Tsunami -Is huge inter-plate earthquake being prepared there?-

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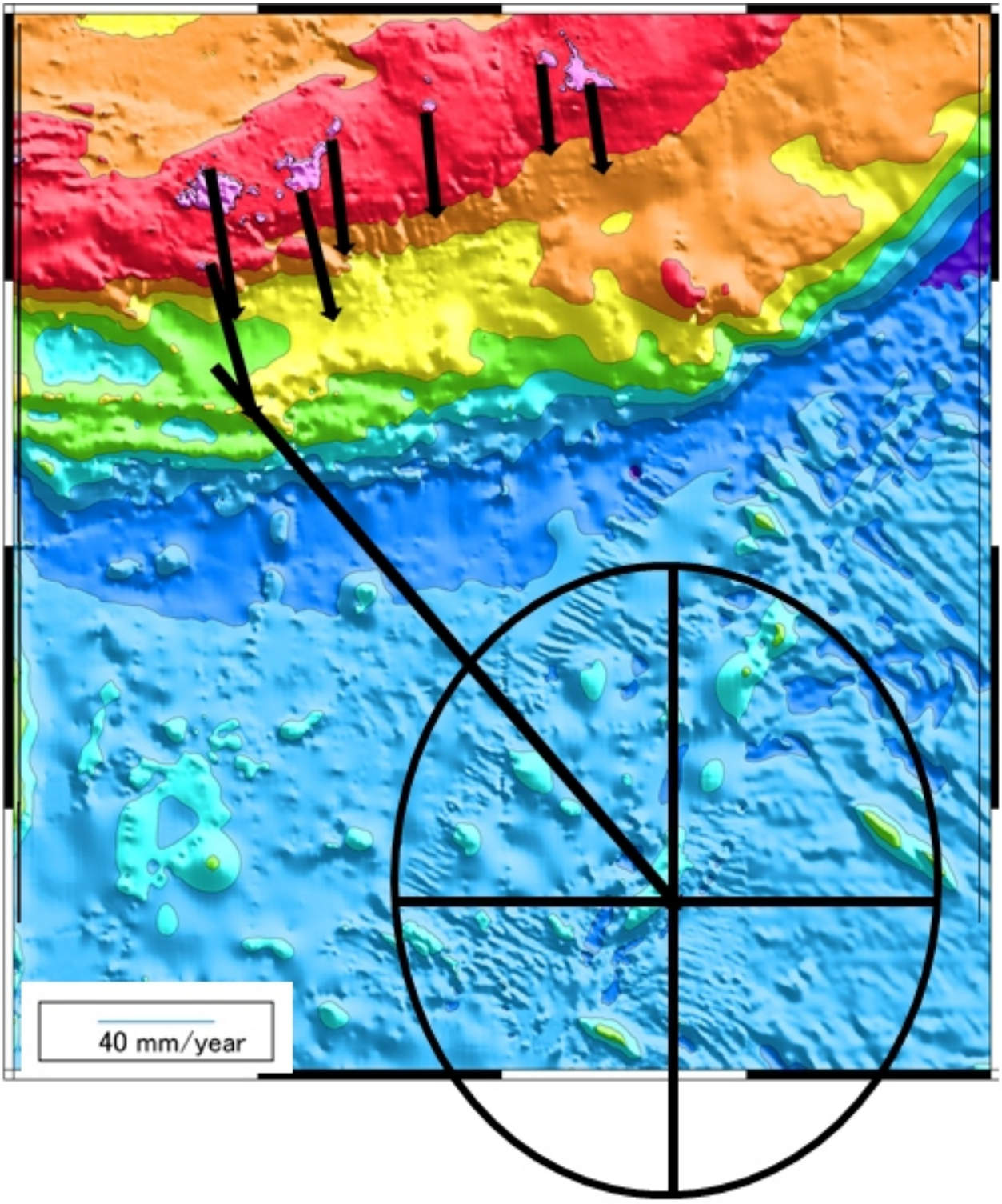
We have conducted GPS/Acoustic measurement at 60 km south to the Hateruma Island. In there, a huge Tsunami struck Yaeyama Islands along west Ryukyu trench in 1771. A huge inter-plate earthquake beneath Ryukyu trench is proposed as the source mechanism of the Tsunami (Nakamura, 2009). If this is the case, the proposed focal area should be coupled in the inter-seismic period. Therefore, we installed a GPS/Acoustic benchmark unit on the proposed focal area in October 2014 and conducted measurement twice with 9 months interval. We obtained about 3,000 and 4,000 available acoustic shots during 24 hours and 30 hours measurements in 2014 and 2015, respectively. As a result, the benchmark showed southeastward displacement of 12±8 cm/yr during the 9 month interval with respect to the GEONET station on Hateruma Island, which suggests trench-normal extension of the Hateruma forearc basin.
Although the result is preliminary because we have conducted measurement only twice, the result suggests that the area is not accumulating compressional strain which causes huge inter-plate earthquake. Additional measurements may also reveal offshore motion of the trench and the mechanism of back arc spreading.
Nakamura, M. 2009a, Fault model of the 1771 Yaeyama earthquake along the Ryukyu Trench estimated from the devastating tsunami. *Geophysical Research Letter*., 36, L19307, doi:10.1029/2009GL039730.

Keywords: Yaeyama Tsunami, GPS/Acoustic geodesy, Ocean bottom crustal deformation



Seismic characteristics around the Kerama Gap in the Nansei-Shoto (Ryukyu) Island arc

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The Nansei-Shoto (Ryukyu) Island arc is generally divided into three parts based on topography, geology, biology and other characteristics. The most significant boundaries are the Tokara Gap between the Tokara and Amami Islands in the northern arc, and the Kerama Gap between the Okinawa and Miyako Islands in the southern arc. Other than the two gaps, some large topographical saddles along the island arc characterize the Nansei-Shoto Island arc. We carried out seismic refraction and reflection surveys to investigate seismic structure around the Kerama Gap, which gives us key information to consider the tectonic evolution of the Nansei-Shoto Island arc-backarc system. Two seismic profiles, ECr25 and ECr31, are designed to cross the Kerama Gap and Miyako Saddle in the southern arc and forearc regions.

Line ECr25 along the forearc has a length of 415 km from the Nansei-Shoto (Ryukyu) Trench at the southwestern end, through the Miyako Saddle, to the Kerama Gap at the northeastern end. Multi-channel seismic (MCS) profile reveals many normal faults in the shallow sedimentary layer below the Kerama Gap and some faults reach to the seafloor, which suggests the deformation is in progress at the present time. The MCS record also shows clear reflection signals from the top of the subducting Philippine Sea plate. The depth of the plate boundary was estimated to be around 15 km below the forearc region from the reflection and refraction measurements. The ECr25 P-wave velocity (Vp) model reveals the top of 4-5 km/s layer is much shallower in the forearc regions to the southwest of the Kerama Gap, where higher free-air gravity anomaly and lower seismicity are different from other region.

Another line ECr31 with a length of 228 km was planned to be located along the Nansei-Shoto Island arc and cross the Miyako Saddle at the southwestern end and the Kerama Gap at the northeastern end. The MCS record for ECr31 show many normal faults beneath the Miyako Saddle and Kerama Gap, which indicates extensional regime along the island arc. Several conspicuous and almost continuous reflectors with small normal faults are detected at 1-2 s below the seafloor of the Miyako Saddle. On the other hand, some reflectors beneath the Kerama Gap are rather discontinuous due to large offsets of the normal faults, which indicates larger deformation in this region.

Vp model of ECr31 reveals a typical island arc structure. Although the thickness of the middle crust with Vp of 6.1-6.5 km/s varies along the seismic line, the variation seems to be independent of the positions of the Kerama Gap and Miyako Saddle. Therefore, the topographical deformation may not reach to the depth of the middle crust. We estimated the Moho depth of around 30 km from PmP arrivals. Some reflection signals from deeper than the Moho are also observed and they may reflect at the top of the subducting Philippine Sea plate or at its oceanic Moho. Traveltime mapping of these signals results in many scattering reflectors and it is difficult to determine the depths of deeper reflectors precisely.

Keywords: Nansei-Shoto (Ryukyu) Island arc, Kerama Gap, marine seismics

Creep rate measurement and fault modeling at the North Anatolian Fault, beneath the Sea of Marmara, Turkey, by means of acoustic ranging

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The North Anatolian Fault (NAF) is the strike-slip fault that passes 1200 km length through the Northern Turkey having about 20 mm/yr of right-lateral motion in average. In the past 100 years, the fault sequentially ruptured from east to west. In 1999, two earthquakes occurred at Izmit (M7.4) and Duzce (M7.2) adjacent to the Sea of Marmara, the south of Istanbul, where it remains unruptured. Because NAF is under the sea, we cannot directly observe its motion by using GNSS or other space geodetic tools. To reveal the strain rate and fault structure of NAF in the Sea of Marmara, we use “direct path acoustic ranging” in this study.
The acoustic ranging can detect relative motion across the fault with millimeter-level precision for 1 km baseline. We installed five instruments at so-called the Western High across the NAF. Round trip time is recorded every 6-hours. At the same time, in-situ temperature, pressure (for sound speed), and tilt (for attitudes) were also recorded. These data can be recovered on-demand through acoustic modem from a ship.
In this talk, we present the ranging data from September 2014 to July 2015. At first, we evaluate sound velocity. Observed temperature variation was quite small (~0.007℃) close to the instrumental resolution, so we applied a polynomial fitting to get smooth variation. Pressure correction was applied only during the first half period, because it was not available due to instrumental failure in the second half. Without pressure correction, small scatter remains in the apparent range, which does not much affect the creep rate determination, though. After correcting instrumental attitude and baseline angle to the fault line, we obtained 4-8 mm/yr of right-lateral motion. Because such extremely large strain rate is unlikely, we consider the observed 4-8 mm/yr movement at the Western High along the NAF is “creep” in the shallow crust out of 20 mm/yr of regional block motion. We will also talk about the fault structure modeled using additional onshore GNSS data.

Acknowledgement: This observation is carried out in the MarDiM, SATREPS promoted by JICA/JST

Keywords: direct path acoustic ranging, the North Anatolian Fault, GNSS, fault modeling, seafloor geodesy

Detailed spatial distribution of microearthquakes beneath the Sea of Marmara, Turkey, deduced from long-term ocean bottom observation

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The North Anatolian Fault (NAF) crosses the Sea of Marmara in E-W direction, accommodating about 25 mm/yr of right-lateral motion between Anatolia and the Eurasian plate. There are many large earthquakes along the 1500 km long NAF repeatedly occurred and interacted each other. The recent large northern Aegean earthquake with Mw=6.9 filled one of the last two seismic gaps along NAF that experienced extraordinary seismic moment release cycle during the last century and confirmed a remained blank zone in the Sea of Marmara. However, this segment keeps its mystery due to its underwater location. Earthquake hazard and disaster mitigation studies in Marmara region are sensitive to detailed information on fault geometry and its stick-slip behavior beneath the western Sea of Marmara. We have started ocean bottom seismographic observations to obtain the detailed information about fault geometry and its stick-slip behavior beneath the western Sea of Marmara, as a part of the SATREPS collaborative project between Japan and Turkey namely MarDiM project “Earthquake and Tsunami Disaster Mitigation in the Marmara Region and Disaster Education in Turkey”. The target area spans from western Sea of Marmara to offshore Istanbul along the NAF. In the beginning of the project, we deployed ten short period Ocean Bottom Seismographs (OBSs) between the Tekirdag Basin and the Central Basin (CB) in September 2014. Then, we added five short period OBSs and deployed them in the western end of the Sea of Marmara and in the eastern CB to extend the observed area in March 2015. We retrieved all 15 OBSs in July 2015 and deployed them again in the same locations after data retrieve and battery maintenance.
From continuous OBS records, we could detect more than 700 events near the seafloor trace of NAF during 10 months observation period whereas land-seismic network could detect less than 200 events. We estimated the micro-earthquake locations using manual-picking arrival times incorporating station corrections. The tentative results show heterogeneous seismicity. The Western High (WH) and CB have relative high seismicity and the seismogenic zone was found to be thicker than the previous estimations done by other researchers. Our result clearly shows that the maximum depth of seismogenic zone is about 24 km beneath the WH and the western half of CB, and this depth suddenly decreases to about 15 km in the eastern half of CB. Our results also suggested that the dip angle of NAF is almost vertical or northward beneath WH, whereas it is about 80 degrees southward beneath the eastern CB and perhaps further decreases to 60 degrees towards the Kumburgaz Basin. These results suggest that some structural or frictional segment boundary is located around 28°E in the middle of CB.

Keywords: Ocean bottom seismographic observation, Sea of Marmara, Seismicity distribution

Along-trough variations and characteristics in the shallow crustal structure of the incoming Philippine Sea Plate at the Nankai Trough

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The Shikoku Basin which produced during 30-15 Ma by backarc spreading of Philippine Sea Plate is subducting to Nankai Trough at the northern margin. It is important to reveal the characteristics of crustal structure of incoming Phippine Sea Plate for understanding the mechanism of large earthquake in Nankai seismogenic zone, the great tsunami event is also known for occuring along the Nankai Trough. In order to reduce a great deal of damage to coastal area from both strong ground motion and tsunami generation, it is necessary to understand rupture synchronization and segmentation of the great Nankai earthquake. We focus on the recent deformation structure in and around the axis of Nankai Trough. However, there are few seismic lines of legacy surveys across the Nankai trough axis. High-resolution seismic reflection surveys have been conducted around Nankai Trough by Japan Agency for Marine-Earth Science and Technology after 2011 in order to image the detailed structure near tough axis. Obtained seismic profiles indicate the many reflectors and faults in the sediments of the Shikoku Basin. We mapped the horizons identified from seismic profiles such as the top of oceanic crust, lower Shikoku Basin facies, upper Shikoku Basin facies, trough-fill sediments in the Shikoku Basin. The well-stratified turbidite deposits are recognized off Kii Peninsula. We will present the incoming crustal characteristics about the western Shikoku Basin, middle Shikoku Basin and eastern Shikoku Basin from our mapping results.
This study is part of ‘Research project for compound disaster mitigation on the great earthquakes and tsunamis around the Nankai Trough region’ funded by MEXT, Japan.

Keywords: MCS Survey, Shikoku Basin, Philippine Sea Plate

The crustal structure of the Ojin-Rise Seamounts, North Pacific.

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Ojin-Rise Seamounts is located between Shatsky Rise and Emperor Seamount Chain. The main portion of Shatsky Rise was formed by impact of the mantle plume head after 148 Ma (Nakanishi et al., 1999). Shatsky Rise consists of three plateau, TAMU, ORI, and Shirshov massifs. The radiometric ages of drilling samples of the three massifs are about 144 Ma for TAMU, 134 Ma for ORI, and about 128 Ma for Shirshov, respectively (Geldmacher et al., 2014; Heaton and Koppers, 2014). The seafloor age around Orin Rise Seamounts is estimated to be 134-125 Ma (Nakanishi et al., 1999). The geophysical measurements (bathymetry, gravity and geomagnetism) and rock sample sampling were conducted in 2014 summer (R/V KAIREI cruise, KR14-07). We therefore present the crustal structure of the Ojin-Rise Seamounts based on the analysis of bathymetric and gravity data.
We use multibeam bathymetric data obtained in KR14-07 and bathymetric grid data reported by Sager et al. (1999) and free-air gravity anomaly data by Sandwell and Smith (2009). We have estimated the oceanic crustal thickness using the method by Kuo and Forsyth (1988) and the state of isostasy and effective elastic thickness using the admittance analysis by McKenzie and Bowin (1976).
Our result shows that the crustal thickness beneath the Ojin-Rise Seamounts is about 12 km, which is two-times thicker than the normal oceanic crustal (e.g., 6 km). The effective elastic thickness is calculated to be about 2.6 km. The state of isostasy is Airy type. We conclude that the Ojin-Rise Seamounts was formed near the spreading ridige about 134-125 Ma. The timing of the formation is close to that of Shirshov Massif, impling that the same volcanic activity might form both Shirshov Massif and Ojin-Rise Seamounts.

Keywords: Ojin-Rise Seamounts, Shatsky Rise, admittance analysis, gravity, bathymetry feature

Estimation of thick crustal distribution of the Ontong Java Plateau

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The Ontong Java Plateau (OJP), which is the largest oceanic plateau on Earth, has an area of 1.86 x 10^6 km^2 (Coffin and Eldholm, 1994), five times Japan's area. Scientific drilling on the OJP has shown that ages of basement basalts below sediments are approximately 120 million years (Ma) (e.g. Shipboard Scientific Party, 2001), suggesting that formation of the OJP was geologically brief. No formation mechanism yet proposed explains all observations. Crustal structure is important for understanding the formation mechanism of oceanic plateaus, and geophysical experiments have been conducted on the OJP since the 1960s. However, only a few experiments addressed the whole crust, i.e., everything above the Moho (e.g. Furumoto et al., 1976, Gladczenko et al., 1997). The Moho depth of the southernmost OJP colliding with the Solomon Islands is about 35 km (Miura et al., 2004). However, the Moho depth of the central OJP has not been determined confidently because of discrepancies in results among different survey methods. In 2010, we conducted a seismic experiment on the central OJP using a large volume airgun array, 100 ocean bottom seismometers (OBS), and a 6 km multi-channel seismic (MCS) streamer cable (Miura et al., 2011). We analyzed the OBS data using a forward modelling approach (Miura et al., 2013), a traveltime inversion approach (Fujie et al., 2013) using first arrival and Moho reflection phases (PmP) with the uncertainty outlined by Korenaga (2011), and a finite-difference amplitude method (Larsen and Grieger, 1998) for reflection phases (Miura et al., 2014, 2015). From these analyses, the Moho depth of the central OJP exceeds 40-km below sea level. To estimate the distribution of the Moho depth or crustal thickness of the OJP outside of the 2010 survey area, we will analyze wide-angle data collected in 1998 by scientists aboard RV *Hakuho-maru* (Araki et al., 1998) and previous results (e.g. Furumoto et al., 1976, Gladczenko et al., 1997) to calculate crustal volume and formation rate. These will contribute to resolving the mechanism(s) by which OJP formed and to assessing the environmental impact of formation.

Keywords: LIPs, OJP, MCS, OBS, crust, Moho

Electrical conductivity structure suggests no plume beneath the Tristan da Cunha hotspot in the southern Atlantic Ocean

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Tristan da Cunha Island is one of the classical hot spots in the Atlantic Ocean, situated at the western end of the aseismic Walvis Ridge which forms a connection to the Cretaceous Etendeka flood basalt province in northwestern Namibia. The discussion about its source (in shallow asthenosphere or deeper mantle) have not reached consensus yet because of lack of the geophysical observations in the area. A marine magnetotelluric (MT) experiment was conducted together with seismological observations in the area in 2012–2013 through a German-Japanese collaboration with the goal to constrain the physical state of the mantle beneath the area. A total of 26 MT seafloor stations were deployed around the Tristan da Cunha Islands and available data were retrieved and processed from 24 stations. We applied iterative topographic effect correction and one-dimensional (1-D) conductivity structure inversion to the data. Then, we conducted three-dimensional (3-D) inversion analysis incorporating the topographic effect, using the 1-D model as the initial model. The local small-scale topography and the far continental coast effects are incorporated as the distortion term in the 3-D inversion. The preliminary result of our analysis shows no evidence of a significant conductive anomaly arising from the mantle transition zone, suggesting that the current magmatic source (major place of melting) of the hotspot activity is in the shallow upper mantle. This is in contrast to results from geochemical analysis, in which samples along the Tristan track exhibit an ocean-island-basalt-type incompatible element pattern pointing to a deep mantle source of the melt. Our findings therefore might indicate that the deep mantle up-welling underneath Tristan da Cunha Islands may be almost dead. A conductive anomaly at about 100 km depth in our derived conductivity model to the southwest of Tristan da Cunha Islands may be as the result of an interaction between the mid-ocean ridge and/or up-welling further south, e.g., beneath the Gough Island, which is the other termination of the Walvis Ridge and shows clearer geochemical evidence for a plume source. This conductor bulges upward beneath a fracture zone just south of the Tristan da Cunha islands. It may suggest that the fracture zone can be a path that melt can transport from the asthenosphere to the seafloor (maybe the islands nearby) although the anomaly was not clearly imaged in upper 20 km depths.

Keywords: marine magnetotellurics, electrical conductivity, upper mantle, hotspot, fracture zone, Atlantic Ocean

Red relief image map and integration of topographic data in and around the Japan Sea

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In recent years, we conducted marine seismic surveys in the Japan Sea with the research vessels of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). In these surveys, high quality bathymetric data by the multi-narrow beam echo sounder have been obtained simultaneously with navigation of vessels. In this report, we describe about red relief image map and DEM (Digital Elevation Model) data which are created by the integration of topographic data in and around the Japan Sea.
We used various accuracy and/or scale data, such as J-EGG 500m gridded data, digital bathymetric contour data (M7000), and GEBCO 2014 30arc second grid data, in addition to multi-narrow beam data. To remove noises from enormous point cloud data, we applied ground filtering algorithms of aerial Lidar processing system. And to check for errors, like artificial irregular peak pits, visualized data by red relief image map. Corrected bathymetric data and land elevation data are gridded by spline interpolation, and jointed to a sheet of DEM dataset compilation at 0.0005 degree resolution.
Created red relief image map from corrected DEM dataset are easily understandable sea floor feature, such as fold structure, volcano, and submerged valley. This bathymetric data and visualizing are beneficial to understand active faults and folds, seismicity, and crustal structure in the Japan Sea.

Keywords: Japan Sea, Bathymetric data, Data integration, Red relief image map, DEM

Huge deep-sea landslide in the Southern Mariana Trench: a preliminary report of 6K-1429 dive

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We have identified a huge deep-sea landslide structure in the Southern Mariana Trench. DSV Shinkai 6500 dive 1429 investigated this structure during YK15-11 cruise of R/V Yokosuka. In this contribution, we will have a preliminary report of the dive and discuss the origin of this structure.

Keywords: Southern Mariana Trench, deep-sea landslide, serpentinized mantle peridotite

Sedimentary structure of muddy turbidites recorded in a terminal basin

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Paleoseismic records of subduction zone are very important to mitigate great earthquake disaster. Terrestrial and marine archive analyses are necessary in order to gain long-term paleoseismic records in contrast to historical documents and ruins. Especially, marine sediments contain high quality pinpoint paleoseismic records because we can locate sampling sites close to epicenters. In order to obtain paleoseismic records from turbidite deposits, the samples should be carefully taken from the site without direct input of terrestrial sediments since turbidity currents are also derived from floods. Because such samples are dominant in fine-grained materials, we have to distinguish fine-grained turbidites from hemipelagic mud. The primary focus of this study is to understand the characteristic of sedimentary structure of seismogenic muddy turbidites already identified by the previous study. The second focus is to carry out detailed analytical and observational analysis of a longer sediment core collected at the same location and discuss the possible scenarios for the seismogenic turbidite distribution.
The samples used in this study include a 46 cm-long multiple core and a 6.7 m-long piston core which were collected from the sedimentary basin southeast off Kii Peninsula during the KS-14-8 R/V “Shinsei Maru” cruise. The sampling site is located at the ENE-WSW elongated basin between the accretionary prism and the Kumano forearc basin without terrestrial sediment supply. The basin exhibits “a terminal basin” that captures all sediments supplied from outside. From the multiple core sample, the Cs^{137} and Pb^{210} concentration indicate that the muddy sediment layer in the upper 17 cm was formed by the 2004 off the Kii Peninsula earthquake. We conducted visual observation, X-ray CT images, anisotropy of magnetic susceptibility (AMS), paleomagnetism, rock magnetism, electrical resistivity measurements and grain size analysis on both the cores.
Muddy seismogenic turbidite observed at the upper 17 cm of the multiple core have thick homogeneous clay layer above the silty lamination. The sequence beneath the muddy seismogenic turbidite shows various orientations oblique to the bedding plane suggesting shaking deformations during the 2004 earthquake. The magnetic susceptibility decreases upwards in the laminated zone. This specific feature suggested that the muddy turbidity current slowly decelerated and settled down the slope. Paleocurrent estimated from the paleomagnetic and AMS measurements is consistent with the slope orientation of the terminal basin. These characteristic features are also recognized in the piston core. From tephra chronology and radiocarbon dating of foraminifera, the interval of the probable seismic event layers almost matches the recurrence time of the known past earthquakes of the Nankai Trough area. In conclusion, the terminal basin is likely to hold most records of past seismic events in this region. Further age determination is required for understanding of the earthquake event history off Kii Peninsula.

Keywords: turbidity current, anisotropy of magnetic susceptibility, X-ray CT, event deposit

Late Neogene to Quaternary turbidite deposition in the northern Japan Basin and its relation to regional tectonics

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Many fine-grained turbidite beds occurred in core at Site U1422 of IODP Expedition 346 on the northeastern Japan Basin. Turbidite sediments contain much feldspar, suggesting grain supply of volcanic materials from the Japanese island arc. Muddy turbidite disappears at around 1.7 Ma. Stepwise decreasing of sedimentation rate at around 1 and 0.6 Ma also reflects the change of uplift mode of the Okushiri Ridge. Both change of turbidite deposition and of sedimentation rate in the northeastern Japan Basin margin might reflect the regional tectonics along the eastern margin of the Japan Sea.

Keywords: turbidite, Eastern margin of Japan Sea, tectonics

Sedimentation of iron deposits in Nagahama Bay, Satsuma Iwo-jima Island:Precipitation behavior of colloid

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Satsuma Iwo-Jima Island, with volcanic activities, is located about 40km south of Kyushu Island, Japan. This island is one of the best places to observe a shallow water hydrothermal system. Nagahama Bay, in the south of Satsuma Iwo-Jima Island, is partly separated from open sea. The seawater appears dark reddish brown color due to colloidal iron hydroxide by the mixing of volcanic fluids (pH=5.5, 50-60 degree Celsius) and oceanic water (Ninomiya & kiyokawa, 2009; Kiyokawa et al., 2012; Ueshiba & kiyokawa, 2012). Very high deposition rate (33 cm per year) of iron-rich sediments was observed in the bay (Kiyokawa et al., 2012). However, precipitation behavior of colloidal iron hydroxide has not been clarified. In this study, I report the results of analysis of deposition experiments of the colloidal particles at the Nagahama bay.

Since the size of the colloidal particles is 1nm~1μm, single particle cannot be precipitated. This arise from precipitation of the particles in the viscous fluid is according to the Stokes' law. Colloidal iron hydroxide has the property of having the electric charges on the surface. The charge on the colloids is affected by pH of its surrounding seawater and can become more positively or negatively charged due to the gain or loss, respectively, of protons (H+) in the seawater. This property affects the stability of the colloidal dispersion.

FE-SEM observation shows that the suspended particles consist of colloidal iron hydroxide (about 0.2μm), on the other hand, the iron-rich sediments are composed of bigger one (>1 μm). This indicates the colloidal iron hydroxide is precipitated by flocculation. We examined the precipitation amount of colloidal iron hydroxide under the various pH environments. The precipitation amount of pH=7.8 seawater 10% higher than that of pH=7.2. This result is roughly follows the theoretical value.

Keywords: Kikai Caldera, Colloid, iron hydroxide

Preliminary results of the CK16-01 Cruise: Scientific drilling operations of coring, in-situ thermometer and geothermal logging tool

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The CK16-01 Cruise by D/V Chikyu was performed at the Iheya-North Knoll and Noho Site, middile Okinawa Trough from 11th, February to 17th, March 2016 in order to investigate the subseafloor hydraulic structure and geology, aiming to construct the genetic model of seafloor hydrothermal deposits. In the first half of the CK16-01 Cruise, logging while drilling (LWD) was mainly done to obtain physical parameter beneath the Iheya-North Knoll and Noho Site, as well as install of the “Kuroko-ore cultivation apparatus” equipped with sensor loggers to monitor the secular changes of pressure, temperature, flow rate and precipitation weight within the Kuroko-ore cultivation apparatus on artificial hydrothermal vents. This Kuroko-ore cultivation apparatus will be recovered after one year by ROV Kaiko Mk-IV. In the latter half of the CK16-01 Cruise, the main operation was coring to obtain drilled core sample together with temperature measurement by in-situ thermometer and borehole logging after coring operation using a geothermal tool bearing pressure, temperature, flow rate and gamma-ray sensors. In this presentation, we report the preliminary results of operations during the latter half of the CK16-01 Cruise.

Keywords: Okinawa Trough, Iheya-North Knoll, Noho Site, seafloor hydrothermal deposit, Kuroko deposit, CK16-01 Cruise

Preliminary results of the CK16-01 Cruise: Scientific drilling in Okinawa Trough using Logging While Drilling tools and installation of long-term monitoring apparatus

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In the period of February to March of 2016, the CK16-01 Cruise by D/V Chikyu was performed at the Iheya-North Knoll and Iheya Minor Ridge in middle Okinawa Trough, in order to investigate the subseafloor hydraulic structure and geology, aiming to construct the genetic model of seafloor hydrothermal deposits under an umbrella of Cross-ministerial Strategic Innovation Promotion Program (SIP). In the former half of the cruise, logging while drilling (LWD) operation was mainly performed to obtain physical parameters beneath both the area, as well as to install of the Long-term monitoring apparatus, "Kuroko-ore cultivation apparatus", equipped with sensors to monitor the secular variation of pressure, temperature, flow rate and precipitation weight within the apparatus on hydrothermal vents artificially made. The precipitation volume of the apparatus will be recovered later to by ROV. In the latter half of the cruise, the main operation was coring to obtain drilled core sample together with temperature measurement by in-situ thermometer and borehole logging after coring operation using a geothermal tool bearing pressure, temperature, flow rate and gamma-ray sensors. In this presentation, we report the preliminary results of operations during the former half of the CK16-01 Cruise.

Keywords: Okinawa Trough, Iheya-North Knoll, Iheya Minor Ridge, Seafloor hydrothermal Deposit, CK16-01 Cruise, Cross-ministerial Strategic Innovation Promotion Program (SIP)

Acoustic and magnetic surveys using AUV Urashima around the hydrothermal sites off Kumejima island in the Mid-Okinawa Trough

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Recently, polymetallic sulfides deposited in seafloor hydrothermal vents have attracted interest as a potential mineral resources for e.g., Cu, Zn, Pb, In, Ga, Ge, Au, and Ag (Schrope, 2007). Development of effective methods for exploring seafloor hydrothermal activity is an important key for future exploitation of this type of deep-sea mineral resource and thus, more efficient methods for exploration of seafloor hydrothermal vents are expected.
Recent progress in near-bottom geophysical and geochemical surveys using autonomous underwater vehicles (AUV) allows us to perform high-resolution surveys in which the signatures of seafloor hydrothermal activity can be detected (German et al., 2008; Kumagai et al., 2010; Nakamura et al., 2013). Moreover, in the last decade, water column observations using multi-beam echo sounder (MBES) systems equipped on a surface ship have also become successfully applied to exploration of seafloor hydrothermal vents (Tanahashi et al., 2014; Kasaya et al., 2015; Nakamura et al., 2015).
During the YK15-14 cruise in 2015, we conducted the shipboard MBES survey by R/V “Yokosuka” and the near-bottom acoustic and magnetic surveys using AUV “Urashima” around the hydrothermal sites in order to reveal the distribution and characteristics of seafloor hydrothermal vent sites off Kumejima island in the mid-Okinawa Trough. The presence and amplitude of hydrothermal plume signals were first detected by acoustic water column imaging with a shipboard MBES system. A total of four AUV “Urashima” dives (Dives #217-220) were completed around the sites. During these dives, we have successfully obtained high-resolution bathymetric data, side scan sonar image, sub-bottom profile, vector magnetic field and chemical sensor data (ORP, turbidity and temperature). The vector magnetic field were measured by three fluxgate magnetometers mounted in the payload space of AUV “Urashima” to investigate the seafloor magnetic features related to hydrothermal alteration processes. The distribution of crustal magnetization are estimated using the magnetic anomalies by the inversion method. Here we report the overview of the YK15-14 cruise and show new results from AUV “Urashima” dives. Then, the characteristics of the hydrothermal sites in the mid-Okinawa Trough will be discussed by comparing with the results from the ROV surveys during the KR15-16 cruise.

Keywords: seafloor hydrothermal exploration, mid-Okinawa Trough, AUV, detailed bathymetry, magnetic anomaly

High-resolution Magnetic Signatures of Irabu Hydrothermal Fields, Okinawa Trough

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Near-seafloor magnetic fields near the active Irabu Hydrothermal fields (IHFs) were obtained by using the AUV *URASHIMA* during the R/V *Yokosuka* cruise YK14-16. The Irabu knolls are located on the axial area of a back-arc rift of the Okinawa Trough and consist of basalt to andesite. The seafloor rock samples from the same region were used for rock magnetic measurements and petrological observations. The integrated analysis of the magnetic anomaly and rock magnetic properties led to the following conclusions:

(i) The IHFs are associated with reduced magnetization reflecting the hydrothermal alteration of magnetic minerals present in the extrusive lavas and the deposits of non-magnetic hydrothermal material.

(ii) The basaltic rocks show high natural remanent magnetization (NRM) intensity ranging from 7 A/m to 214 A/m. The extremely strong NRM was caused by less oxidation, abundant single-domain-titanomagnetite grains formed under proper crystal growth rates, and low Ti content for titanomagnetites. These strongly magnetized host rocks produce large variations of magnetic anomalies in the Irabu knoll, resulting in a clear magnetic contrast between the IHFs and their surroundings areas.

(iii) The low magnetization zones (LMZs) related to the IHFs are located at the rim of the caldera floor in an elongated direction parallel to the local strike of the caldera, and extend into the caldera wall. These observations suggest that the hydrothermal fluids ascended through the caldera fault and caused accumulation of hydrothermal deposits and the occurrence of hydrothermally altered zones in both the caldera floor rim and wall.

(iv) The LMZ extends across several hundred meters along the caldera rim. Compared with similar hydrothermal fields of the Hakurei and Brothers situated in other arc-back-arc volcanoes with summit calderas, it is clarified that hydrothermal systems controlled by caldera faults have horizontal spatial scale equal to or larger than those of detachment-controlled large hydrothermal fields at slow-spreading ridges such as the TAG. It is implied that the permeability structure and style of hydrothermal circulation may play important roles in the formation of the larger demagnetized hydrothermal fluid pathways at caldera-controlled systems.

Keywords: Seafloor hydrothermal system, Marine magnetic anomaly, Rock magnetics, Okinawa Trough

Spatio-temporal scale of seafloor hydrothermal systems: Constraints from borehole and seafloor observations in the Mid-Okinawa Trough

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Drilling, submersible, and surface data suggest that an enormous hydrothermal reservoir with a horizontal extent of ~1500 m lies beneath the Iheya-North hydrothermal field. Heat flow exceeds 10 W/m2 within ~500 m of the Active Site, where active chimneys vent high-temperature fluid. At the Active Site, drilling encountered high-density (hard) layers 1–2 m thick and up to 90 m below seafloor (mbsf), and drilling through these layers led to hydrothermal fluid emission. Measurements of thermal and chemical discontinuities strongly suggest that a hydrological barrier confined the hydrothermal fluid below.
Eastward in the Western Basin, heat flow was up to 0.5–1 W/m2, substantially higher than the regional average (0.1 W/m2), although the surface morphology showed no sign of hydrothermal activity. Farther east, where the seafloor was flat but rough, surface heat flow values, including at IODP Site C0017, were much lower than in the surrounding area. Subbottom temperatures above 40 mbsf at Site C0017 indicated that the heat flow was consistently as low as the surface values (0.03 W/m2), but temperatures increased to 80 °C below 60 mbsf.
We used a 2-D time-dependent hydrothermal circulation model and performed simulations with and without the assumption of a hydrological barrier below the area from the Active Site to Site C0017. Simulations with a hydrological barrier with permeable windows below the Active Site and Site C0017 reproduced the observed hydrothermal conditions between 30 and 300 years after reservoir emplacement. Simulations assuming pure conduction or a continuous barrier could not reproduce the observed conditions.

Keywords: heat flow, Okinawa Trough, IODP, hydrothermal circulation

Post-caldera volcanism and hydrothermal activity revealed by AUV surveys in Myojin Knoll caldera, Izu-Ogasawara Arc, Japan

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Myojin Knoll caldera is one of submarine silicic calderas lying on the volcanic front of the northern Izu-Ogasawara arc and has attracted increasing attention since the discovery of a large hydrothermal field called the Sunrise deposit. Although many detailed surveys using a manned submersible have been conducted in Myojin Knoll caldera, they have explored too limited areas to draw a complete picture of the caldera and the Sunrise deposit. We carried out deep-sea surveys using an autonomous underwater vehicle (AUV) and obtained high-resolution bathymetric and magnetic data and sonar images covering ~70 % of the caldera. Besides post-caldera volcanism in the central cone, it was revealed that volcanic eruptions have commonly occurred in the caldera wall. Regular or irregular mottled patterns are ubiquitous in sonar images from the caldera floor, and those in the northwestern floor correspond to areas Mn precipitation was confirmed by a submersible survey. The Sunrise deposit lies in the foot of the caldera wall and is mainly composed of three ridges growing straight in the sloping direction. Only slight reduction in magnetization is observed in the deposit area, suggesting a dipping alteration zone beneath the Sunrise deposit. Preferential magma intrusion along a NW-SE direction was inferred from the distribution of high magnetization in the central cone and may play a major role in the occurrence and evolution of the Sunrise deposit in the southeastern caldera wall.

Enhanced and asymmetric melting beneath the southern Mariana back-arc spreading ridge, influenced by the subduction of the Pacific plate

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The southern Mariana Trough has distinct features from the remain of the Trough, such as slow seafloor spreading but axial high topography, gravitationally low anomaly and thick crust, slow crustal seismic velocity under the ridge influenced by slab-derived water, lack of currently active subaerial arc volcanoes but signatures of slab-derived or arc components in rocks sampled on and off the ridge axis. These features suggest enhanced melting beneath the ridge and the influence on the back-arc spreading process from water dehydrated from the subducted Pacific slab, which lies beneath the ridge. To reveal the distribution of melt and water in the upper mantle and the upper mantle dynamics in the southern Mariana Trough from electrical resistivity, we conducted a marine magnetotelluric experiment along a ~120 km transect across the ridge at ~13°N. Electromagnetic field data obtained at 9 sites were analyzed to image a 2-D electrical resistivity structure by inversion, after processing the data and striping seafloor topographic distortion from magnetotelluric responses. The obtained 2-D model shows 1) low resistivity at ~10-20 km depth beneath the ridge center but slightly offset to the trench side, 2) moderately low resistivity expanding asymmetrically to the remnant arc side and deeply under the conductor of 1), 3) high resistivity having a constant thickness of ~150 km under seafloor on the trench side, and 4) high resistivity under seafloor thickening from the ridge center up to ~50 km on the remnant arc side. These model features suggest 1) the presence of melt beneath the ridge center, possibly including slab-derived water 2) melt/water-retained mantle produced by asymmetric passive decompression melting of hydrous back-arc mantle, 3) cold and depleted mantle wedge and Pacific slab, and 4) cold and residual lithospheric mantle off the ridge axis. The electrical resistivity structure of the southern Mariana Trough, which clearly contrasts with the structure of the central Mariana Trough at 18°N that is absence of conductor beneath the ridge center, provides insights on the mantle dynamics and its relation to a characteristic tectonics and many observations in the southern Mariana Trough.

Deep-sea geomagnetic surveys across fracture zones and transform faults

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Water exists in the solid earth and affects solid earth dynamics through its circulation. Oceanic lithosphere would work as a carrier of water into the deep mantle. Our approach is the first attempt to understand the role for fracture zone and transform faults through where the water could be transported from the ocean into the oceanic lithosphere. Our targets are Nosappu fracture zone, Marie Celeste transform fault, and Argo transform fault. Nosappu fracture zone locates in the old Pacific lithosphere just before subducting into the deep mantle at the Kuril trench. Marie Celeste transform fault and Argo transform fault are boundaries of two oceanic lithospheres in Indian ocean with a large age offset. We conducted deep-sea geomagnetic field measurements together with surface geophysical surveys across the fracture zone and the transform faults during YK14-09 Yokosuka and KH-15-5 Hakuho-maru cruises. During YK14-09 cruise, we successfully conducted AUV Urashima geomagnetic surveys and surface geophysical surveys at the Nosappu fracture zone between 38°40'N and 40°40'N. We had four AUV Urashima dives across the fracture zone to obtain geomagnetic data. The length of each survey line is about 17 miles, which contain about 13 miles at the AUV depth of 3300m. The exception is one dive, which was forced to end at the middle of the survey line due to an emergency uplift of the AUV. The surface geophysical surveys allow us to collect multi-narrow beam bathymetry and geomagnetic field data, which cover total 1,200 miles in the AUV Urashima dive area. The surface geophysical surveys contain 17 survey lines across the fracture zone with their length of 40 miles for most, and survey lines along the fracture zone cover 110 miles at each side of the fracture zone. During KH-15-5 cruise, we successfully conducted two deep-tow magnetic surveys together with surface geophysical surveys across Marie Celeste transform fault at 65°15'E and Argo transform fault at 66°07'E. We used our deep-sea geomagnetic field measurement system which consists of a depth meter, a proton precession magnetometer, and flux-gate type magnetometers. The length of each survey line is about 25 miles. The intensity of the geomagnetic field at sea surface and at deep-sea with even height from the seafloor (2500 - 4000 m depth) were obtained. The geomagnetic anomaly field at deep-sea shows 2 - 3 times bigger amplitude and also has shorter wave length anomaly than those at sea surface. Our results from Nosappu fracture zone provide magnetization signature beneath the fracture zone. The magnetic boundary in the fracture zone is not a single boundary as predicted by a simple plate boundary model, but two magnetic boundaries parallel to Nosappu fracture zone are identified by the deep-sea vector geomagnetic anomaly field and by seafloor magnetization solution calculated from the surface geomagnetic anomaly field. We will discuss on magnetic property beneath fracture zones and transform faults as a result of reaction with water.

Keywords: fracture zone, transform fault, Deep-sea geomagnetic survey

High-temperature hydrothermal activities around Moho: diopsidites and anorthosites in Wadi Fizh, northern Oman ophiolite

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Reaction products between hydrothermal fluids and uppermost mantle harzburgite-lowermost crustal gabbro have been reported along Wadi Fizh, northern Oman ophiolite. They are named mantle diopsidite or crustal diopsidite. They construct network-like dike crosscutting structures of surrounding harzburgite or gabbro. The mantle diopsidite is mainly composed of diopsidic clinopyroxene, whereas the crustal diopsidite is of diopsidic clinopyroxene and anorthitic plagioclase. Here, we report new reaction product, crustal anorthosite, collected in the lowermost crustal section. It is always placed in the center of the crustal diopsidite network. It mainly consists of anorthitic plagioclase with minor titanite and chromian minerals as chromite and uvarovitic garnet.
Aqueous fluid inclusions trapped in negative crystal are evenly distributed in the crustal anorthosite. Some of them include angular-shaped or rounded daughter minerals as calcite or calcite-anhydrite composite, which were identified by Raman spectroscopic analyses. We estimated their captured temperature at 530ºC at least by conducting microthermometric analyses of the fluid inclusions by Heating-cooling stage. Furthermore, we examined their chemical characteristics by direct laser-shot sampling method operated by laser ablation-inductively coupled plasma-mass spectrometer (LA-ICP-MS). The results indicate that the trapped aqueous fluids contain an appreciable amount of Na, but no K.
Hydrothermal fluids involved in the crustal anorthosite formation transported hydrothermally immobile Cr, which was probably provided from chromite seam in the uppermost mantle section to precipitate chromites and uvarovitic garnet in the lowermost crustal section. Cr got soluble by forming complexes with anions as SO_4^{2-}, CO_3^{2-} and Cl^-. In addition, these hydrothermal fluids transported Fe, Mg, Ti and rare-earth elements. Our temperature estimation for the crustal anorthosite formation requires rather lower temperatures (530–600ºC) with considering microthermometric results and mineral equilibria, thus later circumstance than the mantle diopsidite and crustal diopsidite formation. Therefore, a series of high-temperature hydrothermal events had been significantly contributing to the chemical flux occurring around the boundary between the mantle and crustal sections.

Keywords: Hydrothermal circulation, Mid-ocean ridge, Chemical flux

Two types of basalts erupted in Active rift, Izu-Bonin arc, Japan

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We observed that two types of basalts have erupted in Sumisu rift, Izu-Bonin arc, Japan. High-Zr type basalts have higher concentration of K_2O, Na_2O, Y, Zr, Ni than Low-Zr basalts at similar FeO*/MgO ratio. High-Zr type basalts have higher Nb/Yb, Ce/Yb, Zr,Yb ratio and lower Ba/Th ratio than Low-Zr type basalts. The Sr isotope composition tends to be higher in direction from High-Zr type to Low-Zr type, although the Nd isotope composition of both types are similar. The Hf isotope composition ($^{176}Hf/^{177}Hf$) tends to be lower in direction from High-Zr type to Low-Zr type. The Hf isotope composition of Low-Zr type basalts similar to basalts from Sumisu Caldera in the volcanic front.
Olivines in High-Zr type basalts have higher wt. % NiO than those in Low-Zr type basalts at given Fo contents. Estimated primary olivine compositions are more magnesian (Fo = 92.3) in Low-Zr type basalts compared with those in High-Zr type basalts (Fo = 89.6).
Major element compositions of the calculated primary magmas indicate that the primary High-Zr type magmas segregated from source mantle at deeper than those of Low-Zr basalts (High-Zr: 1-2 GPa; Low-Zr: 2-3.5 GPa).
From the petrological and geochemical factors mentioned above, it is difficult to explain the differences of two types of basalts from different degrees of partial melting of the same source mantle and addition from slab-derived components (for example, sediment melt). Thus, we concluded that the two types of basalts are derived from different source mantle. This may indicate that the mantle beneath Sumisu rift have heterogeneities in the vertical direction (High-Zr type sources are in the shallow part of the mantle and Low-Zr type sources are in the deep part of the mantle). Moreover, Low- and High-Zr type basalts similar to West Philippine Basin MORBs and Shikoku basin basalts, respectively. The mantle heterogeneities beneath the Sumisu rift might have been related to the development of Izu-Bonin arc.
In this presentation, we also discuss the basalts from Myojin and Aogashima rift near the Sumisu rift.

Keywords: Izu-Bonin arc, Active rift, Back-arc basin basalts, Mantle heterogeneity

Researching of alkali-element enrichment using the SEM-EDS mapping analyses of BABB at the site C0012, IODP EXP 333 in the northern Shikoku Basin

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The Shikoku Basin is a back arc basin located westside of the Izu-Ogasawara (Bonin) arc, spreading was from 25 to 15 Ma. The backarc basin basalts (BABB) of the Shikoku Basin were recovered by drilling of DSDP, ODP and IODP researches. The BABB of the Site C0012, south of the Kii Peninsula, operated during the IODP Exp 333, show prominent enrichment of alkali elements. Haraguchi et al. (2015) reported that the identification of host-phase of alkali element by XRD method, and considered alteration environments. In this study, we consider secondary mineralization using mapping analyses by SEM-EDS method, and system of alkali element enrichments.
SiO_2 and MgO contents of these basalts are 47-55 and 5-8 wt%. These basalts show wide variation of enrichment of alkali elements, 2.3-7.5 and 0.4-4.2 wt% of Na_2O and K_2O. Na_2O+K_2O contents show 2 wt% higher trends than other BABBs in the Shikoku Basin at the same SiO_2 contents. The XRD results indicate that the analcime is found from the extremely Na-enriched, more than 4 wt% samples, and thomsonite is also found from many samples. The host phases of K are mainly identified into K-feldspar.
The one of weak point of the XRF analyses is the identification of feldspar. That is, identification of end-member, Ca, Na and K, is difficult because of the peak pattern among these end-member show similar characteristics. Especially, discriminate between anorthite and albite is difficult. Therefore, we attend the mapping analyzed of SEM-EDS method for discrimination of feldspar.
The results of SEM-EDS analyses, feldspar show high Na and K intensity, and the remarkable point is very low intensity of Ca. Therefore, feldspar is considered to completely replacing into alkali feldspar. In the high-Na samples, most feldspars are replaced into albite, on the other hand, high-K samples show K-enriched layer on the rim and clack of feldspar crystals. This K-enriched layer is considered to K-feldspar, equal to the result of XRF method. These observation indicate that the main alkali element-enriched process is albitization. The albitization occur under more than 100°C (e.g. Alt et al., 1986), and albite and K-feldspar occur under higher and lower temperature. The zeolite and clay mineral assemblages support this temperature (e.g. Miyashiro & Shido 1970).
Compared to the lithostratigraphy, the Na and K enrichments are prominent in the layer of low- and high-recovery ratios. And precipitation of zeolite is prominent in the High-Na, equal to low-recovery layers. Therefore, we consider that the Na enrichment occurred under high water/rock ratio with active hydrothermal circulation because of high water permeability of pillow lava. We also assume that the temperature at the path of hydrothermal fluids was high and that at the basement far from the path was low. Under this environment, basement was altered under zeolite facies alteration plagioclase was replace into alkali feldspar and result to enrichment of bulk alkali element enrichments.

Keywords: backarc basin basalts, hydrothermal activity, albitization, mapping analyses

