Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SCG059-01 Room:105 Time:May 26 10:45-11:00

GPS/acoustic seafloor geodetic observation by Japan Coast Guard - summary of fiscal 2010 and plan of fiscal 2011 -

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We have been developing a system for precise seafloor geodetic positioning with the GPS/Acoustic combination technique and deploying seafloor reference points on the land-ward slope of the major trenches around Japan, such as the Japan Trench and the Nankai Trough.

In March, 2008, we installed an acoustic transducer on the hull of the middle-sized survey vessel and started sailing observations. This improvement enabled us to get more stable observation results. In addition, we installed an observation system in the large-sized survey vessel ”Takuyo” in December 2010.

In this presentation, we summarize seafloor geodetic observation results in fiscal 2010 and observation plans of fiscal 2010.

1. Summary of the observation results

(1) Seafloor reference points along the Japan Trench

Two seafloor reference points have been installed off Miyagi Prefecture. From the past observations, seafloor movements toward west-northwest indicating that the crustal strain restarted to reaccumulation at around 2007 were detected. The observation results of fiscal 2010 show the same trend. The velocities of 5.4-5.6 cm/year relative to the stable part of the Eurasian plate have been estimated from the observations from December 2006 to November 2010.

On the other hand, a westward movement of about 2cm/year has been detected at the seafloor reference point off Fukushima Prefecture. This result suggests that the interplate coupling is very weak in this area.

(2) Seafloor reference points along Nankai Trough

Six seafloor reference points have been installed along the Nankai Trough at intervals of about 100 km. From the past observations, the seafloor movements of 2-5 cm/year toward west/west-northwest have been detected at each reference point from the observations after 2006.

2. Plan of fiscal 2011

We are scheduled to conduct seafloor geodetic observations three times each. In addition, we will compare the observation results obtained by the large-sized S/V ”Takuyo” with those obtained by the middle-sized S/V ”Meiyo”, aiming to full-scale operation by Takuyo. Furthermore, in order to complement the blank area off Shikoku, we plan to install a seafloor reference point off Cape Muroto.

Acknowledgements

The installment of the seafloor reference point MYGW was financially supported by Ministry of Education, Culture, Sports, Science and Technology, Japan under the project ’Pilot survey focused on off-shore Miyagi Prefecture’. We thank Dr. Oscar L. Colombo of NASA/GSFC for providing us with the kinematic GPS software ’IT’. We thank the Geographical Survey Institute of Japan for providing us with the GEONET GPS data at 1 sec sampling for our kinematic GPS analyses.

Keywords: seafloor geodetic observation, off Miyagi, Nankai trough, crustal deformation

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SCG059-02 Room:105 Time:May 26 11:00-11:15

Study of efficiency improvement of seafloor geodetic observation

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We have been developing a system for precise seafloor geodetic observation with the GPS/Acoustic combination technique and deploying seafloor reference points on the land-ward slope of the major trenches around Japan, such as the Japan Trench and the Nankai Trough. The primary purpose of our observation is to detect and to monitor the crustal deformation caused by the subduction of the oceanic plate near the plate boundary.

We succeeded in detecting notable seafloor movements associated with, and subsequent to this event. However, the precision of observation and number of observation points are insufficient comparing with terrestrial GPS observation. To detect crustal deformation more precisely, it is necessary to improve precision and densities of observation network.

A precision of estimated position of seafloor reference point are improved using long-time series of observation data. There is trade-off between time length of observation and precision of result. Therefore, to increase a observation points, it is necessary to improve observation method more efficient.

In 2010, we carried out examination to study more efficient observation method at seafloor reference point installed at Sagami bay. In this presentation, we will report the result of these observations.

Keywords: seafloor geodetic observation

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SCG059-03 Room:105 Time:May 26 11:15-11:30

Observation of sea-bottom crustal deformation at Kumano Bay

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Our research group has performed the observation of sea-floor crustal deformation with the system composed of the kinematic GPS positioning and the acoustic ranging at the three stations (KMN, KMS, and KME sites) beneath the Kumano Bay where the large subduction earthquake, Tonankai Earthquake, is anticipated to occur. We measured 13, 18, and 6 times at KMN, KMS, and KME sites, respectively.

The observation shows the steady horizontal displacements of (1.1+/-0.4, -2.4+/-1.0), (1.6+/-0.3, -5.5+/-0.4), (5.4+/-2.2, -6.1+/-3.1) cm/yr at KMN, KMS, and KME sites, respectively. The directions of displacement vector almost coincide with that of plate conversion at the Nankai Trough. The estimated horizontal displacements at some sites are, however, obviously larger than that of relative motion between the Philippine Sea Plate and the Amurian Plate. The error ellipsoid is extremely large at The KME site because of a lack of both observation period and the number of measurement. It is necessary to estimate more precisely based on a continued measurement.

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SCG059-04 Room:105 Time:May 26 11:30-11:45

Application of inclined sound velocity structure to the measurement of ocean bottom crustal deformation

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We are developing a geodetic method of monitoring crustal deformation under the ocean using kinematic GPS and acoustic ranging. The goal of our research is to achieve sub-centimeter accuracy in measuring oceanic crustal deformation by a very short-time measurement like 10 hours. In this study, we focused on lateral variation of acoustic velocity structure in seawater and applied an inclined acoustic velocity structure model to the data analysis.

We have a few measurement sites along Nankai trough. In each site, we deployed a trio of transponders on ocean floor (seafloor benchmark units) within distance comparable with the depth.

An ultrasonic signal is generated from a surface vessel drifting over the benchmark unit, which is received and replied by the benchmark unit. In this system, both acoustic velocity structure and the benchmark unit positions were determined simultaneously for the each measurement using a tomographic technique. This tomographic technique has been adopted on an assumption that the acoustic velocity structure is horizontally layered and changes only in time, not in space. Ikuta et al., (JPGU 2010) reported an approach to improve accuracy of benchmark positioning using a new additional assumption. The additional assumption was that the configuration of the transponders trio constituting one benchmark unit does not change. They determined the time evolution of weight center for the fixed transponder triangle between different measurements using all repetitively obtained data sets at once. This is contrasting to the previous method in which each data set for different measurement was solved independently. This assumption worked well in reducing number of unknown parameters. As a result, repeatability of benchmark positioning improved from 5 cm to 3 cm.

In the new model in this study, we arrowed the velocity structure to be changed horizontally also. The accuracy of the positioning improved to be much better than that by old approach. We adopted this new model and the approach to solve the real data sets. As a result, the repeatability of the benchmark positioning improved from 3.1 cm to 2.5 cm in horizontal component. Although the improvement is not significant, this is of great significance in strategy of analysis. We can adjust freedom of the model or adopt some constraint to make new model to be more robust.

Acknowledgement: This research was promoted by a project of the Japanese Ministry of Education, Culture, Sports, Science, and Technology.

Keywords: Ocean floor, GPS, Acoustic Ranging, Crustal deformation, Transducer

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SCG059-05 Room:105 Time:May 26 11:45-12:00

Inversion of acoustic velocity structure models to develop observing seafloor crustal deformation.

Shuhei Eto[1*], Satoru Nagai[2], Keiichi Tadokoro[2], Tsuyoshi Watanabe[2], Ryoya Ikuta[3]

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Along the Suruga-Nankai trough, major earthquakes have occurred repeatedly. Therefore we should construct a system for monitoring the behavior on plate boundary zones. Although very dense routine geodetic GPS network (GEONET) has been developed, we cannot observe beneath ocean with enough resolution. So our group has tried to develop a system for observing seafloor crustal deformation.

The system becomes possible to observe seafloor benchmarks by combining two techniques; acoustic ranging and kinematic GPS. Using this system, we have achieved an accuracy of about 1-5 cm of horizontal positioning in each observation, but it is not enough to discuss behavior on plate boundary zones. We need to develop our system and consider variations of acoustic velocity structure.

Acoustic velocity structure in ocean varies largely in shallower parts. In present analysis, we assume homogeneous acoustic velocity model with temporal change. To obtain high-resoluted crustal deformation, we estimate with considering the variation of acoustic velocity structure.

Although ray paths of our acoustic ranging are not good to invert full 3-dimensional acoustic velocity structure with temporal variation, we can invert 1-dimension velocity variation with depth for a given short time through some prior information, like a snapshot in some time.

We apply the simple Joint Hypocenter Determination method in seismology [Kissling et al., 1994]. This method allows acoustic velocity structure to exist low-velocity layer such as thermocline. Acoustic ranging data observed by Nagoya University group both in Suruga Bay and Kumano Basin. This paper focused on results and related remarks to Suruga Bay. Another is presented by Nagai et al. [This meeting].

Keywords: acouctic velocity structure, 1-dimensional structure, Variation of space and temporal

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SCG059-06 Room:105 Time:May 26 12:00-12:15

Simultaneous inversion of 1-D sound velocity and positions of benchmarks to develop ocean-floor geodetic observation

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To clarify the behavior on plate boundary zones, especially related with mega-thrust earthquakes, we have needed high-resoluted crustal observation both in space and time. Around Japan, those plate boundaries are located beneath ocean, so our group has tried to develop an observation system for sea-floor crustal deformation.

As a part of these sea-floor crustal deformation measurements, we use an accurate acoustic ranging technique. However, due to variations of acoustic velocity structure, sometimes, estimated position error of seafloor benchmark units becomes larger than ~ 1 cm, which is not useful to identify relative plate motions. For our objectives, we try to invert variations of acoustic velocity structure in ocean to make stable estimation of bench marker positions. Although ray paths of our acoustic ranging are not good to invert full 3-dimesional acoustic velocity structure with temporal variation, we can invert 1-dimension velocity variation with depth for a given short time through some prior information, like a snapshot in some time. We apply the simple Joint Hypocenter Determination method in seismology [Kissling et al., 1994] to acoustic ranging data observed by Nagoya University group both in Suruga Bay and Kumano Basin. This paper focused on results and related remarks on Kumano Basin. Another is presented by Eto et al. [This meeting].

We report our strategy for observation systems and some results from observation data and synthetic data test.

Keywords: sea-bottom crustal deformation measurement, acoustic ranging, sound speed structure in ocean, joint hypocenter determination

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SCG059-07 Room:105 Time:May 26 12:15-12:30

Seafloor geodesy-derived sound speed structure in ocean

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Much efforts have been made for improving accuracy and spatio-temporal frequency of seafloor geodetic observation by means of GPS/acoustic technique, which now provides significant data to the earth science field. Actually, GPS/acoustic surveys have detected some important tectonic events, such as coseismic displacement associated with the 2004 off Kii peninsula earthquake, secular movement at off Miyagi, and co- and post-seismic deformation after the 2005 off Miyagi earthquake. However, comparing with current state of the land-based GPS network, GEONET, improvement in its quality and quantity is required in providing more general scientific purpose.

There three factors that affect the accuracy of GPS/acoustic measurement; kinematic GPS analysis to monitor surface platform, acoustic signal processing in identifying traveltimes, and uncertainty in sound speed in ocean for traveltime-range conversion. Among the three, it is getting obvious through the past survey that sound speed variation is most significant.

Sound speed structure is known to be well approximated by time dependent stratified structure, i.e., depth profile. Furthermore, its effect on seafloor positioning can be expressed time-dependent single scholar quantity that in a depth integral of the profile, called vertical delay. We have succeeded in monitor the variation of the vertical delay with time from a GPS/acoustic measurement, and confirmed that it is well coincided with concurrent physical oceanographic in situ measurement. However, apparent fluctuation in horizontal seafloor position up to 20-30cm is remained even after removal of the vertical delay. To achieve 2-3cm accuracy we need more than one-day survey time to average out the fluctuation. As mentioned above, improvement inefficiency of the survey is required, we have to estimate the factor and evaluate its quantity to correct the positioning. The fluctuation is thought to be spatio-temporal variation of sound speed structure, which must be modeled by a simple assumption that can be estimated by sparse and limited traveltime data. When the spatial scale in the variation is large enough, its can be simply approximated as gradient at our survey point, which can be estimated by adding some extra seafloor transponders to increase traveltime data. However our observed data indicate that this assumption may be wrong and variation sometimes has much smaller scale.

In the decade, the resolution in numerical simulations of ocean variability have been greatly improved, the scale of which is getting closer to our scale of interested. For example, vertical delay mentioned above is found to often have a semi-diurnal time-scale. It is also supported by up to 20m semi-diurnal oscillation in the sound speed profile obtained by concurrent in situ measurements. This has been well modeled by numerical simulation of internal wave that modulated by M2 tidal current by Niwa and Hibiya (2001). In addition, long-timescale spatial variation is related to large scale ocean current and/or middle-scale eddy. We are now compared our observation with data-assimilated reanalysis product of ocean variability, JCOPE2 (Miyazaki et al., 2009), that is opened in public. There still remain a gap in scale between our observation and the numerical simulation, some temporal tendency can be highly expected in the comparison. In this talk, we introduce several example of our observation with comparison of above simulations, and address how do the simulations provide significant information to our side.

Keywords: seafloor geodesy, data assimilatio reanalysis, internal wave, sound speed

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SCG059-08 Room:105 Time:May 26 12:30-12:45

Accuracy evaluation of Kinematic GPS analysis based on the difference of the IGS products (follow-up report)

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The Philippine Sea plate subducts beneath the southwest Japan from the Nankai Trough with a rate of about 4-6 cm/year, where great interplate earthquakes have repeatedly occurred every 100-150 years. To clarify the mechanism of earthquake occurrence at such subduction zones, we require the geodetic data obtained from not only onshore area but also offshore area. However it is difficult to estimate the plate interaction in offshore areas, due to the poverty of those data. For this issue, we have conducted seafloor geodetic observation using GPS/Acoustic techniques around the Nankai Trough since 2004. In this system, we estimate the position of a surveying vessel by Kinematic GPS analysis and measure the distance between the vessel and the benchmark on the seafloor by Acoustic measurements. Next, we determine the location of the benchmark and detected crustal movement on the seafloor. Recently, a number of research institute have conducted seafloor geodetic observation after earthquake occurred in offshore area (Tadokoro et al., 2006), and then speedy solution is desired from a viewpoint of not only scientific research but also disaster mitigation. Although we use the IGS final product for its accuracy, the latency of that is longer, about 13 days or more. On the other hand, the IGS ultra-rapid product is updated every 6 hours with the delay of 3 hours. In the previous study, we compared the kinematic GPS solutions using the IGS final and ultra-rapid products. The rover GPS site was located on the roof of a building at Nagoya University and 5 fixed GPS sites were located on the roof of other buildings whose baseline lengths were 30-150 km. Though the standard deviation of the difference between final and ultra-rapid solutions increases with increasing baseline length, which is about 1.6 mm in 150 km baseline. This result showed that the difference was not significant for seafloor geodetic observations. In this study, we investigate the kinematic GPS solutions based on the difference of the IGS products using GPS data obtained from seafloor geodetic observations, and assess the accuracy and effectivity of the IGS ultra-rapid product.

Keywords: Kinematic GPS, Seafloor geodetic observation, IGS products

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Receiver function for ocean bottom seismograms

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We introduce a receiver function which is appropriate for ocean bottom seismograms to image the seismic structures below the stations. It is an application of the receiver function proposed by Takenaka and Murakoshi (2010, AGU) for deep borehole records, which is an extension of ”S-wavevector receiver function” (SWV-RF), originally introduced for ground surface records by Reading et al. (2003, GRL). Standard receiver function obtained by deconvolving a horizontal record with the vertical record of a teleseismic P wave and its coda, includes the contribution of the sea surface (free surface). The sea surface reflection phases mask the original signals from the subsurface interfaces. The free surface contribution is contained much larger in the down-going components of the seismic wavefields than the up-going ones. The SWV-RF uses only the up-going components, which is defined as the deconvolution of the up-going S-wave component with the up-going P-wave one. In this study we propose a method for extracting up-going P and S waves from the observed seismograms at the ocean bottom stations to calculate the SWV-RFs for borehole and ocean bottom stations based on the structure models from the top to the receiver level. If we have a structure model below the receiver level, we can also calculate the SWV- RFs at any levels (virtual receivers) below the ocean floor. In the presentation we apply this method to synthetic waveform data for a 3D trench-junction model to illustrate the effectiveness of the SWV- RF.

Keywords: receiver function, ocean bottom station, teleseismic body wave

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SCG059-10 Room:105 Time:May 26 14:30-14:45

Crust and uppermost mantle structure of transition between the Oki-Daito Rise and West Philippine Basin

Azusa Nishizawa[1*], Kentaro Kaneda[1], Mitsuhiro Oikawa[1], Yasuhiko Ohara[1], Taisei Morishita[1]

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The broadly-defined Oki-Daito Ridge, one of the bathymetric highs at the northwestern Philippine Sea plate, is divided into three parts, the narrowly-defined Oki-Daito Ridge in the southeast, Oki-Daito Plateau in the northwest and Oki-Daito Rise in the southwest. We conducted seismic exploration to elucidate transitional structure between the Oki-Daito Rise and West Philippine Basin.

The P-wave velocity structure shows that the crustal thickness decreases from 14 km beneath the rise to 6 km at the northwestern end of the West Philippine Basin. The thinning is mainly due to the lower crust. The velocity of the lower crust is reliably deduced from clear later phases propagating in the entire crust and estimated to be 7.2-7.3 km/s at the bottom of the crust, which is rather higher than a typical oceanic crust produced at a mid ocean ridge. Pn velocity is 7.9 km/s beneath the Oki-Daito Rise and increases to over 8.4 km/s below the West Philippine Basin. Such abnormally high Pn velocities of 8.4-8.6 km/s were widely found beneath the West Philippine Basin to the north of the Oki-Daito Escarpment.

A difference in the basin structure from a typical oceanic crust is existence of a constant velocity of about 5 km/s layer with a thickness of 1-2 km in the upper crust. Large reflection signals from 5-10 km below the Moho were identified in many records obtained by ocean bottom seismographs. Similar large reflection signals from about 30 km under the Moho were also detected in the region between the Oki-Daito Rise and Oki-Daito Plateau. Such deep reflection signals may characterize the upper mantle structure in this region.

Keywords: Oki-Daito Ridge, Oki-Daito Rise, West Philippine Basin

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SCG059-11 Room:105 Time:May 26 14:45-15:00

Extremely high crustal production rate of the Izu-Ogasawara-Mariana intra-oceanic arc

Narumi Takahashi[1*], Yoshiyuki Tatsumi[1], Shuichi Kodaira[1], Seiichi Miura[1], Takeshi Sato[1], Mikiya Yamashita[1], Tetsuo No[1], Kaoru Takizawa[1], Naoto Noguchi[1], Yuka Kaiho[1], Yoshiyuki Kaneda[1]

[1]JAMSTEC

The crustal structures across the Izu-Ogasawara-Mariana arc, obtained by Japan Agency for Earth-Marine Science and Technology (JAMSTEC), provides an estimate of the average crustal production rate since 50 Ma. It has been well established that continental crusts have been created as the middle crust of the Izu-Ogasawara-Mariana arc with P-wave velocity of 6.0-6.5 km/s (Suyehiro et al., 1996; Takahashi et al., 2007); however, the production rate of this 'continent' has been still unknown yet. The crustal volume can be calculated by crustal structures obtained by seismic surveys, however, a part of the crustal materials are transformed into mantle through differentiation of crustal materials (Takahashi et al., 2007). Based on a model of Tatsumi et al. (2008), we estimated volumes of transformed crustal materials and calculated the total volumes of arc materials. As shown by distribution of high velocity lower crust beneath the eastern half of the Shikoku Basin, the arc volcanisms also occurred on oceanic crusts produced by backarc opening in the past and the crust has been overprinted by the arc activities after stop of the backarc opening. We, therefore, identified the eastern end of the original oceanic crust using magnetic lineation pattern (Okino et al., 1994) and removed volumes of the oceanic crust from total ones of arc crustal materials. It is then suggested that the total volume of crustal materials across the Izu-Ogasawara-Mariana arc is over 16,000 cubic kilometers per one kilometer. The total volume is higher in the northern Izu-Ogasawara arc and smaller in the southern part. We assumed the volumes of the Kyusyu Paleo Ridge as the remnant arc, and found that the crustal production rate of the oceanic arc is unexpected high value. In this presentation, we introduce crustal image across the arc and the detailed scenario derived the result.

Keywords: oceanic crust, crustal structure, arc growth, OBS, seismic survey

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SCG059-12 Room:105 Time:May 26 15:00-15:15

Tectonic reconstruction of initial stage of Philippine Sea Plate formation

Osamu Ishizuka[1*], Toshitsugu Yamazaki[1], Ogitsu Itaru[1], Yoshihiko Tamura[2], Kenichiro Tani[2], Yumiko Harigane[3], Izumi Sakamoto[4], tomohiro sasaki[5], Youhei Katayama[4], Junki Sumizawa[4], Ryuichi Shitahaku[4]

[1]GSJ/AIST, [2]JAMSTEC, [3]Kanazawa University, [4]Tokai University, [5]Tsukuba University

Recent research in the Izu-Bonin-Mariana (IBM) forearc revealed volcanic section representing earliest record of IBM arc magmatism (e.g., Ishizuka et al., 2006; Reagan et al., 2010). The obtained stratigraphy combined with petrological, geochemical and geochronological study led us to propose a model for subduction initiation along this arc (Ishizuka et al., 2006). This model assumes spontaneous subduction of old and cold, thus, with higher density plate begins to sink beneath younger and hotter plate with lower density (Stern, 2004). This model for subduction initiation, however, has not been tested from a tectonic point of view. To do this, it is necessary to reconstruct tectonic environment at c. 50 Ma and before of Philippine Sea region.

R/V Yokosuka YK10-14 cruise investigated Palau Basin and southern part of West Philippine Basin (WPB) to obtain crucial geological and geophysical data for reconstruction of one of the oldest parts of the Philippine Sea Plate.

Bathymetric and geomagnetic survey in the Palau Basin and southern WPB revealed: 1) Topographic fabric associated with the seafloor spreading can be recognized in the southern WPB. The strike of the topographic fabric in the northern part near the Central Basin Fault is close to E-W, whereas that of the southernmost part is nearly NW-SE, which suggests that the spreading direction of WPB changed clockwise with time. 2) The topographic fabric and magnetic lineations near N-S strike can be recognized in the Palau Basin, suggesting seafloor spreading of E-W direction. This fabric in the Palau Basin curves eastward in the vicinity of the Mindanao Fracture Zone (MFZ). 3) A trough of unknown origin runs WNW-ESE near 5^{o}N, 130^{o}E. 4) Southern and eastern part of the Palau Basin is occupied by numerous seamounts.

Main targets of dredge sampling were: 1) oceanic crust of the oldest part of WPB. 2) oceanic crust of Palau Basin exposed along the fracture zones. 3) volcanic structure within the Palau Basin. 4) basement of Southern Kyushu-Palau Ridge (KPR) which corresponds to the eastern margin of the Palau Basin.

Sampling of the Palau Basin crust along the MFZ, which separates the Palau Basin from WPB, was conducted in 2 regions. One is at c. 130^{o}E, where seafloor in the Palau Basin is relatively deep (generally deeper than 6000m) and shows series of abyssal hills trending N-S to NE-SW. The other region, east of the first one, has much shallower basin floor of 4500 - 4000 m deep. Dredge hauls in these region successfully recovered pillow lava blocks of mainly aphyric basalt with remaining fresh glass rind and olivine-rich dolerite. Sampling of crustal materials in the Palau Basin was also conducted at WNW-ESE trending trough in the middle part of the Basin near 5^{o}N, and recovered olivine basalt with some fresh glass.

Southern part of the Palau Basin is characterized by abundant NE-SW-trending ridges crosscutting N-S-trending abyssal hills. Clinopyroxene-olivine basalts were mainly recovered from these ridges. They are distinct in petrography from basalts from the Palau Basin along the MFZ, but similar to those from near 5^{o}N.

The oldest part of ocean crust of WPB was sampled at the NW-SE-trending scarp at c. 8^{o}26'N. Pillow lava blocks of aphyric basalt were recovered. These samples will provide first reliable age constraint in the southern WPB which can be linked with magnetic anomaly data obtained during this cruise.

In southernmost part of the KPR, eastern escarpment of a ridge between main KPR crest and the Palau Trench was dredged to recover basement of the KPR. This dredge recovered the metamorphic rocks including amphibolites, amphibole schist and siliceous schist, which implies occurrence of non-oceanic crust.

Preliminary geochemical data indicate that basalts from the Palau Basin and the WPB have characteristics of MORB-like backarc basin basalt. Details of geochemical data and $^{40}Ar/^{39}Ar$ ages will be reported in this presentation.

Keywords: Palau Basin, subduction initiation, West Philippine Basin, tectonic reconstruction, ArAr age, magnetic anomaly

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SCG059-13 Room:105 Time:May 26 15:15-15:30

Landslide-related decoupled anomalies of heat flow and pore water chemistry: Nankai Trough off Muroto

yoshifumi kawada[1*], Masataka Kinoshita[1], Tomohiro Toki[2], Ryosaku Higa[2], Takafumi Kasaya[1]

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We observed surface heat flow and biological activity, and sampled push cores near the deformation front of the Nankai Trough accretionary prism off Muroto, in order to obtain relationships between the distribution of fluid discharge and the topography. Fine scale topography near the deformation thrust is characterized by a regularly-spaced stairway-like structure with a period of 1 km across the subduction axis. Each step consists of a flat area of 600-800 m long with a gentle landward down-dipping, and a steep wall of 400-200 m long and 100 m high. Near the foot of each steep wall, the exits of the sequentially thrusts cutting through the decollement are expected. We took an observation line, which crosses the hypothetical exit of the secondary frontal thrust perpendicularly to its strike. We found that the anomalies of pore water chemistry and biological activity were correlated in location, and that the anomalies of heat flow were not always correlated to the former anomalies in location. (1) On a flat place near the ODP hole 808I, regional mean heat flow value of 150 mW/m2 was observed, and neither chemical anomalies nor biological activities was detected. (2) Near the foot of a slope structure where the exit of sequential thrust is expected, high heat flow anomaly as high as 250 mW/m2 was observed, but no other anomalies were detected. (3) On the slope just above the foot, low heat flow anomaly around 120 mW/m2 was observed, and no other anomalies were found. (4) At a flat terrace-like place 40 m above the foot of the slope, where landslide structures were visible, moderately high heat flow anomalies around 200 mW/m2 were observed and both of biological activities (calyptogenas and tubeworms) and chemical anomalies (methane and ammonium) were found. The present observation basically agrees with a commonly accepted qualitative model, in which conduit-like fluid flow upwells through the thrusts and is restricted by near-surface geological structures such as landslides. However, the origin of the high heat flow anomaly observed near the foot of the slope is remained to be solved.

Keywords: Nankai Trough, heat flow, accretionary prism, landslide, pore water, off Muroto

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SCG059-14 Room:105 Time:May 26 15:30-15:45

Topography and structures of Nagahama bay of Satsuma Iwo-Jima island and Kikai Caldera

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The Kikai Caldera is located 50 km south of the Satsuma peninsula of Kagoshima Prefecture in South Japan. The Kikai Caldera produced Akahoya tephra at 7300 years ago by Caldera forming big eruptions. Along the Kikai Caldera, Satsuma Iwo-Jima and Takeshima were identified as outer rim of caldera crater. In Satsuma Iwo-Jima, volcanic activity still well preserved at the Iwo-Dake volcano.

To understand of modern oceanic caldera structure and sedimentation is important to understand Archean greenstone forming environment. Many Archean greenstone belt was reported to understand by caldera models. Sedimentation of iron material is also very important to understand the iron formation at Archean time (eg. Banded Iron Formation).

Here we will report 1) Seismic exploration in Kikai Caldera by KT 1?18 cruse at 2010 August. 2) Shallow ocean topography to use Dual-Frequency Identification Sonar (DIDSON) and malti-narrow beam (SeaBat) at 2010 September. Windynetwork corporation and Toyo Corporation helped to use these sonars.

In Kikai Caldera, there are well preserved listric normal fault and tilted sedimentary sequences in the outer Caldera margin. There is very small sediments within deepest Caldera valley. Based on the multiple core works, the bottom of valley mostly sand rich sequence. Some portion contains hemi-pelagic greenish gray sediments.

At Nagahama bay, there are many conical iron hydrate rich mound system identified. After 2009 dredging result, these iron rich mounds grow up more than few cm pare years. Top of the shallow portion of the mound is formed flat head because erosion by boat floor during low tide.

Keywords: Satsuma Iwo Jima, Kikai Caldera, iron deposit, listric normal fault, sliding

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Relation between sediment and meteorological event for 10 years in Nagahama Bay, Satsuma Iwo-Jima Island, Kagoshima

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Satsuma Iwo-Jima Island, with active rhyolite volcano (Iwo-Dake), is located about 40 km south of Kyushu Island, Japan. Nagahama Bay, which is partly isolated from pelagic sea, is located in the south of Satsuma Iwo-Jima. The seawater is red color attributing to the presence of suspended ferric hydroxide produced by the mixing of volcanic fluids and seawater (Ninomiya and Kiyokawa, 2009).

In this study, the Fishermans port of Nagahama Bay was divided into two areas as E-site and W-site by the T-shaped breakwaters. The breakwaters were extended at W-site in 2000 and 2004. Big breakwater at the entrance of Nagahama Bay was built in December 2006. In March 1998, W-site experienced wide and deep dredging construction. Since then, the thick sediments at W-site have accumulated during the last 10 years. To understand mechanisms of sedimentation in the Bay, we observed stratigraphy of core sample from the Fishermans port in detail and investigated a relation of the stratigraphy of core samples to meteorological and volcanic activity records for the past 10 years.

I) Stratigraphy: 12 cores are collected from E-site (1 core) and W-site (11 cores). These cores consist of ferric hydroxide, sand and tuff bed. Four units are identified from these cores. 1) The Basement unit contains coarse sand bed. 2) The Lower unit contains ferric hydroxide beds and a 1 to 7 cm-thick pink-tuff bed (T1). 3) The Middle unit mainly contains ferric hydroxide bed with a 2 to 8 cm-thick gray-tuff bed (T2) and a 1 to 9 cm-thick gray-tuff bed (T3). Within ferric hydroxide bed, we observed a few sheets of thin tuff beds. 4) The Upper unit contains thick sand and ferric hydroxide beds. Smear slides and SEM observation shows that 1) ferric hydroxide bed contains very fine ferric material, 2) sand bed is composed of terrigenous clastics, volcanic glass and very fine ferric material, and 3) tuff bed contains volcanic glass.

II) Volcanic activity: At Iwo-Jima Island, volcanic ash has fallen intermittently from September 1997 (Shinohara, 2002) to October 2004 (The Meteorological Agency, 2010). The thickness of the tuffs deposited in the Iwo-Jima village near Nagahama Bay was only a few millimeters. After October 2004, volcanic Mt. Iwo-Dake dropped down, and volcanic ash has not been reported at the village.

III) Meteorological records: We compiled record of rainfall, air pressure, wind velocity, wind direction and typhoon date from March 2000 to March 2010, and found the following events. A) Rainfall: Three heavy rain events were identified in the rainy season of 2000 (precipitation 189 mm/day), 2001 (124.5 mm/day) and 2002 (122 mm/day). B) Typhoon: Three strong typhoon events, with maximum wind velocity over 20 m/s, came in 2004 (40.3 m/s, 54.3 m/s and 44.6 m/s), 2005 (43.3 m/s) and 2007 (50.2 m/s). C) Other notable events: Typhoon did not come in 2006 and there is no rainy day, which is precipitation of more than 40 mm/day, in 2003 and 2007.

Conclusions: We identified events in the ferric hydroxide-rich sediment in Nagahama Bay. 1) Based on the record of dredging in Nagahama Bay, we identified that the sediment just above the Basement unit was accumulated in 1998. 2) Three thick tuff beds (T1, T2 and T3) may be correlated to heavy rain events in 2000, 2001 and 2002. 3) Sand bed in the Upper unit may have formed by strong typhoon event during 2004.

Keywords: Iwo-Jima Island, hydrothermal water, ferric sediment, weather, Kikai caldera

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HYDROTHERMAL ACTIVITY AND IRON SEDIMENTATION IN NAGAHAMA BAY, SATSUMA IWO-JIMA ISLAND, KAGOSHIMA

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Satsuma Iwo-jima Island is active volcanic island and 6 x 3 km in size, located 38km south of Kyushu Island, Japan. The reddish brown water along the coast of the Iwo-dake volcano at the center of the island is formed by neutralization through mixing of shallow hydrothermal fluid and seawater. The reddish brown water contains reddish ferrihydrite (Fe3+) that is derived from oxidation of Fe2+ from acidic hot spring (Shikaura and Tazaki, 2001). In Nagahama Bay with its opening to the south, red-colored Fe-rich water is affected by tidal current. Sedimentation of the ferric hydroxide is confirmed to occur in the ocean bottom (Ninomiya and Kiyokawa, 2009). Here we focus other lines of evidence from long term observations and meteorological records as important factor to form thick iron rich sediments.

Core sample: >1m thick Fe-rich sediments have the following lithological characteristics; the upper part, 10-20cm thick is composed of unconsolidated Fe-rich materials and the lower part shows alternation of weakly consolidated Fe-rich orange-colored mud, the organic-rich black mud and volcanic ash layers. The basal part has a distinctive pink ash layer that represents 1997 volcanic activity. Three-dimensional analysis of the sediments suggests that they are alternating sediments during quite weather periods (Iron mud) and reworked sediments (Tuff and Sand). Layer of fine-grained volcanic ash have the feature of fining-upward. All Iron mud samples show high FeO contents about 20˜25wt.%. The depth profiles of FeO and Al2O3 contents show parallel changes. SEM images and XRF results indicate very small (>1 micron) grains of amorphous Fe-bearing minerals such as ferrihydrite and/or feroxyhite. XRD results indicate that Iron mud contains Si-bearing minerals such as quartz, cristobalite and tridymite. Triangular Fe-Al-Zr diagram may indicate multiple origins for each layer in the examined sediment core: e.g. Iron mud is derived from hot spring water because Fe content rate in hot spring water is high, and elevated abundance of Al and Zr indicates that Sand and Tuff are reworked sediments.

Long term temperature monitoring: Measured seawater temperature seems to have fluctuated synchronically with the air temperature. But the temperature of the hot spring water remained rather constant regardless of the seasonal change. We observed that seawater temperature in Nagahama Bay is relatively lower during high tide and higher during low tide, and the difference between high and low peaks in temperature reaches maximum in the period of spring tide and minimum in the period of the neap tide. These observations suggest that an amount of discharged hot spring inversely correlated with that of seawater flowing into Nagahama Bay.

Meteorological and stationary observations: We used meteorological records in the Satsuma Iwo-jima Island and cross-checked with stationary observations, which enabled us to observe color changes of the surface water of Nagahama Bay. It was made clear that prevailing north wind in Nagahama Bay resulted in changes of the color from red to green, most likely by intrusion of open ocean water to the bay.

In Nagahama Bay, ”Iron mud” formed during quite periods of quiet weather and ”Tuff and Sand” formed as reworked sediments by storm and flood event. Neap tide would have induced enough supply of hot spring into seawater and prevailing south wind would have worked as a cap of underlying seawater. The fine-grained Fe-hydroxide formed and deposited during neap tide with prevailing south wind.

Keywords: Hydrothermal activity, Iron sedimentation

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Hydrothermal exploration along the Central Indian Ridge - background and impacts of a hydrogen-rich hydrothermal system

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The Kairei Hydrothermal Field (KHF) is located at the southern end of the Central Indian Ridge (CIR), near the Rodriguez ridge triple junction. The KHF was discovered by ROV Kaiko in 2000, based on the preceding report of hydrothermal plume anomaly detected in Hakuho-maru KH-93-3 cruise in 1993 . The fluids venting from the KHFare characterized by its high concentration of hydrogen, and a hydrogen-based hyperthermophilic subsurface lithoautotrophic microbial ecosystem was confirmed by Takai et al. [2004]. The hydrothermal vent lies on basaltic lava area on the shoulder of ridge axial wall, on the other hand, gabbro and ultramafic rocks are discovered around the KHF [e.g., Kumagai et al., 2008; Nakamura et al., 2009]. The recent submersible dive discovered a group of dead chimneys on the hill north of the KHF, where peridotite is widely exposed. Previous studies on other hydrogen-rich hydrothermal systems inferred that they may be related to the serpentinization of lower crust and/or mantle rocks and be controlled by detachment faulting, however the integrated study based on detailed field observations have not been done. The microbiological production and its impact on deep-sea ecosystem of hydrogen-rice hydrothermal plumes are unknown. The objectives of KH-10-6 cruise (23 Nov. 2010 - 13 Dec. 2010) are, 1) to verify the hypothesis that hydrogen-rich KHF is controlled by the ambient crustal structure and the chemical composition of lithosphere, 2) to estimate the chemical and microbiological fluxes from KHF to seawater through hydrothermal plumes, and 3) to quest an unknown hydrothermal field on the rise, tentatively called Yokoniwa Rise, north of the KHF. During 21 days operation, we conducted one successful AUV dive, 22 dredge hauls, 10 CTD tow-yo surveys, 3 CTD vertical casts, 4 VMPS and 1 MTD plankton net. Total 800 miles of surface geophysical mapping was also done and a 80 miles of deep-tow magnetic profile was obtained. The preliminary results are, 1) A r2D4 #68 dive was done successfully above the Yokoniwa Rise north of the KHF, where the dead chimneys on ultramafic exposure were discovered in 2009. High-resolution side scan image and interferometric bathymetry was obtained with data of chemical and physical sensors. The attached magnetometer could detect the positive anomaly on the dead chimney area. 2) Surface geophysical mapping revealed the detailed feature of CIR-4 segment, where no previous data existed. The result will improve our understanding of spreading history and structural segmentation of the CIR, and will provide a key to consider the tectonic setting of the EHF. 3) Total 80 mile of deep-tow magnetic profile was obtained across CIR-1 segment. The detailed spreading history since 2 Ma was revealed, that will constrain the evolution of detachment faults around the KHF. 4) A number of lower crust / mantle materials were collected around the KHF. Focused dredge hauls on the Yokoniwa Rise will lead us a reliable model of Yokoniwa formation. 5) Systematic sampling of mid-ocean ridge basalts with fresh glass along the ridge axis will provide a good opportunity to study the mantle heterogeneity beneath the southern CIR. 6) Total ten CTD tow-yo surveys and three vertical casts could reveal the spread of hydrothermal plumes and their chemical and physical properties around the Kairei and Edmond Hydrothermal Fields. The anomalies of pH, turbidity, alkalinity, Mn, CO2 and DO were detected around the KHF. Very high concentration of hydrogen was also confirmed. 7) Newly developed pH sensor and turbidity meter were attached to the wire during most of dredge hauls and plankton net operations. Distinct turbidity anomalies were detected at some sites, that could prove the effectiveness of 'dredge-attached' sensors. 8) Approximately double-dense microbial cell density was detected within the hydrothermal plume above the KHF. The detailed distribution will provide a new insight into microbiological flux through the plume.

Keywords: hydrothermalism, Central Indian Ridge, tectonics, petrology, hydrothermal plume

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MORB and mantle peridotite along southern Central Indian Ridge: Preliminary results of dredge during KH-10-6 cruise

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Two active hydrothermal systems, Kairei and Edmond, are found along the Central Indian Ridge (CIR) with intermediate spreading rate (~ 48 mm/year). These hydrothermal system show distinct geochemical signature in their vent fluids. The former, Kairei Hydrothermal field (KHF), is characterized by hydrogen-rich hydrothermal activity (Gamo et al., 2001, EPSL), and it is located at the first segment of CIR. The latter, on the other hand, Edmond Hydrothermal field, show normal or lower hydrogen concentrations (Gallant & Von Damm, 2006, G3), and it is located at the 3rd segment of the CIR.

Recent investigations revealed that the origin of high hydrogen concentrations of the KHF is related to the serpentinization of olivine-bearing mafic to ultramafic rocks, which are exposed around the KHF (Kumagai et al., 2008, Geofluids; Nakamura et al., 2009, EPSL). However, these rocks are collected only from eastern side of the KHF, and detail distributions of olivine-bearing mafic to ultramafic rocks around the KHF was still uncertain.

In KH-10-6 cruise, we performed 10 dredge operations around the KHF in order to reveal the geology of the north of the KHF. Further 12 dredge operations are performed from 1st to 4th segments of CIR. Descriptions of recovered samples during KH-10-6 cruise are as follows.

Yokoniwa-rise, north of the KHF
KH-10-6DR01: ol-phyric basalt with glassy surface; dolerite; gabbro; serpentinized peridotite
KH-10-6DR02: aphyric to sparsely pl-phyric basalt with glass rim
KH-10-6DR03: slightly to highly pl (-ol) phyric basalt. Large pl-phenocryst (up to 2cm in size)
KH-10-6DR04: aphyric to sparsely pl-phyric basalt
KH-10-6DR05: sparsely pl-phyric basalt with glass rim. Large pl-phenocryst (up to 2cm in size)
KH-10-6DR06: aphyric to pl-phyric basalt with glass rim in places
KH-10-6DR08: highly altered dolerite and breccia (green schist facies metamorphism)
KH-10-6DR09: fine- to coarse-grained altered gabbro with dolerite; altered oxide gabbro; serpentinite
KH-10-6DR10: ol-pl phyric basalt with glassy rim; gabbro; amphibolite; serpentinized peridotite
KH-10-6DR11: serpentinized peridotite with deformation (foliation)
KH-10-6DR12: ol-phyric basalt (ol phenocryst up to 2 mm in size); weathered massive sulfide with goethite rim; serpentinized (and weathered) peridotite

CIR-1, ridge axis and off-ridge
KH-10-6DR07: basaltic glass; aphyric basalt
KH-10-6DR20: serpentinized peridotite with serpentine vein
KH-10-6DR21: aphyric basalt with glassy rim; serpentinized peridotite; gabbro
KH-10-6DR22: Mn-coated serpentinite, aphyric basalt, and mud stone

CIR-2
KH-10-6DR17: altered basalt with chlorite vein; altered dolerite
KH-10-6DR18: basalt glass; pl-phyric basalt with glassy rim
KH-10-6DR19: serpentinized peridotite with serpentine vein; gabbro; pyroxenite

CIR-3
KH-10-6DR15: very fresh aphyric basalt with glass rind with pillow lava texture
KH-10-6DR16: very fresh aphyric basalt with glass rind

CIR-4

KH-10-6DR13: pl-phyric basalt with glass rind (pl phenocryst up to 5 mm in size); basaltic glass
KH-10-6DR14: sparsely ol-phyric basalt with glass rim

These observations clarify inter-segment scale petrological differences along southern CIR as well as geological features around the KHF. We present here the petrological preliminary features (petrography, petrology, mineralogy, and microstructures) observed in mafic to ultramafic rocks obtained from the north of KHF and the 1st to 4th segments of CIR.

Keywords: mantle peridotite, mid-ocean ridge basalt, Central Indian Ridge

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Observation of mid-oceanic ridge floor using acoustic video camera

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DIDSON (Dual-Frequency IDentification SONar) is acoustic lens-based sonar. It has sufficiently high resolution and rapid refresh rate that it can substitute for optical system in turbid or dark water where optical systems fail.

Institute of Industrial Science, University of Tokyo (IIS) has understood DIDSON's superior performance and tried to find new method for utilization of it. The observation systems that IIS has ever developed based on DIDSON are waterside surveillance system, automatic measurement system for fish length, automatic system for fish counting, diagnosis system for deterioration of underwater structure and so on. A next challenge is to develop an observation method based on DIDSON for hydrothermal discharging from seafloor vent. We expected DIDSON to reveal whole image of hydrothermal plume as well as detail inside the plume.

We had a chance to participate the cruise YK09-13 (JAMSTEC Shinkai6500 / RV Yokosuka) to Rodriguez segment of Central Indian Ridge, where hydrothermal plume signatures were previously perceived. Several experimental trials based on DIDSON in tank and sea had been done in order to confirm whether flows in water can be detected by acoustical method. These trials showed that DIDSON could detect flow of water even if there was no clear thermal difference between the flow and its surrounding. Observation system based on DIDSON was prepared and equipped on the top of Shinkai6500 in order to get acoustic video images of hydrothermal plumes. In YK09-13 Leg.1 cruise, seven dives of Shinkai6500 were conducted. The acoustic video images of the hydrothermal plumes had been captured in three of seven dives.

Low-quality wire connection between DIDSON and Shinkai6500 limited on data transmission. Only low frequency mode was available, and average frame rate was lower than 1 frame per second. Acoustic image data captured by DIDSON in YK09-13 indicate capability of tool for seafloor observation, even though the data was low-quality and low-quantity ones.

Contrasting density inside the acoustic image of the hydrothermal flow could be distinguished. DIDSON showed its possibility of observation tool that can delineate spatial and temporal change of internal structure of the hydrothermal flows. Mosaic acoustic images showed bottom features of ridge axis. This indicates that DIDSON has a possibility of bottom observation tool, especially on the occasions of turbid or dark water.

Keywords: acoustic video camera, seafloor hydrothermal flow, seafloor terrain observation

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Geological setting and hydrothermal system at southern Mariana Trough: approach from high-resolution bathymetric survey

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To investigate the complex seabed morphology created by volcanic and tectonic processes and hydrothermal venting, near-bottom high-resolution bathymetric mapping of deep-water environment started at fast and slow spreading ridges during the last twenty years. As more recent technological and scientific advance, detailed feature and distribution of vent, fissure, fault, and lava morphology etc. have been well understood. In general, a localized hydrothermal system is mainly organized by interaction between tectonic and volcanic control. The occurrence and/or existence of fault, fissure, and fracture play an important role as formation of hydrothermal conduit (e.g. Humphris et al., 2002; Glickson et al., 2007; Ondreas et al., 2009).

In the study area, southern Mariana Trough, near 12 57'N, 143 37'E, have several hydrothermal systems. Three hydrothermal sites (Snail, Archaean, Pika) are located just on the active backarc spreading axis, the eastern foot of the axial high, and the top of an off-axis seamount about 5 km from the axis, respectively (Ishibashi et al., 2004; Kakegawa et al., 2004, 2008; Urabe et al., 2004), and these are aligned roughly perpendicular to the spreading axis. According to observation of the hydrothermal fluid, the system of on-axis site (Snail) is ephemeral, on the other hand, the two off-axis sites (Archaean and Pika) seem to have longevity of life (Urabe et al., 2004). The topography of sulfide mound, lava morphology, occurrence of fault and fissure, and chemistry of volcanic rock and sulfide deposit at each site has unique characteristic respectively, despite these sites are closely located. Thus, we will discuss that "what is necessary to maintain or develop these system?". The high-resolution bathymetric data for the examination was collected by AUV (autonomous underwater vehicle) URASHIMA in 2009 during the YK09-08 cruise.

Keywords: hydrothermal system, geological setting, Southern Mariana Trough, high-resolution bathymetric survey, lava morphology, sulfide mound

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U-Th radioactive disequilibrium dating of hydrothermal sulfide minerals

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The time scale for a hydrothermal activity is an important factor which controls the evolutionary interaction of chemosynthetic-based communities in a submarine hydrothermal system and "Rock-Fluid -Ecosystem linkage".

Dating techniques involving radioactive disequilibria of ^{235}U, ^{238}U and ^{232}Th decay series have been applied for hydrothermal submarine ore deposits. Among previous studies, ^{230}Th-^{234}U disequilibrium dating applied for massive sulfide mounds from Transatlantic Geotraverse (TAG) deposit on the mid-Atlantic Ridge yielded a wide range of ^{230}Th-^{234}U ages from 2.6 to 38 kilo years. The results indicated episodic activities lasted which more than 30 kyr in the TAG area positioned on a slow spreading ridge. In this study, we have attempted ^{230}Th-^{234}U disequilibrium dating for younger hydrothermal deposits from Okinawa Trough and South Mariana Trough using a Multiple-Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MC) and examined its applicability for dating of younger hydrothermal activity. Before 1990, radioactive counting method was widely used to measure radioactivities of U and Th. But recently, mass spectrometry has made it possible to determine lesser amounts of uranium and thorium with higher precision.

The samples used in this study contain high amounts of sulfide and barite. Pb and Ba causes analytical interferences for U and Th isotope analyses, thus a good separation of the two elements is necessary. A two stage column chromatography was therefore used for the separation process.

The sulfide mineral from Izena hole of Okinawa Trough was separated by acidic decomposition from insoluble barite. The ^{230}Th-^{234}U disequilibrium age of three samples yielded 700 to 1000 years. It has thus been fairly possible to apply the ^{230}Th-^{234}U disequilibrium dating for young age hydrothermal deposits to about several hundred years. However, due to low U/Th ratios in these samples, the precision of this method deteriorates. In addition, it was found necessary to estimate the initial ^{230}Th /^{232}Th ratios to determine the age more accurately. The samples from Archean site of Mariana Trough have higher U/Th ratio and enables more precise dating. Samples from a big chimney form two isochrones yielding 700 to 1800 years.

The results show that we need analyze several samples to see if they form an isochron.

Keywords: U-Th radioactive disequilibrium dating, Hydrothermal vent

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Marine DC resistivity survey at deep-sea mine in the Izu-Bonin arc, Japan

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The recent growth of world-wide requirement of metals demands advanced explorations for finding metal mine and deposits. Here we propose a new way for exploration of buried submarine massive sulphides with marine controlled-source electromagnetic

technique, and magnetic survey. We demonstrated feasibility studies using various marine electromagnetic soundings: magnetometric resistivity (MMR) survey, CSEM survey and marine DC resistivity survey. As a result, we confirmed that the electromagnetic responses of each marine electromagnetic survey are very sensitive to the conductive layer simulating the submarine massive sulphide deposits, which is buried at the depth of several tens meters. We newly developed our own controlled-source EM survey system for AUV and ROV, and the real field test for the ROV-based marine DC resistivity survey system was conducted on Jan-Feb in 2011. The JAMSTEC R/V Kairei and ROV Kaiko 7000II gave us a chance to apply our system to a deep-sea mine at the Bayonnaise knoll, Izu-Bonin arc, off Japan. Our system stably obtained the resistivity information in the seawater at the middle depth of sea, which allows us the system calibration because the seawater electrical conductivity is known. Then, we obtain the apparent resistivity distribution on the seafloor. Although our sounding depth is limited (one system has a few meters and another has several tens of meters), the deep-sea mine zone shows relatively conductive feature compared to the surrounding area. We also found that the resistivity distribution seems to be complicated possibly reflecting heterogeneous geological structures. In addition, the magnetic survey using AUV, to which three-components and total-force magnetometers were attached, was carried out on the same area, and the magnetic anomaly around the knoll was successfully obtained. These results suggest us a possibility of our new CSEM survey with ROV and magnetic survey with AUV to imaging the distribution of exposed and buried deep-sea mine.

Keywords: deep-sea mine, controlled-source, EM survey, ROV, AUV

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Seafloor spreading history in the Natal Valley and Mozambique Ridge deduced from vector magnetic anomalies

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The break-up of Gondwana is the important geological event to have affected the southern hemisphere in the past 200 Myr. The seafloor spreading history revealed by the geophysical survey around the Southern Ocean is one of the vital key to understanding the timing and geometry of early Gondwana break-up. However, magnetic anomaly lineations are less well defined because the existing marine magnetic data are still poor resolution especially in South Indian Ocean.

To reveal more detailed seafloor spreading history in this region during the initial break-up of Gondwana, the shipboard three components magnetic survey were carried out for the first time in the Natal Valley and the Mozambique Ridge off South Africa, using the R/V Pelagia operated by the Nederlands Institute voor Onderzoek der Zee (NIOZ) from 9th April to 1st June 2009.

In northern Natal Valley, complicated strike patterns of magnetic structure are shown, and trends of magnetic anomalies are not consistent with trends of magnetic isochrons reported in previous study. Additionally, characteristic trends are observed between S28/E34.5 and S27/E35. We will present vector magnetic anomaly features in the Natal Valley and the Mozambique Ridge, and discuss the seafloor spreading process in this region.

Keywords: vector magnetic anomalies, magnetic lineation, Gondwana breakup, Natal Valley, Mozambique Ridge

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Preliminary report of the R/V Hakuho-Maru KH-10-7 cruise, Southern Ocean

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The Antarctic Ocean is a key area to understand global environmental changes. Role of Antarctic Ocean is considered to be very important in the Earth system, but data coverage is still poor and further observations are required. The research cruise KH-10-7 by the R/V Hakuho-Maru of Japan Agency for Marine-Earth Science and Technology was conducted in the Indian Sector of the Antarctic Ocean from 17 December, 2010, to 17 January, 2011. The main objectives of the cruise are as follows.

1) Antarctic Cryosphere evolution based on marine geological observations in Conrad Rise and off Lutzow-Holm Bay: Site survey for new drilling proposal.
2) Studies on tectonic history of the Conrad Rise.
3) Quantitative estimation of cyclonic gyre and Antarctic Bottom Water transport in the Australia-Antarctic Basin.
4) Changes of ecosystem due to global warming and/or acidification in the Southern Ocean and following responses of biogenic trace gases in surface seawater.

The R/V Hakuho-Maru left Port Louis, Mauritius, on 17 December, 2010, and arrived at Fremantle, Australia, on 17 January, 2011, after multi disciplinary observations in the Southern Ocean. CTDs, water samplings, sediments sampling, rock sampling and multi channel seismic observations as well as underway observations were carried out during the cruise to attain these objectives. We will present the outline of KH-10-7 cruise and the topics concerning tectonic history of the Conrad Rise briefly.

Keywords: Southern Ocean, Cryosphere, tectonics, sediment, Antarctic Bottom Water, global warming

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Seafloor geodetic observation on S/V ”Takuyo”

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Japan Hydrographic and Oceanographic Department (JHOD) and Institute of Industrial Science, the University of Tokyo have been developing a system for precise seafloor geodetic observation with the GPS/Acoustic combination technique and deploying seafloor reference points on the landward slope of the major trenches around Japan, such as the Japan Trench and the Nankai Trough.

The past observations show intra/interplate crustal movements at seafloor reference points installed along the Japan Trench and the Nankai Trough, with the precision of less than 1cm/year. In addition, the co-seismic seafloor movement associated with the 2005 off Miyagi Prefecture Earthquake (M7.2) and series of crustal movements indicating the beginning of the reaccumulation after the release of crustal strain in the sea area were detected.

In 2008, JHOD installed the acoustic transducer on the bottom of the Survey Vessel ”Meiyo” (550 tons) permanently and started the measurements for the sailing method for observing more efficiently and precisely.

JHOD also installed the new seafloor geodetic observation system on the S/V ”Takuyo” (2,400 tons) in 2010. It is expected that the observations by ”Takuyo” will be more precise in strong tidal area and the observations by JHOD will increase.

In this poster, we will report the system of sailing seafloor geodetic observation mounted on S/V ”Takuyo” and the latest results observed by S/V ”Takuyo”.

Keywords: seafloor geodetic, GPS/A, seafloor reference point, acoustic ranging

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For Advance of Acoustic Ranging for Observing Ocean Crustal Deformation

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Magnitude 8 class interplate earthquakes have occurred in the Suruga-Nankai Trough with the recurrence intervals of about 100-150 years. To reveal process and estimate occurrence of offshore interplate earthquakes, repeated observation of ocean floor crustal deformation is performed there using the observation system using Kinematic GPS positioning and precise acoustic ranging.

There are next two problems for acoustic ranging caused by the delayed signal that is considered the measure signal reflected at the sea surface : 1) cross-correlation coefficient on the true arrival time relatively drops, and the number of observation data decreases, and 2) the delayed signal causes cross-correlation coefficient on the true arrival time to be smaller than that on the lag time, and true arrival time is estimated wrongly. We must develop a method to perform cross-correlation computation automatically in order to determine true arrival time and to use data containing delayed signal. In this study, we performed numerical experiment of composing multiple waves to verify variation of cross-correlation coefficient depended on amplitude rate and delay time of direct and delayed signal.

We made the theoretical reference wave of the fifth-order M-sequence wave with six cycle carrier waves per unit digit same as measure signal. Considering composed two waves assuming reflection once at the sea surface, we combined the reference wave with delayed wave with delay time, DT. Performing cross-correlation procedure with the combined wave and reference wave, we got cross-correlation coefficient CC1 at the arrival time of direct wave and CC2 at the arrival time of reflected wave. Varying the amplitude ratio of reflected wave relative to the direct wave from 0 to 1, we verified the variation of two cross-correlation coefficients. In the same way, considering composed four waves assuming reflection twice at the sea surface, we the verified variation of three cross-correlation coefficients. Delay time of third reference wave supposed as reflected twice signal is 2DT, and cross-correlation coefficient at the arrival time of twice reflected wave is CC3. DT was varied from 1 to 3 because delay lag of observed wave is this variation.

Combining two waves assuming once reflected wave suggested that delayed wave drop cross-correlation coefficient at the true arrival time relatively to decrease useful data. Numerical experiment proved that CC1 changed from 0.7 to 0.75 when we combined direct wave with reflected wave with the ratio of 1 to 1. We can expect increase of data with cross-correlation coefficients less than the threshold 0.7 because CC1 easily drops less than 0.7 due to some noise. Therefore cross-correlation coefficient of retuned signal containing delayed signal decreases caused by measure wave oneself reflected at the sea surface.

For the case of four waves assuming twice reflected wave, CC1 could be less than CC2, and arrival time was read wrongly. CC1 equals CC2 in the only case of combining direct wave with reflected wave with the ratio of 1 to1. Actually, CC1 is larger than CC2 because the theoretical reflectance the sea surface is less than 1.0. CC1 was less than CC2 and CC2 was larger than CC3 in every DT on experiment of combining four waves when the ratio of direct wave, once reflected wave and twice reflected wave was 1 to 2 to 1, respectively. CC1 was sometimes less than CC3. Therefore DT on which it is showed CC1<CC3<CC2 existed, and we demonstrated numerically that CC1 could be minimum. For the actual data of observed returned signal, second peak of cross-correlation coefficient was found in time DT=2.5ms. This fact is consistent in the result of numerical experiment. In consequence, it is caused by measure signal oneself reflected twice at the sea surface that cross-correlation coefficient at the true arrival time was not maximum so that arrival time was read wrongly.

Keywords: Ocean Crustal Deformation, Acoustic Ranging, Advance of Precision, Reflected Signal at the Sea Surface, Cross-corrrelation Procedure, Numerical Experiment

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Layout of buoys and seafloor transponders for next-generation measurement system for ocean floor crustal deformation

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We are developing a geodetic method of monitoring crustal deformation under the ocean using kinematic GPS and acoustic ranging. We deployed benchmarks on ocean floor and determine the positions of them by acoustic ranging from vessel whose position is determined by kinematic GPS technique. Ultrasonic signals are generated from the surface vessel drifting over the benchmarks that replies the signals. Both sound speed structure and the benchmark unit positions are determined simultaneously using a tomographic technique from the two way traveltime of the ultrasonic signals.

We repeatedly carried out measurements at several sites around Nankai trough, South eastern part of Japan. Now the horizontal repeatability is about 3 cm. Although a few measurements in one year enable this repeatability to detect stable deformation rate of the crust due to subduction within few years, unstable temporal variations or faint changes cannot be detected. To monitor the focal area of coming plate boundary earthquakes, real-time monitoring is desirable.

Therefore, we are designing a moored buoy-based next generation measurement system, with which we can continuously monitor the ocean floor crustal deformation.

In the new system, buoys have all the functions which the ship has in the present way. But we need to consider that the positions of the buoys are controlled not by us but by current. We can control only the area of drifting by designing the length of the mooring cables and the buoyancy of the buoys. If we want to make the buoy stable around one point, we can make the cable short but we must make the buoyancy large to avoid sinking by the current, which requires more cost. An appropriate designing of length of the cable and buoyancy is very important.

We theoretically investigated the relationship between buoy-transponder geometry and the accuracy of transponder positioning. We assumed a system consisting of combination of three transponders and three buoys. We calculated the joint probability density function (j-pdf) of the weight center location of the benchmarks, which were called from three buoys in half space homogeneous sound structure, from the synthesized travel time. We defined the FWHM for the peak of j-pdf as an accuracy of the positioning, and then calculated this accuracy with various depths of the benchmarks and geometries of the measurement system.

As a result, we understand relationship between the accuracy of benchmark positioning and the configuration as follows:

1. The appropriate expanse of the benchmarks is about square root of 2 times of the depth. 2. The two triangles by benchmarks and the buoys are preferable being staggered. 3. The accuracy of the benchmark positioning can be kept in the range of 10% worse than the best. 4. If the buoy configuration distorts, 30% shortening of the length of the side makes the accuracy of the positioning 40%worse.

The results suggest that the benchmark positioning accuracy is less robust with distortion of the buoy configuration than with simple shift keeping their configuration. We should design the length of the cables and buoyancy of the buoys to keep the horizontal motion of the buoys not to distort the triangle more than 30% to keep the accuracy in the range from 0 to 40% worse than the best one.

In this study, we investigated the accuracy on assumption that the velocity structure is half-space homogeneous. In addition, we should check up the appropriate number and geometries of the buoys in the case which sound structure changes in space as well as in time.

Acknowledgement: This research was promoted by a project of the Japanese Ministry of Education, Culture, Sports, Science, and Technology. Trajectory data of moored buoy was provided by Dr. M. Kido, Tohoku University. We appreciate it very much.

Keywords: Buoy, Ocean floor crustal deformation, Acoustic ranging, GPS, Transducer

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Microseismicity around the Chile Triple Junction revealed by Long-Term OBSs

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The Chile Triple Junction (CJT) is positioned on the Chile trench. At the CJT, spreading ridges of the Chile ridge system between the Nazca plate in the north and Antarctic plate in the south subduct beneath the South American plate. Because the southern edge of the source region of the 1960 Chile earthquake is close to the CJT, to obtain coupling between the plates is useful to consider expanse of the 1960 earthquake source region. We carried out an earthquake observation in the CJT region using Long Term Ocean Bottom Seismometers (LT-OBSs). Objectives of the observation are to obtain precise seismic activity and seismic structure around the CJT. Furthermore, to reveal deep structure is one of aims of the observation by using tomography and receiver function analysis. Long term seismic monitoring using the LT-OBSs increases reliability of results because many events can be observded.

The LTOBS was developed at the Earthquake Research Institute (ERI) of the University of Tokyo. A three-component 1-Hz seismometer is installed and seismic signals are sampled at 100 Hz using a 20-bit A/D and record the digitized data continuously on the hard disks for one year. All the components are contained in a 50-cm diameter sphere that is made of titanium alloy. The acoustic transponder for LTOBS has the functions of communication, interrogation and anchor release. An observation area is off Taitao peninsula, Chile where the ridge is subducting. The deployment of the LT-OBSs was performed on 1 March 2009 during the RV Mirai MR08-06 cruise. Due to complex seafloor topography, the topography survey using multi-narrow beam acoustic sounder was carried out to determine deploy positions. Since there was no sea floor observation in the study area, spatial intervals of five LT-OBSs were set to be approximately 30km. After the deployment of the LT-OBSs, small airgun was shot along profiles which connect deployed positions of the LT-OBSs. Simultaneously, a hydrophone streamer was towed to collect reflection data. In March 2010, all the LT-OBSs were recovered by the rescue-salvage ship of the Chilean Navy. After the recovery of the LT-OBSs, reproduction of the data were performed on processing system. Many microearthquakes were recorded and arrival times and P- and S-waves were picked up. From preliminary hypocenter location, 167 events are located within the observation network. Typical seismicity in spreading center is seen in seaward side of the trench. This indicates that the oceanic plates are subducting with spreading of two oceanic plates.

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Imaging of initial structure in Izu-Ogasawara arc obtained by seismic reflection experiment

Mikiya Yamashita[1*], Yuka Kaiho[1], Takeshi Sato[1], Tsutomu Takahashi[1], Shuichi Kodaira[1], Narumi Takahashi[1], Seiichi Miura[1], Yoshiyuki Tatsumi[1], Osamu Ishizuka[2]

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t is important to investigate crustal reconstruction for understanding arc evolution. To obtain the knowledge of arc evolution, we should investigate the condition of initial arc crust. In Izu-Ogasawara forearc region, it is known to locate the outcrop of initial arc crust by submarine study. Therefore, Japan Agency for Marine-Earth Science and Technology carried out seismic reflection and refraction surveys in Izu-Ogasawara forearc region in KR10-13 and KR11-01 cruise. Onboard preliminary results show the concave basement along Ogasawara Trough and thin sediments. In this meeting, we will report the preliminary MCS results in these cruises.

Keywords: MCS survey, IBM forearc, initial arc structure

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The configuration of paleo-arc in Izu-Ogasawara forearc region

Mikiya Yamashita[1*], Naoto Noguchi[1], Shuichi Kodaira[1], Narumi Takahashi[1], Seiichi Miura[1], Yoshiyuki Tatsumi[1]

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In Izu-Ogasawara forearc region, it is known to exist two paleo-arcs formed in Oligocene and Eocene age (e.g. Taylor, 1992). It is important to investigate the configuration of these paleo-arcs for understanding of the crustal evolution by backarc rifting. Japan Agency for Marine-Earth Science and Technology has been carried out seismic refraction and reflection survey using 90 OBSs on Izu-Ogasawara forearc region in 2010 (KR10-13 cruise) for understanding the configuration of paleo-arc along from Shinkurose to Ogasawara Trough. Obtained preliminary results show the clear reflection from seamount and sediments in forearc basin.

Keywords: MCS survey, Paleo-arc, rifting

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Multichannel seismic reflection experiment across the southern end of the Nansei-Shoto trench-arc-backarc system

Noriaki Izumi[1*], Daishi Horiuchi[1], Kentaro Kaneda[1], Azusa Nishizawa[1]

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The Nansei-Shoto trench-arc-backarc system to the south of Kyushu, Japan, is characterized by the Okinawa Trough, as a backarc basin, where continental rifting is incipient.

We have carried out a multi-channel reflection experiment to obtain detailed seismic images across the Nansei-Shoto trench-arc-backarc system since 2008.

International cooperative seismic exploration of Taiwan, the United States and France was conducted to elucidate the seismic structure to the west of Yonaguni-jima Island in the southern end of the Nansei-Shoto trench-arc-backarc system (Liu et al.,1995). They pointed out that the crustal structure in the forearc region is influenced by subduction of the Gagua Ridge which is a N-S trending topographic high to the south of the Nansei-Shoto Trench.However, there is almost no investigation aiming at grasp of the deep structure to the east of Yonaguni-jima Island and subducting Gagua Ridge.

We obtained the multi-channel seismic data across the Nansei-Shoto Island arc and backarc by using a 240 channel hydrophone streamer cable of 3000 m in length, shooting a 3-gun cluster airgun, 5.7 liter (350 $inch^3$)x3 in a total volume, at an interval of 50 m.The survey line of north-south direction was designed to cross the southern part of the Yonaguni Submarine Graben in the south of the Okinawa backarc basin and the Okihateruma forearc basin (East Nan'ao Basin) .

The obtained seismic reflection profile showed that a thick sedimentary layer with a thickness of about 2 sec two-way travel time in the forearc basin to the east of Yonaguni-jima Island.The sedimentary layers with almost horizontal reflectors in the upper part on-lap the forearc basement.Horst-and-graben structures in the northern part of the island arc and many intrusions in the trough sedimentary layer are identified, which shows same features obtained to the west of Yonaguni-jima Island by (Liu et al.,1995).

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Features of Multi-Channel Seismic profile in the middle Okinawa Trough

Daishi Horiuchi[1*], Azusa Nishizawa[1], Kentaro Kaneda[1], Noriaki Izumi[1]

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The Okinawa Trough (OT) is a backarc basin accompanying with the Nansei-Shoto arc-trench system. Both of the Nansei-Shoto Island Arc and the OT are divided into northern, middle and southern parts by Tokara Gap, Kerama Gap and their extensions to the northwest. The northern OT has shallow water depth and shaving the trough slope, and the direction of trough axis is NNE-SSW. In contrast, the southern OT has deep water depth and steep trough slope, and the direction of the trough axis is ENE-WSW. The origin of these differences of geomorphic characteristics is presumed that the rifting stage is more advanced in the southern OT than in the northern OT.

Japan Coast Guard has been carried out seismic refraction and multi-channel seismic (MCS) reflection surveys on several survey lines along and across the trench-arc-backarc system to obtain rifting structures, which give further information for estimating the formation process of Nansei-Shoto Island Arc and OT. Japan Coast Guard conducted seismic refraction and MCS reflection surveys on the NW-SE survey line across the trough axis in the middle OT from April to May, 2010. The survey line lies between shallow sea terrace of East China Sea in the northwest and offshore of Tokunoshima Island in the southeast.

According to the MCS profile, the trough slope in the northwest part of the survey line has thick sediment layers with a thickness of more than 5 sec two-way travel time and any normal faults with their throws to the southeast fall cut the thick sediment layer. The trough bottom has thick sediment layers with a thickness of more than 2 sec two-way travel time and many normal faults of southeast fall in northwest region and northwest fall in southeast region cut the thick sediment layer.

The transition area of faults with their throws to the southeast to the northwest locates more closely the trough slope in the northwest of OT than the trough axis estimated from topographic data.

Keywords: Multi-Channel Seismic profile, backarc basin, Okinawa trough

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Refined crustal structure of Ogasawara Plateau - keys to estimate its formation process

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The Ogasawara Plateau is a conspicuous topographic feature on the northwestern Pacific Basin, with an area of larger than 40,000 square kilometers. Its top is approximately with a depth of 1000 m, relatively >4000 m higher than surrounding flat deep oceanic floor. Previous studies revealed that the plateau was covered with thick Cretaceous carbonates and located on the late Jurassic oceanic seafloor, indicating that igneous formation of the Ogasawara Plateau occurred within Late Jurassic to Cretaceous periods.

However its accurate formation model has not been constructed yet. Did concentration of intraplate igneous activities, similar to volcanism forming many seamounts around the Ogasawara Plateau, in the limited area contribute to form its large body? Or did a large-scaled igneous activity occur during a short period?

Japan Coast Guard conducted large-scaled seismic reflection experiments with multi-channel streamer cable and refraction experiments with ocean bottom seismographs on the Ogasawara Plateau with four long survey lines which total length exceeds 2,000 km. Our former seismic data analysis made clear important results that crustal thickness of the Ogasawara Plateau is >20 km, similar to that of the Izu-Ogasawara arc, and that the Ogasawara Plateau seems to collide with the arc on the Philippine Sea plate at a trench. However crustal structure of the plateau has not been analyzed well in detail. To estimate a formation process of the Ogasawara Plateau, a more accurate analysis in a velocity structure of the plateau crust was applied. Its result shows layered structure of the Ogasawara Plateau crust and will give important keys not only to construct its formation model but also to reveal what it is.

Keywords: crustal structure, Ogasawara Plateau

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Volcanic history and surrounding oceanfloor of the Mracus Island, Western Pacific

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Most of seamounts on the western Pacific Plate formed before 70 Ma in the so-called West Pacific Seamount Province (WPSP) which is characterized by relatively short seamount chains maybe indicating a significant short-lived hotspot system (Koppers *et al.*, 2003). The geochronological studies of each Cretaceous seamount, on the other hand, show the long-lived main shield stage of volcanism, because a seamount remained above a hotspot for a long time (approximately 10 m.y.: Hirano *et al.*, 2002). This may be attributed to either of the following two possibilities: 1) An abundant heat supply as in the superplume episode in the Early Cretaceous (Cox, 1991; Larson, 1991; Larson and Kincaid, 1996). 2) Slow absolute motion of the Early Cretaceous Pacific Plate (3-6 cm/yr.) (Duncan and Clague, 1985; Henderson *et al.*, 1984).

The research cruise using R/V *Yokosuka* equipped with the submersible *SHINKAI 6500*, was conducted around the Marcus Island (Minamitori-shima) on May 2010 in order to know the detail history during the formation of the Marcus Island. The shipboard multibeam acoustic surveys showing the detail bathymetry discovered the volcanic cones on seamount slope and the clusters of small conical volcanoes on surrounding abyssal plain (Oikawa and Morishita, 2009; This study). Most of cones are several hundred meters in height and 1-10 km in diameter. We observed the stratigraphy of Cretaceous volcanoes near the Marcus Island using the submersible *SHINKAI 6500*. Highly vesicular lavas were sampled at the volcanic cone on the seamount slope. The olivine-bearing dense lavas, on the other hand, were obtained at the steep slope beneath the lava platform in bathymetry, implying main-shield stage lavas in contrast to volcanic cones probably erupted at the rejuvenated stage during the Marcus Island formation.

Keywords: Pacific plate, Marcus Island, seamount, hotspot, Cretaceous, alkali basalt

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New geophysical data obtained from the southern part of the West Philippine Basin and the Palau Basin

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The West Philippine Basin (WPB) occupies western part of the Philippine Sea Plate (PSP). The spreading history of WPB has not yet been well understood despite accumulation of studies since 1970s. The origin of WPB was first proposed by Uyeda and Ben Avrahem [1972], which proposed that WPB was formed by entrapment of a segment of the Kula-Pacific Ridge in the middle Eocene. Hilde and Lee [1984] and Jolivet et al. [1989] supported the entrapment model. On the other hand, a backarc origin model of WPB was proposed by Lewis et al. [1982], Seno and Maruyama [1984], and Deschamps and Lallemand [2002]. Deschamps and Lallemand [2002] compiled bathymetry, paleomagnetic data, and seafloor age, and suggested that WPB is a back arc basin that had developed between two opposed subduction zones from about 54 to 30 Ma, and that rollback of these trenches provided the driving force for the spreading. They also suggested that WPB underwent a clockwise rotation through the opening, and that the direction of the spreading rotated counter-clockwise. However, the deficiency of the data south of spreading center (Central Basin Fault, CBF) hampered testing this mode.

In this study, we compile bathymetry and magnetic anomaly data of the southern part of WPB and the Palau Basin, which occurs to the south of WPB bordered by the Mindanao Fracture Zone. The dataset includes data from previous cruises of R/V Mirai, and newly obtained data during R/V Yokosuka YK10-14 cruise. The strike of abyssal hills near CBF in WPB is close to E-W, whereas that of the southern part near the Mindanao Fracture Zone is nearly NW-SE. This suggests that the spreading direction of WPB changed counter-clockwisely with time as suggested by Deschamps and Lallemand [2002]. Three component magnetic anomaly data in the Palau Basin suggest occurrence of magnetic lineations close to N-S in strike. Together with N-S trending abyssal hill morphology, it is considered that the Palau Basin was formed by seafloor spreading of an E-W direction.

Keywords: magnetic anomaly, seafloor spreading, Philippine Sea Plate, West Philippine Basin, abyssal hill

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Magnetic anomaly mapping and rock-magnetism of seafloor rocks at the hydrothermal sites in the southern Mariana Trough

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Magnetic anomalies observed in the ocean are basically originated from the variation of magnetization of oceanic crust. Hydrothermal vent activity is a possible cause of reduction of magnetization intensity in the small scale due to alteration of oceanic crust by the fluid circulation. In order to detect magnetic signals resulted from the variations of crustal magnetization under the hydrothermal vent sites area in the southern Mariana Trough, the magnetic field at the hydrothermal sites were measured by using the AUV URASHIMA during the cruise YK09-08.

Three components of the magnetic field were measured by using four fluxgate magnetometers attached to the AUV along the survey lines of 100-300m height from the seafloor. Crustal magnetizations were calculated from downward component of magnetic anomalies assuming a constant thickness source layer (250m). Some of the hydrothermal sites show lower magnetization than those of the surrounding areas. These low magnetization areas suggest that the basaltic rocks have been altered by hydrothermal activities.

In the cruise of Taiga10M, 1-4 m length cores were collected from the seafloor rocks using the BMS (Boring Machine System) of the Hakurei-Maru No. 2. Also, in the nine dives of SHINKAI-6500 during the cruise YK10-11, rock samples were collected from the seafloor. We have been studying remanent magnetization and basic magnetic property of these samples. Preliminary data show that remanent magnetization intensities of fresh basalts are 20-80 A/m and those of altered basalts are of the order of 1 A/m. These measured rock-magnetic data can be used in calculation of crustal magnetization and thus provide a better understanding of the geological structures of the hydrothermal sites.

Keywords: Mariana, hydrothermal activity, magnetic anomaly, rock magnetism

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Study of submarine volcanic activity at the 17N Mariana Trough back-arc spreading axis

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This paper presents the results of detail mapping of volcanic products and tectonic features of the axial valley floor in the 17N segment, Mariana back-arc spreding axis based on the observations of Shinkai6500 submersible.

Subsersible observations dive 1088 and 1089 are consistent with the interpretation of side scan sonar (SSS) image analyses. However, high-backscatter regions in the dive track of 1090 are underlain by pillow lava, indicating the the intensity of backscatter does not always give consistent results with the lithofacies.

General trends of faults, fractures and cracks are 165E and 170E, which are subparallel to and oblique to the spreading axis, respectively. In addition to these, faults, fractures and cracks running at high(Type 1) and acute (Type 2) angles to the spreading axis are present.

Cross cutting relationships between these tectonic features indicate the order of formation from Type 2, Type 1 to Type 3. Type 3 is observed on the latest volcanic products.

Sheet flows do not exist on slopes steeper than 9 degree, where pillow flows dominate, indicating that lava morphology depends on the slope of the basement.

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REE composition of submarine volcanic rocks in the southern Mariana Trough

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Rare earth element composition was analyzed for submarine volcanic rocks taken from the southern Mariana Trough to evaluate the characteristics of source magmas related to the rifting and spreading of southern end of the trough.

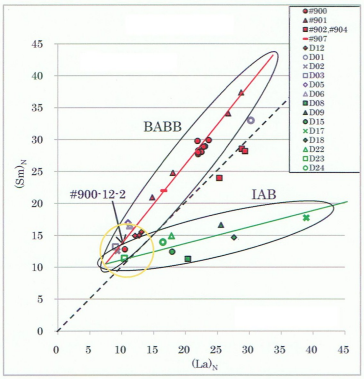
Mariana Trough is a back-arc basin formed in association with the subduction of Pacific Plate beneath Mariana ridge. The southern Mariana Trough is topographically high and flat compared with the middle and north region of the trough. In the studied area, at least three sets of back-arc spreading ridge, and presently active ridge is on the edge of the trough adjacent to the active arc volcanic chain. The active back-arc ridge is separated into three segments, and magma chamber was recognized beneath the boundary between northern two segments. Four rift zones are found on the southern end of the trough, and the most eastern one is presumed to be most active.

Rare-earth elements were analyzed using ICP-MS applied to combination of In-internal standard and standard addition methods. Analytical error was checked using JB-1a, and that of each element concentration was smaller than 5% except Tm and Lu, which were less than 7%.

Volcanic rocks obtained from the active back-arc ridge are basalt and andesite, of which SiO_2 concentration is 50-60%. CI-normalized REE composition patterns of those rocks are similar to that of N-MORB while La and Eu are slightly depleted. Fresh quenched glass layer without Mn coating was recovered from the southern end of active ridge, and the REE pattern of this rock is also similar to N-MORB. Chemical compositions of rocks from the ridge crest just above the magma chamber and the southern end are similar to each other, and the lowest SiO_2 and REEs concentrations among studied back-arc volcanic rocks indicate the most primitive composition of source magma of this area. All rocks except one from remnant ridges at the center of the trough give the REE patterns similar to that of N-MORB.

Volcanic rocks from submarine volcanoes on the four rift zones at the southern end of the trough are basalts, of which SiO_2 concentration is 48-51%. They give LREE-enriched REE patterns except one sample, which was taken from the easternmost zone. Among those rocks concentration of REEs decreases toward the east. The rocks taken from the three different seamounts on the easternmost rift zone, and the rocks from two seamounts give LREE-enriched arc like REE pattern, while, the other gives N-MORB like REE pattern. Normalized La/Sm ratio of the rocks from the rift zones can be plotted on the line having trend of about 4, and one of the endmember ratio is concordant with that of primitive back-arc volcanic rock. The La/Sm ratio becomes higher with increasing SiO_2 concentration, while negative Eu is not observed. Thus, the island-arc volcanic rocks of the studied area have the same source magma as the back-arc volcanic rocks, and the degree of addition of crustal material would be different to verify the chemical composition.

One volcanic rock taken from the easternmost rift zone has N-MORB like REE pattern and similar major chemical composition to the back-arc volcanic rock taken from the southern end of the active back-arc spreading ridge, indicating that spreading has already started at the easternmost rift zone, and probably, the southeastern end of the Mariana Trough is active back-arc volcanic zone.



Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SCG059-P15 Room:Convention Hall Time:May 27 10:30-13:00

Estimation of dose-rates for Mariana hydrothermal sites and comparisons with laboratory measurements

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The Mariana Trough is a present-day spreading backarc basin behind the Mariana Trench, where the Pacific Plate subducts under the Philippine Sea plate. The Mariana Trough is also characterized by active hydrothermal circulation with heat and chemical fluxes from the seafloor. Determination of the timescales of hydrothermal activity in the Southern Mariana trough has become important after the discovery of large hydrothermal plumes, with sudden changes in hydrothermal and volcanic activity in the sea floor. The long-term change of hydrothermal activities is also interesting in respect of ore formations. A systematic geochronological study of hydrothermal activities has not been possible due to the lack of methods which cover the age ranges of interest. In light of this, Electron Spin Resonance (ESR) dating of barites (BaSO4) has been attempted in chimneys deposited from hydrothermal vents at the Archean site in the South Mariana spreading center and in the Okinawa Trough.

Estimation of ESR ages requires evaluation of onsite annual dose-rate estimation or laboratory measurements of radioactivity. Gamma spectroscopy of samples can be performed using scintillation or semiconductor detectors. Semiconductor detectors such as HPGe have high resolutions (˜0.5% at 662 keV), but require cooling at liquid Nitrogen temperatures, and have lower efficiencies in comparison to scintillation detectors. We used a NaI(Tl) scintillation detector for measurements of gamma spectra at the Archean, Urashima, Pika and Snail deep sea hydrothermal sites. The relative dose-rate values are nearly two orders of magnitude higher than background at the Archean sites, and at least an order of magnitude higher at the Urashima site. Furthermore, a correlation was observed between rock type and relative dose-rate at all hydrothermally active sites. At the Archean sites, dose-rates values for dead chimneys were two orders of magnitude higher than background values. However, dose-rates for basalts from Archean and Snail sites were around a factor of 10 higher than background values. At the Pika site, the basalt dose-rates were only a factor of two higher than background. Our presentation will also provide estimates of dose-rate for three samples based on laboratory measurements of U, Th and K using high resolution gamma spectrometry, and investigate the correlation between relative dose-rates estimates with laboratory estimates.

Keywords: radiation, Southern Mariana, ESR, dating, radon

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Optical dating of quartz from hydrothermal sites in Middle and southern Okinawa Trough

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The Okinawa Trough is a 1200 km long, northeast-trending basin behind the Ryukyu Arc (Ishibashi et al. 1988). Since it is a back-arc basin in early spreading, modern submarine hydrothermal activity and mineralization have many characteristics which have aroused wide attention. The long-term change of hydrothermal activities is of interest in respect not only of ore formations but also of evolution of biological communities supported by the hydrothermal activities. Submarine hydrothermal fluids from the Okinawa Trough tend to be strongly influenced by interaction of the hydrothermal fluids with organic matter in the sediment resulting in high alkalinity and NH4+ concentrations of the fluids (Glasby and Notsu, 2003). The fluids also contain high concentrations of CO2 of magmatic origin. A systematic geochronological study of hydrothermal activities has not been possible due to the lack of methods which cover the age ranges of interest.

This paper presents initial results of feasibility studies to date quartz grains from two cores collected from Tarama Knoll, and the Izena Cauldron in the Middle and Southern Okinawa Trough. We extracted quartz from both core samples using standard chemical procedures, and subsequently used the SAR (single-aliquot regenerative) method for estimating the OSL (optically stimulated luminescence) equivalent dose. Preliminary results indicate an equivalent dose of ˜6 Gy for the 1108-MB sample from the Tarama Knoll. For the core sample from Izena Cauldron, equivalent doses have been observed to have a bimodal distribution, and the average equivalent dose based on 9 aliquots is ˜40 Gy. Dose-rates were estimated from K, U and Th measurements using a low background pure germanium gamma ray detector. The presentation will highlight OSL methodologies, and present preliminary ages of hydrothermal activities in the Middle and Southern Okinawa Trough at the above two sites.

References:
G. P. Glasby and K. Notsu, 2003, Ore Geology Reviews, 23, 299.
J. Ishibashi et al., 1988, Geochemical Journal, 22, 107.

Keywords: Okinawa Trough, dating, OSL, quartz, hydrothermal activity

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Spatial scale of hydrothermal circulation in the Iheya north site, inferred from heat flow and other data

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Numerous surface heat flow data were obtained during 2002-2008 in the area of the Iheya-North hydrothermal field in the middle Okinawa Trough, in order to clarify the spatial extent of the hydrothermal circulation system. In 2010, Drilling stidy was carreid out during IODP Expedition 331, and new subbottom temperature data were acquired around the hydrothermal site.

Within a small basin surrounded by knolls, three distinct zones are identified with different heat flow values, which we termed the high-, moderate-, and low-heat-flow zones. In the high-heat-flow zone located near the western edge of the basin, extremely high and widely scattered heat flow values were measured within ˜500 m of the active hydrothermal mounds, venting black smoker fluid of maximum 311 degC. With increasing distance east of the high-heat-flow zone, heat flow gradually decreases from 1.0 to ˜0.1 W/m2 in a region where surface sediment is dominated by clay and a high-resolution bathymetry indicates a smooth seafloor surface. We term this area the moderate-heat-flow zone. Further to the east (˜2 km from the high-heat-flow zone), the seafloor consists of coarser sediment with a rugged surface, and heat flow is very low (<0.1 W/m2), as designated the low-heat-flow zone. We suggest that such anomalously low heat flow can be explained by the recharge of seawater into the formation, and that hydrothermal vents or diffuse flow in the high-heat-flow zone can drive this kilometer-scale hydrothermal circulation within the Iheya-North knoll complex, if the sediment below the moderate-heat-flow zone is impermeable enough to prevent vertical fluid migration but is permeable enough to encourage horizontal flow.

2-dimensional numerical simulation was conducted to estimate possible premeability structure, including impermeable surface layer and permeable zone below. We report results from numerical simulation as well as new IODP data.

Keywords: hydrothermal circulation, Okinawa Trough, Iheya north field, heat flow, IODP

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Release of elements from basaltic rocks at high temperature and high pressure using a flow-type hydrothermal apparatus

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Hydrothermal fluids with a variety of chemical characteristics are generated in the sub-seafloor by reaction of various rocks with seawater under various physical conditions. Chemical diversity of the hydrothermal fluids leads to phylogenetical and physiological diversity of microbes thriving there (Nakamura and Takai, 2009). Experimental evaluation of water-rock reaction under the seafloor is needed to better understand deep-sea hydrothermal systems (Suzuki et al., 2009). To date, many experiments using batch system have been performed. However, there are few experiments using flow system simulating natural environments. Our goal is to develop a flow-type hydrothermal apparatus, to put it to practical use, and to understand marine hydrothermal system better.

We developed a flow-type hydrothermal apparatus that consists of HPLC pumps (flow rate: 6?600 ml/h), a preheating bath (SUS316, 100 ml), a water-rock reaction bath (hastelloy C276, 390 ml) and a cooling bath (SUS316, 5 l). The preheating and reaction baths are equipped with a heater (maximum temp. 300^{o}C and 500^{o}C, respectively). This apparatus can be operated at a pressure up to 50MPa. In the present experiments, the following settings were used: 6 ml/h of flow rate, 250^{o}C for the preheating bath, 400oC for the reaction bath and 40MPa of pressure. Grains of a basaltic rock (300 g) that was collected in the Izu-Oshima Island were used for the water-rock reaction experiment. The surface area of the grains was 4.52 m^2/g, determined by N2-BET method. We operated the apparatus for 1271 hours with rocks and ultra-pure water, for 1920 hours in that with ultra-pure water only, and for 864 hours with artificial seawater. Aliquots of reacted water were collected over time, and then pH and concentration of elements of these samples were determined by pH meter and ICP-AES.

Measured temperature in the reaction bath and pressure were stable at 340^{o}C and 40.1MPa during operation. Although pH in the experiment with ultra-pure water only was stable between 7.0 and 7.3, pH in the experiment with rocks and ultra-pure water was stable between 8.7 and 9.0. Concentration of elements in the reacted water increased with time. Release rates of each element from the basaltic rocks were calculated: Si, 5.25.E-11; Na, 1.93.E-12; Al, 6.34.E-13; K, 2.17.E-13; Fe, 7.72.E-14; P, 3.05.E-14; Li, 1.70.E-14; As, 1.94.E-15; Hg, 6.16.E-16; Ni, 4.62.E-16; Zn, 1.86.E-16; Rb, 3.35.E-17 (mol/m^2/s). In the experiment with the artificial seawater, Fe, Ni and Cr concentration increased.

This is the first report on the release rate of several elements (e.g., P) from basaltic rocks in a flow system under high temperature and high pressure. Our results provide insight into dissolution of basaltic rocks in natural environments under high temperature and high pressure, such as deep subsurface environments. However, some problems rise for the experiment with seawater. Further modification of the hydrothermal apparatus is required to simulate the seawater-rock reaction in laboratory.

Keywords: water-rock reaction, elemental dissolution, deep-sea hydrothermal system, flow-type hydrothermal apparatus, TAIGA project

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SCG059-P19 Room:Convention Hall Time:May 27 10:30-13:00

Long-term gamma-ray observation on deep seafloor off Hatsushima Island in Sagami Bay

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In the multi-disciplinary cabled observatory located on deep seafloor at a depth of 1175 m off Hatsushima Island in Sagami Bay, which was deployed in March 2000, long-term gamma-ray observation with NaI(Tl) detector has been carried out since the deployment of the observatory. The observatory was recovered in March 2002, and re-deployed in November 2002 about 40 m south of the previously deployed location. Since then, gamma-ray observation has been continued at the same position for more than 8 years up to present. Gamma-ray sensor is installed on seafloor whose 3 inch NaI(Tl) scintillation detector is attached downward touching seabed. It has multi-channel (256 ch) pulse height analyzer and energy spectra of gamma-ray can be obtained. It is known that output sinal of NaI(Tl) detector is affected by temperature variation. However, since the water temperature at the observation site on deep seafloor is 3 degree C and is almost constant, the influence with temperature is negligible. On the other hand, some kind of signal drift associated with aging could occur.

The calibration was carried out by using energy peaks of natural radiation, i.e. Bi-214 of U-series, Tl-208 of Th-series and K-40. As the result, channel number that corresponds to each energy peak decreased at almost constant rate. In case of K-40 peak (1461 keV), corresponding channel number decreased as large as 10 channels for the period of 8 years.

As the observational result, significant signal level i.e. net area increase of Bi-214 peak was observed in October 2006. Increase of K-40 was observed when M5.8 earthquake occurred east off Izu Peninsula on April 21st in 2006 which caused mudflow. When M5 class earthquakes occurred on Dec. 17th and 18th in 2009, increase of K-40 seems to be less significant. Tl-208 shows seasonal increase possibly related to the amount of suspended materials in seawater associated with spring bloom at sea surface. This indicates that sedimentation caused by suspended materials could be distinguished from that caused by mudflows through gamma-ray observation. Causes of those observational phenomena will be studied in detail based on further evaluation of long-term gamma-ray data considering those calibration results.

Keywords: gamma-ray observation, NaI(Tl) detector, deep seafloor off Hatsushima Island in Sagami Bay, east off Izu Peninsula earthquake, mudflow, suspended materials

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A reconnaissance for sub-bottom diastrophism and origin of methane hydrate in Toyama Trough, eastern margin of Japan Sea

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On 14-15th June 2010, during the JAMSTEC R/V Natsushima cruise NT10-10 Leg2, a reconnaissance investigation was executed in the north-central Toyama Trough in order to search for the microorganism decomposition type of methane hydrate buried under the sedimentary region along the Toyama deep-sea canyon. Research objectives are the verifications of the following hypothesis: The generation origin of methane which seeps out at the sea bottom of the Toyama Trough seems different in a southern part and an north-central part, and such a difference corresponds to the difference in crustal strain concentration and activity of tectonic movement.

We report our results of the sea-truth inspection with the precise swath bathymetry by multi-narrow beam echo sounding (MBES) utilizing SEABAT 8160 system and visual observations by the 1412th submersible dive of ROV Hyper Dolphin (HPD1142).

The surface ship survey was conducted within the rectangular area enclosed by the coordinates 37d56.0mN, 137d35.0mE, 38d15.0mN, 138d10.0mE. In the survey box three subarea, A1, A2, and A3 are filled with 0.5 to 1.0 miles interval of swaths. The system also acquired back-scattering data available to visualize as side scan sonar image. This bathymetric investigation aims mainly to map any tectonic morphology and the following aspects are pointed out. In the survey area A1 more than eighty-two spots of strong backscattering were recognized. Some source materials such as chemosynthesis livings, carbonate crusts, pock marks bared sandy and/or gravel-rich seabed, buried gas-hydrate dome, etc. are estimated during the MBES survey.

Submersible observation HPD1142:

On the basis of MBES survey in the A1 area NW offing Sadogashima Island, HPD1142 was conducted on the eastern margin of sediment flat of the central Toyama Trough. The vehicle arrived 1785m.w.d. bottomon one of the strong reflective spots which fringe the frontal zone of a debris-flow apron.

The first MBARI corer recovered the oxidized fragile clay, white soft clay and bluish grey colored semi-condensed clay. The middle layer seems like kaolin-like clay derived from eroded part of rhyolites. No outcrop of bedrock was observed through the surveyed route but sometime dense fields of sea anemones were found on muddy bottom. They seem to belong to only one species and stood on buried stones within the surface mud less than several centimeters in thickness. This interpretation was clearly justified by MBARI sampling which recovered bottom materials including a sea anemone and its basement stone. Therefore distribution of numerous sea anemones (density is more than 1-2 individuals per 1 square meters) might indicate spatial distribution of float stones in the muddy floor.

Moreover, bared rocks in larger size were also observed to be foundation of sea anemones. Recovered rock samples are all rhyodacites.

Most interesting is a rubble mound found earlier in the dive, at 1776m.w.d. bottom, where is a little bit higher than the landed point (1785m.w.d.). Most rubble is of rectangular shaped rhyolite but planar carbonate crusts were also observed on the entire mound surface. One tip of carbonate crust was recovered interstitial spaces (matrix) of this rubble mound were filled by pale skin-colored, kaolin clay. Consequently, this mound concluded to be an old vent of a small mud volcano, although it includes many lags of rhyolite and rhyodacite.

To conclude the dive HPD1142, it observed the facies boundary between sedimentary flat and piedmont apron of debris flows, although entire region is covered by fragile mud. The A1 area is composed of an intercalation (alternation) of debris flow deposits and hemipelagic and fluvial (back swamp) formations. The thickness of debris formation would be thickened towards the steep slope of the Sadogasima Island. Ground water discharge is probable more or less in the side of sedimentary flat along the facies boundary zone.

Keywords: Toyama Trough, eastern margin of Japan Sea, strain concentration zone, methan hydrate, submersible dive, neotectonics

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The geophysical intra-segmentation variation at the ultra-slow spreading Southwest Indian ridge 35-40E

Taichi Sato[1*], Kyoko Okino[1], Nobukazu Seama[4], Hiroshi Sato[2], Kentaro Nakamura[3], Ryoko Senda[3], Shiki Machida[5]

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It has been widely accepted for many years that the gross morphology of the mid-ocean ridge spreading centers varies with the spreading rate. Over the last decade, several exceptions to the spreading rate dependency have been reported. Recently, the ridge morphology is thought to be governed by the balance of the melt supply and the spreading rate. In this time, we attempt to understand how the variation of melt supply affects ridge architecture using geophysical observations (bathymetry, geomagnetism and gravimetric).

The Southwest Indian Ridge (SWIR) is an ultraslow spreading system, where the spreading rate is almost constant over the whole system, 14-16 mm/yr. The ridge shows a wide variability of seafloor structure, indicating that the spatial and temporal variation of melt supply may play a critical role in the structural process of mid-ocean ridge. The survey area is between Prince Edward fracture zone and Eric Simpson fracture zone (35-40E), which is one of the first order segments of the SWIR and the length is about 300 km. This segment is fully covered by prominent geoid high anomaly, and the Marion Island, the nearest the hotspot (37 51E 46 52S) from the ridge, is now located on 28 Ma crust about 250 km south from the SWIR. Low Na8.0 (Na_2O contents at MgO=8wt%, indicator of the degree of melting) along the axis within the geoid high area has also been reported.

New swath bathymetry, magnetic data and gravimetric data were acquired in 2008 and 2010 by scientists aboard R/V Hakuho-Maru (KH07-04, Leg2 and KH09-05, Leg4). Basement dredge, seismic survey and electromagnetic survey were also conducted during these cruises. Brief geophysical results were already presented by Sato et al., 2010, so now we focus on the development of oblique spreading subsegment based on the analysis of geophysical and geochemical data. We draw the following conclusions;

1) The continuity of seafloor morphology and magnetic isochrones adjacent orthogonal (35 30E to 36 20E) and oblique spreading subsegment (36 20E to 37 10E) at the western half of the survey area suggest that oblique spreading geometry is not a stable structure at least in the survey area. The current oblique subsegment could be orthogonal spreading segment around 3-4 Ma. Major element variation of the obtained MORBs suggest that the primary melt condition (P, T and major composition) is same at orthogonal and oblique subsegment (Sato et al., 2011). On the other hand, trace elements of the MORBs are slightly higher than the typical MORB (Sato et al., 2011). These results suggest that the slightly difference of the source mantle and the degree of melting may result in the forming of the orthogonal and oblique subsegment.

2) Some volcanic structures and moderate present normal magnetization are observed within the axial valley of the oblique subsegment. These may imply that the oblique spreading segment is not amagmatic segment and the melt supplied to the oblique subsegment is more divided into small scale, resulting in the formation of the third-order segment (Mizuno et al., 2010) through the melt focus process.

3) The asymmetric seafloor morphology and crustal thickness at oblique subsegment may be caused the same process at the inside and outside corner of the ridge-transform intersection. The recovery of mantle peridotites at the northern off-ridge part of the oblique spreading segment can support this idea.

Assuming that the on-axis geochemical variation can extend to that of the off-axis, the ˜3 Myr temporal crustal thickness variation calculated using shipborne gravity (Sato et al., 2010) may be closely related to the difference of the source mantle. However; it should be remembered that the ridge obliquity may encourage the along axis melt migration from oblique subsegment to the adjacent orthogonal subsegment, resulting in the melt focusing.

Keywords: mid-ocean ridge, seafloor morphology, magnetic anomaly, gravity anomaly

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The geochemical intra-segment variation at the ultra-slow spreading Southwest Indian Ridge 35-37E

Hiroshi Sato[1*], Kentaro Nakamura[2], Ryoko Senda[2], Taichi Sato[3], Shiki Machida[4], Kyoko Kanayama[5], Susumu Umino[5], Tomoaki Morishita[5], Hidenori Kumagai[2]

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Mode of spreading style at the mid-ocean ridge might depend on both spreading rate and amount of melt supply. Furthermore, melt supply depend on physical (temperature and pressure) and chemical (composition) of the source mantle. Therefore, the geochemical variations along the ridge with spreading-rate should reflect the deferences physical and chemical variation beneath the ridge.

We attempt to investigate central part of the Southwest Indian Ridge (SWIR) which is one of the ultra-slow spreading systems with spreading date of 14-16 mm/year. The research area is a part of the first order tectonic segment between the Prince Edward and Eric Simpson fracture zones. This segment is considered to be affected by Marion hotspot located south of the SWIR (le Roex et al., 1989). According to T. Sato (2010) and T. Sato et al.(2011), the segment is subdivided into five subsegments: three orthogonal spreading subsegments and two oblique spreading subsegments. In this study, we report geochemical variations of basalts from three subsegments, i.e. western orthogonal spreading subsegment, western oblique spreading subsegment, and central orthogonal spreading subsegment. At eastern end of the western orthogonal spreading subsegment and off-ridge of the western oblique spreading subsegment, topographic height is developed.

We had two cruises (KH-07-4 Leg 2 and KH-09-5 Leg 4) in 2008 and 2010 aboard R/V Hakuho-Maru. During two cruises, we performed 17 dredge operations, and we obtained MORB, mantle peridotite, metamorphic and sedimentary rocks along the central part of the SWIR (Sato et al., 2008, 2010). At the western part of the segment between the Prince Edward and Eric Simpson fracture zones (35.5-37.5E), we performed 7 dredge operations. Geochemical variations are summarized as follows.

1) Most of measured major elements variations can be explained by the crystal fractionation. Estimated compositions of the primary melt, which is back calculated based on equilibrium mineral compositions, for basalt from orthogonal spreading segment and oblique spreading segment have similar compositions. It indicates that the primary melt in this are was finally equilibrated with the mantle under the same conditions (P, T, major composition) even in the different ridge morphology.

2) Basalts from topographic high and oblique spreading segment have enriched compositions in trace elements including rare-earth elements, particularly in highly incompatible elements. Trace element compositions of source mantle calculated by degree of melting (Na8: Na2O content at MgO=8.0 wt%) indicate that basalts from topographic high and oblique spreading segment have enriched compositions in trace elements than those from normal spreading ridge.

3) Helium isotope ratio (3He/4He) of the basaltic glass from oblique spreading segment is approximately 8.0Ra which is similar value to typical MORB.

4) Mantle peridotites are recovered at the northern off-ridge part of the oblique spreading segment, suggesting that avolcanic conditions occurred immediately after formation of the topographic high.

These pieces of information allow us to have the following conclusions.

Geochamical variations along SWIR at 35.5-37.5E are mainly derived from source mantle geochemical heterogeneity particularly for highly incompatible elements. Differences of degree of melting have a small contributions to the geochemical variation. Enrichment in highly incompatible elements is not due to the direct effect of activity of the Marion hotspot although the possibility could not be denied that past hotspot activities metasomatised depleted source mantle.

Keywords: mid-ocean ridge basalt, Southwest Indian Ridge

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Different source of Os among basalts and peridotites from the ultra-slow spreading SWIR from 34E to 40E

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The ridge magmatic systems of all oceans are the place directly forming crusts and are good places to observe how different the crust forms among the mid-ocean ridges which have variable spreading rates possibly associated with amount of melt supply. The geochemical studies especially isotopic studies are effective to get information of source of the supplied melts. To investigate one of the unique ridge systems, the central part of the Southwest Indian Ridge (SWIR), known as an ultra-slow spreading system (14-16 mm/yr) is selected. We had two cruises in 2008 (KH07-4 Leg2) and 2010 (KH09-5 Leg4) aboard R/V Hakuho-Maru and dredged aphyric to porphyritic basalts, peridotites, metamorphic and sedimentary rocks from 17 sites during two cruises from 34E to 40E along SWIR (Sato et al., 2008, 2010). The Re-Os isotope system for basalts and peridotites was applied to identify their source. One of the major advantages using Re-Os system is that they are relatively immune to secondary effects, e.g., sea water alteration and mantle metasomatism. The Os isotope ratios of spinels separated from serpentinized peridotites which dredged from the Prince Edward fracture zone indicated more depleted signature than the mean value of abyssal peridotites (187Os/188Os=0.125). The time of Rhenium depletion (TRD) ages around 1Ga of these spinels show that these peridotites experienced melt extraction at least around 1Ga.

Keywords: ultra-slow spreading, Southwest Indian Ridge, Os isotope ratio

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Pterographical characteristics of Peridotites from near the Kairei hydrothermal field, Central Indian Ocean

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In recent submersible investigation and dredge cruising at near the Kairei hydrothermal field, southern Central Indian Ridge, we have recovered a lot of serpentinized and/or heavy altered mantle peridotites.

For unraveling the ultramafic rock-seawater reaction, we observed petrographically these peridotite samples especially in term of relic primary minerals such as olivine, pyroxene and spinel. Most sample generally shows that develop a typical mesh-rim texture of lizardite with brucite or magnetite at olivine and form bastite at pyroxene rim. Other secondary minerals such as talc and tremolite are occurred from a few samples.

Based on the result of these petrographical observation, we are going to identify secondary minerals using Raman spectroscope and measure the mineral chemical composition of these minerals by EPMA and LA-ICP-MS.

Keywords: Kairei hydrothermal field, serpentinized peridotite, low-tempreture alternation, serpentine, talc

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Petrology of gabbroic rocks from the Godzilla Megamullion in the Parece Vela Basin, Philippine Sea

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Godzilla Megamullion is the largest Oceanic core complex (OCC) with a dimension of ˜125km x ˜55km, occurs in the Parece Vela backarc Basin, within the Philippine Sea (Ohara et al., 2001). OCCs are domal bathymetric highs interpreted as portions of the lower crust and/or upper mantle exposed via low-angle detachment faulting (e.g., Tucholke et al., 1998).

Recent cruises (KR03-01, KH07-02 and YK09-05) recovered gabbroic rocks and plagiogranites from 16 localities along the surface of Godzilla Megamullion In this contribution, we will report petrographical analysis of the gabbroic rocks.

Gabbroic rocks are classified into leucocratic gabbro, gabbro, olivine gabbro and Troctolite (based on olivine-plagioclase-pyroxene systematics (Streckeisen, 1976)) or leucocratic gabbro, leucocratic hornblende gabbro, pyroxene hornblende gabbro and hornblende pyroxene gabbro (based on pyroxene-plagioclase-hornblende systematics (Streckeisen, 1976)). The volume of olivine gabbro and troctolite are 5% or less.

Leucocratic hornblende gabbro, pyroxene hornblende gabbro and hornblende pyroxene gabbro contain hornblende, clinopyroxene, plagioclase and Fe-Ti oxide. These gabbros are further classified into several lithological types on the basis of modal and mineralogical assemblage as shown below:

1. Fe-Ti oxide rich type: this type contains abundant Fe-Ti oxide (17 vol% as maximum), hornblende and plagioclase (maximum An = 50). Range of #Mg in clinopyroxene is 42-73.
2. Fine grain type: this type has relatively primitive composition (FeO/MgO = 0.94-1.88). Range of #Mg in clinopyroxene is 73 - 78.
3. Coarse grain type: this type mainly consists of plagioclase (mean An = 50, maximum An = 75) and clinopyroxene (range of #Mg = 73-87), and poor in hornblende. FeO/MgO ratio of bulk composition is 0.53-1.07.
4. Sheared type: this type includes mylonite and amphibolite, products of shearing and subsequent retrograde metamorphism within the lower crust (Harigane et al., 2008)

Olivine gabbro contains plagioclase (An = 68-77), clinopyroxene (#Mg = 73-88) and olivine (Fo = 84-86). Troctolite contains plagioclase (An = 72-83), and olivine (Fo = 87-88).

Olivine gabbro, troctolite and coarse grain type gabbro, which have relatively primitive composition, were recovered only from the vicinity of the beakeaway of Godzilla Megamullion. On the other hand, Fe-Ti oxide rich type and plagiogranite, which have relatively evolved composition, were recovered from all over the surface of Godzilla Megamullion. It should be noted that these evolved lithologies were were particularly abundant near the termination of Godzilla Megamullion.

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

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Sediment Wave in the Conrad Rise (Preliminary result of KH10-7 cruise)

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Sediment waves are often formed in association with bottom currents and turbidity currents. Reconstructing the development of these sediments can provide clues to understand paleo-currents and related oceanic environments. The Conrad Rise, located in the Southwestern Indian Ocean, is expected to have sediments that are affected by the environmental change such as glacial-interglacial cycle, because it is located between the subtropical front and the northern limit of the drift ice. A series of sediment waves are discovered at the Conrad Rise in the KH07-4 cruise, but the quantity of data is not enough to reconstruct paleo-currents. Accordingly, additional multi-beam bathymetry and seismic reflection surveys were conducted in the KH10-7 cruise in order to reconstruct the sedimentary environments.

The sediment waves are located at all depth range of the survey area between 2400 and 3400 m. Wave length are 1-2 km, lateral height is 5-40 km, and maximum height of crest is ca.150 m. Their strikes are variable but roughly arranged in parallel or slightly oblique to the contour lines. Morphology of sediment waves is variale in the northern, middle, and the southern part of the survey area. In the northern area, they have WNW-trending linear sediment waves. Heights of waves are higher compared with the other areas. In the middle area, NW- to nearly NS-trending sediment waves are observed. Some arcuate and crosscutting sediment waves are observed. In the southern area, highly continuous, arcuate sediment waves are observed.

The sedimentary strata in the survey area are divided into three units, A, B, and C in descending order based on seismic facies and their external forms.

The Unit A has 0.1-0.5 sec thick in the two-way travel time (TWT), with thickening southward external form. This unit is transparent with continuous reflectors inside. Reflectors are parallel to its upper surface. The migration of sediment waves is observed but less than a wave length. A strong reflector (A-1 reflector) is observed at the middle of the unit. The amplitude of the reflector is weak in the southern area whereas strong in the northern area. The depth of the reflector varies in each waves, especially in the northern area.

The Unit B has 0.1-0.2 sec thick in TWT, with lens-shaped external form. A strong reflector is observed at its upper surface. Though the upper surface shows undulation parallel to the sediment wave, internal reflectors are not parallel to the upper surface. Local erosional truncation is observed. Reflectors in the lower part are low-amplitude and poorly continuous ones.

The Unit C is 0.7 sec thick at maximum in TWT, with similar seismic facies to that of the Unit B. Its upper part has strong reflectors whereas transparent in the lower part. Reflectors are onlapping to the basement with basin-fill external form.

Based on these observations, we interpreted sedimentary environments of the Conrad Rise. In the seismic profiles, migration of sediment waves is little and the unit A shows continuous and transparent facies, thus significant change of the bottom current is not expected during sedimentation of the unit. Unit B is interpreted as a kind of local landslide deposit. Component of the unit is not uniform because it has some strong reflectors inside. Erosional truncation at its upper surface indicate that the unit is eroded during the sedimentation of the unit A. The component of the Unit C can be similar to that of the unit B.

The significant change of sedimentary environment is observed only twice at the boundaries of sedimentary units. Thus, these changes are not corresponding to cyclic change such as glacial-interglacial cycles. In order to reconstruct the bottom currents, we need to observe the relationship between the bottom current and sediment waves.

Keywords: Southern Ocean, Sediment Wave, Conrad Rise, Bottom Current

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Driving force and internal deformation of the Pacific plate deduced from two-dimensional GPS analysis

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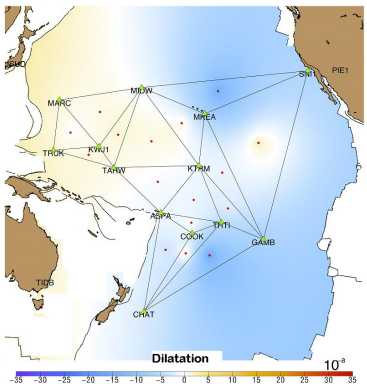
The motion of the Pacific plate using GPS data has been estimated previously, e.g., Larson et al., 1997 and Beavan et al., 2002. Beavan et al. analyzed up to 11 years of data from 1990 to 2001 for twelve stations on the Pacific plate. Their analysis showed that the GPS sites offshore of southern California are presently moving 4-5 mm/yr relative to the predicted Pacific plate velocity whereas the easternmost sites in South Island, New Zealand, are moving about 3 mm/yr relative to the Pacific plate. However, the two-dimensional distribution and the cause of the deformation of the plate were not clear.
Therefore, this study aimed to determine the Pacific plate motion and intra-plate deformation by adding new GPS data, and to infer the cause of the internal plate deformation from the estimated two-dimensional pattern of the dilatation of the Pacific plate.
GPS data from 1998 to 2006 of fourteen stations on the Pacific plate are used for this analysis, including seven IGS stations, five GSI stations, and two stations of Western Pacific Integrated Network of GPS (WING). We applied a linear approximation to the nine years of data of each set of daily coordinates.
The result shows that the Pacific plate is dilated in the western part and is contracted in the east. This can be explained by expansion near the subduction zones and by contraction near diverging ridges. This mechanism is in harmony with the theory that the plates are driven mainly by slab pull and ridge push forces, introduced first by Forsyth and Uyeda, 1975.



Keywords: Pacific plate, internal deformation, driving force of plate motion, GPS, dilatation

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Slab pull force and direction of plate motion

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Gordon,1978 showed two endpoints of subduction zone of a plate can represent the direction of the plate rotation by the sum of the slab pull forces. But the Pacific Plate, for instance, is not subducting at some subduction zones such as the New Hebri-des trench and New Britain trench, but some other plates are subducting below the the Pacific plate. This means that those part of trenches should not be included for the calculation of the direction of the plate motion.

We developed a method for computation of Euler poles of plate rotations with various parameters, e.g., distribution of subducting slabs, slab length/thickness/density, and dip angles. New Euler pole of the Pacific Plate rotation estimated about 20 degree southward from that of Gordon,1978.

Keywords: slab pull force, driving force of plates, Euler pole