Results of physical property measurements obtained during the CHIKYU cruise CK16-05 of hydrothermal fields at the middle Okinawa Trough.

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The middle Okinawa Trough, located along the Ryukyu-arc on the margin of the East China Sea, has several active hydrothermal fields. Cruise CK16-05 of D/V CHIKYU targeted one of the largest hydrothermal fields, the Izena hydrothermal field, and conducted coring operations. Site C9027 is located on the center part of the Northern sulfide mound. Four other sites where we can observe the subseafloor sulfide layer were drilled along an eastward transect from the Northern mound (Sites C9028, C9026, C9025 and C9032 from west to east). Two additional reference sites (C9029 and C9030) located to the north and northwest of Site C9027, where the subseafloor sulfide layer is not distributed, were also drilled. Here, we present the results of physical property measurements obtained by using CHIKYU's on-board laboratory.

Drilled core samples from the Northern mound (Site C9027) mainly consisted of sulfide-rich rocks. The total recovered core length was 5.09 m and core recovery rate was only 3.9 %, due to the difficulty of coring operations in this material. These core samples exhibited the highest thermal conductivity (18.37 W/m·K) and the highest P-wave velocity (7,613 m/sec) of all sites, which is consistent with an abundant occurrence of sulfide minerals.

The four sites along the eastward transect from the Northern mound (Sites C9028, C9026, C9025 and C9032) consisted of hemi-pelagic sediment, hydrothermal altered sediment, pumiceous gravel and sulfide layers. Conspicuous peaks in the results of physical property measurements such as a notably high grain density were observed within the cores from all four sites, suggesting that a large sub-seafloor sulfide layer is widely distributed in this area.

Core samples from the two reference sites (Sites C9029 and C9030) mainly consisted of pumiceous gravel and mud, and total recovered core lengths were 84.5 m and 61.4 m with recovery rates of 53.7% and 66.7%, respectively. Physical property data from these two sites did not exhibit the conspicuous peaks that were observed in the sites associated with the sub-seafloor sulfide layer.

Using whole physical property data, we will also present a first-order sub-seafloor physical property model for the Izena hydrothermal field in this presentation.

Keywords: seafloor hydrothermal deposit, CHIKYU, Physical Property, Izena

Chemical and isotopic compositions of interstitial water from the Izena hydrothermal field

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In the previous SIP cruises, several hydrothermal sites have been drilled in the Iheya North Knoll, and distribution of sulfide ore deposits and hydrothermal fluids have been unraveled. However, the sulfide ore deposits in the Iheya North Knoll are relatively small to understand detailed formation processes of a massive hydrothermal ore deposits, particularly factors controlling the scale and grade of the deposits, which will be useful for exploration of large and high-grade deposits. In the Izena Hole, two hydrothermal active fields have been reported, and they have been called Hakurei and JADE sites (Halbach et al. 1989). At Hakurei site, several mounds up to tens of meters in height lie in lines. A potential sulfide ore body has been also pointed out beneath the mound of sulfide by JOGMEC (http://www.jogmec.go.jp/news/release/news_06_000130.html). In this study, coring was conducted around the massive hydrothermal ore deposits at Hakurei site, and chemical compositions of interstitial water and headspace gases from sediments or volcanic rocks were investigated. The purposes of this study are (1) to investigate the influence of hydrothermal activities on the chemistry of interstitial water and headspace gas and (2) to understand how the distribution of hydrothermal fluids below the seafloor is related to the growth of massive hydrothermal ore deposits.

Keywords: Izena Hole, hydrothermal system, interstitial water, chemical and isotopic compositions

Physical Properties of massive sulfide samples at the Iheya North Knoll Hydrothermal Area, Off-Okinawa, Japan

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Seafloor massive sulphides (SMS) around seafloor hydrothermal active zone are attractive due to the general growth trend of global economical activities. Since the SMS is located below the deep seafloor, which restricts a number of boreholes for land-based mineral explorations, deep seafloor geophysical surveys (e.g., electromagnetic, magnetic, gravity and seismic surveys) are conducted to image the detailed distribution of SMS below seafloor. However, the complicated lithological structure around SMS interrupts the good interpretation of sub-seafloor structure by using sole geophysical technique. For example, low resistivity value is expected for SMS, but the evaluation of amount of metal deposits is not enough only from the resistivity structure.
In this study, we try to include the physical properties (and amount of metal deposits) obtained from laboratory experiment using rock core samples to add better constraint to the joint inversion, recently used for physical models based on the geophysical explorations. The rock samples of SMS were obtained by ROV and submersible exploration around the hydrothermal active areas in the Okinawa Trough, Japan. From 21 core samples, resistivity, density, porosity, natural remanent magnetization (NRM) are measured. The chemical components are obtained by X-ray fluorescence (XRF) analysis.
The measured result indicates a correlation between resistivity, NRM, density and concentration of metal. For example, the resistivity values measured in laboratory indicates pretty low features. The resistivity cannot be explained by the conventional Archie’ s law, and modified one (called as parallel circuit model). We newly develop a rock physics model of resistivity for massive sulphide in this study. In our model, a direct connection term between conductive solid and conductive liquid to the conventional model. As a result, our new model well explains the measured resistivity trend, especially samples including large amount of pyrite. The contribution of conductive material in rock sample indicates high correlation to the amount of Cu, Fe, Zn. We conclude that the higher conductivity of rock matrix and higher NRM are possibly relates to the high metal contents and can be a good index for mineral deposits.

Keywords: Hydrothermal Area, Massive Sulfide, Rock Physics

Possibility of the large-scale hydrothermal alteration zone (Bosei-site) observed around the northern part of outer-rim of Sumis caldera, Izu-Ogasawara Arc

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There are some submarine calderas on the volcanic front of Northern Izu-Ogasawara Arc. Volcanic massive sulfide deposits were reported from some of these caldera. Geological and bathymetric investigations with acoustic water column anomalies survey were carried out around the Smith caldera, in 2016. Plural small mounds and spur were confirmed as a geographic characteristic on north side outer rim of a volcanic crater. And also it was confirmed a plural number acoustic water column anomalies in a range of approximately 5km.By the dredge sampling around the outer rim area where underwater acoustic water column anomalies was observed, a large quantity of volcani-clastic rocks were sampled. All of these rocks are lapilli stone and lapilli tuff samples, and these rocks were subjected to conspicuous alteration which generally caused them to turn reddish and sinter developed in a rock margin. We performed microscopy and X-ray diffraction analysis to examine the origin of the red material, but the iron related material was not detected. However, by the quantitative analysis result of these sinter matrix, Fe_2O_3 more than 60wt.% was confirmed at the maximum. Needles of cristobalit are dispersed throughout in the vesicles of lapilli stone. So, we estimate that the low-temperature hydrothermal activity happens in a northern outer rim of Smith caldera area. Judging from distribution of acoustic water column anomalies and dredge sample, the scale may happen in a wide area of approximately 5km in northern rim of Smith caldera.

Keywords: hydrothermal alteration zone, Submarine caldera

Hydrothermal activity and sub-seafloor serpentinization on the Yokoniwa Rise developed in the Central Indian Ridge: Constraints from AUV mapping and rock magnetisms

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Exposures of ultramafic mantle rocks are extensively distributed within slow spreading environments, where alteration processes significantly influence submarine ecosystems and result in high concentrations of metals. The location and spatial extent of hydrothermal activity are difficult to constrain; however, studies of near-seafloor magnetic field can highlight these features because crustal magnetic minerals can be destroyed or created by hydrothermal processes. Therefore, investigating magnetic signatures in these ultramafic-hosted hydrothermal systems is important for detecting active and inactive hydrothermal sites and their mineralization states.

High-resolution vector magnetic measurements were performed on an inactive ultramafic-hosted hydrothermal vent field, known as Yokoniwa Hydrothermal Field (YHF), using a deep-sea manned submersible *SHINKAI 6500* and an autonomous underwater vehicle (AUV) *r2D4*. The YHF has developed at a non-transform offset massif near the Rodrigues Triple Junction of the Southeast Indian Ridge, Southwest Indian Ridge, and Central Indian Ridge. Dead chimneys were widely observed around the YHF along with a very weak venting of low-temperature fluids so that hydrothermal activity of the YHF was almost finished. The rock samples collected around the YHF and in the slope of the Yokoniwa Rise were utilized for measurements of physical and rock magnetic properties, and petlogical ivestigation.

The distribution of crustal magnetization from the magnetic anomaly revealed that the YHF is associated with enhanced magnetization, as seen at the ultramafic-hosted Rainbow and Ashadze-1 hydrothermal sites of the Mid-Atlantic Ridge. The results of rock magnetic analysis on seafloor rock samples (including basalt, dolerite, gabbro, serpentinized peridotite, and hydrothermal sulfide) showed that only highly serpentinized peridotite carries high magnetic susceptibility and that the natural remanent magnetization intensity can explain the high magnetization of Yokoniwa. These observations reflect abundant and strongly magnetized magnetite grains within the highly serpentinized peridotite. The detailed magnetic hysteresis measurements demonstrated that single-domain (SD) magnetite was formed during the later stage of serpentinization, and it is assembled inside of mesh structures with strong magnetostatic interactions. Comparisons with the Rainbow and Ashadze-1 suggest that in ultramafic-hosted hydrothermal systems, strongly magnetized magnetite and pyrrhotite form during the progression of hydrothermal alteration of peridotite. After the completion of serpentinization and hydrogen production, pyrrhotites convert into pyrite or nonmagnetic iron sulfides, which considerably reduces their levels of magnetization. Our results revealed origins of the magnetic high and the development of subsurface chemical processes in ultramafic-hosted hydrothermal systems. Furthermore, the results highlight the use of near-seafloor magnetic field measurements as a powerful tool for detecting and characterizing seafloor hydrothermal system.

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Keywords: Seafloor hydrothermal system, Serpentinization, Magnetic anomaly, Rock magnetism, Slow-spreading ridge

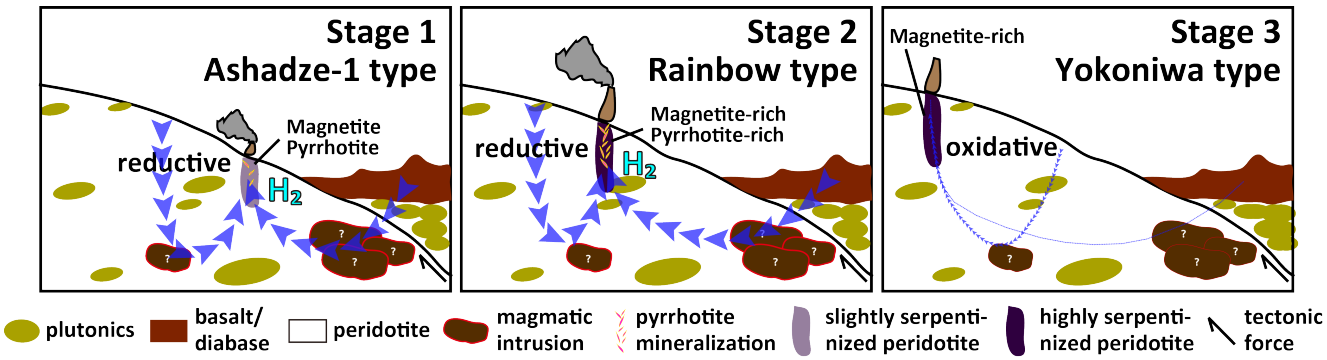

Figure. Model of magnetic mineral formation. Model showing the 3-stage formation history of magnetic minerals in ultramafic-hosted hydrothermal systems.
Stage 1: some magnetized magnetite and pyrrhotite form thorough serpentinization and sulfide mineralization under reductive conditions,
Stage 2: large quantity of magnetized magnetite and pyrrhotite are accumulated thorough serpentinization and sulfide mineralization under reductive conditions,
Stage 3: only magnetized magnetite remains as main magnetic source under oxidative condition after serpentinization of host rock.

Geomorphological features of the Southern Mariana Trough spreading center obtained from near-bottom surveys using the AUV Urashima

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We characterized field-scale geomorphological features at the sea-floor spreading center in the southern segment of the Southern Mariana Trough back-arc basin to understand its crustal formation in fine-scale. The Southern Mariana Trough is a currently active back arc basin, and it has fast spreading morphologic and geophysical characteristics (e.g. axial high), suggesting an abundant magma supply, even though the full spreading rate is categorized as slow spreading (e.g. Seama et al., 2015). Bathymetry and geomagnetic field data in the Southern Mariana Trough show highly asymmetric seafloor spreading; much faster spreading in the west side of the spreading axis compared to the east side (Seama and Okino, 2015). They estimated the spreading rate of the southern segment as 46 km/Myr with its half rate of 33 km/Myr for the west side and 13 km/Myr for the east side. We analyzed near-bottom acoustic survey data along an axial relief in the southern segment to obtain fine scale topographic map and back-scatter images. The near-bottom acoustic survey during JAMSTEC YK09-08 cruise was conducted using the AUV Urashima, in which a 120 kHz side-scan sonar and a 400 kHz multi-beam echo sounder are mounted. Seven survey lines along spreading axis cover 2.5 km by 0.9 km area along and across the spreading axis, respectively. The topographic map and the back-scatter images together with eight dive observation data acquired by the submersible Shinkai 6500 allow us to derive characteristic features at the sea-floor spreading center. The current active spreading axis is identified by six mounds with their diameters of 100-300 m; the mounds are in line parallel to the axial high in the southern segment and they are composed by pillow lavas without sediment. The mounds are divided into two groups that probably show fine scale different ridge segments; three mounds in the south are more active with their height of 10-25 m, while three mounds in the north are a few meters high, and two groups have a 100 m offset in line parallel to the axial relief. Further, we found asymmetric geomorphological features at the spreading center in small-scale (< 1 km scale). A lot of fault scarps and lineaments parallel to the axial axis exist in the topographic map and the back-scatter images, respectively, and their locations show high asymmetry; many of them locate in the northwest side of the axial axis, but few exist in the southeast side. The small scale asymmetric geomorphological features near the current spreading axis provide an important constraint on the style of the highly asymmetric seafloor spreading in the Southern Mariana Trough back-arc basin.

Keywords: Southern Mariana Trough back-arc basin, asymmetric seafloor spreading, near-bottom acoustic survey

Tectonics of long-offset oceanic transform faults along the Central Indian Ridge

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Oceanic transform faults, conservative plate boundaries in light of plate tectonics, are one of the first-order features of global seafloor. It connects offsets of mid-ocean ridge system up to 400km in length, controlling thermal structure, mantle flow, magmatism and hydrothermalism at mid-ocean ridges. Transform fault is also a good recorder of past and present plate motion and the fault wall is a tectonic window for investigating deep crust / upper mantle lithology. Although the recent numerical studies show that contribution of seawater infiltration along oceanic transform faults is not negligible in global water flux, the degree and spatial extent of serpentinization around the faults system remain poorly constrained. Oceanic transform faults (OTF), especially long-offset transforms where two extremely different age plates are juxtaposing, are thus interesting research target, however the previous field observations are very limited. We mapped the Marie Celeste OTF of 215 km offset as a part of Central Indian Ridge magmatism and hydrothermal activity studies in 2006 and discovered several characteristic features within and around the OTF. Then, we revisited the area January, 2016 and conducted detailed surveys along and across the Marie Celeste and other three OTFs in order to investigate the tectonics, evolution and fluid influence.

Among four transform faults we surveyed, three OTFs (OTF1, 2, and 3) are associated with prominent median ridges near ridge-transform intersections.Median ridges have been reported along both fast- and slow-slipping oceanic transform faults. But the origin of this shallow topography is still enigmatic. Previous studies have proposed along-transform volcanism, intrusion or diapirism of serpentinite, and transpression or localized compression resulting from change of plate boundary geometry. We collected basalt, dolerite, gabbro samples along the middle to upper slope of median ridge of OTF1. The median ridge is sheared and current principal transform deformation zone seems to extend north of the median ridge. Preliminary zircon U-Pb age dating from a recovered sample [Orihashi, personal comm.] shows 13.25+-0.24 [Ma], that is almost same age as the northern wall (=~12 Ma). These observations may suggest that the median ridge is a portion of the northern transform wall which was detached along the present deformation zone.

Previous studies have shown that slow-slipping transform faults are characterized by more positive RMBA (residual mantle gravity anomalies) than their adjacent ridge segment, due to thinning of crustal thickness towards segment ends. We calculated RMBA in our study area, assuming 6-km thick crust and three-dimensional mantle flow. OTF2, where the relative plate velocity is 38 mm/yr., is associated with RMBA of ~0 mGal that is almost same level as the adjacent ridge segment. This result is consistent with spreading rate dependence of gravity anomalies along OTFs by Gregg et al. [2007]. OTF1 (Marie Celeste) shows more negative anomaly than the adjacent ridge segment. A negative RMBA suggests mass deficit along OTF1, which could indicate serpentinization of mantle materials, increase of rock porosity, and/or relatively thick crust. It may suggest the effect of increased rock porosity and serpentinization enhanced by long-offset transform fault, that is usually hidden by effect of crustal thinning. Another possibility is more fast-spreading like crustal structure, that is suggested by off-axis large volcanoes and sheet lava flow within the axial valley at the ridge segment south of OTF1.

Keywords: oceanic transform fault, fracture zone, median ridge, gravity anomaly, Central Indian Ridge, serpentinization

Crustal structure and tectonic setting of the abyssal basin southeast of the Ontong Java Plateau, western Pacific Ocean

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Ontong Java Plateau(OJP) is located north of the Solomon Islands in thewestern Pacific Ocean. The area of OJP is about 1.9×10^6 km^2. Deep-sea drilling samples indicate that most of the OJP was formed rapidly about 120 Ma at mid-southern latitude in the Pacific Basin. Taylor (2006) proposed that the OJP was formed as a single large volcanic province together with the Manihiki and Hikurangi plateaus, called Ontong Java Nui (Chandler et al., 2012). The OJP is surrounded by the East Mariana, Pigafetta, Nauru, Ellice, Stewart, and Lyra basins. The former three basins (East Mariana, Pigafetta, and Nauru) were formed at the Pacific-Izanagi and Pacific-Phoenix ridges, respectively (Nakanishi et al., 1992). The tectonic history of the latter three basins (Ellice, Stewart, and Lyra) is, however, unknown because of lack of magnetic anomaly lineations. It is thus unclear whether OJP was formed at mid-oceanic ridges or away from active plate boundaries. To expose the tectonic history of Ellice, Stewart, and Lyra basins, we conducted the multichannel seismic reflection survey in the basins as well as OJP during the research cruise MR14-06 Leg 1 by R/V Mirai of JAMSTEC. After the regular data processing, we found several tectonic structures in the basins. The relief of the acoustic basements in the basins are not overall smooth. We found several igneous diapirs in Stewart and Ellice basins, implying that the volcanism occurred after the formation of the basins. We identified normal faults in the southern part of Stewart Basin, probably caused by the plate bending owing to the Pacific Plate subduction. We discovered the graben structures in the OJP situated at the northern and southern franks of the Stewart Basin. The graven structures were formed at the beginning of the formation of the Stewart Basin. Taylor (2006) concluded the basin was formed by NW-SE rifting during the separation of OJP and Manihiki Plateau around 120 Ma. Neal (1997) proposed another model, in which the NE-SW rifting and spreading event formed the Stewart and Ellice basins around the basin around 80 Ma. Our study prefers the model by Neal et al. (1997).

Keywords: Ontong java plateau, multichannel seismic reflection survey, large igneous provinces

Deep structure offshore eastern Australia from wide-angle refraction seismic data: from the Tasman Sea to the Lord Howe Rise

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The eastern Australian margin was shaped during the fragmentation of eastern Gondwana in the Late Cretaceous. This led to the opening of the oceanic Tasman Basin and to the formation of sub-parallel ridges and basins, including the Lord Howe Rise. The deep structure of the area is still unknown. In March-May 2016 onboard the R/V *Kairei*, the first large-scale crustal experiment in this region was conducted by JAMSTEC and Geoscience Australia with the deployment of 100 ocean-bottom seismometers (OBS) along a 680 km profile at 27.2˚S. The OBSs registered clear refracted arrivals from the crust and the mantle that are recorded at very large offsets of up to 300 km. The variation in the offset of the triplication point between these two refracted arrivals suggests strong crustal thickness variation along the profile. Both pre- and post-critical reflected phases from the Moho (PmP) are also very clearly recorded by the OBSs. We performed first-arrival tomographic inversion to analyze the data The initial layered P-wave velocity model was built using the basement reflection interpreted from coincident multi-channel reflection seismic data andthe PmP arrivals were used during the inversion to constrain the thickness of the crust. The final tomographic Vp model confirms the strong variations in crustal thickness and allows the identification of distinct crustal domains along the profile: Below the Tasman Basin is an oceanic domain with 7 km thick crust; further east, thicker crust (14 km) is present below the Dampier Ridge where granitic rocks have been dredged; directly east of the Dampier Ridge, the crust thins to 8 km below the Middleton Basin; the northern Lord Howe Rise has ~20 km thick crust. Below the northern Lord Howe Rise, lateral variations in upper crustal velocities are associated with Moho relief. Some areas show higher velocities (Capel Basin) compared to surrounding areas (Faust Basin). We propose that these lateral variations are related to weakly-expressed SW-NE oriented lineaments through the northern Lord Howe Rise that link to the Barcoo-Elisabeth-Fairway fracture zone in the oceanic Tasman Basin. Similar variations in crustal velocities are observed in the west below the Dampier Ridge. These variations are also associated with Moho topography. We suggest that the SW-NE trending lineaments linked to major fracture zones active during the opening of the Tasman Basin may have strongly controlled the latitudinal segmentation of the Lord Howe Rise, the Dampier Ridge and adjacent areas. The nature of the crust within the different crustal domains will be inferred using gravity modelling and by comparing the modeled P-wave velocities with previously published results from the western Pacific region. This comparison will help to better understand the processes that led to the fragmentation of eastern Gondwana.

Continuous formation processes of the shallow plate boundary fault in the Japan Trench reproduced by analog modeling experiments

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Large earthquakes and tsunamis have repeatedly occurred along the Japan Trench. In the 2011 Tohoku-Oki earthquake (Mw 9.0), the fault rupture extended to the shallow portion of the Japan Trench. These large slips on shallow decollement resulted in the huge tsunami that devastated much of the east coast of Japan. Therefore, it is key to understand the history of fault formation near the trench for the disaster prevention. At the 2011 earthquake, the slip of the plate boundary fault reached to the trench, and the seafloor of the outermost part of the landward trench slope horizontally moved approximately 50 m toward the trench, and uplifted approximately 7 to 10 m (Fujiwara et al., 2011, Science). The large fault rupture and propagation might be due to the essentially weak fault material and dynamic weakening, suggested by high-velocity frictional experiment on fault zone material (Ujiie et al., 2013, Nature Geoscience) and borehole temperature measurement (Fulton et al., 2013, Nature Geoscience) during the IODP JFAST study.

Our previous study (Koge et al., 2014, EPS) applied the theory of critically tapered Coulomb wedge to 12 transects of Japan Trench before the 2011 earthquake, in order to obtain along-trench variations of frictional properties (especially, effective frictional coefficient of the plate boundary megathrust). The results show that the area of high effective frictional coefficient has characteristic topographies (e.g. seamount or well-developed horst-and-graben structure) on subducting plate, and effective frictional coefficient closely correlates with the near-trench slip distribution during the 2011 earthquake. However, it has not been sufficiently considered how the topography affects the processes of wedge formation and internal deformation. This is because the seismic profiles represent snapshots at certain times. The kinematic history should be reconstructed using structural geological principals and techniques or can be forward modeled through analog modeling.

Therefore, in order to understand the formation history of the shallow plate boundary faults which was related to the 2011 earthquake, we conducted analog model experiments reproducing that the half-graben structure subducts the frontal wedge. In the experiments, deformation of the sand layer was photographed at intervals of 5 seconds, and then these snapshots were analyzed with digital image correlation (DIC) to show the temporal transition of the fault activity inside the wedge. Our experiments show that the fault activity changes at the following four stages when the frontal part of the wedge reaches half-graben structure. Stage 1: The front of the wedge stacks when the wedge enters the graven. Stage 2: The wedge starts to grow (uplift) by forming a branch fault. Stage 3: A new frontal thrust is formed, and the activity of the branch fault is stopped. Stage 4: The frontal thrust continues the activity with that a decollement is torn and eventually step down to half-graven as a new thrust.

For future work, by comparing these experimental results with the seismic structure, it would lead to an understanding of the fault formation and development processes at the toe of the trench landward slope.

Keywords: Japan Trench, Analog model, sandbox

A high-resolution seismic image of possible fluid migration pathway associated with the 2011 Tohoku earthquake

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Large megathrust earthquakes along subduction zones pose a seismic and tsunami threat to densely populated coastal cities. The 2011 Tohoku earthquake (M9.0) ruptured the interface between the subducting Pacific plate and the overlying Okhotsk plate, yielding massive tsunamis. Pore fluid along the plate interface might play an important role in the occurrence of large megathrust earthquake. Helium isotopes are useful in identifying the origin of fluids and may provide the key information about the source of interplate fluids. Geochemical evidences demonstrated a sharp increase in mantle-derived helium in bottom seawater near the rupture zone one month after the 2011 Tohoku earthquake. The timing and location indicate that fluids were released from the mantle on the seafloor along the plate interface. The movement of the fluids was rapid with a velocity of ~4 km per day, suggesting that over-pressurized fluid is discharged along the plate interface. Considering the location of helium isotope anomalies at the forearc seafloor, there must be fluid migrations along out-of-sequence thrust (OOST) fault planes from the plate interface up to the forearc seafloor. However, the fluid migration pathway, i.e., OOST fault plane, has never been identified so far, probably because of low-resolution seismic image.
In order to elucidate the fluid behavior along the OOST fault plane, we have carried out geophysical and geochemical investigations in the Tohoku forearc using R/V Shinsei-maru (KS16-17 cruise) in November 2016. During the cruise, we have done: (1) high-resolution seismic imaging by parametric sub-bottom profiler (SBP), (2) seafloor mapping by multi-beam echo-sounder, (3) bottom seawater sampling by CTD sampler, (4) seafloor sediment sampling by multiple corer, and (5) onboard magnetic and gravity observations. We observe a clear seismic reflection image of fault scarp on a high-resolution SBP line near the Site N3 at which the helium isotope anomaly was observed one month after the 2011 Tohoku earthquake. A possible OOST fault is likely to produce tilting structure of the topmost sedimentary layer. Despite low continuity of the reflector, deep crustal multi-channel seismic reflection data exhibit a possible OOST fault plane with reverse polarity reflection upward from deep plate-interface, suggesting the fluid migration along the fault associated with the 2011 Tohoku earthquake. In this paper we will show preliminary results of the cruise KS16-17.

Keywords: high-resolution seismic image, fluid migration pathway, Tohoku earthquake

Plate boundary temperature at the prism slope estimated from topographically corrected BSR-derived heat flow in the Nankai Trough

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Seismogenic zones have been investigated in numerous studies to understand the occurrence mechanisms of earthquakes and tsunamis at subduction zones. Temperature on the plate interface is considered to bound the upper and lower limits on the seismogenic zone, whose temperatures are estimated to be around 100–150˚C and 350–450˚C, respectively [*Hyndman and Wang*, 1993, JGR]. Thus, temperature along the plate boundary fault should be a significant player governing the seismogenesis of plate boundary faults. Subseafloor temperature is known to be affected by various phenomena. For example, undulation of seafloor relief is one of the major factors disturbing thermal regime especially in shallow part of subseafloor. However, few studies have considered the topographic effect to estimate the plate boundary temperature, while studies taking into account the effect might be required for the precise estimation. This study focuses on the temperature at the upper limit of the seismogenic zone around 100˚C at the prism slope off southwest of Kii peninsula where the number of studies is restricted. First, we mapped the distribution of BSRs in the Nankai subduction zone. Second, we modeled a two-dimensional thermal structure to topographically correct BSR-derived heat flow in areas of undulating seafloor. Third, we estimated the plate boundary temperature one-dimensionally using topographically uncorrected and corrected BSR-derived heat flow by assuming uniform thermal conductivity with depth.
Distance from the trench axis of plate boundary temperature of 100˚C is approximately 25 km calculated from the uncorrected BSR-derived heat flow off southwest of Kii peninsula. On the other hand, the distance is approximately 22 km calculated from the corrected BSR-derived heat flow there. This suggests the depth of upper limit of the seismogenic zone on the plate interface shifts 450 m associated with the topographically corrected thermal structure.

Shallow crustal structure at the northern Okinawa Trough based on seismic reflection survey

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The Okinawa Trough, a backarc basin of the Ryukyu (Nansei-Shoto) island arc-trench system to the southwest of Kyushu, Japan, is considered to be in the stage of continental rifting caused by the subduction of the Philippine Sea plate. The crustal extension beneath the trough is in progress and its degree varies from north to south. We, Japan Coast Guard (JCG), conducted several geological and geophysical investigations including seismic refraction surveys with ocean bottom seismographs (OBSs) and seismic reflection surveys to obtain fine seismic structural images related to the rifting process in the Okinawa Trough.

In this report, we will show a multi-channel seismic reflection (MCS) profile in the northern Okinawa Trough. The seismic line is N-S trending along the trough strike and its length is 563 km: the line starts from the continental shelf to the east of Goto Islands at the northernmost, through the Danjo Basin, to the west of Yokogan-Sone bank, intersects the volcanic front to the north of Io-Torishima Island, and ends to the northwest of Okinoerabu Island at the southernmost line. Except for about 200 m depth at the northern end of the survey line, the water depth gradually becomes deeper from 700 m at the north to 1,200 m at the south. We employed a trigun cluster with a total capacity of 1,050 (350×3) $inch^3$ and 3,000 m multi-channel hydrophone streamer with 240 channels to record the seismic signals from airgun shots. Totally 11,363 shots were fired at every 50 m on the survey line. The acquired MCS data were processed through a band-pass filter, deconvolution, normal move out correction and CMP stacking.

We divided the seismic line into three parts based on the characteristics of the seafloor topography and the MCS records, and described them from north to south. The northern part corresponds to the area from the continental shelf to the Danjo Basin. The water depth abruptly changes from 200 m at the shelf to 800 m at the center of the basin. The MCS profile shows a thick sedimentary layer with the maximum thickness of around 4,000 m beneath the Danjo Basin. We interpreted the structure as a “syn-rift” accumulating sediments while the ongoing crustal extension.

In the middle part, from the south of the Danjo Basin to 90 km west of the volcanic front, the water depth varies from 700 to 1,000 m southwardly. There are some NE-SW trending bathymetric highs with heights of 200-300 m on the seismic line. The seafloor topography between the knolls is rather flat and the MCS records show there are sedimentary layers below the flat seafloor. However, we can see lots of normal faults in the sedimentary layer and these faults don’t reach up to the seafloor.

The southern part of the line is characterized by lineaments of the seafloor topography with strikes of NE-SW or ENE-WSW. The NE-SW orientation is parallel to the volcanic front in this region. There are many seafloor undulations and knolls with heights of 300-500 m. The MCS records reveal a number of igneous intrusions and normal faults which deform the sedimentary layer and the seafloor.

Keywords: Okinawa Trough, crustal structure, seismic reflection survey

The 1st Sea Trial of 2-D Seismic Reflection and Refraction Surveys in Suruga Bay, Central Japan, by TUMSAT (1st Report)

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Tokyo University of Marine Science and Technology (TUMSAT) establish a new school for Marine Resource and Environment from April 2017. We adopt a new portable 2-D seismic reflection survey system in order to educate our students to the observation technology and methodology in an oceanic area and under sea floor and also to research the features under sea floor such as plate boundary area, etc. In this report, we show the outline of the first sea trial of seismic reflection and refraction surveys in Suruga Bay, Central Japan, conducted by TUMSAT, and its prelimary results.

Our portable seismic system consists of three 10-ft containers for the seismic air-gun sources, an air compressor system, and streamer-cable system, together with some controllors and recording systems in a dry laboratory. The air-gun source system consists of two pairs of Bolt Twin-Gun (a pair of 1900LL, 260 cu.in x 2) and can be towed at both gunwales. Hydrophone receivers array consists of Hydroscience digital streamer cable which has 96 channels with a sensor interval of 6.25 m inside a cable of 600 m long, and SEAMAP Tailbouy to measure the location at the tail of the cable. Research vessel ‘Shinyomaru’ was renewed on 2016. Its principle specifications: length, beam, and gross tonnage are 65 m, 12.5m, and 986 tons, respectively.

We conducted the 2-D seismic reflection survey and refraction survey with 21 ocean bottom seismometer in Suruga Bay, from Nov. 13 to 19, 2016, in order to test the system specification in a ocean area. Suruga Bay (i.e., Suruga trough) is located at the plate boundary between the Philippine sea plate and Eurasia plate. We therefore tried to clarify a shallow structure in this important area by means of both seismic reflection and refraction surveys. Four surrey lines (i.e., A to D line) were located at the eastern, northern and western area of Suruga Bay with a total measurement distance of about 74 km. Air gun was shot at an interval of 50 m under a ship speed of about 3.5 knot.

Preliminary results of seismic section shows variable bathymetric features and structure under the sea water. For example, beneath A-Line we can find a sedimentary layer with a thickness of ~100 m under the sea floor and it lays above the layer boundary with a strong reflection which may be related with the topography around the coast. The details of our result will be shown in a poster presentation.

Acknowledgements:
We appreciate the big cooperations by Shizuoka prefucture Federation of Fisheries Cooperative Associations and many Fishery Cooperatives around Suruga Bay to understand our study. We thank Tokai University for helping us in an ocean by a vessel ‘Hokuto’. We have a collaborative project with JGI, Inc. and Geosys Inc. and also thank their cooperations. Finally, we greatly thank Shinyomaru's crews and many staffs of our university for their encouragement and kindness.

Keywords: Suruga Bay, seismic reflection and refraction survey

Continuous 3-component geomagnetic observation in Yona, Okinawa Prefecture at the research and education facility of University of the Ryukyus

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University of the Ryukyus and National Institute of Information and Communication Technology (NICT) are implementing an on-land continuous 3-component geomagnetic measurement as the joint project "Study and development on the geomagnetic-variation measurement in the subtropical area" at Yona, Kunigami Village, Okinawa Prefecture, one of the research and education facilities of the university. The location is 26.76 degrees north and 128.22 degrees east, 12m altitude. The purpose of this study of NICT is to detect the geomagnetic effect due to the space-environment variation such as the solar activity, whereas University of the Ryukyus is aiming at establishing the method of calibration of offshore geomagnetic survey data around the Ryukyu Islands. Geomagnetic horizontal component, declination and vertical component are observed and recorded at this station every one minute. Data from April 1996 up to October 2011 are available as of now although there are several periods of lack of observation. After that, the magnetometer was updated in 2016 and the observation was re-started.

The authors are showing some results of a trial analysis of the on-land geomagnetic observation in 2011. The geomagnetic total force intensity shows a variation of daily variation with 30nT in amplitude, although more than 100nT change takes place corresponding the solar activity due to the occurrence of sunspots (based on the National Astronomical Observatory observation). The result of the spectrum analysis of the data in 2011 shows the peaks of at, 15, 5, 2, 1.3, and 1 day periods.

Geographic Survey Institute of Japan (GSI) is also collecting 3-component geomagnetic data in Okinawa Prefecture, at 26.630 degrees north, 128.127 degrees east, 140m altitude in Higashi Village. Both NICT and GSI data shows positive correlation approximately. However, the NICT values are about 120nT smaller and the change rate shows by about 1.3 times larger compared with GSI values.

Keywords: on-land continuous geomagnetic measurement, calibration of surface-ship geomagnetic data

Feasibility study on long-term monitoring of seafloor deformation with ocean bottom pressure recorders of pop-up type

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Precise pressure observation at the seafloor is an effective mean to detect vertical crustal deformation in offshore areas. A small sensor of high precision and low power consumption enables to build an ocean bottom observation system to make continuous observations for one to two years. The ocean bottom pressure observation networks deployed to monitor tsunami are expected to allow monitor vertical deformation of the seafloor in the seismogenic regions. Several studies have demonstrated that the bottom pressure data can detect transient signals associated with activities of submarine faults or volcanos. Time constants of the detected events were mostly shorter than a month but it would be difficult to detect tectonic events of much slower deformation rates by the seafloor pressure motoring. Since many plate boundary zones on the earth are located beneath oceans, observations of longterm deformation at the seafloor are invaluable to understand dynamics of plate interaction, formation and development. The most significant reason of the difficulties in detecting slow crustal deformations by the pressure observation is lack of the knowledges about longterm fluctuations appearing in the pressure records obtained at the seafloor. In this paper, we discuss about characteristics of ocean bottom pressure records in long, more than a couple of months, period based on the actual data obtained by the repeating deployment of free-fall/pop-up type bottom pressure recording systems in the Japan Trench area for about 10 years and also by recent laboratory experiments. Most of the obtained pressure time series show evident longterm temporal variations irrelevant to the actual motion of the seafloor but could be attributed to the instrumental instabilities. The pattern of the temporal variation on the record seems similar to one another when we compare the records obtained by the identical pressure sensor, suggesting that the observed pressure records contain a characteristic response specific to the sensor. Previous laboratory experiments on the response of pressure sensors of the same kind showed a transient behavior after applying high pressure has several similarity to those we see on the seafloor observation records. This suggest that the sensor specific characteristics can be known through laboratory tests and can be removed from the records of the seafloor monitoring to extract pressure changes associated with actual seafloor motions. Motivated by this idea, we are carrying out a long-term laboratory experiment in which the pressure sensor previously used in the field observations are exposed to well-controlled high pressure to know longterm behavior of the sensor under the pressure equivalent to the deep sea. We are making another experiment to know longterm stability of a clock install in our pressure recorders. Since the clock supplies a time base to measure oscillation frequency of the pressure sensor, its stability can also account for longterm drift in the pressure data obtained by the instruments.

Keywords: Seafloor geodesy, Pressure monitoring, Longterm deformation

Evaluation of drift characteristics of pressure sensors for improving long-term pressure monitoring at seafloor

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This study focuses on the drift characteristics of pressure sensors used for seafloor pressure monitoring, on the basis of the experimental results obtained at calibration laboratory for years. Pressure sensors with high resolution and short-time stability have been used for detecting transient tectonic movements. To use these pressure sensors for long-term pressure monitoring at seafloor, and to quantitatively evaluate the vertical tectonic deformation from the pressure data, the drift characteristics of the sensors need to be precisely evaluated. In usual case, the drift behavior of a pressure sensor can be evaluated and estimated by repeating calibrations at a regular interval. Regarding seafloor pressure monitoring, however, it would be difficult to periodically collect and calibrate the pressure sensors installed at seafloor. Furthermore, the drift characteristics of pressure sensors depend on the conditions of use; the drift of the sensor used under constant high pressure application may be different from that measured with a typical calibration procedure. Thus, the drift characteristics of the sensors should be evaluated in the similar pressure condition as the actual use.
In this study, the drift characteristics of pressure sensors have been evaluated at the pressure calibration laboratory in National Metrology Institute of Japan to improve the accuracy of the seafloor pressure measurements for a long time period. The devices under test are quartz Bourdon-tube pressure sensors whose maximum allowable pressure is 103 MPa (15,000 psi). The pressure of 100 MPa has been applied to the test pressure sensors for a long period of time. During the pressure application, the sensors were calibrated at 100 MPa using a pressure balance as the standard. The calibration results, the deviation of the sensor's output from the standard value, at 100 MPa rapidly changed immediately after the pressure application. As time proceeded, the change rate became small and almost constant. After 140 days from the pressure application, one sensor was depressurized to atmospheric pressure. The calibration results at 100 MPa changed in the opposite direction and returned to the initial value after 90 days from the pressure release. In contrast, the other sensor, which has been kept at 100 MPa for more than two years, showed a constant drift. In addition, during the pressure application of 100 MPa, the pressure was intermittently released to atmospheric pressure for a short time, and the outputs at atmospheric pressure were also obtained. The results at 100 MPa and atmospheric pressure showed a similar trend, showing that the zero drift of the sensor is the main cause of the observed drift. From the experimental results, we discuss measures to appropriately evaluate and compensate the drift characteristics of pressure sensors used for pressure monitoring at seafloor.

Keywords: Pressure monitoring, Long-term drift, Pressure calibration

Estimating bottom current velocities from ocean-bottom-seismometer records

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Current velocities in the lowermost meters of the ocean are poorly understood and not often measured. At the same time, they strongly affect the stability of benthic ecosystems.
Ocean-bottom-seismometers (OBS) are long-term installations of seismic sensors on the sea floor, which typically last for months and which have covered various parts of the global oceans in the last decades. The German OBS type LOBSTER has a peculiar design choice in the form of a ten-meter long head buoy cable that is very susceptible to current strumming. While this signal may be a nuisance for seismological observations, it does contain information: We present a method to estimate the current velocity in the lowermost ten meters from the noise created by that cable and compare noise-estimated current velocities with measurements of a colocated acoustic profiler.
Since this seismometer type has been widely used in different settings and depths worldwide in the last decade, this data may be a valuable and completely novel observable for physical oceanography and biology.

Keywords: Ocean bottom seismology, Benthic zone, Currents

Extraction and visualization of submarine geo-information in Mid-Okinawa Trough using underwater video records

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In recent years, many exploration data such as seabed topography images, biological, geochemical and geophysical data, and drilling survey data have been acquired for marine mineral resources exploration. For more effective use of these data in practical applications to exploration and exploitation, we have started to extract and compile geo-information using video image data obtained by diving surveys with the Shinkai 6500, the Hyper Dolphin and the Deep-Toe in and around Mid-Okinawa Trough. The extracted data from the video records includes geo-information on the location of the survey vessel (latitude, longitude, depth, altitude, submarine heading), seabed geological features (rock/ lava, sulfide zone, sand/ mud, ripple mark, gravel), seabed structural features (faults/ cracking, chimney, hot water/ spring water), and biological features (biomat, biological communities). These data are summarized in the event log along the vessel route for each dive. The compiled data are imported into the GIS software so as to easily search and visualize seabed geo-information for making future survey and research plans. By adding drilling data and geophysical survey data obtained by many other research institutes to the database, the GIS database newly created is expected to be used to extract detailed three-dimensional geo-information of the exploration target sea area in future.

Unite the Power! DARWIN, GANSEKI & COEDO Get Integrated!

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Japan Agency for Marine-Earth Science and Technology (JAMSTEC) archives data and samples obtained by JAMSTEC research vessels and submersibles as common properties of the human society, and publishes them for further uses with scientific/educational purposes [1]. The NUUNKUI data sites, which consist of several data sites for various data and sample types, perform the central role of JAMSTEC data publication [2].
JAMSTEC applies occasional updates to NUUNKUI data sites for improved usability, emerging datasets, and advanced informatics technologies. In 2016, JAMSTEC decided to reorganize these data sites for effective data publication. Three data sites named DARWIN [3], GANSEKI [4], and COEDO [5], which stand for online databases of cruise/dive information, rock sample information and sediment core sample information, respectively, will be integrated into a single system in the spring 2017.
DARWIN disseminates metadata and observation data of JAMSTEC cruises and submersible dives. Previously, sampling activities and submersible video/photo archives were registered on DARWIN as URLs to different data sites designated for particular data/sample types, and these data sites also provided URLs to DARWIN cruise/dive information as mutual references. Through the data site update described here, geological sample information and browsing functions of GANSEKI and COEDO are incorporated into the new DARWIN and they become seamlessly available on a single interface. In the new DARWIN, users can search geological samples by thumbnail browsing, map area, keyword filtering, and metadata constraints, and handling of associated data become more flexible in respect to the applicable data format and capacity. For rock samples, onboard sample photo and microphotographs of surface texture will be newly publicized, whereas for sediment core samples, searchability of photo images is improved and geochemical data entry becomes newly available.
This data site update also includes implementation of interactive map functions that are similar to those of previous “JAMSTEC Data Site Portal [6]”. Using these functions, users can browse JAMSTEC observation activities plotted on a map and search data and samples on an interactive map and obtain URL list for their data sites. However, the previous system has become obsolete after years of services, and security and usability problems have become obvious. This data site update improves usability of map search and visualization of search results, and users can effectively search data and sample information without concerns for particular cruise and dive.

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[5] "COEDO: Sediment Core Sample Database" http://www.godac.jamstec.go.jp/coedo/e (preexisted URL)
[6] "JAMSTEC Data Search Portal" http://www.godac.jamstec.go.jp/dataportal/index_eng.html (preexisted URL)

Keywords: Marine Geology, Database, Curation, Geological Sample

