# Initial break-up process of Gondwana around the Natal Valley and the Mozambique Ridge, off South Africa.

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The Natal Valley and the Mozambique Ridge are considered to be formed during the initial break-up stage of Gondwana, however the detailed opening process is not well defined because of the poor geophysical survey data set in this region. To understand the crustal nature and history of the Natal Valley and the Mozambique Ridge, vector magnetic data are obtained during R/V Pelagia cruise 2009. Vector magnetic anomalies and magnetic boundary strikes are calculated from vector magnetic data. The total magnetic anomalies around this region are compiled by using those calculated by vector magnetic anomalies and marine magnetic anomalies from National Geophysical Data Center (NGDC) as well as the EMAG2 digital magnetic anomaly data set. Intensity of the crustal magnetization is deduced from the total magnetic anomalies incorporated with ETOPO1 topography data and offshore global sedimentation model. 2D magnetic block models are also estimated along some of the magnetic anomaly profiles. Moreover, crustal thickness is estimated from satellite derived gravity anomalies using with ETOPO1 topography and offshore global sedimentation model.

It is unlikely that the total magnetic anomalies in the northern Natal Valley (NNV) indicate the magnetic lineations proposed by previous studies. Low intensity of crustal magnetization similar to that of adjacent African continental area is observed on the area of the thick crust (about 14km) that is predominant in the NNV. The thick crust (about 14km) with the low intensity of magnetization most likely shows stretched continental crust. Areas of high intensity of crustal magnetization (more than +3A/m) with thin crust (about 12km) would represent the basaltic crust, and account for about 30% in the NNV. Magnetic boundary strikes obtained in the NNV most likely indicate the boundaries between basaltic intrusion and the stretched continental crust. The basaltic intrusion might be related to Karoo volcanism. In the southern part of the southern Natal Valley (S-SNV), NW-SE magnetic boundary strikes along the total magnetic anomaly profiles show the magnetic isochrones M10-M0 proposed by previous studies. Several fracture zones are suggested from the magnetic boundary strikes and intensity of crustal magnetization along observation lines. In the northern part of the southern Natal Valley (N-SNV), low intensity of crustal magnetization with the 9~11km crustal thickness are observed and these imply the stretched continental crust similar to the stretched continental crust area of the NNV. The N-SNV most likely shows the edge of the stretched continental crust, and seafloor spreading in the S-SNV started at the time of M10. In the northern part of the Mozambique Ridge (N-MOZR), features of intensity of crustal magnetization and crustal thickness are also similar to those in the NNV, suggesting the same formation process of the NNV. In contrast, high intensity of crustal magnetization is dominated in the southern part of the Mozambique Ridge (S-MOZR). The magnetic boundary strikes show the clear NW-SE trend however the magnetic anomaly pattern is not clear and crustal thickness is thicker more than 11km. High intensity of crustal magnetization and thick crust probably indicates that the S-MOZR was formed with excessive volcanism such as hotspot. NW-SE trend of magnetic boundary strikes may represent the trend of the spreading ridge. These results suggest that there is continental ocean boundary between the N-MOZR and the S-MOZR.

We will present the crustal features deduced from magnetic anomalies and gravity anomalies in the Natal Valley and the Mozambique Ridge, and discuss about the initial break-up process of Gondwana in this region.

 

Keywords: vector magnetic anomalies, break-up of Gondwana, Natal Valley, Mozambique Ridge

 

# Seismicity at the Kairei Hydrothermal Vent Field Near the Rodriguez Triple Junction in the Indian Ocean: Part 2

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1. Introduction

In the first segment of the central Indian Ridge from the Rodriguez triple junction, the Kairei hydrothermal vent field exists and discharges hydrothermal fluid with rich hydrogen. Serpentinized peridotite and troctolites, and gabbroic rocks were discovered on the seafloor around the Kairei hydrothermal field. These rocks (originally situated at several kilometers beneath seafloor) exposed around the Kairei field may cause the rich hydrogen fluid. At the Kairei field, hydrogen-based various hydrothermal vent fauna were found. In the "TAIGA" Project (Trans-crustal Advection and In situ reaction of Global sub-seafloor Aquifer), this area is a representative field of "TAIGA" of hydrogen. To investigate how the deep-seated rocks are uplifted and exposed onto seafloor, and the hydrothermal fluid circulates in subsurface, we conducted a seismic refraction/reflection survey and seismicity observation with ocean bottom seismometers (OBSs).

In JpGU 2015, we reported that we found more than 5000 micro earthquakes in this area during the 50 days seismicity observation. A swarm of micro earthquakes exists at a location about 1-3 km northwest of the Kairei field. The depth of the swarm is up to about 8km. The focal mechanisms in the swarm are normal type. An another swarm exists at the first segment of the central Indian Ridge. The depth of the swarm is deeper than that near the Kairei field.

This presentation will show relocated hypocenter distributions by HypoDD program (Waldhauser, 2001) which can estimate relative location of earthquakes.

2. Observation and methods

We conducted a seismic survey around the Kairei hydrothermal field from January 27 to March 19 in 2013 using S/V Yokosuka of Jamstec (YK13-01, YK13-03). We used 21 OBSs.

We redetermined hypocenter locations by HypoDD program (Waldhauser, 2001). We used an averaged 1D velocity structure at the swarm areas from the 3D structure estimated by Takata et al. (2015).

3. Results

The depth of the swarm at the Kairei field is about 4-7km. The focal mechanisms in the swarm are normal type. The depth of the swarm at the first segment of the central Indian Ridge is about 6-8km. This swarm is divided into upper and lower parts, and both incline at about 60-70°toward west. The focal mechanisms in the swarm are normal type.

To determine more detailed 3D velocity structure, we will determine hypocenter distribution and velocity structure by TomoDD(Zhang and Thurber, 2003).

Acknowledgements

We thank the captain and the crew of S/V Yokosuka of Jamstec for their support. This work was supported by Grant-in-Aid for Scientific Research on Innovative Areas of the Ministry of Education, Culture, Sports, Science and Technology (Grant Number 20109002, TAIGA project).

Keywords: TAIGA Project, hydrothermal area, seismicity

 

# Preliminary report of KH-15-5 R/V Hakuho-maru cruise: Long-offset transform and ridge processes along the Central Indian Ridge 13-18°S

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KH-15-5 R/V Hakuho-maru cruise was conducted from 17th to 26th, January, 2016 along the Central Indain Ridge 13°-18°S. The objective of this cruise is to elucidate the contribution of long oceanic transform faults to global water flux and to explore the magmatic and hydrothermal activities along the ridge north of 18°45'S. During the cruise, we conducted geophysical mapping, deep-tow magnetic survey, rock samplings and CTD hydrocasts along the Marie Celeste transform fault, Argo transform fault and northern part of Seg-18 of the Central Indian Ridge under the collaboration with Mauritius Oceanographic Institute and Korean Institute of Ocean Science and Technology. The principal results of the cruise are summarized as follows.
1. Two deep-tow magnetic profiles across two active transform faults are done. A proton magnetometer and two three-component magnetometers were attached to the system. We succeeded to recover the variation of total magnetic filed intensity along ~45km profiles.
2. Along the Marie Celeste transform fault, we conducted 3 dredge hauls and 3 CTD hydrocasts. We recovered various kinds of rocks constituting oceanic crust, gabbroic lower crust to basaltic lava. CTD profiles and water sampling were successfully done from 5000m water depth, mainly for deep-sea microbiological studies. A turbidity meter attached to the dredge wire detected anomaly near the bottom on the median ridge.
3. Along the northern part of the CIR-Seg18, we conducted 6 dredge hauls. Two sites are located at the neo-volcanic zone within ridge axial valley, where we recovered very fresh lava. Three sites are designed to collect samples from off-axis area and slightly altered basalt samples are recovered. Last dredge haul was done at the lower part of an oceanic core complex, where an altered gabbro was recovered.
4. Four CTD hydrocasts were done along the ridge axis of Seg-18. We detected turbidity and transmissiometer anomalies, indicating the hydrothermal activity.

Keywords: mid-ocean ridge process, transform fault, hydrothermal activity, oceanic crust

 

# Re-estimation of the evolution history of the West Philippine Basin

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The evolution and spreading history of the northernmost area of the West Phillipine Basin (east of the Luzon Okinawa Fracture Zone, north of Benham Rise and Urdaneta Plateau) in the Philippine Sea Plate was re-tested through the recent marine geophysical (direct magnetic total force observation and that estimated by the observation by the 3-component geomagnetic measurement) data by JAMSTEC fleets cruises and the hydrographic survey expeditions by the Japan Coast Guard. The result suggests that the area was constructed by the seafloor spreading during 23-30Ma just after around 33Ma, the cessation of the spreading at the Central Basin Spreading Centre (CBSC) and the Huatung Basin (the northwesternmost area of the WPB, between Gagua Ridge and Taiwan Island). The result is consistent with the dating from the collected rock samples by the JAMSTEC's ROV cruises in this area.

Keywords: West Philippine Basin, Geomagnetic anomaly

 

# Seismic structure of continental rift and off-axis volcanism in the Okinawa trough back-arc basin

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Back-arc basins are a primary target to understand lithospheric evolution in extension associated with plate subduction. Most of the currently active back-arc basins host well-developed spreading centers where active seafloor spreading and creation of the oceanic crust have already occurred. However, rift structure at its initial stage, a key to understand how the continental lithosphere starts to break in a back-arc setting, is poorly documented. The Nansei-Shoto subduction zone forms a trench-arc-back-arc system from Kyushu, SW Japan, to Taiwan and provides a superb site for studying the interaction between the plate subduction and the rifting process in a continental back-arc basin. Behind this ~1,200-km-long subduction zone, the Okinawa trough forms an active continental rift zone along the southeastern end of the Eurasian plate. Although the total length of extension is estimated no more than 80 km (Sibuet et al., 1995), its rifting style is significantly variable along the trough: The northern and middle Okinawa trough is characterized by shallow bathymetry (< 1000 m) and has a wide (up to 230 km) basin structure. In the southern Okinawa trough, on the other hand, the maximum seafloor depth exceeds 2,000 m and a relatively narrow (60-100 km wide) topographic depression is formed along left-stepping en echelon rift axes. Early seismic studies suggest that crustal separation and active seafloor spreading has occurred in the central and southern Okinawa trough, whereas recent studies reveal that there exists over-15-km-thick crust beneath the rift axes even in the southern part where the deepest seafloor occurs, indicating that the whole part of the Okinawa trough is still at a stage of continental rifting (Hirata et al., 1990; Sibuet et al., 1998). Yet the fault system accommodating the crustal extension and its along-trough variation are little documented. The Okinawa trough is also known for active hydrothermal system discharging high temperature fluids, implying that the crustal rifting enhances the transfer of high-temperature magmatic bodies from the deep mantle up to near the seafloor. However, the relative roles of magmatic input and tectonic stretching in controlling the whole rifting system remain poorly understood.

Toward understanding the tectonic and volcanic processes associated with the continental back-arc rifting, JAMSTEC has been carrying out active-source seismic experiments in the Okinawa Trough. Multichannel seismic (MCS) reflection data and OBS refraction data were collected in the southern Okinawa trough (24-26ºN) in 2013 and in the northern Okinawa trough (29-30ºN) in 2015. Based on the data set, we present structural models of the Okinawa trough The MCS reflection data in the southern part show an almost symmetric rift system across the rift axis: Within the basin the sedimentary layers are highly cut by inward-dipping normal faults. Just beneath the rift axis a narrow intrusive structure is imaged, but a stable magma chamber is not observed on axis. Instead, a possible melt lens is found ~10 km horizontally away from the rift axis towards the arc. The rift structure over the possible magmatic body is disturbed, suggesting the off-axis volcanism is young or probably still active. Associated with the rifting process, the crust thins significantly from the original thickness of ~25 km and the thinnest crust of ~10 km occurs just beneath the rift axis. We interpret that the southern part of the Okinawa trough is at a transitional stage from continental rifting to seafloor spreading. The northern part of the Okinawa Trough, on the other hand, exhibits much wider deformed zone. This structural variation may be influenced by the southward increase in rifting rate along the Okinawa trough from ~2 cm/yr to ~5 cm/yr (Argus et al., 2011).

 

Keywords: Continental rift, back-arc, active-source study

 

# Bathymetry and crustal structure of Taisho Bank and its vicinity in the southern Okinawa Trough

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Japan Coast Guard has conducted detailed bathymetric and multi-channel seismic reflection surveys in the southern Okinawa Trough. In this contribution, we will report detailed bathymetric feature and crustal structure of the Taisho Bank and its vicinity, thereby discussing the formation process of the bank.

Keywords: Okinawa Trough, Rifting, Bathymetric survey, Multi-channel seismic reflection survey

 

# Spatial distribution of faults and their features in the middle Okinawa Trough on the western offshore region of Amami Oshima island.

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A numerous normal faults locate on the seafloor of the middle Okinawa Trough from the recent bathymetric surveys and the multichannel reflection seismic surveys by Hydrographic and Oceanographic Department, JCG. The predominant direction of them is N60E on the western offshore area of Amami Oshima island. The central axis of graven is shifted to the northwest side from the central axis of the depression of the middle Okinawa Trough, and arranged the left-stepping en echelon.

Keywords: Okinawa Trough, fault topography, normal fault

 

# Occurrence and formation process of kaolin minerals in seafloor hydrothermal fields in the Okinawa Trough

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Abundant and diverse occurrence of hydrothermal clay minerals has been documented for seafloor hydrothermal fields in the Okinawa Trough, where the fluid discharge zone develops within thick sediment layer. Previous studies on clay minerals in sediments collected during IODP Expedition 331 conducted in 2010 revealed zonal distribution of alteration minerals, which was characterized by dominant occurrence of smectite - chlorite - illite along the depth beneath the seafloor of Iheya North Knoll. Another noteworthy was identification of kaolinite in shallow layer (shallower than 15 mbsf: meters below seafloor), because it suggests acidic alteration as well as high temperature alteration has occurred in the hydrothermal environment. We found occurrence of kaolin minerals in drilling sediment cores recently obtained from other sites in Iheya North Knoll. We studied their detailed occurrence and characteristics using XRD analysis and SEM-EDS observation, with a view to understanding their formation process.

The one sediment core was obtained from Site 9016B (27º46.6' N, 126º54.6' E, depth = 1124 m) during CK14-02 cruise conducted in 2014 using *D/V CHIKYU*. Site 9016B is located ~1 km apart from the activity center of Aki Site. Among the drilling core of 140 m total length, kaolin minerals were identified mainly recognized as at a depth from 8.5 to 11.0 mbsf, where alteration was visually observed as white colored. Within this range, dominant kaolin minerals changed along the depth; halloysite of fine spherules (~1 μm) at 8.7 mbsf, halloysite of tubular shape and kaolinite of hexagonal plates at 9.1 mbsf, dickite of block morphology (~15 μm) at 10.8 mbsf. Kaolin minerals were minor in the sediment from 11.0 mbsf and not identified in 11.4 mbsf, where illite and anhydrite appeared as dominant altered minerals. Together with recognition of unaltered volcanic material even in 9.1 mbsf, this change would reflect steep gradient of physical and/or chemical condition below the seafloor according to expected formation temperature of each kaolin mineral.

The other sediment core was obtained from Site BMSI-4 (27º47.4' N, 126º53.9' E, depth = 1048 m) by shallow drilling during BMS11 cruise conducted in 2011 using *R/V Hakurei No.2* . Site BMSI-4 is located about 300 m apart from the activity center of Original Site. Over most part of the obtained core of ~4.0 m length, occurrence of kaolinite was identified in sediment intensely altered as white gray colored. Within the 4 m range, amount of kaolinite increased along the depth, likely replacing smectite that was dominant in the layer shallower than 1.9 mbsf. Whereas neither halloysite nor dickite were identified. With recognition of sandy sediment without alteration in the surface (<0.05 mbsf) and induration of altered sediment including dolomite at 3.6 mbsf, abundance of kaolinite may reflect steep gradient physical and/or chemical condition below the seafloor.

Alteration zones of kaolin minerals recognized in these two sediments are commonly characterized by limited thickness of a few meters, and by subadjacent indurated sediment layer (anhydrite at Site 9016B and dolomite at BMSI-4) probably formed by high temperature alteration. Formation of kaolin minerals in these vertical profiles is difficult to be attributed to hydrothermal interaction related to mixing between upflow of the hydrothermal fluid component and seawater-like porewater. Rather, focused lateral flow of acidic fluid is more likely to explain well steep gradient in the

 

divergence or abundance of kaolin minerals. It is notable that occurrence of sulfide minerals such as sphalerite was recognized in both the upper and lower boundaries of the kaolin minerals alteration zone. The lateral flow of acidic fluid may play an important role in transportation of metal elements in subseafloor sediment layers.

Keywords: acid hydrothermal alteration, scientific ocean floor drilling, seafloor hydrothermal system, kaolinite, Okinawa Trough

 

# Bathymetric survey and indicators of hydrothermal activity in the Amami Calderas using autonomous underwater vehicle

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## 1. Introduction

Amami Calderas are located on the volcanic front in the central Ryukyu Arc. Fe-Mn crusts of hydrothermal origin (Yokose et al., 2010, Gekkan Chikyu) and A Kuroko-type polymetallic sulfide ore enriched in Sb and Ag (Kumamoto University, 2012, Press Release) were dredged in the Amami Calderas. Although these dredged samples indicate the presence of hydrothermal activity, no direct evidence has not been obtained yet.

## 2. Method

Japan Coast Guard conducted high-resolution geophysical surveys with S/V *Takuyo* and AUV *Gondou* from 2013 to 2015 in the Amami Calderas. Large-scale bathymetry and water column data was acquired with hull-mounted EM710 and EM122 multibeam echo sounder (MBES) on S/V *Takuyo.* High-resolution bathymetry, sidescan sonar (SSS) imagery, and temperature data were obtained with Sonic2022 (400 kHz) MBES, EdgeTech2200M SSS (120 kHz) and SBE49 FastCAT CTD sensor on AUV *Gondou*, respectively. AUV was set to maintain a constant altitude of 50-70 m above the bottom.

## 3. Result

Plumes were detected as water column anomalies with MBES EM710 and EM122 at 4 sites in the Calderas at depths between 350 and 700 m. AUV survey were conducted at 3 sites and small depressions with width of several meters to dozens of meters were confirmed. Acoustic water column anomalies were also detected on SSS imagery in the 3 sites. Some plumes rises steeply from seafloor and others rises in smoke-shaped. Positive temperature anomalies were observed at plume-detected areas. Lineaments trending E-W or ENE-WSW are well-developed around these four sites and these north-facing and south-facing lineaments form graben structure.

## 4. Discussion

Plumes detected with ship MBES are considered to be bubble plumes associated with volcanic or hydrothermal activity, but some plumes in combination with positive temperature anomalies detected by AUV surveys can be interpreted as hydrothermal plumes. These hydrothermal systems in the Amami Calderas may be constrained by E-W or ENE-WSW trending faults which were probably formed by the rifting activity in the central Okinawa Trough, backarc basin of the Ryukyu Arc.

Keywords: high-resolution bathymetry, hydrothermal activity, autonomous underwater vehicle, Amami Calderas, central Ryukyu Arc

 

# Magmatic activity around Iotori-shima Island in the Central Ryukyu, based on geophysical characteristics

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The Ryukyu Arc extends approximately 1,200 km between the islands of Kyushu and Taiwan, where the Philippine Sea Plate subducts northwestward under the Eurasian Plate. From east to west, the arc consists of the Ryukyu Trench, the Ryukyu Islands, the volcanic front (Tokara Islands), and the Okinawa Trough. Volcanic front and the Okinawa Trough are the main volcanic active area in the Ryukyu arc. It is widely considered that these two magmatic activities are separated in the North Ryukyu, but toward to the Central Ryukyu, these convergent with Okinawa Trough [e.g., Geshi and Ishizuka, 2007]. We conducted marine geophysical surveys around Iotori-shima Bank in the Central Ryukyu. The Iotori-shima Bank is a huge volcanic construction located west of Iotori-shima Island [Ishizuka et al., 2014], but the detail is still unclear. Based on the seafloor morphology, magnetic anomaly, and gravity anomaly, we will describe magmatic and tectonic activities of the Central Ryukyu around Iotori-shima Bank.

Many submarine volcanoes are identified in the southwest of Iotori-shima Island. The extension of volcanic front southwest of Iotori-shima Island is already pointed out [Sato et al., 2014] and this implies that the two kinds of magmatic activities in the volcanic front and Okinawa Trough do not necessarily converge at the Central Okinawa Trough. In addition, submarine volcanoes which would belong to the ancient volcanic front [Sato et al., 2014] are also observed just north of Igyo-Sone Bank. This suggests that the ancient volcanic front is limited in the southern part of Central Ryukyu.

West of the volcanic front, many submarine volcanoes including Iotori-shima Bank are identified. Southwest of Iotori-shima Bank, ENE-SSW trending many seafloor lineaments are observed. These would be normal faults caused by back arc tectonic activity, but are not observed in the Iotori-shima Bank. Higher Bouguer anomaly is observed at where lineaments are observed; therefore, this gravity anomaly would imply crustal thinning caused by back arc rifting, although the main back-arc rifting is centered far west of the survey area. Iotori-shima Bank is characterized by a caldera structure and many submarine volcanic knolls. Dipole magnetic anomalies are observed on relatively-small submarine knolls, on the other hand, the largest submarine knoll located southwestern part of the caldera is not accompanied by dipole magnetic anomaly. The relatively low magnetization intensity inside the caldera suggests that collapse of volcanic knoll, destruction of magnetic minerals, and/or originally low magnetization. Upward-continued Bouguer anomaly shows NE facing transition over the Iotori-shima Bank. This suggests that the Bank is under the influence of back-arc rifting, however, seafloor lineaments are not observed on its surface.

Keywords: Seafloor morphology, Magnetic anomaly, Gravity anomaly, Ryukyu arc

 

# Discussion on the relationship between the shallow geological condition around the northern Okinawa trough area and a magnitude (M) 7.1 earthquake offshore west of Satsuma peninsula on November 14 2015

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On November 14, there was a magnitude (M) 7.1 earthquake offshore west of Satsuma peninsula. JMA reported the CMT mechanism of the earthquake was a strike-slip fault type with NW-SE direction of its tension axis. But before the earthquake, no earthquake over M7 has been reported in the area. Japan Coast Guard conducted multi-channel seismic reflection and wide-angle refraction seismic surveys around the area before the earthquake. The time migration image shows several normal faults accompany with topographic gaps of the top of the sediment layers. The direction of the faults is NE-SW which corresponds to the tension axis of the earthquake. The general trend of the Okinawa trough, NNE-SSW, is different to the normal faults direction, but it looks similar to the general direction of topographic highs that are scattered in the northern Okinawa trough. We are going to discuss the shallow geological condition and the tectonics around the area using the result of our surveys.

Keywords: culstal strucuture, MCS

 

# Active shallow structures of the Nankai forearc region off Hyuga

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Active deformation structures have been well investigated by swath bathymetry survey, submersible dive, MCS survey and deepsea drilling in the Nankai subduction zone. However, few studies have focused on the structure off Hyuga, the western tip of the Nankai Trough, due to limited research activity. The general trend of the Nankai accretionary prism is NE-SW to ENE-WSW from off Tokai to off Ashizuri. In contrast, the trend of the forearc basin and the prism slope off Hyuga is NNE-SSW, which is the same trend as the Ryukyu trench. The Hyuga basin located between the Ashizuri spur and the Kyushu-Palau Ridge apparently shows no distinct trenchward limit such as the outer ridges observed at the other regions of the Nankai margin. Our objective of this study is to obtain high resolution subsurface structures of the Hyuga forearc region and to evaluate recent tectonic activity.

We carried out deep-towed subbottom profiler (SBP) survey by ROV NSS (Navigable Sampling System) during R/V Hakuho-maru KH-15-2 cruise. High resolution profiling was successfully conducted by a chirp system of EdgeTech DW-106. The first target is the NNE-SSW trending Oyodo Knoll developed eastward of the Hyuga basin. The SBP shows the almost symmetrical ridge morphology cut by active flexures on both sides suggesting compressional deformation. Although faults are not detected at the surface sequence at least down to 60 meter except for two minor reverse faults, sediment thickness changes across the flexures indicate continuous deformation to the present. The second target is the western margin of the Hyuga basin where steep slopes suggestive of fault control are distributed from north to south. Two transects of SBP surveys are conducted at the southern and central regions of the western margin. SBP records of both transects show active flexures with relative landward uplift. The southern site is characterized by a V-shaped depression landward of the flexure and its sediment fill indicative of transtensional deformation. The central site also shows undulation of basin sedimentary layers landward of the flexure suggesting strike slip deformation. Our high-resolution subbottom profiles of the Hyuga forearc region revealed that the topographic framework have been formed by ongoing active deformations under high sedimentation rate.

Keywords: subbottom profiler, active flexure, active fault

 

# Crustal structure from the Wakasa Bay to the western Yamato Basin, Japan Sea, deduced from marine seismic survey

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We participated in the “Integrated Research Project on Seismic and Tsunami Hazards Around the Sea of Japan” conducted by the MEXT of Japan; in particular, we performed seismic surveys from the R/V KAIREI in the Japan Sea beginning in 2014. In August 2015, we conducted a marine seismic survey to study the crustal structure around the area from the Wakasa Bay to the western Yamato Basin. This survey area is located in a region where the focal mechanism transitions from a reverse fault to a strike-slip fault (e.g., Mikumo, 1990; Terakawa and Matsuura, 2010) and where several earthquakes with a magnitude of 6.5 or larger have occurred in the past 100 years. Furthermore, the primary active faults in this study area have been estimated to exist in the margin of the Oki trough and the marginal terrace (e.g., Okamura, 2013; the Committee for Technical Investigation on Large-scale Earthquake in Sea of Japan, 2014).
The formation of source faults in the Japan Sea is divided into at least two types. One type is formed when reverse faults have been reactivated by inversion tectonics (e.g., Okamura et al., 1995). The other type is formed by a reverse fault occurring in the boundary of the crustal structure (e.g., No et al., 2014). Therefore, revealing the relationship between the crustal structure and tectonic history is one of an important key in the research of the source faults in the Japan Sea. In particular, because the Yamato Basin is the only large basin in the Japan Sea that is capable of being fully investigated (as a result of the exclusive economic zone), research on the crustal structure of the Yamato Basin contributes to the discussion of the source faults that formed in the land-side margin of the Yamato Basin.
We conducted multichannel seismic reflection (MCS) surveys along nine lines. Some seismic lines were crooked to avoid the many fishing operations and equipment located in the survey area. To obtain high-quality MCS data, we shot an air gun array with 50 m spacing. The tuned air gun array had a maximum capacity of 7,800 cu in (approximately 130 L) and consisted of 32 air guns. The standard air pressure was 2,000 psi (approximately 14 MPa). The air gun array was kept 10 m below the sea surface throughout the experiment. During the air gun shooting, we towed a 444-channel hydrophone streamer cable. The group interval was 12.5 m, and the cable was approximately 6 km long. The towing depth of the streamer cable was maintained at 12 m below the sea surface by depth controllers. The sampling rate and record length were 2 ms and 16 s, respectively. Moreover, the air gun array with a shot spacing of 200 m in the seismic refraction/reflection survey conducted using 54 ocean bottom seismographs (OBSs). Moreover, the airgun array with a shot spacing of 200 m in the seismic refraction/reflection survey by 54 OBSs used almost the same configuration as the MCS survey. In addition, because onshore-offshore seismic profiles in the south extension were conducted by Ito et al. (2006), Nakanishi et al. (2008), and Earthquake Research Institute (2016), we are able to obtain the crustal structure imaging of the central Japan, ranging from the Nankai Trough to the Japan Sea.
We present an outline of the crustal structure obtained from preliminary results of MCS imaging and the P-wave velocity structure of the study area.

Keywords: Japan Sea, Yamato Basin, Crustal structure, MCS, OBS

 

 

# 13 year continuous observation of ambient gamma ray at cold seepage site on deep seafloor with a multidisciplinary cabled observatory off Hatsushima Island in Sagami Bay

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At cold seepage site on deep seafloor off Hatsushima Island in Sagami Bay at a depth of 1175 m, multidisciplinary observation of deep-sea environment has been carried out since 1993 with a cabled observatory. The present observatory, to which a gamma ray sensor with 3 inch NaI(Tl) scintillation detector was attached, was deployed in March 2000 about 40 m north of the present location, recovered in March 2002, and re-deployed at the present location in November 2002. After the re-deployment, the observation at the same location continued up to date for more than 13 years. The specifications and preliminary observational results before the 2011 off the Pacific Coast of Tohoku Earthquake (hereafter "off Tohoku Earthquake") occurred are described in Refs. 1 and 2. In this presentation, the result of the long-term gamma ray observation to date will be reported.
Major events observed were as follows;
After the off Tohoku earthquake occurred, rapid signal level increase of Bi-214 and K-40 was observed. This would not be associated with the off Tohoku Earthquake itself, but would be associated with the mudflow caused by the Eastern Shizuoka Prefecture Earthquake (M6.4) which occurred on March 15, 2011; 4 days after the off Tohoku Earthquake.
After this event, significant event was not recognized except the abrupt signal level fluctuation associated with the underwater work with remotely operated vehicle (ROV) near the observatory.
Since December in 2014, gradual signal level decrease of Bi-214 was observed, while the signal level decrease of K-40 started gradually shortly after the off Tohoku Earthquake, roughly in October 2011. The effect of Cs-137 associated with atomic plant accident on the signal level of Bi-214 should be considered.
Throughout the observation period, predominant event is the significant signal level increase of Bi-214 in October 2006, whose fluctuation pattern was different from the other fluctuations associated with the disturbance on seafloor caused by the sedimentation or the underwater work with the ROV. It would reflect the sub-bottom incident associated with tectonic deformation.
References
1) Kumagai, et al., *Gamma Radiation* (Intech, Croatia, 2012), DOI:10.5772/36392, p.64.
2) Iwase and Takahashi, JpGU meeting 2011, SCG059-P19 (2011).

Keywords: NaI(Tl) scintillation detector, mudflow, multidisciplinary cabled observatory

 

# Observation of sea floor vertical motion at the Boso slow slip region

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1. Introduction

To mitigate earthquake hazards, it is important to understand earthquake generation processes and forecast earthquakes through numerical simulation using earthquake generation models. To assess the models, we make a forecast of the next step by the models, then check this through observations, and make correction in the models. We should continue this revising process in several times. Since earthquakes have long recurrence time, we need usually hundreds or thousands years to assess the models. The Boso slow slip events (SSE) have short recurrence time as a few years, and locate in a depth where earthquakes occur (about 10-20 km). Hence, we can obtain data for two or three SSE cycles and assess the models within 10-15 years, if we may be able to treat earthquakes and slow events as events of the same category. The present observation is the first step of this assessment process. From vertical movement on the sea floor using ocean bottom pressure gauges (OBPs), we investigate the slip area of the Boso SSE.

2. Observation and analyses

We conducted an ocean bottom pressure survey at the southeast area of the Boso SSE from September 2013 to July 2015 using R/V Hakuho-maru and R/V Natsushima of JAMSTEC. In this survey period, the Boso SSE occurred from December 2013 to January 2014. We used three OBPs made by ERI, University of Tokyo, with a pressure gauge, 8B2000-2 or 8B7000-2 by Paroscientific Inc., and recorders equipped an atomic clock, SA.45s CSAC by Microsemi Co.

In analyses, we conduct transformation from pressure data to depth data, at first. Then, resampling, removal of tide components, estimation of correlation component with temperature, estimation of oceanic fluctuation from correlation between observation stations, smoothing, and removal of long-term trend due to instrumental aging are performed on the data. From these analyses, we try to estimate vertical movement on the sea floor.

3. Results

The estimated movement before and after the 2013-2014 Boso SSE shows no significant movement larger than the standard deviation of the estimated vertical movement.

Acknowledgement

We thank the captains and crew of R/V Hakuho-maru and R/V Natsushima of JAMSTEC for their support. This work was supported by JSPS (25287109).

Keywords: Boso slow slip, pressure gauge, ocean bottom observation, vertical motion

 

# Development of on-demand buoy observation system for crustal displacement

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We have developed an on-demand buoy observation system for crustal displacement and tsunami since 2012 in collaboration with Japan Agency for Marine Earth Science and Technology, Tohoku University and Japan Aerospace Exploration Agency. This system has some characteristics, which are use of pressure sensor on the sea bottom and precise point positioning system on the buoy to detect vertical crustal displacement, acoustic measurement between the buoy and seafloor transponders, slack mooring for realtime observation in high speed sea current with the velocity of over five knots. In addition, we adopted double pulse for acoustic data transmission of the pressure sensor data from sea bottom. Collected data from the sea bottom and through the acoustic measurement is sent to the land station using iridium satellite. We succeeded observation of micro tsunami propagated from the Iqique tsunami, Chile, in the Nankai Trough area. We collect pressure sensor data on the seafloor pressure unit with a sampling of 15 seconds in tsunami mode via a wire-end station below 1000 meters from the sea surface, and carry out above acoustic measurement with the sampling of one week. A buoy station on the buoy controls all actions related to the collection of the data for the observation and navigation, saving data, and data transmission to the land station. However, we need to revise to realize long term observation of one or two years and improvement of the reliability for the observation. We have issues on a rate of the data recovery, due to inhomogeneous of the acoustic characteristic of the seafloor pressure unit, contamination of reflection signals from the sea surface into the data transmission signals from the seafloor pressure unit to the wire-end station, troubles on the wire line between the wire-end station and the buoy by buoy rotation, and so on. Therefore, we revised the observation buoy system, which includes change of the flame of the seafloor pressure unit to improve acoustic characteristic, installation of the precise point positioning systems using MADOCA system and MB-ONE to derive vertical crustal displacement from seafloor pressure data, improvement of the control system on the buoy station to enable to start observation according to orders from the land station, and attachment of a fin to control the buoy rotation. And we tuned action flow to decrease electrical consumption and adopted solar panels as the batteries of the entire of the system. To improve accuracy of the acoustic measurement, we need to decrease the slack ratio. We succeeded it from 1.6 to 1.58 at this moment. We try to decrease the slack ratio more to realize accurate acoustic measurement. In this presentation, we report the current sea trials, which started in January, 2016.

Keywords: crustal displacement, real-time observation, buoy

 

# 4-D active monitoring of time-variant ocean bottom structure including a gas chimney type deposit methane hydrate by using seismic wave simulations

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Recently the studies of methane hydrate (*ie.*, MH) have been developed and a lot of MH reservoir areas were found around Japan. They are characterized by following two types of origin/deposit (1) thermal decomposition origin (*ie.*, gas chimney type deposit) and (2) biodegradation origin (*ie.*, sand filling type deposit) (Matsumoto *et al.*, 2009). Some 3-D seismic surveys were conducted in the Sea of Japan to clarify the feature of an ocean bottom structures with a gas chimney type deposit of MH (*e.g.*, Saeki *et al.*, 2009). To avoid any environmental pollution accompanying to MH developments in future, it is necessary to actively and continuously monitor the changes of geophysical and geochemical properties of the ocean bottom structure including MH deposit. We therefore have developed a 4-D active monitoring methodology and technology to observe a time-variant reservoir such as MH or oil-gas reservoir under the water (*e.g.*, Tsuruga *et al.*, 2013).

In this study we show the preliminary results of characteristic wave phases of reflected wave from MH reservoirs and some effective seismic source- receivers array designs through simulating the seismic wave filed by means of a finite difference method (Larsen, 2000). We calculated seismic waveform records on three types of underground seismic structure models as follows: (Model-1) a horizontal multilayered structure model, (Model-2) a horizontal multilayered structure model including a thin MH layer and (Model-3) a horizontal multilayered structure with a chimney type MH deposit in a sand stone layer. The horizontal multilayered structure model consists of four layers with a sea water, a MH or sand stone, mud stone, over an igneous basement rock.

As the results, Model-1 is the horizontal multilayer structure, so no characteristic wave phase is observed. Then the reflect wave from the MH deposit travels faster than that from sea water in the Model-2. It is because MH deposit has higher velocity. Finally, the MH deposit in Model-3 is in the sand stone layer, so the wave that is not reflected from the horizontal layer is observed. Also, we found some effective seismic phase to monitor the time-variant MH reservoir and then tried to optimize an effective source-receivers array design, the preliminary result showed that two types of receivers arrays are effective to monitor the changes of seismic velocity in a MH reservoir by using some particular seismic phases reflected at the boundary of a surface-type MH layer. One of the arrays is constructed my both a horizontal array and a vertical one with seismic active sources located at the sea bottom as we call it, ‘T-type array’. Also the other is called ‘H-type array’ which consists of a horizontal array and two vertical arrays with the seismic source at the sea bottom.

Keywords: Methane hydrate, Monitoring, Time-lapse

 

# High quiality 4-D active monittoring of an ocean bottom strucuture by inovative active seismic systems

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We have been developing new method and technology to monitor the geophysical and/or geochemical changes in time and space of an ocean bottom structure including some reservoirs such as methane hydrate, oil-gas and seabed resources by using an autonomous underwater vehicle (AUV) as an innovative observation platform.
The ocean system is a total system which consists of a physical, chemical, biological and earth's processes. Tokyo University of Marine Science and Technology is encouraging to develop the effective ocean survey technology and to educate students in order to contribute to an environmental assessment during an ocean development. A real time high-quality monitoring of the various environmental perturbations accompanying to underwater developments is very difficult but we know that the measurements of high-density high-quality accurate data in both 3-D space and 1-D time will be very effective and useful particularly by means of the resource such as AUV and ships. We assumed our survey target area including a reservoir is a relatively narrow squared area with several 100s meters to a few kilometers in length and about 2000 m in deoth. The steps in the study are: (1) to develop an active seismic monitoring system with active sources and receiver arrays by using AUV effectively combining with both a mobile observation system towing in water and a self-controlled observation system installed at the sea floor, and (2) to do test of both observation systems in water simultaneously in a target area. Then it is (3) to evaluate the data quality and quantity for detecting the geophysical changes of underground structure to establish the basic active monitoring method and technology in an oceanic area. Recently we have three major objectives of our study as follows: (A) to understand the seismological feature quantitatively from the wave field simulation with a reservoir of ocean bottom resources such as methane hydrate and submarine hydrothermal deposits as a target (*e.g.*, Tsuruga *et al.*, 2010; Tachibana and Tsuruga, 2015; Mogi and Tsuruga, in this meeting) and (B) to investigate a ACROSS field test to detect the changes of wave fields by an air-injection on a land area (*e.g.*, , Kasahara *et al.*, 2012; Tsuruga *et al.*, 2012) as well as (C) to develop observation system (*e.g.*,, Tsuruga *et al.*, 2013). In this report we show the preliminary results of the developments of portable seismic source system which is towed in water. We show that our active seismic source system and receiver array system have small IC tips of atomic clock and GPS system as an accurate clock in water. We could thus solve a big problem of clock precision in water.
In future after the observation system will be complete, we will do some field tests in oceanic area at the above mentioned step-(2) and finally we will progress to a new observation integrated strategy to monitor any other time-variant items of geochemical and biological observation as well as the geophysical ocean bottom structure.

Keywords: ocean bottom , 4D monitoring of understructure, development of ocean bottom resources, AUV

 

# Development of database system for integrating various models of seismic velocity structure and geometry of the subducting plate around Japan

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To estimate strong motions caused by earthquakes that could occur in Japan in future and predict seismic hazards, it is necessary to create an accurate model of geometry of the subducting plate and seismic velocity structure, particularly obtained by offshore seismic survey and observations. Most of various kinds of seismic velocity structure models including plate boundary around Japan are presented. However, they are managed individually by each organization constructing the model. To create a new and accurate model of geometry of the subducting plate and seismic velocity structure model, first we need to integrate existing models and clarify the spatial distribution of models regardless of their kinds. Here we have developed database system to store the data of various kinds of velocity structure and plate geometry around Japan. In this database system, various seismic structure models are stored as data, which are three-dimensional (3D) seismic velocity models obtained by seismic tomography, plate geometry, 2D seismic velocity structure models, 2D plate geometry obtained by offshore seismic survey, and hypocenter distribution determined by offshore observation and JMA. Using this database system, users can obtain several structure models at once. This database system can provide not only original data of models but also equal interval grid data, and KML data. The equal interval grid data is output as the text file and have the same scale for all kinds of models, which are produced by bicubic-interpolation of original data. On GUI of the database system, users can know what kind of models and hypocenter distribution exist around the Japanese Islands graphically, and obtain the data of different kinds of models existing in the rectangle region specified by users. The region is specified by setting a profile and the distance from the profile in the map on GUI. The equal interval grid data of 3D seismic velocity model is prepared for the vertical cross section cut by the profile specified by user, which show the distribution of seismic velocity or velocity perturbation. The equal interval grid data of plate geometry are created for the region specified by user. The equal interval grid data of 2D seismic velocity structure model and 2D plate geometry model are created from all data of the models crossing the region and selected by user. Using KML files provided by the database, the data of different kinds of models are visualized in Google Earth at once. Therefore this database system with Google Earth will enable us to create a new accurate model of geometry of the subducting plate and seismic velocity structure around Japan. Acknowledgement: This study is carried out as ‘Research project for Development of seismological information database for modeling seismic velocity structure offshore around Japan’ funded by MEXT, Japan. We are grateful to all who have kindly agreed to the incorporation of their model and data into our system. The earthquake catalog used in this study is produced by the Japan Meteorological Agency, in cooperation with the Ministry of Education, Culture, Sports, Science and Technology. The catalog is based on seismic data provided by the National Research Institute for Earth Science and Disaster Prevention, the Japan Meteorological Agency, Hokkaido University, Hirosaki University, Tohoku University, the University of Tokyo, Nagoya University, Kyoto University, Kochi University, Kyushu University, Kagoshima University, the National Institute of Advanced Industrial Science and Technology, the Geographical Survey Institute, Tokyo Metropolis, Shizuoka Prefecture, Hot Springs Research Institute of Kanagawa Prefecture, Yokohama City, and Japan Agency for Marine-Earth Science and Technology. We are grateful to Zhu Riming, Co. Ltd. VisCore, for his skill to develop this database system and data conversion system from the original data to KML.

 

 