Submission date 2015/09/30

Cruise Summary

1. Cruise Information

Cruise ID KR15-14

Name of vessel KAIREI

Title of the cruise New phase of Ocean Hemisphere Project: Imaging the normal oceanic mantle by advanced ocean bottom observations KR15-14「KAIREI」 / 「KAIKO Mk-IV」

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Representative of the Science Party [Affiliation] Utada, Hisashi [Earthquake Research Institute, University of Tokyo]

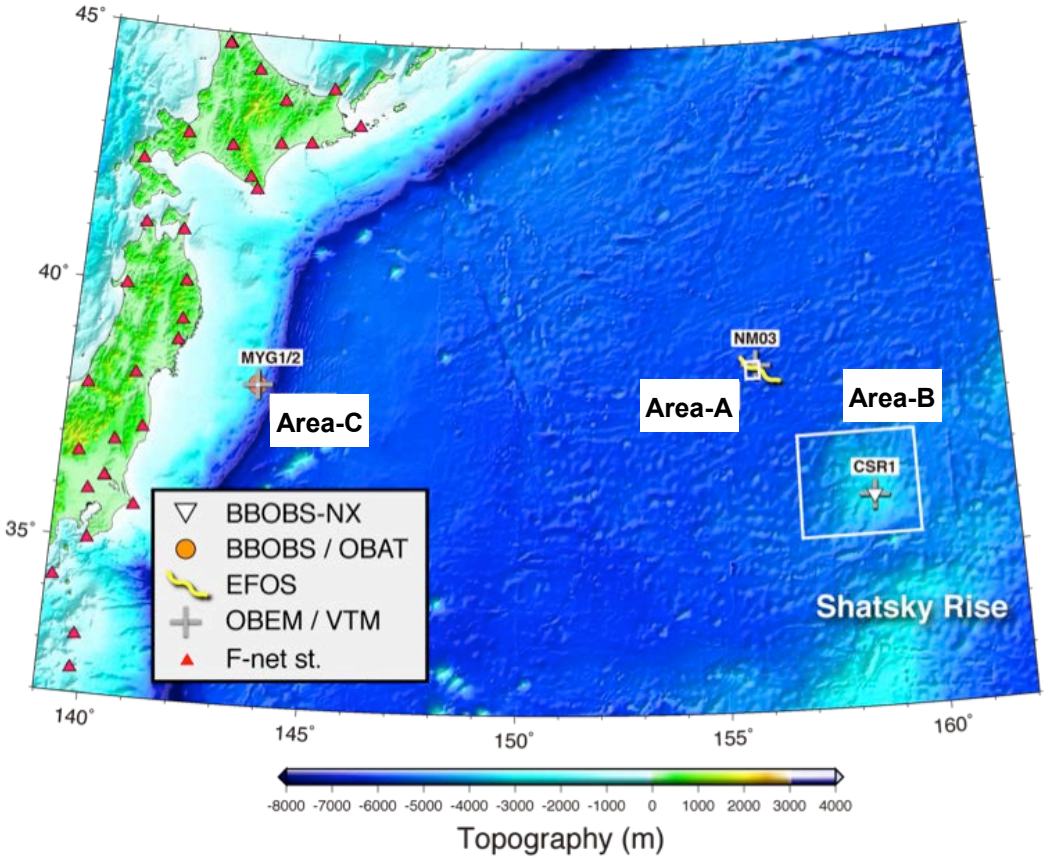
Title of proposal Imaging the normal oceanic mantle by advanced ocean bottom observations

Cruise period 2015/09/11 ~ 2015/09/19

Ports of departure / arrival Yokosuka / Miyako

Research area NW Pacific, and Japan Trench off Miyagi

Research map



2. Overview of the Observation

2.1. Purpose and background

We proposed and funded by Grant-in-aid for specially promoted research (JSPS) to conduct a research program in 5 years toward understanding of the mantle dynamics from an innovative observational approach by answering two fundamental questions in Earth science:

(a) ***What is the physical condition for the lithosphere-asthenosphere boundary (LAB)?***

(b) ***Is the mantle transition zone (MTZ) a major water reservoir of the Earth?***

The "normal" ocean floor is the best window to approach these questions as it allows us to see the inside of the Earth through it without the disturbance due to the thick and heterogeneous continental crust. However, any approach, if ever attempted, has not yet been successful because of technological difficulties in obtaining high-quality geophysical data in the ocean.

The present investigators had led the Ocean Hemisphere network Project (OHP) in 1996-2001, in which a network of geophysical observatories was built in the western Pacific region. Data from the OHP network, especially from broadband seismographs on land and under water, precise magnetometers, submarine cables to measure electric field, successfully provided improved global images of the Earth's interior in terms of seismic velocities and electrical conductivity (e.g., Utada et al., ***GRL***, 2003). During the OHP project, we had also developed a set of new portable ocean bottom instruments, broadband ocean bottom seismometers (BBOBSs) and ocean bottom electro-magnetometers (OBEMs).

These new observation technologies have been fully utilized in the 5-year Stagnant Slab Project (SSP) that succeeded the OHP since 2004. In the SSP, we have carried out a long-term (3 years in total) joint observation of BBOBSs and OBEMs in the Philippine Sea (Shiobara et al., ***EOS***, 2009) to study the MTZ where the subducted Pacific slab appears to be stagnating. We have made significant contributions to the SSP by obtaining results such as the estimation of water content in the MTZ by joint interpretation of seismic and electromagnetic tomography (Koyama, Utada et al., ***AGU Monograph***, 2006) and the seismic evidence for water transportation deep into the mantle by subducting slab (Kawakastu & Watada, ***Science***, 2007). We also revealed the upper mantle structure in this region by analyzing BBOBS data (Isse et al. *PEPI*, 2010) and OBEM data (Baba et al., *PEPI*, 2010). From the northwest Pacific Ocean, Kawakatsu et al. (*Science*, 2009) presented seismic evidence that indicates the lithosphere-asthenosphere boundary to be a sharp seismic discontinuity. Integration of these pieces of evidence obtained by existing technology is undoubtedly useful to solve two questions, but it is not enough.

Recently, we developed further innovative instruments (**BBOBS-NX**: broadband ocean bottom seismometer next generation; **EFOS**: Earth electric field observation system). By improving the mechanical coupling between the sensor housing and seafloor sediments, the **BBOBS-NX** (Shiobara et al. *IEEE-JOE*, 2013) enables us to record horizontal seismic motions, as well as vertical ones, with a typical noise level comparable to land observations. This gives us a strong advantage over other OBS's because it allows us to apply station-based powerful seismic analysis methods commonly used on land, such as the

receiver function and shear-wave splitting analyses, for ocean bottom data. The **EFOS**, on the other hand, measures the electric voltage difference at the seafloor by using a 10 km long cable. Compared to the OBEM measuring the electric field with a spacing of only 5 m, it successfully reduces the noise level to 1/10 or lower so as to provide reliable estimates of electromagnetic responses in a wide period range (1,000-500,000 s) that have high sensitivity to the electrical conductivity in the upper mantle and in the MTZ. Therefore, we are now capable of providing strong constraints to answer the two questions **(a)** and **(b)** listed above by applying our advanced observational technologies to the "**normal oceanic mantle**" (as opposed to the mantle beneath subduction zones, hot spots or mid-oceanic ridges).

In KR10-08 conducted in June 2010, we started a pilot experiment of the NOMan project, in which two BBOBS-NXs and one EFOS are deployed together for the first time in our experience, as well as 3 BBOBSs and 5 OBEMs of conventional type. We expected this pilot experiment would provide us a good opportunity to train ourselves for instrumentations, observations, data processing and analyses.

The KR11-10 cruise was planed as the first phase of the main observation of the project, recovering instruments deployed in the pilot experiment, and deploying more number of BBOBS-NXs and EFOSs as well as BBOBSs and OBEMs. However, we had to change our cruise plan so that only conventional instruments (BBOBSs and OBEMs) which do not need KAIKO 7000-II dive operations are going to be recovered and deployed. The recovery and deployment of advanced instruments (BBOBS-NX and EFOS) were postponed to be conducted in the summer of 2012 by the KR12-14 cruise. The KR11-10 cruise was carried out from November 16 to 30, 2011. Due to a bad weather condition, we recovered only one BBOBS and one OBEM at the site NM04, and re-installed them in the area A (NW of the Shatsky Rise). In the area B (SE of the Shatsky Rise), we successfully deployed 8 BBOBSs and 8 OBEMs, respectively. Every instrument was equipped with batteries sufficient for two-year deployment, so to be recovered in the summer of 2013 by using the chartered working vessel. In September 2014, we recovered most of instruments during the KR14-10 cruise except for the EFOS and the OBEM at the site NM03, under unexpectedly good weather and sea condition. The main aim of this cruise became the final recovery for these two instruments at the site NM03 in the Area-A.

2.2. Research Areas and observations

In this cruise, we planned to perform additional deployments of new instruments at Area-B and Area-C and one dive at the Area-C to recover the VTM (vector tsunami meter), after the main aim at the site NM03. At the Area-A, the self-popup recovery of the OBEM, and two KAIKO Mk-IV dives for recoveries of the recorder unit and the cable drum of the EFOS system were planned. At the Area-B, two-years-long observation by using the BBOBS-NX, the OBEM and the OBDC (ocean bottom Doppler current profiler) was planned with one dive. It is designed as a part of the pilot observation for the coming "normal oceanic mantle" project that we are applying now. At the Area-C, the BBOBS with a tilt measurement function and the OBAT (ocean bottom accelerometer and tilt-meter with pressure gauge and

current meter) were planned to be deployed for the long-term test observation for one year at the same place. The VTM was deployed in 2013 and did not reply at the normal recovery time after several months.

2.3 Summary of result

Due to approaching typhoons on Sep. 9, we should postpone the departure of the cruise on Sep. 11. This three days delay forced us to make large change of the cruise plan, we finally stop to visit the Area-B. On Sep. 14, we reached the site NM03 and safely recovered the OBEM. On next day, Sep. 15, the KAIKO Mk-IV #656 dive was conducted to recover the recording unit of the EFOS system. The recording unit was come back to the deck in the sample basket. Because of bad weather forecast, we terminated the work in the Area-A, and moved to the Area-C just after the on-deck of the KAIKO Mk-IV. In the early morning of Sep. 17, the BBOBS and the OBAT were deployed and determined their positions on the seafloor. Then, the KAIKO Mk-IV #657 dive was started to find and recovery the VTM. We found the VTM, but seven glass spheres (4 floats and 3 housings) were imploded. For the research of the cause and also for some elements survived, the VTM was recovered to the ship.

Recovered OBEM and EFOS's recording unit contained the data of whole deployment periods. The BBOBS was checked that correctly started its recording through the acoustic communication.