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KAIREI and KAIKO Mk-IV Cruise Report

KR15-14

New phase of Ocean Hemisphere Project: Imaging the normal oceanic mantle by advanced ocean bottom observations

NW Pacific, and Japan Trench off Miyagi

Sep. 11 – 19, 2015

Japan Agency for Marine-Earth Science and Technology

(JAMSTEC)

Contents

Cover photo: The EFOS recording unit recovered in the sample basket of KAIKO Mk-IV (left), and white powder like object that was a part of glass spheres due to the implosion (right).

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」
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	Refer Fig. 1

2. Researchers, vessel crew, KAIKO Mk-IV operation team and marine technician

Chief scientist [Affiliation] Hajime Shiobara [Earthquake Research Institute, University of Tokyo]

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

Science party (List) [Affiliation, assignment etc.]

Hajime Shiobara [ERI, University of Tokyo, cheif]

Tetsuo Matsuno [ERI, University of Tokyo, co-cheif]

Hiroko Sugioka [D-EARTH, JAMSTEC, support]

Noriko Tada [D-EARTH, JAMSTEC, support]

Li Ruibai [ERI, University of Tokyo, support]

Vessel crew

Captain	TAKAFUMI AOKI
Chief Officer	HIROYUKI KATO
Jr.Chief Officer	TAKAAKI SHISHIKURA
2nd Officer	TOMOYUKI TAKAHASHI
3rd Officer	KEIJI ITAHASHI
Chief Engineer	MINORU TSUKADA
1st Engineer	SHINICHI IKUTA
2nd Engineer	KATSUTO YAMAGUCHI
3rd Engineer	HIROKI TANAKA
Chief Electronics Operator	TAKEHITO HATTORI
2nd Electronics Operator	TOSHIHIKO YUASA
Boat Swain	KAZUO ABE
Able Seaman	NAOKI IWASAKI
Able Seaman	HIROTAKA SHIGETA

Able Seaman	KOSEI KAWAMURA
Able Seaman	HIDEAKI NAKATA
Sailor	KOHEI SATO
No.1 Oiler	MASANORI UEDA
Oiler	KEIYA TANIGUCHI
Oiler	MAKOTO KOZAKI
Assistant Oiler	DAIKI SATO
Assistant Oiler	HIROMU FUKUDA
Chief Steward	TOYONORI SHIRAISHI
Steward	MASAO HOSOYA
Steward	TORU MURAKAMI
Steward	YOSHITAKA YAMAMOTO
Steward	YOSHIE HIDAKA

KAIKO Mk-IV operation team

Operation Manager	HOMARE WAKAMATSU
2nd ROV Operator	JUNYA NIIKURA
2nd ROV Operator	KIYOSHI TAKISHITA
2nd ROV Operator	SEIJI SHIGETAKE
2nd ROV Operator	RYU ASAI
2nd ROV Operator	SHOTA IHARA
3rd ROV Operator	TAKUMA GOTO
3rd ROV Operator	KENTARO MURASAKI

Marine technician

Morifumi Takaesu [NME, support & management]

3. Observation

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 et al., ***AGU Monograph***, 2006) and the seismic evidence for water transportation deep into the mantle by subducting slab (Kawakatsu & 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 (1000–500000 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.

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, as mentioned above. At the Area-A, the self-popup recovery of the OBEM, and two KAIKO Mk-IV dives for recoveries of the recording unit and the cable drum of the **EFOS** system were planned. At the Area-B, a 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 new "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 position, where we made a similar observation in 2013–2014. The VTM was deployed in 2013 and did not reply at the planned recovery time after several months. The cause of this trouble was estimated in the anchor releaser system from the previous dive recovery of the quite similar instrument in Feb. 2015.

Summary of result

Due to approaching two typhoons on Sep. 9, we should postpone the departure of the cruise on Sep. 11, and waited in the Tokyo Bay until late afternoon. This almost three days delay forced us to make large change of the research plan. We finally canceled to visit the Area-B. On Sep. 14, we reached the site NM03 and safely recovered the OBEM (Photo 1). On the 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 (Photo 2). We also checked existence of the OBEM deployed in 2010 nearby the **EFOS**, which was imploded two glass spheres (Photo 3). Because of the 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 (Photos 4–6) were deployed and determined their positions on the seafloor (Fig. 3). Then, the KAIKO Mk-IV #657 dive was started to find and recover the VTM (Fig. 4). We found the VTM, but seven glass spheres (4 floats and 3 housings) were imploded (Photos 7–9). For the research of the cause and also for some elements survived, the VTM was recovered to the ship.

The OBEM and **EFOS**'s recording unit at the NM03 site contained the data of whole deployment periods. The BBOBS deployed in the Area-C was checked that correctly started its recording through the acoustic communication.

Cruise log

Date	Local Time	Description	Position / Weather / Wind, Sea condition (Noon)
11.Sep	08:00	Scientists party onboard a vessel	Yokosuka port section No.4
	09:00	Let go all shore line & left JAMSTEC	35-19.7N, 139-40.6E
	09:35	let go anchor at Yokosuka port section No.4	Fine but Cloudy
	10:30	Scientific meeting	ESE-2 (Light breeze)
	11:00	Onboard lecture for evacuation and onboard life	1 (Sea Calm Rippled)
	13:30	Meeting for 7K dive plan	0 (No Swell)
	15:00	Heaving anchor, left Yokosuka port section No.4	Visibly: 8'

12.Sep	13:15	Briefing about KAIKO Mk-IV	North West Pacific
		---	35-42.4N, 143-32.5E
			Fine but Cloudy
			NW-4 (Moderate breeze)
			2 (Sea Smooth)
			4 (Moderate Average)
			Visibly: 8'
13.Sep	00:00	Put ship's clock ahead 30 min for Ship's Mean Time	North West Pacific
(JST+0.5H)		---	37-15.1N, 149-29.8E
(UTC+9.5H)			Fine but Cloudy
			WSW-4 (Moderate breeze)
			2 (Sea Smooth)
			3 (Moderate Short)
			Visibly: 8'
14.Sep	00:00	Put ship's clock ahead 30 min for Ship's Mean Time	North West Pacific
(JST+1H)	09:55	Arrived at research area (site A)	38-45.6N, 155-55.0E
(UTC+10H)	10:04	XBT measurement	Fine but Cloudy
		Send out release command to OBEM at site NM03	SSE-4 (Moderate breeze)
	10:38	Confirmed OBEM left from sea floor	3 (Sea Slight)
	13:37	Floated on the surface	2 (Low Swell Long)
	13:47	Recovered OBEM on deck	Visibly: 8'
	14:22	Carried out MBES site survey (~14:54)	
	14:58	Carried out figure eight turn	

15.Sep	07:46	Hoisted up KAIKO Mk-IV	North West Pacific
(JST+1H)	07:52	Launched and start 7K#656 operation	38-45.8N, 155-54.7E
(UTC+10H)	10:40	Vehicle lift off from launcher	Fine but Cloudy
	10:56	Landed on the sea floor (Depth: 5762m)	ENE-4 (Moderate breeze)
	12:43	Left the sea bottom (Depth: 5762m)	3 (Sea Slight)
	15:39	KAIKO Mk-IV floated	2 (Low Swell Long)
	15:50	Recovered KAIKO Mk-IV and finished her operation	Visibly: 8'
	16:40	commenced proceeding to area C	

16.Sep	09:00	onboard scientific seminor by Prof. Shiobara	North West Pacific
(JST+1H)		---	38-30.5N, 149-27.1E
(UTC+10H)			Fine but Cloudy
			North-4 (Moderate breeze)
			3 (Sea Slight)
			2 (Low Swell Long)
			Visibly: 8'
17.Sep	00:00	Put ship's clock aback 1 hour for Ship's Mean Time	off Miyagi pref. Japan Trench
(JST+0H)	05:00	Arrived at research area (site C)	38-15.0N, 143-35.2E
	05:15	XBT measurement	Fine but Cloudy
	05:32	Carried out MBES site survey (~05:47)	SW-3 (Gentle breeze)

Date	Local Time	Description	Position / Weather / Wind, Sea condition (Noon)
	06:34	Deployed OBAT at site MYG1	2 (Sea Smooth)
	06:42	Deployed BBOBS at site MYG1	2 (Low Swell Long)
	07:18	Carried out positioning caribration of OBAT, BBOBS (~08:05)	Visibly: 8'
	09:05	Hoisted up KAIKO Mk-IV	
	09:12	Launched and start 7K#657 operation	
	11:17	Vehicle lift off from launcher	
	11:31	Landed on the sea floor (Depth: 3373m)	
	14:01	Left the sea bottom (Depth: 3373m)	
	16:06	KAIKO Mk-IV floated	
	16:22	Recovered KAIKO Mk-IV and finished her operation	
	17:03	Recovered VTM	
	17:30	commenced proceeding to ISHINOMAKI bay	

18.Sep	06:50	Arrived at ISHINOMAKI bay	ISHINIMAKI bay
	16:05	Heaving anchor, left ISHINOMAKI bay	38-20.7N, 141-19.8E
		---	Fine but Cloudy
			South-3 (Gentle breeze)
			2 (Sea Smooth)
			1 (Low Swell Short)
			Visibly: 8'
19.Sep			

Dive information

KAIKO Mk-IV #656 dive

September 15, 2015 at the site NM03 in the Area-A.

Dive map in Fig. 2.

KAIKO Mk-IV #657 dive

September 17, 2015 at the site MYG2 in the Area-C.

Dive map in Fig. 4.

4. Acknowledgements

We thank for the captain and crew of R/V KAIREI, the KAIKO Mk-IV operation team and a scientific support staff of NME. This study is partly supported by KAKENHI (15H02122).

5. Notice on Using

Notice on using: Insert the following notice to users regarding the data and samples obtained.

Figures and photos

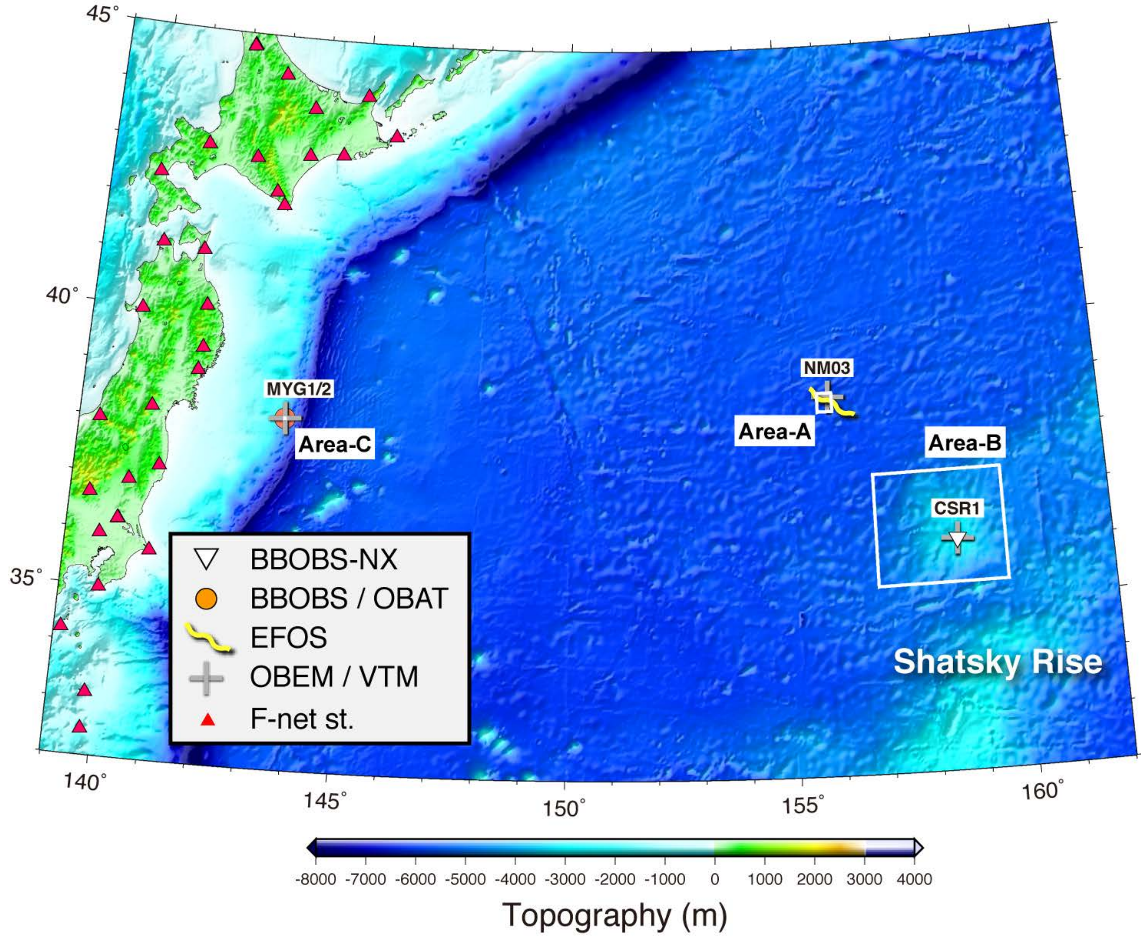

Figure 1. Map of research areas.

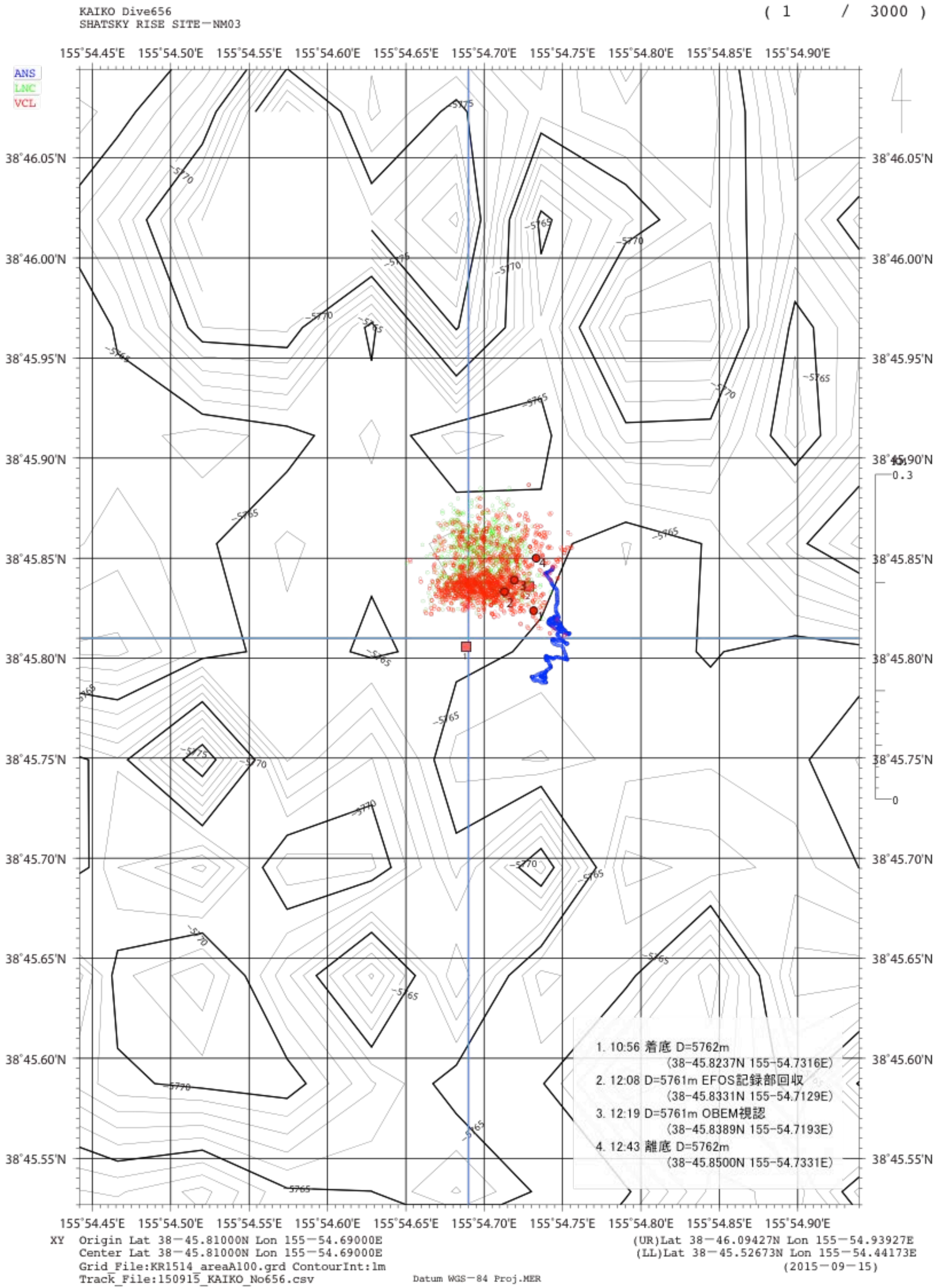

Figure 2. Map of the KAIKO Mk-IV dive #656. The square symbol labeled as 2 shows the imploded OBEM position.

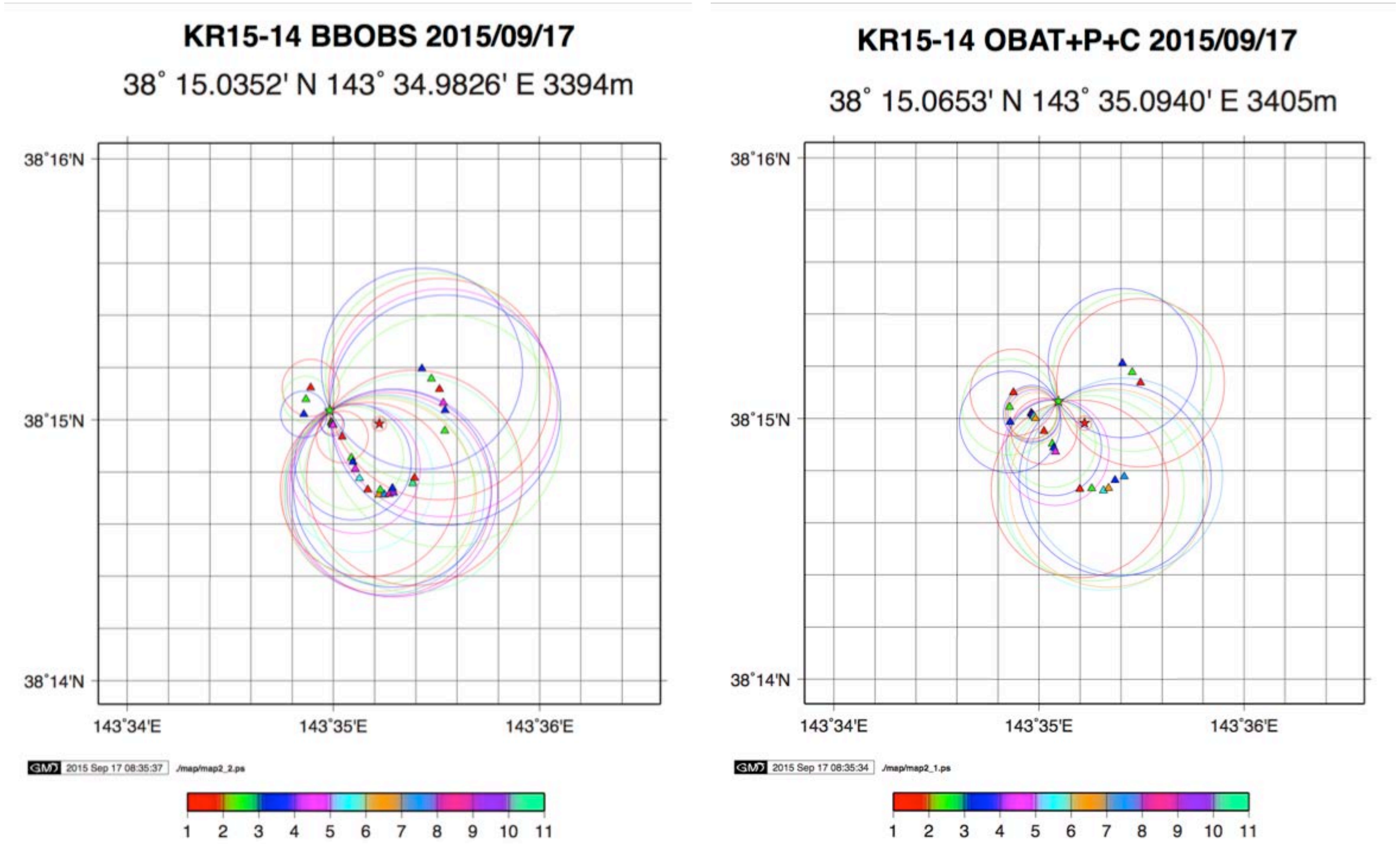

Figure 3. Positioning maps of the BBOBS and the OBAT. Both OBS will stop recording on 2016/10/01-00h (UTC). The OBAT started before deployment, and the BBOBS was started on 2015/09/16-22:30 (UTC), manually.

KAIKO Dive657
MIYAGI－OKI

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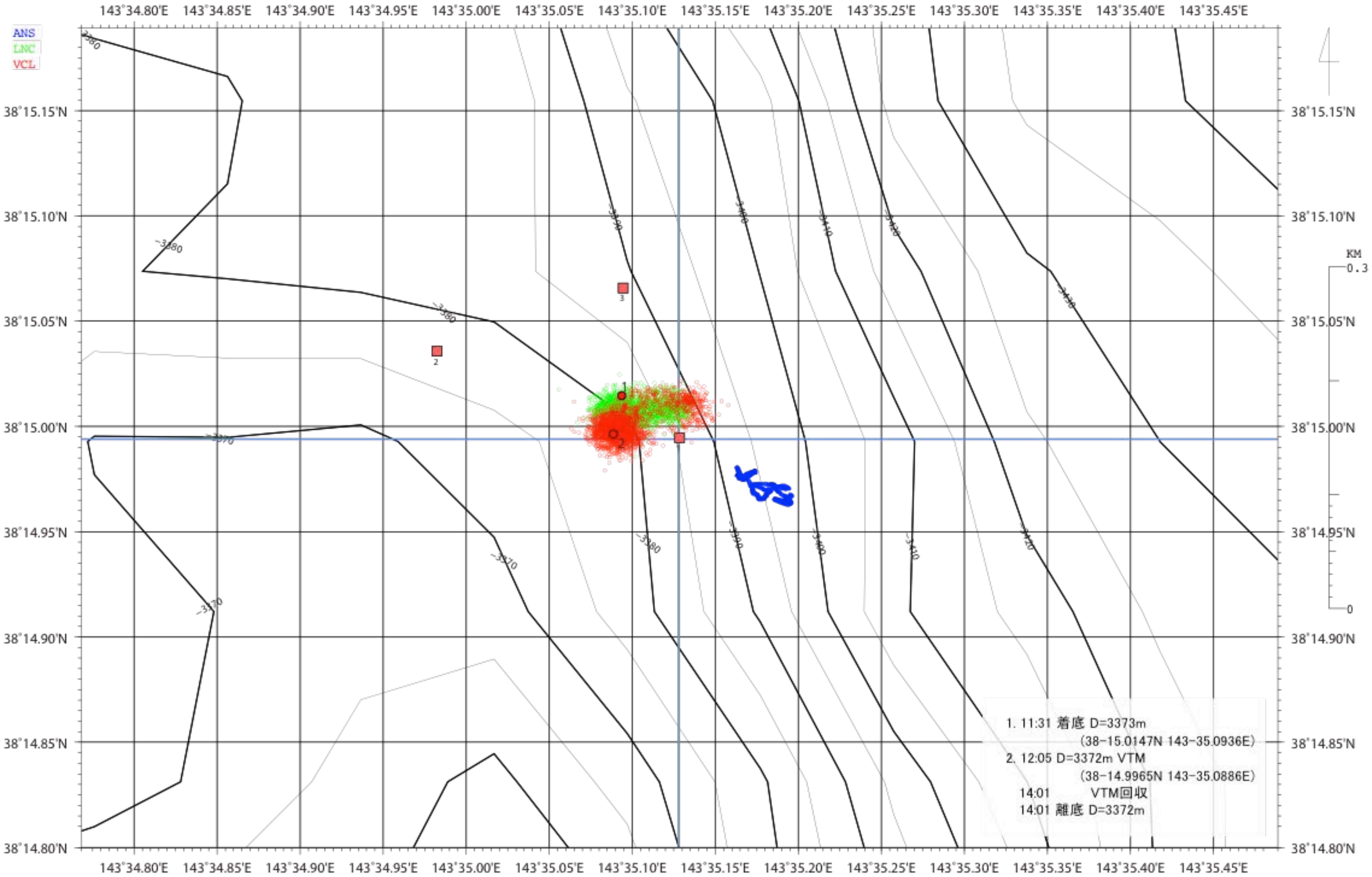

XY Origin Lat 38－14.99400N Lon 143－35.12800E
Center Lat 38－14.99400N Lon 143－35.12800E
Grid_File:KR1514_areaC150.grd ContourInt:5m
Track_File:150917_KAIKO_No657.csv

Datum WGS－84 Proj.MER

(UR)Lat 38－15.18911N Lon 143－35.48873E
(LL)Lat 38－14.79989N Lon 143－34.76827E
(2015－09－17)

Figure 4. Map of the KAIKO Mk-IV dive #657. Square symbols show positions of the BBOBS (labeled as 2) and the OBAT (labeled as 3), respectively.

Photo 1. The OBEM recovered with the first long-term data at the site NM03.

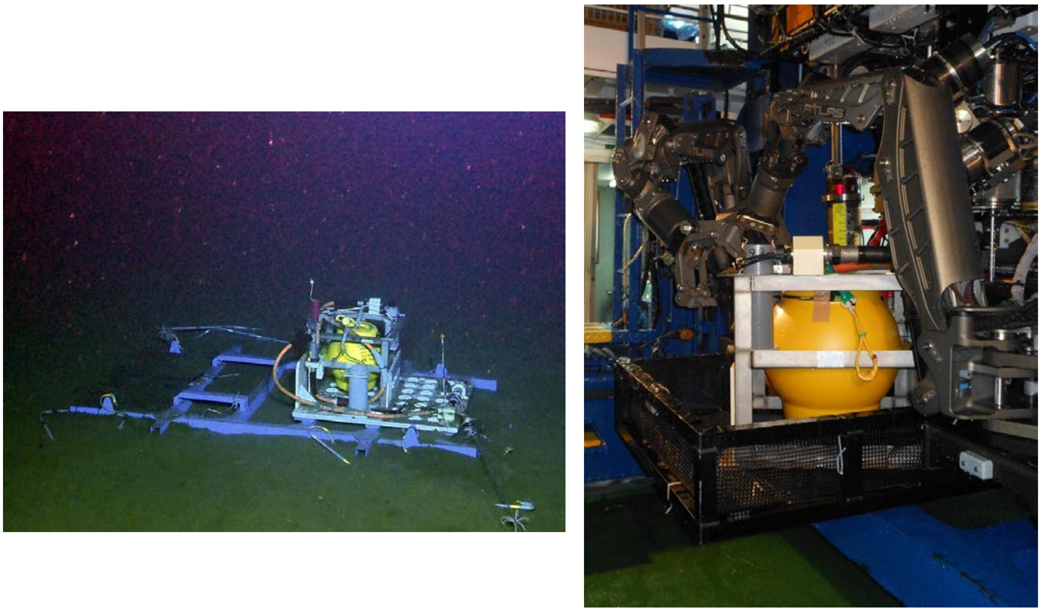

Photo 2. The EFOS recording unit replaced in 2012 on the frame deployed in 2010 (left), and the unit recovered in the sample basket of the KAIKO Mk-IV (right).

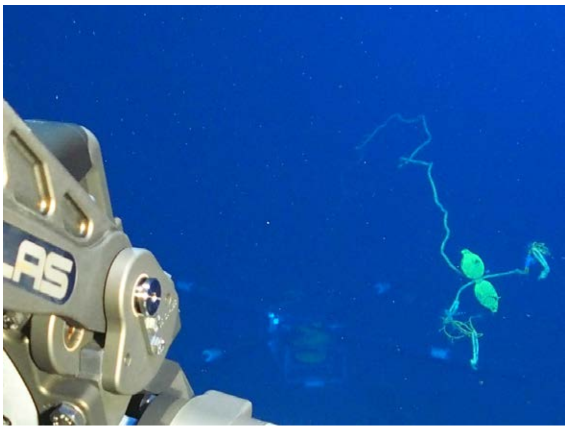

Photo 3. The floating rope of the OBEM imploded near the EFOS.

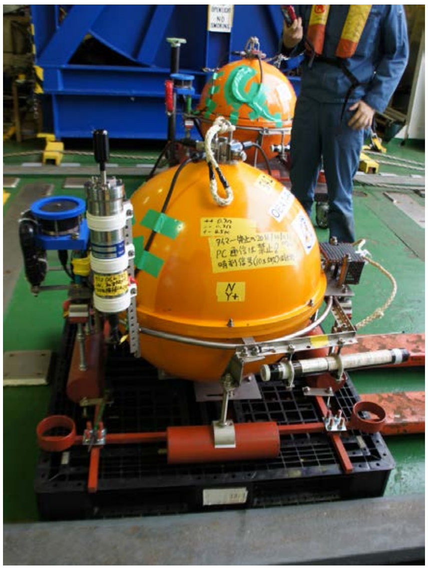

Photo 4. The OBAT (front) and the BBOBS (back), those were deployed in the Area-C.

Photo 5. The rear view of the OBAT. The absolute pressure gauge (left) and the electro-magnetic current profiler (right) are equipped with the acceleration / tilt sensor on the leveling unit inside of the Ti sphere.

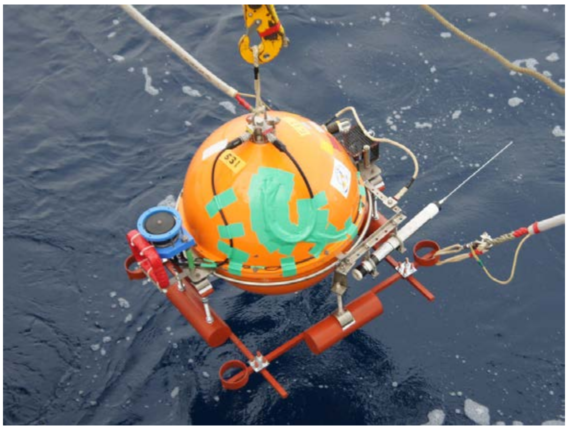

Photo 6. The BBOBS with 3 component mass position data logging soon before the launching.


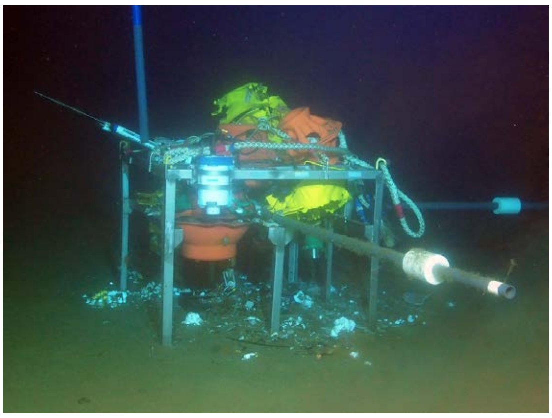

Photo 7. Overviews of the VTM damaged by implosions of seven all glass spheres.


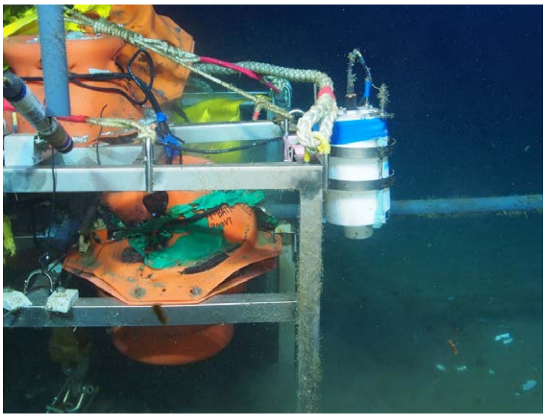

Photo 8. A part of the net covering a glass sphere was seen (left). White objects at the seafloor are glass powder due to implosion. The DPG (white cylinder) looks fine (right).

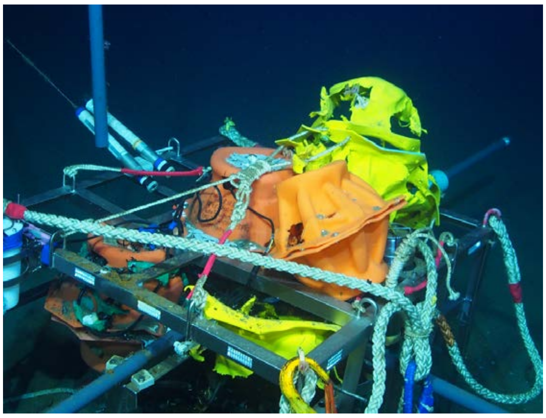
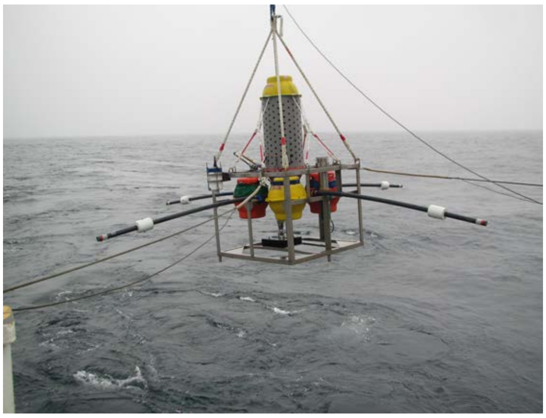

Photo 9. The large gray PVC pipe in the right photo became small pieces. The smaller hardhat (light orange) with a glass float was inside of the pipe. Three orange hardhats contained Li cells and the magnetic sensor and the data recorder of the OBEM.