4.24.02

Retrieve of Ocean Bottom Electro-Magnetometers (OBEMs) in the Mariana region

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1. What is the OBEM?

The ocean bottom electromagnetometer (OBEM) can measure magnetic and electric fields on the ocean floor. The attached sensors and electronics are summarized in Figs. 1 and 2. We have two different type of OBEM as shown in Figs. 1-2 and Photo. 1-4, however, the design for sensors, electrical circuits and releaser are basically same. The fluxgate-type magnetometer, voltmeter, and tilt meter are packed in a pressure glass sphere. Silver–silver chloride electrodes are attached to the end of each pipe. We can record three components of the magnetic field and two horizontal components of the electric field on the memory card. Li Batteries and acoustic transducer circuits are packed in other glass spheres.

On the basis of the electromagnetic induction theory, we can estimate the electrical conductivity distribution in the crust and the mantle depth. Usually, observed fluctuation of electric field is highly correlated with the magnetic fluctuation. This fact is explained by the electromagnetic induction; the natural magnetic fluctuation generates the electric field in the seawater and also below the sea floor. Amplitude of the induced electric field depends on the conductivity of the crust and the mantle. Therefore, the ratio of the electric field to the magnetic field obtained by OBEM can give us information of the conductivity structure below the seafloor. An example of the mantle conductivity structure belw the East Pacific Rise obtained by the OBEM survey (so called the MELT experiment; detailed in Evans et al.1999) is shown in Fig. 3 (Goto et al., prep.). The OBEM survey indicates the asymmetric mantle structure below the EPR. It may be related to the heterogeneity of volatile content in the mantle.

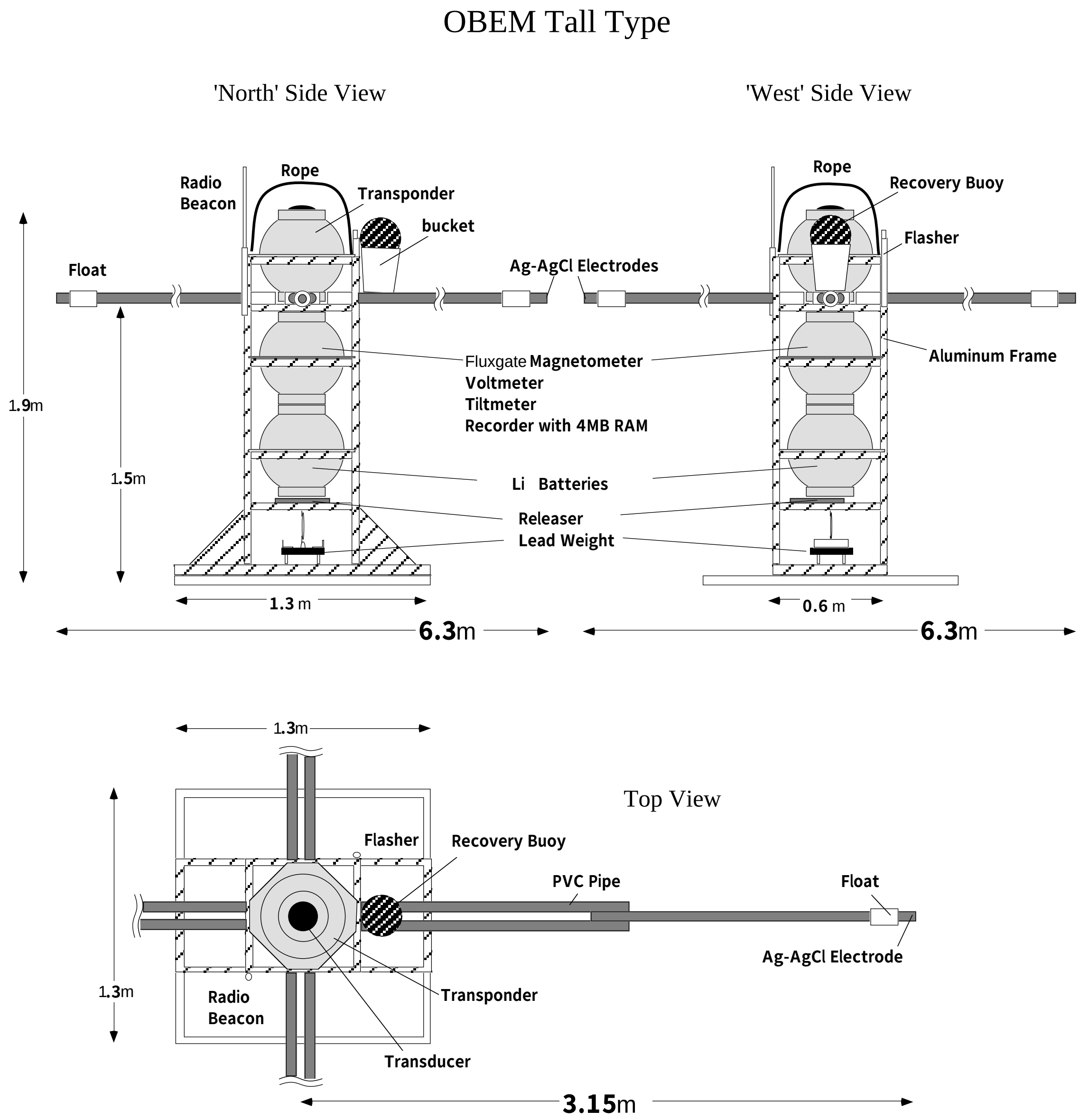


Fig. 1. Side and top views of Japanese OBEM (tall type). These OBEMs are deployed at site 8 and 10 in the Mariana Region (see maps shown later). This tall type has been used for these 10 years. Its total weight in air is 130kg (without the lead weight).

OBEM Half Type

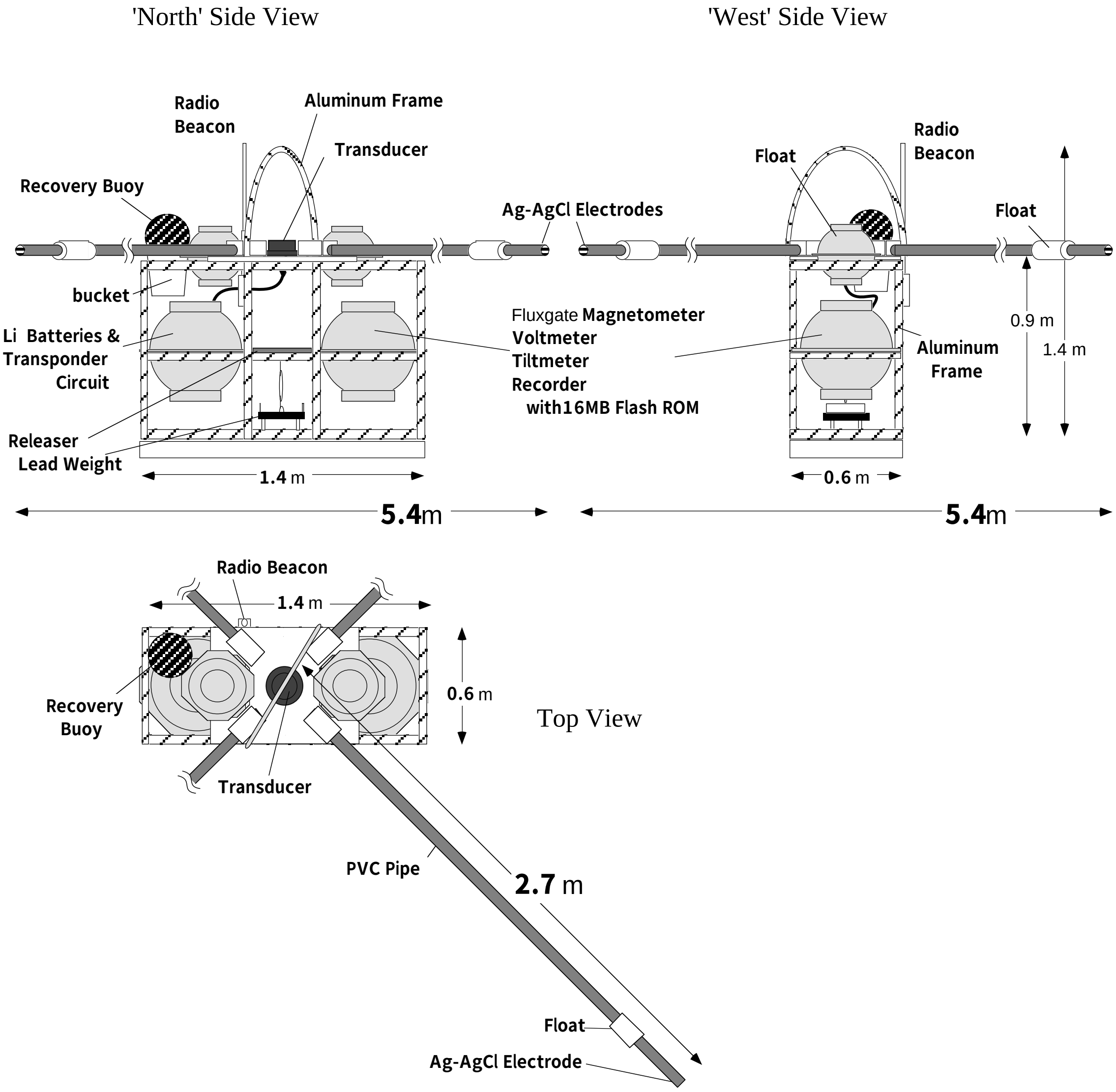


Fig. 2. Side and top views of Japanese OBEM (half type). This OBEM is deployed at site 9 in the Mariana region (see maps shown later). This was newly developed in 1999. Its total weight in air is 130kg (without the lead weight).

Photo 1. OBEM Tall Type in the submarsible hanger on R/V Yokohama.

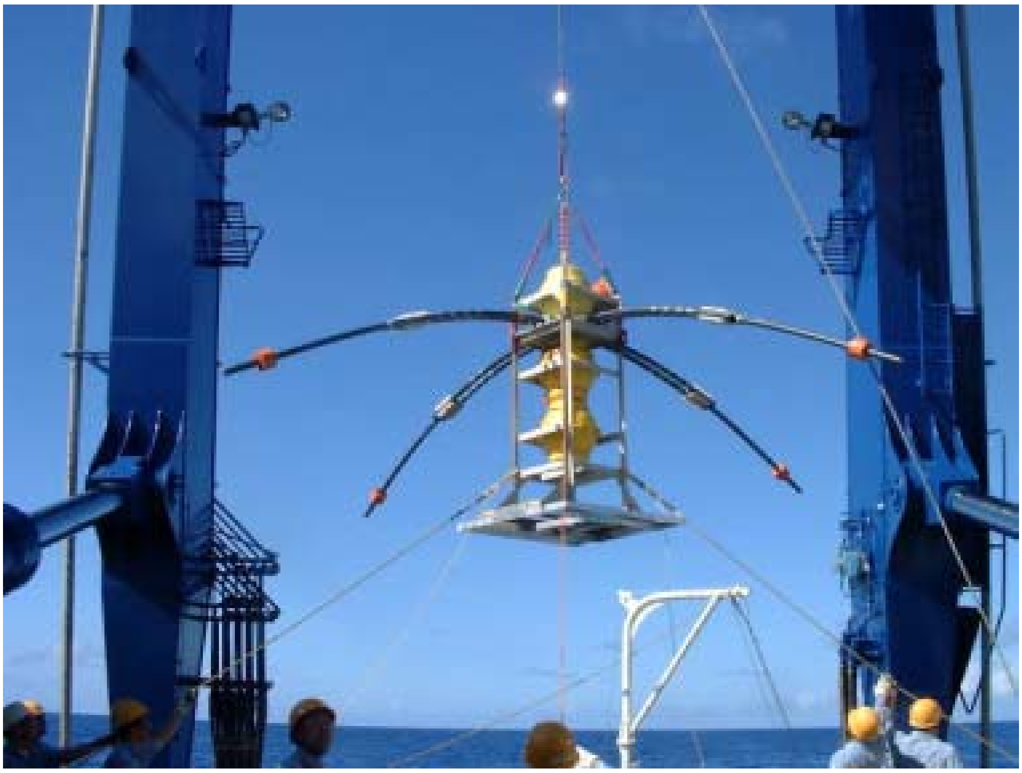


Photo 2. OBEM Tall Type before deployment.

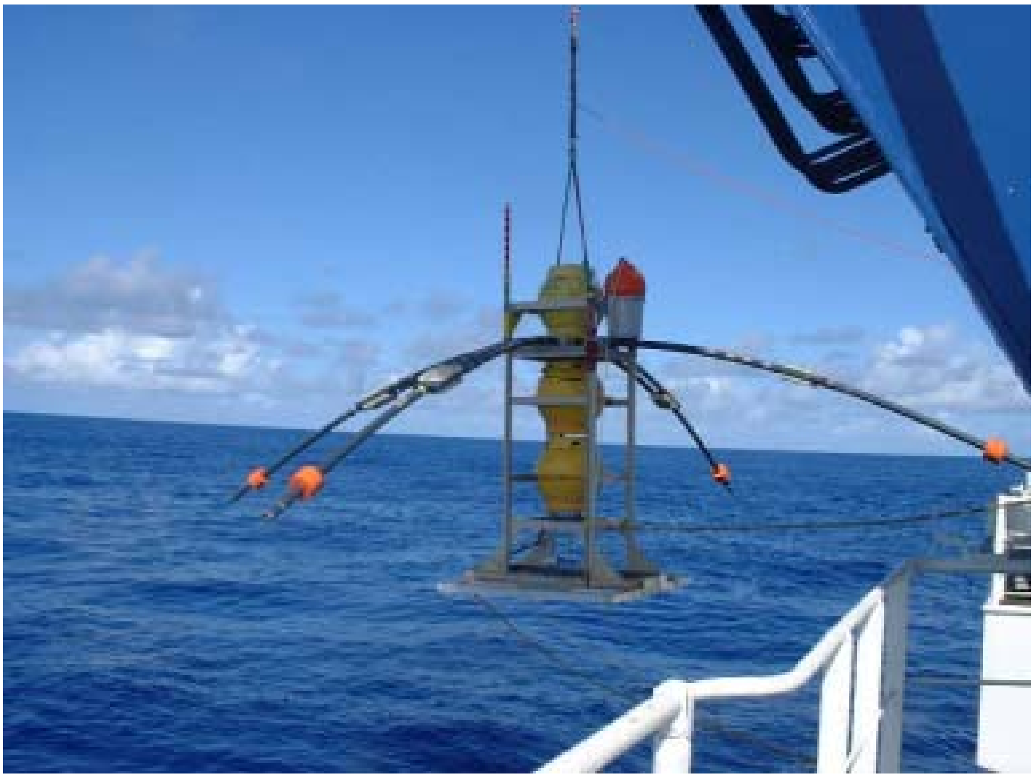


Photo 3. OBEM Tall Type before deployment.

Photo 4. OBEM Half Type built in hanger deck.

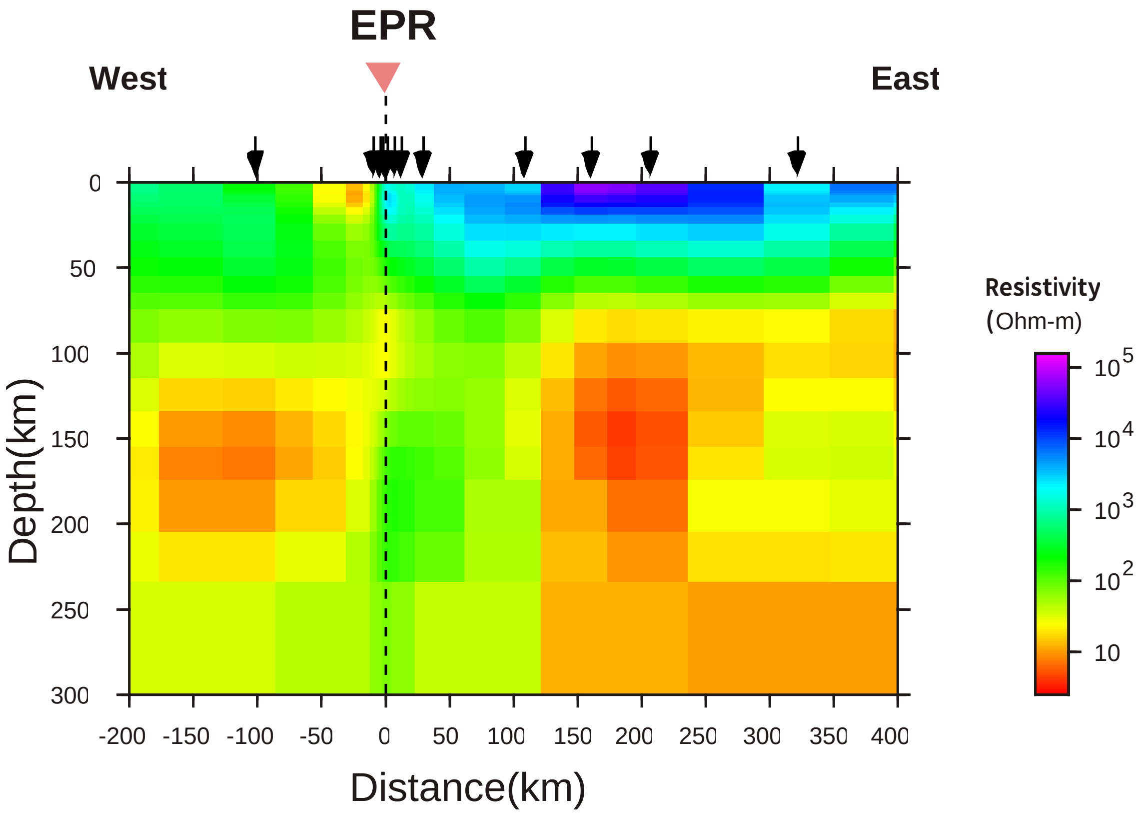


Fig. 3. Resistivity structure below the East Pacific Rise. Arrows indicate OBEM locations. Red color indicates 'low resistive' or 'high conductive' area.

2. How to retrieve the OBEM around the Mariana Islands

We deployed 10 OBEMs (6 of them by Earthquake Research Institute, Univ. Tokyo and 4 of them from Kobe Univ.) in the Mariana region. The deep conductivity structure beneath the slow spreading axis of the Mariana Trough is focused intensively in this study. Also, regional and mantle conductivity structure across the whole Mariana region (through the trench, the arc and the back-arc area) will be revealed by this OBEM array. The site locations are shown in Fig. 4 with a long-term OBS array.

Three of them are located near the Mariana Islands (Fig. 5), which are candidates for retrieved OBEMs in the cruise EW0203 by R/V Maurice Ewing. Two tall-type OBEMs were deployed at sites 8, 10 and a half-type OBEM is deployed at site 9, respectively. Unfortunately, problems have been found on the acoustic transponder attached on the OBEM at site 10. Therefore, we will try to recover the OBEMs at sites 8 and 9 at first. If we have extra time, we will try to recover the OBEM at site 10. Information for the three OBEMs is summarized on Tables 1-3.

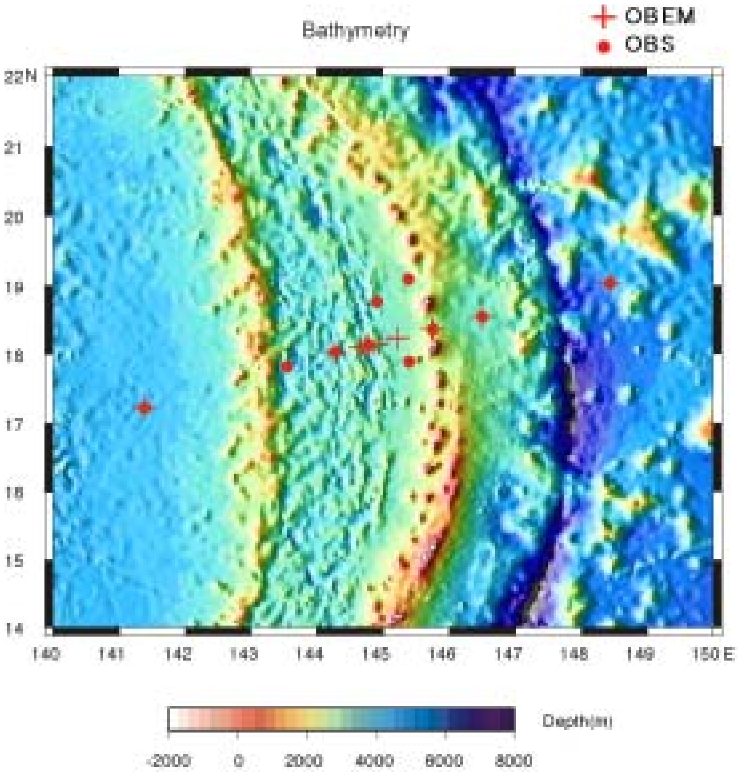


Fig. 4.
Bathymetry Map of the Mariana region. Circles and crosses indicate positions of LT-OBS and OBEM deployed in the cruise by R/V Yokosuka, JAMSTEC.

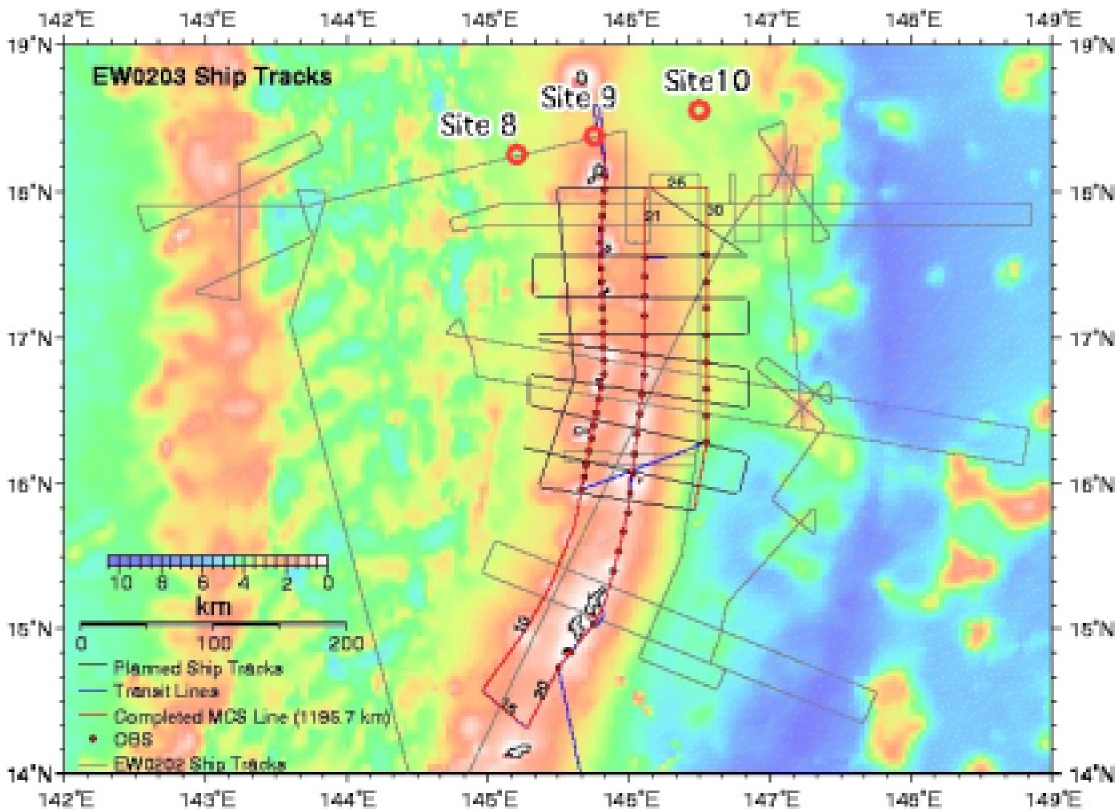


Fig. 5. Site locations of three OBEMs near the Mariana Islands (red circles) with EW0202/0203 ship tracks.

Basic Information about the OBEM around the Mariana Islands

Site No.	OBEM Type	Deployed position (WGS-84)			Estimated settled position (WGS-84)		
		Latitude	Londitude	Depth	Latitude	Londitude	Depth
8	Tall	18 14.0522N	145 13.0646E	3654m	18 13.9581N	145 13.0855E	3618m
9	Half	18 22.0294N	145 45.0387E	2730m	18 21.8340N	145 44.9411E	2729m
10	Tall	18 33.0502N	146 30.0234E	3699m	**********	**********	*****

Table 1. OBEM site locations. Note that the settle position at site 10 was not obtained due to trouble on acoustic communication.

Site No.	OBEM ID	Set time (UTC)	Start time (UTC)	Sampling int. (sec)	Electric dipole length (m)
8	TT1	2001.9.29 5:44:28	2001.10.1 23:00:00	60.0	6.290
9	TT5	2001.10.6 6:25:11	2001.10.8 23:00:00	60.0	5.260
10	TT2	2001.10.6 5:46:41	2001.10.8 23:00:00	60.0	6.105

Table 2. OBEM recording information.

Site No.	OBEM ID	Flashing light	Radio Beacon		Acoustic release system	
			Frequency	Code	Vender	Release code
8	TT1	mounted	43.528MHz	JS1084	Benthos	A (Tx: 10.0kHz, Rx: 11.0kHz)
9	TT5	Not attached	43.528MHz	JS1106	Nichiyu	3C
10	TT2	mounted	43.528MHz	JS164	Benthos	F (Tx: 12.0kHz, Rx: 9.0kHz)

Table 3. Information of the flashing lights, radio beacon, and acoustic release system.

OBEM Recovery Process (with approximate time).

1) Ship's Position = Above the estimated settle position of OBSM (Table. 1)
2) Put the acoustic transducer into the sea from the waist deck. The deck unit of transducer is set in the CTD room.
3) Send pings. Slant ranges between the ship and the OBEM are measured.
4) Send the acoustic release code. The OBEM burns the release wire, and drops the weight **(10 min)**.
5) (After sending the release code)
   Measure slant ranges every 1min to confirm lifting of the instruments and its ascending speed. The estimated time at surface is calculated.
6) (After estimating time)
   Ship's Position = several hundred meters away from the estimated settle position (same as OBS recovery)
7) (After shifting)
   The OBEM comes up by self-buoyancy. The ascending speed is about 35 m/min.
   (104 min at site 8, 78 min at site 9 and 106 min at site 10, respectively)
   Slant ranging is measured every about 15 minitues.
8) Measure slant ranges frequently before the estimated surface time. The acoustic transducer is attached on the top of the OBEM, so that slant ranging will not be obtained if the OBEM at the surface. Note the final slant range.
9) (The following procedure is basically same as OBS).
   Search the OBEM on the sea surface. Turn on radio to receive the signal from the radio beacon. The flashlight is visible in nighttime. Note that the OBEM at site 9 does not have flasher, so that it should be recovered in daytime.
10) If found, head the ship to the OBEM (same as picking up OBS).
11) Grab the OBEM. A towline, fixed to the frame, is released from the OBEM (see Fig. 6 and Photo 5). We can grab the towline or a frame / a thick rope on the top of the OBEM (Fig. 6). The towline is strong enough to lift up the OBEM. Then, make a node and hang it on the hook of the crane. Finally, pick up the OBEM and put it on the A deck. **(30 min)**
    Please log the time and the location at out-of-water.
12) Go to the next point after the OBEM is tied down. Long arms attached to the OBEM are removed on the deck.

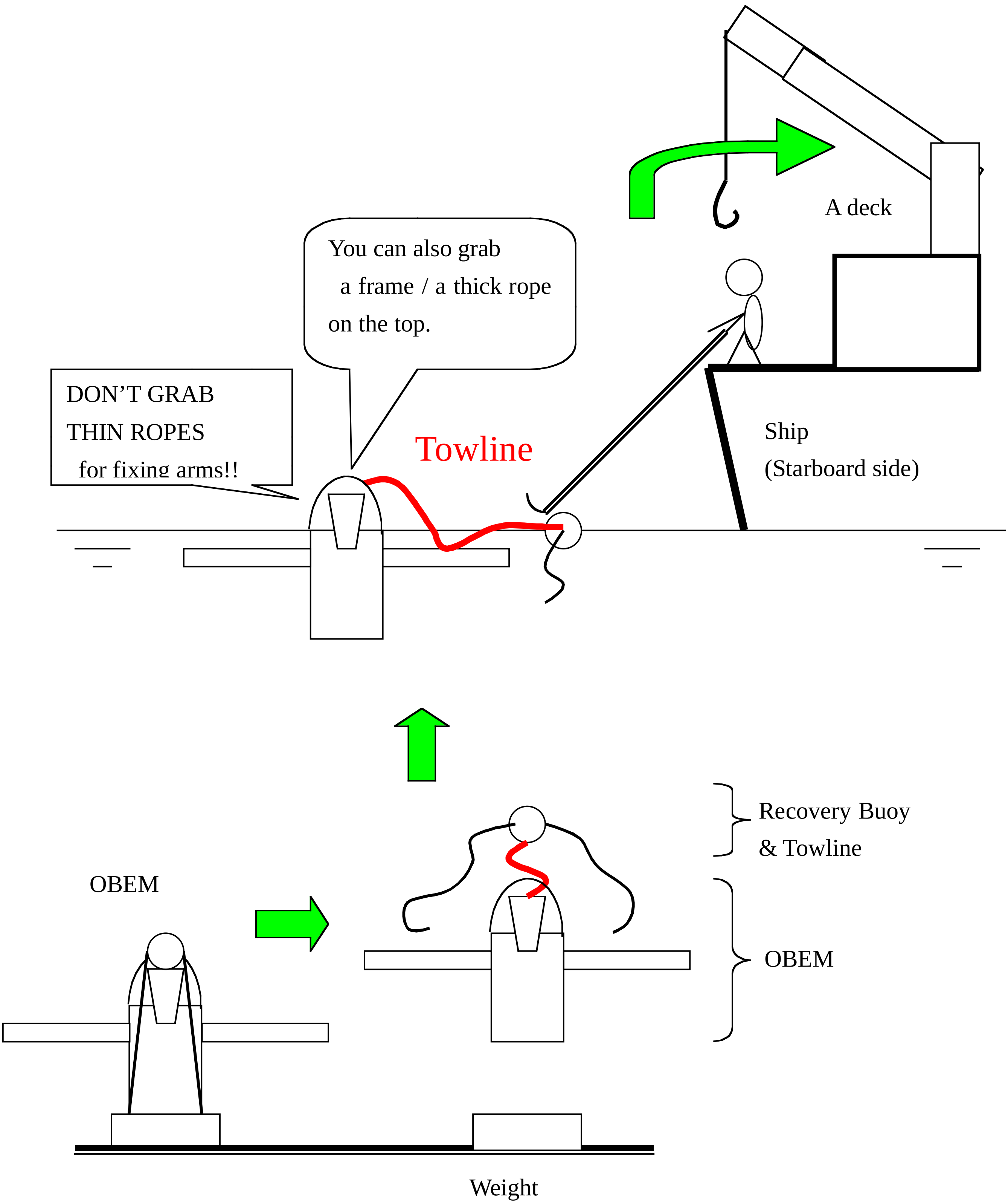
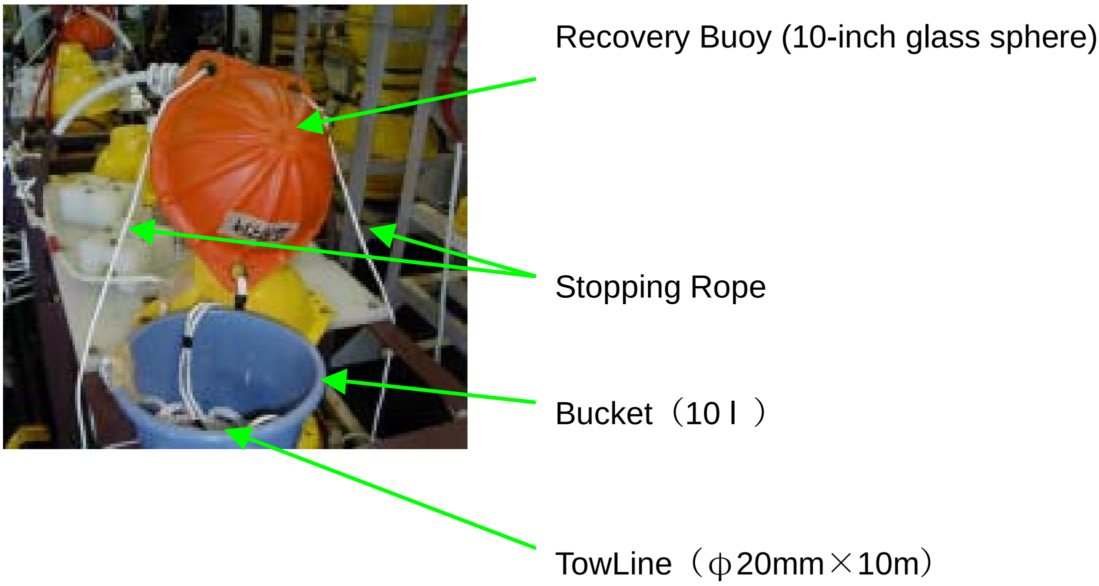
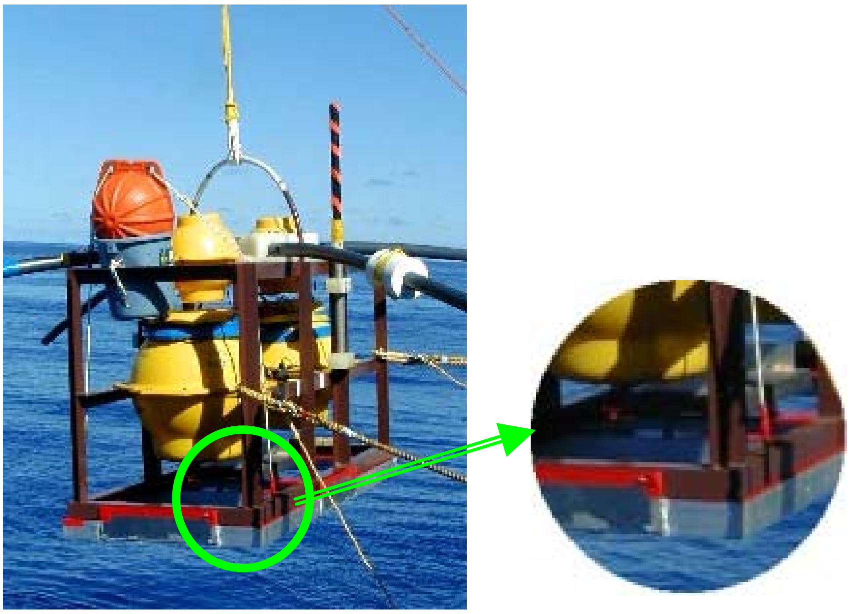


Fig. 6. How to release the towline for the OBEM





Stopping ropes are clamped between the frame and the weight.

Photo 5. Towline for recovery of OBEM. When we send acoustic command to release the weight below OBEM, stopping ropes are also released. Then towline (rope) with length of 10 m appears.

3. Retrieve of the OBEMs

We retrieved two OBEMs at sites 8 and 9 (Photos 6-8). The time table for the recovery is summarized in Table 4. We did not go to site 10 in this cruise.

Site No.	Release Command (UTC)	Liftoff Time (UTC)	Ascending Speed	On Surfece (UTC)
8	2002.4.23 10:09	10:15	33.7m/min	12:02
9	2002.4.23 16:01	16:06	36.6m/min	17:18

Table 4. Recovery time for the OBEMs.

Photo 6. OBEM (TT1; site 8) at the surface. The recovery buoy was released. The tag line was picked up by using a fishing rod.

The recovery procedure is almost same as the planned one in the previous chapter except for the acoustic ranging. Because of strong surface current, the drift speed of the ship was 2 - 3 knots. Our portable transducer cannot be used when the ship keeps its position. Therefore, we did not measure the acoustic range continuously after confirming the liftoff of the OBEM and calculating the ascending speed. The final slant ranging was measured 10 minutes before the estimated surface time, then the ship moved to and kept the pick-up position. We measured horizontal distances between the ship and the OBEM position when we sent pings. This effort made us calculate the depth of the OBEM, so that the ascending speed is decided precisely. As a result, the estimated surface time was very close to real one within 2 minutes difference. Finally, we fortunately found the OBEMs at the surface. The radio beacon signal was received by a handy radio. Although we does not have direction detectors, the radio was quite useful to know the OBEM at the surface.

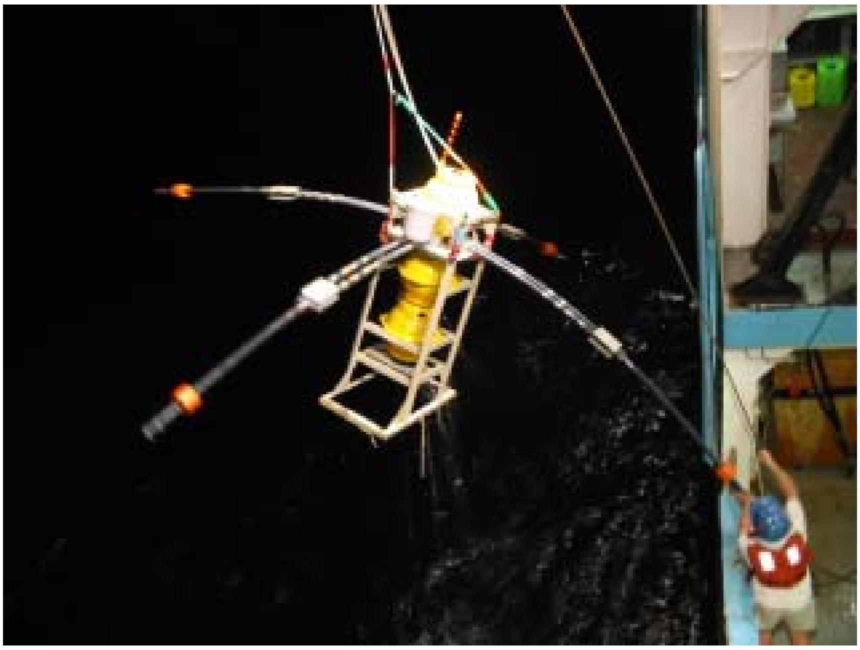


Photo 7. OBEM (TT1); site 8) pulled out of water.

Photo 8. OBEM (TT5; site 9) on the A deck

Site No.	Record Start (UTC)		Record End(UTC)		Sample Nuber
8	2001.10.1	23:02:00	2002.4.23	8:46:00	292905
9	2001.10.8	23:01:00	2002.4.22	23:00:00	282240

Table 5. Data information obtained by the OBEMs.

The electric and magnetic field variations are obtained without any recording problem. The data information is summarized in Table 5. An example of recorded magnetic and electric signals are shown in Fig. 7. Both X and Y components are horizontal, and those axes cross at right angles. Although two components are based on the instrument coordinate, two OBEMs approximately turned to the south direction on the ocean floor by chance. The X component nearly coincide with the southward component, and Y component is approximately similar to the westward component. Unfortunately, an electric field (Ex) at site 9 were not obtained because of the cable break of the S electrode at the deployment.

The data quality is pretty good at both sites 8 and 9. In both magnetic and electric fields, the daily variations are visible. Also magnetic fluctuations with shorter period (e.g. at 20000-21000, 27000-30000 data points in Fig. 7) are recognized in both electric and magnetic fields. This high correlation between the electric and the magnetic fields implies the electromagnetic induction in the earth.

We can clearly recognize that the induced electric field is quite different between sites 8 and 9. Although the amplitude of magnetic fluctuation is similar between two stations, observed electric field is quite different. The OBEM at site 8 (near the Mariana Islands) shows larger amplitude of the induced electric field than at site 9 (eastern end of the Mariana Trough) as shown in Fig. 7. It implies that electrical conductivity below site 8 is less than site 9. More detailed structure will be revealed by precise analysis after this cruise. In this fall, we will recovery eight left OBEMs. Then, we can make a regional conductivity structure around the Mariana region.

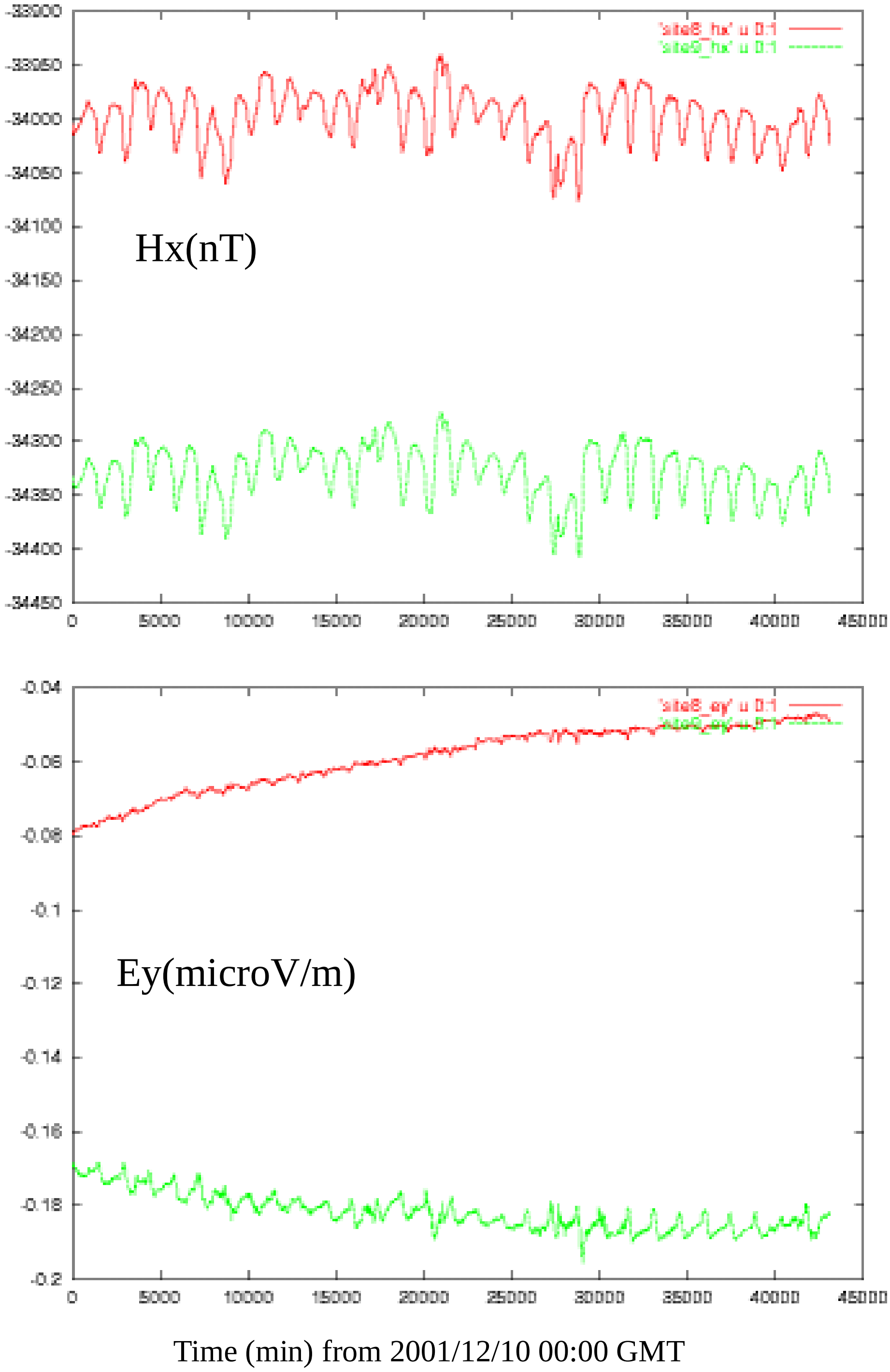


Fig 7. An example of observed magnetic and electric fields at sites 8 (red) and 9 (green). X and Y axes for observation turn to south and east approximately. The time series is plotted from 2001/12/10 00:00:00GMT to 2002/01/08 23:59:00 (30 days). 1 data point = 1 minute.

4. Acknowledgemet

We are grateful for the captain, James O'Loughlin and the crew on R/V Maurice Ewing for their onboard operations. We deeply appreciate Simon Klemperer, Andrew Goodlife and other researchers to give us chances to retrieve the Japanese OBEMs. T.G. gives many thanks to Masahiro Ichiki (JAMSTEC), Nobukazu Seama (Kobe Univ.), Kiyoshi Baba (WHOI) and Hisashi Utada (ERI, Univ. Tokyo) for the deployment of the OBEM and their support to the recovery.