Preliminary Report of KR02-14 Kairei cruise

○Nobukazu Seama[*1] Tada-nori Goto[*2] Yoshifumi Nogi[*3] Masahiro Ichiki[*4] Takafumi Kasaya[*2]
Noriko Tada[*5] Hisanori Iwamoto[*5] Kazuya Kitada[*5] Tetsuo Matsuno[*5] Shigeo Yoshida[*6]
Yoshifumi Kawada[*6] Makoto Ito[*7] Rie Ishii[*7] Kaoru Takizawa[*7] Kiyoshi Suyehiro[*2]
Hisashi Utada[*8] and Masashi Shimoizumi[*9]

We conduced the KR02-14 Kairei cruise in Mariana area to achieve three different purposes. First, we recovered three OBEMs (Ocean Bottom Electro-Magnetometers) that were deployed during the YK01-11 Yokosuka cruise in October 2001. They recorded 7-13 month length data, which will be used to image the overall mantle conductivity structure across the Mariana subduction system. Second, surface geophysical (bathymetry, gravity, and magnetic) data were obtained to characterize the back-arc spreading evolution of the Mariana Trough and back-arc seamount chains on the west of the West Mariana Ridge. Finally, we conducted a magnetometric resistivity (MMR) experiment around the Alice Springs Field hydrothermal site using a newly developed MMR system. We confirmed validity of the system and the data analysis would lead us to understand overall features of the hydrothermal system.

Keywords : Mariana area, OBEM recovery, Surface geophysical survey, MMR experiment

＊1 Research Center for Inland Seas, Kobe University, 2746 Iwaya, Hyogo 656-2401, Japan
＊2 Deep Sea Research Department, JAMSTEC, Yokosuka, Kanagawa, 237-0061, Japan
＊3 National Institute of Polar Research, Itabashi, Tokyo 173-8515, Japan
＊4 IFREE, JAMSTEC, Yokosuka, Kanagawa, 237-0061, Japan
＊5 Graduate School of Science and Technology, Kobe University, Nada, Kobe 657-8501, Japan
＊6 Department of Earth and Planetary Sciences, Nagoya University, Nagoya 464-8602, Japan.
＊7 NME, Yokosuka, Kanagawa, 238-0004, Japan
＊8 Earthquake Research Institute, University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo 113-0032, Japan
＊9 Kyushu Polytechnic College, Kita-Kyushu 802-0985, Japan

1. Introduction

We report on the KR02-14 Kairei cruise (October 28-November 11, 2002; see the cruise log in Appendix) in the Mariana area for three purposes. The first purpose is to recover OBEMs (Ocean Bottom Electro-Magnetometer) in the Mariana area (Fig.1). We have conducted a preliminary seafloor MT experiment using OBEM as a first step towards imaging the deep conductivity structure across the central Mariana subduction system from the subducting Pacific plate, fore-arc, island arc, the Mariana Trough backarc basin to the Parece Vela Basin. We deployed 10 OBEMs during the YK01-11 Yokosuka cruise in October 2001 (Goto et al., 2002a), recovered two of them during a R/V Ewing cruise in April (Goto et al., 2002b), and tried to recover the rest of them during this cruise. This study has two objectives; 1) to understand the melt structure feeding the slow spreading axis of the Mariana Trough and 2) to image the overall mantle conductivity structure across the Mariana subduction system. Since we are planning an international (Japan, US, France, and Australia) cooperative magnetotelluric survey in 2005-2006, our results would be the pilot study. Our final goal would be to obtain 1) a detailed 2D conductivity section across the central Mariana subduction system, which includes three upwellings of serpentine diapir, volcanic front, and back-arc spreading center, and 2) the 3D conductivity image of each upwelling. The resulting electrical models will address issues of hydration of the mantle wedge resulting from subduction and the nature and distribution of subsequent melting.

The second purpose is a surface geophysical survey to fill data gaps of previous cruises. Multi-narrow beam bathymetry, gravity field, and magnetic field data were collected. The data would characterize the back-arc spreading evolution of the central Mariana Trough and back-arc seamount chains on the west of the West Mariana Ridge.

The third purpose is to test a magnetometric resistivity (MMR) sounding system, which is so-called the MOSES (Magnetometric Off-Shore Electrical Sounding) system (Edward et al., 1981). The system has been newly developed by Kobe University and JAMSTEC as a joint research to derive the electrical conductivity structure of a shallow part of

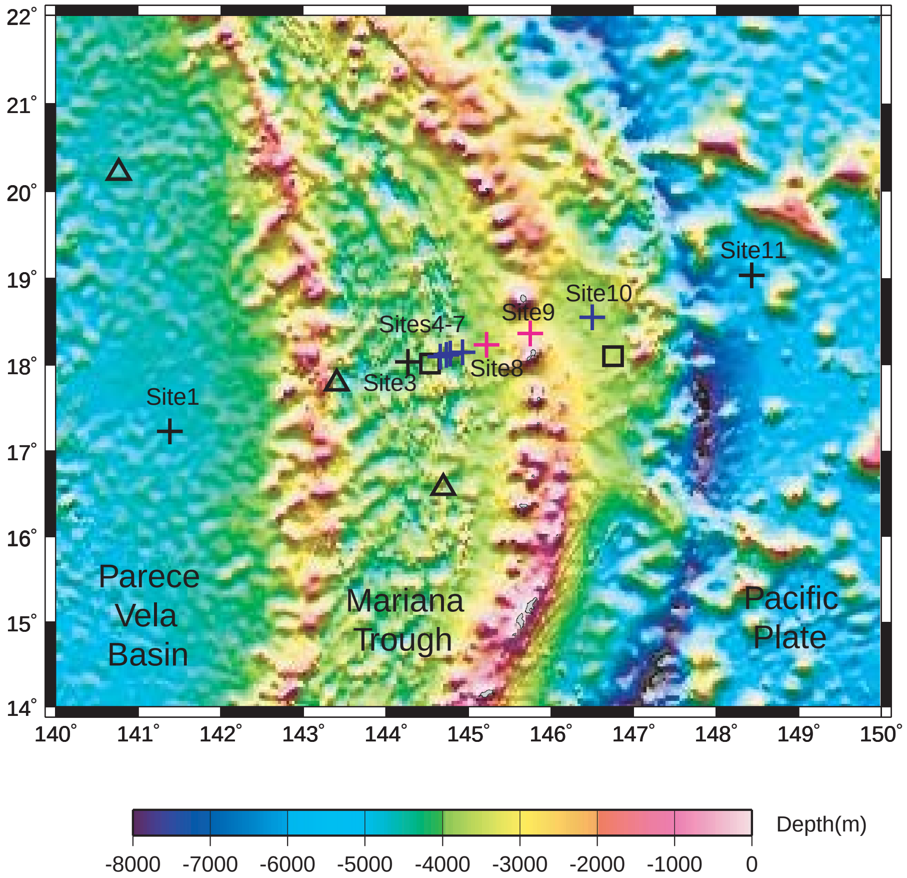


Fig. 1 Locations of ocean bottom electro-magnetic field observation sites in the central Mariana area. Black crosses, OBEM recovered during the KR02-14 cruise; red crosses, OBEM recovered during a R/V Ewing cruise (Goto et al., 2002b); blue crosses, OBEM not recovered during the KR02-14 cruise; triangles, electro-magnetic field observation sites of the Ocean Hemisphere Project, Japan (Seama et al., 2000); squares, electro-magnetic field observation sites by Filloux (1987). Color image of bathymetry map is from smith and sandwell (1994).

the oceanic crust. Our first target for the system is a hydrothermal site, because the electrical conductivity of the seafloor depends primarily on seawater within the crust (amount, spatial distribution, temperature, and salinity). We tested the system at the Alice Springs Field (18˚12.9'N, 144˚42.5'E) in the Mariana Trough spreading center, where the water temperature of 267˚C from the hydrothermal vent was measured (Fujikura et al., 1997). The results would allow us 1) to evaluate our system performance, 2) to establish a new method modified from the original MMR method for better performance, and 3) to understand overall features of the hydrothermal system.

2. OBEM recovery

Ten OBEMs were installed on the seafloor in YK01-11 Cruise in October 2001 in order to investigate the upper mantle electrical conductivity structure beneath the Mariana trench-arc-backarc system (Goto et al., 2002a). Two OBEMs had already been recovered during R/V Ewing cruise in April 2002 (Goto et al., 2002b). We tried to recover the rest of them in this KR02-14 Cruise, but could recover only three of them. Three different types of OBEMs were used in the observation, which were MELT-type (Fig.2), OHP-type (Fig.3) and KOBE-type. The locations and the status of recovering the OBEMs are shown in Fig.1 and Table 1. The fundamental information of the data obtained and the instrumental resolution are shown in Table 2 and Table 3, respectively. The built-

Table 1 Locations, depth, OBEM types and status of ocean bottom electro-magnetic field observation sites which were deployed during the YK01-11 Yokosuka cruise in 2001 (Goto et al., 2001a). Status A, OBEM recovered during the KR02-14 cruise; B, OBEM recovered during the R/V Ewing cruise; C, OBEM not recovered during the KR02-14 cruise. The locations are obtained by acoustic positioning except for the OBEM site 10 (*) which is the location of the deployment.

Site No.	Latitude (N)	Longitude (E)	Depth(m)	OBEM Type	Status
1	17˚13.854'	141˚23.040'	4688	MELT	A
3	18˚02.167'	144˚16.068'	3859	OHP	A
4	18˚05.964'	144˚39.596'	3548	KOBE	C
5	18˚07.088'	144˚44.042'	3875	KOBE	C
6	18˚07.881'	144˚46.833'	3480	KOBE	C
7	18˚08.925'	144˚55.614'	3274	KOBE	C
8	18˚13.958'	145˚13.086'	3618	MELT	B
9	18˚21.834'	145˚44.941'	2729	OHP	B
10*	18˚33.050'	146˚30.023'	3699	MELT	C
11	19˚02.138'	148˚26.231'	5516	MELT	A

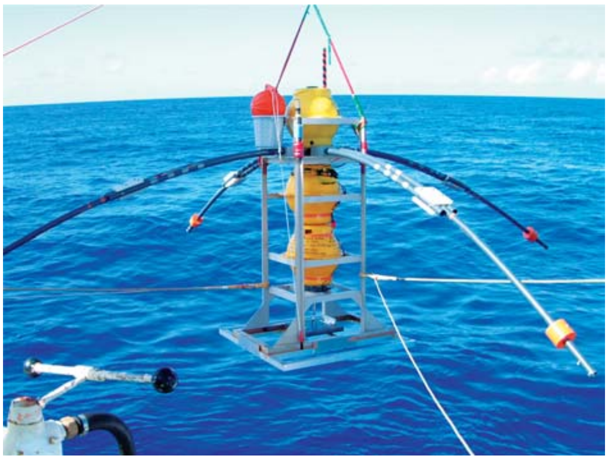


Fig. 2 The outside appearance of ERI MELT-type OBEM.

Fig. 3 The outside appearance of ERI OHP-type OBEM.

Table 2 Data status recoreded by OBEMs recoverd during KR02-14.

Site No.	Start Time (UTC)	End Time (UTC)	OBEM Time Deviation from GPS Time	Sampling Interval	Number of Data
1	30/Sep./2001 23:02	24/Apr./2002 7:01	OBEM clock was down	60 sec.	295,680
3	2/Oct./2001 23:01	30/Oct./2002 23:00	+165 sec.	60 sec.	567,360
11	6/Oct./2001 23:02	30/Apr./2002 7:01	OBEM clock was down	60 sec.	295,680

Table 3 Instrumental specification of OBEMs.

OBEM Type	Sensor	A/D	Dynamic Range	LSB
MELT	Magnetic field	16 bits	±330 nT	0.01 nT
	Electric field		±10 mV	0.31 μV
	Tilt		±55 deg.	0.0017 deg.
OHP	Magnetic field		±330 nT	0.01 nT
	Electric field		±10 mV	0.31 μV
	Tilt		±9 deg.	0.00026 deg.
	Temperature		> 0˚C	0.01˚C
KOBE	Magnetic field	20 bits	±400 nT	~0.0008 nT
	Electric field		±10 mV	0.019 μV
	Tilt	16 bits	±45 deg.	0.0014 deg.
	Temperature		-40~100 ˚C	0.0021˚C

Table 4 The voltage difference among all electrodes of OBEMs recovered in KR02-14 cruise. N, S, E, and W denote four electrodes of each OBEM and GND is used for the common electrode. The N electrode of the site 3 (*) is used as a common electrode for this measurement.

Site No.	N	S	E	W	GND
1	0.66	0.29	0.70	0.00	E electrode
3	0.00*	1.55	-0.63	broken	0.31
11	0.98	0.99	5.68	0.88	E electrode

in clock of the OHP-type OBEM had gained 165 seconds during the one year observation. Thirteen electrodes were recovered in this cruise and only one electrode had broken. The Filloux-type electrode (Filloux, 1987) was used in this observation and fine electric field variation data were collected. Since the MELT-type and the OHP-type OBEMs stored batteries for 7 months and 1 year observations, respectively, the MELT type OBEMs' power was all down and the clocks were dead, while the OHP-type OBEM was still alive and the information of the time mark was able to be retrieved just after the recovery.

Electromagnetic field, tilt and temperature variations at each site are shown in Fig.4. Excellent data were collected at the site 1. The geomagnetic micropulsations are recorded well on about 21, 27, 36 and 55 days after the deployment and electric field variations are also clearly obtained corresponding to the geomagnetic activities. The electrodes reached states of equilibrium in the first two months as shown in the time series figure (Fig.4). The small ripples in the time series figures represent diurnal variations that are utilized in the Sq analyses. We were also able to collect good data at the site 3 within about 270 days. However, the records of magnetic field and tilt variations suddenly became wrong afterward probably due to the power supply, while the electric field measurement was not affected. The temperature data are also fine for all the period, but they often contain outliers. The magnetic field variations of the site 11 are acquired well except recordings between 140 and 150 days. But, the electric field data of the site 11 contains a serious problem, which is probably caused by an unstable condition of the electrodes. We measured voltage differences among all the electrodes of the OBEMs just after the recovery (Table 4). The result indicates the common electrode of the OBEM at the site 11 (the E electrode) deviates from the others. Thus, the site 11 data is not suitable for magnetotelluric analysis and we will apply geomagnetic depth sounding and/or Sq variation analyses to the site 11 data.

3. Surface geophysical survey

We conducted a surface geophysical survey to characterize the back-arc spreading evolution of the central Mariana Trough and seamount chain structure in the eastern margin of Parece Vela basin (Fig.5). Multi-narrow beam bathymetry, gravity field, and magnetic field data were collected with a 9-km track spacing and 13-14 knot ship speed. The DGPS (differential global positioning system) was used to derive the best ship location. One of the important objectives of the geophysical mapping was to fill a gap in high-resolution gravity data as well as bathymetric data.

Multi-narrow beam bathymetric feature was obtained by SEABEAM2112 (Fig.6). Further, the SEABEAM2112 also provides a backscatter image, which will be processed after the cruise. An XBT was done at the OBEM site 1 on 29th, October; that is the first day to survey in Mariana Trough. The result of the XBT was used to estimate the sound velocity of the seawater that reflects water depth by the SEABEAM2112 afterward throughout the rest of the cruise. The water depth data before this XBT was calibrated using an XBT result, which had been obtained by the previous KR02-13 Kairei cruise in Mariana Trough.

Gravity field data were obtained from a shipboard gravimeter (KSS-31, Bodenseewerk Perkin-Elmer GmbH). Free-air gravity anomaly (Fig.5) was calculated by subtracting the normal gravity field and correction of the Eotvos effect using the DGPS data. The gravity field data at the Yokosuka port measured by a gravimeter (CG-3M, Scintrex) will be used to correct the data drift.

Magnetic field data are collected by two instruments; a shipboard three-component magnetometer (STCM: Isezaki, 1986), which measures the vector of the geomagnetic field using deck-mounted fluxgate magnetometers and gyros, and a ship-towed proton precession magnetometer which measures the intensity of the geomagnetic field. The STCM is the system which has already been installed on board the R/V Kairei

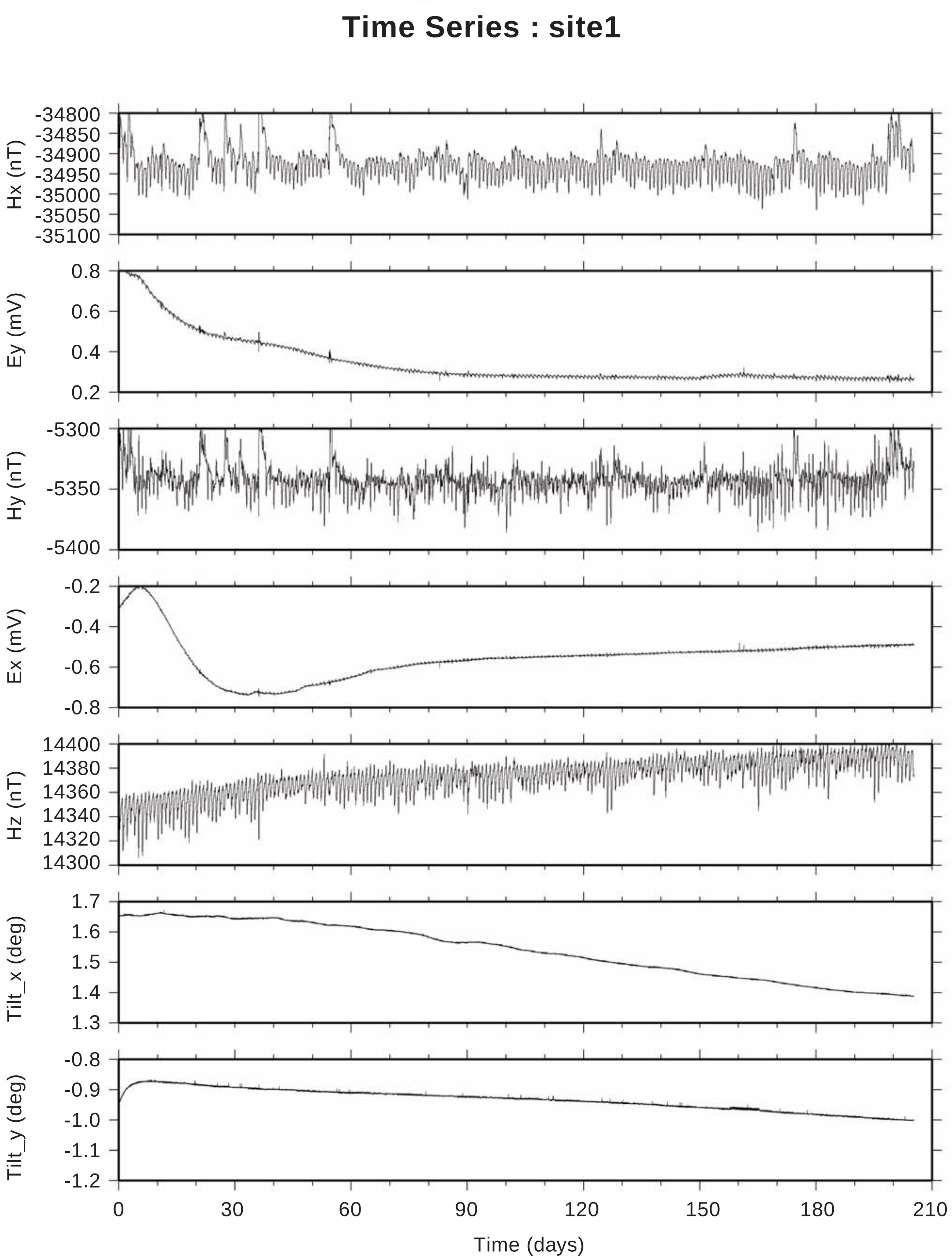
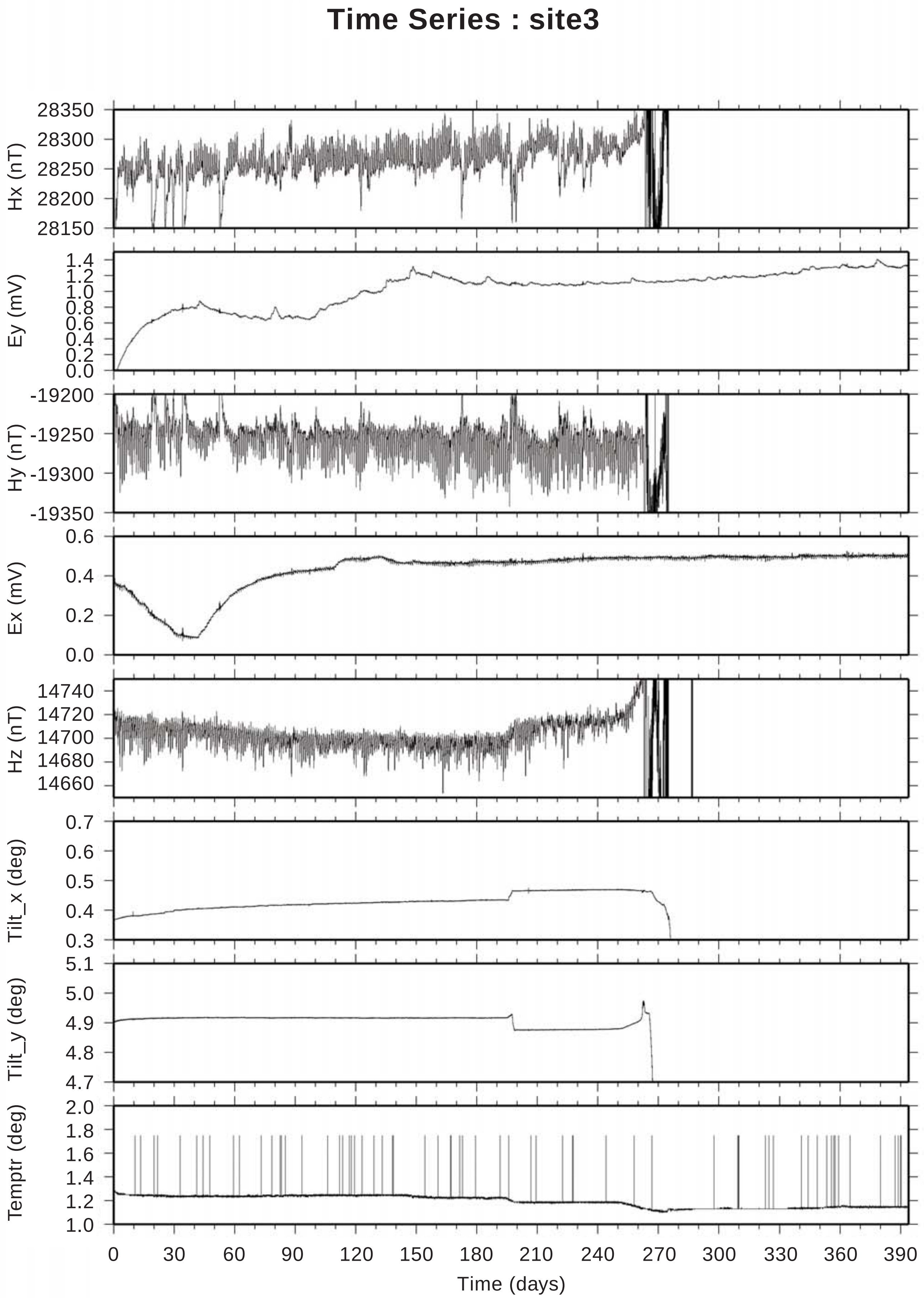
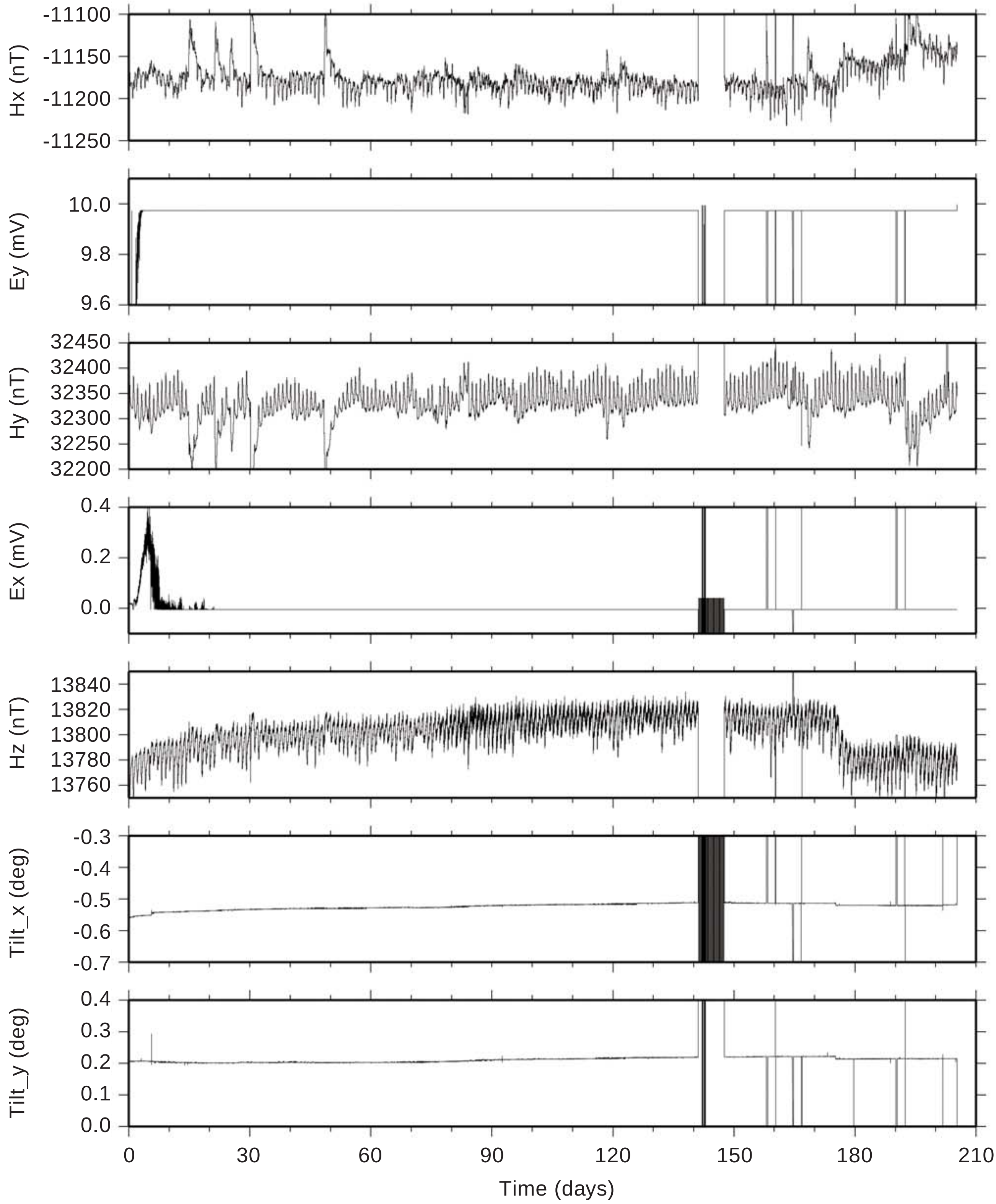


Fig. 4 Time series of electromagnetic field variation and instrumental tilt data observed by OBEMs at the site 1, the site 3, and the site 11 recovered in the KR02-14 cruise. Temperature data are also shown in the bottom only in the site 3. H, E, and Tilt show geomagnetic filed, electric field, and instrumental tilt data with their subscripts of x, y and z correspond to northward, eastward and downward components, respectively.


Time Series : site3
Hx (nT)
28350
28300
28250
28200
28150
Ey (mV)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Hy (nT)
-19200
-19250
-19300
-19350
Ex (mV)
0.6
0.4
0.2
0.0
Hz (nT)
14740
14720
14700
14680
14660
Tilt_x (deg)
0.7
0.6
0.5
0.4
0.3
Tilt_y (deg)
5.1
5.0
4.9
4.8
4.7
Temptr (deg)
2.0
1.8
1.6
1.4
1.2
1.0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Time (days)

Time Series : site11



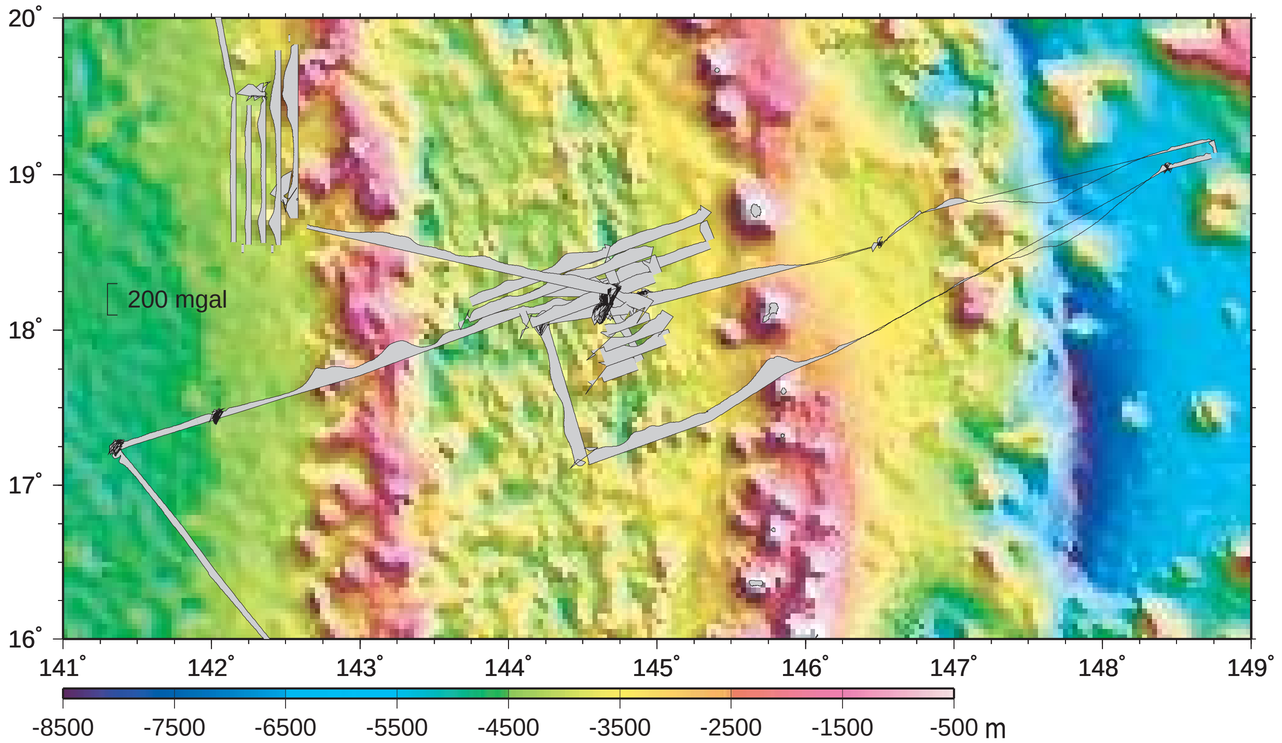


Fig. 5 Free-air gravity anomaly along the ship tracks in the central Mariana area. Positive anomalies are shaded. Color image of bathymetry map is from Smith and Sandwell (1994).

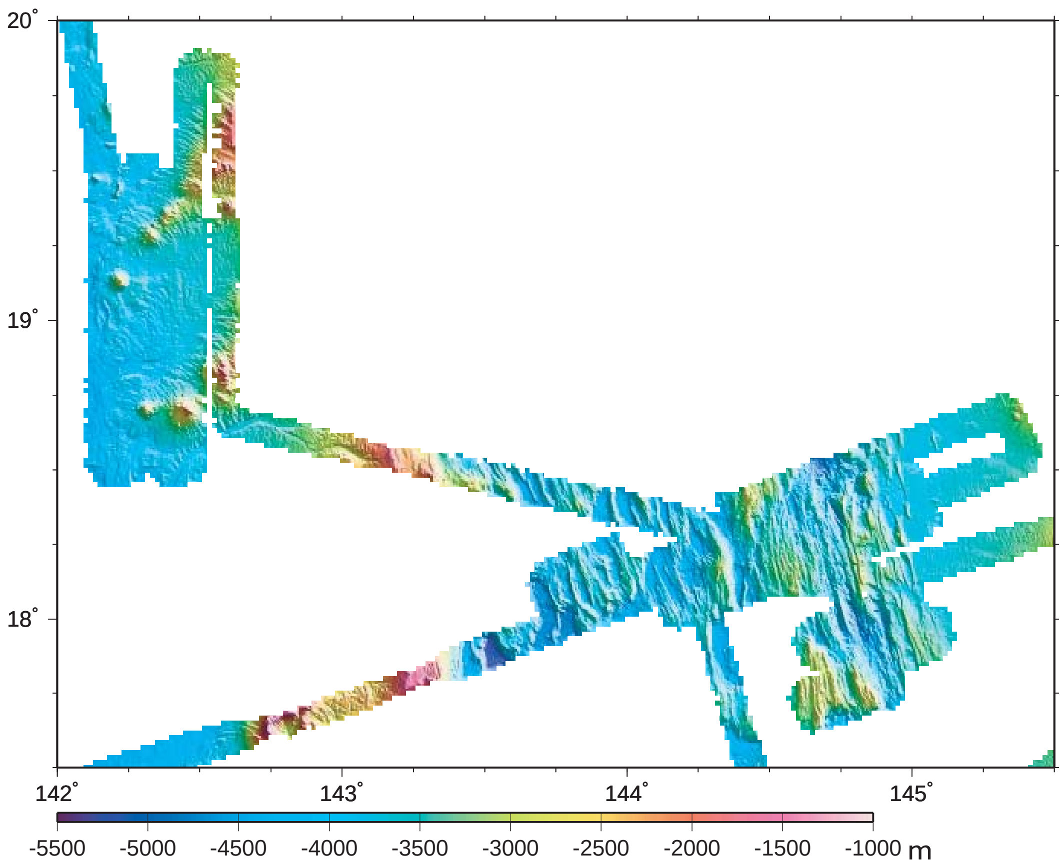


Fig. 6 Bathymetric map in the central Mariana Trough and the eastern margin of Parece Vela basin obtained during the KR02-14 cruise.

and its performance is as follows: Magnetometer sensors can measure the range of ±100,000 nT with the resolution of 1 nT. The vertical attitude sensor is composed of fiber gyros and accelerometers, attaining the pitch and roll angle resolution of 0.0055 degrees and its accuracy of ±0.2 degrees (< 30 degrees). The sampling rate is 8Hz. Geomagnetic total intensity anomaly (Fig.7) is obtained by subtracting the 2000 International Geomagnetic Reference Field (IGRF2000; IAGA Division I Working Group 1, 2001) from the proton precession magnetometer data. Since the Mariana region is near the geomagnetic equator, vector geomagnetic anomaly field is especially useful to understand its tectonics. It is because total intensity anomaly amplitudes are often much reduced depending on the orientation of the ambient geomagnetic field and magnetic lineation while these have no effect on vector anomalies (Isezaki, 1986). The STCM data contain the effects of ship's magnetic field, which is required to be corrected in order to derive the real geomagnetic field. Twelve constants related to the ship's permanent and induced magnetic field are estimated using the data of "Eight figure turn". "Eight figure turn" are made by steering the ship tight circle, both clockwise and counter clockwise rotation. During the cruise, "Eight figure turn" were conducted three times and those are listed in Table 5.

Our data allow us to cover whole the central Mariana Trough between 16° and 19° combined with previous cruises (KH92-1, Y96-13, YK99-11 and YK01-11). The morphology in this area shows 7 spreading axis segmentations. The non-transform offsets, that define the ridge segments, can be traced off-axis in the western side. The direction of the spreading fabric in the southern part of this area changes dramatically from NNW-SSE to almost N-S trend; that is interpreted as a result of the change in the spreading direction. Further analysis combined with crustal age estimation by vector geomagnetic anomaly would allow us to reveal whole tectonic evolu-

Table 5 Locations of "Eight figure turn" during KR02-14 cruise.

No.	Date	Time(UT)	Latitude (N)	Longitude (E)
1	2/Nov.	08:14-08:33	18°13.567'	141°41.833'
2	8/Nov.	04:44-05:03	19°30.283'	142°21.458'
3	9/Nov.	05:00-05:08	23°40.236'	141°18.331'

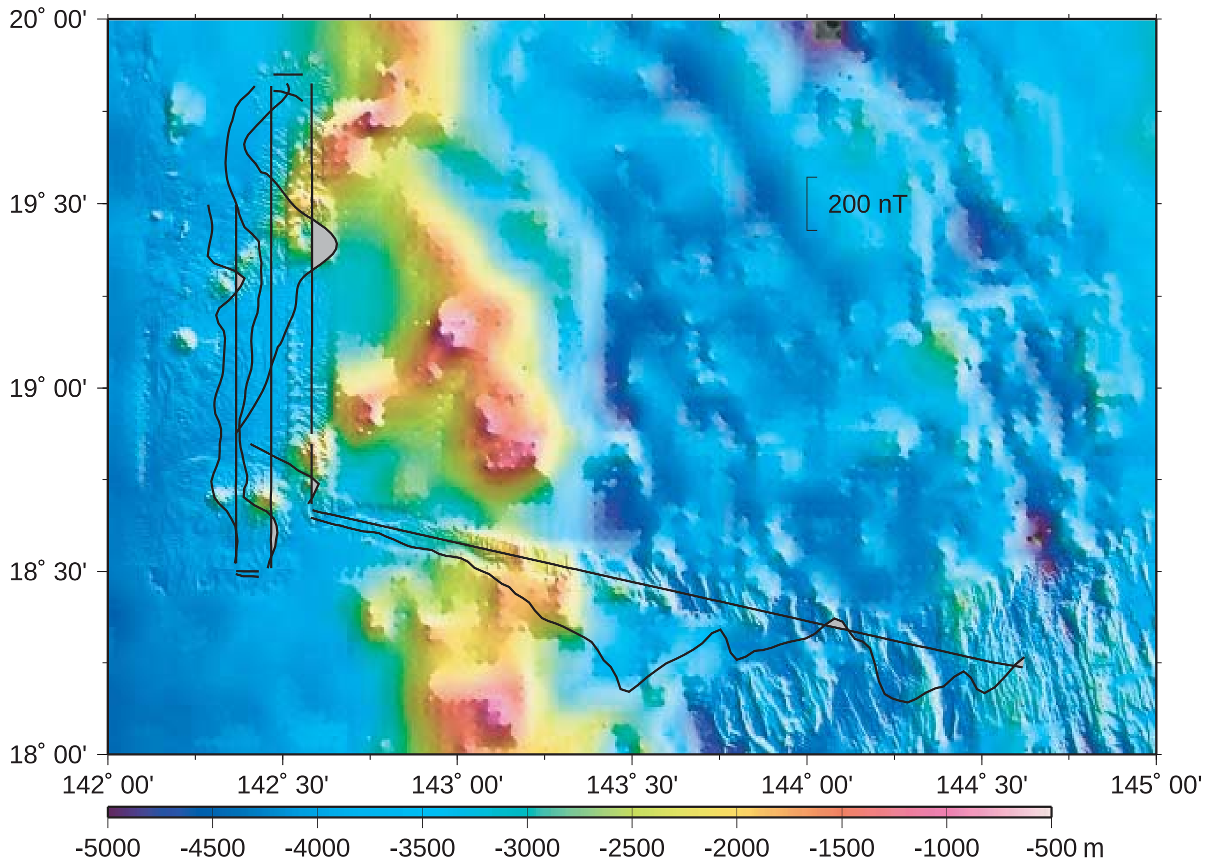


Fig. 7 Total intensity of geomagnetic anomaly along the ship tracks. Positive anomalies are shaded. Color image show bathymetry map obtained during the KR02-14 cruise combined with that of Smith and Sandwell (1994).

tion in this area. Moreover, gravity data would enable us to understand the following points with relation to the spreading process of the back-arc basin: 1) variation of crustal thickness that reflects the amount of the melt supply at the spreading axes, 2) contribution from plate cooling, and 3) contribution from subcrustal density variation that probably reflects the pattern of mantle upwelling, temperature variations, and/or distribution of partial melt.

4. MMR experiment

We have developed a system using the magnetometric resistivity (MMR) method (Fig.8), which is useful to estimate electrical conductivity structure of a shallow part of the oceanic crust. The MMR method is a magnetic technique and involves two components; a source and receivers. The source is an electric current between two electrodes; one is just under the sea surface (surface electrode) and the other is near the

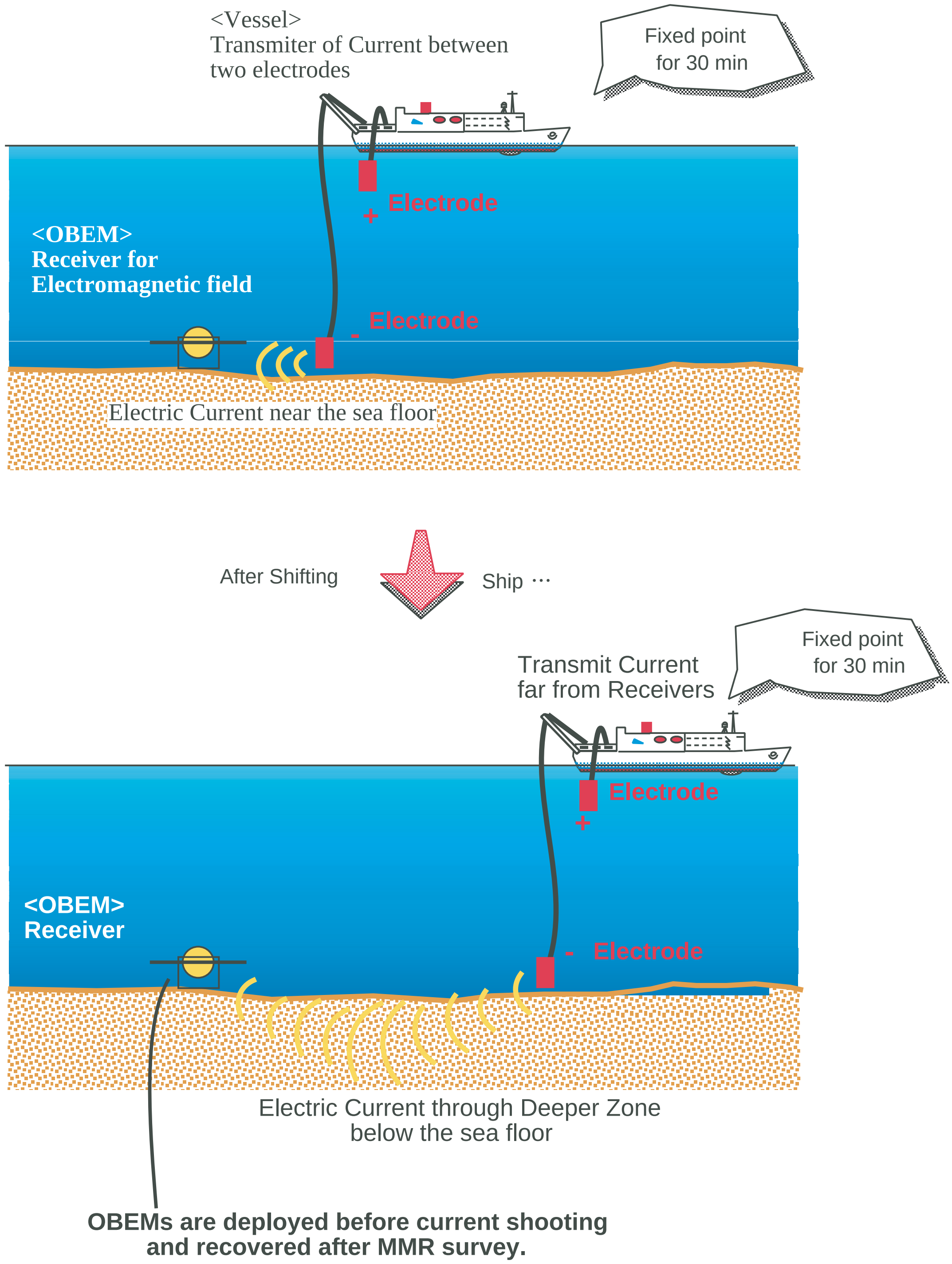


Fig. 8 Schematic figure of MMR experiment.

seafloor (bottom electrode). The receivers are ocean bottom electro-magnetometers (OBEMs), which measure three components of magnetic field variation and three components of electric field variation. The procedure of our MMR experiment is as follows:

1) Deploy OBEMs as the MMR receivers.
2) Estimate the OBEMs' locations using acoustic ranging and the GPS.
3) Deploy a winch cable with a bottom electrode and an acoustic unit at the end until the bottom electrode is close to the sea floor.
4) Deploy a surface electrode near the sea surface (20m in depth).
5) Move the vessel to a source site, with avoiding a collision of the bottom electrode with the sea floor.
6) Adjust the winch cable length to keep the bottom electrode at 20 m height above the sea floor.
7) Supply an electric current between the surface and bottom electrodes for about 30 minutes with acoustic positioning for the bottom electrode.
8) Repeat from 5) to 7).
9) Recover the acoustic unit and both electrodes.
10) Recover the OBEMs.

We conducted our MMR experiment around a hydrothermal vent site, the Alice Springs Field (18°12.9'N, 144°42.5'E, 3600 m depth) in the central Mariana Back-Arc Basin, where the water temperature of 267°C from the hydrothermal vent was measured (Fujikura et al., 1997). A hydrothermal site is a suitable target for a MMR experiment to understand overall features of the hydrothermal system, because the electrical conductivity of the crust depends primarily on seawater within the crust (amount, spatial distribution, temperature, and salinity).

We deployed 6 OBEMs as the MMR receivers arranged on the two lines perpendicular to the ridge axis direction (Fig.9). The OBEMs were launched from the deck, and then sank to seafloor by self-weight. They drifted away from the position

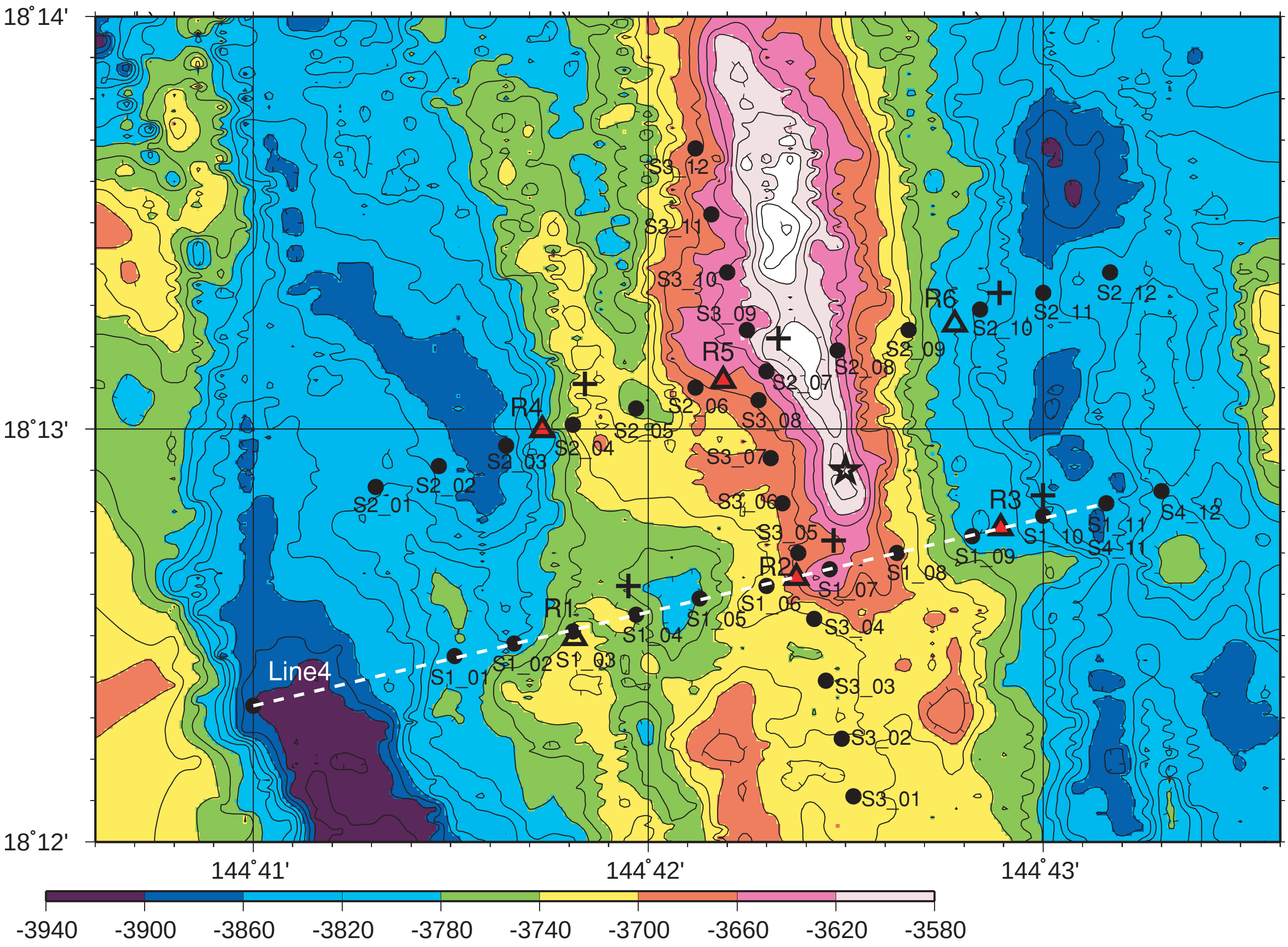


Fig. 9 Locations of OBEMs and source sites of the electric current for our MMR experiment with color image of bathymetry map. Crosses, locations of the OBEM deployments; triangles, positions of the OBEMs estimated by acoustic positioning (Table 6); a star, the Alice Springs Field hydrothermal vent. Two triangles with blank indicate that we failed to obtain the data. Solid circles with labels show the source sites of the electric current supply (Table 7). A white dashed line denotes the Line 4.

we originally planned on the way to seafloor due to oceanic currents. The positions of the OBEMs on the ocean bottom are estimated by acoustic ranging (Table 6). The OBEMs that we used for the MMR experiment are all Kobe type OBEMs (Fig.10). All the OBEMs measure three components of magnetic field variation, two components of instrument tilt and temperature with the sampling interval of 1 second. Only two OBEMs used for R2 and R5 sites also measure three components of electric field variation, because not enough electrodes were available for this experiment. They have pipes for attaching five Filloux-type silver-silver chloride electrodes (Filloux, 1987). Fluxgate type magnetometers, voltmeters, and tilt meters are packed in a pressure-resistant glass sphere for each OBEM. The OBEM has another glass sphere that contains both the battery and transponder. The clock of the OBEM was set to the GPS clock before the deployment, and was compared again after the recovery. The comparison indicates the time accuracy of the OBEMs during the experiment was kept within 1 second.

Table 6 Positions of OBEMs estimated by acoustic positioning in MMR experiment. RMS denotes root mean squares of the positions in meter.

Site No.	Latitude (N)	Longitude (E)	Depth(m)	RMS.
R1	18°12.495'	144°41.814'	3763	4.0
R2	18°12.640'	144°42.375'	3713	6.5
R3	18°12.760'	144°42.893'	3854	6.8
R4	18°12.998'	144°41.732'	3828	5.0
R5	18°13.118'	144°42.190'	3722	8.2
R6	18°13.254'	144°42.776'	3881	4.6

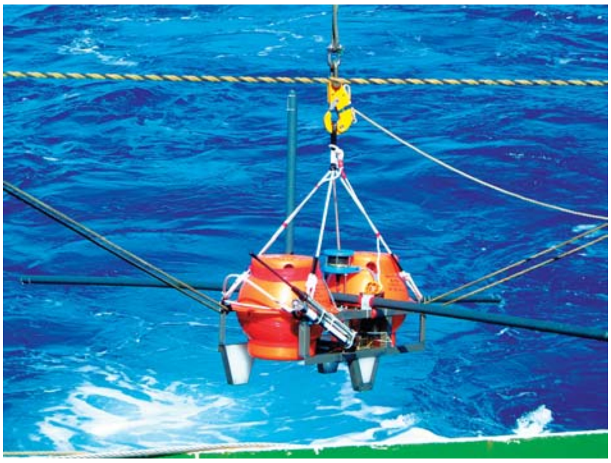


Fig.10 The outside appearance of Kobe-type OBEM with pipes for the electrodes used for the MMR experiment.

The MMR source of the electric current was supplied at 36 source sites and along the Line 4 around the Alice Springs Field (Fig.9). We followed our MMR experiment procedure mentioned above for the source sites. In case of the Line 4, the electric current was continuously supplied for about 4 hours, while the "Kairei" shifted along the Line 4 with the ship speed of 0.5 knot. This data will be used to establish a new method modified from the original MMR method for better performance. The waveform of the electric current is rectangular with its amplitude of 19 amperes and its period of 16 seconds (Fig.11), which was supplied by an onboard unit (Fig.12) between the surface and the bottom electrodes (Fig.13).

Two kinds of acoustic positioning methods were used to estimate the position of the bottom electrode. The first way is to use the "Kairei" SSBL system (Fig.14) with a transponder fixed to the winch wire at 1m above the bottom electrode. The scatter of positions by this method suggests the accuracy of 100 m. The other way is based on the acoustic unit (so called "fish", Fig.15) fixed to the winch wire at 100 m above the bottom electrode. The fish measured depth, altitude, and slant ranges to the ship and also to each OBEM with accuracy of nearly 1 m. An onboard acoustic unit (Fig.14) communicates with the fish acoustically and controls it.

The data that we obtained from the OBEMs are summarized in Table 8. We got complete data from three OBEMs at the sites R2, R4 and R5. The OBEM at the site R3 recorded data for about 3.4 days resulting in lack of the Line 4 data. The OBEM at the site R1 recorded the data only for 1 minute. We could not recover the OBEM at the site R6, because it would not leave from the bottom even if we could communicate with it. An example of magnetic and electric variation data due to the electric source current is shown in Fig.11. The magnetic and electric variation with period of 16 seconds, which corresponds to the electric source current, is visible in this case because the separation between source and receiver is close enough. The variation became invisible when the separation became larger, but we could derive the small signal due to the electric source current by the stacking method. The signal will be used to estimate electrical conductivity structure of a shallow part of the oceanic crust around the Alice Springs Field hydrothermal site.

5. Concluding Remarks

We obtained three different types of data sets during the KR02-14 Kairei cruise in the Mariana area; 7-13 month length of OBEM data from three sites, surface geophysical (bathymetry, gravity field, and magnetic field) data, and MMR experiment data. We will analyze three OBEM data sets combined with existent Mariana EM data (totally 8 sites) to image the overall mantle conductivity structure across the Mariana subduction system from the subducting Pacific plate, fore-arc,

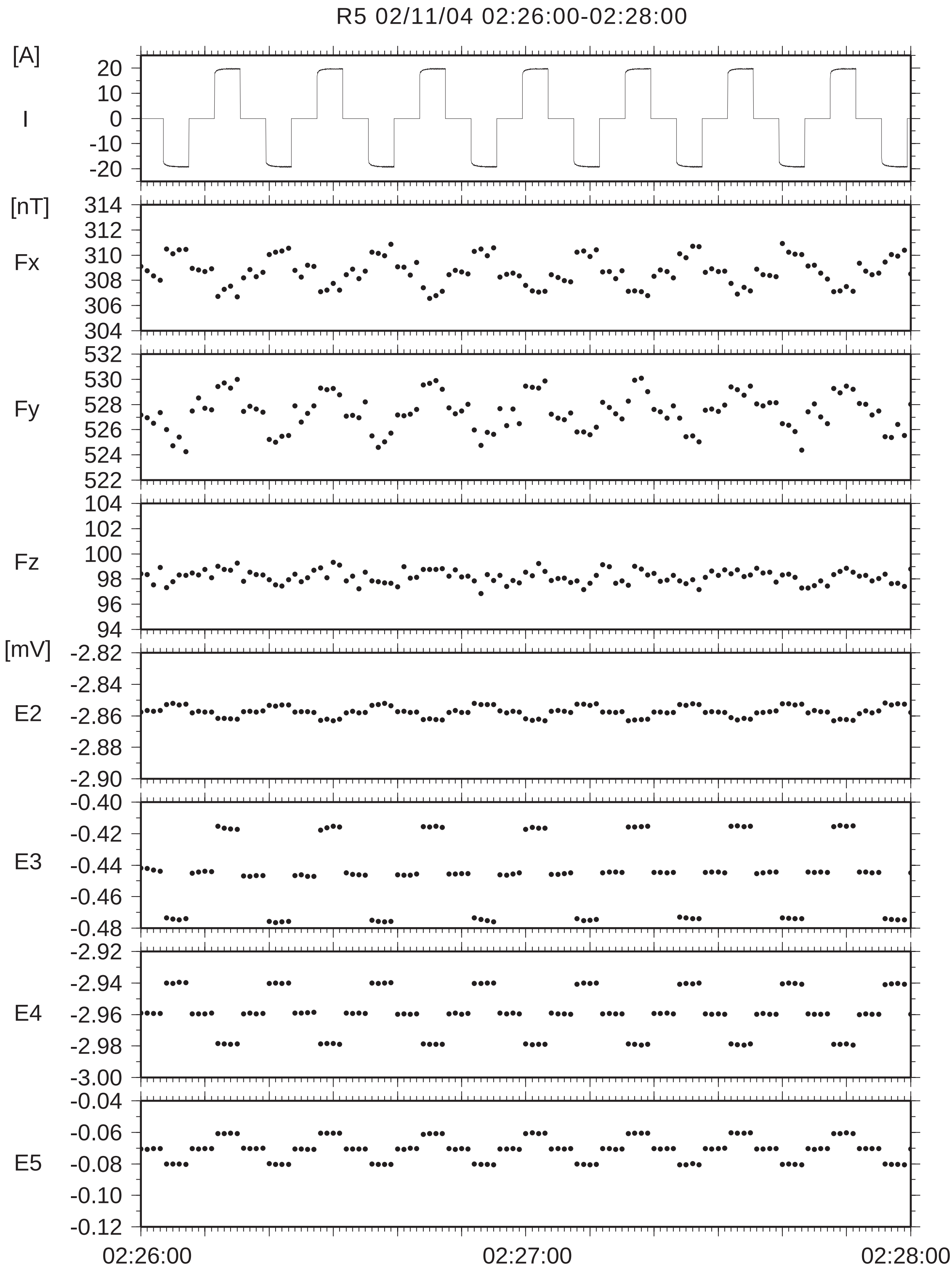


Fig. 11 An example of data obtained by the MMR experiment. "I" indicates time series of the electric current data supplied by the onboard unit. Fx and Fy show magnetic filed variations of two orthogonal horizontal components and Fz is that of downward component recorded by OBEM. E2, E3, E4 and E5 are the electric field variations obtained by four electrodes of OBEM with respect to the common electrode (E1).

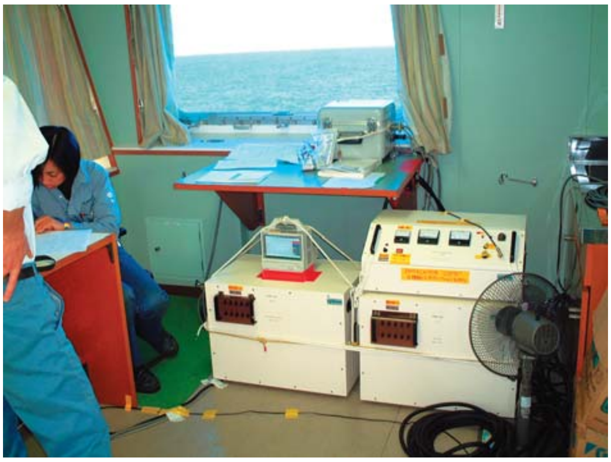


Fig.12 On board transmitter and power units for the electric current used for the MMR experiment.

Fig.13 Electrode to supply the electric current used for the MMR experiment.

Fig.14 Acoustic unit on board (right) and Kairei's SSBL system (left) for positioning the bottom electrode.

Fig.15 Acoustic unit (so called, "fish") fixed at 100 m above the bottom electrode for positioning the bottom electrode.

Table 7 Locations of the source sites where the electric current was supplied for the MMR experiment. The electric source current was continuously supplied from s4_00 to s4_11 in the Line 4 with the ship speed of 0.5 knot.

Line 1

Site No.	Latitude (N)	Longitude (E)
s1_01	18˚12.45'	144˚41.51'
s1_02	18˚12.48'	144˚41.66'
s1_03	18˚12.51'	144˚41.81'
s1_04	18˚12.55'	144˚41.97'
s1_05	18˚12.59'	144˚42.13'
s1_06	18˚12.62'	144˚42.30'
s1_07	18˚12.66'	144˚42.46'
s1_08	18˚12.70'	144˚42.63'
s1_09	18˚12.74'	144˚42.82'
s1_10	18˚12.79'	144˚43.00'

Line 2

Site No.	Latitude (N)	Longitude (E)
s2_01	18˚12.86'	144˚41.31'
s2_02	18˚12.91'	144˚41.47'
s2_03	18˚12.96'	144˚41.64'
s2_04	18˚13.01'	144˚41.81'
s2_05	18˚13.05'	144˚41.97'
s2_06	18˚13.10'	144˚42.12'
s2_07	18˚13.14'	144˚42.30'
s2_08	18˚13.19'	144˚42.48'
s2_09	18˚13.24'	144˚42.66'
s2_10	18˚13.29'	144˚42.84'
s2_11	18˚13.33'	144˚43.00'
s2_12	18˚13.38'	144˚43.17'

Line 3

Site No.	Latitude (N)	Longitude (E)
s3_01	18˚12.11'	144˚42.52'
s3_02	18˚12.25'	144˚42.49'
s3_03	18˚12.39'	144˚42.45'
s3_04	18˚12.54'	144˚42.42'
s3_05	18˚12.70'	144˚42.38'
s3_06	18˚12.82'	144˚42.34'
s3_07	18˚12.93'	144˚42.31'
s3_08	18˚13.07'	144˚42.28'
s3_09	18˚13.24'	144˚42.25'
s3_10	18˚13.38'	144˚42.20'
s3_11	18˚13.52'	144˚42.16'
s3_12	18˚13.68'	144˚42.12'

Line 4

Site No.	Latitude (N)	Longitude (E)
s4_00	18˚12.33'	14˚41.00'
↓		
↓		
↓		
↓		
↓		
↓		
↓		
↓		
↓		
s4_11	18˚12.82'	144˚43.16'
s4_12	18˚12.85'	144˚43.30'

Table 8 Data acquisition period of each OBEM for the MMR experiment.

Site No.	Start Time (UTC)		End Time (UTC)	
R1	2/Nov./2002	11:01:40	2/Nov./2002	11:02:29
R2	2/Nov./2002	11:01:33	6/Nov./2002	22:29:55
R3	2/Nov./2002	11:01:28	5/Nov./2002	20:16:47
R4	2/Nov./2002	11:01:33	7/Nov./2002	3:30:13
R5	2/Nov./2002	11:01:17	7/Nov./2002	3:15:56

island arc, the Mariana Trough backarc basin to the Parece Vela Basin. The resolution would be comparable to a global seismic tomography because of the sparse site coverage. But, the results would be good for the first step and the pilot study for the international (Japan, US, France, and Australia) cooperative magnetotelluric survey that we are planning in 2005-2006 to get fine structure like regional scale seismic tomography. The surface geophysical data filled a gap in high-resolution gravity and bathymetric data in the Mariana Trough and would characterize the back-arc spreading evolution of the Mariana Trough and also back-arc seamount chains on the west of the West Mariana Ridge. We completed the MMR experiment successfully, and confirmed validity of our newly developed MMR system. The analysis of the MMR data would lead us to understand overall features of the Alice

Springs Field hydrothermal system. Furthermore, the method of towing the electric current source would have a high potential for better performance to estimate electrical conductivity structure of a shallow part of the oceanic crust, especially when the position of the bottom electrode is well determined all the time.

Acknowledgements.

We gratefully recognize the efforts of the officers and crew (Hitoshi Tanaka, captain) of the R/V Kairei during the cruise. N. Togashi, M. Miyamoto, and A. Sou (Marine Work Japan) gave us technical advice and help to use our MMR system on board R/V Kairei. We thank all the support staffs in JAMSTEC, especially K. Kashiwase, H. Nakai, S. Suzuki, K. Hashimoto and K. Shibata, for their wonderful work to lead the cruise successful. Rob Evans, John Bailey, and Alan D. Chave help us to make Filloux-type electrodes for the OBEMs. K. Mitsuzawa allows us to use his transponder. This study was supported by Special Coordination Fund 'Archaean Park Project', Ministry of Education, Culture, Sports, Science & Technology (MEXT), Japan, by Grant-in-Aid for Scientific Research (B) (2) (No. 12440116) and (A) (2) (No. 14253003), Japan Society for the Promotion of Science (JSPS), and by ERI-IFREE cooperative research project, 'Investigation of the upwelling and downwelling of the mantle flow by long-term mobile geophysical array observations'.

References

1) R. N. Edwards, L. K. Law, J. M. DeLaurier, "On Measuring the Electrical Conductivity of the oceanic crust by a Modified Magnetometric Resistivity Method", Journal of Geophysical Research, 86 (B12), 11609-11615, (1981).

2) J. H. Filloux, "Instrumentation and Experimental Methods for Oceanic Studies" in Geomagnetism Vol. 1, J. A. Jacobs, Eds.(Academic Press Inc., Florida, 1987), Chap. 3, pp.143-248.

3) K. Fujikura, T. Yamazaki, K. Hasegawa, U. Tsunogai, R. J. Stern, H. Ueno, H. Yamamoto, Y. Maki, S. Tsuchida, T. Kodera, H. Yamamoto, C.-H. Sun, T. Okutani, "Biology and Earth Science Studies by Submersible Shinkai 6500 System of deep-sea Hydrothermalism and Lithosphere in the Mariana Back-ark Basin", JAMSTEC 13, 1-21, (1997).

4) T. Goto, N. Seama, H. Shiobara, K. Baba, M. Ichiki, H. Iwamoto, T. Matsuno, K. Mochizuki, Y. Nogi, S. Oki, K. Schwalenberg, N. Tada, K. Suyehiro, H. Mikada, T. Kanazawa, Y. Fukao, H. Utada, "How Geophysical Experiments in the Mariana Region: Report of the YK01-11 cruise", InterRidge News, 11 (1), 22-24, (2002a).

5) T. Goto, N. Seama, M. Ichiki, K. Baba, K. Schwalenberg, N. Tada, H. Iwamoto, H. Utada, K. Suyehiro, H. Toh, "The Mantle Conductivity Structure below the Marianas Island Arc", Eos Trans. AGU, 83 (47), Fall Meet. Suppl., Abstract, F1321, (2002b).

6) IAGA Division I Working Group 1, "IGRF2000", (2001).

7) N. Isezaki, "A new shipboard three-component magnetometer", Geophysics, 51 (10), 1992-1998, (1986).

8) N. Seama, K. Baba, H. Utada, M. Ichiki, H. Toh, M. Kikuchi, H. Miyano, N. Tada, K. Nakase, K. Tashiro, "Preliminary results of ocean bottom magnetotelluric survey across the Philippine Sea", Eos Trans. AGU, 81 (48), Fall Meet. Suppl., Abstract, F348, (2000)

9) W. H. F. Smith and D. T. Sandwell, "Bathymetric prediction from dense satellite altimetry and sparse shipboard bathymetry", Journal of Geophysical Research, 99, 21803-21824, (1994).

(Manuscript received 15 January 2003)

Appendix

Shipboard Log of KR02-14 Kairei cruise in the Mariana area

Day & Times on Ship's Time	Note	Weather / Wind & Sea Condition at Noon
LCT(UT-10h)		
Sun.27/10/'02	R/V Kairei is under anchorage to Gauam	bc/3(ESE)
	Scientists on board R/V Kairei	
Mon.28/10/'02		
1305	Departure from APRA-Harber Guam	bc/2(N)
	Transit	
1556	Start of MNBEMS mapping survey	
Tue.29/10/'02		bc/4(E), 4
0657	XBT (17˚12.180'N, 141˚24.401'E)	
0726	OBEM Site 1, Send Releace Command	
0906	OBEM Site 1, On Deck	
1018-1258	MNBEMS mapping survey	
1310-1705	Test of MMR	
1717	Start of MNBEMS mapping survey	
Wed.30/10/'02		bc/5(E), 4
0558	Stop of MNBEMS mapping survey	
0605	OBEM Site 7, Send Releace Command	
	Set up OBEM for MMR	
1452	OBEM Site 10, Send Releace Command	
1820	Start of MNBEMS mapping survey	
Thu.31/10/'02		bc/5(ENE), 4
0548	Stop of MNBEMS mapping survey	
0602	OBEM Site 11, Send Releace Command	
0902	OBEM Site 11, On Deck	
0911	Start of MNBEMS mapping survey	
Fri.1/11/'02		bc/5(ESE), 4
0550	Stop of MNBEMS mapping survey	
0601	OBEM Site 3, Send Releace Command	
0822	OBEM Site 3, On Deck	
1004	OBEM Site 4, Send Releace Command	
1115	Shift to Site 5	
1141	OBEM Site 5, Send Releace Command	
1319	Shift to Site 6	
1338	OBEM Site 6, Send Releace Command	
1516	Shift to Site 5	
1554	Try recovery OBEM Sites 5 and 6	
Sat.2/11/'02		bc/4(SE), 3
0725	Stop Recovery of OBEM	
0842-1314	Test of Release Devices (MMR_OBEM)	
1344	Launched of MMR_OBEM Site R6	
1359	Launched of MMR_OBEM Site R2	
1419	Launched of MMR_OBEM Site R5	
1432	Launched of MMR_OBEM Site R3	
1449	Launched of MMR_OBEM Site R1	
1458	Launched of MMR_OBEM Site R4	
1617-1812	Acoustic positioning of OBEMs	
1814-1833	Eight figure turn	
Sun.3/11/'02		bc/3(E), 2
0509	Stop of MNBEMS mapping survey	
0552	Start of MMR survey (Line1)	
1942	End of MMR survey (Line1)	
1956	Start of MNBEMS mapping survey	
Mon.4/11/'02		bc/4(E), 3
0530	Stop of MNBEMS mapping survey	
0542	Start of MMR survey (Line2)	
1943	End of MMR survey (Line2)	
1953	Start of MNBEMS mapping survey	

Day & Times on Ship's Time	Note	Weather / Wind & Sea Condition at Noon
Tue.5/11/'02		r/5(NNE), 3
0509	Stop of MNBEMS mapping survey	
0538	Start of MMR survey (Line3)	
1929	End of MMR survey (Line3)	
1940	Start of MNBEMS mapping survey	
Wed.6/11/'02		bc/5(E), 4
0710	Stop of MNBEMS mapping survey	
0740	Start of MMR survey (Line 4)	
1602	End of MMR survey (Line 4)	
1749	OBEM Site 4, Try Recovery	
Thu.7/11/'02		bc/3(E), 2
0458	OBEM Site 4, End of Recovery	
0552	MMR_OBEM Site R2, Send Releace Command	
0631	MMR_OBEM Site R5, Send Releace Command	
0710	MMR_OBEM Site R3, Send Releace Command	
0800	MMR_OBEM Site R2, On Deck	
0810	MMR_OBEM Site R6, Send Releace Command	
0846	MMR_OBEM Site R5, On Deck	
0902	MMR_OBEM Site R1, Send Releace Command	
0909	MMR_OBEM Site R3, On Deck	
0940	MMR_OBEM Site R4, Send Releace Command	
1033	MMR_OBEM site R1, On Deck	
1115	MMR_OBEM Site R4, On Deck	
1400	End of OBEMs Recovery	
1406	Start of Proton magnetometer survey	
1410	Start of MNBEMS mapping survey	
1447-1503	Eight figure turn	
Fri.8/11/'02		bc/4(ESE), 3
1505	End of Proton magnetometer survey	
Sat.9/11/'02		bc/5(NW), 4
0000	LCT=JST (UT-9h)	
0728	Out of Survey Area	
	Transit	
1400-1408	Eight figure turn	
Sun.10/11/'02	Transit	bc/5(NW), 4
Sun.10/11/'02	Transit	
	Arrival at Yamashita-Harber Yokohama	

Wind; 0: 0-0.2 m/sec, 1: 0.3-1.5 m/sec, 2: 1.6-3.3 m/sec, 3: 3.4-5.4 m/sec, 4: 5.5-7.9 m/sec,
5: 8.0-10.7 m/sec, 6: 10.8-13.8 m/sec, 7: 13.9-17.1 m/sec, 8: 17.2-7.9m/sec, 9: 20.8-24.4 m/sec,
10: 24.5-28.4 m/sec, 11: 28.5-32.6 m/sec, 12: more than 32.6 m/sec
Weather; b: Blue Sky (Cloud 0-2), bc: Fine but Cloudy (Cloud 3-7), c: Cloudy (Cloud 8-10),
d: Drizzling rain, r: Rain, q: Squalls, o: Overcast (Cloud 10)
Sea Condition; 0: Calm(Glassy), 1: Calm(Rippled), 2: Smooth(Wavelets), 3: Slight, 4: Moderate,
5: Rough, 6: Very rough, 7: High, 8: Very high, 9: Phenomenal
MNBEMS; Multi-narrow beam (SEABEAM2112)