

Long-term ocean bottom earthquake observation in the East Pacific Rise

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Detailed and continuous observation of seismicity of mid ocean ridge is very important to investigate seafloor spreading episode. But, no practical ocean bottom seismometers (OBSs) designed for long-term observatory has been available until recently. We conducted an ocean bottom earthquake observation, in the Ridge Flux '97 expedition leg 1, using new OBS which we have been developing for long-term seismological observation. Two sets of OBSs were deployed by the "Shinkai6500" at the hydrothermal area in the East Pacific Rise. Other long-term monitoring instruments, ocean bottom pressure/range meters and acoustic ranging system, were also deployed in same area where OBSs are. These instruments will continue to work until September 1998, the scheduled time of recovery. We think that comparing the data from the OBSs with the ones from other monitoring instruments will give important keys to seafloor spreading at mid ocean ridge.

Keywords : Mid ocean ridge, East Pacific Rise, Hydrothermal area, Long-term ocean bottom seismometer, seismicity

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1. Introduction

Long-term detailed monitoring of seismicity in and around mid ocean ridge is essential in order to reveal the processes of oceanic crustal generation in the region. However, it is difficult now for us to observe seismicity of ridge areas, i.e. seafloor far from the lands, by land-based seismological networks.

Fox et al.(1995) has developed a method to detect earthquakes occurred on mid oceanic ridge using military hydrophone array and obtained some results. But, their objective was just to detect earthquakes than to observe earthquakes in detail. Therefore, Fox's method will not give us enough information on each earthquake to discuss though the system is useful. We think that constructing ocean bottom seismological observatories is necessary to observe earthquake activities on mid ocean ridge in detail.

We have been developing high-performance ocean bottom seismometer (OBS) for long-term observation. In July 1997, two OBSs were deployed by manned submersible "Shinkai6500" at RM28 site ($18^{\circ}26'S, 113^{\circ}23'W$), one of the most active hydrothermal area on the East Pacific Rise (Fig. 1). This was the first step of a trial of long-term earthquake observation on mid oceanic ridge. The two OBSs will continue to work until September 1998, the projected time of recovery. We report briefly in this paper on the outline of the observation and OBS used in the observation.

2. Long-term Ocean bottom seismometer

Photo 1 shows appearance of long-term OBS that we have been developing. We selected Russian made titanium-alloy sphere with 50cm diameter for a housing of the OBS, in terms of avoiding corrosion of pressure housing. Titanium-alloy sphere was tested to be able to use at 6,000 m depth

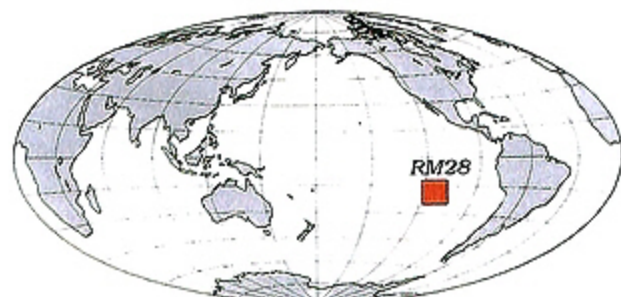


Fig. 1 Location of the RM28 hydrothermal site on the East Pacific Rise.

before shipping.

LE-3Dlite (Lennartz Co. Ltd.) was used for geophone of the OBS. Three component geophones are mounted on gimbal mechanism system. Photo 2 shows gimbal unit for the LE-3Dlite. The gimbal unit is equipped with two tiltmeters and compass. The two tiltmeters, which have 0.1 degree accuracy, are used to control geophone leveling. This gimbal system stabilize the geophones at any angle within ± 20 degrees.

Each outputs of three geophones and one hydrophone are amplified by ultra-low-noise and low-power amplifiers, and then fed to each 22 bit A/D converter continuously. Signals are sampled at 128/64 Hz. Data are stored on the memory temporarily. When 80% of the memory are filled with the data, the data on the memory are recorded to the hard disk drives. The OBS have SCSI connection hard disk drives (maximum 8 drives). The continuous recording period can be adjusted to any period within one year by increase or decrease of drives.

Power to all electrical circuits (CPU, geophone, gimbal system, HDD) are supplied by lithium battery cells (BCX72 3B76, Electrochem Lithium Batteries). Though the number of battery cells we need depends on how long we continue to observe, approximately 34 cells for 3 month long observation.

The OBS is equipped with acoustic release mechanism. When an acoustic release command around 10kHz is sent from the on-board unit to the acoustic transponder with which the OBS equipped, the acoustic transponder charges electric current to barast weight releaser unit and then barast weight is released by electrical corrosion. We have been developing the way to communicate by acoustic signal in the sea. We can control the OBS from the on-board control unit by this acoustic communication method, for example, on/off of geophones, leveling of geophones, setting/unsetting of recording time and so on. We can also get the data stored on the HDD from the on-board control unit. The acoustic data transfer system at 2400 bps were accomplished. We are now aiming to develop the system that can transmit the data at higher rate.

3. Deployment and observation

In the Ridge Flux '97 expedition Leg 1 (Urabe et al., 1998), we designed an OBS array which consists of two

long-term OBSs and four temporal OBSs. This OBS array covers the hydrothermal area, in the RM28 site, which was found in the MODE '94 cruise to the Southern East Pacific Rise, in order to detect earthquakes occurring there. Deployments of two sets of long-term OBSs were carried out by submersible "Shinkai6500" in its Dive #377 (July 20, 1997).

3-1. Deployment of long-term ocean bottom seismometers

We had to deploy two long-term OBSs (#500 and #550) during the "Shinkai6500" Dive #377. The "Shinkai6500" cannot take the two to the sea floor at once, due to the limit of payloads. We launched the shuttle elevator to transport one (#550) of the two long-term OBSs to the sea bottom beforehand (Photo 3). The other one (#500), second weights

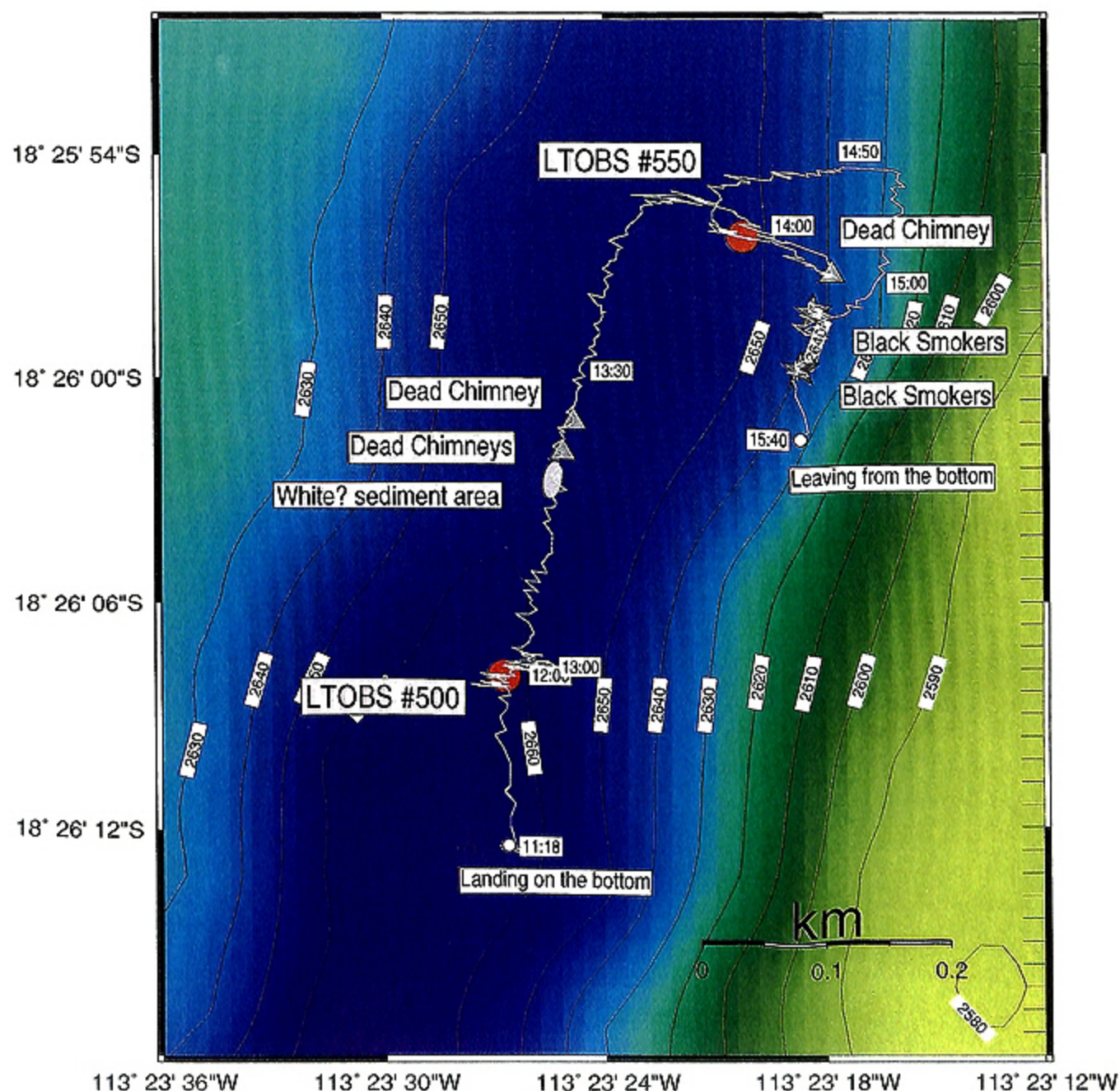


Fig. 2 Positions of the two long-term OBSs with "Shinkai6500" dive track line at the RM28 site. Red circles indicate positions of the long-term OBSs. "Shinkai6500" #377 dive track line (white thin line) was drawn with remarkable objects we observed. Isobaths are drawn in 10m interval. Long-term OBS: #500(18°26.13'S, 113°23.44'W), #550(18°25.94'S, 113°23.34'W).

and mini transponder (#12), were put on the basket of the "Shinkai6500" and then dove with the "Shinkai6500" (Photo 4). We started the Dive #377 after locating the position of the shuttle elevator by acoustic triangulation. The shuttle elevator landed at ($18^{\circ}26.13'S$, $113^{\circ}23.43'W$), middle of the axial graben of the RM28 site.

The "Shinkai6500" landed near to the shuttle elevator. We found a good space to deploy the OBS around there (Fig. 2). The #500 OBS was located on thin sediment covered pillow lava ($18^{\circ}26.13'S$, $113^{\circ}23.45'W$), and we put the second weights on the anchor frame of the #500 OBS. The weight of the OBS's anchor system was originally designed as nearly 40kg. However we reduced the weight of the OBS's anchor from 40kg to 25kg so that the total weight of the OBS can be less than the maximum permissible payload of the "Shinkai6500". This is why the Long-term OBS needed the second weights. After that, we set the mini transponder (#12) beside the #500 OBS in order that we could find the OBS easily in the recovery cruise. Photo 5–8 show the procedures how the #500 OBS was deployed.

After finishing deployment of the #500 OBS, we approached to the shuttle elevator. The first thing we did there was to move the #550 OBS to the Shinkai6500's basket which #500 OBS had been put in. We processed three niskin water samplers attached to the shuttle elevator next, and then waited for the shuttle elevator to be released from the bottom for a while. It had been released without any troubles and was retrieved about 1 hour later.

The #550 OBS was planned to be placed near the active hydrothermal vents such as the Kasuga shrine and the Dragon teeth. The "Shinkai6500" headed northward within the axial graben to approach to these hydrothermal vents. We had seen the floor of the graben covered by pillow lava with thin sedimentary layer all the way to the vent field. Several fissures cut into the pillow lava floor along the graben. The widest one we met was as wide as the "Shinkai6500" could dive into it. There were many signals of hydrothermal activities not so long ago such as dead chimney field and white sediment field.

We were trying to deploy the #550 OBS on the foot of the hydrothermal vent on the eastern escarpment, and the "Shinkai6500" ascended the steep escarpment with heading to the east. However, no appropriate place for the OBS was found on the eastern escarpment. We had to

come back to the axial graben floor to set the #550 OBS. The deployment of the #550 OBS was proceeded in the same way as for the #500 OBS. The #550 OBS was put on a thinly sediment covered pillow lava ($18^{\circ}25.94'S$, $113^{\circ}23.34'W$), and then we placed the second weights on the anchor frame of the OBS.

3-2. Temporal ocean bottom seismological observation

The OBS array consists of two OBSs described in the previous section can detect seismicity but can not get much information about earthquakes (ex. hypocenter, origin time). We performed temporal earthquake observation using 4 sets of pop-up type OBS to locate hypocenters with data from two new OBSs and four temporal OBSs, even though observation period (1998 July 18–1998 July 30) was not long enough to detect enough number of earthquakes. This temporal earthquake observation allowed us to get detailed information to discuss not only seismicity but also the area where earthquake occurred. Fig. 3 shows distribution of the OBSs.

Four temporal OBSs were recovered successfully. Data from those four OBSs showed that there were several microearthquakes, whose signal duration was less than 10 s, occurred in and around the RM28 area during temporal observation. Appearances of their wave forms were quite similar to the ones Kaiho et al.(1996) observed at EPR $18^{\circ}22'S$.

Hypocenter determination was applied to the data from earthquakes which were caught by four OBSs. One dimensional P-wave velocity structure model based on the result by Nishizawa et al.(1996) was assumed. This model was a simplified one and still is controversial in terms of how we estimate low velocity area expected to exit beneath rise crest. We show preliminary results of locating hypocenters in this paper (Fig. 4). Five earthquakes located near the RM28 site. This is a signature of steady crustal movement. We could not determine locations of sources for several tens earthquakes occurred outside the RM28 site. They seemed to occur on rise crest of the EPR judging from arrival time difference among the OBSs.

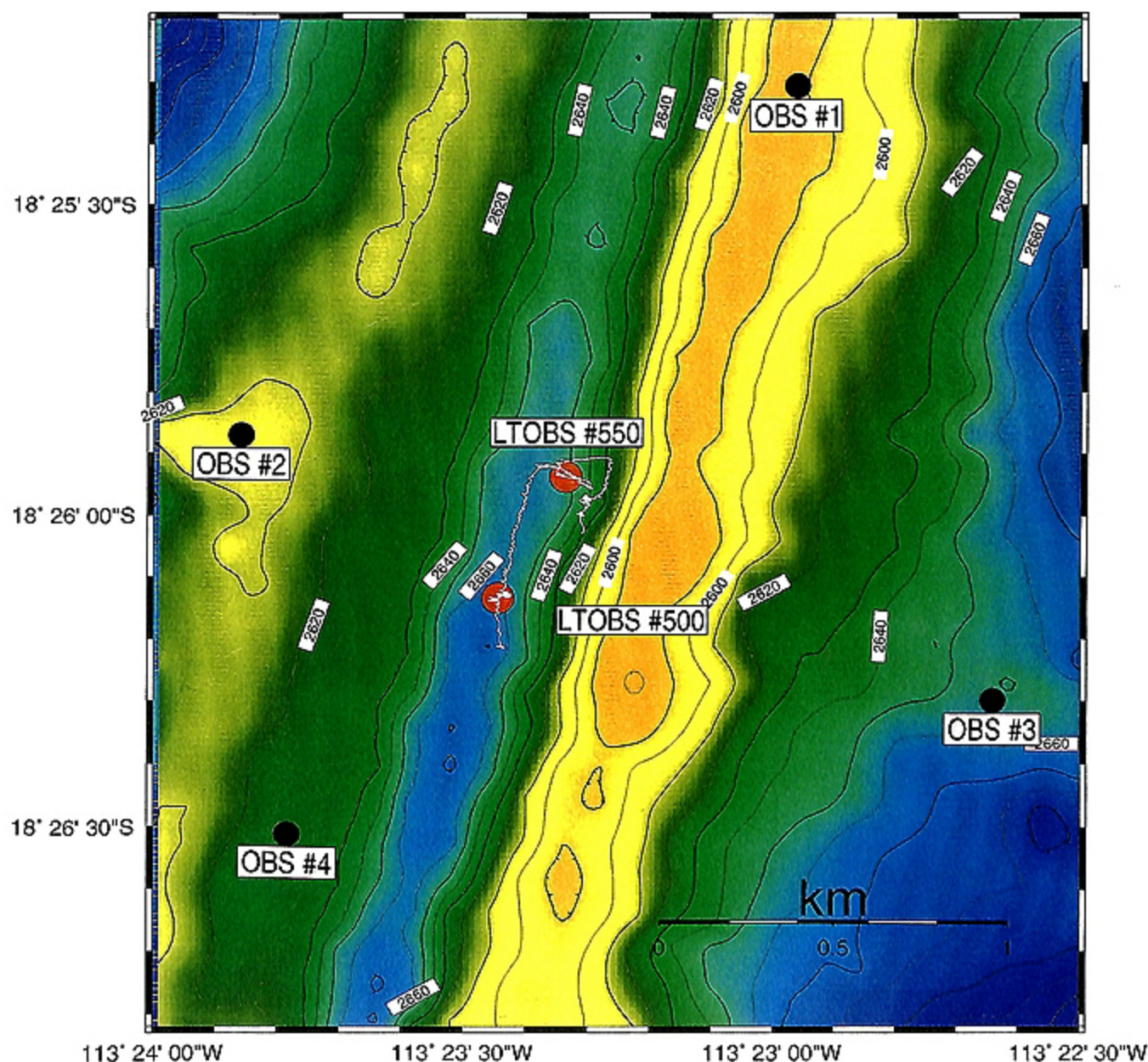


Fig. 3 Distribution of OBS array and "Shinkai6500" dive track line at the RM28 site. Red and black circles indicate positions of long-term OBSs and temporal pop-up type OBSs, respectively. White thin line shows the track line of the "Shinkai6500" dive #377. Isobaths are drawn in 20m interval. Long-term OBS : #500 (18°26.13'S, 113°23.44'W), #550 (18°25.94'S, 113°23.34'W). Temporal pop-up type OBS : #1 (18°25.31'S, 113°22.98'W), #2 (18°25.87'S, 113°23.85'W), #3 (18°26.29'S, 113°22.66'S), #4 (18°26.52'S, 113°23.76'S).

4. Future plan

Ocean bottom pressure/range meters (OBPRs) (Fujimoto et al., 1998) and sea floor acoustic ranging system (SeaFAR) (Nagaya et al., 1997) were deployed and has been working at the RM28 site in addition to the long-term OBSs. The recoveries of these instruments are scheduled in September 1998.

Temporal ocean bottom observation showed that there were seismicity in and around the RM28 site. Comparing

the data from the OBSs with ones from OBPRs and SeaFAR will give us important keys to understand how these seismicity contributes to the crustal movement of the mid ocean ridge.

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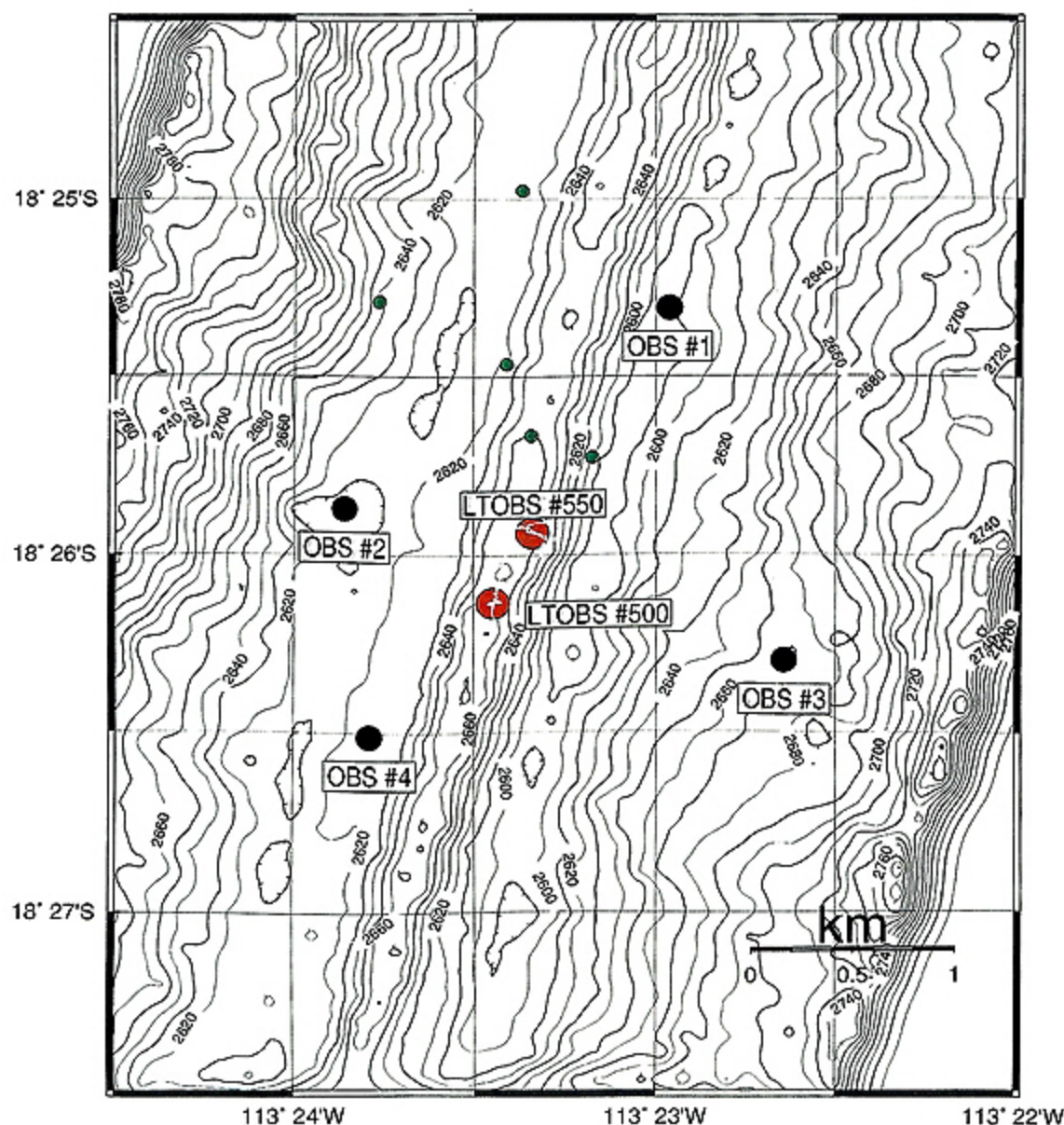


Fig. 4 Preliminary results of the temporal ocean bottom earthquake observation. Red and black circles denote long-term OBSs and temporal pop-up type OBSs, respectively. Green circles indicate epicenters of microearthquakes which we could locate.

deployment of long-term ocean bottom seismometers.

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(Manuscript received 23, July 1998)

(Notice) Photos are given on the following page.



Photo 1 Appearance of a long-term ocean bottom seismometer.

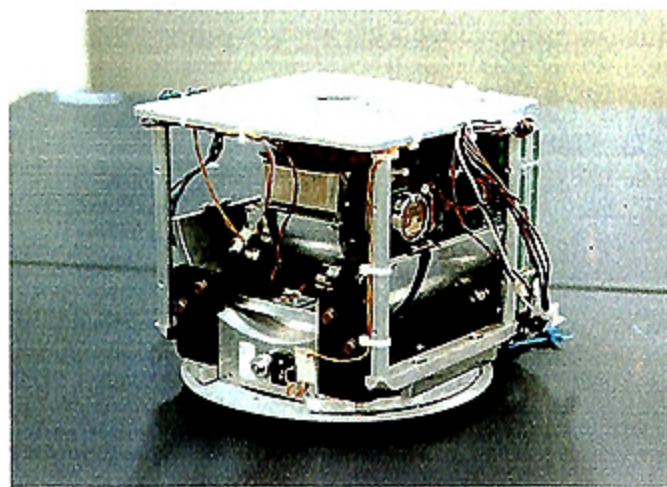


Photo 2 Gimbal unit for the LE-3Dlite.



Photo 3 The deployment of the long-term OBS (#550) using the shuttle elevator.

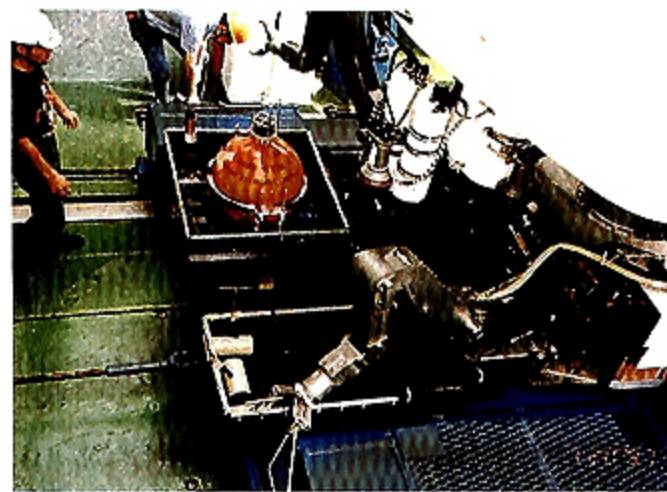


Photo 4 The long-term OBS (#500) was put on the sample basket of the "Shinkai6500".



Photo 5 The long-term OBS (#500) was situated by the "Shinkai6500" on a flat pillow lava, in consideration of directions of three component geophones.

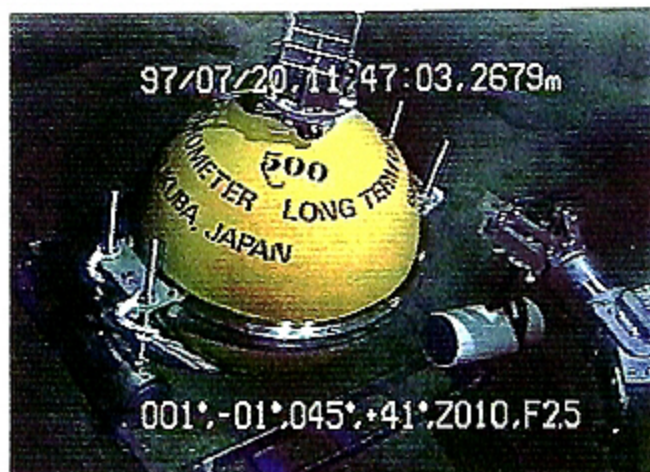


Photo 6 We put a second weight on the anchor frame of the #500 long-term OBS.



Photo 7 Another second weight was put on the other side of the anchor frame.

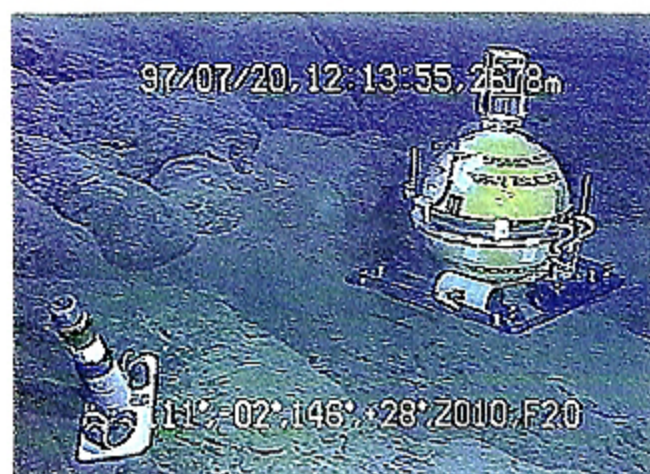


Photo 8 After finishing deployment of #500 long-term OBS, the mini transponder(#12) was set besides the OBS as a marker.