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Recent developments of ocean bottom seismic and electromagnetic instruments operated by ROV

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Imaging the Earth's interior by geophysical observations provides essential information to understand geodynamic processes, revealing peculiar features of mantle structure such as stagnation of subducted oceanic slabs, anomalies suggesting the presence of water in the transition zone, strong heterogeneities at the core-mantle boundary, changes in the seismic velocity and electrical conductivity at the lithosphere-asthenosphere boundary. However, these results are mostly obtained by analyzing data from temporal observation networks and/or permanent observatories on land. Although large-scale array studies have also become possible to exploit oceanic mantle by deployment of conventional instruments such as BBOBS (broad-band ocean bottom seismometer) and OBEM (ocean bottom electro-magnetometer), further improvement of observational technology is anticipated to overcome the relatively low data quality. Here we present recent developments of two instruments in the University of Tokyo, the BBOBS-NX (broad-band ocean bottom seismometer of next generation) and the EFOS (Earth's electric field observation system), both of which are operated by the remotely operated underwater vehicle (ROV). These new instruments provide data of much higher quality than conventional instruments.

The BBOBS is a powerful tool for a highly mobile observation, but only limited methods of seismological data analysis can be applied because of the high noise level in horizontal components data compared to those from land observatories. As the main cause of the high noise level seems bottom currents, one solution to reduce the noise level is the buried sensor in the seafloor sediment. In the BBOBS-NX, each of three component sensors is housed in a bullet-shaped pressure case, and these 3 cases are rigidly connected to keep the orthogonal directions. This sensor unit is attached at the base of a titanium sphere housing that contains the recorder, the acoustic transponder and batteries. The whole apparatus is deployed from a ship by a free-fall so that the sensor unit penetrates well into the seafloor sediment. Then the ROV operation follows: the titanium sphere housing is untied from the sensor unit and is replaced a few meters away from the sensor unit. The noise level can significantly be reduced by (1) better coupling between the sensor unit and the seafloor, and (2) decoupling between the sensor unit and the titanium sphere housing, which may be shaken by bottom currents. Test experiments conducted in the Philippine Sea confirmed its high performance. The averaged noise level of the BBOBS-NX is comparable to that of the land observatories in periods of longer than 10 seconds.

The OBEM consists of an electrometer and a magnetometer equipped in two glass spheres. The electrometer measures the electric field by using a pair of electrodes separated by 5 – 6 meters. The data analysis is usually limited in a period band between 500 and 50000 seconds, because longer periods are affected by electrode drift, and shorter periods by attenuation in the seawater. This limitation can be overcome by measuring the electric field with a large electrode separation, as noise is independent but signal is almost proportional to the electrode separation. The EFOS, by installing a long (3 – 10 km) cable with an aid of the ROV, improves the data quality both at shorter and longer periods, which are sensitive to resolve the top of upper mantle and the mantle transition zone, respectively.

Both new observation systems are already in practice, and we are planning a large-scale array study in the northwestern Pacific Ocean. New findings on the oceanic mantle structure are expected by a combined use of BBOBS-NX's and EFOS's, as well as conventional instruments (BBOBS and OBEM). This observation starts from June 2011 by using the R/V KAIREI and the ROV KAIKO 7000II (JAMSTEC).