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Electrical conductivity imaging of ”Normal Oceanic Mantle”

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Horizontal flow zone between up-welling and down-welling of the mantle convection, which occupies large portion of the ocean floor, is thought to represent ”normal” mantle that is away from tectonic activities. The research group of Normal Oceanic Mantle Project consists of researchers in Earthquake Research Institute (ERI), The University of Tokyo, and Japan Agency for Marine-Earth Science and Technology (JAMSTEC) have investigated normal oceanic mantle by means of marine geophysical observations to elucidate two fundamental questions of the Earth Science; 1) What is the physical condition for the lithosphere-asthenosphere boundary (LAB)? 2) Is the mantle transition zone (MTZ) a major water reservoir of the Earth? We set the target field to two areas, which are northwest (Area A) and southeast (Area B) of Shatsky Rise in the northwestern Pacific, and have carried out seafloor electromagnetic (EM) surveys using ocean bottom electromagnetometers (OBEMs) and electric field observation systems (EFOSs) since 2010. Total 36 OBEMs were deployed at 17 sites in Area A and 8 sites in Area B through this project.

We have reported preliminary analysis of part of the data and 1-D electrical conductivity structure models for Area A and Area B, before. We have conducted new trial for the seafloor measurement in 2012-2014, that the sampling intervals were switched between 10 and 60 seconds by timer during the observation (60 seconds were conventionally used). This procedure expects that we can obtain the MT impedance for the periods shorter than conventional approach and we can consume the battery more efficiently. We used BIRRP (Chave and Thomson, 2004) for the MT response estimation. We could not obtain good MT responses for the period shorter than several hundred second by the conventional application of BIRRP. However, BIRRP yielded better result with the option of two-stage processing. We obtained good MT responses down to about 50 seconds for 9 sites in Area A and 1 site in Area B. Also, We found that the MT responses obtained by 60 second sampling data produce downward bias in the apparent resistivity for the period shorter than about 400 seconds. Then, we used the MT responses obtained by 10 second data for the periods shorter than 400 seconds, and those obtained by 60 second data for longer periods for the following analysis.

We have averaged MT responses for Area A and Area B, respectively, and then estimated 1-D conductivity structure correcting the effect for the land-ocean distribution and seafloor topography. For Area A, the conductivity of the upper most lithosphere (crust) was constrained much better than the previous analysis. This must be because of the extension of the periods in the new MT response. For Area B, 10 second data were available for only one site so that we analyzed the MT responses obtained from 60 second data for the periods down to 480 seconds to produce the average response. As the result, new 1-D model does not show a strange curve at 50-100 km depths and high conductivity peak at about 170 km depth, which were seen in the old model. These features are thought to be fakes due to smoothness constraint of the inversion and downward biased apparent resistivity at periods shorter than 400 seconds. The thickness of highly resistive layer, which is thought to be cool lithospheric mantle, is similar with the previous results. It tends to be thinner for Area A compared with Area B and significantly thinner than Area C (off the Bonin Trench).

The crustal age for the Areas A, B, and C are about 130, 140, and 147 Ma, respectively. Based on plate cooling with age, the age difference cannot produce significant difference in the thermal structure. Consequently, the difference in the electrical conductivity of the upper mantle for the three areas cannot be explained by the simple cooling process of homogeneous mantle.

Keywords: oceanic upper mantle, northwestern Pacific, ocean bottom electromagnetometer, magnetotellurics, electrical conductivity structure