Electrical conductivity can support heterogeneity of the upper mantle composition beneath petit spot in northwestern Pacific

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The mantle composition beneath a petit spot area, where is about 600 km offshore from Japan Trench in northwestern Pacific, is discussed through electrical conductivity obtained by seafloor magnetotelluric (MT) survey.

The seafloor MT data were collected using ocean bottom electromagnetometers (OBEMs) at four sites with the spacing of 100-150 km, between May and August, 2005. The survey was conducted as a part of the petit spot multidsciplinary project. The petit spot is young volcanic activity on very old (about 130 Ma) oceanic plate. This volcanic field is associated with neither any plate boundaries nor hot spots. To elucidate the magma generation process of this new-type volcanic activity, a collaborative study of various geophysical and geochemical approaches has been carried out. The MT survey aims to constrain the physical state of the lithosphere and asthenosphere where the petit spot melt is probably generated.

The acquired electromagnetic field variation data were analyzed with robust processing after appropriate corrections of the instrumental tilt and clock. The MT responses were obtained in the period range between 480 and 122,880 seconds. Geomagnetic transfer functions were not obtained with significant coherence in the period range. The MT responses are quite similar among the sites: The off-diagonal apparent resistivities split in shorter periods. The diagonal apparent resistivities are more than one order smaller than the off-diagonal ones. These features suggest that the lateral heterogeneity in electrical conductivity is less significant beneath the survey area. The splitting of the off-diagonal elements and non-zero diagonal elements are likely attributed to large-scale structure around the survey area.

Effect for the ocean-land distribution and seafloor topography on the MT responses was modeled and stripped. The corrected responses became close to one-dimensional (1-D) feature as the off-diagonal elements are close each other and much larger than the diagonal elements. The determinants of the MT impedance tensor at the four sites are averaged and inverted using Occam 1-D inversion (Constable et al., 1987). The obtained 1-D model shows a conductive layer is underlaid by thick resistive layer and its peak (0.05 S/m) is at about 200 km depth.

The mantle temperature may be calculated from the conductivity using an experimental result for dry olivine (Constable et al., 1992). The obtained temperature is lower than the dry solidus for garnet pyrolite. Instead, assuming the temperature as GDH1 model (Stein and Stein, 1992) for 130 Myr old mantle, we can calculate water content in olivine using an experimental result by Wang et al. (2006). The resultant water content is at most about 0.0015 wt%, which is again too small to decrease solidus and generate partial melting. A possibility that the pyrolitic mantle with more water was dried out by partial melting and the melt enhances the bulk conductivity is not realistic because the analysis of rare earth elements of the petit spot basalt suggest the melt fraction of only 0.01 %, which is too small to enhance the bulk conductivity and to dry out the sold phases.

The above discussion suggests that the conductivity model does not support the melt generation in the asthenosphere. The inconsistency between the conductivity model and the existence of the petit spot volcanoes may be explained by contribution of material like eclogite which the solidus is much lower than pyrolitic mantle. An analysis of radio isotopes of the petit spot basalt suggests contribution of materials recycled from oceanic crust (Machida, 2007). However, the effect of water on olivine conductivity is still on debate. Yoshino et al. (2006) showed that the water effect is not as significant as Wang et al. suggested, indicating more water is required to explain a conductivity value. If olivine contains 0.015 wt% of water, the pyrolitic mantle may be partially molten.