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Origin of the petit-spot melt suggested from electrical conductivity structure

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Petit-spot is young volcanic activity on very old (about 130 Ma) oceanic plate characterized as a clump of small knolls which erupted strong to moderate alkaline basalt. 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, marine magnetotelluric (MT) surveys were carried out using ocean bottom electromagnetometers (OBEMs) in May - August, 2005 and in May, 2007 - August, 2008. Total nine OBEMs were deployed and seven of those were successfully recovered with good quality data. We compiled data at two other sites collected in July, 2003 - November, 2004 and analyzed the nine sites data in total in this study. We first estimated a one-dimensional (1-D) electrical conductivity structure model which explains the data of all sites averagely correcting topographic effect on the observed MT responses. Then, we carried out 3-D inversion analysis using the 1-D model as the initial and prior model. The 3-D inversion program that we used is WSINV3DMT (Siripunvaraporn et al., 2005) but modified for seafloor MT data by Tada et al. (2012).

The obtained 3-D model shows two distinct features. 1) The lithospheric mantle beneath the petit-spot field at 37.5N, 149.8E (Yukawa Knolls) is relatively more conductive than surrounding area. The conductivity is about 0.003 S/m at about 70 km depth. This feature is depicted as thinned resistive layer in the vertical section. 2) High conductivity (~0.1 S/m) layer at around 200 km depth is not isolated beneath the petit-spot field but rather distribute widely beneath the survey area except for the area to the northwestern area of the Yukawa Knolls. Checker board inversion and forward modeling tests support that these features are reasonably resolved by the data.

The electrical conductivity can be converted into temperature or melt fraction under some assumptions, using results of conductivity measurement of minerals in laboratories. We take the partition of H_2O and CO_2 in minerals and melt and the condition of partial melting into account for the conversion based on Hirschmann (2010). Then, the electrical conductivity at 200 km depth can be explained by small fraction (0.004-0.033%) of hydrous silicate melt but the temperature is unrealistically high (1600-1700 C) but explained by 0.25% of carbonated melt on realistic temperature (1400 C) above the solidus of peridotite including H_2O and CO_2. The sampled petit-spot lavas are very vesicular, indicating that significant amount of H_2O and CO_2 were dissolved in the incipient melt. From the above discussion, we speculate that the asthenospheric mantle is partially molten and the melt is extracted to the lithosphere (and partly to the seafloor) by the petit-spot activity.

Keywords: petit-spot, northwestern Pacific, electrical conductivity, ocean bottom electromagnetometer, magnetotellurics