Undulation of 410-km discontinuity beneath the Philippine Sea plate as inferred from geomagnetic vertical gradient sounding method

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Six ocean bottom electromagnetometers (OBEMs) had been deployed for 8 months from November, 1999 along an approximately 1,500km profile traversing the Philippine Sea from the northwest to southeast direction. The profile was further supplemented by successive two one-year deployments of an OBEM at the Daito Ridge situated in the northwest portion of the profile. These OBEM deployments have yielded high quality geomagnetic vector field variation continuously recorded at the seafloor for several tens of days to two years by one-minute sampling. A total of 7 sites occupy the profile, three of which were placed on the West Philippine Basin, two on the Shikoku-Parece Vela Basin and the remaining two on the presently spreading Mariana Trough.

In this paper, vertical gradient sounding (VGS) method was applied to the seafloor geomagnetic data in order to derive a two-dimensional (2D) electrical conductivity section beneath the Philippine Sea. The VGS method utilizes the attenuation of the horizontal geomagnetic components in the seawater to delineate the electrical structure below the seafloor. The method has the following advantages over conventional magnetotelluric (MT) method:

(a) It is irrelevant to near-surface distortions of the seafloor electric field that severely affect MT responses to the conducting Earth (Toh, 2005).

(b) Recent advance in seafloor geomagnetic measurements (Toh et al., 2004) enables stable determination of geomagnetic response functions (including VGS responses) at much longer periods than the MT method.

The VGS responses were estimated by taking ratios between horizontal geomagnetic variation observed at the seafloor and that on land in the frequency domain. As for the land reference, Kanoya Geomagnetic Observatory was chosen since it is the closest observatory to the profile. The raw time-series were carefully corrected for both clock gain/delay and tilt variation, and detided prior to the frequency analysis by Chave et al's (1987) robust remote reference code. As a result, accurate VGS response estimates were derived at 13 periods ranging from 1,000s to 100,000s. The spatial distribution and period-dependence of the VGS estimates have been further inverted by Uchida and Ogawa's (1993) ABIC minimization method to yield the electrical 2D section corresponding to the subsurface induced electric currents that flow parallel to the profile.

The characteristics of the derived 2D section can be summarized as follows:

(1) Shallow structures consist of resistive layers whose thicknesses/conductivities reflect the age difference of each oceanic basin.

(2) Around the 410-km discontinuity, the mantle is highly conductive with significant lateral change in both conductivities and depths to the discontinuity, viz., a shallower and more conductive region is resolved beneath the West Philippine Basin than beneath the Shikoku-Parece Vela Basin and the Mariana Trough.

The second feature can be interpreted in terms of mineral physics in the mantle transition zone. Inoue et al. (1995) has found the presence of hydrous wadsleyite that can host as much as 3 wt% of water. Wood (1995) examined the effect of water on the 410-km discontinuity and theoretically predicted the lower pressure of the olivine-wadsleyite transition under hydrous, near-saturated conditions. Wood's (1995) estimate for the maximum pressure difference as large as 1.0 GPa (around 30km in depth) has recently been confirmed by an experimental study (Smyth and Frost, 2002). This implies that the resolved lateral change in both conductivities and depths around the 410-km discontinuity is in support of the presence of hydrous wadsleyite beneath the West Philippine Basin. Further study is needed to determine the amount of water present around the 410-km discontinuity, and to examine the consistency between the depth resolution of the 2D section and the petrologically predicted undulation of the 410-km discontinuity in the presence of water.