The interpretations of velocity discontinuity and transverse isotropy in the D2 layer beneath Antarctic plate

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A bottom layer with a thickness of several hundred kilometers in the mantle has been recognized to be anomalous and the layer is called the D double prime (D2) region. A large-scale pattern of high velocity material in the lower mantle, such as beneath circum Pacific region, is related to accumulations of subducted slabs which have sunk to the base of the mantle. Beneath the regions, the seismic anisotropy and the velocity discontinuity at the top of the D2 layer have been reported. The global mapping of both the heterogeneity and the anisotropy of the shear wave velocity in the lowermost mantle helps us to understand the dynamics of the whole mantle.

The lowermost mantle beneath the Antarctic Plate has accumulated slabs subducted at Peru-Chile and Tonga-Kermadec Trench and it is a possibility that the D2 layer is one of the thick regions in our Earth. In this study, we discuss the observed seismic evidences of the anisotropy and discontinuity in the D2 layer, the process and the mechanism constructing the D2 layer to compare with the global seismic features and the tectonics which has been many reported now. The results provide data for the global mapping of both the heterogeneity and the anisotropy of the shear wave velocity in the lowermost mantle.

In this study, we investigate the velocity discontinuity and anisotropy in the D2 layer beneath Pacific Antarctic Ridge (PAR), Bellingshausen Sea (BHS) and Scotia Sea (SCO). Before searching for the D2 anisotropy, we should remove the effects of upper-mantle anisotropy, and also correct travel time anomalies due to the heterogeneity in the shear wave velocity in the upper- and mid-mantle. We assume PREM-like shear velocity structure for SV and the discontinuity structure for SH in the lowermost mantle. The velocity model is changed relative to PREM within the range from -1.5% to +1.5% at the depth of 2600km, -2.0% to +2.0% at the CMB, 2500km to 2700km at the depth of the discontinuity, and 0.5% to 3.25% in the velocity jump. We calculate the differential travel times among S, ScS, Sdiff, Scd and SKS, and the root mean square (RMS) for the residuals assessing the models. We evaluate the optimum model by the average values of these three differential travel time residuals.

In the results, the velocity jump is 2.0% in three regions. However the depths of D2 discontinuity beneath both BHS and SCO is 50km deeper than that PAR (2550km). We estimate the difference of the temperature of post-perovskite phase transition between PAR and BHS and SCO is about 500K from the difference of the discontinuity depth adopted by the Clapeyron slope. The studies of the time-averaged geomagnetic field at the CMB for the past five million years proved that the stationary patches of intense field existed just beneath PAR, suggesting the lower temperature condition for a long duration. The subduction started about 120Ma beneath BHS and SCO, although about 180Ma beneath PAR which was one of the oldest subduction zones in the Earth. This implies that colder subducted slabs are laying beneath PAR relative to beneath BHS and SCO.

We generally observe VSH fast transverse isotropy in the D2 layer beneath three regions. The estimated anisotropy is up to 2.0%. The degree of transverse isotropy becomes small with depth in our models. Shear stress and strain fields near the CMB produces sheet stacking structure of the post-perovskite. Weaker anisotropy near the CMB relative to the discontinuity depth means that the stress and strain field is not uniform but complex at the base of mantle. The difference of the velocity between VSV and VSH is about 0.5% beneath PAR that is larger than that beneath BHS and SCO. There are hot spots near PAR. The lowermost mantle flow, thus, exists from the subduction to the hot spots. This may be a cause of the rapid horizontal shear flow beneath PAR relative to our regions in the Antarctic Plate, attributing to the transverse isotropy about 200km above the CMB beneath PAR.