Waveform inversion for 3D anisotropic structure in D″ beneath the Northern Pacific: Constraints on mineralogy and flow in the lowermost mantle

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The D″ region is the lowermost several hundred km of the mantle immediately above the core-mantle boundary (CMB) and its base is in contact with the liquid outer core composed of iron alloy. Since the D″ region is the thermal boundary layer (TBL) at the base of the Earth's mantle, and the solidus of its constituent materials is thought to be close to the mantle geotherm, vertical and lateral variations of temperature and chemical composition associated with the Earth's thermal evolution are expected. Since chemically and thermally distinct subducted slabs would interact with the hot TBL above the CMB, and disturb the lowermost mantle, understanding the thermal and chemical evolution processes of the D″ region under subduction zones is essential to better understand the Earth's evolution.
The D″ region beneath the northern Pacific is of particular geodynamical interest because the paleo-Izanagi and present Pacific plates have been subducting beneath the northwestern margin of Laurentia since ~250 million years ago (Müller et al. 2016), which implies that paleoslabs could have reached the lowermost mantle. Suzuki et al. (2016) inferred the detailed three-dimensional S-velocity structure in the lowermost 400 km of the mantle beneath the northern Pacific. They hypothesized a prominent sheet-like lateral high-velocity, interpreted as paleoslabs, and a prominent low-velocity anomaly block immediately above the CMB below the high-velocity anomalies, which they interpreted as a TBL. In order to verify the above hypothesis and obtain geodynamical information, we infer 3D anisotropic structure beneath the northern Pacific in this study.
We conduct waveform inversion (Kawai et al. 2014) to infer the variation of the values of the TI (transverse isotropic, i.e. radial anisotropic) elastic constants *L* and *N* (Note that *L* is related to V_{SV} and *N* is related to V_{SH} when the shear wave propagates horizontally) straightforwardly in the lowermost mantle beneath the Northern Pacific, using a total of ~18,000 (~9,000 transverse and ~9,000 radial component) broadband body-wave seismograms. We used deep- and intermediate-focus events recorded at epicentral distances 70 to100 degrees at seismic stations of the USArray. The data are filtered in the period range of 20 to 200 s (i.e. 0.005 to 0.05 Hz) using a Butterworth bandpass filter. By using an S/ScS time window which is sensitive to the D″ structure we could image small-scale structure with finer resolution than previous tomographic studies.
The observed anisotropy is interpreted as due to the deformation-induced alignment of crystal caused by mantle flow for either Mg-perovskite (Mg-Pv), Mg-post-Perovskite (Mg-pPv), Ferro-periclase (Fp) or a combination thereof. In order to relate the flow geometry to the anisotropic geometry, we assume the dominant glide system and elastic constants of each mineral under the lowermost mantle condition based on high pressure experiment and theoretical calculation studies (e.g., Tsujino et al. 2016, Yamazaki et al. 2006 for deformation experiments; Wentzcovich et al. 2006 for ab initio calculation). We interpret the inferred 3D anisotropic structure based on above assumption, and we find the horizontal flow which could be related to subducted paleo-slabs is dominant in this region, and we also find vertical flow which could be related to the plume induced by slab sinking.

キーワード：最下部マントル、波形インバージョン、異方性、D"領域
Keywords: the lowermost mantle, waveform inversion, anisotropy, D" region