

## 論文の内容の要旨

3-D isotropic and anisotropic structure in the lowermost mantle beneath the circum-Pacific inferred using waveform inversion: Constraints on geodynamics above the core-mantle boundary

(波形インバージョンによる環太平洋下の最下部マントルの3次元等方S波速度及び異方性構造の推定：核-マントル境界上のダイナミクスの制約)

氏名                      鈴木 裕輝

In this study, we extended our group's localized waveform inversion methods to infer 3-D transverse isotropic structure with a vertical symmetric axis (VTI), applied it to a large dataset to infer the large-scale heterogeneity in a broad area, obtained new data from seismic array observations, and confirmed that the method used in this study is sufficiently robust to infer 3-D structure.

The lowermost several hundred km of the Earth's mantle immediately above the core-mantle boundary (CMB), commonly called the D'' (Dee double prime) region, is the thermal boundary layer (TBL) of mantle convection and play a major role in governing the modality of convection in the mantle. The D'' region especially beneath past and present subduction zones provides clues for understanding the dynamics of the Earth's mantle, because thermally and chemically distinct slab materials can perturb the temperature and mantle flow. Hence, it is important to study (i) whether primordial material exists in D''; (ii) how thermal and chemical heterogeneity has developed in D'' especially beneath subduction zone in order to understand the thermal and chemical evolution of the Earth.

Although previous tomographic studies found a large low S-velocity (seismic shear wave velocity) provinces (LLSVPs) in the lowermost mantle beneath the Pacific, due to a lack of resolution it remains unclear whether the LLSVP consists of clusters of small-scale low-velocity anomalies or a large-scale anomaly. We recently deployed a seismic array in Thailand (TSAR) which provides a dataset with wide azimuthal coverage at the western Pacific LLSVP. We assemble the new dataset including waveforms recorded by TSAR, conduct waveform inversion for the 3-D shear wave velocity structure, and find high-velocity anomalies extending vertically to a height of

~400 km above the CMB beneath the Philippine Sea and small-scale low-velocity anomalies with a diameter of ~300 km at the CMB beneath New Guinea. As the locations of the high-velocity anomalies are consistent with the past Izanagi-plate subduction boundary, the high-velocity anomalies can be interpreted as the cold subducted slab remnant. With a diameter of ~300 km, low-velocity anomalies can be interpreted as a small-scale thermal-plume cluster which is explained by mainly thermal effect, rather than a part of thermo-chemical pile, although we cannot rule out the possibility that the low-velocity anomalies are small-scale chemical anomalies. Chemical heterogeneities resulting from basalt entrained to the base of the mantle by past subduction or as long-lived (~4 Gyr) remnants of chemical differentiation in the early Earth, can be expected at the CMB. However, the amplitude of low S-velocity anomalies in our inferred model suggest that chemical composition anomalies with an impurity content of 5–6 percent produce at most ~+1 percent density anomaly. This implies that chemical anomalies could be entrained by the convection and thus could not survive in the lowermost mantle about 4 Gyr. We therefore conclude that: (1) the shape of the low-velocity anomalies in our inferred model beneath the western Pacific appear to be plume clusters rather than a large-scale anomaly such as a thermo-chemical pile; (2) while the LLSVP may be due to the chemical effects, the inferred S-velocity structure around the edge of the western Pacific LLSVP found by this study is likely to be explained by mainly thermal effects.

Since the D'' region is considered to be destination of chemically and thermally distinct cold subducted oceanic lithosphere (slab) which interacts with the hot TBL above the CMB and cause the disturbance of temperature and flow in the lowermost mantle, we conduct waveform inversion to infer the isotropic and anisotropic S-velocity structure of D'' beneath the northern Pacific in order to understand the thermal and chemical evolution processes of the D'' region beneath the subduction zone. We analyzed not only transverse but also radial component of a large number of waveforms recorded by full USArray broadband seismic stations in the US during 2004–2015. Inferred 3-D isotropic S-velocity structure shows high-velocity anomalies possibly corresponding to subducted Izanagi slab, which reach the CMB, and low-velocity anomalies continuous from the CMB to 400 km above the CMB possibly associated with the hot material of the thermal boundary layer immediately above the CMB. We then conduct waveform inversion to infer the 3-D anisotropic structure within D'' beneath the Northern Pacific in order to infer the flow direction at the lowermost mantle. The observed positive and negative perturbation of anisotropic parameter ( $\delta \xi$ ) is corresponding to horizontal and vertical flow in D'', respectively, taking into account the recent progress of mineral physics. Hence, it is found that paleo-Izanagi plate subducted ~240 Ma reaches the

lowermost mantle, lies almost horizontally, and is inducing vertical upwelling flow of the hot material of the thermal boundary layer.

Our inferred seismic structure would suggest that:

- (i) the LLSVP (at least the western part of the Pacific LLSVP) consists of an aggregate of smaller-scale low-velocity could be explained by mainly thermal effect, suggesting that the existence of low viscosity material in D'' beneath the western Pacific and the vigorous small-scale convection;
- (ii) the slab sinks into the lowermost mantle beneath the northern Pacific with a low dip angle. This implies that segregation of basalt from depleted material could occur in this ~100 Myr, suggesting that the lowermost mantle beneath the subduction zone could be chemically distinct due to the accumulation of the basaltic materials enriched in the incompatible elements and radiogenic elements.