論文内容の要旨

論文題目　Whole Mantle V_P/V_S Tomography

（全マントルV_P/V_Sトモグラフィー）

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General introduction

Understanding of tomographic image in terms of dynamics of the Earth's interior requires knowledge of what causes lateral variation of seismic wave velocities. One way of distinguishing origins of heterogeneity is to compare observed tomographic velocity anomalies to those predicted by mineral physics. The purpose of this study is to model three-dimensional V_P/V_S ratio variation which is suitable to be measured for laboratory experiments but rarely derived seismologically. We focus on using broadband S-P differential travel times, since P and S information corresponds originally. The V_P/V_S tomography model so derived can be undergone direct comparison of those from laboratory measurements. In this paper, we show the measurement procedure of S-P differential travel times, inversion technique for modeling V_P/V_S ratio, and the resultant V_P/V_S tomographic model. We also show the P to S velocity anomaly ratio R tomography as an application of this inversion technique.

1. Measurement of S-P travel times

Picking an arrival time of S wave is in general difficult, and waveform correlation is a method to solve this problem. We take into account the physical dispersion which is characterized by two parameters t* and f_0 to synthesize S waveform from observed P waveform by correcting attenuation effect. S-P differential travel time is measured by cross-correlating synthetic and observed S waves for the first half cycle. The reference frequency f_0 is conventionally set to 1 Hz. We, however, found a systematic discrepancy of about 0.5 s between cross-correlated and handpicked S-P times. This indicates a higher value for the reference frequency that is consistent with the onset frequency of short-period body waves. The 0.5 s discrepancy disappears when the reference frequency is taken to be 2 Hz. We, therefore, used 2 Hz as the reference frequency of teleseismic body waves.

2. Inverse problem for Vp/Vs ratio

Observed and reference S-P times can be written as follows by using Vp/Vs ratio,

observation time : $$Ts - Tp = \int_S (Vp/Vs)(dls/Vp) - \int_P dlp/Vp \qquad \text{--- (1)}$$

reference time : $$(Ts^{ref} - Tp^{ref}) = \int_S (Vp/Vs)_{ref}(dls/Vp^{ref}) - \int_P dlp/Vp^{ref} \qquad \text{--- (2)}$$

We handpicked P onsets among those 13,500 S-P times, and prepared 13,000 of them. They are compared to the predicted time from P tomographic model of Fukao et. al., [2001] to be found that they are in good agreement. This indicates the equivalence of Vp and Vp^{ref} in the above equations. Setting $(Vp/Vs)-(Vp/Vs)_{ref}$ to the unknown parameter to be modeled, the subtraction of (1) and (2), can be solved as a linear inversion problem.

$$(Ts - Tp) - (T_S^{ref} - T_P^{ref})_O = \int_S \left[Vp/Vs - (Vp/Vs)_{ref}\right](dls/Vp^{ref}) \qquad \text{--- (3)}$$

3. V_P/V_S tomographic model

Using Vp/Vs and P tomographic models, three-dimensional V_S distribution can be derived as Vs = Vp / (Vp/Vs). These models are shown in Fig.1. The old Indian plate which closed Tethys sea can be seen beneath India where smaller Vp/Vs values are detected. Note also that slow anomalies beneath Solomon and Samoa islands in S model (circled by solid lines) have significant difference in Vp/Vs model, indicating the cause of velocity anomalies of the two regions may be originated from different factors.

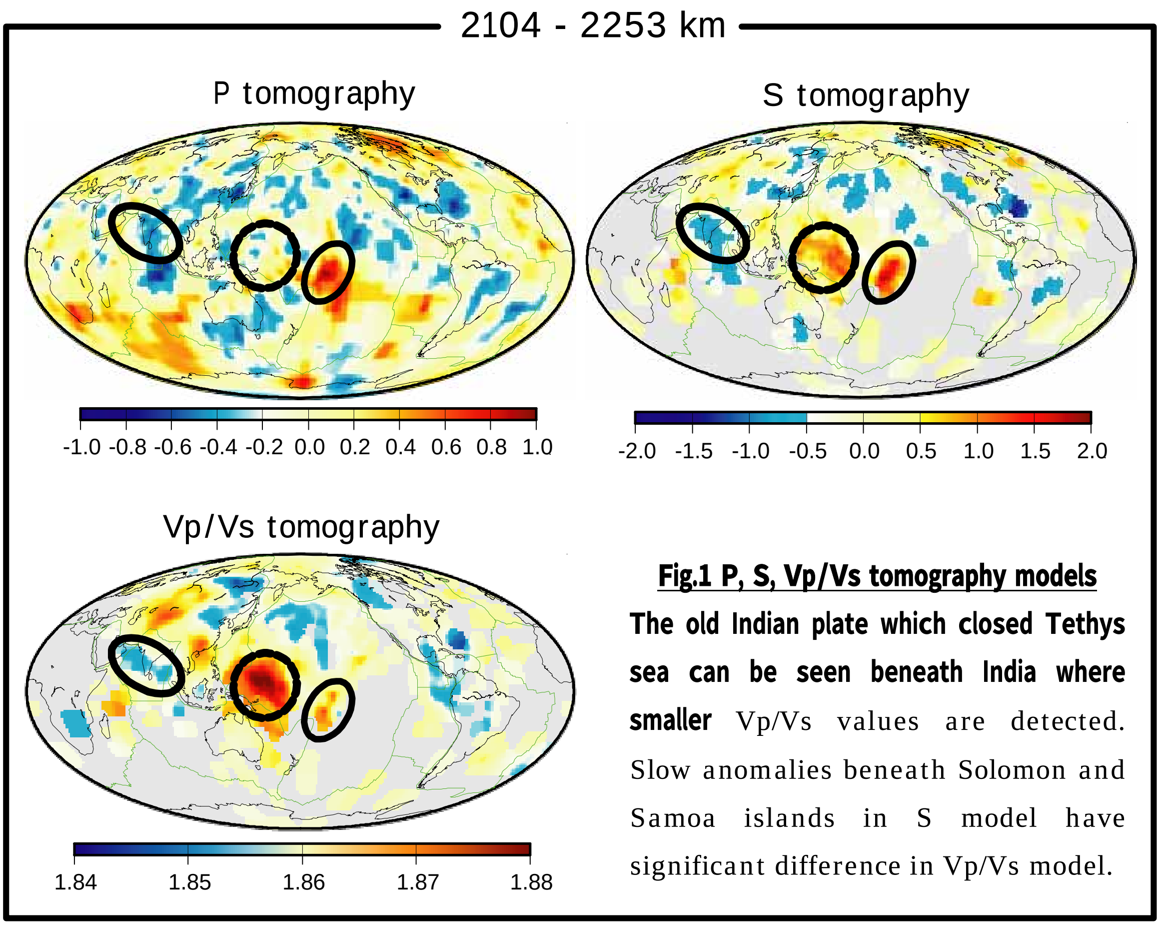

Fig.1 P, S, Vp/Vs tomography models

The old Indian plate which closed Tethys sea can be seen beneath India where smaller Vp/Vs values are detected. Slow anomalies beneath Solomon and Samoa islands in S model have significant difference in Vp/Vs model.

4. R tomography

The tomographic technique of V_P/V_S ratio can be applied to model three-dimensional distribution of R. Suppose $S_{P,S}$ is the slowness of P and S waves which consists one-dimensional and fractional slowness of S^O and δS . Let R be defined as,

$$R = R_O + \delta R = \frac{\delta S_S / S_S^o}{\delta S_P / S_P^o}$$

the observed and reference times can then be written as

observed equation : $$Ts - Tp = \int_S (S_S^o + R\left(\frac{V_P}{V_S}\right)_o \delta S_P)dls - \int_P (S_P^o + \delta S_P)dlp \quad \text{---(4)}$$

reference equation : $$Ts^{ref} - Tp^{ref} = \int_S (S_S^o + R_o\left(\frac{V_P}{V_S}\right)_o \delta S_P)dls - \int_P (S_P^o + \delta S_P^{ref})dlp \quad \text{---(5)}$$

Assuming S_P=S_P^{ref} as we confirmed previously, we again obtain a linear equation for inversion with model parameter of δR;

$$(Ts - Tp) - (Ts^{ref} - Tp^{ref}) = \int_S \delta R\left(\frac{V_P}{V_S}\right)_o \delta S_P dls \quad \text{---(6)}$$

The resultant model is shown in Fig.2. R will take a laterally uniform value provided that seismic velocities are perturbed only by lateral temperature heterogeneity through the anharmonicity effect, not through the anelasticity effect. Derived tomographic R model shows comprehensive increase with respect to depths, but varies about +/-0.3 in terms of standard deviation. Taking into account the over all correspondence between low R regions and slab regions, or high R regions and slow V_S regions, the lateral variation of R may indicates the lateral patterns of Q. This implication may suggest that most of the velocity anomalies in the lower mantle can be explained as the thermal effects and the heterogeneity between seismological observations and temperature dependent laboratory measurements are localized such as in Solomon islands region at depth 2000 km having anomalous V_P/V_S ratio. These features could not be inferred by comparing only one-dimensional R plots of mineral physics predictions and seismological observations (Fig.3). We emphasize the importance of preparing three-dimensional distributions of V_P/V_S ratio or R values in interpreting seismic tomography into mantle dynamics by the use of mineral physics measurements.

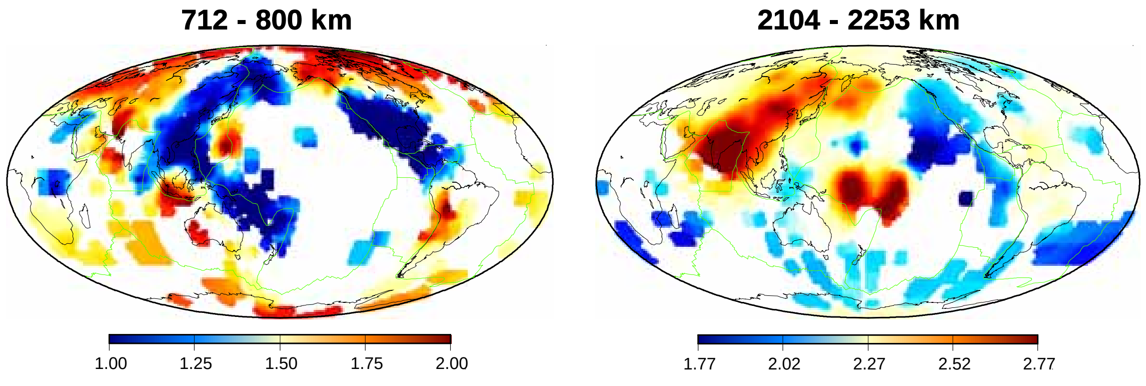

Fig.2 R tomographic model

Smaller values of R are dominated in slab regions such as the Western Pacific, North and South America, or Tonga at depths about 1000 km. These regions are expected to be less attenuative (high-Q) so that anelastic effect contributes little to R so that smaller values of R are expected from the mineral physics view point. Large values of R are dominated in regions of V_S slow anomalies. Large negative anomaly in S velocity perturbation makes R significantly large (2000 km). It is easily inferred that attenuative (low-Q) media increases R both through the anhamonic and anelastic effects.

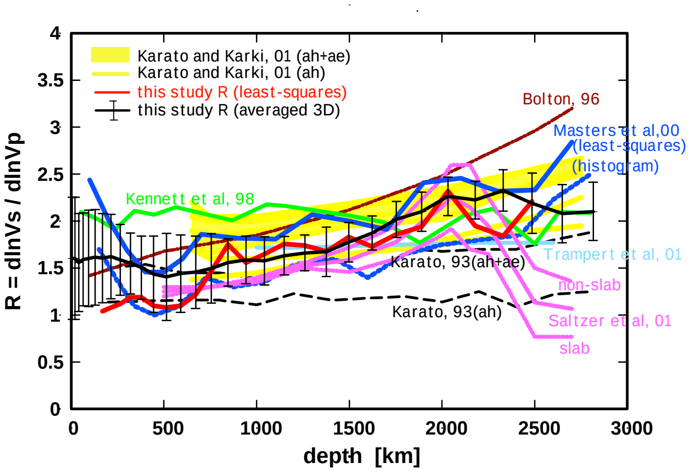

Fig.3 spherically averaged R with other studies

Spherically averaged R is plotted in black solid line with standard deviation. Our data is between predicted R values with and without anelastic effect by Karato and Karki, [2001] which may vary depending on attenuation factor.