Azimuthal variation of lithospheric heterogeneity in the northwest Pacific inferred from Po/So propagation characteristics

*Takashi Furumura[1], Brian LN Kennett[2]

1. Earthquake Research Institute, The University of Tokyo, 2. Research School of Earth Sciences, The Australian National University

1. Observed azimuthal variation of Po/So propagation
Oceanic Pn/Sn waves (often referred to as Po and So waves) are high-frequency arrivals with a long coda that travel for large distances across the Pacific. The nature of Po/So propagation is controlled by strong scattering in the oceanic lithosphere which is characterized by laterally elongating quasi-lamina (Shito et al., 2013; Kennett and Furumura, 2013; 2014).

Observations of Po/So waveforms at the ocean bottom station WPAC in the northwest Pacific (160E, 41N) show that the shape of Po/So phase has a large azimuth dependency, suggesting an azimuthal variation in the lithospheric heterogeneity distributions. Record from earthquakes near Kamchatka, to the north of WPAC, show sharp rise in the Po/So phase followed by a burst of water reverberation signals (Fig.1–Event A). Po has a high-frequency precursor before the arrival of the main phase. From a Tohoku earthquake (Event B), west-southwestward from WPAC, the observed Po/So exhibits a long spindle-shaped coda. In this direction, the precursor is low-frequency and subsequent high-frequency components are much delayed.

The direction of the sharp Po/So rise and high-frequency precursor (Event A) corresponds to the direction in which the maximum Pn wavespeed anisotropy was observed (e.g., Shimamura, 1984; Shinohara et al, 2008) that is the former Pacific plate spreading direction (155 deg. north) and is orthogonal to the trends of magnetic anomalies (Nakanishi et al., 1992).

2. 3D FDM simulation
3D FDM simulations were performed to examine the azimuthal variation of Po/So properties associated with lateral variation of lithospheric heterogeneity. The area of simulation was 512 km by 512 km by 128 km, discretized with a 0.0625 km grid size. The 1D isotropic velocity structure was based on Kodaira et al. (2014), however, sedimentary layer (Vp=1.6 km/s, Vs=0.2 km/s, 0.4 km thick) was not included for high-frequency (6 Hz) simulations. A Von Karmann stochastic random heterogeneity with a 3% standard deviation was superimposed on the reference structure in oceanic lithosphere following Kennett and Furumura (2013), with a larger correlation distance (ax=10 km) parallel to the linearity of magnetic anomaly, and much shorter correlation distances in the perpendicular and vertical directions (ay=az=0.5 km). A slightly larger heterogeneity than normal (2%) was used to emphasize the effect of long-range propagation in this small FDM model. A combined explosive and torque source was set at the corner of the model with a depth of 20 km, which radiated P and S waves isotropically in all directions.

The result is shown in Fig. 2a with a snapshot of the P and S wavefield after 42 sec from the earthquake initiation, demonstrating that a large and long coda is formed in the X direction parallel to the elongated heterogeneity after multiple scattering of high-frequency signals. On the other hand in the orthogonal (Y) direction, a sharp rising Po/So phase is maintained for large distances.

A record section of the vertical-component velocity and envelope at epicentral distance of 410 km is shown in Fig.2b as a function of azimuth from the source. The simulated Po/So waveform for propagation in the direction orthogonal to the elongated heterogeneity structure shows a sharp Po/So rising edge followed by burst of water reverberations, whereas in the direction parallel to the heterogeneity distribution there is a long spindle-shaped Po/So coda. Further, we find that the high-frequency (>2 Hz) component of Po arrives earlier for the heterogeneity perpendicular direction and slower in parallel direction.

The observed high-frequency Po/So wavespeed anomalies caused by scattering in laterally varying lithospheric heterogeneity may partially contribute to the observed large (about 5%) Pn/Sn wavespeed anisotropy in northwestern Pacific that is generally explained by the cause of preferential orientation of olivine crystal axis or opening clacks in the structure.

Acknowledgement
We thank Ocean Hemisphere Network Data Center for providing OBS data and ERI and Supercomputer Center at Univ. Tokyo to use the Oakforest-PACS supercomputer.

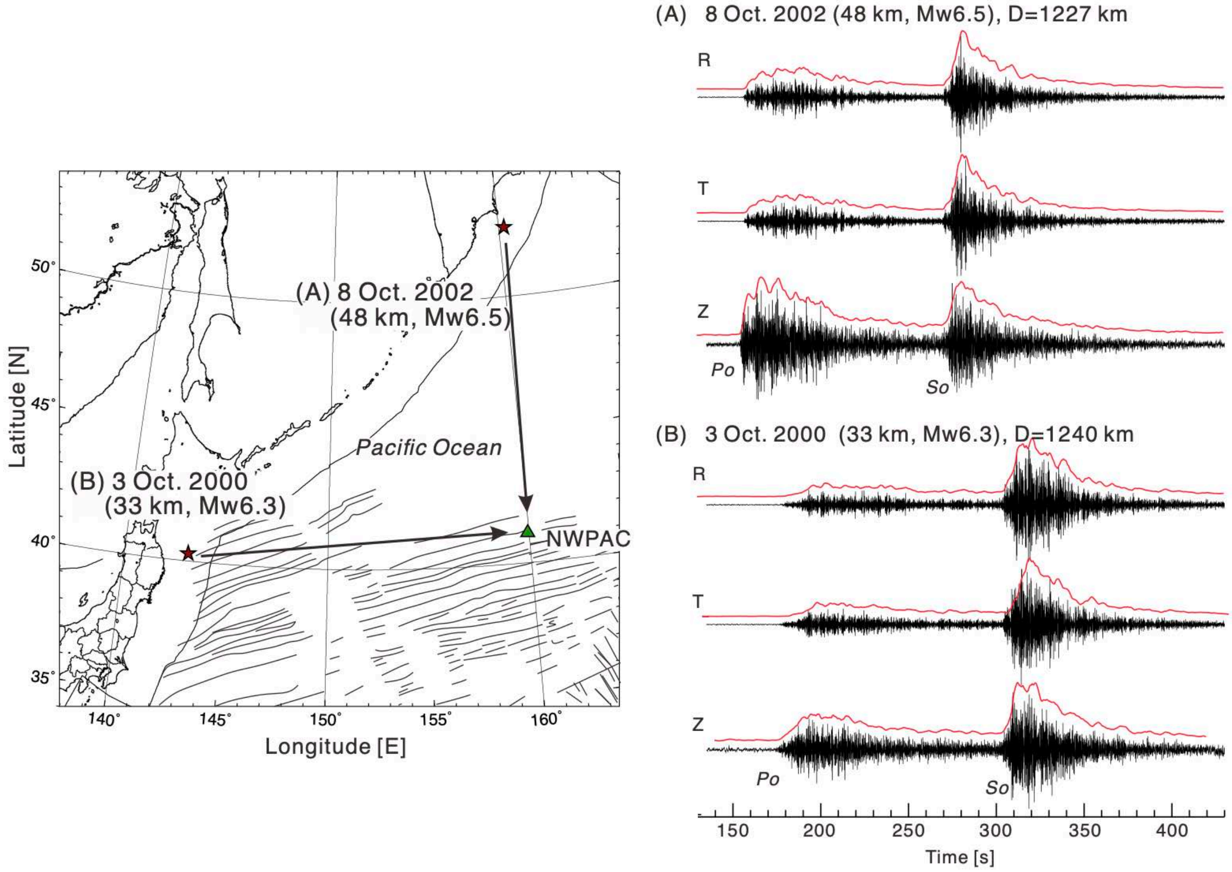

Figure 1. Comparison of 3-component OBS record at NWPAC for events at similar distances those occurred near (a) Kamchatka and (b) Tohoku. A high-pass filter (>3 Hz) was applied and envelopes were smoothed. Left map shows the location of earthquakes, station, and lineaments of magnetic anomaly (Nakanishi, 1992).

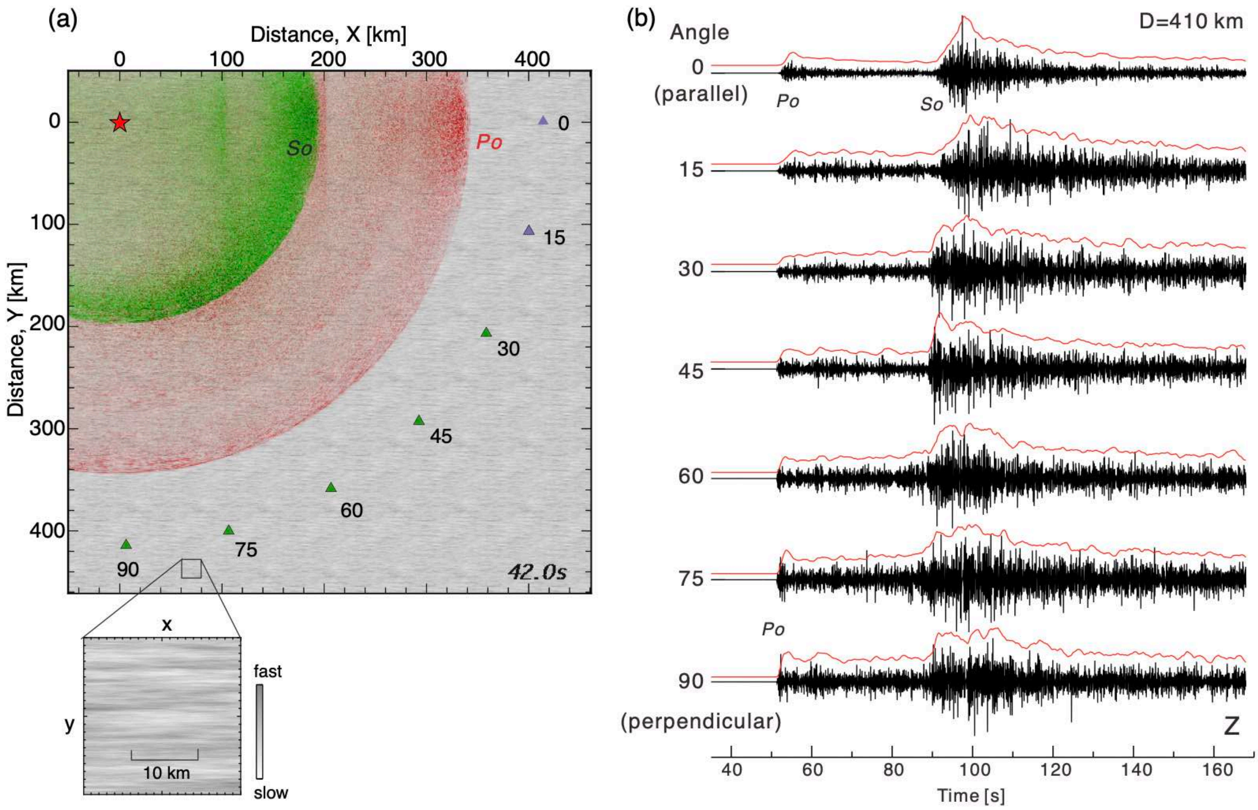

Figure 2. (a) Snapshots of seismic wavefield at ocean bottom obtained by 3D FDM simulation after 42 s from earthquake initiation. P is shown in red and S in green. (b) Record section of vertical component velocity and smoothed envelope at stations of 410 km epicentral distance as a function of azimuth from the source (0 and 90 deg. represent the parallel and perpendicular directions to elongated heterogeneity distribution). Each trace of record section is normalized by maximum.