論文の内容の要旨

Method and practice of broadband ocean bottom seismology: case studies in the western Pacific

（広帯域海底地震学の手法と実践：西太平洋域アレイ観測への適用）

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This thesis developed methods to overcome three technical challenges in broadband surface-wave array analysis. I applied the improved method to the in situ seismograms recorded in the oldest Pacific Ocean and measured Rayleigh-wave phase velocity at a period range of 5–200 s and Love-wave phase velocity at a period range of 5–100 s. The measured phase velocities are inverted to one-dimensional isotropic, radially and azimuthally anisotropic shear-wave velocity structures.

With the short thermo-chemical evolution history and a simple crustal structure, imaging of the oceanic mantle is essential to elucidate the nature of the lithosphere-asthenosphere system (LAS), which is the most representative system of plate tectonics. Broadband surface-wave array analysis provides continuous imaging of the LAS from the seafloor to a depth within the asthenosphere. The method was previously applied to various oceanic basins, and the obtained high-resolution imaging led to an awareness of the variable dynamics within the asthenosphere.

There, however, still exists technical challenges in broadband surface-wave array analysis, which hamper our investigation into the LAS. In this thesis, I developed methods to overcome three challenges and analyzed the seafloor records obtained by an array of broadband ocean bottom seismometers (BBOBSs) deployed along the 170-Ma isochrone, the Oldest-1 Array, where the eastern edge of the array overlaps an

ancient ridge-ridge-ridge (RRR) triple junction.

The first challenge is the high noise level of the long-period oceanic seismograms. Long-period data (>10 s) at seafloor stations tends to have higher noise levels than at land stations due to tilt noise and compliance noise, which originated from seawater. Noise reduction processing is essential to maximize the use of data. I established a noise reduction method for the vertical component seismograms of the BBOBS by modifying pre-existing method and applied it to the Oldest-1 Array data set. Using noise-reduced data, I measured Rayleigh-wave phase velocities up to a period of 200 s, and structures in a depth of 200–300 km were successfully constrained by the direct observation.

The second challenge is the measurement of short-period (<30 s) phase velocities. It is difficult to achieve a stable measurement in a seafloor array due to the long interstation distances and small numbers of stations. Therefore, I improved pre-existing ambient-noise analysis and realized a more stable and physically more appropriate measurement with smaller uncertainties. I measured Rayleigh- and Love-wave phase velocities at a period range of 5–25 s and 5–10 s, respectively.

The third challenge is measuring long-period (>30 s) Love-wave phase velocities. Although Love waves are crucial to understanding the LAS, the measurement of Love-wave phase velocities has been rare because of technical difficulties. Due to the characteristics of the oceanic structure (thin crust and mantle low-velocity zone), several different modes of Love waves have close or even overlapped arrival times, resulting in mode interference. Therefore, if Love waves are analyzed without any special care, the measured phase velocities are potentially biased. In order to measure less-biased fundamental-mode love-wave phase velocity, I devised a method to measure phase velocity by treating the Love waves as a superposition of the fundamental and first higher modes. I measured the fundamental-mode Love-wave phase velocities in a period range of 33–100 s.

I then inverted the measured phase velocities and obtained one-dimensional radially and azimuthally anisotropic structure beneath the Oldest-1 Array, which involve both horizontally propagating vertically and horizontally polarized shear waves (V_{SV} and V_{SH}). I compared the obtained isotropic shear-wave velocity (V_{SV}=V_{SH}) structure with that of the other two ocean basins of different ages (130 and 140 Ma). There is no significant difference in the high-velocity Lid (Moho–60 km) among the three regions, whereas it is difficult to explain the velocity difference within the low-velocity zone (80–150 km) only by cooling associated with the age difference.

The azimuthal anisotropy at shallow depths (<50 km) differs between the eastern and western areas of the array. The intensity of azimuthal anisotropy is ~3.7 % and the fastest direction is quasi-perpendicular to the predicted past seafloor spreading direction in the western area of the array, while the intensity is ~1.6 % and the fastest direction largely deviates from the predicted past seafloor spreading direction in the eastern area of the array. The intensity of the azimuthal anisotropy at depths deeper than 50 km is weak (~1 %), and the direction of the fast axis is in the east-west direction, which is different from the absolute plate motion. The radial anisotropy is estimated in two layers (Moho–60 km and 60–240 km). The shallow radial anisotropy in the eastern area is $V_{SH}>V_{SV}$ by 7.5 ± 1.0 % while it is 3.4 ± 1.1 % in the western area. The deep radial anisotropy is estimated to be $V_{SH}>V_{SV}$ by 2–8 %.

Both azimuthal and radial anisotropy are significantly different between the eastern and western areas within the Oldest-1 Array, which may reflect the complication of the evolution of the early Pacific plate, which involves the RRR triple junction. Radial anisotropy is stronger than azimuthal anisotropy and likely to be consistent with a conventional notion of the olivine fabric type (A-type olivine).

This thesis improved broadband surface-wave array analysis by overcoming three technical challenges and estimated the isotropic, azimuthally and radially anisotropic shear-wave velocity structures, which are all crucial to discuss the structure and mantle flow in the oceanic lithosphere-asthenosphere system. The realization of obtaining all three types of structures means that seismic observations are ready to be compared to rheological studies and to constrain various hypothesized structures by direct observations in the future.