論文内容の要旨

論文題目：Seismic characteristics of out-of-sequence thrusts and plate boundary décollements: In-situ pore pressures, velocity structure, and geometries of Nankai accretionary prism faults

（分岐断層とデコルマの特性：南海トラフ付加体における断層周辺の間隙水圧、速度構造と、その形状）

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ABSTRACT

The characteristics of out-of-sequence thrusts (OOSTs) and plate boundary décollements in plate convergent margins are important for understanding the nature of earthquake mechanisms and deformation features of the accretionary prism. Especially pore pressure characterization is critical for understanding fault strength, structural development, and taper angle of the accretionary prism. In addition, pore pressure has been postulated to influence the position of the shallow limit of seismogenic faulting behavior through its control on effective stress and consolidation state. In the Nankai

Trough, large earthquakes in excess of M 8 have occurred every ~150 years and caused large-scale destruction to Japanese society. *Tsunami* due to earthquake slip along the OOSTs also caused disasters to the Japanese coastal cities. To reveal the characteristics including pore fluid pressure of the seismogenic OOSTs and the décollements in the Nankai accretionary prism, I applied several geophysical applications to seismic reflection data.

Firstly I measured acoustic properties of discrete samples from a fossil Nobeoka OOST outcrop in Kyusyu under confining pressures to reveal structure of the OOST because the deep OOST has been never drilled and its characteristics have been estimated mainly from seismic reflection polarity. I observed strong anisotropy of velocities and quality factors in the hanging wall of the Nobeoka OOST attributed to foliation of pelitic-phyllite. In contrast, the footwall is composed of brittlely deformed, chaotic shales and fine sandstones, and velocities in the footwall are lower than those in the hanging wall, and the anisotropy is weaker than that in the hanging wall. Furthermore, the velocities and quality factors just above the fault core are high, because cracks are filled by quartz and number of the open crack should be small. Amplitude variation with offset (AVO) modeling utilizing contrasts in P-wave and S-wave velocities and densities between the hanging wall and footwall of the Nobeoka OOST indicates that fractures filled with overpressured fluid likely account for angle-dependent reflection amplitudes of the active Kumano OOST in the Nankai Trough off Kii peninsula.

I characterized the active Kumano OOST off Kii peninsula via finite-difference time-domain (FDTD) modeling. Because dominant frequencies of the seafloor reflection and the deep OOST refection are much different, I used an attenuated seafloor reflection as a source wavelet for the simulation study. To obtain the attenuated wavelet, firstly, quality factor within the accretionary prism was estimated as 100 ~ 130 by applying spectrum division technique to seismic reflection data. Considering the estimated quality factor, then, I could calculate attenuated seafloor waveforms. The simulation results using the attenuated seafloor waveforms revealed that the velocities of hanging wall are higher than those of footwall, and the velocity structure is consistent with the fossil Nobeoka OOST. Considering the estimated quality factor, furthermore, velocity contrast at the active OOST could be estimated as 700 ~ 1800 m/s.

Although the Kumano OOSTs have strong reflection amplitude in the deeper parts, the shallower parts of the OOSTs are ambiguous. Therefore, the identification of their distributions is difficult on the original profiles. To investigate geometry of the shallower parts of the OOSTs, I calculated seismic attributes (e.g., instantaneous phase) from the seismic reflection data. By using phase information of seismic signal, I could determine detailed three-dimensional (3-D) geometries of the shallower parts of the OOSTs. Because the reflection amplitude of the shallower OOSTs is lower than that of the deeper OOSTs, pore pressure contrast at the shallower OOSTs may be small compared to that at deeper OOSTs. The reflection amplitude of the OOST is lower seaward of the point where several OOSTs are branched. It may suggest that pore pressure contrast at the OOSTs becomes small due to the release of fluid when the OOSTs are branched. At the landward parts of the branched point, on the other hand, the low permeable barrier due to shear stress originates contrast in pore pressure at the OOSTs.

The plate boundary décollement is another large-displacement thrust within the accretionary prism. The décollement seems to step down to the top of the oceanic crust around the OOST in the Nankai Trough accretionary prism off the Muroto peninsula. Therefore, the OOST and décollement are related for each other. Furthermore, because slip along the décollement may occur after the earthquake slip along the OOST, properties of both OOST and décollement are important to discuss stress state within the accretionary prism. To investigate variations in physical properties accompanying the development of the décollement, I used a neural network analysis of seismic attributes derived from 3-D seismic reflection data gathered in the Nankai Trough off the Muroto peninsula. This analysis resulted in a detailed map of the geological features along the décollement and revealed a drastic change in physical properties at the sole of the proto-thrust (the most seaward imbricated thrust). Ocean Drilling Program (ODP) data suggest that the décollement physical property change coincides with the initiation of plate boundary slip. Furthermore, changes in the structure of the accretionary prism and reorganization of the décollement geometry also attend the initiation of plate boundary slip.

The décollements in the Nankai and Barbados accretionary prisms are commonly characterized using seismic data, including reflection polarity, seismic velocity, and seismic attributes. However, previous researches using seismic reflection data usually focused on the décollement reflection itself and did not estimate pore pressure distribution around the décollement. From seismic interval velocity, therefore, I predicted pore fluid pressure distribution within the Nankai Trough accretionary prism off the Muroto peninsula quantitatively. To reveal pore pressure distribution, I developed a theoretical based method. From crack aspect ratio spectrum estimated from laboratory and logging data, I calculated theoretical velocities parameterized by effective pressures via Differential Effective Medium (DEM) theory. By iteratively fitting the theoretically calculated velocity to the seismic interval velocities, I estimated in situ effective pressure within the accretionary prism. Then, pore pressure could be obtained by subtracting the effective pressure from confining pressure. Our results demonstrate that high pore fluid pressure (overpressure) occurs within the subducting sedimentary sequence. The increase in overburden load due to thickened prism and low permeable barrier along the décollement may increase the pore pressure of the underthrust sequence. Furthermore, overpressure within the accreted sequence occurs landward of the deformation front. The increase in horizontal compaction within the accreted sequence and low permeable marine sediment may raise pore fluid pressure.