論　文　の　要　旨

題　目　Effect of water-saturated cracks on seismic velocity and transport properties of oceanic crust
（海洋地殻の地震波速度と輸送特性に対するクラックと水の影響）

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Geophysical observations, such as seismic and electromagnetic surveys, have revealed that the presence of pore water is closely related to many geodynamic processes at various tectonic settings of the oceanic lithosphere. To quantitatively interpret those geophysical data and understand the subsurface fluid behavior, knowledge of cracks, which act as a fluid pathway and storage in the oceanic crust, is essential in the context of their geometry, distribution, and scale. This thesis provides experimental and theoretical constraints on the effects of microscopic and macroscopic water-saturated cracks on the geophysical properties of the oceanic crust based on comprehensive laboratory measurements and data analyses using core samples from the Oman Drilling Project.

Electrical resistivity and P- and S-wave velocities were measured under dry and water-saturated conditions for discrete cubic samples recovered from the Oman Drilling Project Hole GT3A. The experimental results reveal that electrical resistivity and elastic wave velocities are differently correlated with porosity. Performing joint inversion of the measured electrical and elastic properties combining an effective medium model and a statistical crack percolation model, the variations in electrical and elastic properties can be quantitatively related to the crack microstructural parameters: crack density and aspect ratio, as well as connectivity of cracks evaluated from crack density. Those data suggest that the oceanic crust can have wide ranges of abundance and geometry of microcrack.

To further understand the spatial distribution of microcracks in the oceanic crust, analyses of the continuous P-wave velocity structure measured by onboard whole-round Multi-Scanner Core Logger (MSCL-W) data for Hole GT3A were conducted. The representative elementary volume (i.e., REV), which is defined as a unit volume at which the physical properties become uniform, was estimated by calculating average P-wave velocities with increasing the window length. The results demonstrate that the scale of heterogeneity of microcrack structure in the oceanic crust can be on the order of a few meters. This suggests that the pore pressure within the REV scale, caused by the seismic wave loading, is not able to reach an equilibrium state, which means the elastic moduli that are derived from the seismic velocity measurements can represent an unrelaxed state, which is different from the conventional assumptions.

As well as microcracks, there should be large-scale fractures in the oceanic crust, which potentially affect macroscopic geophysical properties. To assess the fracture porosity and permeability of the oceanic crust, X-ray CT images of the core sections collected from the GT sites of the Oman Drilling Project were used for analysis. The spatial distributions and geometry of

macroscopic vein minerals, which can be considered to reflect the paleo-porosity structure in terms of macroscopic fractures, were quantified. The results show that despite having low paleo-porosity of ~0.1%, the oceanic crust can have significantly large paleo-permeability ranging from 10^{-9} m^2 to 10^{-13} m^2. This highlights the importance of taking the effect of macroscopic fractures on transport properties into account when interpreting geophysical data.

Finally, an upscaled geophysical property model is developed based on the characteristics of pore structure in the oceanic crust inferred from the data presented in the above studies. The upscaled model implies that the microcracks and fractures may have different impacts on the seismic and transport properties of the oceanic crust. The findings of this thesis can provide new insights that aid the quantitative interpretation of geophysical data from the in situ oceanic crust.