低温のマントル岩石のレオロジーに対する水の効果
Effect of water on the rheology of cold mantle rocks: An experimental study

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Rheology of mantle rocks at low temperatures (< 800°C) is fundamental to comprehend the occurrence of earthquakes in the mantle lithosphere. Previous axial deformation experiments on natural dry peridotite revealed that glide-controlled crystal-plasticity is the dominant deformation mechanism at 600°C while brittle deformation also contributes increasingly at lower temperatures (Druiventak et al., 2011). Water infiltrating into oceanic and fore-arc mantle is expected to significantly affect the rheology of cold mantle rocks. A manner in which water influences the rock rheology varies depending on the mode of presence of water: (1) Aqueous fluid reduces the effective normal stress and promote brittle deformation. (2) Water incorporated into nominally anhydrous minerals reduces the strength of plastic deformation (Katayama and Karato 2008). (3) Hydrous minerals produced via hydration reaction can decrease the frictional and plastic strength of mantle rocks (Escartin et al., 2001). However, it is still unknown which effect becomes more dominant after aqueous fluid penetrates in to the dry cold mantle.
In order to evaluate the effect of water on the cold mantle rheology, we performed deformation experiments on natural dunite from the Horoman peridotite complex by using a Griggs-type apparatus at a temperature of 600°C, a confining pressure of 1.0 GPa, and a strain rate of $2.9\cdot10^{-6}$ s^{-1} in both dry and wet (1 wt% H_2O) conditions. Dunite was mostly composed of olivine (Ol) with minor amount of Al-bearing orthopyroxene (Opx; ~7 vol%) and serpentine veins (< ~5 vol%). Yield stress of dry dunite was 800 MPa, which is slightly lower than that obtained in the previous experiment (Druiventak et al., 2011; ~1000 MPa) while the strength of dunite in wet condition was reduced to 600 MPa and it gradually decreased down to ~500 MPa after reaching the peak strength. Textural observations indicated that pre-existing serpentine veins with an angle of ca. 45° to the shortening axis preferentially accommodated the deformation in dry condition. In wet condition, such a localized shear deformation in the pre-existing veins was not observed, and instead a large shear fault which divided the sample into two parts was formed with an angle of ca. 30° to the shortening axis. Along this fault, grain size of Ol and Opx (initially > ~100 μm) were significantly reduced down to several μm and talc along with Al-serpentine were formed in the matrix of the fine primary minerals through the preferential Opx reaction (Nakatani and Nakamura, 2016). On the basis of textural observations, it was suggested that high fluid pressure promoted cataclastic flow along the fault before reaching the peak strength and subsequent hydrothermal reaction in the fine grained region resulted in gradual decrease in the strength via the formation of weak phyllosilicates.
In both dry and wet experiments, clear shear faults were observed. Effective friction coefficients (μ_{eff}) at the peak and final strengths for wet experiment were calculated to be 0.23 and 0.19, respectively, which were lower than that calculated in dry condition (0.29). The reduction of μ_{eff} at the peak strength was attributed to the high fluid pressure while the formation of weak phyllosilicates might increasingly contribute after the peak strength. The hydrothermal shear experiment on Ol and Opx aggregate with weight proportion of Ol:Opx = 7:3 showed that μ_{eff} decreased down to 0.07-0.13 with increasing shear strain due to the formation of abundant talc along shear planes (Hirauchi et al., 2016). The relatively high

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μ_{eff} after the peak strength in this study could be explained by less effective talc formation due to the low strain during the experiment and small amount of Opx in the starting material. Our experimental results suggested that water infiltrated into the cold mantle leads to frictional deformation even at 600°C where the ductile deformation is considered to be dominant in dry condition.

キーワード：マントル、水、レオロジー、地震、摩擦変形
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