Frictional experiments of Ice under the low temperature conditions and implication for rheological structure of Mars

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The existence of water in the Mars is a key to consider the surface environment, evolution and future exploration. The temperature of the Martian interior is lower than that of the Earth, and the cryosphere of Mars is thought to be more extensive (Clifford et al., 2010). Therefore, the water likely exists as the ice in the shallow part of Martian lithosphere. In this study, we conducted the two-phase frictional experiments using ice and soda-lime glass mixture to investigate the effect of ice on the rheological structure of the Martian lithosphere. Based on the calculated rheological structure of Mars, we estimated the elastic thickness (Katayama et al., 2019) and attempted to infer the distribution of subsurface ice of Mars.
Gouge samples with ice volume ratios of 0%, 20%, 50%, and 100% were prepared from powder of ice and soda-lime glass (grain size<100 μm). Frictional experiments were conducted using a biaxial testing machine at Hiroshima University. The normal stress was 10 MPa, and a shear stress was applied to sample at a constant velocity of 3 μm/s. During experiments the temperature conditions were changed from −60 ºC to −30 ºC to investigate the temperature dependence on friction coefficient. Our frictional experiments indicated that the friction coefficient decreases with increasing the volume ratio of ice. On the other hand, the temperature dependence of the friction coefficient increased with the volume ratio of ice. From these experimental results, we constrained a friction law that expresses the relationship between ice volume ratio, temperature, and friction coefficient.
The rheological structure of the Martian lithosphere was calculated for 18 regions using the flow-law and constructed friction law. The temperature profile for Martian interior were calculated from the concentration of heat-producing elements as determined from Gamma Ray Spectrometer (GRS) data and from the heat conduction equation (Azuma and Katayama, 2017). The calculated rheological structures show that the presence of ice could reduce the lithospheric strength due to low friction coefficient of ice, leading to stress and shear localization. The lithospheric strength indicates the lowest value at the depth of temperature of 0 ºC, where the effect of water on friction changes from ice friction to pore pressure. In addition, we compared the elastic thickness calculated from the rheological structure with the observed elastic thickness. However, the cryosphere of Martian interior is not thick enough to influence the elastic thickness and it is difficult to estimate the distribution of subsurface ice of Mars from the elastic thickness. On the other hand, the calculated rheological structure of Mars for 18 regions indicated that the Martian lithosphere tends to be wet conditions.

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