Evolution of rheological structure of Mars

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Change of the rheological structure significantly influences the Martian evolution, which might results in the different tectonics operated in between Mars and Earth. Here we show the evolution of rheological structure of Martian lowlands (North Pole) and highlands (Solis Planum) under wet and dry conditions. The thermal state of the past and present planetary interior can be calculated from surface heat flow and the present-day abundance of the radioactive isotopes ^{238}U, ^{235}U, ^{232}Th, and ^{40}K [*Turcotte and Schubert*, 2002]. Rheological structure can be inferred from flow laws that indicate the strength of solids, which is dependent on strain rate, temperature, water content, and chemical composition [*Frost and Ashby*, 1982; *Karato and Jung*, 2003]. In plastic deformation region, power-law creep is generally used to infer the rheological structure and heat flow [*Grott and Breuer*, 2008; *Ruiz et al*., 2008; *Grott and Breuer*, 2010], and this type of flow law is commonly applied to high-temperature creep. However, the Peierls mechanism becomes dominant at low temperatures and high stresses [*Tsenn and Carter*, 1987]. In this mechanism, strain rate is exponentially proportional to applied stress. In this study, the Martian rheological structure is determined not only from Power-law creep but also from the Peierls mechanism and diffusion creep. In brittle deformation region, Byerlee’s law (m=0.6-0.85) is generally used to calculate the rock strength. We took the low frictional coefficient such as clay mineral (m=0.2-0.6) into account [Morrow et al., 2000; Kubo and Katayama, 2015].
The rheological structure of Mars determined in this study indicates that shallow deformation on Mars is mostly controlled by the Peierls mechanism, and that application of power-law creep on its own leads to an overestimation of lithospheric strength. The effect of water is also significant. Our results show that the presence of water would have delayed increases in lithospheric strength on Mars. Moreover recent studies found from the hydrogen isotopes in Martian meteorite that the water loss during the pre-Noachian was most significant [Kurokawa et al., 2014]. Given the evolution of water reservoirs on Mars, the lithospheric strength on Mars may have significantly increased at 4 Ga, suggesting that Mars changed to severe environment in where development of plate boundaries, plate motion, and plate subduction were limited.

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