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The temporal evolution of rheological structure of Martian interior

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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 238U, 235U, 232Th, and 40K [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, and chemical composition [Frost and Ashby, 1982; Karato and Jung, 2003]. Power-law creep is generally used to infer 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. 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. Our results show that the presence of water would have delayed increases in elastic and lithospheric thickness on Mars, in addition to decreasing the elastic thickness through reduced rock strength and the production of incompetent crust and mantle. The lithospheric strength of the North Pole for a wet rheology at 4 Ga might have had a moderate strength of 200?300 MPa. Likewise, the lithospheric strength of the Solis Planum at 2?4 Ga was probably moderate, indicating that the rheological structures of the North Pole at 4 Ga and of Solis Planum at 2?4 Ga under wet conditions might have allowed the formation of plate boundaries, which are necessary for the initiation of plate tectonics.

Keywords: Mars, Rheological structure, Plate tectonics, Lithosphere, Peierls mechanism, Temporal evolution