Effect of iron content on viscosity of ringwoodite and its implication for the rheology of the Martian mantle

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Viscosity of Martian mantle has been estimated to be 2-6×10^{22} Pa·s from glacial isostatic adjustment of Mars’ s north polar region, which is 1-2 orders of magnitude higher than that of the Earth (e.g., Lau et al., 2016; Samuel et al., 2019; Broquet et al. 2025). The Martian mantle is mainly composed of olivine and wadsleyite/ringwoodite as well as the Earth’ mantle and hence the viscosities of these minerals are key to understand the rheology of the Martian mantle. The previous study on olivine viscosity showed that Fo_{90}, which is representative of the Earth’ s mantle composition, is approximately one order of magnitude larger than that of Fo_{75}, which may be representative in the Martian’ s mantle. The lower viscosity of Mars can be explained by lower temperature in the Martian mantle estimated to be ~200 °C lower than that of the Earth (Samuel et al., 2022). On the other hand, viscosity of deeper portion of the Martian mantle is not constrained from mineral physics due to the lack of experimental data on the wadsleyite and/or ringwoodite. In this study, we conducted the deformation experiments on ringwoodite to investigate the effect of iron content on viscosity.

We prepared ringwoodite aggregates with Mg# 40 and 75 as starting materials at 19 GPa and 1200 °C. Then we deformed two ringwoodite samples simultaneously by D111-type high-pressure deformation apparatus at 17 GPa and 1200 °C with displacement rate of d-ram of 2 μm/min. The samples were arranged in series along the deformation axis to have the same stress in the cell assembly. After experiments, we estimated the strain rate during deformation from the change of sample lengths.

Deformation mechanism in the present study may be dominated by dislocation creep as well as previous olivine deformation (Zhao et al., 2009) from microstructural observation including the wavy grain boundaries and dynamic recrystallization during deformation. Strain rate of ringwoodite with Mg# 40 is only ~1.5 times larger than that with Mg# 75. This iron effect is much smaller than the effect on olivine (Zhao et al., 2009), indicating the more than one order of magnitude higher viscosity than that inferred from observations (Broquet et al. 2025). To understand the observed viscosity, we need to investigate the additional factors such as effects of water, microstructure, and deformation mechanism.

Keywords: Mars, Viscosity, Ringwoodite

