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Constraining viscosity of bridgmanite under lower mantle conditions

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The rheology of the mantle is a key factor which constrains the dynamics of convection as well as many geologic features. Mineral physics is an efficient approach to model rheology from the properties of minerals and rocks under high pressure. Bridgmanite, i.e. (Mg,Fe,Al)(Si,Fe,Al)O_3 with the orthorhombic perovskite structure is now considered to be the main constituent of the bulk lower mantle along with (Mg,Fe)O ferropericlase and $CaSiO_3$ perovskite. The rheology of this mineral is thus of primary importance. However, bridgmanite is only stable under lower mantle conditions for which measurements of mechanical properties are extremely difficult.

In this framework, the dislocation behaviour in $MgSiO_3$ bridgmanite was investigated in recent studies, in order to assess its creep properties. Dislocation glide appears to be extremely difficult under pressure (Kraych et al. 2016). However, this is not the only possibility for dislocations to move and produce strain. At high temperature, dislocations interact strongly with vacancies and by absorbing them, can move by climb. This deformation mechanism (dislocation climb), and possibilities for creep involving it, have received little attention although it had been originally suggested that it might be relevant for rheology in planetary interiors (Nabarro 1967). Boioli et al. (2017) have demonstrated by dislocation dynamics modelling that dislocations in bridgmanite moving by climb only could lead to steady-state creep with a strain-producing efficiency superior to diffusion creep. The main implication of this discovery is that the grain size is not a factor controlling rheology of bridgmanite in the lower mantle. Although pure climb creep is mediated by dislocation motion, diffusion represents the key to the rheology of bridgmanite.

In the present study, we revisit the available data on diffusion in bridgmanite under lower mantle conditions. The results are incorporated into a pure climb creep (Nabarro) model to propose constraints on the viscosity of bridgmanite in the lower mantle.

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