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The importance of phase morphology for rheology of ferropericlase-bridgmanite mixtures

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The rheology of the Earth's lower mantle is poorly constrained due to a lack of knowledge of the rheological behaviour of its constituent minerals. In addition, the lower mantle does not consist of only a single, but of multiple mineral phases with differing deformation behaviour. The rheology of Earth's lower mantle is thus not only controlled by the rheology of its individual constituents (bridgmanite and ferropericlase), but also by their interplay during deformation. This is particularly important when the viscosity contrast between the different minerals is large. Experimental studies have shown that ferropericlase may be significantly weaker than bridgmanite and may thus exert a strong control on lower mantle rheology.

Here, we thus explore the impact of phase morphology on the rheology of a ferropericlase-bridgmanite mixture using numerical models. We find that elongated ferropericlase structures within the bridgmanite matrix significantly lower the effective viscosity, even in cases where no interconnected network of weak ferropericlase layers has been formed. In addition to the weakening, elongated ferropericlase layers result in a strong viscous anisotropy. Both of these effects may have a strong impact on lower mantle dynamics, which makes is necessary to develop upscaling methods to include them in large-scale mantle convection models. We develop a numerical-statistial approach to link the statistical properties of a ferropericlase-bridgmanite mixture to its effective viscosity tensor. With this approach, both effects are captured by analytical approximations that have been derived to describe the evolution of the effective viscosity (and its anisotropy) of a two-phase medium with aligned elliptical inclusions, thus allowing to include these microscale processes in large-scale mantle convection models.