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Elongation inhibition in two-phase media due to surface tension effects

Marcel Thielmann[1,2] and Marcin Dabrowski[3]
[1]Bavarian Geoinstitute, University of Bayreuth, Bayreuth, Germany (marcel.thielmann@uni-bayreuth.de)
[2]Institute for Geosciences, University of Bonn, Bonn, Germany
[3]Computational Geology Laboratory, Polish Geological Institute, Wroclaw, Poland

The rheological properties of Earth's lower mantle have a strong impact on global mantle dynamics. Previous studies have shown that the deformation of the ferropericlase-bridgmanite mixture may be strongly controlled by the morphology of the weaker ferropericlase. Due to elongation of weak ferropericlase clusters, the bulk viscosity of the two-phase mixture is significantly lowered and become anisotropic. As a result, this transient microstructural evolution may have a strong impact on the overall rheology of the lower mantle.

Existing numerical models of this process often do not consider that the elongation of ferropericlase during deformation may be counteracted by interfacial diffusion. This diffusion reduces the interfacial energy and may result in an increased rounding rate that reduces the deformation-induced elongation. However, it is unclear under which conditions this process has an impact on the overall dynamics and bulk rheology of a two-phase mixture. A scaling analysis of the governing equations reveals that the dynamics of the given system are mainly influenced by the ferropericlase-bridgmanite viscosity ratio and by the ratio of viscous to interfacial forces.

To explore the impact of these two properties on the dynamics and bulk rheology of the ferropericlase-bridgmanite mixture, we employ numerical models. In these models, interfacial diffusion is approximated by adding a surface tension term to the governing equations and by directly resolving the ferropericlase-bridgmanite interface using body fitted meshes. The results show that for a range of model parameters, rounding due to surface tension may have a significant impact on the morphological evolution of the ferropericlase inclusions and may thus also exert some control over the rheology of the lower mantle.