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Detailed microstructure of two-phase lower mantle mineral analogs from SEM and EBSD

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The rheology and viscosity of the lower mantle influence convection, heat transport through the mantle, slab subduction, and many surface processes. Plastic flow in the lower mantle depends on the deformation mechanics of its constituent mineral phases – mostly bridgmanite, (Mg,Fe)SiO_3, with a smaller percent of the rheologically weaker ferropericlase, (Mg,Fe)O. For deformation in a (mostly) two-phase system with large strength contrast, such as in the lower mantle, microstructure greatly influences deformation and rheology.

We examined microstructures of an analog two-phase system of the lower mantle before and after deformation using scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD). Halite (NaCl) and neighborite ($NaMgF_3$) were used as analogs to lower mantle minerals ferropericlase (Mg,Fe)O and bridgmanite $MgSiO_3$, respectively, and deformed up to 50% strain at 4 GPa confining pressure and average strain rates of 2×10^{-3} s^{-1}in the D-DIA. One goal of our microstructural analysis is to help determine whether deformation in the bulk of the lower mantle occurs by diffusion creep or by dislocation creep, which has been long debated.

Previous X-ray diffraction and microtomography studies of these samples (Kaercher et al. *submitted*) show the weaker NaCl is likely interconnected at just 15 percent volume and greatly reduces crystallographic preferred orientation (CPO) in $NaMgF_3$, while NaCl itself develops either very little or heterogeneous CPO. New SEM and EBSD results show that NaCl deforms primarily by subgrain rotation recrystallization (a recrystallization mechanism active during dislocation creep) at 200°C, resulting in drastically reduced grain sizes. While we have less information for the $NaMgF_3$ due to difficulties polishing soft, hydrophilic NaCl and harder $NaMgF_3$ together, it appears that $NaMgF_3$ grains remain the same size. This suggests that periclase may control deformation in the lower mantle resulting in a weaker, more viscous lower mantle. Results here also demonstrate how dislocation creep may occur in the bulk lower mantle without producing large scale crystallographic preferred orientation and seismic anisotropy.