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Influence of olivine to wadsleyite/ringwoodite phase transformation on the rheology of the subducted slabs in the transition zone

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We conduct two sets of experimental studies to examine the influence of a phase transformation (from olivine to wadsleyite (and ringwoodite)) on the rheological properties of materials in the mantle transition zone including those in a subducting slab. First, we investigate the microstructural evolution during the olivine to wadsleyite phase transformation with the emphasis on grain-size and distribution of new grains. A series of experiments were conducted to transform olivine aggregates to form wadsleyite (and sometimes ringwoodite) under the controlled P-T-t paths. We observed both grain-boundary (heterogeneous) and intra-granular nucleation, and developed a model to map the dominant mechanism on the P-T space. Based on this model we simulate the microstructural evolution and found that although intra-granular mechanism dominates all cases at the beginning of the transformation, the final microstructure is controlled by grain-boundary nucleation. For the latter, we observed a quick "site saturation" along grain-boundaries followed by the growth of grain-size and the growth of wadsleyite layer into the olivine grains. The observed grain-size is controlled mostly by grain-growth not by the Avrami length as suggested by Riedel-Karato (1996, 1997). This model suggests strong influence of temperature and water content on the weakness of the newly formed wadsleyite necklace.

In addition, we performed the direct tests to compare the creep strength of olivine and wadsleyite (and ringwoodite) in the dislocation regime under the conditions in/near the transition zone. Our results show that at low water content, wadsleyite and ringwoodite are stronger than olivine in the dislocation creep regime, whereas when grain-size is reduced substantially, wadsleyite (and ringwoodite) becomes weaker than olivine.

Based on these observations we conclude that the rheology of the transition zone is controlled by a number of factors including grain-size, water content and temperature. Since grain-size is strongly affected by temperature and water content (Nishihara et al., 2006), we expect that there is an important feedback between rheological properties and temperature-water content in the transition zone. Consequently, the rheological properties of the transition zone are likely spatially heterogeneous and would evolve with time.

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