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Generalization of the microstructural evolution in polymineralic mantle shear zones: an attempt to make a grain size evolution map

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Localization of deformation in shear zones is a common feature in the Earth's crust and upper mantle (e.g., thrusts, strike slip faults). The evolution of such high strain zones is often long lasting, incorporating variations in physical (e.g. P, T) and chemical conditions with time. As previously inferred from studies on peridotite shear zones, second-phase minerals (e.g. spinel, pyroxenes) can be important in localizing strain as they can keep the olivine matrix grain size small. The influence of second phases on the olivine grain size and their affect on strain localization has not yet been quantified in detail.

To determine the importance of second phases in localizing strain in the mantle, three different peridotite shear zones (Semail, Oman; Othris, Greece and Lanzo, Italy) were analyzed and compared. For the three shear zones, a range of microstructures, from porphyroclastic tectonites to ultramylonites were investigated. These microstructures are related to continuous strain localization under retrograde conditions.

The microstructural analysis focuses on the influence of the second-phase content on the olivine grain size. To quantify the second-phase content, the Zener parameter (Z) is used, where Z=dp/fp; second-phase grain size/second-phase volume fraction. A small Z value corresponds to a high amount of second phases. Similar to previous studies performed on calcite mylonites, each of the different mantle microstructures can be subdivided into two different microfabric types: (a) second-phase controlled microstructures, where the olivine grain size increases with decreasing Z value. (b) recrystallization controlled microstructures, where the olivine grain size shows no dependence on the second-phase content and remains constant with increasing Z. The olivine grain size for both microfabric types becomes smaller with decreasing temperature and strain rate. Despite being active in different geodynamic frameworks, the investigated peridotite shear zones all show the same relation between the Zener parameter and the olivine grain size for the deformation under retrograde conditions. In terms of deformation mechanism, a change from dislocation creep towards diffusion creep dominated deformation can be inferred on the base of CPO weakening and grain size reduction with both decreasing Z and decreasing temperature.

The excellent correlation of the microfabrics between the different shear zones allows a generalization of the microstructural changes in form of a grain-size evolution map. From a geodynamic point of view, such maps provide great potential for the investigation of deformation in mantle shear zones because they can be applied as a tool to determine the deformation conditions in the mantle and their variations in space and time.