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Semi-brittle deformation of olivine

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Experiments on dunite were carried out in a servohydraulically-controlled deformation apparatus to analyze semi-brittle deformation of olivine, which can be expected to play an important role in the upper mantle of the oceanic lithosphere during the seismic cycle, e.g., at mid ocean ridge transform faults and in the downgoing slab or in the mantle wedge of subduction zones. The experiments were performed at RT, 300°C and 600°C, a constant strain rate of 10-4s-1 and confining pressures of 1.0 GPa, 1.5 GPa and 2.0 GPa. As starting material we used coarse-grained dunite from the Almklovdalen peridotite complex (Western Norway). The dunite comprises ca. 90% of olivine, ca. <10% orthopyroxene and small amounts of spinell and chlorite. The observed strength at 15% of permanent strain ranges from 0.8 GPa to 2.4 GPa. At 1.0 GPa confining pressure, all experiments yield differential stresses between Beyerlee-law and Goetze-criterium, indicating semi-brittle behaviour at all temperatures. In contrast, at higher confining pressure (2.0 GPa) and temperatures of 300°C and 600°C experiments yield differential stresses below Goetze-criterium, indicating a significant contribution of crystal-plastic deformation. The resulting microstructures were investigated by optical and electron microscopic techniques (SEM/EBSD, TEM). In agreement with the mechanical data, the microstructures reveal concurrent brittle and localized crystal-plastic deformation of olivine. In all experiments, transgranular cracks and sets of parallel intragranular microcracks occur in olivine. Most of the microcracks are oriented at $\sim$30° to 45° to the shortening direction. Some of the microcracks are crystallographically controlled. Adjacent to microcracks, olivine contains a high density of straight [001] dislocations. Shear zones developed in samples deformed at RT and 300°C.