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Experimental Deformation of Diopside Single Crystals at Mantle P and T: Mechanical Data and Deformation Microstructures

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Clinopyroxenes (cpx) are major constituents of eclogites and are present in excess of 10 vol.% at most depths in the pyrolitic upper mantle. Among mantle minerals, they exhibit the strongest anisotropy for seismic wave propagation. Cpx plastic properties may thus significantly affect both mantle rheology and seismic anisotropy. Yet, no study of cpx rheology at high-pressure (typically $P > 3$ GPa) has been reported so far, while recent developments in high-pressure deformation devices coupled with synchrotron radiation allow now investigating the rheology of mantle minerals and aggregates at the extreme pressure and temperature (T) of their natural occurrence in the Earth.

In order to investigate the effect of P on cpx rheology, steady state deformation experiments were carried out on gem quality oriented diopside crystals in the Deformation-DIA apparatus (D-DIA, see Wang et al., 2003, Rev. Scientific Instr., 74, 3002) that equipped the X17B2 beamline of the NSLS (Upton, NY, USA), at P ranging from 3.8 to 8.8 GPa, T in the range 1100°-1400°C, and with differential stress (σ) ranging between 0.2 and 1.7 GPa. Three compression directions were chosen in order to activate either $1/2$ <110>$\{1\bar{1}0\}$ dislocation slip (duplex) systems together, or [100](010) and [010](100) systems together, or again [001] dislocation slip in (100), (010) and {110} planes. Constant σ and specimen strain rates ($\dot{\varepsilon}$) were monitored in situ using time-resolved synchrotron X-ray diffraction and radiography, respectively. Transmission electron microscopy (TEM) investigation of the run products revealed that dislocation creep was responsible for sample deformation.

Comparison of the present high-P deformation data with data obtained at room-P - on similar diopside crystals deformed at comparable T-σ conditions (Raterron and Jaoul, 1991, JGR, 96, 14277) - allows quantifying the effect of P on the activity of $1/2$ <110>$\{1\bar{1}0\}$ duplex systems. This translates into an activation volume V^* = 17 ± 6 cm^3/mol in the corresponding creep power law. Our data also show that both $1/2$ <110> dislocation slips and [001] have comparable activities at mantle P and T, while [100](010) and [010](100) slip systems remain marginal. These results show that P has a significant effect on high-T dislocation creep in diopside, the higher the pressure the harder the crystal, and that this effect is more marked for $1/2$ <110> slips than for [001] slip. Our results also allow discriminating between the different assumptions proposed in the literature in visco-plastic self-consistent (VPSC) modelling of cpx aggregate deformation (e.g., Bascou et al., 2002, J. Structural Geology, 24, 1357), in order to better interpret the lattice preferred orientations (LPO) observed in naturally deformed eclogites.