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High temperature and high strain deformation of anorthite-diopside aggregates: contrasting rheological and microstructural data

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We investigated high-temperature creep of fine-grained anorthite-diopside two-phase aggregates with diopside contents of 25 - 50 vol.%. Samples were fabricated by hot isostatic pressing of fine-grained synthetic anorthite glass and natural crystalline diopside powders at T = 1150˚C and P = 300 MPa. Specimens consisted of fine-grained ($< 5\ \mu$m) anorthite matrix or anorthite/diopside matrix containing coarser diopside inclusions (20 – 100 μm). Samples contained traces of water (0.1 - 0.05 wt.%). In wet samples $<$ 1 vol.% melt was observed, but gain boundaries were found to be melt-free in transmission electron microscopy. Axial deformation tests were performed at T = 1000 – 1200˚C, P = 300 MPa, at constant flow stresses of 20 to 200 MPa. Torsion tests were carried out at T = 1070 – 1180˚C, P = 400 MPa, at constant torque or constant twist rate. We obtained equivalent shear strain rates of 3x10^{-4} to 4x10^{-5}s^{-1}.

In both axial and torsion deformation the samples presented dominantly Newtonian flow, with a stress exponent n = 1 indicating diffusion controlled creep. The flow laws obtained in axial and torsion deformation are comparable. Comparison with previously reported results shows that in general, strength of two-phase aggregates increase with increasing diopside content and grain size. In torsion, relative strength depended on initial loading conditions and strain.

SEM (scanning electron microscopy) of twisted samples showed substantial microfracturing of larger diopside inclusions and pronounced recrystallization of diopside rims. At diopside/anorthite interfaces observed in TEM (transmission electron microscopy) we often found very high dislocation densities and recrystallization features as dislocation arrays and cell structures. Both observations indicate substantial local stress enhancement and localized dislocation creep in the vicinity of diopside inclusions. Conversely, the fine grained matrix showed evidences of grain boundary sliding mechanisms as cavitaion coalescence leading to ductile damage. Cumulated microcracking of the diopside inclusions and the fine grained matrix resulted in sample failure at finite shear strains around 3.5. Our observations suggest that deformation of lower crustal ultramylonites may be largely dominated by Newtonian flow although local microstructures may indicate high dislocation creep activity.