Geophysical Research Abstracts
Vol. 17, EGU2015-11310, 2015
EGU General Assembly 2015

Deformation mechanisms of pyroxenes in a sheared mafic granulite from the Seiland Igneous Province (northern Norway)

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A detailed microstructural and EBSD study was performed on a sheared mafic granulite from the Seiland Igneous Province (northern Norway) to investigate the deformation mechanisms of clino- and orthopyroxenes in a continental lower-crust mafic shear zone. Shearing occurred at T ≈750-820 degC, P ≈0.75-0.95 GPa, following magmatic emplacement and granulite facies riequilibration under dry conditions.

The sample consists of clinopyroxene [Ca0.47,Mg0.35,Fe0.18]Si2O_3 + orthopyroxene [Ca0.1,Mg0.5,Fe0.4]Si2O_3 + plagioclase porphyroclasts (ranging in size from 25 to 650 μm) embedded in a fine-grained matrix (7 μm average grainsize) of cpx + opx + plag and qtz. The cpx and opx porphyroclasts show varying degrees of elongation, with the opx reaching aspect ratios up to 16 and the cpx reaching rare maxima of 7. Elongated opx grains display activity of the {100}<001> and {100}<010> slip systems. Many porphyroclasts have low aspect ratio (≈80% < 3) and show intracrystalline bands of recrystallized grains, as well as micro-boudinage with recrystallized grains in the boudin necks. All porphyroclasts have strong internal misorientations (undulatory and sweeping extinction) and a general lack of recovery features (subgrains). The new grains, with the same composition of the porphyroclasts, shows no host-control. The poly-phase matrix lacks of a crystallographic preferred orientation (CPO).

These results suggest that crystal plasticity was not the main deformation mechanism in opx and cpx, and that recovery leading to dynamic recrystallization was not efficient despite the high P-T conditions of deformation. The absence of a CPO in the poly-phase matrix and the well mixed phase distribution are consistent with grains-size-sensitive creep (GSS). We speculate that GSS creep in the matrix has imposed a bulk high strain rate, which hampered crystal plasticity and recovery. High strain rates produced work hardening, causing microcracking and microboudinage in many pyroxene porphyroclasts. Diffusion-assisted growth of cpx and opx fragments produced a fine-grained matrix that localized strain through diffusion creep and grain boundary sliding.

Our findings highlight the interplay between brittle and viscous processes even at conditions which typically show crystal plastic deformation. Although fracturing cannot accommodate strain at lower crustal conditions, it can be an effective grain-size reduction mechanism resulting in GSS creep and strain localization. Thermodynamic modelling and mineral chemistry will shed light on syn-kinematic metamorphic reactions and possible melt-rock interactions.