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Mineral reactions and strain localization in a sheared mafic granulite infiltrated by melt (Seiland Igneous Province, Norway)

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This study investigates the deformation mechanisms of a metagabbroic dyke experiencing syn-kinematic melt-rock interaction in a continental lower-crustal shear zone in the Seiland Igneous Province (northern Norway). Solid state shearing occurred at T ≈750-820 °C, P ≈0.75-0.95 GPa and was coeval with melt infiltration from dehydration melting of adjacent metasediments, as evident from thin leucosome veinlets within the dykes.
The mylonite consists of cpx [Ca0.47,Mg0.35,Fe0.18]SiO_3 + opx [Ca0.1,Mg0.5,Fe0.4]SiO_3 + pl (An77Ab22Or1) porphyroclasts with localized grt and ilm coronas, embedded in a fine grained matrix of cpx + opx + pl + qtz + ilm ± kfs. Porphyroclasts range in size (diameter) between 25 to 650 μm, whereas the fine grain matrix is consistently below 10 μm (average 4-7 μm). Porphyroclasts show varying degrees of elongation, with the opx reaching aspect ratios of 1:16 and the cpx reaching rare maxima of 1:7. Cpx and pl porphyroclasts are micro-fractured and micro-boudinaged with fine-grained material infill. Texturally, opx porphyroclasts display a marked crystallographic preferred orientation (CPO) and activity of the {100}<001> and minor {100}<010> slip systems, whereas cpx and pl porphyroclasts are randomly oriented. All porphyroclasts have strong internal misorientations (undulatory and sweeping extinction) and lack recovery features (subgrains). The fine-grained polyphase matrix wrapping the porphyroclasts displays weak to absent CPO, with the exception of opx that shows a {100} poles-to-planes maxima perpendicular to the foliation. Based on the microstructure, we argue that a large part of the matrix is the product of metamorphic reactions in the presence of melt. To test this hypothesis, the interaction between the studied mafic dyke and an adjacent felsic leucosome was modelled using Perple_X for P-T conditions ranging between 7-9 kbar and 700-1000°C. Results show that the syn-kinematic mineral assemblage (opx + cpx + pl + qtz + ilm ± kfs) can be the product of melt-rock interaction for melt fractions up to 20 wt% (at ca.850°C). Further constrains using the quartz abundance narrows this field.

We believe that melt infiltration during shearing has strong implications for the rock's rheology, as it promotes weakening by dramatic grain-size reduction through nucleation of fine-grained material. Interconnected fine grained material deforms by grain size sensitive creep (GSS), imposing high viscosity contrasts between porphyrclasts and matrix and hampering dislocation creep and recovery. Deformation by GSS creep is supported by the small grain-size (7μm average diameter), by lack of CPO in the matrix (except for opx, interpreted as a result of oriented grain growth) and by phase mixing. We ruled out dynamic recrystallization as a mechanism to produce the fine grained pyroxene matrix as there is no evidence of subgrains in the porphyroclasts.