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Strain localization in lower crustal shear zones due to granular flow of syndeformational reaction products

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Ductile shear zones are common in the Anorthosite-Mangerite-Charnockite-Granite (AMCG) suite in the Lofoten-Vesterålen islands (Northern Norway), and typically consist of narrow structures (1 cm to 1 m in thickness) with very sharp boundaries to the host rock. In this contribution we examine the deformation microstructures and synkinematic mineral assemblages of several shear zones developed from a mangerite (monzonite) protolith.

The mineral assemblage in the host mangerite indicates dry conditions (feldspars + clinopyroxene $\pm$ orthopyroxene), whereas the mineral assemblage in the shear zones consists of sodic plagioclase + K-feldspar + quartz + hornblende + calcite + biotite + ilmenite $\pm$ clinopyroxene and indicates hydrated conditions. Hornblende-plagioclase geothermometry yields upper amphibolite- to granulite facies conditions during shearing (727-753˚C, 0.5 GPa, at X albite=0.86).

The onset of strain localization is accompanied by the following breakdown reaction of clinopyroxene: clinopyroxene + sodic plagioclase + H2O+CO2 $\pm$ K-feldspar –> quartz + hornblende + calcite $\pm$ biotite. At the estimated deformation conditions, a marked rheological contrast between strong hornblende and weak quartz and calcite should be expected if the deformation were accommodated by intracrystalline plasticity. Quartz and calcite are expected to form elongated and flattened grains wrapping hornblende porphyroclasts. However, hornblende, quartz and calcite occur in polymineralic aggregates where all the three phases have equant shape and homogeneous grain size (18-24 μm). This kind of microstructure suggests that the reaction products have deformed dominantly by granular flow. This interpretation is supported by the common occurrence of isolated grains of hornblende at the triple junctions between quartz grains, consistent with heterogeneous nucleation of the amphibole.

Feldspars deform by pervasive cracking. New grains of sodic plagioclase and K-feldspar nucleate along cracks and form a bi-mineralic aggregate where the two phases show homogeneous grain size (mean grain size = 26 μm) and equant shape.

In summary, shear zone formation is invariably associated with a preliminary stage of cracking and fluid infiltration, which triggers syndeformational metamorphic reactions and grain size reduction. Cracking at the estimated deformation conditions requires high differential stresses, and indicates a high strength of the lower continental crust at the onset of the deformation. The high strength is likely to be explained with the original mineral assemblages being dry: The viscous deformation only proceeds associated with hydration reactions. Activation of diffusion creep processes takes place only in the reaction products. Whether mechanically weak or strong minerals are formed is irrelevant for the subsequent diffusion creep deformation.