Transient weakening in mafic rocks as a consequence of combined reactions and diffusion creep: localization of deformation in the strong lithosphere

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Non-metamorphosed mafic rocks dominantly consist of mechanically strong minerals: pyroxenes and plagioclase. From experimental data it is expected that these minerals can only deform by crystal plasticity at very temperatures, close to the solidus temperatures of mafic rocks. Yet, mafic rocks exhibit extensive viscous deformation structures and high strain features in many tectonic settings at lower temperature. Most instances of deformed mafic rocks indicate that deformation has taken place at different P,T-conditions than those of the crystallization of the original minerals. As plagioclase, pyroxene, and amphibole compositions are very sensitive to ambient P and T conditions, even small changes in the P,T-conditions cause the metastability of these minerals and will lead to a change in composition of existing phases or to nucleation of new phases, i.e., to mineral reactions. Reactions will cause at least transient weakening of the phase assemblage, because the dissolution of old and precipitation of new phases may be part of what can be termed « incongruent pressure solution » (Beach 1979). We will present examples from naturally and experimentally deformed rocks to explore these processes in more detail.

Naturally deformed eclogite samples from the Bohemian Massif and from the Tauern window show strong CPO of omphacite, consistent with previously observed patterns. Chemical data of omphacite and garnet indicate well developed mineral zoning for individual grains, pointing to preferential growth of omphacite and garnet in the elongation direction during deformation. Deformation took place over a large part of the prograde (pressure increasing) P,T-path. Garnet grains do not show any CPO. Aspect ratios of omphacite grains are higher than those of garnet indicating faster growth rates of omphacite in the elongation direction. These observations suggest deformation by diffusion creep rather dislocation creep. The results are consistent with low stresses during deformation. The CPO of omphacite appears to form from a preferential growth of grains, which have their [001] direction parallel to the extension direction during deformation (preferential growth of certain orientations). Garnet appears to grow preferentially in the extension direction regardless of the crystal orientation.

In experiments, two processes of diffusion creep deformation have been observed: (1) fibrous growth of new phases (typically amphiboles and pyroxenes) and (2) fine grained mixtures of at least 2 new phases. The grain size in fine grained phase mixtures is stabilized by pinning of grain boundaries. Both processes may occur in combination and produce microstructures common in naturally deformed rocks. In this way, at least transient weakening can be induced during metamorphic reactions, even if reaction products can be mechanically strong minerals.

Beach, A., 1979. Pressure solution as a metamorphic process in deformed terrigenous sedimentary rocks. *Lithos*, 12, 51-58