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► **To cite this version:**

Sina Marti, Renée Heilbronner, Holger Stünitz, Oliver Plümper, Martyn Drury. Solution-mass transfer and grain boundary sliding in mafic shear zones - comparison between experiments and nature. 19th EGU General Assembly, 2017, Vienne, Austria. pp.3203. hal-03552762

HAL Id: hal-03552762

<https://hal.science/hal-03552762>

Submitted on 2 Feb 2022

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Solution-mass transfer and grain boundary sliding in mafic shear zones – comparison between experiments and nature

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Grain size sensitive creep (GSSC) mechanisms are widely recognized to be the most efficient deformation mechanisms in shear zones. With or without initial fracturing and fluid infiltration, the onset of heterogeneous nucleation leading to strong grain size reduction is a frequently described process for the initiation of GSSC. Phase mixing due to reaction and heterogeneous nucleation during GSSC impedes grain growth, sustaining small grain sizes as a prerequisite for GSSC.

Here we present rock deformation experiments on 'wet' plagioclase – pyroxene mixtures at $T=800^{\circ}\text{C}$, $P=1.0$ and 1.5GPa and strain rates of $\sim 2\text{e-}5 - 2\text{e-}6$ 1/s, performed with a Griggs-type solid medium deformation apparatus. Microstructural criteria are used to show that both, grain boundary sliding (GBS) and solution-mass transfer processes are active and are interpreted to be the dominant strain accommodating processes. Displacement is localized within shear bands formed by fine-grained ($\sim 300 - 500\text{nm}$) plagioclase (Pl) and the syn-kinematic reaction products amphibole (Amph), quartz (Qz) and zoisite (Zo).

We compare our experiments with a natural case - a sheared mafic pegmatite (P-T during deformation $\sim 0.7 - 0.9$ GPa, $610 - 710^{\circ}\text{C}$; Getsinger et al., 2013) from Northern Norway. Except for the difference in grain size of the experimental and natural samples, microstructures are strikingly alike.

The experimental and natural P- and especially T-conditions are very similar. Consequently, extrapolation from experiments to nature must be made without a significant 'temperature-time' trade-off, which is normally taken advantage of when relating experimental to natural strain rates. We will discuss under which assumptions extrapolation to nature in our case is likely feasible.

Syn-kinematic reactions during GBS and solution-mass transport are commonly interpreted to result in an ordered (anticlustered) phase mixture. However, phase mixing in our case is restricted: Mixing is extensive between Pl + Zo + Qz and Amph + Qz, but clustering is common between Pl + Amph. We present microstructural evidences, that phase mixing between Pl and Amph (the most abundant phases) is enhanced by the presence of quartz. Accordingly, quartz forming reactions or external sources (e.g. through fluid infiltration) may play a crucial role in deformation of mafic rocks, which has not been recognized thus far.