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Experimental deformation of a mafic rock – interplay between fracturing, reaction and viscous deformation

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Deformation experiments were performed on natural Maryland Diabase ($\sim 55\%$ Plg, 42% Px, 3% accessories, 0.18 wt.-% H_2O added) in a Griggs-type deformation apparatus in order to explore the brittle-viscous transition and the interplay between deformation and mineral reactions. Shear experiments at strain rates of $\sim 2e-5$ /s are performed, at $T=600, 700$ and $800^\circ C$ and confining pressures $P_c=1.0$ and 1.5 GPa.

Deformation localizes in all experiments. Below $700^\circ C$, the microstructure is dominated by brittle deformation with a foliation formed by cataclastic flow and high strain accommodated along 3-5 major ultracataclastic shear bands. At $700^\circ C$, the bulk of the material still exhibits abundant microfractures, however, deformation localizes into an anastomosing network of shear bands (SB) formed from a fine-grained ($\ll 1 \mu m$) mixture of newly formed Plg and Amph. These reaction products occur almost exclusively along syn-kinematic structures such as fractures and SB. Experiments at $800^\circ C$ show extensive mineral reactions, with the main reaction products Amph+Plg (+Zo). Deformation is localized in broad C' and C SB formed by a fine-grained ($0.1 - 0.8 \mu m$) mixture of Plg+Amph (+Zo).

The onset of mineral reactions in the $700^\circ C$ experiments shows that reaction kinetics and diffusional mass transport are fast enough to keep up with the short experimental timescales. While in the $700^\circ C$ experiments brittle processes kinematically contribute to deformation, fracturing is largely absent at $800^\circ C$. Diffusive mass transfer dominates. The very small grain size within SB favours a grain size sensitive deformation mechanism. Due to the presence of water (and relatively high supported stresses), dissolution-precipitation creep is interpreted to be the dominant strain accommodating mechanism. From the change of Amph coronas around Px clasts with strain, we can determine that Amph is re-dissolved at high stress sites while growing in low stress sites, showing the ability of Amph to accommodate strain via dissolution precipitation creep.

The transition from dominantly brittle, to dominantly viscous deformation is determined by the onset of diffusive mass transport. In the transitional regime, reaction kinetics are strongly dependent on strain energy and viscously deforming SB form most likely from an initial brittle stage in a dominantly brittle behaving rock. Viscous deformation in our experiments takes place at comparatively low experimental T , providing a realistic phase assemblage and likely deformation mechanism for the lower crust.