

Coupling of reactions and deformation at high pressure and temperature: experiments on plagioclase-pyroxene assemblages

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Synkinematic mineral reactions play an important role for the mechanical properties of polymineralic rocks. Mineral reactions (i.e. nucleation of new phases) lead to grain size reduction and produce fine-grained polymineralic mixtures, which have a strongly reduced viscosity because of the activation of grain-size sensitive deformation processes. The deformation processes significantly enhance mineral reaction rates during the metamorphic evolution.

In order to study the effect of chemical composition on the reaction/deformation processes we have performed rock deformation experiments on 'wet' (~ 0.1 w.t.% H_2O) assemblages of plagioclase-pyroxene assemblages in a Griggs-type solid-medium deformation apparatus. As representative of the lower crust, the starting material was composed of plagioclase (PLG: An60), and two types of orthopyroxenes: one Mg-rich OPX (from peridotite, En89-Fs10) and one Fe-rich OPX (from granulite, En70-Fs29). The starting grain size was ~ 10 to $20 \mu m$. Deformation experiments were conducted at constant shear strain rate of $10^{-5} s^{-1}$, a confining pressure (P_c) of 1 GPa and temperatures ranging from 800 to 900°C.

In all samples, the assemblages with a larger amount of reaction products at peak stress are significantly weaker than the ones with less reaction products, demonstrating that reaction progress is a first-order control on strength. In addition, PLG + Mg-rich OPX samples show a more pronounced weakening after initial peak stress compared to PLG + Fe-rich OPX samples. This effect is caused by differences in the connectivity of weak material constituted by reaction products. The connectivity is a complex variable, which results from the interrelationship of strain and reaction progress, and it varies between the two starting materials (Fe-OPX vs. Mg-OPX), for the same proportions of OPX + PLG.

Both assemblages of PLG + Fe-OPX and PLG + Mg-OPX deformed to high shear-strain show abundant reaction products, which include amphibole (AMPH), OPX of different composition, and Na-rich-PLG, but AMPH and Na-rich PLG in the PLG + Fe-OPX assemblages grows mainly as thick coronas around the OPX in low-strain zones and as partly interconnected aggregates in high-strain zones. In contrast, in PLG + Mg-OPX the reaction products are dominated by OPX. These reaction products are very fine-grained and more connected, forming high-strain zones through the sample. Thus, the main differences between Fe- and Mg-rich OPX assemblages are: (i) Larger grain size in Fe-OPX assemblages and (ii) More interconnected reaction products in Mg-OPX assemblages. Experiments conducted at identical P,T-conditions, but without deformation (hydrostatic expts.) or deformed only to peak stress show a much smaller amount of reaction products, distributed as thin discontinuous rims along PLG-OPX interphase boundaries. This indicates that deformation significantly accelerates reaction progress.

When applied to natural shear zones, our experimental results suggest that the feedback between deformation and mineral reactions can lead to very large differences in mechanical strength caused by small initial differences in composition of the minerals.