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Experimental deformation, partial melting, and compositional changes in perthitic K-feldspar at high pressure and temperature

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Feldspars are the most abundant minerals in the continental crust and therefore it is fundamental to understand their deformation processes in order to determine the rheology and the mechanical properties of the continental crust. There are only few mechanical data available for K-feldspar and its deformation mechanisms at high pressure and temperature are still poorly understood.

We performed (i) axial compression experiments on natural perthitic K-feldspar single crystals (compression normal to the {010} plane), (ii) shear experiments (on 10-20 μm grain size powder obtained from the same perthitic K-feldspar) and (iii) hydrostatic experiments (on powder and single crystals). The experiments were carried out in a solid medium Griggs-type deformation apparatus at T of 900°C, confining pressures varying form 0.75-1.5 GPa and axial shortening ranging from 3 to 40% at a strain rate of $\sim$ 10-6 s-1.

The mechanical data for K-feldspar at 900° C and 1.0 GPa indicate flow stresses of 450-500 MPa (clearly below the Goetze criterion) and a decrease in peak strength with increasing confining pressure (flow stress at 1.5 GPa is 330 MPa), suggesting that the deformation is at least partly accommodated by viscous processes. However, microstructural observations reveal that the deformation is localized along conjugate cracks, where we observe formation of gouge, compositional changes (homogenization of the composition), presence of melt, nucleation and growth of new grains, and increased porosity.

Compositionl homogenization is related to the cracking processes (homogenized zones have the same orientation as the cracks and shear zones (40° to σ1)). The fine-grained fragments of the gouges have an intermediate chemical composition between the K-feldspar (Ab8 An0 Or92) and the albite lamellae (Ab98 An1 Or1) of the starting material. Locally, homogenization seems to overgrowth and heal the cracks and is generally associated with development of porosity.

The presence of melt has been detected by SEM and light microscope. In the single crystal experiments the melt pockets are distributed along homogenized zones and are therefore related to the cracks. The melt pockets commonly contain small crystals (<10μm) with an idiomorphic shape and an intermediate chemical composition (Ab25 An1 Or74). Along cracks with displacement those crystals are oriented. In experiments with powders the melt fraction is higher and is distributed around the single grains, which are completely homogenized (Ab 21 An0 Or79).

Based on the observations described above we suggest that the deformation of feldspar at high pressure and temperature is promoted by fracturing, which produces conjugate cracks and fine grained gouge. Melt is segregated along the cracks and accommodates the viscous deformation (facilitating the movement along the cracks (lubrication)), but it does not produce a pronounced weakening of the rock. Homogenization, which is also triggered by cracking, appears to occur by dissolution-precipitation creep, where the very fine fragments of the gouge act as nucleation sites. The porosity is interpreted to be the residual intragranular free space of the gouge, which has been homogenized and partially healed.