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A combined structural and numerical analysis of fine-grained siliciclastic rocks to quantify the rheological parameters during ductile flow in the middle crust

I. Kenis (1), J.L. Urai (2), W. van der Zee (2,3), Ch. Hilgers (2), M. Sintubin (1)

1. Structural Geology and Tectonics group, K.U.Leuven, Belgium
2. Geologie-Endogene Dynamik, RWTH Aachen, Germany
3. Now at the GeoMechanics International, Mainz, Germany

A long-standing problem involves the quantification of the constitutive equations that describe the rheology of the middle crust (7-12 km). Modelers commonly use generic viscosity contrasts or laboratory-derived flow laws under the assumption that they can be extrapolated over several orders of magnitude to geological conditions. The upper part of the crust is usually modeled using a brittle-frictional faulting rheology, whereas the lower part is described using power-law creep equations describing crystal-plastic flow of monomineralic rocks. However, at present, laboratory methods are not sufficient to accurately constrain the rheology of polyphase rocks deforming in the subsurface at geologic strain rates. Moreover, solution transfer processes play an important role in allowing low stress and their contribution to the overall ductile deformation in major shear zones, subduction zones,... is highly underestimated and generally not been taken into account in geodynamic models. As a consequence the strength of polyphase quartz-rich rocks located in the middle crust may be much lower than predicted by conventional models based on flow laws from dislocation creep. Additional constraints on rock rheology are needed from careful field and observational studies and mechanical modeling.

We present a combined structural and numerical analysis of fine-grained siliciclastic rocks deformed in the middle crust at around 350-400 ºC. We use these as natural laboratories to quantify the rheological parameters during flow at geologic strain

rates. The results of our analysis demonstrate that fine-grained siliciclastic rocks in the middle crust have a Newtonian viscous rheology, approximately ten times weaker than wet quartz. These results are in good agreement with the microstructures in the fine-grained siliciclastics showing that the dominant deformation mechanism in these rocks during ductile deformation in the middle crust is pressure solution creep. As a consequence, the strength of polyphase quartz-rich rocks located in the middle crust is much lower than predicted by conventional models based on flow laws from dislocation creep. Because fine-grained siliciclastic rocks control the rheology of the middle crust in many sedimentary basins, our results provide new quantitative parameters for geodynamic modelling in which a flow law for dissolution precipitation is essential.