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Combining natural microstructures with composite flow laws: An improved approach for the extrapolation of lab data to nature?

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In order to predict rheology of deformed natural rocks, geologists have to rely on the extrapolation of lab data towards natural conditions via constitutive flow laws. The fundamental requirement for this procedure, however, is the occurrence of identical processes in the lab and in the natural example resulting in the same microstructures. In case of high strain mylonites, for example, dynamic steady state microfabrics develop resulting in specific grain size distributions (CSD), shape preferred orientations (SPO) and crystallographic preferred orientations (CPO). Although stable on the sample-scale, these parameters change continuously on the grain-scale and are maintained by the balance of different fabric modifying processes (e.g., grain size reduction vs. grain growth). The contribution of the individual processes, however, will change in dependence of the physical and chemical conditions during deformation. In order to apply an experimentally derived flow law in nature, it is therefore not only required that the same processes occurred in the experimental and natural sample but also that their relative rates were identical. These points, however, are highly questionable since many of the physical parameters (e.g. strain rate) have to be extrapolated over several orders of magnitudes.

A way out of this problem can be found by combining full grain size distributions with composite GSS+GSI flow laws. In this way, competing end member flow laws can adjust each other in dependence of the steady state microfabric and the physical conditions of deformation. We applied this approach to natural carbonate mylonites from the Helvetic Alps, Switzerland. For steady state microstructures, our calculations

indicate an increasing GSS component with increasing temperature at geologically constrained strain rates of 10^{-10} – 10^{-11} s^{-1}. The modeling results are consistent with microstructural observations of the natural mylonites: in these rocks, dynamically steady state microfabrics show a systematic change in grain size, grain size distribution and grain aspect ratio with temperature while crystallographic preferred orientations remain of similar strength. When single value mean grain sizes are used rather than grain size distributions, rheological modeling fails to give reasonable results. Further, paleostresses estimated from conventional recrystallized grain size piezometers were found to be unrealistically high, but were reduced to 80-100 MPa when results of the composite modeling were used. Hence, combining composite flow laws with microstructural data from natural mylonites forms a promising approach for a better extrapolation of experimental data to nature and therefore provides new insight into changes in rheology during large-scale geodynamic processes.