Geophysical Research Abstracts
Vol. 15, EGU2013-7469, 2013
EGU General Assembly 2013

Evaluating flow laws for dynamically recrystallized quartz based on field data

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The extrapolation of experimentally controlled deformation conditions, and the resulting relations between physical parameters acting during ductile deformation, to nature is considered controversial (see Herwegh et al., 2005 and references therein). Whereas the relationship between flow stress and recrystallized grain size can be empirically derived from lab experiments using paleopiezometers (e.g. Stipp & Tullis, 2003), the relation between recrystallized grain size, strain rate, differential stress, temperature and activation energy for dislocation creep requires further constraints. For these relations, various power law flow laws for dynamically recrystallized quartz were proposed over the past years (Paterson & Luan, 1990; Luan & Paterson, 1992; Gleason & Tullis, 1995; Hirth et al., 2001, Rutter & Brodie, 2004). The variations in the flow laws are mainly characterized by different starting materials, experimental conditions, the activation energy for dislocation creep and the stress exponent n.
In this study we compare and evaluate experimentally derived flow laws regarding their reliability for the prediction of rheology of background deformation of naturally deformed crystalline samples from mylonites of the Aar massif (Swiss Central Alps).

The majority of samples comprises highly deformed rocks (e.g. Central Aare granite), which exhibit severe grain size reduction. This reduction dominantly occurred by subgrain rotation (SGR), in the case of low temperature overprint by bulging recrystallization (BLG). Towards elevated temperatures, grain boundary migration (GBM) and SGR recrystallization were active. Along the metamorphic gradient (300 - 475°C) quartz microstructures and associated recrystallized grain size distributions indicate steady state mean grain sizes. The quantification of the metamorphic gradient (temperature, pressure, water fugacity) over the sampling area allowed the application of flow laws, yielding variations of 6 orders of magnitude in deformation rates between different calibrations for one corresponding grain size. The calibrations of Paterson & Luan (1990) and Hirth et al. (2001) yield most reliable results for peak metamorphic conditions, which are in line with the geological framework. Strain rates range between 10E-13 and 10E-10 s-1 (Paterson & Luan, 1990) with corresponding flow stresses between ca. 200 MPa (BLG) to ca. 20 MPa (SGR and transition SGR-GBM). Nevertheless, the applicability of single flow laws shall be discussed in greater detail.

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