Geophysical Research Abstracts
Vol. 12, EGU2010-9460, 2010
EGU General Assembly 2010

Shear rates measurements in natural shear zones using quartz piezometers.

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Whether deformation within the deep continental crust is fundamentally concentrated in narrow shear zones or distributed in wide zones stays a major controversy of the earth sciences. This is in part because direct measurements of ductile strain or strain rate are difficult, especially when deformation is intense as it is the case in ductile shear zones. Paleo-shear stress can be evaluated by using paleo-piezometers that link shear stress to the size of recrystallized minerals. Such piezometers are calibrated by microphysical models or experimental studies. Indirect measurements of strain rate in natural rocks can be achieved using shear stress, an estimation of the temperature of deformation, and assuming a flow law. However, such estimates have rarely been validated by independent constraints. By comparing shear rates calculated from paleopiezometry, and measured in situ in the same outcrop we determined the more appropriate paleopiezometer and power flow law in order to generalize the method to other outcrops.

Within the Ailao – Red River shear zone (ASSR, SE Asia) paleo strain rates during the Miocene left-lateral shear are estimated between 1*10-13 s-1 and 2*10-13 s-1 from tectonic considerations. At site C1, by combining dating of syntectonic dykes and measurements of their deformation, the strain rate is calculated between 3 and 4*10-14 s-1 between 29 to 22 Ma, (Sassier et al., JGR, 2009). Quartz ribbons of sample YY33 from the same outcrop show continuous dynamic recrystallisation (DRX) mechanisms, characterized by subgrain rotation nucleation, and growth by grain boundary migration (Shimitzu et al. JSG, 2008). This dislocation creep regime is compatible with the microphysical models of Twiss (Pure Ammp. Geoph., 1977) and Shimitzu (JSG, 2008) and the experimental piezometer of Stipp and Tullis (GRL, 2003). The measured quartz grain size range between 10 and 960 µm, while the mean recrystallized grain size is 112.2 ± 1.5µm. The associated paleostress is 29.14 ± 4.71 MPa with Shimitzu et al. (JSG, 2008) piezometer, which is the most appropriate given the grain size. Quartz lattice preferred orientation (LPO) suggests deformation temperatures around 400 °C. The calculated strain rate is 2.3*10-14 s-1 with Hirth (J. Earth Sciences, 2001) flow law or 3.9*10-16 s-1 with that of Gleason and Tullis (Tectonophysics, 1995). Strain rates in natural quartz ribbons under conditions of regime of continuous DRX appear better approximated by the paleopiezometer method if using Hirth (J. Earth Sciences, 2001) power flow law.

We have applied that method to several samples of the ASRR and Karakorum shear zone. Using the Shimitzu piezometer and the Hirth flow law, we measured paleo-stress ranging between 19.7 and 41.3 MPa for the ASRR and between 15.1 and 35.1 MPa for the Karakorum fault zone. Corresponding deformation temperatures are respectively at 400 – 600°C and 450 – 500°C. The associated strain rates range from 5.7*10-15 s-1 to 2.2*10-12 s-1 in the ASRR and from 1.7*10-15 s-1 to 2.5*10-13 s-1 for the Karakorum. The dispersion of the values can be interpreted in terms of localization of the deformation within the ductile shear zones and local geothermal gradient.