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# Testing paleo-piezometers: constraints from a natural example

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Whether deformation within the ductile continental lithosphere 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 strain or strain rate are difficult, especially when the deformation is intense like in ductile shear zones. It is thus important to measure other physical parameters like shear stress and temperature that may help to evaluate the strain rate. Shear stress is measured by using paleo-piezometers that link shear stress with the size of the recrystallized minerals (olivine, quartz or feldspar). Such piezometers are calibrated by microphysical models or experimental studies. Some have been used in natural examples to estimate shear stress and even strain rates by considering the temperature of deformation and assuming a flow law. However, such estimates have rarely been validated by independent constraints. We have tested quartz paleo-piezometers within a major shear zone (the Red River Shear Zone, SE Asia) where the average strain rate can be evaluated from large scale constraints.

From quartz microstructures in thin sections, we identify mechanisms of dynamic recrystallisation as belonging to dislocation creep regimes 2 and 3. The microphysical model of Twiss (*Pure Appl.Geoph.*, 1977) and the experimental piezometer of Stipp and Tullis (*GRL*, 2003) are considered to be the most suitable piezometers for these dislocation creep regimes. The recrystallised grain sizes measured in each samples vary between 70 and 120 $\mu$m. Associated mean stresses vary between 15.62 MPa to 23.43 MPa with the Stipp and Tullis's piezometer and between 24.12 MPa and 34.06 MPa with the Twiss piezometer. From the LPO of quartz, we have determined the deformation temperature for each sample and calculated the corresponding strain rate using a classical power flow-law. The flow law leads to strain rates between 2.10 $*10^{-14}s^{-1}$ and 8.07$*10^{-13}s^{-1}$ with the shear stresses from the

experimental piezometer; whereas the strain rates are between 1.24*$10^{-13}$s$^{-1}$ and 3.65*$10^{-12}$s$^{-1}$using the Twiss piezometer.

Three independent constraints on the Red River Shear Zone give slip rates between 3 and 6 cm/yr from 32 to 15 Ma. For a 10 km wide shear zone, this corresponds to strain rates between 1*$10^{-13}$s$^{-1}$ and 2*$10^{-13}$s$^{-1}$. We conclude that both the experimental and theorical piezometers are applicable in natural examples under conditions of creep dislocation regimes 2 and 3 and for strain rates on the order of $10^{-13}$ s$^{-1}$. The Stipp and Tullis's piezometer appears to be valid for larger recrystallised grain sizes than those advised by the authors but tends to underestimate shear stress, whilst the Twiss tends to overestimate it.