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Stress Measurements in the Earth's Crust – Recrystallized Grain Size Piezometry Revisited

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The dynamically recrystallized grain size is the most reliable paleo-piezometer to determine the differential stress in the Earth's crust and mantle. Knowledge on the stress magnitude is enigmatic to quantify tectonic processes in orogens and plate tectonic forces in general. Owing to this significance, a considerable number of research groups has proposed different theoretical concepts of piezometers in the last couple of years. The recrystallized grain size has been suggested to be not only a function of stress, but also of temperature, strain rate, strain and other parameters. In the meantime, data of experimental studies and from natural shear zones have been collected. Hence, empirical piezometer models and theoretical concepts can be confronted with these data sets. A recrystallized grain size compilation of quartz mylonites from shear zones worldwide indicates that specific grain sizes are less frequent corresponding to transitions in the recrystallization mechanisms. This indicates that the recrystallized grain size development is significantly controlled by the different recrystallization mechanisms in natural mylonites. This relationship should be constrained by any valid piezometer or dynamic recrystallization model which is, however, not the case. Most of the piezometer models assume a temperature dependence via an activation energy term. While the majority of these models predicts a decrease in recrystallized grain size with increasing temperature one implies an increase with increasing temperature. However, neither a decrease nor an increase has reliably been shown by deformation experiments on different minerals. In fact, experimental data on dislocation creep of quartz do not show any temperature-dependence within the error of the given stress-recrystallized grain size measurements. A strain rate dependence is – if at all – less important and also not constrained by experimental data. Also a water-dependence of the piezometer does not exist for quartz and there is contradicting experimental evidence for olivine. Experimentally deformed quartz samples display 2d- recrystallized grain size distributions close to a normal distribution with a slight tendency to a positive skewness. The dispersion of the distribution does not change over the experimental range of strain (7 – 46 %) and also not with the volume proportion of recrystallized grains (2 – 60 %). Hence, increasing strain does not change the recrystallized grain size distribution. In summary, no dependence on temperature, strain rate, strain, grain size distribution and water content can be observed for the quartz piezometer. There is only evidence for the dependence on the recrystallization mechanism. Therefore, it is recommended to refer to the original empirical piezometer relationship in which the recrystallized grain size is only a function of the differential stress when measuring stress in the Earth's crust.