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A note of caution on the use of quartz c-axis opening angle as deformation thermometer

Rüdiger Kilian (1), Luiz Morales (2), and Michael Stipp (3)

(1) University Basel, Department of Geosciences, Basel, Switzerland (ruediger.kilian@unibas.ch), (2) ScopeM - ETH Zürich, Switzerland, (3) Institute of Geology, Faculty of Geo- and Atmospheric Sciences, University of Innsbruck, Austria

A common feature of quartz crystallographic preferred orientations (CPO) is the presence of an opening angle on c-axis pole figures. The opening angle is defined by the angle of the arc between the intersection of girdle-shaped or distinct point maxima with the periphery of the pole figure in a standard kinematic reference frame (XYZ-tectonic reference frame with Y parallel to the center of the pole figure). It has been observed to systematically vary with metamorphic grade and is suggested to serve as a geothermometer and is thought to reflect the synkinematic temperature of quartz deformation (e.g. Law, 2014; Faleiros et al., 2016). There are, however, a number of caveats related to the method, as it remains unclear if and how strain, strain rate, water content, recrystallization mechanism, or other parameters influence the final CPO. Additionally, the way the opening angles are measured might be a big source of error, leading consequently to different temperatures for the same sample. Similar to naturally deformed quartz, opening angles have been determined for experimentally deformed quartz rocks (at very different temperatures and strain rates) and even pressure corrections have been suggested. However, no reasonable physical explanation has been given in way given as to why the c-axis opening angle should scale with temperature and why such corrections should be valid.

CPO data obtained from experimentally deformed Black Hills Quartzite, a quartzite mylonite of the Moine Thrust and other natural examples are presented to stimulate a discussion on the usability of the opening angle as a thermometer. Two of the addressed issues are (i) if the result may critically depend on the exact way the opening angle is measured and more importantly, (ii) if within a single sample or experiment, the opening angle varies significantly without evidence for temperature fluctuations but may be controlled by other factors such as variations in the dynamic recrystallization microstructure. We found, for example, within a single experimental sample deformed at a fixed temperature and certain deformation conditions (e.g. at 915°C, 1.5 GPa and a strain rate of 1e-5 /s) an opening angle increase with an increasing aspect ratio of the quartz grains. Similar trends can be observed for variations in grain size or the amount of intragranular deformation. Based on those observations, we suggest that the processes which control the opening angle in quartz c-axis pole figures are not sufficiently understood to allow for the opening angle to be used as a thermometer.

References:

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