Development of ‘Subgrains’ by Water-Assisted Cataclasis

Bas den Brok
Geologisches Institut ETH, Sonneggstrasse 5, CH-8096 Zürich, Switzerland.
denbrok@erdw.ethz.ch

Minerals deformed ductile are often broken-up in numerous small ‘subgrains’, especially in case of quartz when deformed under Greenschist facies metamorphic conditions. Prior to about the nineteen sixtees, such subgrains were seen as a product of *cataclastic* deformation, of ‘crushing’ of the minerals. The subgrains were assumed to be slightly rotated fracture-fragments (clasts) healed together afterwards. The presence of abundant tiny fluid inclusions frequently observed at subgrain boundaries was held indicative of the role of water in the healing process. Nowadays, subgrains are believed to develop by dislocation creep, and the ‘old’ idea of cataclastic subgrain formation has been abandoned. The presence of subgrains is even used as an argument for dislocation creep. Yet, there is clear experimental evidence that subgrains *can* (also) be formed by cataclasis. When quartz is deformed ductile in the presence of ~1 vol% of added water at high P-T conditions in a Griggs machine, deformation by slow, rate-dependent, water-assisted cataclasis (WAC) takes place and subgrains are developed. These experimental subgrains cannot easily be distinguished from natural examples. Apparently there are subgrains and subgrains, and different mechanisms can lead to their formation. The question is how to distinguish the ones from the others.

Subgrain formation by WAC can be studied *in-situ*, under the microscope, on very soluble elastic-brittle salts (K-alum, Na-chlorate). From such *in-situ* observations we learned much about subgrain formation by WAC. The most important and unexpected observations made are: (i) WAC is a slow and rate-dependent process. (ii) Microcrack propagation direction is extremely sensitive to local stress, which is strongly affected by the cracking itself. Cracks therefore generally are not straight, but have irregular shape, suddenly make large turns. Cracks locally even propagate perpendicular to the maximum bulk compressive stress (like with pressure solution undercutting). (iii). Once formed, the cracks may continue changing shape, at least as long as the samples are under stress. Straight parts of cracks may become irregular in shape due to instability of the crack walls, irregular parts of cracks may become straight, maybe driven by minimalising crack surface energy. (iv). Cracks also migrate sideways (possibly because of differences is stress between the opposing crack walls). In this way fracture fragments change shape and start to look more like grains and subgrains.

Further study is needed to look for criteria by which ‘dislocation creep subgrains’ can be distinguished from ‘cataclastic subgrains’.