den Brok, S.W.J. (1994) Development of crystal plastic like deformation microstructures in quartz by micro-fracturing and solution/precipitation creep. 5. Symposium Tektonik - Strukturgeologie - Kristallingeologie, Göttingen, 7-9 April 1994. Göttinger Arb. Geol. Paläont., Sb1, 37-38, 1994.

DEVELOPMENT OF CRYSTAL PLASTIC LIKE DEFORMATION MICRO STRUCTURES IN QUARTZ BY MICRO FRACTURING AND SOLUTION/PRECIPITATION CREEP

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In deformation experiments performed with a Griggs-type solid-medium apparatus on natural quartz mono- and polycrystals (grain size 150-250 µm) at a temperature of 800°C, a confining pressure (P_c) of 1200 MPa, a strain rate of 10^{-7} s^{-1}, finite uniaxial compressive strains in the range 0.1-0.5, and in the presence of ~1 vol-% of added water (at a pressure approaching P_c) a deformation microstructure was developed that is characterised by:

inter- and intragranular micro-fractures oriented parallel to the shortening direction (Z); these micro-fractures have an irregular outline, i.e., the fracture walls show euhedral overgrowth of quartz (either by precipitation of material dissolved elsewhere, or by local redistribution of material within the fracture to lower the fracture surface energy). The fractures are further characterised by abundant voids (fluid inclusions) and channels, and also by the presence of small new (sub)euhedral quartz grains having either almost similar, or completely different crystallographic orientations compared to the fractured (mother) crystal. These small new grains are interpreted to be precipitated out solution in the fractures. The differential stress versus strain rate data obtained in experiments at strain rates of 10^{-5}, 10^{-6}, and 10^{-7} s^{-1} and otherwise similar conditions follow a power law with a stress exponent <1.3 which is consistent with solution/precipitation creep being the dominant deformation mechanism.

In most cases, either side of the micro fractures show a slightly different crystallographic orientation, indicating that slight rotation of the fractured blocks occurred. Together with the irregular shape of the fractures this gives the impression of unsteady undulatory extinction*. It is only due to the presence of the voids and channels in the fractures, and hence the presence of euhedral crystal faces, and due to the presence of recognisable offsets in the case of the deformed monocrystalline material, that the fractures can be recognised as such. Would they have been healed completely, then they would have been very difficult to distinguish from the usual undulatory extinction and subgrains that are commonly attributed to dislocation creep. The small new grains would give the impression of recrystallised grains, developed by rotation- or grain boundary migration recrystallisation.

It is suggested here, that in many naturally deformed quartz rocks the presence of unsteady undulatory extinction, subgrains, and/or small new grains may also be explained by micro fracturing plus solution/precipitation processes, rather than by dislocation creep. (It should be noted that this is not a new idea, but as old as the microscopical study of quartz deformation microstructures. Until about 1960 most students of quartz optical deformation features interpreted the presence of unsteady undulatory extinction, subgrains, and small recrystallised grains in terms of brittle processes accompanied by solution mass transfer [see, e.g., Rosenbusch 1885, 1887; Zirkel 1893; Becke 1903; Sander 1930; Griggs & Bell 1938]) Examples will be shown, and comparison made between experimentally and naturally deformed material.

* With unsteady undulatory extinction (unstetige undulöse Auslöschung) is meant the type of undulatory extinction where the extinction varies in an unsteady, discrete way, in contrast with steady or wavy undulatory extinction (stetige undulöse Auslöschung) where extinction varies smoothly.

Literaturverzeichnis:

BECKE, F. (1903): Über Mineralbestand und Struktur der krystallinischen Schiefer. Denkschriften der math.-naturwissensch. Classe der kaiserl. Akad. d.Wissensch. zu Wien. Bd. LXXV. 1-53.

GRIGGS, D.T. & BELL, J.F. (1938): Experiments bearing on the orientation of quartz in deformed rocks. Geol. Soc. Am. Bull. 49, 1723-1746.

ROSENBUSCH, H. (1885): Mikroskopische Physiographie der Mineralien und Gesteine. Ein Hülfsbuch bei mikroskopischen Gesteinsstudien. Teil I: die petrograpisch wichtigen Mineralien. Schweizerbart, Stuttgart.

ROSENBUSCH, H. (1887): Mikroskopische Physiographie der Mineralien und Gesteine. Ein Hülfsbuch bei mikroskopischen Gesteinsstudien. Teil II: mikroskopische Physiographie der massigen Gesteine. Schweizerbart, Stuttgart.

SANDER, B. (1930): Gefügekunde der Gesteine. Springer, Wien.

ZIRKEL, F. (1893): Lehrbuch der Petrographie, Teil I, Bd. I, 2. Auflage, Engelmann, Leipzig.