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Open grain boundaries of quartz as fluid pathways in metamorphic rocks

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TEM analyses coupled with SEM/FIB sequential imaging of quartz from a metamorphic contact aureole and from greenschist-facies regional metamorphism shows that quartz grain boundaries are partly open on the nanometre scale. Three different types of voids occur: (i) up to 500 nm wide open zones parallel to the grain boundaries, (ii) cavities of variable shape and up to micrometer size along the open grain boundaries, and (iii) cone-shaped, nanometre-sized depressions at sites where dislocation lines meet the open grain boundaries. From animations generated with a pile of 100 pictures it is obvious that in three dimensions the larger cavities are interconnected and form channel-like structures which 'migrate' along the grain boundaries and change in dimensions and shape. Consequently, the partly connected open grain boundaries and cavities form a pathway for fluid percolation. Comparison between the measurements and the results of semi-quantitative modelling indicates that the partially open grain boundaries most probably result (i) from reduction of cell dimensions during cooling below the diffusion threshold of quartz ($\sim$300°C; Voll, 1976) and (ii) from the fact that this reduction is anisotropic, i.e. different for different crystallographic directions (Kihara, 1990).

Preliminary imaging of phase boundaries of quartz, plagioclase, K-feldspar, amphibole and pyroxene and of grain boundaries in calcite show similar features: several hundred nanometre wide open zones parallel to the boundaries and cavities of variable shape and size, often with euhedral segmentation. In addition, newly-grown, partly euhedral crystalline matter of similar composition as the neighbouring minerals may cover the open grain boundaries. These observations indicate locally strong dissolution-precipitation processes within a connected network of open grain and phase boundaries.

All these minerals are common in rocks of the middle and lower continental crust, which partly cooled from higher temperatures to temperatures below the minerals' diffusion thresholds. Consequently, open grain and phase boundaries should be a common phenomenon in these rocks and probably have important effect on their physical properties, such as strength and shear resistance, fluid flow and reactivity, elasticity and storage capability.

References:
Kihara, K., 1990. An X-ray study of the temperature dependence of the quartz structure. European Journal of Mineralogy 2, 63-77.
Voll, G., 1976. Recrystallization of quartz, biotite and feldspars from Erstfeld to the Leventina Nappe, Swiss Alps, and its geological significance. Schweizerische Mineralogische und Petrographische Mitteilungen 56, 641-647.