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Quartz Microstructures, the Key to Unravel an Orogenic History

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Quartz veins in siliciclastic rocks contain useful information to decipher the orogenic history from burial to orogenic contraction and eventual orogenic collapse. Applying fluid inclusion and/or stable isotope studies on veins enable us to constrain the P-T conditions during orogenic history and also to estimate the origin of fluid flow assisting the deformation. At low greenschist metamorphic conditions (250°C - 350°C), development and deformation of such veins is liable to fracturing and recrystallisation, the latter because of the onset of quartz plasticity. In order to correctly assess the results of fluid inclusion and/or stable isotope studies, it is imperative that the timing of fracture opening, quartz infill and deformation is well-constrained. Macro- to microscopic fabric and microstructural studies on early, syn- to late orogenic veins, performed in different low-grade metamorphic slate belts, illustrate how detailed information on vein development during orogenic history provides crucial constraints on the interaction between fluids and geodynamics.

Vein infill of early orogenic bedding-normal quartz veins that are related to the latest burial stages of a Palaeozoic rift basin (High-Ardenne slate belt, Belgium, Germany), has been used to deduce the evolution of veins from a hairline fabric to a complex, composite vein fill. The majority of the veins are centimetre-thick with a fibrous to elongate-blocky fabric that has grown by ataxial and syntaxial mechanisms (Van Noten 2011 and references therein). The key parameter that controlled the formation of these early orogenic veins is that crystal growth exceeded the fracturing velocity. The alignment of pseudosecondary fluid inclusion planes within fibrous crystals and secondary inclusion planes cutting through the crystals are particularly useful to deduce the incremental steps of vein opening and later fracturing respectively, eventually serving as a proxy for the stress-state of the basin at the time of vein formation (Van Noten et al. 2011).

Synorogenic, foliation-parallel veins are recognised in a thick metapelite-quartzite Palaeozoic sequence (Central Armorica, Brittany, France) (Berwouts et al. 2008; Berwouts 2011 and references therein). The fracture opening occurred parallel to a bedding-parallel foliation in the metapelitic rocks. The quartz infill consists of elongate-blocky quartz crystals, which are folded and contain bulging recrystallisation. The quartz microstructures suggest that precipitation of quartz occurred faster than the development of the fracture. A microscopic study shows that fluid inclusions in these veins are always secondary, i.e. formed after the quartz infill.

Late-orogenic Palaeozoic veins (High-Ardenne slate belt, Belgium) range from thin, planar veins to thick, complex vein systems (Van Baelen 2010 and references therein). All veins initiated as steep extensional fractures (cf. thin veins). Shearing sub-parallel to the foliation became dominant during progressive non-coaxial deformation. This resulted in a very oblique opening of some of the fractures (cf. thick veins). These veins show a rim of saddle dolomite and an overgrowth of blocky quartz suggesting an opening velocity exceeding the crystal growth. The thin veins have a fibrous to elongate-blocky infill, suggesting a more or less equal opening and infill velocity. After infill of both vein types, deformation continued, as evidenced by the development of planar microstructures. One specific generation of rectangular fluid inclusions could be related to the development of these planar microstructures in quartz.

These case studies demonstrate that if the timing of emplacement of veins within the structural context is known, the internal microstructural fabric of quartz veins is a crucial key to unravel the geodynamic evolution of an orogenic system. Moreover, correlating the shape and orientation of fluid inclusions to vein formation, allows understanding the results of mineralogical and geochemical analysis properly. Eventually this enables to deduce P-T conditions during each specific veining event and hence during the whole orogenic history.


