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Causes of basin inversion, Blue Ben, Somerset (photo C. Stevenson)

The stress state of the brittle upper crust during early Variscan tectonic inversion and its influence on high-pressure compartments

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In the frontal part of the Rhenohercynian foreland fold-and-thrust belt (High-Ardenne slate belt, Eifel, Germany), two successive types of quartz veins, oriented normal and parallel to bedding, are interpreted to reflect the late Carboniferous tectonic inversion affecting the siliciclastic Ardenne-Eifel basin at the onset of the Variscan orogeny. Fracturing and sealing occurred in Lower Devonian multilayer sequences in upper-crustal levels. This study aims at constraining pressure-temperature conditions of both vein types, to be able to reconstruct the conditions of fossil high-pressure compartments during early Variscan tectonic inversion.
A detailed structural analysis shows that the bedding-normal veins developed in a regional consistent stress field under low differential stresses controlling the regional quartz vein alignment. Precipitation occurred in equilibrium with the host rock under low-grade, anchizonal metamorphic conditions with maximum burial temperature up to 250°C. In the vein fill, quartz commonly occurs as elongated-blocky ataxial crystals (sub)perpendicular to both vein walls and contains crack-seal host-rock inclusions indicating that these extension veins repeatedly re-opened and sealed by near-lithostatic fluid-pressures, as recorded in the fluid inclusions. Bedding-normal veins still reflect the extensional stress regime during the latest stages of the Ardenne-Eifel basin development.
The presence of bedding-parallel quartz veins is the first evidence of a compressional stress regime. Bedding-parallel veins, mostly present at the interface between two lithologies and folded across the hinge zone without thickness variation, show a pronounced composite bedding-parallel fabric, consisting of bedding-parallel host-rock inclusion bands and bedding-perpendicular inclusion trails. Quartz crystals show a strong variability in grain size indicating brittle cataclasis during vein formation. They are affected by recrystallisation during progressive veining and subsequent deformation. These macro- and microscopic observations indicate bedding-parallel thrusting preceded the formation of folds and the regional development of cleavage. Microthermometry of fluid inclusions suggests that lithostatic to supralithostatic fluid pressures were responsible for veining. These bedding-parallel veins thus reflect a brittle deformation in a strong upper crust that occurred at larger differential stresses than during the previous bedding-normal veining event, but still low enough to allow the formation of extension veins.
Fluid redistribution thus occurs during transition between two stress regimes in a sedimentary basin which has been recognised in mesozonal ore deposits around the world. The tectonically induced transition from an extensional to a compressional stress regime is accompanied by the increase of pore-fluid pressure up to near- or supralithostatic. These high fluid-pressures are only possible under relatively low values of differential stresses, in compartmentalised high-pressure reservoirs and are thus easier to maintain during the tectonic inversion than during syntectonic deformation, as shear fractures will develop due to the increased differential stress.