The geodynamic evolution of hydrothermal vein deposits in the Madan metamorphic core complex, Bulgaria

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Carbonate replacement and vein-type lead-zinc deposits and silicic dyke swarms are associated with the Madan Dome in the Central Rhodope region, South Bulgaria. Interpreted as a large metamorphic core complex, the Madan Dome is well suited for a study of the geodynamic relationships between extension, magmatism and hydrothermal ore formation. High-precision geochronology in conjunction with detailed field observation is used to date the thermal to hydrothermal history of the complex.

In the Late Cretaceous, a compressional stage led to large-scale thrusting and amphibolite facies metamorphism in the Rhodope region. This was followed by a widespread extensional collapse during the Oligocene, marked by a detachment system, leading to exhumation of highly metamorphosed rocks, including migmatites in the footwall. The detachment fault is crosscut by undeformed silicic dykes, which are in turn crosscut by the ore veins and overprinted by associated sericite ± carbonate alteration. Magmatism thus postdates the extensional movement, and hydrothermal mineralization occurred during or after silicic magmatism.

Rb-Sr-isochrons of biotite and feldspar and Ar-Ar- dating on biotite yielded cooling ages of gneisses of both hanging- and footwall of about 35.5 Ma. Ar-Ar ages of white mica in skarn mineralization preceding the main Pb-Zn mineralization event yield very similar ages of 35.5 Ma. U-Pb dating on zircons of the silicic dykes dates their emplacement at 32 - 30 Ma ago. New Ar-Ar measurements of sericite associated intimately with the main vein-hosted Pb-Zn mineralization reveal mica crystallization ages of 30.5 - 29 Ma.

The Rb-Sr data indicate that cooling of footwall and hanging wall occurred at the same time, shedding doubt on a major extensional detachment as the cause for exhumation the Madan Dome. Magmatism and hydrothermal ore formation are coeval, but postdate uplift by about 3 - 6 Ma. Isotopic tracing work will be used next, to clarify whether the temporal relation reflects a direct genetic link between magmatism and hydrothermal ore formation.

Fluid flow and element mobility in middle-crust shear zones of collisional orogens: insights from the Mont Blanc Massif shear zone network

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Networks of kinematically-related shear zones in late Hercynian granitoids in the Mont Blanc massif have localised fluid flow, hydrothermal alteration and associated vein formation during their formation at mid-crustal depths during Alpine collision. The shear zones are mylonitic in the core of the massif, and become cataclastic near its SE rim. They have developed in response to NW-SE shortening and vertical extension. Calcite-quartz $\delta^{18}O$ thermometry on shear-hosted veins in the massif and in the adjacent Helvetic nappes indicates temperatures around 400°C during shear zone formation. Mineral assemblages in the shear zones reflect similar temperatures and relatively high pressures (6-7 kbar). Geochemical changes due to fluid-driven alteration, while the shear zones were active, are compatible with generally small volume changes. Three main reaction types are recognised from the margin to the core of the shear zones: (1) in the NW part of the massif, biotite-plagioclase are replaced by epidote-muscovite; (2) in the SW part of the massif, biotite is replaced by muscovite and epidote is absent; (3) chlorite is a major phase in the cores of various shear zones. Very variable depletion/enrichment patterns of major, trace and Rare Earth Elements (REE) are interpreted to reflect major differences in (1) fluid chemistry, (2) fluid flow directions relative to P/T gradients, and (3) connectivity between elements of the shear network and fluid reservoirs, in different parts of the shear network. REE, in particular, can be very mobile and locally exhibit both enrichments and depletions, which are controlled by the stability /instability of REE-bearing phases including allanite, aeschynite, bastnäsite and monazite. C, O and H stable isotope signatures of vein assemblages associated with the shear zones indicate that fluid chemistries have been influenced by two reservoirs. In the core of the massif, the shear networks have facilitated escape of reduced fluids from deeper crustal fluid reservoirs, whereas near the SE margin of the massif there is evidence for mixing with fluids originating from the Helvetic nappes cover sequence.