2.5.12

Geochemical simulation of veining and an explanation for bulk mass transfer in fractured rocks

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Low permeability "basement" rocks apparently contribute mass to some hydrothermal systems because isotopic and geochemical signatures of basement locally appear in overlying ore deposits. Continuum models for thermally or mechanically driven flow in porous media generally fail to account for the vanishingly low intrinsic permeability of crystalline rocks, and commonly also postulate that broadly distributed flows are responsible for mass transfer. The role of cm- to m-scale fracturing and veining as the prime mechanism of long-distance mass transfer in such rocks has not been closely examined, the assumption being that mass transfer could only be local. We propose here that chemical interaction between wallrocks and fluids during fracturing cycles is adequate to explain most of the mass transfer observed in low permeability rocks, particularly also because visible chemical alteration in such rocks is typically dominated by veins and related alteration. The "reactor-style" geochemical modelling package HCh uses the Gibbs minimization method for titration, flow-through and more complex fluid-rock interactions for conditions up to 800°C and 500 MPa. The simulations demonstrate fluid-wallrock interaction followed by isolation of the modified fluid, pressure (or temperature) change, and mineral precipitation in a vein. Differential mass transfer is caused by the varying solubilities of minerals, with Ti- and Al-bearing minerals confined to wallrocks, others precipitating in veins. Using a variety of rocks and fluids representative of greenschist to amphibolite hydrothermal systems worldwide, simulations of pore pressure decreases of up to 10 MPa (similar to those measured during modern seismogenic events) produced good correlation with observed field-based vein infill and wallrock alteration patterns. Both the field observations and models suggest that this method of differential mass transfer dominates most mid- to lower crustal (sub-solidus) metal transport.

2.5.13

Element transfer during shear zone development, episyenitisation and vein formation. Insights from the Mont-Blanc massif (French Alps)

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The Mont-Blanc massif (MBM) is an external crystalline massif of the western Alps, constituted of gneisses and a granitic intrusion buried and exhumed during the alpine orogenesis. Episyenitic alteration develops as haloes surrounding horizontal open veins that are connected to NNE-SSW and N-S vertical shear zones (SZ). Both structures are contemporaneous and result from the exhumation (pop-up) of the MBM during the Alpine event (47 and 10 Ma). Strong petrological and geochemical changes result from fluid/rock interaction along these features. A coupled petrological, geochemical and thermobarometric study allows the characterisation of fluid and mass transport processes at middle crustal depths during orogeny.

Episyenites and SZ show very different behaviors in terms of elements gains/losses. SZ are characterized by strong mass transfer of all majors, traces and REE. Subsequent mass gains/losses estimated in SZ are high, implying high fluid/rock ratios and time-integrated fluid fluxes of the order of 10^6 m^3 fluid/m^2. Episyenites result from the leaching of quartz and biotite creating a high porosity (up to 30%) and the recrystallization of new phases (albites, adularias, secondary quartz and vermicular chlorites). Despite these petrological changes, only Si, Fe and Mg are depleted while the other elements are almost immobile.

The usual interpretation of episyenites resulting from fluid/rock interaction with an agressive fluid or in response to drastic temperature changes is not available in the MBM. Episyenitisation is interpreted in this massif as the result of vein opening during exhumation. Pressure changes resulting from vein opening coupled with diffusion from dissolving areas to open vein migth explain the crystallisation of quartz in the vein and the surrounding episyenitic alteration haloes.