Hydrothermal vein formation by extension driven dewatering of the middle crust

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Hydrothermal deposits in extensional settings are common worldwide. Fluid characteristics are usually interpreted as reflecting mixing of meteoric water with deeper crustal brines. ”Fluid circulation” is often invoked as the mechanism for fluid ascent and mixing. However, the driving force for such a circulation remains unclear. Here we present a new model to explain the upward release of significant amounts of fluid from the middle and upper crust in extensional settings.

The isostatic balance during extensional thinning of the crust causes exhumation of mid- and deep-crustal rocks while the upper part of the crust is eroding or subsiding, resulting in basin formation. The difference in compressibility between fluid in pores and solid rock has a significant effect on fluid pressure evolution. The overburden or matrix pressure decreases during exhumation while the pore fluid pressure is steady due to the relative incompressibility of rocks. Pores with initially lithostatic pore fluid pressure immediately exceed the actual decreasing lithostatic pressure and release their fluid by hydrofracturing. A 100 MPa decompression results in the release of approximately 5% of the available pore fluid. Pores with a hydrostatic fluid pressure drain part of their content through connected pores to regain a hydrostatic fluid pressure.

The amount of released fluid can be calculated if the crustal thickness and the amount of exhumation are known. Other controlling factors are the depth dependent porosity and the depth and density dependent thermal expansion. Assuming lithostatic pore fluid pressure, 1 % porosity, and a standard crustal thickness, a maximum amount of about 0.00035 km^3/km^2 fluid is released for every one percent of crustal extension. Taking into account thermal expansion at a geothermal gradient of 30°C/km, 0.5 % porosity, hydrostatic fluid pressure and 50 % fluid lost to mineral reaction, gives an estimate of the minimum amount of fluid release of 0.00003 km^3/km^2 for every one percent of crustal extension. These two values bracket the expected actual release of excess fluid per square km of extending crust.

The model is applied to the Schwarzwald ore district, SW Germany, where five different mineralization groups can be distinguished by geochemistry and age. They all formed during periods of extensional tectonics. The fluid volume required to precipitate the known deposits of the various groups are quantified and compared to the fluid volume generated by our model. It appears that the fluid volumes required to build the Schwarzwald hydrothermal ore deposits can adequately be explained by our model.

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