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Dynamic coupling between fluid flow and vein growth in fractures: a 3D numerical model

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Fluid flow is one of the main mass transport mechanisms in the Earth's crust and abundant mineral vein networks are important indicators for fluid flow and fluid rock interaction. These systems are dynamic and part of the so called RTM processes (reaction-transport-mechanics). Understanding of mineral vein systems requires coupling of these processes. Here we present a conceptional model for dynamic vein growth of syntaxial, posttectonic veins generated by advective fluid flow and show first results of a numerical model for this scenario. Vein generation requires three processes to occur: (i) fracture generation by mechanical stress e.g. hydro-fracturing, (ii) flow of a supersaturated fluid on that fracture and (iii) crystallization of phase(s) on or in the fracture. 3D synthetic fractures are generated with the SynFrac code (Ogilvie, et al. 2006). Subsequently solutions of the Navier-Stokes equation for this fracture are computed by a computational fluid dynamics code called GeoDict (Wiegmann 2007). Transport (advective and diffusive) of chemical species to growth sites in the fracture and vein growth are computed by a self-written MATLAB script.

The numerical model discretizes the wall rock and fracture geometry by volumetric pixels (voxels). Based on this representation, the model computes the three basic functions for vein generation: (a) nucleation, (b) fluid flow with transport of chemical species and (c) growth. The following conditions were chosen for these three modules. Nucleation is heterogeneous and occurs instantaneously at the wall rock/fracture interface. Advective and diffusive flow of a supersaturated fluid and related transport of chemical species occurs according to the computed fluid flow field by GeoDict. Concentration of chemical species at the inflow is constant, representing external fluid buffering. Changes/decrease in the concentration of chemical species occurs only due to vein growth. Growth of nuclei is limited either by transport of chemical species to the growth site or by incorporation of material into the crystal structure. Hence a flexible growth rate is applied that adapts for both cases. After reaching a threshold value of generated vein material, the simulation is stopped and the generated geometry exported. Subsequently the fluid flow field for the new geometry is simulated by GeoDict, followed by simulation of vein growth. By iterative calculations of fluid flow and vein growth we couple the two processes and simulate dynamic vein growth. Although the model is very simplistic in the current state, we anticipate that it reproduces crucial characteristics of vein growth and hence yield further insights into vein generation in 3D.

Ogilvie SR, Isakov E, Glover PWJ (2006) Fluid flow through rough fractures in rocks. II: A new matching model for rough rock fractures. Earth and Planetary Science Letters 241:454-465

Wiegmann A (2007) Computation of the permeability of porous materials from their microstructure by FFF-Stokes. In: Prätzel-Wolters D (ed) Berichte des Fraunhofer ITWM, vol. 129, Kaiserslautern, p 24