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Impact of fracture geometry on fluid flow

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Fluid flow and fluid-rock interaction in porous media and along natural fractures are important processes for mass transfer in the Earth crust. Traces of such processes are found in the geological record by abundant vein networks in the earths crust. Vein generation is characterized by dynamic reaction-transport-mechanical-processes and so a thorough understanding of vein formation is only possible by coupling of these processes. Advective fluid flow on fractures is directly related to the geometric properties of the fracture (e.g. roughness). The feedback mechanisms between the two were studied generating a suite of synthetic fractures with systematically differing geometric properties and subsequent simulation of fluid flow on these. Synthetic fractures are computed using the SynFrac code developed by Ogilvie et al. (2006). They describe fractures by the two surfaces confining it, which are rough, self-affine and matched to some degree. For this reason, crucial input parameters to SynFrac are fractal dimension and surface matching parameters. Range of input values for these parameters is taken from values determined on natural fractures by Ogilvie et al. (2006). In order to enable fluid flow simulation, the generated 3D fractures are discretized into a voxel representation. Fluid flow is then simulated by solving the Navier-Stokes equation in these structures using GeoDict (Wiegmann, 2007). GeoDict is an integrated simulation package intended for the prediction of porous material properties. Amongst others, one module (FlowDict) is dedicated to the simulation of fluid flow in porous materials and offers a wide variety of robust numerical solvers. FlowDict results include the hydraulic parameters of the fracture (e.g. permeability tensor etc.) but also the flow field of the fracture. Based on these results mass transfer based particle transport along the fractures are simulated by solving the equation for advective-diffusive particle motion. Results of the simulations show a positive correlation between fracture permeability - fracture roughness and fracture permeability - mismatch between the two fracture surfaces. This behaviour derives from the SynFrac inherent positive correlation of roughness and mismatch with average aperture widths. Hence changing one of these parameters affects not only one fracture feature but two. In order to eliminate this effect, the average aperture width of the synthetic fractures is adjusted to a common value by vertical movements of the fracture surfaces. For these cases, it is expected that a negative correlation between roughness and permeability exists. Numerical simulations for these conditions are currently undertaken. Comparison of the simulated fracture permeability and predictions by the cubic law, depict an overestimation of the permeability by the cubic law of about one order of magnitude for the observed range of average apertures. Fluid flow fields and particle transport simulations show that fluid velocities and related particle transport are heterogeneously distributed over the fracture. In consequence related processes e.g. vein growth are expected to behave heterogeneous as well. For this reason advective transport and vein growth are likely to be dynamically coupled.

Ogilvie, S. R., Isakov, E. & Glover, P. W. J., 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: Berichte des Fraunhofer ITWM (ed Prätzel-Wolters, D.), pp. 24, ITWM, Kaiserslautern.