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Flow, transport and reactions in fractured porous media

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Reactive flow and transport in geological formations occurs in many situations, during natural processes or due to human interventions (deposition – bioclogging, dissolution and precipitation – the formation of karsts).

In order to model such situations, one has to solve a coupled system of equations. The first one describes the flow inside two structures, namely the porous medium and the fractures; basically, they are Darcy like equations. The second equations describe the transport and the
reactions which occur inside the two structures. In addition, one needs constitutive equations in order to predict evolution of these two structures; for instance, one needs an evolution law for permeability as a function of porosity.

Three major steps are needed for the numerical solutions. First, an unstructured tetrahedral mesh of the fractures and of the porous matrix located in between is constructed; a particular attention should be paid to the well region since the casing has different properties than the surrounding porous medium. Second, the Darcy equations are discretized and solved, in a finite volume formulation; previous codes have been improved by the systematic use of triple control volumes. Third, the evolution of the solute concentration has to be calculated. This last point is the most difficult one if one wants to avoid numerical diffusion and also inaccurate transfers between the fractures and the media. Various schemes have been tried and the most efficient one is a non linear flux limiting scheme (FLS) of the Superbee type. Because of its importance, the results obtained with the various schemes will be illustrated and discussed. The FLS scheme has been developed for the triple control volume which is a major improvement with respect to the previous codes that were developed in our group.

Various physical situations will be illustrated. The theoretical situation of transfer between an isolated circular disk and the surrounding medium is calculated analytically and by the numerical code. Some former numerical experiments were performed in a long parallelipipedic box of fractured porous medium with impermeable side walls or lateral spatially periodic boundary conditions. These results will be compared to the ones obtained with the new code.

Finally, the injection of fluid through a well will be detailed. Several regions will be distinguished, namely the well casing, an artificial fractured zone which surrounds the well (with fractures which are mostly perpendicular to the well) and the initial fractured porous medium far from the well. The evolution of these three zones with time will be studied depending of the physico-chemical properties of the casing and of the fractured medium itself. A sensitivity analysis of the major parameters will be presented such as the fracture density (and therefore their percolating character or not), the Péclet and Péclet-Dahmkohler numbers which characterize the flow and the reactive transport.