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Modeling and comparative study of fluid velocities in heterogeneous rocks

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Detailed knowledge of the distribution of effective porosity and fluid velocities in heterogeneous rock samples is crucial for understanding and predicting spatially resolved fluid residence times and kinetic reaction rates of fluid-rock interactions.

The applicability of conventional MRI techniques to sedimentary rocks is limited by internal magnetic field gradients and short spin relaxation times. The approach developed at the UNB MRI Centre combines the 13-interval Alternating-Pulsed-Gradient Stimulated-Echo (APGSTE) scheme and three-dimensional Single Point Ramped Imaging with T_1 Enhancement (SPRITE). These methods were designed to reduce the errors due to effects of background gradients and fast transverse relaxation. SPRITE is largely immune to time-evolution effects resulting from background gradients, paramagnetic impurities and chemical shift. Using these techniques quantitative 3D porosity maps as well as single-phase fluid velocity fields in sandstone core samples were measured.

Using a new Magnetic Resonance Imaging technique developed at the MRI Centre at UNB, we created 3D maps of porosity distributions as well as single-phase fluid velocity distributions of sandstone rock samples. Then, we evaluated the applicability of the Kozeny-Carman relationship for modeling measured fluid velocity distributions in sandstones samples showing meso-scale heterogeneities using two different modeling approaches. The MRI maps were used as reference points for the modeling approaches.

For the first modeling approach, we applied the Kozeny-Carman relationship to the porosity distributions and computed respective permeability maps, which in turn provided input for a CFD simulation – using the Stanford CFD code GPRS – to compute averaged velocity maps. The latter were then compared to the measured velocity maps. For the second approach, the measured velocity distributions were used as input for inversely computing permeabilities using the GPRS CFD code. The computed permeabilities were then correlated with the ones based on the porosity maps and the Kozeny-Carman relationship.

The findings of the comparative modeling study are discussed and its potential impact on the modeling of fluid residence times and kinetic reaction rates of fluid-rock interactions in rocks containing meso-scale heterogeneities are reviewed.