EGU22-8053
https://doi.org/10.5194/egusphere-egu22-8053
EGU General Assembly 2022

Sub-rock typing and its influence on pore-scale, image-based simulations of multiphase flow in complex geological rocks

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Image-based pore-scale modeling is an important method to study multiphase flow in permeable rocks. However, many rocks have pore size distribution that are so wide that they cannot be resolved in a single pore-space image. The accurate identification and characterization of this sub-resolution porosity have received extensive attention, due to its crucial impact on porosity and permeability estimation. To date, several modeling methods incorporate this information to improve the simulation of multiphase flow in complex rocks. The challenge is that the microporosity's flow properties are difficult to characterize in images, and to include in models, of representative volumes. In this study, a novel sub-rock typing method was proposed to better characterize and classify microporous regions in rock samples, and to reduce the uncertainty of image-based pore-scale modeling of such samples. To this end, we performed capillary drainage experiments with brine and decane on two water-wet rock samples (Estaillades limestone and Luxembourg sandstone). Laboratory-based Micro-CT was used to image intricate pore structures and fluid occupancy changes at controlled capillary pressure steps during drainage. We proposed a novel workflow to generate 3D, micrometer-scale capillary pressure maps, which we combined with porosity maps to classify zones of microporosity types (sub-rock types). This was used to extract multi-scale pore network models and perform multiphase flow simulations. We found that the new approach yielded a good match with macroscopic experimental measurements, and significantly improved the prediction accuracy of the fluid distributions on a pore-by-pore basis. The results illustrate the importance of characterizing microporosity for simulations in heterogeneous rocks. The workflow can be applied to other complex geological porous rocks to improve modeling and simulation of subsurface multiphase flow.