Title: Relative Permeability Upscaling in Porosity Systems with Under-resolved Features Using Image-Based Rock Physics.

Objectives

Image-Based Rock Physics (IBRP) simulation of petrophysical properties based on sub-micron to micron-scale images of very fine-grain rocks is constrained by the resolution and range of various imaging techniques used. Unlike some conventional sandstone and carbonate reservoir rock where a single microCT volume images nearly all of the significant pores and pore throats, many low-permeability rock types contain phase regions with micro-pores and pore throats, including intergranular microcrack pores, that are not accurately resolved at the required microCT scale needed for a representative elementary volume (REV) for the whole rock. Properties for these regions are obtained at a finer-scale or using a different measurement method and these properties then assigned to the phase regions at the larger REV scale. This study explores the methodology involved in obtaining and assigning microcrack properties in microCT rock images and demonstrates a workflow to handle uncertainty in the location and properties of microcracks using two representative low-permeability sandstones.

Methods/Procedures/Process

The workflow combines microCT images of a mini-plug sample (~5^3mm^3), which represents the rock REV, with FIB-SEM images (~20^3µm^3) of regions of various types of observed microporosity (including intergranular microcrack pores) which occur within the REV sample. Different representative types of microporosity regions were imaged and properties calculated from the higher-resolution FIB-SEM image volumes. For some fraction of microCT microporosity regions the type of microporosity and associated assigned properties was not known and a modeling approach for assignment was constructed. For intergranular microcrack pores a sub-resolution micro-fracture model was numerically constructed, honoring the mineral facies morphology and microporosity types assigned based on their respective distributions. Resultant porosity, capillary pressure and single- and multiphase-flow simulations on the larger REV volume were cross-validated with independent core analysis measurements.

Results/Observations/Conclusions

This study illustrates a successful workflow for assigning properties, obtained at finer scales or using other measurement methods, to regions in the REV. The resulting pseudo-rocks exhibit the same whole rock pseudo-porosity, permeability, capillary pressure, and drainage relative permeability as core analysis measurements. This methodology, or something similar, is required to integrate IBRP and core analysis.

Applications/Significance/Novelty

It is expected that the majority of low-permeability rocks require an assignment and upscaling methodology similar to that developed in this study for IBRP computations and integration with core analysis. Using this methodology IBRP offers deeper understanding of building blocks of the pseudo-properties measured by core analysis. IBRP also offers the ability to measure/compute relative permeabilities that are nearly physically impossible to measure on core and the ability to construct synthetic rocks that allow evaluation of complete suites of rocks and their properties.