Automated Quantitative Micromodel Image Analysis Applied to High-Pressure CO_2 Foam Injections

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Abstract. Porous micromodels enable multiphase pore level visualization with displacement mechanisms and flow phenomena. Imaging during fluid injection tests is typically performed as a time lap series of images, where each image contains static information such as grain size, geometry and distribution; location of pore throats, pore bodies and porosity (in field of view). Each image also contains dynamic information related to the distribution of fluids (aqueous, gaseous and oleic), interfaces between immiscible fluids and droplets of trapped fluids. The dynamic information change between each acquired image during fluid injection, generating very large image files during normal injection tests in typical micromodels. Micromodels with regular and repeated patterns (such as pillars or squares) have fewer possible fluid distributions during injection compared with irregular patterns based on real rock thin sections. The high image resolution necessary to capture a large field of view, rapidly changing fluid distributions, the presence of multiple fluid phases and moving interfaces easily generate several 100s of GB of information during a single injection test, and an effective and rigours image analysis protocol for automated quantitative analysis of observed displacement mechanisms is needed.

The rapid advancement of computer power and image analysis tools enable our research community to perform quantitative analysis of extreme amounts of image data on fluid displacement at the pore scale. An automatic, systematic interpretation that transforms images to meaningful statistics and information, minimizing biased, time-consuming manual interpretations is a valuable tool. The strength of computer vision is its high throughput, both with respect to the number of images analyzed, particularly important in dense time lap series, but also in its ability to capture all features of interest occurring in the micromodel pore structure.

We outline an automated workflow that converts time-lapsed images during CO_2 foam injection to quantitative analysis of important pore level phenomena such as bubble density, fluid saturations and sweep efficiency. An experimental protocol using high pressure micromodels with irregular pore space is outlined. Procedures to capture high resolution images across the micromodel and enhance the field of view, and how to prepare images for further analysis using open source software libraries for scientific image processing are discussed. Software to perform tasks as identifying, describing and counting features of interest is described, incorporating well-known and documented image processing methods. Quality control and comparison to manual analysis is presented to demonstrate the power of the new automated image processing workflow.