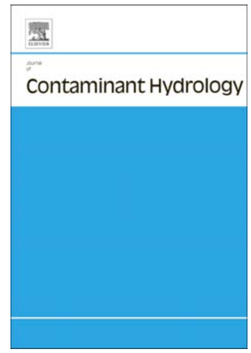

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Characterization of Reactive Flow-Induced Evolution of Carbonate Rocks using Digital Core Analysis- Part 1: Assessment of Pore-scale Mineral Dissolution and Deposition

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Abstract

The application of X-ray micro-computed tomography (μ-CT) for quantitatively characterizing reactive-flow induced pore structure evolution including local particle detachment, displacement and deposition in carbonate rocks is investigated. In the studies conducted in this field of research, the experimental procedure has involved alternating steps of imaging and ex-situ core sample alteration. Practically, it is impossible to return the sample, with micron precision, to the same position and orientation. Furthermore, successive images of a sample in pre- and post-alteration states are usually taken at different conditions such as different scales, resolutions and signal-to-noise ratios. These conditions accompanying with subresolution features in the images make voxel-by-voxel comparisons of successive images problematic. In this paper, we first address the respective challenges in voxel-wise interpretation of successive images of carbonate rocks subject to reactive flow. Reactive coreflood in two carbonate cores with different rock types are considered. For the first rock, we used the experimental and imaging results published by Qajar et al. (2013) which showed a quasi-uniform dissolution regime. A similar reactive core flood was conducted in the second rock which resulted in wormhole-like dissolution regime. We particularly examine the major image processing operations such as transformation of images to the same grey-scale, noise filtering and segmentation thresholding and propose quantitative methods to evaluate the effectiveness of these operations in voxel-wise analysis of successive images of a sample. In the second part, we generalize the methodology based on the three-phase segmentation of normalized images, microporosity assignment and 2D histogram of image intensities to estimate grey-scale changes of individual image voxels for a general case where the greyscale images are segmented into arbitrary number of phases. The results show that local (voxel-based) porosity changes can be decomposed into local mineral dissolution and deposition. Moreover, it is found that the microporosity evolutions are differently distributed in the samples after the reactive coreflood experiments. In the last part of the paper, for the case of quasi-uniform dissolution, we combine the tomographic images with numerical calculations of permeability along the core to characterize the relationship between changes in permeability and the fractions of the mineral dissolved and deposited. A consistency is found between the calculated longitudinal permeability changes and the quantified distribution of mineral dissolved and deposited along the sample.

Keywords: Micro-CT imaging; Dissolution; Deposition; Carbonate; Microporosity; 2D Histogram

1. Introduction

The pore structure of carbonate rocks undergoes substantial changes during a wide variety of geochemical processes such as acidizing of petroleum reservoirs, geological storage of CO_2 and contaminant transport in groundwater resources. Mineral dissolution and precipitation are major reactions that occur during reactive flow through porous media (Araque-Martinez and Lake, 2000). The physicochemical interactions between the injected fluids and the porous rocks may release fine particles which are carried along flow paths. While chemical dissolution generally enlarges the pore space and increases pore connectivity, the clogging of pore throats resulting from precipitation and also dissolution-induced particle release decreases the overall flow in the medium. The evolution of pore structure induced by dissolution and deposition may, in turn, significantly change the petrophysical and transport properties of the rock. In particular, porosity, permeability and the distribution of permeability are the key parameters in determining well production rates, predicting reservoir performance and identifying potential production and injection zones. A better understanding of dissolution and deposition mechanisms in porous rocks at the pore scale will lead to improved estimates of porosity and permeability since dissolution/deposition as well as fines migration and clogging have a direct influence on

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