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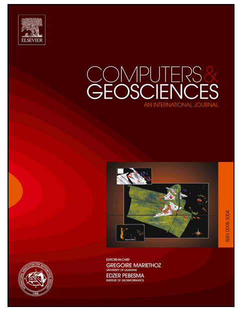

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An Investigation into Preserving Spatially-distinct Pore Systems in Multi-Component Rocks using a Fossiliferous Limestone Example

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Abstract

Limestones containing abundant disc-shaped fossil *Nummulites* can form significant hydrocarbon reservoirs but they have a distinctly heterogeneous distribution of pore shapes, sizes and connectivities, which make it particularly difficult to calculate petrophysical properties and consequent flow outcomes. The severity of the problem rests on the wide length-scale range from the millimetre scale of the fossil's pore space to the micron scale of rock matrix pores. This work develops a technique to incorporate multi-scale void systems into a pore network, which is used to calculate the petrophysical properties for subsequent flow simulations at different stages in the limestone's petrophysical evolution. While rock pore size, shape and connectivity can be determined, with varying levels of fidelity, using techniques such as X-ray computed tomography (CT) or scanning electron microscopy (SEM), this work represents a more challenging class where the rock of interest is insufficiently sampled or, as here, has been overprinted by extensive chemical diagenesis. The main challenge is integrating multi-scale void structures derived from both SEM and CT images, into a single model or a pore-scale network while still honouring the nature of the connections across these length scales. Pore network flow simulations are used to illustrate the technique but of equal importance, to demonstrate how supportable earlier-stage petrophysical property distributions can be used to assess the viability of several potential geological event sequences. The results of our flow simulations on generated models highlight the requirement for correct determination of the dominant pore scales (one plus of nm, μm, mm, cm), the spatial correlation and the cross-scale connections.

Key words: Carbonates; *Nummulites*; Multi-scale pore network; Two-phase flow

1. Introduction

Over the last decade, a considerable body of work has focused on using pore-scale images of rocks to derive quantitative estimates of emergent physical properties, such as those associated with fluid flow (see Blunt et al. 2013 for a comprehensive review). The vast majority of approaches use three-dimensional (3D) digital rock models, at a small scale, derived either through tomographic methods (e.g. Vinegar et al. 1987, Flannery et al. 1987; Ketcham and Carlson, 2001; Arns et al. 2005), or as reconstructed from 2D images (e.g. Øren and Bakke, 2003; Okabe et al. 2004; Wu et al. 2006; Kopf et al. 2007; Chen and Wang, 2010; Tahmasebi et al. 2012). The tomographic grey-level images are further segmented into two phases, solid components and the pore space, although in some studies, fluid phase distributions are also determined (Pak et al. 2015). These provide 3D solid-pore (binary)

[1] Authorship statement:
Dr Zeyun Jiang, PhD, wrote the manuscript, clarified the ideas, developed the methodology, and carried out the analysis on pore network simulations;
Prof Gary D. Couples, PhD, pioneered at the ideas and the framework with many in-depth interpretations of numerical results;
Dr Helen Lewis, PhD, conceived the ideas, steered the development and was regularly instrumental in guidance;
Dr Alessandro Mangione, PhD, provided Nummulites templates and basic geological knowledge plus quantified characteristics of Nummulitic rocks.