Preface

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Understanding the fundamental physics of fluid flow and transport in porous media is central for a variety of fields dealing with mass and heat transfer in subsurface systems, such as oil and gas fields. Flow and transport characteristics of reservoir environments are typically described in terms of representative macroscopic parameters to capture the manifestation of more complex pore-scale phenomena. Recent improvements in computational processing speed have made the application of numerical physically-based pore-scale models more practical, together with the development of non-invasive microscopic imaging technology that provides us with the observations necessary to test the physics and assumptions applied to the models. For example, it is possible to model detailed spatial evolution of reacting species, fluid distribution and trapping in porous media and compare them with direct experimental observations. The articles selected for this special issue on pore-scale flow and transport processes in petroleum reservoirs contribute to current understanding in the aforementioned research.

Mirzaei and DiCarlo present three-phase gravity drainage experiments in mixed-wet and oil-wet systems, and compare their results against continuum model predictions to investigate the importance of three-phase gravity drainage for terciary oil recovery processes in mixed- and oil-wet reservoirs. Later, Zaretskiy, Geiger and Sorbie apply pore-scale modelling of reactive solute transport in a digitised Fontainebleau sandstone sample to describe wettability alteration in enhanced recovery processes. In particular, their model captures dynamic processes that involve interaction of ionic species associated with chemical reaction and their effect on multiphase flow properties.

In addition to coupling fluid flow with reaction mechanisms, the coupling with rock mechanics can reveal valuable information about rearrangement of grains, grain-grain contacts and consequently changes in the pore structure and associated transport properties of a porous medium. Along those lines, Prodanović, Holder and Bryant show preliminary results from three-dimensional pore-scale coupling of capillarity-dominated flow and grain-grain mechanics. Landry and Karpyn use X-ray computed microtomography images of a fractured permeable medium in combination with single-phase lattice Boltzmann modelling to simulate creeping flow in fractures at the pore scale. Their study investigates the effect of permeable walls on the apparent fracture permeability, and presents comparisons against empirical and semi-analytical methods for determination of fracture permeability from fracture geometry and matrix permeability. Although highly permeable, fractures are also subject to fluid trapping due to the interplay of surface forces between the resident fluids and the solid surface, thus leading to the so-called Jamin effect. Hsu, Glantz and Hilpert studied the Jamin effect in a pore doublet model and demonstrate a strong dependence on contact angle hysteresis.

As a result, they suggest that relative permeability should depend on contact angle hysteresis, which effectively decreases the mobility of residual oil blobs.

The work by Dewers, Heath, Ewy and Duranti describes the application of dual beam focused ion beam-scanning electron microscopy to observe nano-pores in a mudstone formation, the Jurassic Haynesville Fm., which is currently a new and burgeoning shale gas play in the USA. Their flow simulations show the influence of connectedness and how pore topology can influence the extent of dead-end pores. Moreover, they propose a hierarchical pore conceptual model that may be extended to other shale gas mudstones. On the implementation of upscaling methods to bridge pore and continuum scales, Sun, Mehmani, Bhagmane and Balhoff present a paper on the upscaling of permeability in heterogeneous porous media using mortars, a domain decomposition method. A large pore network is decomposed into 100 smaller networks and then coupled with the surrounding models to determine accurate boundary conditions. Their results compare favourably to the more computationally intensive approach of upscaling the media as a single model and provide an alternative for multi-scale modelling that preserves boundary conditions.

The articles presented in this issue highlight the importance of understanding pore-scale processes to better represent macroscopic flow and transport characteristics of petroleum reservoirs. These manuscripts also address scientific challenges faced in the prediction of the behaviour of subsurface geologic systems, including the assessment of a variety of effective medium properties such as absolute and relative permeability, dispersivity, capillary pressure, and wettability.

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