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A semi-analytical model for capillary entry pressure of pores in carbonates with varying wettability states

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Abstract. Pore-network modeling has served as a practical simulation tool for predicting multiphase flow functions (e.g., relative permeability and capillary pressure curves) of porous media, owing to its superior computational efficiency. However, in traditional pore-network models, the rock pore space is largely simplified, and the fluid flow and solute transport are solved in a network of pore elements with idealized geometries. Such simplification can lead to inaccurate predictions when the original pore space features highly diverse and complex geometries as those observed in carbonates. To address this issue, we propose to couple the pore-network modeling approach with a semi-analytical model that can faithfully and efficiently predict capillary entry pressure and the corresponding fluid configuration of piston-like displacements using real, two-dimensional (2D) images of the pore space. To this end, an algorithm for identifying and extracting 2D pore cross sections from the corresponding 3D images of the pore space is developed and incorporated within an existing pore-network extraction platform. Enhanced pore networks, which contain images of real pore and throat cross sections, are constructed from high-resolution micro-computed tomography (micro-CT) images of carbonate rock samples. Next, we apply the semi-analytical model to the pore and throat elements of the enhanced pore networks to estimate their capillary entry pressures under different wettability conditions. The results are then compared against predictions obtained from a traditional pore-network model on a pore-by-pore basis. We show that characterizing the multiphase flow properties of the carbonate pores with a sole reliance on the inscribed radius and the shape factor, which is a common practice adopted in traditional pore-network models, is insufficient. We further explore other geometric properties (e.g., convexity, solidity, and aspect ratio) of the pore space and analyze their effects on the final estimation of the capillary entry pressures.