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Modeling the Evolution of Permeability in Carbonates

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ABSTRACT

Carbonate pore structure and therefore permeability is controlled in large part by unique diagenetic events and products, and a complex wettability structure that is often dominantly weakly-oil wet. This produces a highly diverse array of pore types and size, styles of connectivity and tortuosity, and in turn flow behaviours. While changes in porosity can be directly related to diagenetic petrographic characteristics such as cement distribution and dissolution features, quantifying how these textures control attendant changes in permeability is more challenging. The impact of individual diagenetic events and their products on flow properties can, however, be isolated and modelled using 3D pore architecture models. Porosity and permeability evolution through many diagenetic scenarios often display several ‘diagenetic tipping points’ where the decrease in permeability is dramatically larger than expected for the associated decrease in porosity. The effects of diagenesis also alters the capillary entry pressures and relative permeabilities, so providing trends that can be applied to real rocks. In turn, such diagenetic pathway models can be used to provide constraints on predicted flow behaviour during burial and/or uplift scenarios using ‘diagenetic back stripping’ of carbonate rocks. In dominantly microporous carbonates, average pore radius controls single-phase permeability, but has minimal effect on multiphase flow. When moldic mesopores are added to a microporous matrix, they only impact flow when directly connected: micropores control the magnitude of single-phase permeability. Recovery, however, is dependent on both wetting scenario and pore-network homogeneity: under water-wet imbibition, increasing proportions of microporosity yield lower residual oil saturations. Process-based models of early cementation (isopachous and syntaxial) show that isopachous cement is effective in closing pore throats and limiting permeability, but permeability changes due to syntaxial cement growth (preferentially on monocrystalline grains) is highly dependent on monocrystalline grain location and direction of the grain crystal axis, as this can create a highly ‘patchy’ distribution of cement.