Zoning in on Carbonate Microcrystal Diagenesis

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ABSTRACT

The diagenetic history of calcite microcrystals that occlude microporosity is complex and often tortuous, yet vital in the effective reservoir characterization of petroleum, concrete aggregate, water, and carbon sequestration reservoirs as well as affecting chemostratigraphic correlations. Although ubiquitous in carbonate rocks, microporosity is often ignored or simply called “micrite.” This term does not convey the range of microcrystal chemistry and morphology that nature presents and that strongly correlate to petrophysical properties.

Specific diagenetic environments and processes may in fact be partially responsible for the wide variety of crystal and pore throat geometries. Zoning within macrocrystals can represent different environments and are relatively straightforward and easy to recognize due to morphology and chemical composition. On the micron-scale, zonation is not only difficult to sample, but difficult to quantify. Bulk analyses yield compositions that represent mixes between different diagenetic trends, obscuring the composition of specific zones.

Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) were used in an effort to explicate diagenetic zoning within the micro-pore systems of carbonate reservoirs. Systematic analyses of a core taken from the Tor Formation (Late Campanian to Maastrichtian) within the Ekofisk petroleum field in the North Sea in fact show zoning within microcrystals. The Tor Formation is a deep-water “depositional” chalk, which at its time of deposition was comprised of mostly of coccolithophores, which are composed of the most thermodynamically stable carbonate mineral—Low-Mg Calcite. Microcrystals range in size from 1 to 10 microns, and zonation within these microcrystals is evident. Mg/Ca ratios in mmol/mol shift from the core to the rim of the crystal. In each sample, zonation was noted, ranging from a large variation (22.2 to 5.7 mmol/mol Mg/Ca) core to rim, to small variation (9.7 to 7.6 mmol/mol Mg/Ca) core to rim. There is a 21% decrease in helium porosity with depth, which correlates to change in crystal morphology from clustered-loose to fitted-partial. This zonation suggests a more complex diagenetic history. Investigating less stable, high-Mg or aragonitic facies, will likely present more complex zonation because these species are thermodynamically less stable and are often subject to meteoric diagenesis.