CARBONATE POROSITY AND PERMEABILITY: PATTERNS AND PREDICTION

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ABSTRACT

In the study of carbonate diagenesis we are striving to understand the controls on cementation, dissolution, compaction and dolomitisation. Although we do have a great knowledge of the processes involved, and the textures generated are well documented from around 50 years of concerted research, we are almost struggling in our efforts to be able to predict porosity in carbonates in frontier basins ahead of drilling.

The controls on the diagenesis of carbonate sediments have become clearer over the years and the general trends in diagenetic and geochemical change of sediments from the near-surface through shallow to deep burial and then uplift are well known. In the near-surface, porosity loss is largely the result of cementation which may take place in marine and meteoric environments, but porosity may be generated by dissolution, especially in the meteoric realm. The prevailing climate is very important, controlling water chemistry and fluid flow in the meteoric environment, and degree of hyper/hypo-salinity in the shallow-marine. Sea-level change determines the nature and circulation path of fluids in platform-margin carbonates, and this can be deduced from sequence stratigraphic analysis. The facies itself is also an important factor in porosity evolution. The degree of early cementation has a major effect on later compaction; moderate early cement, preserving some useful primary porosity, may render a carbonate less likely to porosity loss during burial. The rates of carbonate diagenesis can be approximated from studies of Quaternary carbonates, where complete stabilisation of original metastable mineralogy may take up to 3-400,000 years.

Zones of preferential cementation are commonly developed in carbonates and these can produce permeability barriers which may lead to horizontal compartmentalisation of a reservoir unit. Two common types of permeability barrier are hardgrounds and exposure surfaces. The first are primarily formed in shallow-marine lime sands, often during pauses in sedimentation, as during a sharp transgressive interval. Seawater then circulates through the near-surface sediment, leading to precipitation of marine cements. Thicknesses of hardgrounds are typically several to a few 10s of cm, but they may be laterally very extensive (many 100's of m). Overlying transgressive mudrocks may thicken the permeability barrier. Exposure surfaces may be levels of high-inter/supra-tidal cementation or pedogenesis, where chiefly micritic cements produce cemented layers up to 0.5 m thick. These features, common in peritidal carbonates, may extend for several km; they are typical of late HS-FS-LS systems tracts. Shale partings and pressure dissolution seams may also give rise to permeability barriers.

Vertical/sub-vertical permeability barriers are produced by preferential cementation along small faults and fractures, and so are generally developed later, through burial compaction and tectonic stresses. Strong fluid movement along fractures may lead to their rapid cementation whereas matrix porosity may be preserved in adjacent host sediment.

Although porosity decrease with burial is normal, porosity may be regenerated at depth through dissolution. This is especially common in carbonates with early anhydrite and dolomite, which may dissolve when undersaturated porefluids are released by faulting from adjacent aquifers or driven by hydrocarbon maturation.

A knowledge of the climate and pattern of sea-level change and systems tracts of a carbonate platform, can help in predicting early diagenesis. Timing of fracturation relative to fluid movement and oil generation is also critical to porosity development.