Reservoir Quality Controls in Permo-Carboniferous Sandstones of Saudi Arabia

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Deep Permo-Carboniferous sandstones (Unayzah Reservoir) of Saudi Arabia contain large reserves of sweet natural gas. The reservoirs consist of sandstones and siltstones deposited over a 40-50 million year period in a variety of environments as the Arabian Plate moved from high to low latitudes: periglacial aeolian and fluvial, hot-arid aeolian, hot-humid marginal marine. Stratigraphy is complex, correlation is difficult, and reservoir quality prediction is uncertain at best.

Porosity and permeability vary significantly at all depths of burial. Plots of thousands of core plug data, however, suggest two end-member trends. One trend is dominated by coarser, relatively clean sandstones variably cemented with quartz overgrowths. A second trend consists of finer, more feldspathic sandstones dominated by diagenetic fibrous illite. For any given porosity, permeability is typically an order-of-magnitude (or more) greater in the quartz trend than in the illite trend. Therefore, interpretation of seismic or log porosity signatures requires additional information to ascertain whether the porosity is accompanied by sufficient permeability to be productive.

Fluid inclusion analysis combined with kinetic modeling help constrain timing of quartz cementation, and by inference, timing of illite cementation. Although there is evidence of early hydrocarbon charging, no examples of hydrocarbon-preserved porosity have been identified. Anomalously high porosity and permeability are instead due to early grains coats (either clay or microquartz) associated with pedogenesis. Pedogenesis also destroys reservoir quality below thick soil horizons where infiltrated (illuviated) clays and oxides plug porosity for ten's of feet in dune and fluvial sandstones that otherwise would have been excellent reservoirs.