Impact of Hydrothermal Fluid Flow on Conventional and Un-conventional Carbonate-Rich Reservoirs, Midcontinent USA

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ABSTRACT

Hydrothermal fluid flow in Ordovician, Mississippian, and Pennsylvanian reservoir rocks of the Midcontinent is partially responsible for generating the porosity in those reservoirs (Ramaker et al. 2014), as well as hydrocarbon migration and local thermal maturation. The hydrothermal fluid flow occurred in three late stages (King, 2013). Fluid flow was controlled by stratigraphic discontinuities, fault and fracture systems, and temperature-controlled density differences. These controls are critical in localization of some of the reservoirs in the Midcontinent.

Ordovician, Mississippian, and Pennsylvanian strata in Kansas all show fracturing, megaquartz, silica dissolution, carbonate dissolution, baroque dolomite, MVT minerals, and calcite after stylolitization. Cathodoluminescence petrography, fluid inclusions, 87Sr/86Sr, and d18O indicate hydrothermal fluid flow affected Ordovician-through-Pennsylvanian stratigraphic units. The history is simplified into three phases of hydrothermal fluid flow (86-144ºC). All show evidence of thermal pulses, suggesting tectonic valving.

Fluid inclusion data indicate *Phase 1* was from brines near seawater salinity, interpreted as connate fluids migrating out of the Anadarko and/or Arkoma basins, likely during the Pennsylvanian or early Permian. Fluids were associated with a separate gas phase, and they precipitated megaquartz.

Phase 2 led to precipitation of baroque dolomite. Fluid inclusion data indicate high salinities (20 wt. %) and 87Sr/86Sr indicate advective fluid flow across long distances. d18O data indicate the Ordovician-Mississippian section acted as an aquifer in vertical communication, leading to warmer fluids and preferred fluid flow toward the top of the Mississippian. The shale-rich Pennsylvanian section acted as a leaky confining unit. This phase of fluid flow was associated with oil migration and likely occurred late in the Permian or after.

Phase 3 of hydrothermal fluid flow was complex, and is recorded by calcite cements. Spatial variation of d18O and 87Sr/86Sr indicate cessation of advective fluid flow and initiation of localized vertical fluid flow, possibly directly out of the basement. Comparison of fluid inclusion temperature and salinity data to modern reservoir conditions indicate that this phase clearly predates the current fluid flow and thermal regime, but played a part in evolution of the reservoir system.

The first two phases of hydrothermal fluid flow are associated with fracturing, silica dissolution and carbonate dissolution. Much of the porosity, typically assumed to originate from subaerial weathering, may have been generated by these late hydrothermal fluids. The fluids

followed fracture systems and were concentrated along the tops of hydrothermal aquifers by stratigraphic discontinuities and temperature-controlled density differences. This model for hydrothermal porosity formation helps to explain the spatial variation in reservoir quality in the Mississippian and leads to an enhanced model for locating the best producers. The Mississippian to Cambrian-Ordovician section acted as a regional aquifer and Pennsylvanian acted as a leaky confining unit. In the regional aquifer cross-formational connections allowed lower density, warmer fluids to concentrate at the top of the aquifer. Reservoir porosity is partially controlled by hydrothermal fluid migration enhancing the porosity in areas where fractures and faults led to preferred hydrothermal fluid flow, especially close to the top of the regional aquifer. Better porosity is related to late structure and stratigraphic control on fluid flow.

For the third phase of hydrothermal fluid flow, further study is necessary. A driver could be localized faulting and fracturing associated with Laramide or other deformation. Fracturing and vertical fluid flow clearly could have had an impact on late hydrocarbon migration. As these systems are highly localized, their identification may be key in predicting location of some of the best producers.