Cores from the Trenton – Black River (Ordovician) HTD Play in the Quackenbush Hill Field, Chemung County, New York

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Summary

Since the late 1800s, oil and gas have been produced from structurally controlled hydrothermal dolomite (HTD) reservoirs in the Upper Ordovician Trenton and Black River formations of eastern North America, within the Michigan and Appalachian Basins. The first discoveries were in the dolomites of the Lima-Indiana trend in Ohio and Indiana. Over 500 Mmbo and more than 1 Tcf of gas have been produced from the Lima-Indiana trend, giving it the status of the first giant oil field in the world. During the 1950s, the giant Albion Scipio Field was discovered in southern Michigan. Here, discrete pods of dolomite occur along a trend of en echelon structural lows. The Albion Scipio field has produced more than 250 Mmbo since its discovery.

In 1986, gas was discovered in laterally discontinuous dolomites in the Black River Group in south-central New York State. Since this initial discovery, 33 Black River gas fields have been recorded. Most of these fields are between 7000 and 10,000 ft deep. The Quackenbush Hill Field was discovered in 2000 and is located in Chemung County, New York. The Quackenbush Hill Field has produced nearly 90 BCF to date from 13 gas wells. One of the most prolific wells, the Lovell #1323, a vertical gas well, has produced 20.6 Bcf cumulative gas, since December 2000. This well is still producing at a high rate, greater than 5 Mmcf per day.

Structurally, the Quackenbush Hill Field is defined by two long, narrow, fault-bounded en echelon, structural lows (or grabens). Displacement along these seismically-subtle faults, indicate both dip-slip and wrench movement. The structural lows principally formed as a result of transtensional faulting interpreted to have developed during Taconic convergence, and the reservoir dolomites are spatially and genetically localized where negative flower structures have developed. The dolomite formed from supersaturated hot brines flowing up basement-rooted faults and associated fractures. The surrounding limestone is tight and serves as both lateral and top seal for this diagenetically-trapped gas.

The Quackenbush Hill Field offers a rather unique opportunity to observe the rock record from a single Black River graben feature as there are three cored penetrations (Gregory #1446, Gregory #1446A, Schwingle 2) of the same stratigraphy. The Gregory cores, a vertical and a subsequent sidetrack, exhibit pristine limestone in the original vertical well and pervasive dolomite in the whip. Located some 760m to the southwest of the Gregory wells, the Schwingle 2 Hz well was drilled across a graben feature and successfully recovered 10m of core. This oriented horizontal core provides an interesting record of lateral variability (or consistency) in fractures, fabric and reservoir quality. In particular, the horizontal core exhibits different generations of fractures, vug development and pressure solution, and the relationship of each to changes in principal stress directions (kinematic indicators).

Four attributes of HTD plays that appear to be nearly universal, are: a) laterally-restricted reservoir, b) facies cross-cutting high-temperature dolomitization, c) low to moderate matrix porosity development, and d) clear structural control on dolomitization. All four attributes are readily evident at Quackenbush Hill Field, and the Gregory cores neatly underscore the first three of these.

Abrupt lateral shifts from tight limestone host to porous dolostone can be readily observed in analogous outcrop examples or in MVT deposits (where closely spaced diamond drill holes or open pit excavations reveal the complex geometry of dolostone gangue mineralization). In the oil and gas sector, this lateral transition is more commonly inferred than observed, and is rarely evidenced from core in closely spaced wells. The two Gregory wells are only 64m apart where they are cored and intersect the Trenton-Black River contact. In the Gregory #1446 well, the Trenton Fm. is composed of dark grey stylo-nodular skeletal lime wackestones to packstones of low energy, turbid but open marine aspect. These strata disconformably overlie light medium grey brown peritidal (and pedogeneic) carbonate of the Black River Fm. Both intervals are tight. In the Gregory #1446A sidetrack, the precisely same stratigraphy and facies are completely dolomitized. No reservoir quality is developed within the dolomitized Trenton, but the peritidal carbonates of the underlying Black River average 2.7 % porosity and 22.5 md Kmax. Other noteworthy observations to be made on these core include:

- The dolomitization is mimetic resulting in fine fabric preservation.
- Pressure solution is largely a post-dolomite phenomenon.
- There is local development of “zebra-like” fabrics.
- Extensive eogenetic (penecontemporaneous vadose) alteration is overprinted by a significant post-consolidation subaerial (karst?) diagenetic event.

The core recovered from the Schwingle 2 Hz well was entirely dolomitized and has an average porosity of 3.2% and average Kmax of 0.11md. Structural analysis of the kinematic indicators available from this core lead to the following conclusions (Agle & Jacobi; 2006):

- There were multiple fluid events within changing stress fields
- Stylolites have acted as fluid conduits as evidenced by veins precipitated along several stylolite trends
- WNW-trending veins are most often associated with zones of vuggy porosity
- Early stages of stylolitization and veining are likely Taconic, though later events are also probable
- Several observed stresses may be very local and restricted to and influenced by the bounding faults of the graben

Current investigations seek to characterize the matrix-replacive dolomites and associated saddle dolomite cements in terms of petrography, stable and radiogenic isotopes and fluid inclusions. Published data (Langhorne, 2006) from saddle dolomites in the Black River from New York (but excluding Quackenbush) indicate a range of delta O^{18} values of -9.4 to -11.7$^{o}/_{oo}$ PDB, with Th values of 110 to170^{o}C, salinities from 13.2 to 15.5 wt% and a marginally radiogenic (compared to Ordovician seawater) strontium signature (.7085 - .7092).

References

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