Woodford-Sourced Oil in the Mississippian STACK Play: A Two-Phase Migration Model

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ABSTRACT

Reservoirs of the Mississippian Meramec/Osage system in the central Oklahoma STACK play produce hydrocarbons across a wide range of liquids yields. Organic material is not present in sufficient abundances in these reservoirs for the system to be self-sourced with hydrocarbons. Forty-five produced oils from Devonian and Mississippian reservoirs were analyzed through bulk molecular chemistries, biomarkers and carbon isotope on saturate and aromatic fractions. These geochemical data suggest that Mississippian oils of the Meramec and Osage units were derived from the source rock in the Devonian Woodford Shale. These oils show similar isoprenoid distribution (IP 13 to IP 20) and C29 sterrane (m/z 218) from saturate biomarkers; a minor variations in carbon isotope and triaromatic steranes which are in alignment with variation of thermal maturity in these oils.

Woodford maturity, Woodford well GOR (gas-oil-ratio) production and structural depth have all failed to provide accurate predictions of Meramec liquids production. We propose that this is because hydrocarbons migrated into the Meramec/Osage system from the Woodford source in multiple lateral and vertical charging episodes.

We present a new two-phase model of hydrocarbon migration for the STACK play. In this model, thick deposits of organic-rich Devonian Woodford Shale in western Canadian County (AKA Cana Core) provided the most significant hydrocarbon source for the STACK Play. Overpressure associated with kerogen maturation and petroleum transformation drove waves of progressively lighter hydrocarbons upward and outward from the Cana depocenter into the Meramec siltstone, where they were sealed by the Chester Shale above. System permeability in the Meramec was low enough to prevent development of a conventional hydrocarbon column. Rather, early-generated oil displaced formation water, and was in turn displaced by gas condensate and then dry gas. The result of this radial hydrocarbon migration is observable in arcuate GOR contours which wrap around the Cana Woodford depocenter. Further modification of this geometry resulted from preferential hydrocarbon migration along high-permeability conduits within Meramec reservoir units.

A second phase of migration carried very light hydrocarbons from the Devonian system vertically into Mississippian reservoir units immediately adjacent to certain N-S trending faults and other structures. In some areas this secondary charging dramatically altered the fluid mix predicted by regional trends. The association of this second phase of migration with only certain structures provides a useful clue in reconstructing the tectonic evolution of the area.

This model of hydrocarbon migration is consistent with observed reservoir pressure trends and explains the GOR distribution of Meramec wells.