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An Interpretation of Core-Derived Water Saturations Using Water Isotope Analysis

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ABSTRACT

Gas-in-place (GIP) models play a critical role in the assessment and valuation of unconventional reservoirs, the quantification of recovered hydrocarbon, completion simulation, and production modeling. Integral to these models is an accurate quantification of hydrocarbon and water saturations within pores. Standard Gas Research Institute (GRI)-based shale core analysis involves determination of the in situ fluid saturations by measuring the amount of water and oil extracted from the sample, often via the Dean Stark method. Reported core water saturations for the Marcellus Shale in southwestern Pennsylvania and northern West Virginia average approximately 30% of the pore volume. However, calculations of cation exchange capacity (CEC) demonstrate that the clays in the reservoir are under-saturated (often >75% desiccated) with respect to water, indicating the clays would absorb water, a phenomenon commonly observed when spraying water on the core surface. Furthermore, the full load of water pumped during completions is rarely captured during the flowback, suggesting its possible uptake by the formation. In order to understand the nature of water/rock interactions in the Marcellus Shale, several field and lab experiments were carried out on core and cuttings. Wax preserved full diameter core were extracted using a Dean Stark apparatus and the fluids were analyzed for oxygen and deuterium isotopes. When these data points are plotted on a $\delta18O$ and $\delta2H$ plot, they follow an evaporation trend that originates at the isotopic signature of the surface waters used in the drilling mud. The same trends can be seen by plotting flowback water isotopes with time. These observations would suggest that some portion of the water extracted during GRI shale core analysis is an artifact of the drilling process and not in situ, yielding an underestimation of gas-filled porosity and resultant calculated GIP. Finally, the fractionation of oxygen and deuterium isotopes may be impacted by present day reservoir temperature, permeability, porosity, clay content, and thermal maturity history, or a combination of these factors. On-going studies are focused on understanding how these factors alter the isotopic signature of the waters extracted from core and during flowback.