

Williston Basin Petroleum Systems: Inferences from Oil Geochemistry and Geology¹

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ABSTRACT

The Williston Basin has often been used as a model for petroleum exploration and production in basins around the world, so it is appropriate to update and accurately describe its functional petroleum systems. The fact that carbonate source rocks in the Madison Group were overlooked for many years demonstrates the need for careful assessment of effective petroleum systems. Using geochemical data from 106 oil samples and extensive literature references, an up-to-date assessment of petroleum systems in the Williston Basin is provided by geochemical analysis of dead oils from 16 producing horizons. Oil and source rock extract fingerprinting and biomarkers have been used to type oils and correlate sources in the Williston Basin. This work combines these published results with light hydrocarbon data from whole oil gas chromatographic fingerprinting of oils. While light hydrocarbon yields are affected by sample handling and storage, this study demonstrates that these oils can be distinctly typed and correlated using light hydrocarbon data. Overall, these data further elucidate the dominant Madison Group petroleum system in the Williston Basin, while also elucidating secondary petroleum systems including the Duperow, Red River, and Bakken-Lodgepole systems as well as other minor systems.

Light hydrocarbons segregate the oils into distinct families and are a useful means of typing oils, evaluating maturity, calculating generation temperatures, and assessing oil mixes. Madison Group oils sourced by Madison carbonate source rocks are enriched in 6-carbon ring light hydrocarbons, toluene and methylcyclohexane. While this 6-ring preference is generally thought to be indicative of terrestrially sourced oils, these oils are definitively derived from carbonate or marly shale source rocks. Bakken oils are enriched in 5-carbon ring light hydrocarbons such as the alkylated cyclopentanes, which appears characteristic of a clay-rich, marine shale source. Red River oils are enriched in normal paraffins and exhibit characteristic Ordovician-sourced (*G. prisca*) oil fingerprints. Other unique petroleum systems revealed by these data include the Tyler, Duperow, Winnipegosis, and the Deadwood oils. Other oils in this study are related to the above oil types, e.g., the single Spearfish oil groups with Madison oils, Nisku oils are principally grouped with Bakken oils, and Interlake oils type primarily with Red River oils.

Mixing of oils does not occur extensively in the U.S. Williston Basin based on interpretation of oil fingerprints of oil samples and laboratory mixtures of Madison, Bakken, and Red River oils. Commingled production yields oils with hybrid characteristics that can be discerned by fingerprint and biomarker data.