

Implications of Bakken-Bakken(!) and Lodgepole-Bakken(!) Petroleum Systems and Their Characteristics and History for Petroleum Potential in Unconventional Upper Devonian and Lower Mississippian Rocks

Kirk G. Osadetz*

Geological Survey of Canada, 3303 33rd Street, NW, Calgary, Alberta, Canada, T2L 2A7

Zhuoheng Chen

Geological Survey of Canada, 3303 33rd Street, NW, Calgary, Alberta, Canada, T2L 2A7

zchen@nrcan.gc.ca

And

Mark Obermajer

Geological Survey of Canada, 3303 33rd Street, NW, Calgary, Alberta Canada, T2L 2A7

Abstract

A number of distinct petroleum systems and plays occur within the Upper Devonian and Lower Mississippian successions of western Canada. The best described of these are the Bakken-Bakken(!) and Lodgepole-Bakken(!) Petroleum Systems of the central and eastern Williston Basin. However, similar but less well characterized and distinctive petroleum systems occur westward into the Cordillera. Everywhere the generalized stratigraphic succession consists of an upward succeeding bituminous predominantly black shale, overlain by a middle sandstone to siltstone member, the primary reservoir; which is succeeded by an upper bituminous predominantly black shale that is overlain by lime mudstones to wackestones that include laminations to beds and even members of a brown to black bituminous lime mudstone within the lower part of the succeed Carboniferous carbonate succession.

The Bakken-Bakken(!) and Lodgepole-Bakken(!) Petroleum Systems of the central and eastern Williston Basin are relatively well described and their depositional and thermal histories are well characterized. Despite being subject to intensely elevated heat flow that accompanied Mississippian and Pennsylvanian tectonics the sources did not become thermally mature until burial by the Mesozoic and Tertiary Foreland Basin successions. Immense volumes of oil were both generated and expelled from both the Bakken and Lodgepole source rocks. Hydraulic fracturing of the source rock intervals is not inferred without stress augmentation from tectonic sources. Residual oil in the Bakken shales is the source of an overpressure that persists to the present day, while the Lodgepole source remains normally pressured. Typically Bakken shales in central Williston Basin have residual porosities in the range of 2-5% accounting for their very low permeabilities, persistent overpressure and low petroleum storage. However the details of the migration history from both source rocks is not well understood. For example, the Rocanville Field of the Bakken-Bakken(!) petroleum system suggests many hundreds of kilometers of lateral migration through the Bakken Formation and the Sinclair field shows that much oil migrated even past the subcrop limit of the Bakken middle member reservoir. In the region underlying parts of eastern Montana (Richland County) similar migration into the southwestern part of the basin results in another significant, primarily unconventional play.

Westward the depositional setting of Bakken shales changes as a persistent anoxic water column effect is observed, especially west of the 4th meridian. Correspondingly the composition of Bakken-Bakken(!) petroleum system oils changes and there is little indication for a Lodgepole-Bakken(!) petroleum system, although oils inferred to be sourced from both Bakken and Lodgepole source rocks occur commonly higher in the succession, especially in Mesozoic reservoirs, in a region where biodegradation commonly affects oils from both source rocks pervasively. As one moves progressively westward, across the crest of the Sweetgrass Arch and equivalent structures these petroleum systems are both less well described and less readily apparent. Rich potential petroleum source intervals are identified in both the Exshaw and Banff successions, but the number of pools attributable to these sources diminishes to be almost insignificant, although most oils found in Lower Cretaceous reservoirs of this region are probably derived from these Paleozoic source intervals.

Within the southern Front Range the succession resembles that of the central Williston Basin, as the rich bituminous sources deposited on the toe of the distal Carboniferous carbonate ramp reappears. Thermal history models suggest that both the Exshaw and Lodgepole source became mature prior to their involvement in the deformation and that they too matured under the Foreland Basin loading, well east of the deformation limit, but that the up dip extensions and limits of source rocks exposed in the Cordillera are largely missing any significant conventional oil pools that can be easily attributed to the Upper Devonian and Lower Carboniferous source rocks. Considering the inferred volume of Exshaw and Lodgepole source rocks that matured and expelled petroleum prior to their deformation in the Cordillera the situation is enigmatic.

Recent re-valuation of this succession in southwestern Alberta has identified formation characteristics similar to those observed in the Williston Basin that are serving for the basis of a “Bakken” tight oil play in southern Alberta, a feature that appears entirely consistent with the nature of the succession and the history of its hypothetical petroleum systems. It is uncertain whether the difference in the amount and nature of the conventional resource attributed to these source rocks in southern Alberta represents an unidentified and unquantified risk or an untapped opportunity for the play in this region. The recent industrial activity in southern Alberta emphasizes the need to better understand and characterize the entire Bakken/Exshaw-Lodgepole/Banff set of petroleum systems to permit a clearer understanding of the size of the potential resource that may be found and the controls on its various plays and play fairways.