Quantitative Analysis of Petroleum Systems of the Beaufort-Mackenzie Basin, Arctic Canada: An Integrated Approach*

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The Beaufort-Mackenzie Basin is a petroleum exploration frontier region in Arctic Canada that has attracted considerable industry attention and investment. It contains more than 14 km of post-rift Upper Cretaceous to Cenozoic deltaic and marine sediments and is underlain in part by Jurassic to Lower Cretaceous syn-rift strata and Triassic to Proterozoic pre-rift carbonate and clastic sediments. Published resource assessments for significant conventional discoveries yield estimates of 277.3×10^6 m^3 (1.744 billion bbl) recoverable crude oil and 332.4×10^9 m^3 (11.74 TCF) of recoverable natural gas and estimates for the remaining undiscovered recoverable petroleum are 856.5×10^6 m^3 (5.39 billion bbl) and 1.5×10^{12} m^3 (53.3 TCF) for crude oil and natural gas, respectively (Dixon *et al.,* 1994). Gas hydrates form an immense unconventional gas resource with estimated volumes of raw natural gas in place exceeding total conventional gas estimates by a factor of approximately 2.3 to 5.6, depending on gas hydrate saturation (Osadetz and Chen, 2010).

For over eight years, the Geological Survey of Canada has been involved with an industry-government funded quantitative study of Beaufort-Mackenzie petroleum systems and has assembled and interpreted digital seismic data, and log and drilling data for over 250 exploration wells. In addition, specialized analyses were undertaken on an extensive set of core, cuttings and oil samples. Study activities include biostratigraphy, palynology, organic geochemistry, organic petrology, geophysics, structure, stratigraphy, log analysis, petrophysics, water geochemistry, apatite fission track thermochronology, basin modeling, and petroleum resource assessment and mapping. This integrated work has led to new ideas on oil source rocks and an improved understanding of the geological factors controlling pore pressure and temperature for this area.

Ice-bearing permafrost (defined by log, temperature and velocity survey data) varies by over 700 m in thickness across the basin and forms an important upper thermal boundary for constraining basin geotherms and the gas hydrate stability zone. It is thinnest along the southern (landward) basin margin and in the deformed and erosionally exhumed western part of the basin, and is thickest in rapidly deposited Cenozoic strata of the eastern shelf beneath the Beaufort Sea. Geothermal gradients (from drill-stem tests and corrected bottom-hole temperatures) vary between 25 to 35 °C/km across most of the basin; higher gradients (30 to 50 °C/km) are associated with major fault zones and thicker crust on the southeastern basin margin. Primary overpressure (defined by log, mud weight and pore

pressure data) is associated with thick, undercompacted Cenozoic strata; the depth to overpressure varies by more than 3 km and is controlled by basin structure and sedimentation rate. Hydrocarbon leakage is documented by thick gas hydrate zones above conventional petroleum accumulations (Osadetz and Chen, 2010) and by gas chimneys and the presence of diagenetic minerals and foraminifera alteration above breached petroleum reservoirs. New oil-source studies suggest that a significant contribution from deep Cretaceous and older sources (mature marine organic matter) has been overlooked due to extensive biomarker contamination from Tertiary rocks (lower maturity terrestrial organic matter). These results suggest a dynamic petroleum system with deep, active petroleum generation and vertical migration and mixing of petroleum in shallower reservoirs.

References

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