Regional Hydrochemistry of Deep Formation Waters in the Williston Basin (Canada–U.S.A.): Implications for Fluid Migration in the Basin

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Rostron, B.J. (2006): Regional hydrochemistry of deep formation waters in the Williston Basin (Canada–U.S.A.): Implications for fluid migration in the basin; *in* Gilboy, C.F. and Whittaker, S.G. (eds.), Saskatchewan and Northern Plains Oil & Gas Symposium 2006, Saskatchewan Geological Society Special Publication 19, p215.

Abstract

The regional groundwater flow system in the Williston Basin (Canada–U.S.A.) is one of the best examples of a large-scale confined aquifer system in the world. With its well defined recharge and discharge areas separated by approximately 1000 km horizontal and 1 km vertical distance, the basin is an ideal natural laboratory to study regional groundwater flow and hydrochemistry. Springs and shallow water wells in the recharge and discharge areas, along with deeper oil and gas wells, allow for detailed sampling and geochemical analyses of formation waters along flow paths.

Recently collected geochemical and isotopic data from more than 1000 wells across the basin provide new insights into the present- and paleo-hydrogeology of the basin. Results indicate: 1) the hydrochemistry of the basin must be mapped on hydrogeological (not political) boundaries; 2) many aquifers have similar water chemistries, yet unique isotopic fingerprints; 3) the unique isotopic fingerprints have proven useful for identifying drilling-mud contaminated test samples and leaking oil wells; 4) analysis of bromine concentrations and stable isotopic compositions provide evidence that at least some of the brine in the basin owes its origin to evaporated seawater and not just dissolved evaporites as previously thought; 5) trace-element data reveal the brines in the basin are rich in "economic minerals" including bromine, iodine, lithium, and calcium that may be commercially extractable; 6) calcium-rich brines in the centre of the basin may be associated with relict calcium-rich seawaters; and 7) hydrocarbon migration pathways have been variably impacted by evolving hydrodynamic conditions.

These observations show that the hydrochemistry and hydrogeology of the basin are more complex than previously thought. Mixing, not depth, appears to control water compositions. Portions of the basin appear to respond rapidly to changes in boundary conditions including: the recharge areas; midline areas that have experienced extensive salt dissolution; and present discharge areas that appear to show evidence of glacially driven recharge. Other portions of the basin appear to have had little to no fluid flow despite being continuous and highly permeable.

Insights gained from hydrochemical data provide an improved understanding the present- and paleo-fluid migration in the Williston Basin.

Keywords: Williston Basin, hydrogeology, hydrochemistry, fluid migration.

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