

## Chemostratigraphic Correlation of Horn River Group, Central Mackenzie Corridor, Northwest Territories

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### Summary

Refinement of the Horn River Group stratigraphic framework (Hare Indian, Ramparts and Canol formations) in the Mackenzie Plain area of the Central Mackenzie Corridor, Northwest Territories (NWT) is fundamental to shale reservoir exploration. Trends in whole rock lithogeochemical data throughout the succession have revised correlation in outcrop and within the subsurface, particularly where the carbonate-dominated Ramparts Formation is absent and organic-rich, fine-grained siliciclastics of both the Canol and Hare Indian formations are visually similar. The main trends used in a chemostratigraphic zonation of the succession include enrichments in uranium, changes in the silica to zirconium ratio, fluctuations in both the terrigenous input profile (a summation of aluminum oxide, iron oxide, potassium oxide, and titanium oxide) and thorium to uranium ratio, enrichment in calcium oxide, and elevation in trace elements such as molybdenum, vanadium, and nickel. These trends also characterize subunits of each formation: the Hare Indian Formation consists of a basal Bluefish Member and upper Bell Creek member (proposed, not yet formalized), the Ramparts Formation often contains an organic rich Carcajou member, and the Canol Formation is differentiated into a basal recessive member, middle resistant member, and upper recessive member.

### Introduction

The Devonian Horn River Group (Pugh, 1983) in the Mackenzie Plain exploration area of NWT consists of two units of organic-rich, fine-grained siliciclastics (Hare Indian and Canol formations), separated locally by the carbonate-dominated Ramparts Formation. The region contains one conventional oil field at Norman Wells which produces oil out of the Kee Scarp Member reef carbonates of the Ramparts Formation. The source rock for this field is the Canol Formation (Snowdon et al., 1987). Excellent source rocks occur in all levels of the Horn River Group, but primarily in the Canol Formation and Bluefish Member of Hare Indian Formation (Gal and Pyle, 2012; Pyle and Gal, 2012, 2013; Pyle et al., 2011). New exploration investment in the Canol shale oil play fairway is underway in the central Mackenzie Valley. The Mackenzie Plain Petroleum Project Phase I (2009-2014) is a field-based and subsurface study being conducted through the Northwest Territories Geoscience Office. One project goal is to utilize the excellent outcrop analogs in the Mackenzie Plain area and adjacent Franklin and Mackenzie Mountains to refine the stratigraphic correlation of the Horn River Group. A reference

section is designated from which chemostratigraphic correlations can be extended within Mackenzie Plain, and ultimately to other basins regionally such as Liard and Horn River basins to the south.

### **Theory and/or Method**

The project has involved study of more than 25 outcrop localities and data from 26 exploration wells. From more than 1600 m of outcrop, strata have been measured and described. Spectral gamma ray measurements were taken at either one-metre or three-metre intervals at outcrop, and chip sampling occurred through one-, two-, or three-metre intervals depending on the thickness of the units. Chip samples from both outcrop and the subsurface were analysed to evaluate organic-richness and source rock potential using Rock-Eval, total organic carbon (TOC), and vitrinite (or vitrinite equivalent) reflectance. Mineralogy was determined semi-quantitatively using X-ray diffraction (XRD). Whole rock litho-geochemistry provides abundances of major oxides and trace elements.

For outcrop sections, the spectral gamma ray profiles are mimicked by TOC trends in organic-rich intervals, as well as by the concentrations of U. These trends for each unit can be compared to gamma log profiles. Chemostratigraphic zonation of the succession is also based on relative variations in the element ratio of SiO<sub>2</sub>/Zr. In the Canol Formation, for example, this ratio shows a trend higher than the other units indicative of a high biogenic silica content and lower terrigenous input (Wright et al., 2010). Two proxies for terrigenous input are enrichment in the summation of major oxides (Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, K<sub>2</sub>O and TiO<sub>2</sub>), and elevated Th/U ratio (Hildred and Rice, 2012). CaO enrichment serves as a proxy for carbonate-rich intervals. Trace elements such as Mo, V, and Ni can serve as proxies for depositional redox conditions to indicate parts of the succession where reducing conditions may favour the preservation of organic carbon. One proxy is the calculated EFV (enrichment factor of vanadium, after Tribovillard et al., 2006), which shows degrees of enrichment or depletion relative to the average shale.

Semi-quantitative modal mineralogical changes throughout key sections and wells have also been important in characterizing the units of the Horn River Group. For example, the amount of quartz characterizes the subunits of the Canol Formation, and decreases within the overlying Imperial Formation. The Hare Indian Formation is characterized by containing chlorite and kaolinite whereas the Canol Formation contains ubiquitous muscovite.

### **Conclusions**

The application of chemostratigraphy to the Devonian Horn River Group has refined correlation between outcrops and resulted in significant revisions to tops picks in the subsurface. Where shale-on-shale packages of Hare Indian Formation overlain by Canol Formation were labelled as "Horn River undivided", whole rock geochemistry has led to the differentiation of these formations, and subdivision of the Hare Indian into two members (Bluefish and Bell Creek, the latter of which is newly proposed). New geochemistry data has also adjusted tops picks of the Canol Formation, by differentiating the Imperial Formation as having higher terrigenous input, lower TOC and U values, and lower SiO<sub>2</sub>/Zr ratio trends. Variations in major oxides and trace elements, when used in conjunction with gamma logs (or gamma ray spectrometry at outcrop), TOC values, and mineralogy differentiate stratigraphic units. Canol Formation is very high in silica, also indicated by the high amount of quartz in samples analysed by XRD, and much of this silica is biogenic. In contrast, Hare Indian Formation had a large contribution of sediments from detrital sources, and contains chlorite and kaolinite. Thorium to uranium ratios differentiate Bluefish and Canol units from Ramparts Formation and Bell Creek member.

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