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Correlation of Devonian Horn River Group in Mackenzie Plain, Central Mackenzie Corridor, NWT

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Summary

Refinements to the correlation of the Devonian Horn River Group are being made within the Mackenzie Plain exploration region, Central Mackenzie Valley in the Northwest Territories. The succession consists of two units of organic-rich, fine-grained siliciclastics called the Hare Indian Formation (including Bluefish Member) and Canol Formation, which are separated locally by the carbonate-dominated Ramparts Formation. A Middle Devonian reef within the Ramparts Formation is the reservoir for the conventional oil field at Norman Wells; however, this formation has a limited distribution. Where it is not present, the shale-on-shale package of Hare Indian and Canol formations in outcrop and subsurface were designated as “Horn River undivided”. Stratigraphic correlation of the succession is being refined through study of more than 25 outcrop localities within the plain and its adjacent mountain ranges (Franklin and Mackenzie mountains; Figure 1), and through correlation with select exploration wells. Excellent outcrop exposures provide a means to better understand formational contact relationships, map regional facies and thickness variations of shale units, and characterize units lithologically using Rock-Eval pyrolysis, mineralogy, and lithogeochemistry. The goal is to designate a reference section from which correlations may be extended regionally to other basins such as Liard and Horn River basins to the south.

Introduction

The conventional oil field at Norman Wells has produced more than 250 million barrels of oil from a Middle Devonian reef within the Ramparts Formation (NEB production data). Organic-rich black shale of the Canol Formation is the source rock for this reservoir (Snowden et al., 1987) and is extensive throughout Mackenzie Plain in Central Mackenzie Valley. Evaluation of the shale oil and shale gas potential of the Canol Formation and other organic-rich units within the Devonian Horn River Group is the focus of a five-year (2009-2014), field-based and subsurface project being conducted through the Northwest Territories Geoscience Office. Petroleum potential data from measured outcrop sections and stations have been released in two reports (Pyle et al., 2011; Pyle and Gal, 2012), as well as from select subsurface wells (Gal and Pyle, 2012). The project also aims to improve regional correlation of shale units in the Horn River Group and interpret their depositional and tectonic histories.

Methods

In three field seasons, more than 1600 m of strata in outrcrop were measured and described. Data collected include spectral gamma ray measurements at either one-metre or three-metre intervals at outcrop, and chip sampling through one-, two-, or three-metre intervals depending on the thickness of the unit. The following analyses have been undertaken: 1) evaluation of organic rich shale for source rock potential (Rock-Eval, total organic carbon, and vitrinite (or vitrinite equivalent) reflectance); 2)

mineralogy (semi-quantitatively, using X-ray diffraction); 3) whole rock geochemistry; and 4) biostratigraphy using radiolarians and conodonts. Correlation of organic-rich subunits between the outcrops and select wells integrate the outcrop scintillometer profiles and available gamma logs, trends in high organic carbon, trends of lithogeochemistry profiles (abundances of major oxides and trace elements), and time lines from biostratigraphy.

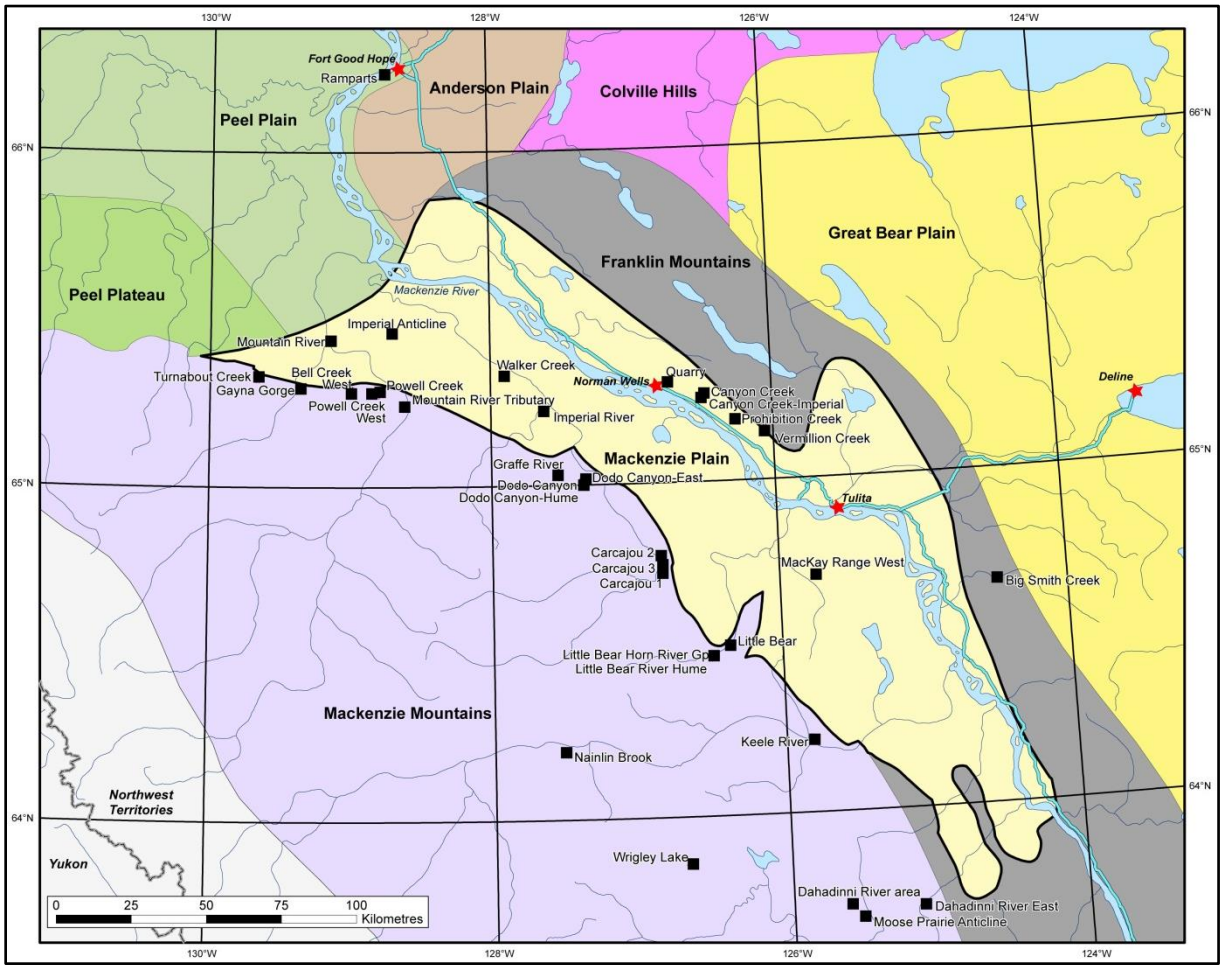

Figure 1: Location map of key outcrop sections and stations in Mackenzie Plain.

Conclusions

The basal Bluefish Member of the Hare Indian Formation is a regionally extensive unit of black shale and limestone that reliably marks the onset of Horn River Group deposition. In outcrop, it lies unconformably on uppermost limestone and shaly limestone beds of the Hume Formation, and varies from 2.0 m to 20.0 m thick. In the subsurface, it thickens to the south and west (from 3.0 m to 63.0 m thick). From preliminary analytical results, this unit has excellent source rock potential with an average total organic carbon (TOC) content greater than 5%. It is also quartz-rich (up to 66%). The upper Hare Indian Formation gradationally overlies the Bluefish Member but is limited depositionally in the study area where it is typically associated with the Ramparts Formation. In outcrop, silty limestone and calcareous shale of the upper Hare Indian Formation ranges from 7.5 m to 130 m thick, to greater than 250 m thick in the subsurface. The upper Hare Indian Formation is a poor source rock (average TOC 0.13%). The Hare Indian Formation is characterized by a higher concentration of light rare earth elements compared to other units. This distinct signature will aid in lithogeochemical correlation, particularly where Horn River Group strata remain undivided such as in the southwestern part of the study area.

The carbonate-dominated Ramparts Formation is also localized in its distribution and gradationally overlies the upper Hare Indian Formation where it is developed. The Ramparts Formation varies greatly from 10 m to more than 200 m thick in outcrop and the subsurface, to 0 m south and east of Norman Wells. It contains some rich source rocks within the “Carcajou member” (average 4.05% TOC), and similar to the upper Hare Indian Formation, contains variable amounts of quartz and calcite as dominant minerals.

The Canol Formation in outcrop can be differentiated into a basal recessive shale and mudstone-dominated unit, a middle resistant unit of siltstone, silty dolostone beds, very siliceous shale and mudstone, and an upper recessive shale-dominated unit. It abruptly overlies the Bluefish Member (where the upper Hare Indian and Ramparts formations are absent), or gradationally overlies the Ramparts Formation. It ranges from less than 20 m thick to greater than 150 m thick from measured outcrops and in the subsurface it varies from 14 to 233 m thick across Mackenzie Plain. It gradually thickens to the south and west, and is typically thin where the Ramparts Formation is thick. The Canol Formation contains excellent source rocks (average TOC >5%), and contains 82-90% average modal quartz.

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