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Results of a field and laboratory investigation of organic-rich Horn River Group shales in the southern Peel Plateau, NWT

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Summary

During the summer of 2016 two outcrops of the Horn River Group in the Peel Plateau region of the Northwest Territories were described and sampled. The outcrops were strategically selected based on their location to fill areal data gaps in the regional database. The results of the study will complement previous outcrop and well studies of the Horn River Group extending from the Mackenzie Plain into the Peel Plateau and Peel Plain regions, and will be used in future basin analysis and modeling. This talk presents the results of the field work and subsequent laboratory analyses.

Introduction

The Givetian-Frasnian aged Horn River Group comprises the Hare Indian, Ramparts, and Canol formations, and is present over large areas of the Mackenzie Plain, Peel Plain and Peel Plateau regions of the Northwest Territories. Historically, most industry, academic, and government research has focused on the Mackenzie Plain, where the rocks are good to excellent source rocks for hydrocarbons and are thermally mature over large areas. Recently, the organic-rich shale Bluefish Member of the Hare Indian Formation and the Canol Formation have been the focus of research as self-sourcing unconventional reservoirs with excellent economic potential. These units are present not only in the Mackenzie Plain, but extend west into the Peel Plateau and Peel Plain regions. Here, however, well and outcrop control is limited and sparse. The Arctic Red River East and Flyaway Creek outcrops of the Horn River Group were selected for examination to fill areal gaps in the Peel Plateau region.

Method

A total of 122 m of section was measured, described, and sampled at the two outcrops – 70 metres at Arctic Red River East (ARRE) and 52 metres at Flyaway Creek (FCC). Spectral gamma-ray measurements and samples for geochemical, mineralogical, and isotope analysis were taken at one-metre intervals. In total seven representative carbonate samples were collected for conodont analysis. The total organic carbon (TOC) content and source-rock quality were determined with a source-rock analyser through pyrolysis. Thermal maturity of the rocks was assessed through T_{max} data obtained from the source-rock analyser in addition to vitrinite reflectance analysis. Whole-rock lithogeochemical analysis of major, minor, and trace elements was used to provide proxies for various palaeoenvironmental indicators (terrestrial input, silica source, and palaeoredox conditions. X-ray diffraction (XRD) was used to determine the mineral make-up of the rocks. Carbon in organic matter, and carbon and oxygen in carbonate isotope analysis was used as a palaeoclimate proxy. Conodont analysis was used as a chronostratigraphic dating tool.

Results

At both localities the base of the outcrop comprises nodular carbonate strata of the Hume Formation. The Hume formation is conformably overlain by the Bluefish Member of the Hare Indian Formation. The Bluefish Member is ~6 m thick at ARRE and ~11 m thick at FCC, and consists of tentaculid-rich black shale with minor grainstone and packstone interbeds. Gamma-ray readings are high at both localities (>200 API), interpreted to be the result of elevated uranium concentration (> 14 ppm at ARRE and ~10 at FCC), and attendant high TOC content (2.84-8.20 %). Silica content in the Bluefish Member is moderate and variable (59-66%), except for carbonate rich beds where it is as low as 4%, which was reflected by lower rock brittleness noted in the field. Based on the terrigenous input profile (TIP - the summation of Al_3O_2+Fe_2O_3+KO_2+TiO_2) and the thorium to uranium ratio (Th/U), it is of the Bluefish Member, it is inferred that terrestrial input was low, but increasing through time. Paleoredox indicators, including the nickel to cobalt ration (Ni/Co) and the enrichment factor of vanadium (EFV), suggest that the Bluefish Member was deposited under at least partially anoxic conditions (EVF >1 and Ni/Co ratio >7).

The conformably overlying Bell Creek Member of the Hare Indian Formation comprises heavily weathered, grey and rust-coloured, friable shale. At ARRE the Bell Creek Member is 15 m thick, whereas at FCC it is poorly exposed, but is likely ~1 m thick. Gamma-ray readings are lower in the Bell Creek Member (100-200 API), a trend followed by lower TOC content (0.88-5.46%) and lower uranium concentration (3-14.6 ppm). Silica content is overall lower in the Bell Creek Member, with an increasing trend in its upper few metres (33-79%). The TIP and Th/U ratio indicate that the Bell Creek Member received an increasing amount of terrestrial sediment, with a sudden decrease in the upper few metres of the unit. The paleoredox indicators suggest sustained oxic conditions through most of the Bell Creek Member (EFV ~1 and Ni/Co ~7).

The Canol Formation conformably overlies the Bell Creek Member, but at neither outcrop was the contact well exposed. The top of the Canol Formation was not observed at either outcrop; the measured section of the Canol Formation at ARRE is 49 metres, and at FCC 45 metres. Gamma-ray readings are variably and locally high in the Canol Formation (134- >300 API), with variable uranium concentrations of 3.4-14.6 ppm and medium-high TOC content of 3.1-8.12%. Silica content in the Canol Formation is consistently high between 64 and 90%, which was reflected by increased rock hardness and brittleness in the field. Terrigenous input is consistently low throughout the Canol Formation. Palaeoredox indicators are variable, but suggest initial anoxia in the lower ~10 metres of the Canol Formation (EFV >1 and Ni/Co ratio >7), oxic and/or dysoxic conditions for ~ 20 metres in the middle portion (EFV ~1 and Ni/Co ratio ~7), then a rapid return to anoxic conditions in the upper ~5 metres.

The results of source rock maturity based on T_{max} and vitrinite reflectance indicate that the rocks are poor candidates for these analyses. T_{max} data for ARRE have a mean of 604 °C, with a minimum of 463 °C and a maximum of 623 °C. For FCC the results are more consistent, with a minimum of 621 °C, maximum of 624 °C and mean of 623 °C. Note that the detection limit of the source-rock analyser is 624 °C. With the exception of the low values obtained from ARRE around 463-466 °C, the other values are well outside the expected range in this region based on previous well-derived data. These results will be confirmed through a second set of analysis, and further examined to explain the discrepancy. The vitrinite reflectance data are highly scattered, with a minimum of 0.65, maximum of 2.12, and a mean of 1.25. The results are likely unreliable due to the small grain size of the organic matter and noted oxidation halos around many particles.

Results of the stable isotope analysis and conodont identification will be analysed early in 2017, and will complement the above results. Collectively, these data will be used as input for a new research initiative focused on basin analysis and basin modeling of the Horn River Group in the Northwest Territories.

Conclusions

Two outcrops in the southern Peel Plateau of the Northwest Territories were examined in detail in the field and sampled for laboratory analyses. The focus was on the Horn River Group, which in the Mackenzie Plain has proven hydrocarbon potential; the current outcrops were strategically selected to fill areal gaps in the knowledge base of these rocks. The geochemical analyses add new insights into the origin and depositional environment of these rocks, indicating a changing sediment delivery system and ocean circulation conditions. The results of the source rock maturity analyses have, however, been called into question, as they are well outside the expected range (T_{max} data), or highly random (vitrinite reflectance), and will need to be re-examined. Nonetheless, the available data will be a valuable addition to future basin analysis and modelling efforts of the Northwest Territories sedimentary basins.