Petroleum potential of the Middle-Upper Devonian Canol Formation in north Yukon: report on field investigations in 2013

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Summary

The Yukon Geological Survey is conducting research to evaluate the petroleum potential of Devonian-Carboniferous shale units in north Yukon. The Middle-Upper Devonian Canol Formation was the focus of field studies in summer 2013. Stratigraphic sections in the southern Richardson and northern Ogilvie mountains were systematically measured and sampled in an effort to characterize and correlate the Canol Formation within the Yukon, and to assess the formation's regional hydrocarbon potential, both as a source rock and a shale reservoir. This study presents preliminary results for three Canol Formation stratigraphic sections. The information acquired from these outcrops will be instrumental in understanding the Canol Formation in the subsurface of Eagle Plain Basin and Peel Plateau and Plain oil and gas regions. The study is timely as the Canol Formation is currently being explored as an unconventional hydrocarbon resource in the Northwest Territories' central Mackenzie Valley.

Introduction

The Canol Formation is a Middle-Upper Devonian shale and chert unit that is present in Yukon and Northwest Territories. Previous studies have identified it as a potential hydrocarbon source rock, but its lithology, geochemistry, age, stratigraphic relationships and distribution in Yukon have not been systematically described. In an effort to improve our understanding of this potential resource in Yukon, the Yukon Geological Survey initiated a possible multi-year study of the Canol Formation and stratigraphically adjacent strata in north Yukon. In summer 2013, YGS geologists visited outcrops of Canol Formation in the southern Richardson and the northern Ogilvie mountains to document, in detail, its stratigraphic character and to collect samples with which to evaluate its petroleum potential. Laboratory results and further fieldwork are anticipated in 2014.

Background

The north Yukon is relatively underexplored for oil and gas with most activity concentrated in Eagle Plain Basin and Peel Plateau and Plain. Historically, exploration in the region has focussed on conventional targets, specifically Paleozoic carbonates (e.g. Devonian Ogilvie Formation) and Carboniferous siliciclastic units (e.g. Mississippian Tuttle Formation) trapped in anticlinal structures mapped at surface (Osadetz ***et al***., 2005). The majority of exploration in the region occurred in the 1960s and 1970s; however, renewed interest in Eagle Plain Basin has resulted in four new exploration wells in the southeastern part of the basin since 2012, together with successful land dispositions in 2007, 2009 and 2010. To date, Canol Formation strata were intersected in twenty oil and gas exploration wells in Peel Plateau and Plain, Eagle Plain Basin and northeast of Kandik Basin (Fraser and Hogue, 2007; Northern Cross Yukon Ltd., 2013).

The unconventional potential of the north Yukon has not yet been assessed; however, several studies have identified potential source rocks in the region, including the Canol Formation (e.g. Pugh, 1983; Snowdon et al., 1987; Link et al., 1989; Gal et al., 2009; Fraser et al., 2012). A recent scoping study of unconventional oil and gas potential in Yukon (Hayes and Archibald, 2012), which used existing geological data to evaluate Yukon's sedimentary basins for unconventional oil and gas potential, identified good to very good shale gas prospectivity in the Canol Formation in north Yukon, with further detailed geoscientific work recommended.

In adjacent Northwest Territories, the Canol Formation has been proven as the source rock for the Norman Wells oil field (Kee Scarp Member; Snowden et al., 1987). It is also a current unconventional exploration target in the central Mackenzie Valley, NWT where several companies are focussed on evaluating the shale oil potential of both the Canol Formation and the older Middle Devonian Bluefish Member of the Hare Indian Formation.

Location & methods

The Canol Formation was measured at three locations in north Yukon: Trail River, on the eastern flank of Richardson Mountains (NTS 106 L/6); White Fox Creek; on the western flank of the Richardson Mountains (NTS 116 I/16); and at kilometre 211 on the Dempster Highway (NTS 116G/8) in the northern Ogilvie Mountains. The sections in the Richardson Mountains coincide with the location of the former early to middle Paleozoic Richardson trough (Lenz, 1972), a north-south oriented deep water marine basin flanked by carbonate platforms. In Richardson Trough, the Canol Formation overlies calcareous shale and chert of the Middle Devonian Road River Group and underlies mudstones of the Upper Devonian Imperial Formation. In the northern Ogilvie Mountains, the Canol Formation overlies fossiliferous platform carbonates of the Middle Devonian Ogilvie Formation and underlies either Devonian or Carboniferous strata (e.g. Ford Lake Shale, Hart River or Nation River formations; Pigage 2009).

Sections were measured and described in detail. Sampling at each section involved: spectral gamma-radiation readings at one-metre intervals and collection of chip samples through two metre intervals for source rock and thermal maturity analyses (Rock-Eval/total organic content) and lithogeochemistry (ICP-ES and MS). Samples for microfossil biostratigraphy (conodonts, radiolarians and pollen) and vitrinite reflectance were also collected near formation contacts. One bentonite layer was sampled for U-Pb dating. All lithologies were sampled for XRD mineralogy. Most samples are currently being analyzed with results anticipated in 2014.

Field Observations

A near-complete section of Canol Formation was measured on Trail River, where it consists of 229.3 of rhythmically bedded siliceous shale and chert in varying proportions. Siliceous shale and chert are black, and weather grey to black or brown with a distinctive yellowish orange, dark red and apple-green weathering residue. Siliceous shale is very fissile, and occurs as both a recessive, finely-laminated unit in beds up to 3 cm thick, and a more resistant, thicker-bedded unit with beds up to 10 cm thick. Chert is very resistant, non-fissile and is laminated in beds up to 16 cm thick. The geochemistry of the Canol Formation is distinctive from both the underlying Road River Group and overlying Imperial Formation, displaying higher concentrations of silica, molybdenum, vanadium, and uranium and lower concentrations of aluminum, iron, magnesium, and potassium. The Canol Formation at this location is non-fossiliferous, locally contains large (2.5 by 0.9 m), isolated concretions, and contains intervals rich in pyrite. The basal contact of the Canol Formation is marked by distinct elemental changes between units as well as spikes in barium, lead, zinc, and nickel concentrations. Ni-Zn-PGE mineralization was discovered in this interval at the Nick Property approximately 190 km south of this location, prompting extensive regional exploration.

On White Fox Creek, 180 m of Canol Formation strata were measured over five separate intervals that were separated by covered areas. The formation here consists of rhythmically bedded siliceous shale and chert similar to that observed on Trail River, however, siliceous shale dominates throughout the section. Part of this section is 'fire-baked' and bright red-pink in colour from oxidation of pyrite and combustion of organic matter, likely caused by landslide activity (Mathews and Bustin, 1984). The basal contact with the Road River Group is not as distinctive lithologically as on Trail River, however, subtle geochemical changes such as an increase in silica, and decrease in aluminum, iron and magnesium, and lead concentrations up-section likely delineate the contact. Graptolites occur in Road River strata, while the Canol Formation is mainly unfossiliferous, with possible tentaculid impressions occurring very rarely on bedding planes. Large, laterally-elongate (5.0 by 3.0 m) calcareous concretions occur locally within the Canol Formation. Pyrite-rich horizons occur particularly in the lower part of the section.

In the northern Ogilvie Mountains, a 110 m section of shale and mudstone with minor chert considered to be stratigraphically equivalent to the Canol Formation was measured near kilometre 211 on the Dempster Highway. The section at this locality differs both lithologically and geochemically from the Richardson Trough sections, being less siliceous, more recessive and containing smaller (up to 8 cm diameter) and more abundant concretions. The rocks at this locality also have higher overall concentrations of aluminum, iron, lead potassium and thorium and slightly lower concentrations of uranium. No fossils were observed in this section; however, a bentonite horizon measured at the base of the section was sampled for U-Pb dating.

Future Studies

Petroleum potential, mineralogical, and age data for the measured sections will be available in 2014. Additional fieldwork is planned for summer 2014. Identifying new Canol Formation sections will be a critical first step in continuing the research as exposure is limited. Correlating surface sections to subsurface well logs and core in the region will also help to define the variability of the Canol Formation within the region. This study forms a part of a larger initiative to understand unconventional shale resources in Yukon.

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