Petroleum Source Rock Analysis of the Upper Devonian Torquay Formation of South Eastern Saskatchewan

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Summary

As a part of the ongoing Williston Basin Phanerozoic Fluids Project, certain methodologies have been developed to quantitatively evaluate and simulate petroleum systems within the Paleozoic succession. This study examines the geochemical characteristics of the (Three Forks Group) Torquay Formation of Southern Saskatchewan. Using an integrated approach involving the high resolution sampling of core, RockEval 6 pyrolysis and organic petrography an assessment of the source rock potential of the Torquay was conducted.

This study shows that although two, relatively thin, organic rich zones exist in the Torquay Formation within southern Saskatchewan, they are marginally mature. Generally values for total organic carbon are below 0.5 wt %, only exceeding 1.0 wt % at 1015.5m-1016.5m with hydrogen indices below 250. RockEval 6 analyses indicates that most of the organic matter is Type II to III, with some IV, petrographic analysis indicates the absence of terrestrial material, therefore strongly suggesting the presence of reworked material or the occurrence insipient oxidation. This preliminary analytical examination suggests that the Torquay Formation has limited source potential within southern Saskatchewan.

Introduction

The source rock geochemistry of the Torquay formation has been largely understudied, leaving to speculation the origin of Torquay Formation oil within southern Saskatchewan. Currently, the Torquay formation produces petroleum in multiple locations across southern Saskatchewan, in which the brecciated dolostones and doloarenties provide the permeable reservoir quality rocks that hold economical accumulations of petroleum. Studies have been conducted to assess reservoir characteristics (Kreis et al., 2006), but no study has been carried out to assess the presence or absence of organic matter or petroleum source rock potential.

This study concentrates on generating geochemical data for the Torquay formation of Southern Saskatchewan, targeting those wells with good core recovery. Samples were collected from wells 01-14-001-08W2, 16-32-001-04W2, 13-19-009-31W1, spanning the northern rim of the Williston Basin from the Manitoba/Saskatchewan border to the deepest portion of the basin within Saskatchewan along the US/Canada border. A high resolution data set for the upper Torquay was generated by sampling core at the cm to mm scale, to facilitate the analysis of trends or variations due to the presence of fine laminations. Unlike the traditional source analysis approach, which are based upon bulk rock samples with a low sampling frequency throughout a particular formation, this study sampled each lithological change and lamination to get the most detailed interpretation of changes in organic matter accumulation and kerogen Type throughout the Torquay. The principle analytical focus was placed on the upper Torquay, dominated by brecciated argillaceous dolostones and doloarenites, and the lower Torquay characterized by an alternation of red, oxidized beds with green argillaceous beds.

Method

Core samples were collected and washed. Samples for RockEval analysis were obtained from samples of core using a drill press with fitted with either a 5.0 or 2.0 mm masonry drill bit. Extracting samples in this fashion enabled the sampling of individual laminations rather than bulk samples of the rock giving a more detailed geochemical profile, providing on a millimeter scale the recognition of minor changes in TOC, S1, S2, and Hydrogen Index through the Torquay. The methodology utilized for RockEval analysis followed the standard method, as outlined by Espatalie *et al* (1977) and Peters *et al* (2005), petrographic analysis was conducted using a Leitz Orthoplan microscope configured for UV/fluorescence reflected-light microscopy.

Data taken from the geochemical analyses provided was pairing with detailed lithological logs to obtain a more accurate depiction of paleoenvironment, controls on sediment and organic matter deposition and alteration, as well as cyclic trend in sedimentation and organic accumulations. Data generated by RockEval analysis, lithologic evaluations as well as petrophysical logs was used to assign member designations to the Torquay. Use of petrophysical logs was required in portions of the formation where core was not available for study. These un-cored portions of the formation were primarily located stratigraphically lower than the first appearance of the oxidized mudstones (or red-beds), likely do to their economic insignificance.

Results and Discussion

Results attained from the sampled wells provided a large volume of highly detailed information that allowed for potential source evaluation. The results from well 13-19-009-31W1, seen in the geochemical logs (Figure 1), portray a cyclic nature of organic material within the upper portion of the

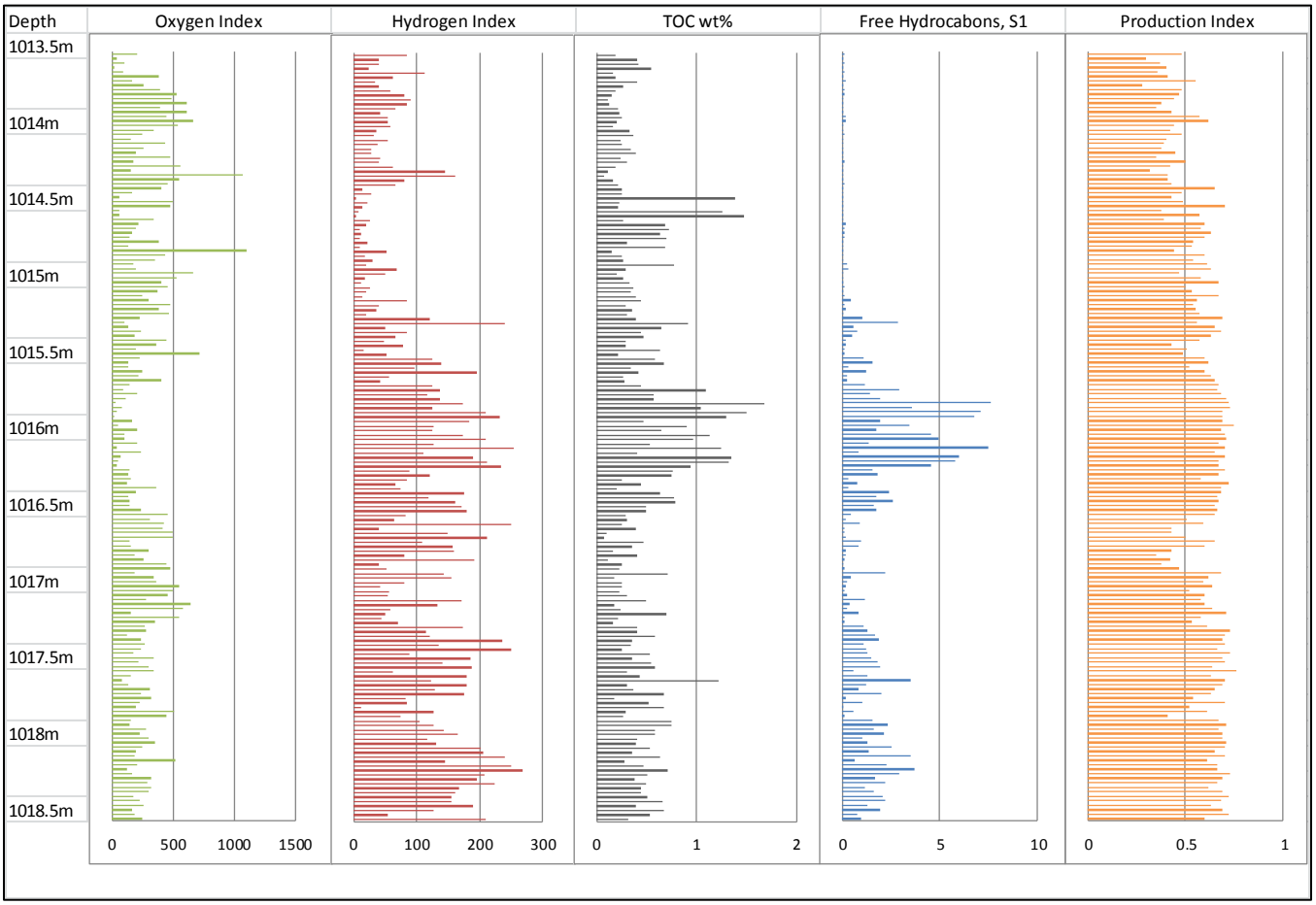

Figure 1 - Geochemical logs for the upper Torquay in well 13-19-009-31W1, note that the log spans a depth from 1013m to 1018.5m representing the cored interval.

Torquay between depths 1013.5m to 1018.5m; fluctuations in RockEval parameters are relatively in-sync throughout the formation, indicating cycles of organic matter and sediment deposition rates.

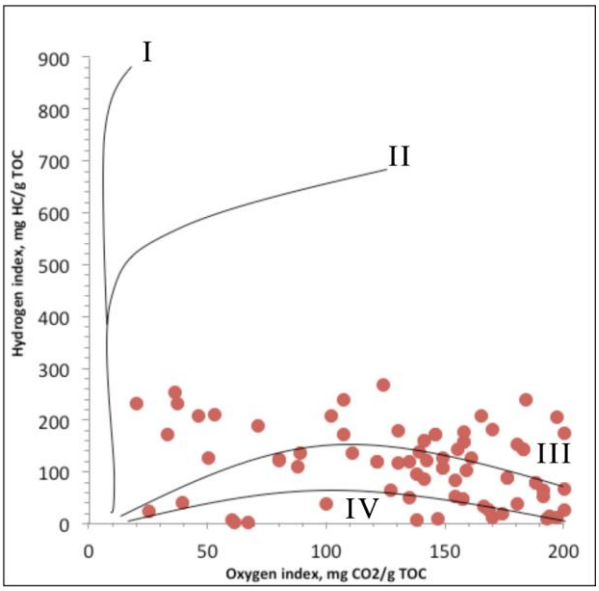

Figure 2 - HI v OI cross plot for the Torquay formation. Analyses based upon core.

Between 1015.5 to 1016.5m and associated with fine argillaceous interlaminations, is a zone with relatively higher TOC (1.7 wt %) and S1 values higher than the remainder of the upper Torquay (Figure 1). Low values of Tmax throughout the formation (i.e., below 425 Celcius) signifying that the organic matter is thermally immature and associated with a poorly developed hydrocarbon content. Low values of Tmax through the formation support this assumption (Peters et al., 2005). The Hydrogen Index v Oxygen Index cross-plot suggests that the kerogen content within the formation to be that of Type II to III and some Type IV (Figure 2). However, Type III kerogen is typically associated with terrigeneous organic matter, which is absent in those samples analysed. Petrographic analysis revealed the presence of amorphous organic matter, generally characterized by a yellow-orange fluorescence of moderate intensity with no land derived organic material. Such a finding strongly suggests that the organic matter within the Torquay has undergone some form of 'degratation' with the loss of hydrogen-rich material, yielding a false Type III. Type IV kerogen is typically taken as representative of residual organic matter.

The production indexes (PI) values for the upper Torquay show considerable variation (Figure 3), with the majority of the values plotting outside of the zone of significant oil generation (i.e., between 0.1 to 0.4)

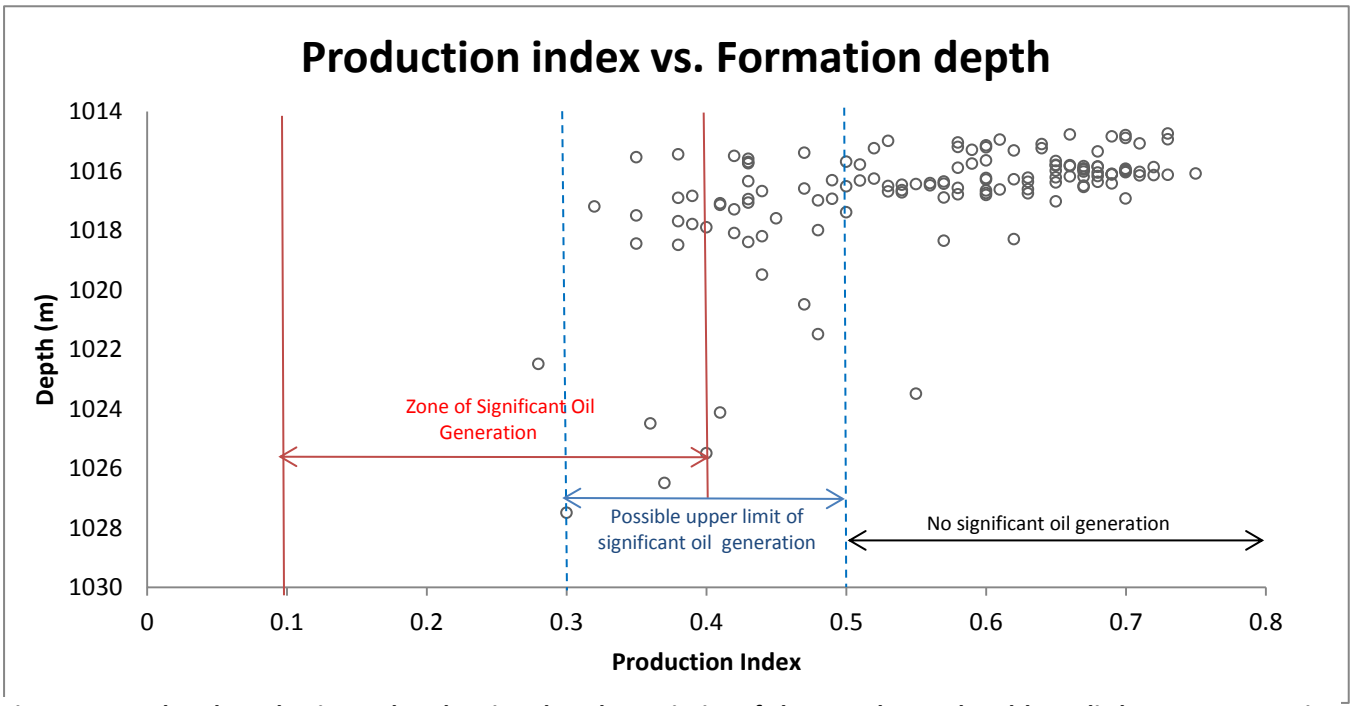

Figure 3 RockEval production Index showing that the majority of the samples analyzed have little to no generation potential. Analyses based upon core.

(Espitalie et.al, 1977). However, many of the plotted values may not be accurate as S2 values are less than 0.2 mg HC/g rock, indicating that very little organic matter within the upper Torquay at 13-19-009-31W1 has or is capable of significant oil generation. Production indexes viewed along side total organic carbon and hydrogen index show that samples with the highest amount of S1 (hydrocarbons within them have have PI values above 0.4, meaning the sample at this locallity are uncapable of sigificant oil generation, suggesting that the hydrocarbons recorded as S1 are not indigeneous.

Conclusions

Many conclusions can be drawn from that data generated throughout this study, though the most important one is the value of conducting detailed, high-resolution geochemical data that can give information on the cyclic nature of organic accumulations within a formation. The petroleum source potential of the Torquay formation, within southern Saskatchewan would appear quite low due to the presence of thermally immature to marginally mature kerogen that possesses a relatively low Hydrogen Index. However, two relatively thin zones of moderate potential were identified that may exhibit genuine generative potential deeper within the basin.

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References

Espitalie, J., Madec, M., Tissot, B. and Leplat, P. (1977) Source rock characterization method for petroleum exploration. In: Proceedings of the Offshore Technology Conference, May 2–5, 1977, OTC, Houston, TX, p. 439–44.

Hunt, J. M. (1996) Petroleum Geochemistry and Geology, Second Edition. W.H. Freeman and Company, New York, U.S.A. p. 491.

Kreis, L.K., Costa, A.L., and Osadetz, K.G. (2006): Hydrocarbon potential of Bakken and Torquay formations, southeastern Saskatchewan; in Gilboy, C.F. and Whittaker, S.G. (eds.), Saskatchewan and Northern Plains Oil & Gas Symposium 2006, Saskatchewan Geological Society Special Publication 19, p.118-137.

Peters, K.E., Waters, C.C., Moldowan, J.M. (2005) The Biomarker Guide, Second Edition, I. Biomarkers and Isotopes in the Environment and Human History. Cambridge University Press, Cambridge, UK.