High Resolution Organic Facies of the Bakken Formation, Williston Basin, Saskatchewan, Canada

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Summary

The focus of this high resolution study is to characterize the organic matter in the Bakken Formation within the Canadian portion of the Williston Basin using the concept of organic facies. Organic facies for this study will be defined using both geochemical (i.e. RockEval) and petrographic characteristics of organic matter in order to distinguish areas within the Upper and Lower Bakken with the greatest hydrocarbon generative potential.

Introduction

This project is part of a large, integrated assessment of the Phanerozoic fluids and the petroleum systems of southern Saskatchewan that is being conducted at the Universities of Alberta and Regina. The overall goal of this project is to examine, analyze and characterize the fundamental processes involved in the generation, migration and entrapment of hydrocarbons in Phanerozoic strata, specifically regarding how and where hydrocarbons in the Saskatchewan subsurface were generated and where and when they migrate over geologic time to help determine where they are most likely to have been trapped at the present time.

This particular study seeks to characterize the type and occurrence of organic matter within the Bakken formation using the concept of organic facies as defined by Jones and Demaison (1982) and Tyson (1995), and initiated by Stasiuk (1996) within the Williston and Western Canada Sedimentary basins.

An organic facies is a mappable subdivision of a stratigraphic unit, distinguished by variations in their petrographic characteristics with disregard of inorganic constituents. Figure 1 shows the possible variation in organic facies across a hypothetical basin, according to Jones (1987).

The concept of organic facies recognizes the interdependency between an organism and depositional environment, including: water depth; water chemistry; the type and availability of nutrients; temperature; redox potential, and the proximity to land (Tyson, 1995). Therefore a spatial or temporal change in one, or all of these factors would conceptually favour a given organism or assemblage of organisms, which in turn has been shown to impact the generative potential of a given source rock horizon (see Tyson, 1995). Mapping organic facies across a given horizon can help identify greater or lower hydrocarbon generative potential beyond that of a simple assessment of total organic carbon content or Kerogen Type, as demonstrated and applied by previous studies within southern Saskatchewan (Stasiuk, 1996; Seibel, 2002; Stasiuk and Fowler, 2004).

Using high resolution core sampling, this study seeks to identify and define the basin-wide temporal and spatial variations in source rock quality for the Bakken formation within the Canadian portion of the Williston Basin using the concept of organic facies. Organic facies will then be mapped spatially and temporally across the study area to definitively express areas of the greatest hydrocarbon source potential.

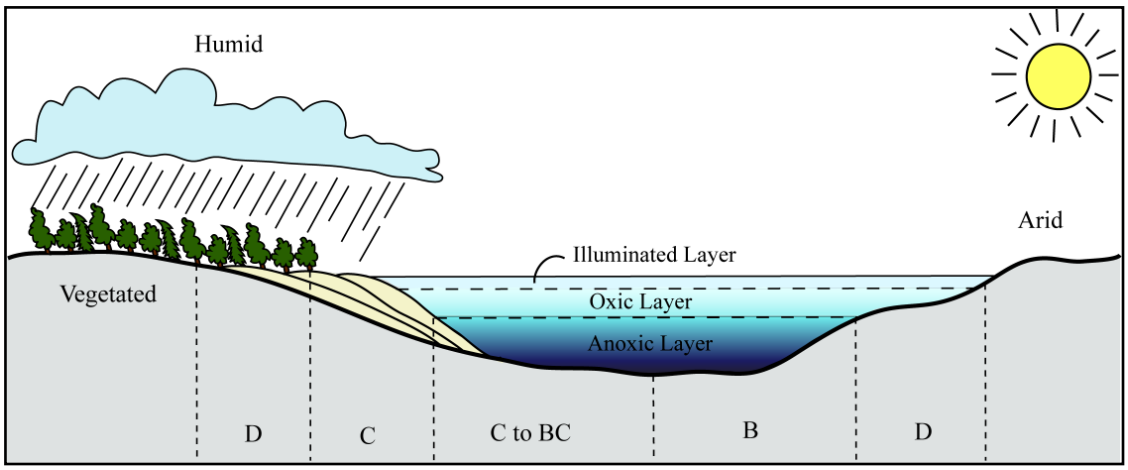

Figure 1: Profile relating organic facies types to a sedimentary depositional environment and associated environmental conditions (i.e. climate, oxygen levels). Organic facies A and AB are not show they form under anoxic lacustrine settings with no (A) or minimal (AB) terrestrial input. (modified from Jones, 1987).

Method

A preliminary suite of 19 vertical boreholes along transects, trending north-south and east-west, across the Canadian portion of the Williston Basin were selected based upon the inclusion and availability of core within the Upper and Lower Bakken formation. Cores were logged and samples taken at regular, closely spaced intervals.

Samples were subsequently subdivided into three sub-sets for petrographic and geochemical analysis. Petrographic (maceral) analysis was conducted on two sets of samples, which includes epoxy-mounted crushed (2 to 4mm) samples (sub-sample 1) and oriented samples cut perpendicular to bedding (sub-sample 2) mounted in low-fluorescing epoxy resin. Samples were subsequently polished using a modified version of the procedure in Mackowsky (1982), mounted on a glass slide with “Fun-Tac” using a Leitz leveling press and examined using a Leitz Orthoplan research microscope calibrated for both white and auto fluorescent reflected light at an overall magnification of x500. Point count analysis was conducted using a Swift point counter with an inter-point and inter-line distance of 50µm, 500 individual analyses were recorded per sample.

The third sub-sample was crushed to <0.0625mm (silt-sized) and analyzed using a DaVinci Industries Rock-Eval 6 analyzer, providing Total Organic Carbon (TOC), Hydrogen Index (HI), Oxygen Index (OI), Tmax, S1, S2 and S3 (Espitalié et al, 1977). The analysis protocol used is the standard Rock-Eval 6 method.

Results/Discussion

There have been a number of organic facies studies previously conducted within the Canadian portion of the Williston Basin, specifically within the Winnipegosis (Stasiuk, 1991; Stasiuk et al, 1991), Yeoman (Stasiuk, 1991), Winnipeg (Seibel, 2002) and Bakken Formations (Stasiuk 1991, Stasiuk et al, 1991; Stasiuk, 1996; Stasiuk and Fowler, 2004). However, studies were typically conducted using a ‘low resolution approach’ often with only a few samples selected per well. The work of Seibel (2002) demonstrated the significance of adopting a ‘high-resolution’ sampling protocol and a basin-wide approach. Furthermore, previous organic facies studies often rely on petrographic characteristics, as recognized in reflected light microscopy (white/autofluorescent light), using the Jones and Demaison (1982) or Jones (1987) definitions as the basis for their source rock characterization for organic facies differentiation.

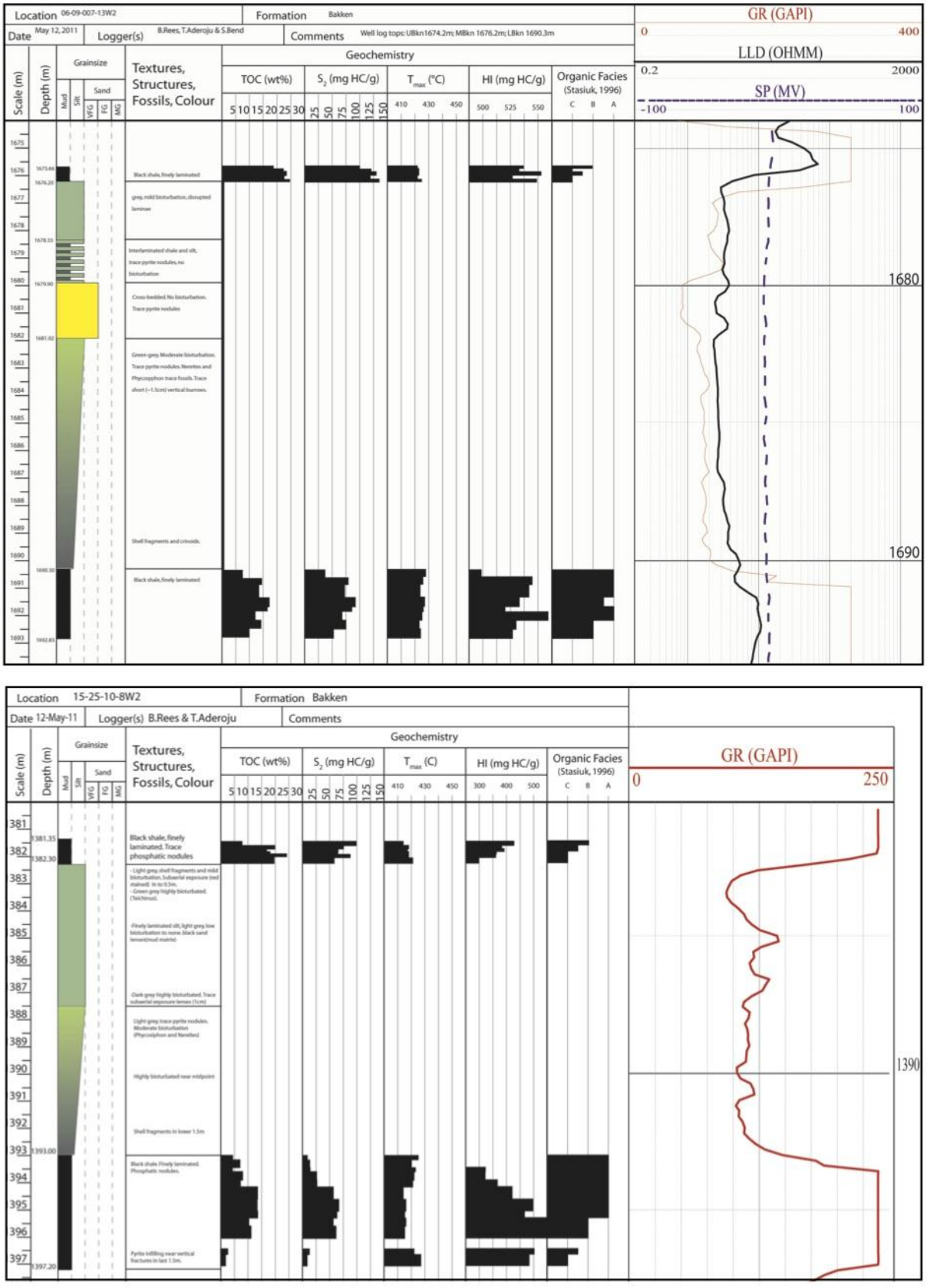

Figure 2: Composite core logs for two wells. Upper log: 'A' is for well 6-9-7-13W2; and Lower log 'B' is for 15-25-10-8W2 depicting in columns left to right TOC, S2, Tmax, HI, organic facies and well-log signatures

This study will amalgamate the organic facies definitions of Jones and Demaison (1982) and Tyson (1995) in which the organic facies are distinguished using maceral assemblage and geochemical signature, with reference to variations in lithofacies and associated petrophysical log characteristics. The organic facies types used are those defined by Stasiuk (1996). Black shales, such as those of the upper and lower Bakken formation, are often regarded as homogenous. However, even the preliminary work of this study has shown that not only do these shales exhibit a high degree of variability in the quantity and quality of organic matter, both with depth and across the basin.

Within the composite core logs shown in Figure 2 the temporal variations in the quantity and quality of organic matter is expressed as changes in geochemical characteristics (e.g., TOC, S2 and HI) and with respect to the organic facies. The Upper Bakken formation depicted in Figure 2A has a overall high but variable (16 to 24wt%) TOC. The organic facies for the Upper Bakken also vary with depth from organic facies *B to C*. In comparison the Lower Bakken has a TOC of greater variance, from 4 to 17wt% TOC, in which the maximum TOC occurs with in the mid-section of the Lower Bakken. The organic facies of the Lower Bakken degrades from an algal-rich *organic facies A* to the more diffuse *organic facies C* with depth. It is important to note that the organic facies of Upper and Lower shales are markedly dissimilar and can not be considered as having the same hydrocarbon source potential. Even at this preliminary stage in the study, several distinct horizons of organic facies can be recognized in both the Upper and Lower Bakken Formation. In previous studies this variance was not recognized due to difference in sampling protocol. This higher resolution study allows for the expression of detailed source rock characterization both depth wise through the Upper and Lower Bakken and across the basin.

Conclusion

There is a compositional difference between the upper and lower shales of the Bakken formation that is significant, with implications for marked dissimilarity in generative potential. Also, within both the Upper and Lower Bakken shales there is a variation in TOC and organic facies with depth. Clearly the quality and quantity of organic material exhibits a marked variation, this is profound, as variations in a given source rock will be expressed as variance of the hydrocarbon generative potential.

Acknowledgements

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