[PS]High Resolution Organic Facies of the Bakken Formation, Williston Basin, Saskatchewan, Canada*

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Abstract

This presentation will present preliminary results of a high-resolution organic facies study that is currently being conducted on the Bakken Formation within the Saskatchewan portion of the Williston Basin. Jones and Demaison (1982) and Jones (1987) defined organic facies as a mappable subdivision of a designated stratigraphic unit, distinguished from the adjacent subdivisions on the basis of the character of its organic matter without regard to the inorganic aspects of the sediments. Tyson (1995) suggested that the concept reflect a body of sediment containing a distinctive assemblage of organic constituents, which can either be recognized by microscopy or is associated with a characteristic bulk organic geochemical composition. This study amalgamates both concepts, subdividing a given stratigraphic unit (spatially and temporally) into organic facies that are distinguished by variations in maceral assemblage and geochemical signature, with reference to variations in lithofacies and associated petrophysical log characteristics.

Organic facies is a relatively new concept within the field of petroleum geology and only a few isolated studies have been conducted within the Williston Basin. A high-resolution organic facies study of the Bakken Formation incorporates petrographic and geochemical analysis of core-derived samples, selected at closely spaced intervals throughout the Upper, Middle and Lower Bakken. Each core is initially logged and gross characteristics described then subsequently sampled. Petrographic analysis involves point-count analysis of macerals under white and fluorescent light; whereas RockEval is used to geochemically characterize each subdivision. Essentially, the organic petrology data obtained from the epoxy-mounted samples is coupled with the RockEval data to define organic facies, which are then plotted on a depth-wise core log and compared to wireline log signature (e.g. GR, Resistivity), TOC, S2, kerogen Type and other key characteristics. Preliminary results, based on this higher resolution approach, show detailed temporal (i.e. depth-wise) variations in maceral/kerogen Type that reflect gross variations in TOC and log signature. Building upon the earlier work of Stasiuk (1991, 1996), who defined the Bakken shales to consist of three organic facies, this work is able to show subtle variations within earlier defined facies that may, in turn, reflect variations in production across the northern part of the basin.

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Study Overview

This study is a part of a larger research project called the Saskatchewan Phanerozoic Fluids and Petroleum Systems Project (SPFPSP) The goal of the SPFPSP is to improve our understanding regarding how and where hydrocarbons within the Saskatchewan subsurface were generated and when they migrated over geologic time. This portion of the SPFPSP is to characterize the organic matter both laterally and temporally in the Bakken Formation black shales (petroleum source rocks) and other Palaeozoic source rocks using the source rock characterization technique of Organic Facies.

In the broader context of source rock characterization, this research also asks the following questions: Is it meaningful to characterize the generative potential of a given source rock, such as the Bakken, by TOC alone? Is it meaningful characterize a source rock, such as the Bakken, only using bulk geochemical analysis? Is it meaningful to use wireline logs to characterise source potential? Is it meaningful to use a single sample from entire interval when evaluating the source potential of a given interval?

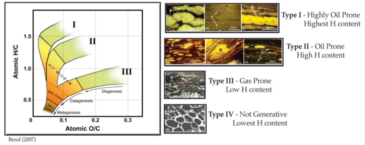
Organic Matter, Macerals & Kerogen Type

- Organic Matter in a petroleum source rock or oil shale is commonly refered to as kerogen and is defined as: 'the organic matter that is insoluble in non-oxidizing acids, bases and organic solvents.' (Hunt, 1996)
- Macerals are the visible constituents or organic matter within organic rich rocks such as coal, oil shale, and petroleum source rocks, recognized by their petrographic and geochemical characteristics.

Three main maceral groups: Vitrinite, Liptinite & Inertinite

- The liptinite group are generally considered the most significant group with respect to the production of petroleum.
- Macerals within the liptinite group are diverse in orgin and generative potential.
- Macerals within the vitrinite and inertinite groups are most commonly found in coals and considered a detriment to the formation of a viable petroleum source rock.

Kerogen Types



Bend (2007)

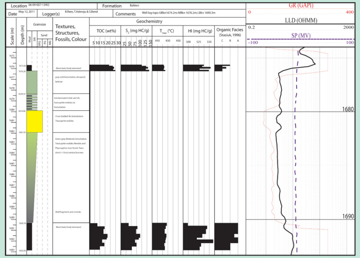
High Resolution: Necessary

The composite log Well B (see map) on the right includes:

- Lithological features
- Bulk rock geochemical characteristics from Rock-Eval analysis
- Organic facies data (from Stasiuk, 1996)
- E-log signatures (Gamma, SP, and Resistivity)

This composite log is a demonstrates that a single sample from a given petroleum source rock will not be representative for the whole interval.

- Example: TOC values vary from 7.61 to 22.66 wt%. If a single sample was chosen at either the upper or lower ranges of TOC and extrapolated to the whole interval this would result in extreme differences in estimatehydrocarbon generative potential.



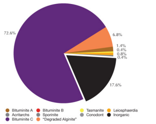
Furthermore, estimating source potential from gamma well-log response is not possible. Gamma response is consistantly high for the whole interval and shows none of the variations present in the geochemical characteristics.

Kerogen Typing: The Averaging Effect

- Type II kerogen is the most commonly reported kerogen Type when characterized using bulk chemistry analysis alone.
- Many such reports probably reflect the 'geochemical averaging' of a mixture of two or more different kerogen within the same sample/interval.
- For example: a sample/interval containing both Type I and Type III kerogens will generate either a 'false Type II' of a highly diminished Type I. *This has serious implications for the assessment of 'exploration risk'.*
- Bulk geochemical analysis (Rock-Eval/Elemental analysis) alone cannot unequivocally characterize true generative potential.

Geochemical & Petrographic Data for the Same Sample

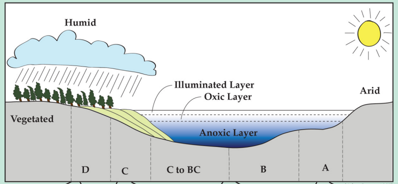
Well X - Lower Bakken 1696.97m



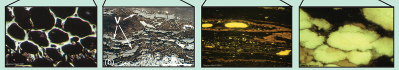
Rock-Eval Results:
TOC (wt%): 6.81
S2 (mg/g): 34.12
Tmax (C): 420
HI: 501
OI: 22

Organic Facies

Organic Facies is a petroleum source rock characterization technique which utilizes both geochemical and petrographic data to divide a given petroleum source rock into mappable units as an expression of hydrocarbon generative potential.



(After Jones, 1987)



Changes in Organic Facies Across A Generalized Basin

- The diagram on the left demonstrates the changes in the organic matter content of a petroleum source rock across a given basin.
- Moving from Organic Facies D to A (in the diagram to the left) represents the changes in hydrocarbon generative potential expressed here as the reduction of terrestrial to more algal-rich organic matter.

The application of organic facies allows for the mapping of the slight changes in organic matter, thus hydrocarbon generative potential, within a given petroleum source rock aross the formation of interest.

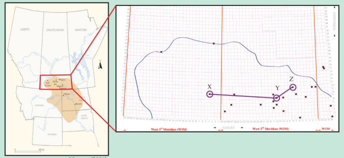
Methodology

This study uses the concept of high resolution organic facies to characterize the organic matter found within the upper and lower shales of the Bakken Formation.

- Core samples have been taken at regular, closely-spaced (~10cm/4in) intervals from 24 wells (see map) across the Canadian portion of the Williston Basin.
- Petrographic analysis is conducted on whole rock sample mounted in epoxy and examined in auto-fluorescent and reflected white light via point-count analysis. Microscopy is performed under air or oil immersion with an overall magnification of 500 times.
- Geochemical data is obtained from the pyrolysis of samples in a DaVinci Rock-Eval 6.
- Organic facies will be mapped temporally and spatially (3 dimensions) across the area of interest using either Schlumberger: Petrel or Surfer 8.
- Organic facies defined for the Bakken by Stasiuk (1996) will be used as a base for this study with the intent of expanding on the idea because of the higher resolution of this study.

Study Area

Samples have been gathered across the Canadian portion of the Williston Basin within the Bakken formation. The selected wells are depicted below.



Vigrass (2006)

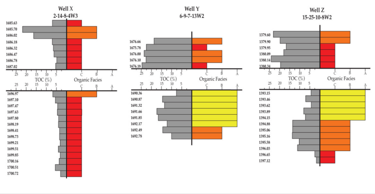
Preliminary Results

Below are three comparative bar graphs (Total Organic Carbon versus Organic Facies) and summary composite logs. All geochemical data is derived from Rock-Eval 6 pyrolysis. Organic petrographic data was recorded from point counting. Organic facies A through C are from the definitions from Stasiuk (1996).

Stasiuk's defintions (1996, see below) are not the final organic facies to be used in this study. Additional organic facies to those defined by Stasiuk have been observed in Well A, where the amorphous organic matter is quite diffuse and inorganic content (such as quartz silt grains) is prevalent throughout the majority of the samples.

Preliminary trends show a decrease in hydrocarbon generative potential towards the west expressed as a reduction of TOC coupled with a reduction in bituminite (AOM) and alginite content for both the Upper and Lower shales. These results also show a large variations in the characteristics of the organic matter within these black shales; they are not homogeneous.

TOC vs Organic Facies



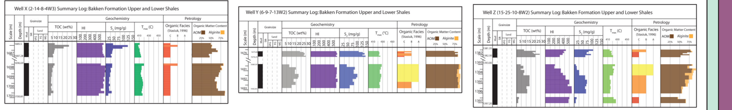
Organic Facies for the Bakken Formation (From Stasiuk, 1996)

A: Abundant, relatively large (up to 350 microns), thick walled unicellular alginite

B: Bituminite with maceral inclusions dominated by relatively small spiny acritarchs and unicellular alginites, smaller than those in organic facies (most are <20 microns but up to 100 microns). Sporinite may or may not be present

C: Similar to organic facies B but contains a more diffuse bituminite and a presistent contribution of terrestrial-derived sporinite and floral inertinite

Summary Composite Logs



Summary/Significance

Argillaceous rocks are most often thought to be entirely homogeneous. Estimating source potential from gamma well-log response is not possible. Rock-Eval Kerogen Type is a chemical average of sub-maceral composition.

These preliminary results demonstrate that there are variations in organic matter type (thus kerogen Type) as well as variations in geochemical characteristics with depth and along section. This means that the the generation potential will also vary. Mapping these variations in organic facies across the basin will provide a better understanding of the gneration potential within the Upper and Lower Bakken. Ultimately the results of this study could lead to the discovery of oil producing zones within the Northern Williston Basin.

References

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