

# The Bakken Formation of Saskatchewan: A High Resolution Geochemical Evaluation

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## Summary

This paper presents the preliminary results from an on-going study of the Madison-Bakken petroleum system of the Williston Basin, particularly with respect to oil-source correlations and Bakken source potential. This study seeks to examine and investigate areas of anomalous (i.e., early) generation and geochemically map the variations within and between Bakken Formation in Saskatchewan.

## Introduction

The Williston Basin is a prolific petroleum provenance that contains a number of petroleum systems (Dow, 1974; Williams, 1974). All of the known systems have been extensively studied, typically defined using the genetic relationships between pooled oils and oil-source characteristics (e.g. Osadetz *et al.*, 1992). It is also generally regarded that the oils present within the Canadian portion of the Williston Basin have migrated from long distance sources elsewhere within the basin (Osadetz *et al.*, 1992; Li *et al.*, 1998).

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.

Through the application of petroleum geochemistry, this study aims to test our present understanding of the Bakken petroleum system within the northern part of the Williston Basin, with a specific focus on southern Saskatchewan. More specifically, this study aims to examine oil-source relationships through the application gas chromatographic-mass spectrometry (i.e. biomarker analysis) and an examination of organic sulphur compounds within oils and source extracts, with the aim of determining the possible role of sulphur in the early generation of oil within potential sources conventionally considered 'immature'.

## Experimental

High resolution sampling was conducted by obtaining up to 20 samples per well within the Bakken Formation. Core samples were cleaned and weathered surfaces were removed before sample preparation. The evaluation of hydrocarbon potential and thermal maturity was achieved using Rock-Eval pyrolysis. Source extraction was also carried out using soxhlet extraction method and the extract fraction subsequently fractionated using liquid column chromatography into saturate, aromatic and NSO fractions. Further analysis was done using gas chromatography and gas chromatographic-mass

spectrometry to investigate the distribution of sulphur compounds in the aromatic fractions as well as biomarker compounds in both aromatic and saturate fractions. The amount of total sulphur present in the sample was also examined using LECO Elemental Analyzer.

## Results and Discussion

Previous studies (e.g. Osadetz & Snowdon, 1995) have characterized the Lower and Upper Bakken Formation to be organic rich, typically with total organic carbon contents in excess of 10wt%, and generally as immature/marginally mature within the Canadian portion of the Williston Basin based on Rock-Eval  $T_{max}$  and vitrinite reflectance data (% $V_R$ ) (Stasiuk, 1994; Osadetz & Snowdon, 1995). Source characterisation of the Bakken Formation shows that the Bakken Formation is also typically composed of mainly Type II kerogen with 'pockets' of Type I.

High levels of sulphur were detected within extract of the Lower Bakken in particular, exhibiting a systematic variation along a north-south and east-west transect. High levels of sulphur can be highly significant, because it has been suggested, through studies based elsewhere, that some Type II kerogen may contain significantly high amounts of organic sulphur, known as Type II-S kerogen. Type II-S kerogens are recognized as capable of generating hydrocarbons at relatively low levels of thermal maturity (e.g. Sinninghe Damsté *et al.*, 1989). In this study, the total sulphur was compared for Bakken samples, with the aim of establishing any correlation and determining the possible role of organic sulphur in the early generation of oil within potential sources that are conventionally considered 'immature'.

## Conclusion

Investigation of Bakken extracts in this study clearly shows that the lower and upper Bakken Formation contain substantial amount of elemental sulphur prior to removal of elemental sulphur during source rock extraction. These variations in sulphur content have been mapped, although the search for organic sulphur compounds amenable to the early generation of oil is at present ongoing.

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