GeoConvention 2015
GEOSCIENCE
new horizons
Telus Convention Centre • 4-8 May 2015 • Calgary, AB Canada

Molecular characterization of source rocks from the Second White Specks Formation in the WCSB

Jingping Ma, Haiping Huang and Steve Larter*
Department of Geoscience, University of Calgary

Summary

This study presents the geochemical results of the source rock characterization of samples from two outcrops and one well from the Second White Specks Formation in Western Canada Sedimentary Basin (WCSB). The organic matter shows a generally increase in TOC ranging from 0.63 to 10.04 wt% towards the east with dominantly Type II kerogen. The molecular maturity parameters and the rock-eval data indicate a thermal increase towards the west. The molecular source input parameters suggest an increase terrigenous input from east to west. The vertical fluctuation of some molecular ratios suggesting depositional environment changing during deposition is obvious especially in the core samples where sediments are immature. Our study provides deep understanding controls on and potentials of biogenic shale gas in the east and shale oil in the west.

Introduction

In the WCSB, the Second White Specks Formation was deposited during the Latest Cenomanian to Middle Turonian (91 – 93 Ma) and has been proved to be an effective source rock (Bloch, 1993). The TOC content ranges from 2 to 12 wt % with an average value of 5.1 wt% (Bloch, 1999), and it generally increases towards the northeast and reaches an average of 10 wt% in the eastern margin of the Western Interior Seaway (Simons, 2003). The Van Krevelen diagram indicates Type II kerogen and the Hydrogen Index are generally greater than 200 mg HC/g TOC (Bloch, 1993) with an average value of 300 mg HC/g TOC in the west and 420 mg HC/g TOC in the east. The T_{max} increases systematically from east to west due to increasing burial depth. Due to very low porosity and permeability of the Second White Specks, large proportion of generated hydrocarbons remain in the source rock and it may act as potential reservoirs for shale oil and shale gas accumulations.

Methods

The samples were collected from the Second White Specks Formation in Highwood River (HR), Cadomin Railway station (CAD) outcrops and a well located roughly between Edmonton and Lloydminster (Well A), Western Canada. Organic materials are extracted by *Soxhlet Extraction*. After de-asphaltene, the hexane-soluble fraction amenable to the *Solid-Phase Extraction* (SPE) was separated into saturated hydrocarbons and aromatic hydrocarbons and polar fraction (Bennett and Larter, 2000). The saturated and aromatic hydrocarbons were analyzed by Gas Chromatography - Mass Spectrometry (GC-MS) with internal standards added for quantitative purpose. Molecular parameters were selected to track the vertical variation of sedimentary facies and lateral variation of thermal maturity. From the suite of compounds observed, as a function of maturity in the sample suites obtained, a model of component concentration versus maturity were developed.

Meanwhile, we chose closely located coupled samples with contrasting lithology (laminated shale-lenticular siltstone, shale-intebedded siltstone, shale-concretion) from HR outcrop to do sequential extraction. The sample was firstly crushed to 0.8-1.0 cm particles and extracted by dichloromethane (DCM) under room temperature; secondly, the extracted particles was crushed into smaller size (around 0.5 cm) and extracted again by DCM; finally, the particles were powdered and extracted in *Soxhlet* with DCM. This three-step extraction allows us to investigate the distribution of hydrocarbons in different states - in readily available pores, less inaccessible pores and finally the remaining oil in the pore systems and the kerogen of the sample. This approach and sample set will allow us to study local fractionations of petroleum within individual source rocks and also allow us to build up a set of data, enabling a maturity dependent compositional model for the source rock to be developed.

Results

On average, the Second White Specks Formation have 5.73 wt% TOC and 410°C T_{max} in Well A, 2.09 wt% TOC and 448°C T_{max} in the HR outcrop and 1.48 wt% TOC and 458°C T_{max} in the CAD outcrop with dominantly type II kerogen. The vitrinite reflectance in these 3 locations are 0.45%, 0.7% and 1.0%, respectively. Relatively low pristane/phytane (Pr/Ph) ratios of samples from the Well A suggest highly reducing depostional envrionment. Maturity related parameters from saturated hydrocarbon fraction such as Pr/*n*-C_{17} and Ph/*n*-C_{18} ratios, Ts/(Ts + Tm), C29 steranes $\beta\beta/(\alpha\alpha + \beta\beta)$, 20S/(20S + 20R) and from aromatic hydrocarbon fraction such as trimethylnaphthalene [TMNr = 1,3,7-TMN/ (1,3,7-TMN + 1,2,5-TMN)], tetramethylnaphthalene [TeMNr = 1,3,6,7-TeMN/ (1,3,6,7- + 1,2,5,6- + 1,2,3,5-TeMN)], methylphenanthrene index [MPI1 = 1.5 × (2MP + 3-MP)/(P + 1MP + 9MP)] and methyldibenzothiophene ratio (MDR = 4-MDBT/1-MDBT) indicate that samples from Well A are thermal immature while these from HR and CAD outcrops are thermal mature. The absolute concentrations of individual component or compound class such as C_{10}-C_{20} *n*-alkanes, C_{29} steranes and methylphenathrenes show systematic variation with increasing thermal maturity. Source input parameters such as C_{21}/C_{23} tricyclic terpane ratios suggest that more terrigenous input occurs at CAD and much less influence at Well A. An obvious internal fluctuation of some geochemical ratios in each location may demonstrate depositional environment variation and variable terrigenous input influence during the deposition. The sequential extraction shows clear difference in *n*-alkanes, C_0-C_5 alkylnaphthalenes and C_0-C_3 alkylphenathrenes distributions. Higher adsorption capacity in heavier molecular of the similar structure exerts significant impact on shale oil production.

Conclusions

The Second White Specks Formation was deposited under anoxic bottom waters within the Western Interior Seaway (WIS) during the Latest Cenomanian to Middle Turonian, a time of sea level maximum which resulted in a transgressive condensed section. The east-west decreasing trend in TOC is possibly resulted from increase hydrocarbon generation towards the west and it is also possibly associated with depositional facies variation and increased clastic dilution towards the west. A number of geochemical facies and maturity parameters were examined in an attempt to evaluate the source rock potential of the Second White Specks Formation. Results show that a vertical fluctuation which might be resulted from sedimentary facies is especially obvious in the core samples and that thermal maturities display a lateral increase from the core samples to CAD outcrop. It is necessary to do more study in the sedimentary facies variation existing both in vertical and lateral trend.

Acknowledgements

The author thanks the sponsors of the Canada Foundation for Innovation (CFI), Natural Sciences and Engineering Research Council (NSERC) of Canada and Canada Research Chairs.

References

Bennett, B., Larter, S.R., 2000. Quantitative separation of aliphatic and aromatic hydrocarbons using silver ion-silica solid-phase extraction. Analytical Chemistry 72, 1039-1044.

Bloch, J., Schroeder-Adams, C., Leckie, D. A., McIntyre, D. J., Craig, J., and Staniland, M. (1993). Revised stratigraphy of the lower Colorado Group (Albian to Turonian), Western Canada. Bulletin of Canadian Petroleum Geology, 41(3), 325-348.

Bloch, J.D., Schröder-Adams, C. J., Leckie, D. A., Craig, J., and McIntyre, D. J., 1999. Sedimentology, micropaleontology, geochemistry, and hydrocarbon potential of shale from the Cretaceous Lower Colorado Group in Western Canada. Geological Survey of Canada.

Simons, D. J. H., Kenig, F., and Schröder-Adams, C. J. (2003). An organic geochemical study of Cenomanian-Turonian sediments from the Western Interior Seaway, Canada. Organic geochemistry, 34(8), 1177-1198.