

A SOURCE ROCK EVALUATION USING A HIGH RESOLUTION MICROANALYSIS APPROACH OF THE DEVONIAN BIRDBEAR FORMATION IN SOUTHERN SASKATCHEWAN

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Summary

This paper presents the results from a high resolution, integrated geochemical and petrographical analytical assessment of source rock potential of the Devonian Birdbear Formation in southern Saskatchewan. The Birdbear Formation in borehole 12-23-15-14W2 was previously identified as having source potential, although at an unspecified depth. This study uses the high resolution sampling of core to clearly define zones of high source potential and those that have none within a correlatable lithologic framework. The Birdbear Formation is highly laminated in places and particularly within zones of relative source potential. This study utilizes a form of microanalyses, i.e. sampling at the millimeter to centimeter scale to more accurately define the geochemical and petrographic characteristics of each source layer as compared to bulk (meter scale) analyses typically employed. In this way two zones have been identified as having source potential, the stratigraphically higher zone has TOC ranging from 3.63 to 16.87 wt. % and the stratigraphically lower zone has TOC ranging from 0.89 to 7.07 wt. %, characterized as Type I and Type I/II. UV/fluorescence petrographic analysis has identified the organic matter as amorphous kerogen, classified as Bituminite. The T_{max} range of the analysed samples is from 408 to 439°C with an average of 427°C which indicates the samples are immature to marginally mature. This study shows the importance of microanalyses (millimeter to centimeter scale) in comparison to bulk (meter scale) analyses.

Introduction

This study is an integral part of the ongoing Saskatchewan Phanerozoic Fluids Project (SPFP) initiated by the Universities of Alberta and Regina. The overall goal of the SPFP is to understand how and where hydrocarbons were generated in the subsurface of Saskatchewan and where and when they may have migrated over geologic time, and determine where they are most likely to occur at the present time. An essential component of the SPFP is to collect and develop geochemical and petrographical data representing the analysis of source potential for a given number of geological formations that ultimately will become part of an integrated petroleum systems analysis for southern Saskatchewan. Since the essential component of a petroleum system is a mature source rock, it is fundamentally important to assess source rock potential. A petroleum source rock is defined as a fine grained sedimentary rock that has naturally generated and released enough hydrocarbons to form a commercial accumulation of oil and/or gas. A 'potential source rock' is one that is determined to be immature at a given depth but is recognized as having the potential to generate petroleum at greater depth of burial. When characterizing a source rock, three important factors must be determined: the quantity of organic matter, the quality of the organic matter and the level of thermal maturity (Tissot and Welte, 1984; Hunt, 1996; Peters *et al.*, 2005).

Methods

The borehole 12-23-15-14W2 was selected based upon core availability and the decision to follow up on the GSC's previous assessment using the same core. A total of 30 samples were taken based on the premise of creating a detailed depth-wise profile particularly through zones of geochemical significance. A rock saw was used to cut length-wise samples that permitted a depth-wise assessment of source potential. Zones of interest were those that were argillaceous-rich (dark colored relative to carbonate lithology) and most likely organic-rich. Within these zones of specific interest, samples were obtained at the centimeter to millimeter scale for high resolution sampling. To obtain samples for micro-scale analysis (millimeter to centimeter scale) a microdrill was used to pinpoint the finely laminated argillaceous and organic-rich layers creating a single set of 67 depth-wise samples out of the original 30 collected which were subsequently analysed using a Vinci Labs Rock-Eval 6. Six samples from the original 30 were selected for petrographic analysis using UV/fluorescence microscopy based upon the presence of argillaceous laminae and results obtained from Rock-Eval analysis.

Results and Discussion

Rock-Eval pyrolysis indicates the majority of the cored interval is non-source (Figure 1), meaning the TOC is less than 0.5 wt. % which is commonly regarded as the minimum threshold for a potential source rock (Peters *et al.*, 2005). With this being said, there are two zones with elevated TOC (> 0.5 wt. %) which occur from 1275.55 to 1275.58 m and from 1281.12 to 1282.88 m. The stratigraphically higher zone has TOC ranging from 3.63 to 16.87 wt. % and the stratigraphically lower zone has TOC ranging from 0.89 to 7.07 wt. % (Figure 2).

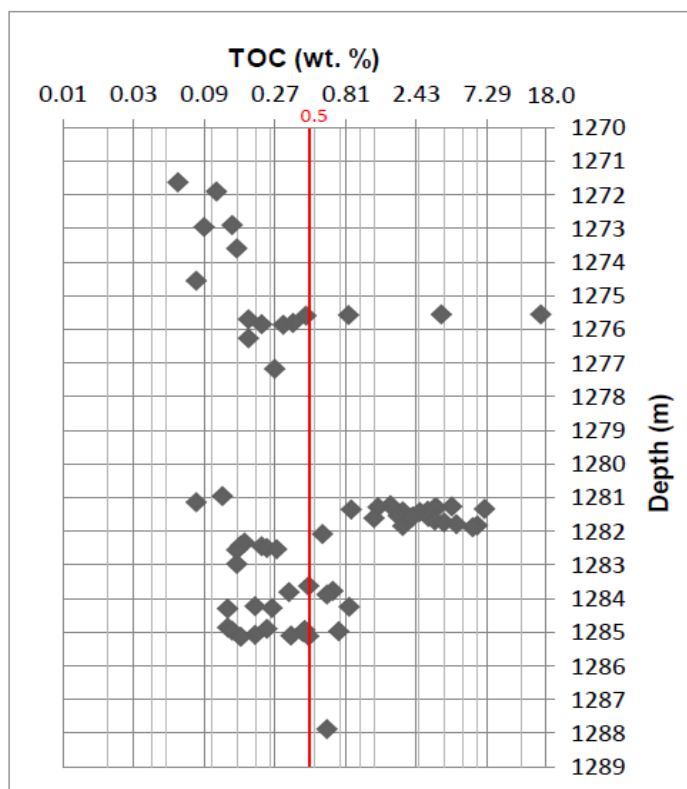


Figure 1: Depth-wise profile (semi-logarithmic scale) of TOC (wt. %) of the sampled interval of 12-23-15-14W2. Red line indicates 0.5 wt. % TOC which is considered the minimum threshold for potential source rocks (Peters *et al.*, 2005).

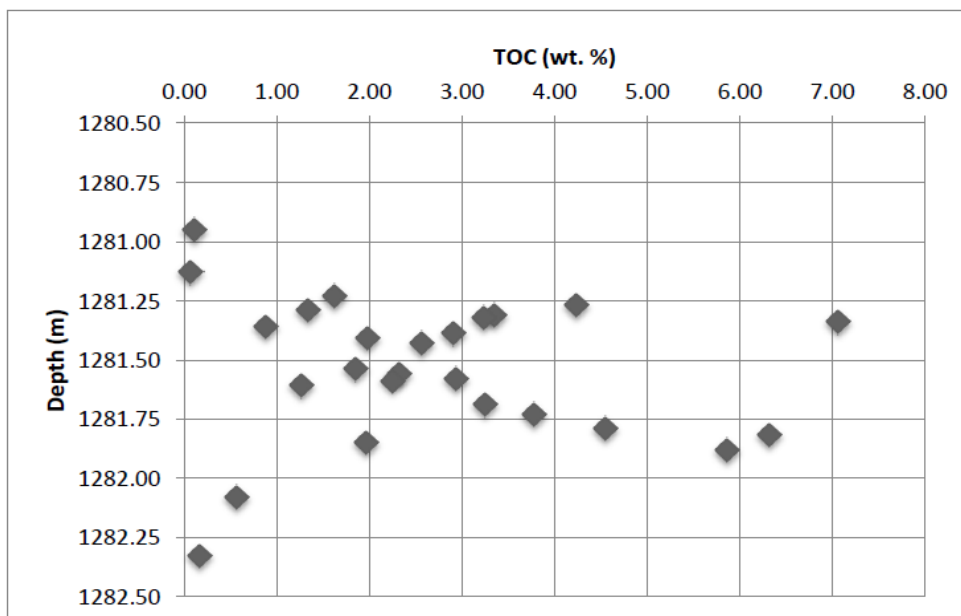


Figure 2: Depth-wise profile of TOC (wt. %) at elevated interval (All data points from 1280.95 to 1282.33 m).

It is important to note that over such a small interval, the scale of sampling (i.e., millimeter to centimeter scale) is critical when analysing the quantity of organic matter as it documents significant ranges over small intervals when using Rock-Eval pyrolysis (Figure 3). Figure 3 shows that TOC, along with other Rock-Eval parameters, all vary over an even smaller interval (i.e., millimeter to centimeter scale). The TOC for Sample B ranges from 1.63 to 7.07 wt. % and from 1.98 to 6.33 wt. % within Sample F. The highest values are consistently associated with the argillaceous laminae, whereas the lower TOC values (i.e., at 1281.29 m) are associated with the interleaving layer.

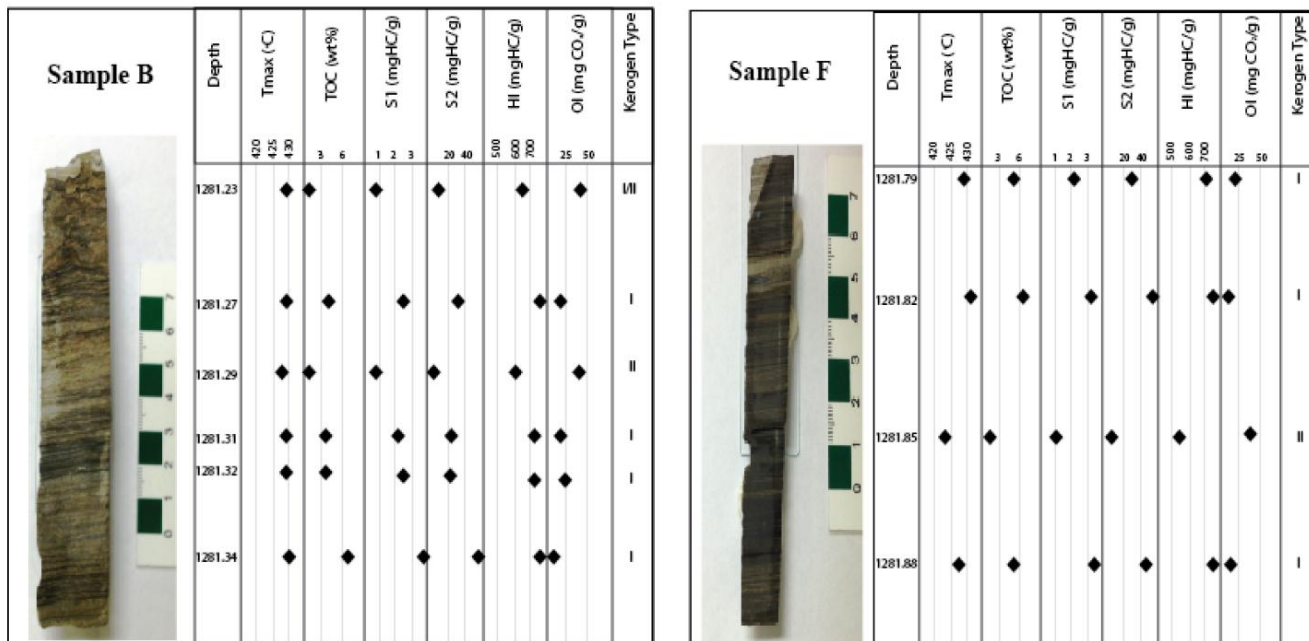


Figure 3: High resolution microanalysis geochemical profiles for selected samples. *Sample B* – 1281.22 to 1281.35 m and *Sample F* – 1281.75 to 1281.89 m.

The Kerogen Type was determined by plotting samples on an X, Y plot of Hydrogen versus Oxygen Indices in which it showed the samples from this borehole as Type I and Type I/II. UV/fluorescence petrography supports this geochemical data as the kerogen is of amorphous nature and classified as Bituminite. The T_{\max} range of the analysed samples is from 408 to 439°C with an average of 427°C which indicates the samples are immature to marginally mature. By comparing the GSC study to this study it is apparent that different approaches regarding sampling and analytical techniques lead to different results and hence interpretations. The GSC used a bulk method of analysis in which samples were crushed and taken as an average over an unspecified sampling interval, which is the conventional method of sampling and sample preparation for Rock-Eval pyrolysis. In this present study, argillaceous layers that were deemed specific zones of interest based upon the premise that they may contain organic matter were sampled exclusively from those organic-rich layers, no matter how thin, and no interleaving non-source (i.e., additional carbonate mineral matter) diluted the samples. This comparison suggested that bulk analysis does indeed overestimate OI and the eventual under-estimation of source potential.

Conclusions

The data generated in this study is evidence that Rock-Eval pyrolysis works effectively as a microanalysis technique because it documents the range of the amount and quality of organic matter on a millimeter to centimeter scale. This study confirms that a high resolution approach integrating Rock-Eval pyrolysis and petrographic analysis is effective for classifying the quantity of organic matter (TOC), the quality of organic matter (Type) and the level of thermal maturity, which are all factors when characterizing the source potential of a given formation. This high resolution approach should be applied where a formation appears highly laminated rather than the conventional bulk analysis approach which tends to underestimate TOC and ultimately the source potential. Although the Birdbear at this well location has been identified as having source potential, the organic matter is still relatively immature at this depth. For future work I recommend that this depth-wise high resolution microanalysis be applied to a number of other depth intervals of the Birdbear Formation within southern Saskatchewan and closer to the depositional center of the Birdbear Formation in the Williston Basin to determine the distribution and spatial extent of the source potential, as well as changes in the thermal maturity of the organic matter (i.e., at greater depths).

Acknowledgements

This project would not have been possible without funding from the Saskatchewan Ministry of Energy and Resources and the Petroleum Technology Research Center. Also, a special thanks to Titi Aderoju for assistance with sample preparation and using the Rock-Eval 6.

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