



## Ordovician petroleum source rock potential in Hudson Strait Basin

Shunxin Zhang

Canada-Nunavut Geoscience Office

### Summary

The Paleozoic strata in the Hudson Strait Basin are partially exposed on Akpatok Island, Ungava Bay, Nunavut, which include the Upper Ordovician Amadjuak, Akpatok, and Foster Bay formations. The bituminous, argillaceous limestone in the Foster Bay Formation on Akpatok Island are good petroleum source rock with total organic carbon (TOC) values between 1.52% and 4.19%. The Ordovician laminated limestone cores from shallow drillings in the Hudson Strait proved to be good to excellent petroleum source rocks with TOC values between 2.36% and 12.78%. These source rocks contain Type II kerogen; they are immature for petroleum generation. Therefore, a target for mature source rocks in the Hudson Strait Basin would be Ordovician source rocks which have been deeply buried by Mesozoic deposits that could have provided sufficient load on the Ordovician source rocks.

### Introduction

Hudson Strait Basin is one of the three intracratonic basins (Hudson Bay, Hudson Strait and Foxe basins) in northern Canada; the basin includes the Hudson Strait and Ungava Bay (Pinet et al. 2013; Fig. 1). It is underlain primarily by the Lower Paleozoic sedimentary rocks (mainly carbonates) that lie on top

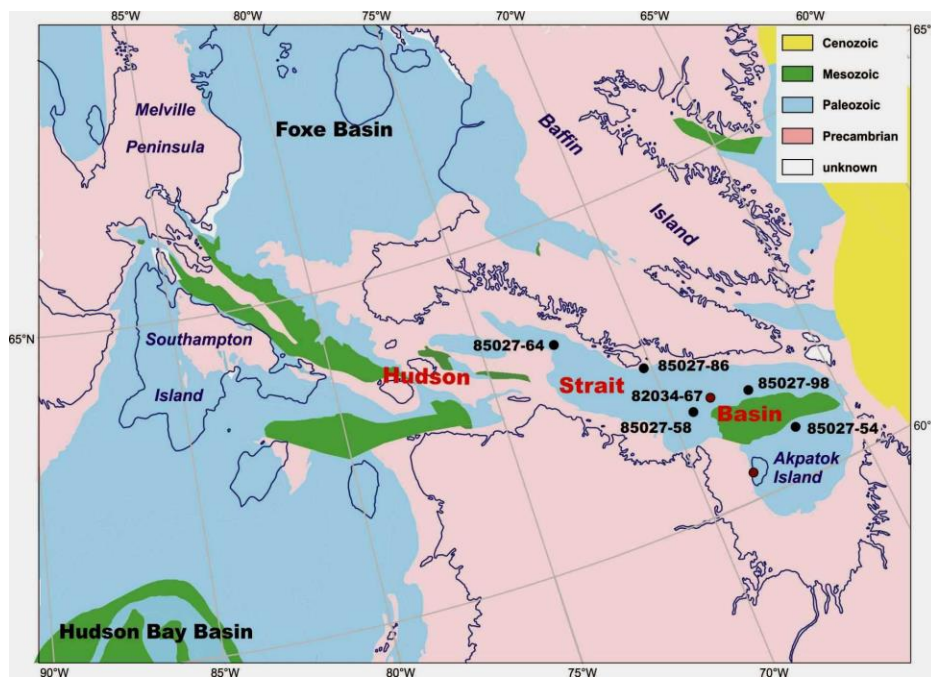


Figure 1. Simplified geological map of Hudson Strait Basin and vicinity (modified from Wheeler et al., 1997) with shallow drilling and well locations (both black and red dots; red dots indicate source rock locations)

of Precambrian bedrocks. During 1970s and 1980s, shallow drillings revealed that Upper Ordovician carbonate rocks underlie most of the western part of Hudson Strait, together with Silurian and possibly younger rocks in the eastern part of the strait (MacLean et al. 1986; MacLean 2001). The Premium Homestead Akpatok F-26 well and ground stratigraphic study on Akpatok Island in Ungava Bay (Workum et al. 1976) recognized that Middle and Upper Ordovician strata are distributed below sea level and outcropped above sea level, respectively. Additionally, 0.51-2.11% TOC were reported from the Upper Ordovician rocks (Macauley 1987).

With the increased interest in hydrocarbon exploration in the Canadian Arctic, it is apparent that new data are needed to help re-assessing the petroleum potential of the Hudson Strait Basin. The Nunavut Energy Project of the Canada-Nunavut Geoscience Office (CNGO) and the Geo-mapping for Energy and Mineral (GEM) Program of Natural Resources Canada (NRCan) have defined a project to improve knowledge about Paleozoic stratigraphy, thermal maturity and petroleum potential in the basin. This includes detailed studies of 1) the Lower Paleozoic stratigraphy, biostratigraphy and petroleum potential on Akpatok Island, and 2) the existing short cores from the early shallow drillings in Hudson Strait.

### Field Investigation on Akpatok Island

Stratigraphic units exposed on Akpatok Island were previously recognized as the Boas River and Akpatok formations (Sanford and Grant 1990, 1998, 2000). Their biostratigraphic ages and correlations, in particular the stratigraphic position and age of the organic rich “Boas River” Formation, were largely based on limited data. New detailed field observations and lithostratigraphic and biostratigraphic studies have recognized three stratigraphic units, namely the Amadjuak, Akpatok and Foster Bay formations (Zhang 2017). The occurrence of the conodont *Amorphognathus ordovicicus* in the outcrops of the lower Foster Bay Formation and in the bituminous, argillaceous limestone rubble (Fig. 2), as well as the graptolites *Anticotia decipiens* and *Rectograptus socialis* in the rubble, indicate that the stratigraphic position of the bituminous, argillaceous limestone unit is most likely in the lower Foster Bay Formation (Zhang 2017), rather than between the Amadjuak and Akpatok formations as interpreted by Sanford and Grant (1990, 1998, 2000).

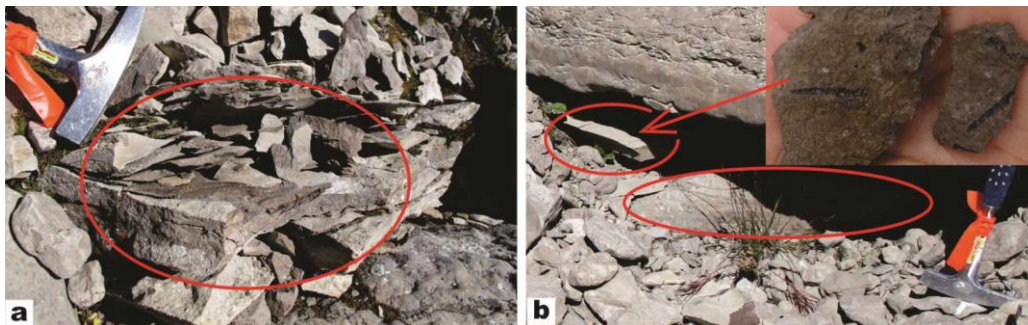


Figure 2. Bituminous, argillaceous limestone rubble on Akpatok Island

The Rock Eval<sup>6</sup> data show that the bituminous, argillaceous limestone rubble on Akpatok Island contain TOC between 1.52% and 4.19%, and yield immature Type II Kerogen (Fig. 3).

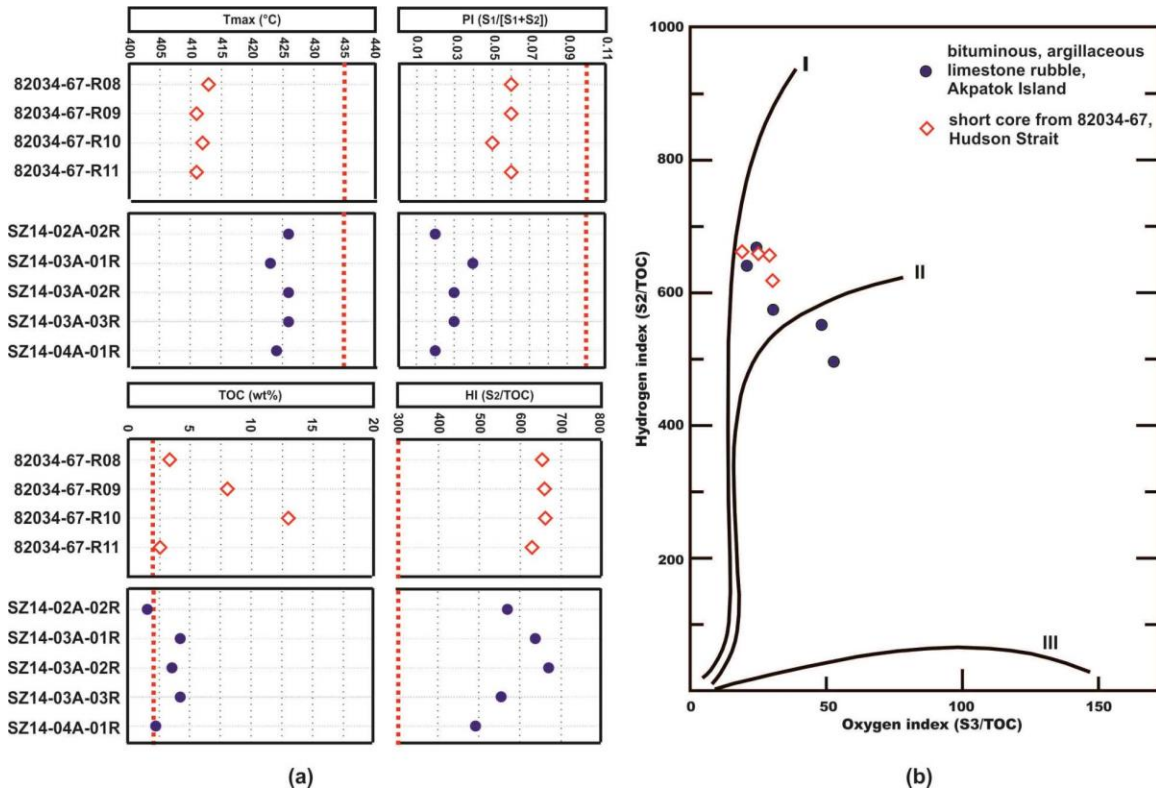


Figure 3. a) Selected Rock-Eval<sup>6</sup> pyrolysis parameters with samples from Akpatok Island and Hudson Strait; the thick vertical red dashed lines indicate thresholds for organic maturity ( $T_{max}=435$ ;  $PI=0.1$ ) and good hydrocarbon source rock attributes ( $TOC>2\text{wt}\%$ ;  $HI>300$ ); b) Modified van Krevelen diagram showing the relationship between hydrogen and oxygen indices (see Zhang 2013 and Zhang and Mate 2015 for details)

### Studies of shallow cores from the early exploration in Hudson Strait

Rocks with possible Ordovician age were short-cored at six stations in Hudson Strait during two cruises (82034-67; 85027-54, 58, 64, 86, 98) (MacLean 1986; Fig. 1). All rocks short-cored from five stations during cruise 85027 are limestone with TOC less than 0.5%; but those from station 67 during cruise 82034 are limestone laminated with black shale (Fig. 4), which is similar to that in the Upper Ordovician Red Head Rapids Formation on Southampton Island (Zhang 2008). Of the 11 samples collected from 82034-67 for Rock-Eval<sup>6</sup> analysis, four yield TOC between 2.36% and 12.78%, which are from those black shale layers (Fig. 4b) preferentially collected from the laminated limestone; and the rest of the samples with  $TOC<1\%$  are from nearly pure limestone samples. The Rock Eval<sup>6</sup> data show that these source rocks yield immature Type II kerogen (Zhang 2013; Fig. 3).



Figure 4. Short core from Station 67, Cruise 82034, Hudson Strait. a: parts of the short core; b: view of cross section from part of top core showing the black shale layers

## Discussion and Conclusions

The Rock Eval<sup>6</sup> analyses for the organic rich samples from Akpatok Island and shallow drillings in Hudson Strait show that the Hudson Strait Basin preserves good to excellent petroleum source rocks in the Upper Ordovician succession; however, they are immature for petroleum generation. In Hudson Strait Basin, the known Paleozoic rocks are the Ordovician carbonates, which include 339 m below sea level penetrated by the Premium Homestead Akpatok F-26 well (Workum et al. 1976) and 281 m exposed on Akpatok Island (Zhang 2017). It is unclear whether Paleozoic rocks younger than Ordovician occur in the basin. Apparently the known Paleozoic rocks are not thick enough to provide sufficient load on the Upper Ordovician source rocks to generate oil. However, it is worthy of noting that all the analyzed samples were collected from locations where there are no Mesozoic rocks identified. In Hudson Strait, seismic surveys indicated that Mesozoic rocks exist in several areas (MacLean et al. 1986; MacLean 2001; Fig. 1). If these Mesozoic sediments were thick enough and created sufficient load on top of the Paleozoic rocks, then the Ordovician source rocks could be heated enough to generate oil in the basin.

## Acknowledgements

This study is part of the Hudson-Ungava Project under NRCan's GEM-2 program and CNGO's Nunavut Energy project. It is financially supported by both GEM-2 and the CNGO. Logistic support in the field was provided by the Polar Continental Shelf Project. Many thanks are extended to D. Lavoie (Geological Survey of Canada, (GSC Quebec) for his organization of the project and participation in the fieldwork on Akpatok Island and to B. MacLean (GSC Atlantic) for his assistance in collecting short core samples. Many thanks also go to the Inuit from Kuujuaq, northern Quebec, for their field assistance on Akpatok Island, and to R. Stewart (GSC Calgary) for undertaking the Rock-Eval<sup>6</sup> sample preparation and analysis.

## References

- Macauley, G. 1987. Geochemistry of organic-rich Ordovician sediments on Akpatok and Baffin Islands, Northwest Territories. Geological Survey of Canada Open File Report OF1502, 27 p.
- MacLean, B. 2001. Bedrock geology of Hudson Strait and Ungava Bay. *In* Marine Geology of Hudson Strait and Ungava Bay, Eastern Arctic Canada: Late Quaternary sediments, depositional environments, and late glacial-deglacial history derived from marine and terrestrial studies, B. MacLean (ed.), Geological Survey of Canada, Bulletin 566, p. 65-69.
- MacLean, B., Williams, G.L., Sanford, B.V., Klassen, R.A., Blakeney, C., and Jennings, A. 1986. A reconnaissance study of the bedrock and surficial geology of Hudson Strait, N.W.T. Current Research, Part B, Geological Survey of Canada, Paper 86-1B, p. 617-635.
- Pinet, N., Lavoie, D., Dietrich, J., Kezhen Hu, K., and Keating, P. 2013. Architecture and subsidence history of the intracratonic Hudson Bay Basin, northern Canada. *Earth Science Reviews*, **125**: 1-23.
- Sanford, B.V., and Grant, A.C. 1990. New findings relating to the stratigraphy and structure of the Hudson Platform. Geological Survey of Canada Current Research, Part D, Paper 90-1D, p. 17-30.
- Sanford, B.V., and Grant, A.C. 1998. Paleozoic and Mesozoic Geology of the Hudson Bay and Southeast Arctic Platform. Geological Survey of Canada Open File Report OF3595, 2 sheets.
- Sanford, B.V., and Grant, A.C. 2000. Geological framework of the Ordovician system in the southeast Arctic Platform, Nunavut. *In* Geology and paleontology of the southeast Arctic Platform and southern Baffin Island, Nunavut. Edited by A.D. McCracken and T.E. Bolton. Geological Survey of Canada Bulletin 557, p. 13-38.
- Wheeler, J.O., Hoffman, P.F., Card, K.D., Davidson, A., Sanford, B.V., Okulitch, A.V., and Roest, W.R. (comp.), 1997. Geological Map of Canada, Geological Survey of Canada, Map D1860A.
- Workum, R.H., Bolton, T.E., and Barnes, C.R. 1976. Ordovician geology of Akpatok Island, Ungava Bay, District of Franklin. *Canadian Journal of Earth Sciences*, **13**: 157-178.
- Zhang, S. 2008. New insights into Ordovician oil shales in Hudson Bay Basin: their number, stratigraphic position, and petroleum potential. *Bulletin of Canadian Petroleum Geology*, **56**: 300-324.
- Zhang, S., 2013. Rock Eval<sup>6</sup> and Vitrinite Reflectance Data from Baffin Island Shelf and Hudson Strait; Geological Survey of Canada, Open File 7341, 32 p.
- Zhang, S. 2017 (in press). Upper Ordovician conodont biostratigraphy and revised lithostratigraphy and geological map, Akpatok Island, Ungava Bay, Nunavut. *Canadian Journal of Earth Sciences*.
- Zhang, S., and Mate, D.J. 2015. Geological reconnaissance for Ordovician stratigraphy and petroleum potential, Akpatok Island, Nunavut. *In* Summary of Activities 2014, Canada-Nunavut Geoscience Office, pp. 79-88.