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# Rock-Eval/TOC data for twelve wells from the Labrador Shelf, Eastern Canada, offshore Newfoundland and Labrador

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## Introduction

This Open File contains results of Rock-Eval/TOC pyrolysis of well core and cuttings samples collected from twelve petroleum boreholes drilled on the Labrador Shelf, Eastern Canada.
Cuttings samples have been analyzed typically on a 30 foot or 10 meter spacing over the depth intervals noted for the wells listed below. Every effort was made to obtain a representative sample from the vial of cuttings, but because of the small sample size, mixed lithology samples may not always be completely representative and mixed lithology intervals may yield some scatter in the data.
The data are reported in *.pdf (portable document file) and *.xls (MS Excel) formats. All analytical work was done at the Organic Geochemistry Laboratory at the Calgary Office of the Geological Survey of Canada using Rock-Eval 6 Turbo (RE 6) instrument equipped with a Total Organic Carbon analysis module.

| Well name | Depth interval | | |
|---|---|---|---|
| BJARNI O-82 | 445 | 2615 | m |
| GJOA G-37 | 1450 | 3998 | m |
| HEKJA O-71 | 740 | 4566 | m |
| HERJOLF M-92 | 1500 | 13400 | ft |
| HOPEDALE E-33 | 900 | 2060 | m |
| KARLSEFNI A-13 | 10803 | 13530 | ft |
| NORTH LEIF I-05 | 435 | 3420 | m |
| POTHURST P-19 | 1605 | 3835 | m |
| RALEIGH N-18 | 1000 | 3785 | m |
| ROBERVAL K-92 | 640 | 3870 | m |
| RUT H-11 | 735 | 4093 | m |
| SOUTH LABRADOR N-79 | 730 | 3571 | m |

Depth units used (feet or meters) are those in which the original well was drilled and logged, and in which the samples are currently labelled. The stratigraphy used is the most recent GSC picks from the on-line “Basin” database, which are usually those of Phil Moir. The significance of the analytical data is briefly discussed in this report.

## Experimental

Rock-Eval/TOC analysis provides fast and reliable characterization of the quantity and quality of sedimentary organic matter, as well as its thermal maturity. All samples were analyzed on a Rock-Eval 6 Turbo (RE 6) instrument equipped with a Total Organic Carbon analysis module. A typical RE 6 experiment is initiated with heating of a pulverized rock sample at 300ºC for 3 min in nitrogen atmosphere, when naturally occurring hydrocarbons (free and adsorbed) are volatilized. The oven temperature is then steadily increased to 650ºC at a rate of 25ºC/min and decomposition of kerogen occurs. The amount of hydrocarbons volatilized at 300ºC and evolved from kerogen during the ramped heating are quantitatively determined by a flame ionization detector, and recorded as the S1 and S2 peaks, respectively. The final stage involves oxidation and combustion of the residual organic matter at 850ºC. The temperature measured at the maximum of the S2 peak is referred to as Tpeak while Tmax is calculated by subtracting about 40ºC from Tpeak (the exact correction is determined using a manufacturer standard). The amounts of CO and $CO_2$ are quantitatively determined by infrared detectors. Additional details on the RE6 instrument are available in Behar et al. (2001).

The percentage of carbon in $CO_2$ formed during oxidation and in the hydrocarbon peaks S1 and S2 is used to define the total organic carbon content (TOC), expressed as a weight percentage. The determination of the quality of organic matter is based upon the calculation of Hydrogen (HI) and Oxygen (OI) indices (HI=100xS2/TOC, OI=100xS3/TOC) which are related to the atomic H/C and O/C ratios (Espitalié et al., 1977). The OI versus HI cross plots ("pseudo van Krevelen diagrams") can be used as an organic matter type indicator at low and moderate maturities. The Tmax is an indicator of relative thermal maturity. According to Espitalié et al. (1985) the oil window is defined by the following Tmax ranges: 440º-448ºC (Type I organic matter), 430º-455ºC (Type II organic matter) and 430º-470ºC (Type III organic matter). A cross plot of Tmax versus HI is often used to constrain estimations of organic matter type and its thermal maturity, while the Production Index (PI=S1/[S1+S2]) is used to indicate hydrocarbon staining of a sample or as an additional maturity parameter.

Rock-Eval results correlate to other techniques (Espitalié et al., 1985; Tissot and Welte, 1978). Petroleum source rock potential is sensitive to lithology, TOC and S2 values. It is common practice to rate carbonate rocks with lower TOC comparable with clastic rocks richer in organic matter. Extractable hydrocarbon yields from leaner carbonate rocks are comparable to bitumen-rich clastic rocks (Tissot and Welte, 1978, p. 430; Gehman, 1962). The organic matter associated with carbonate rocks is often more hydrogen-rich and thermally labile than that in fine-grained clastic rocks. As a result, more TOC in carbonate rocks may be transformed into bitumen compared with average clastic source rocks of comparable maturity.

Rock-Eval/TOC parameters have significance only above threshold TOC, S1 and S2 values. If TOC is ≤ 0.3% then all parameters have questionable significance and the experiment suggests no potential. Oxygen Index (OI), S3/TOC, has questionable significance if TOC is ≤ 0.5%. Both Tmax and Production Index (PI = S1/(S1+S2)), have questionable significance if S1 and S2 values are less than or equal to about 0.35 mg HC/g rock. Results can be affected by mineral matrix effects due to either retention of generated compounds, generally lowering the S1 or S2 peaks, while increasing Tmax, or liberating inorganic $CO_2$ and increasing S3 and OI. These effects are important if TOC, S1 and S2 are low, and not significant where sources have TOC values > 5%. OI values > 150 mg/g TOC suggest either low TOC or a mineral matrix $CO_2$ contribution during pyrolysis. Generally, a TOC content of at least 2% is needed for a petroleum source rock. Note that TOC and Hydrogen Index decrease with increasing thermal maturity due to hydrocarbon generation. Additional guidelines on the interpretation of Rock-Eval data may be found in Peters (1986), Snowdon (1995) and Sykes and Snowdon (2002).

## HOPEDALE BASIN WELLS

### Bjarni O-82

Data is from 445 to 2615 m over a Saglek Formation to Bjarni Formation interval. Tmax values indicate that the organic matter is immature throughout the analyzed interval. TOC contents are extremely low (<0.25% TOC) for the Saglek Formation in the uppermost part of the well. TOC contents are then generally high (mostly >2%) throughout the Mokami, Kenamu and Cartwright formations but with low HI values that are mostly less 100 indicating the organic matter has little hydrocarbon potential. Within the Mokami Formation, there are two samples at 1190 and 1210 with higher TOC (10.98 and 12.46%) and HI values (201 and 196) but very high OI values and anomalously low Tmax values of 302°C and 305°C suggesting possible contamination. TOC contents show a decreasing trend with depth through the Markland Formation and are mostly less than 1% for the upper part of the Bjarni Formation that was analyzed. There are two samples in the lower part of the well with extremely high TOC contents at 2165 and 2555 m (36.22% and 27.37%). The 2165 m sample has a low HI value of 108, a high OI value (112) and a Tmax significantly lower than surrounding samples that suggests possible contamination, possibly by the lignosulphonate/lignite in the drilling mud used in this well. The 2285 m sample has a higher HI value of 284, a very low OI value of 6 with Tmax of 424°C and may represent an interval with some hydrocarbon potential.

### Herjolf M-92

Samples were analyzed from 1500 to 13400 ft (457-4084 m) from the Saglek

Formation to basement. Tmax shows a good trend with depth. Tmax values for higher TOC samples in the Alexis Formation towards the bottom of the well are ~447-448°C, corresponding to calculated vitrinite reflectance equivalents of about 0.89 to 0.91% VRo. This suggests that the organic matter is in the middle of the oil window at the bottom of the well.

In the upper part of the well, within the Saglek, Mokami, Kenamu, Cartwright and Markland formations many samples have high TOC contents, with up to 6.5% within the Mokami Formation. However, HI values are almost all less than 100 for this section and it just has some minor gas potential. The Lower Cretaceous Bjarni Formation has an even higher organic matter content with TOC contents up to 10.85% for a sample from 11090 ft. This sample has a HI of 335 suggesting some potential to generate oil. Other Bjarni samples have lower HI values but several are in the 200-300 range which suggests this interval has significant gas condensate potential and is the most likely source of the Labrador Shelf gas and condensate discoveries (Fowler et al., 2005). Below the Bjarni Formation, the Alexis Formation also has intervals of higher TOC contents with HI values up to 223 such as for the 12800-12890 ft interval.

**Hopedale E-33**

The analyzed samples were from 900 to 2060 m from the Mokami Formation to basement. There is no trend in Tmax with increasing depth. This is due to a combination of the limited depth range of the samples, and that many have low TOC and S2 values. Vitrinite reflectance indicates that the organic matter is immature throughout the interval penetrated by the well.

No interval in this well shows potential to generate oil. There are some intervals with high TOC contents such as the 1360-1540 m interval within the Kenamu Formation where all samples are 2.15 to 3.2%. However, all HI values are less 100 except for two samples. One is just above the basement and has a TOC of only 0.55% and a HI of 144. The other is from 1962.1 m and is the only Bjarni Formation sample analyzed. It has TOC content of 3.16% and a HI of 195 and could be an indicator that the Bjarni Formation may have hydrocarbon source potential in this well, as seen elsewhere on the Labrador Shelf.

**North Leif I-05**

Samples were analyzed from 435 to 3420 m over a Saglek Formation to Alexis Formation section. Tmax shows a good trend with depth, showing immature values of 417-420°C in the upper part of the Mokami Formation and ~439-440°C at the base of the Bjarni Formation This shows good agreement with measured vitrinite reflectance which is 0.78% VRo at 3410 m (Avery, 2005). Hence, the Bjarni Formation is in the early part of the oil window.

The upper part of the well shows many intervals with high TOC contents, especially in the Kenamu and Cartwright formations. These samples all have low HI (<100) and hence little hydrocarbon potential. The Bjarni Formation shows high TOC contents with almost all samples greater than 2% and many greater than 5%. One sample from 3340 m has a TOC content of 42.67% suggesting a coaly interval. HI values are higher than for the overlying formations, with all samples greater than 100, and many greater than 300. One sample from 3080 m has a TOC content of 4.59% and a HI of 404. The organic matter type is mostly Type II-III within the Bjarni Formation which therefore has potential to generate gas with minor liquids.

**Roberval K-92**

The samples analyzed were from 640 to 3870 m over a Saglek Formation to Paleozoic section. Tmax does not show a good trend with depth and neither does it show the large increase in maturity that is shown by vitrinite reflectance crossing the unconformity between the Alexis Formation and the Paleozoic at 3544 m. This may be because the TOC contents of the Paleozoic samples are mostly very low and where higher could be the result of cavings from overlying intervals. Vitrinite reflectance indicates the Mesozoic section is immature to early mature with respect to hydrocarbon generation with a reflectance of 0.74% at 3490 m near the base of the Alexis Formation (Avery, 2009).

The section penetrated at Roberval K-92 does not show any hydrocarbon potential. Many samples have low TOC contents and even those that have higher values, such as the 2200-2380 m interval which has TOC contents of 2.44 to 4.37%, have low HI values indicating Type III organic matter. The 3099.50 m sample has a TOC content of ~35% and a HI of 110, suggesting coaly beds at this depth.

**South Labrador N-79**

Samples from 730 to 3571 m from Saglek Formation to Precambrian basement were analyzed. Tmax shows a good trend of increasing with depth in this well. At ~900 m, at the top of the Mokami Formation it is 413-415°C and increases to ~440°C at 3540 m, just above the basement, suggesting the organic matter is in the early oil window (~0.75% VRo). Based on Tmax, hydrocarbon generation would be expected to start around 2800 m..

At the top of the well, from 730 to 1070 m, samples have low TOC contents (<1.3%) and low HI values (<100). TOC contents increase through the lower part of the Mokami Formation until 1500 m with most samples having 2-3.3% TOC. HI values are mostly less than 100. Below this there is a drop in TOC at the top of the Cartwright Formation followed by another interval with higher TOC contents (>2% and up to 6.12%) and low HI (40 - 136) throughout the remainder of this unit. TOC contents decrease in the Markland Formation with most samples 1-2% with HI less than 100,

although the 3100-3160 m interval has some higher TOC contents of 2-3%.
As organic matter is Type III throughout this well, there is just potential to generate gas.

## SAGLEK BASIN WELLS

### Gjoa G-37

The analyzed samples were from 1450 to 3998 m over the Saglek Formation to Markland Formation section. TOC values range up to 2% but HI values are less than 100 throughout the section except for two samples which still have HI values of less than 150. Hence no intervals with significant hydrocarbon potential were penetrated in this well. Tmax does not show a good trend with increasing depth which is a function of the low S2 values for many of the samples. Avery (2004a) reported a vitrinite reflectance of about 0.65% at 3800 m which suggests organic matter is early mature at the bottom of the well.

### Hekja O-71

The analyzed samples were from 740 to 4566 m from Saglek Formation to basement. The "unknown basalts" comprising the basement are over the 3545 to 4566 m interval but based on the Rock-Eval data comprise the 3560m and deeper samples. This interval generally has low TOC contents but there are occasional samples with values above 0.5% indicating that there are either sediments within the basalts, these are actually metasediments, or there were cavings.
Over the Saglek Formation to Gudrid Formation sequence, Tmax shows a trend of increasing with increasing depth, albeit with several perturbations because many samples have S2 values too low to give reliable Tmax values. Samples over the 3460-3540 interval have elevated TOC contents and Tmax values that should have value as indicator of maturity. They show a range of Tmax values of 425 to 430°C which corresponds to a vitrinite reflectance range of 0.49 to 0.58%. This in good agreement with the measured vitrinite reflectance at 3450 m which is 0.58% (Avery, 2004b).
There are some intervals with high TOC contents, including the upper part of the Leif Member of the Kenamu Formation from 2160 to 2260 m with several depths having values greater than 5%, especially 2180 m which has ~37.25%. HI values for these samples are between 105 and 157 except for the 2180 m sample which is higher with an average of 257. Another organic-rich interval occurs in the lower part of the Leif Member between 2860-2920 m with TOC contents up to 55.9% and HI values up to 180, and also in the 3200-3270 m interval in the upper part of the Gudrid Formation which has TOC contents greater than 10% and up to 57.68% and HI values up to 193 suggesting Type III to III-II organic matter. The variation in TOC and HI between

different samples from the same depths over these latter two organic-rich intervals suggests a mixed lithology of coaly and shaly beds. The gas condensate tested at Hekja O-71 was suggested by Fowler et al. (2005) to be sourced from these Early to Middle Eocene to Late Paleocene coaly siliclastics and coals that contain liptinite-enriched organic matter with a high resinite component.

**Karlsefni A-13**

A limited section from 10803 to 13530 ft (3293 to 4124 m) of Cartwright Formation to basement was analyzed in this well. Samples have high TOC contents throughout this section, especially in the Cartwright Formation where most are in the 3-4.4% range. However, every sample has a HI less than 100 indicating no significant hydrocarbon potential, especially as the Tmax values suggest the organic matter is immature to early mature over the analyzed section.

**Pothurst P-19**

Samples from 1605 to 3835 m over a Mokami – Kenamu formations interval were analyzed. There is no consistent trend of increasing Tmax with increasing depth. Over the upper part of the Mokami Formation this is a function of the low S2 values which imply Tmax is not reliable. In the Kenamu there are higher S2 values but Tmax still shows a wide range.

TOC contents and HI values are very low for most of the Mokami Formation In the lower Mokami Formation below 3065 m, there are higher TOC contents. In particular samples from 3125 and 3135 have high TOC contents (23.37 and 6.51%) and high HI values (246 and 753) but also extremely high OI (246 and 753) and anomalously low Tmax values (314 and 318°C) that suggest these are probably contaminated. Most Kenamu Formation samples have TOC contents between 1-2% and HI values less than 100. There is an interval from 3615 to 3835 m that show TOC contents greater than 2% but HI are less than 100 with one exception which is 126. Hence, the organic matter is Type III at best over the analyzed section with little hydrocarbon potential.

**Raleigh N-18**

The analyzed samples were from 1000 to 3785 m over a Saglek Formation to Gudrid Formation section. There are mostly very low TOC contents over the Saglek, Mokami and upper part of the Kenamu formations from 1000 to 2220 m. There are a few exceptions, most notably at 1750 m which has a TOC of 8.44% but a very low HI of 18 and Tmax of 370°C suggesting it could be contamination. Between 2220 and 3100 m, almost all of the Kenamu Formation samples have TOC contents greater than 1%, often much higher, especially the 2590 to 2680 m interval where most samples are

greater than 10%, suggesting a coaly interval. This latter interval has HI values in the 130-200 range. From 2685 to 2940 m samples are mostly greater than 2% TOC with HI values in the 100-150 range. Most samples below 2940 m have TOC contents greater than 1% and HI values less than 100.
In the upper part of the well there is no trend in Tmax because of the very low organic content. For the rest of the well, Tmax appears to show two trends with depth. One is from 2220 to 2585 m where Tmax is ~425 to 430°C. At 2600 m, the very high TOC samples show a drop in Tmax to 415°C. Tmax increases with increasing depth for the rest of the well with values of about 435°C at total depth.

**Rut H-11**

Samples were analyzed from 735 to 4093 m over a Saglek Formation to Markland Formation section. Tmax shows a good trend with increasing depth over the 1900 to 3885 m interval increasing with from 410° to 433°C, from immature to early mature. There is then a jump to 449°C at 3915 m followed by a gradual trend back to lower values. The 3915 m Tmax result could be an anomalous value, but as it corresponds to a similar jump in reported measured vitrinite reflectance values in this this well (Basin Data Base), this suggests it could be related to a geological feature such as an intrusion.
TOC contents are very low in the upper part of the well from 735 to 1810 m over the Saglek and upper part of the Mokami Formation. There is then a gradual increase in TOC contents with depth until the Kenamu Formation after which they are high for the rest of the well. There are occasional samples in the lower Mokami Formation have very high TOC contents (1845, 1965 and 1995m) of greater than 10%. For these high TOC samples and over the 1965 to 2205 m interval, HI values 100-200. From 2235 to 2805 m, TOC contents are generally higher (>2%) but HI are less than 100. From 2835 to 3520 there are high TOC contents (2.40 to 4.33%) with HI values of 100-150. Below this, TOC contents remain greater than 2% but HI are less than 100. Hence Type III organic matter is dominant throughout this well. Consequently there is some potential to generate gas but little for liquids.

## Selected References

Avery, M.P., 2004a. Vitrinite Reflectance for Esso-H.B. Gjoa G-37. Geological Survey of Canada Open File Report 4843, 14p.

Avery, M.P., 2004b. Vitrinite Reflectance for Aquitane et al Hekja O-71. Geological Survey of Canada Open File Report 4842, 15p.

Avery, M.P., 2005. Vitrinite Reflectance for Petro Canada et al. North Leif I-05. Geological Survey of Canada Open File Report 4978, 15p.

Avery, M.P., 2009. Vitrinite Reflectance for Total Eastcan et al. Roberval K-92. Geological Survey of Canada Open File Report 6052, 13p.

Behar, F., Beaumont, V. and Penteado, H.L.De.B., 2001. Rock-Eval 6 Technology: Performances and developments. Revue de l' Français du Pétrole, v.56/2, p. 111-134. http://ogst.ifp.fr/articles/ogst/pdf/2001/02/behar_v56n2.pdf.

CNLOPB, 2007. Schedule of Wells: Newfoundland and Labrador Area. http://www.cnlopb.ca/wells/

Espitalié, J., Laporte, J.L., Madec, M., Marquis, F., Leplat, P., Paulet, A. and Boutefeu, J., 1977. Méthode rapide de charactérisaion des roches méres de leur potential pétrolier et de leur degré d'évolution. Revue de l'Institut Francais du Pétrole v. 32, p. 23-42.

Espitalié, J., Deroo, G. and Marquis, F., 1985. Rock Eval Pyrolysis and Its Applications. Preprint; Institut Francais du Pétrole, Géologie No. 27299, 72 p. English translation of : La pyrolyse Rock-Eval et ses applications, Premiére, Deuxiéme et Troisiéme Parties, in Revue de l'Institut Francais du Pétrole, v. 40, p. 563-579 and 755-784; v. 41, p. 73-89.

Fowler, M., Stasiuk, L. and Avery, M., (2005) Potential petroleum systems in the Labrador and Baffin Shelf areas, offshore north eastern Canada. In: Organic Geochemistry: Challenges for the 21st Century v. 1, Book of Abstracts for 22nd International Meeting on Organic Geochemistry, Seville, Spain, September 2005, p. 463-464.

Gehman, H.M.Jr., 1962. Organic matter in limestones; Geochimica et Cosmochimica Acta, v. 26, p. 885-897.

Peters, K.E., 1986. Guidelines for evaluating source rock using programmed pyrolysis; Bulletin of the American Association of Petroleum Geologists, v. 70, p. 318-329.

Snowdon, L.R., 1995. Rock-Eval Tmax suppression: documentation and amelioration. American Association of Petroleum Geologists Bulletin, v. 79, p. 1337-1348.

Sykes, R. and Snowdon, L.R., 2002. Guidelines for assessing the petroleum potential

of coaly source rocks using Rock-Eval pyrolysis. Organic Geochemistry, v. 33/12, p. 1441-1455.

Tissot, B. P. and Welte, D. H., 1978. Petroleum formation and occurrence; Springer-Verlag, Berlin, 538p.