

Open File #5672 (CD-ROM)
Rock-Eval/TOC data for eleven NE British Columbia boreholes
(map areas 94-I to 94-P)
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INTRODUCTION

Cuttings samples have been analyzed using a Rock-Eval/TOC pyrolysis apparatus on a typically 30 foot or 10 metre spacing over the depth intervals noted for the eleven wells listed below from northeastern British Columbia, map sheets 94-I to 94-P. The samples are from the Geological Survey of Canada archive set for British Columbia wells and therefore a maximum of 100 mg of material is available for any depth. Duplicate or repeat analyses cannot be run if an instrument failure is suspected and thus the data are presented in an unedited form and must be used with caution. Every effort is made to obtain a representative sample from the vial of cuttings, but because of the small sample size, mixed lithology samples may not be completely representative and mixed lithology intervals may yield some scatter in the data.

<i>Well name and location</i>	<i>Depth Range</i>
TEXACO NFA HAY RIVER NO.1 D-022-B/094-I-09	630-7400 ft
BA SHELL KLUA B-049-F/094-J-09	10-7950 ft
PAN AM SHEEP C-086-D/094-J-12	750-10300 ft
JOINT VENTURE NO.1 C-010-E/094-N-07	40-5880 ft
AQUIT ELF JULIA B-014-A/094-O-01	50-8260 ft
IOE PAN AM VISCOUNT A-077-D/094-O-11	50-10450 ft
IMPERIAL PAN AM LA BICHE B-055-E/094-O-13	40-9930 ft
BP ET AL FORTUNE D-061-A/094-O-15	1020-9890 ft
CPOG THETLAANDOA D-001-G/094-P-06	10-7780 ft
PAN AM PAULSEN A-041-J/094-P-09	50-6820 ft
CNRL ET AL HELMET C-054-J/094-P-15	400-2150 m

Depth units used (feet or metres) are those in which the original well was drilled and logged, and in which the samples are currently labelled. Formation names and depths listed at the end of each well are those obtained from the files of the British Columbia Government Oil and Gas Commission. These stratigraphic tops, which are also used in the GSC-Calgary SAMS database, are in most cases likely the tops provided by the original operators of these wells. In this open file, no attempt has been made to review the stratigraphy. As most of these wells were drilled several decades ago, before the stratigraphy in this area of NE British Columbia was reviewed, some terms are no longer in current use and some of the tops may be incorrect, and hence misleading. Therefore, the stratigraphic data should be treated with caution.

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. Pyrolysis experiments were conducted using Delsi Rock-Eval II unit equipped with a Total Organic Carbon analysis module. A typical Rock-Eval experiment was initiated with heating of a pulverized rock sample at 300°C for 3 min in helium atmosphere, when naturally occurring hydrocarbons (free and adsorbed) are volatilized. During the next stage, the oven temperature is steadily increased to 600°C at a rate of 25°C/min and decomposition of kerogen occurs. The final stage involves oxidation and combustion of the residual organic matter at 600°C. The amount of hydrocarbons volatilized at 300°C and evolved from kerogen at 300°C to 600°C is quantitatively determined by a flame ionization detector, and recorded as the S1 and S2 peaks, respectively. The temperature measured at the maximum of the S2 peak is referred to as Tmax. The quantity of organic CO₂ generated from 300°C to 390°C, determined by a thermal conductivity detector, comprises the S3 peak. The percentage of carbon in CO₂ formed during oxidation at 600°C 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 ($HI = S2/TOC \times 100$, $OI = S3/TOC \times 100$) which are related to the atomic H/C and O/C ratios (Espitalie 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 Espitalie et al. (1985) the oil window is defined by the following Tmax ranges: 440°-448°C (Type I), 430°-455°C (Type II) and 430°-470°C (Type III). A cross plot of Tmax versus HI is used to constrain estimations of organic matter type and its thermal maturity, while the Production Index ($PI = S1/[S1+S2]$) is used to indicate staining of a sample or as an additional maturity parameter.

Rock-Eval results correlate to other techniques (Espitalie et al., 1985; Tissot and Welte, 1978). Source rock potential is sensitive to lithology, TOC and S2 values. It is common practice to rate carbonate rocks with lower TOC comparable with richer clastic rocks. Extractable HC yields from leaner carbonate rocks are comparable to richer 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 less than or equal to 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 less than or equal to 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. These either retain generated compounds, generally lowering the S1 or S2 peaks, while increasing Tmax, or by liberating inorganic CO2 and increasing S3 and OI. These effects are important if TOC, S1 and S2 are low, an effect not significant where sources have TOC values greater than 5%. OI values greater than 150 mg/g TOC suggest either low TOC or a mineral matrix CO2 contribution during pyrolysis. Generally, a TOC content of at least 2% is needed for a source rock. Note that TOC and Hydrogen Index decrease with increasing thermal maturity due to hydrocarbon generation.

BOREHOLE SUMMARIES

Brief comments are provided on the results of the Rock-Eval analyses of samples from each well. These are not meant to be comprehensive but simply to point out the salient features and obvious problems that are apparent in the data. There has been no attempt to put the results into a regional context. The data in this Open File is complimentary to other GSC Open File Reports of Rock-Eval data (see list provided) and to regional maturity maps for Devonian (Stasiuk and Fowler, 2002) and Lower Cretaceous strata (Stasiuk et al., 2002). According to data obtained from BC Government Oil and Gas Commission, all of the analysed wells are currently designated as abandoned except for the Helmet C-054-J/094-P-15 well which is designated as suspended with a gas pool in the Jean Marie Formation.

TEXACO NFA HAY RIVER NO.1 D-022-B/094-I-09

Samples analysed from this well ranged from Lower Cretaceous to Precambrian. There are no obvious source rock or stained intervals in this well. The Devonian to Precambrian section generally has low TOC contents of less than 0.5%. There is no indication in this well for the well known Keg River or Exshaw source intervals (e.g. Fowler et al. 2001). The Gething section does have a higher TOC content with samples generally greater than 1% TOC that contain immature Type III-II organic matter. The Tmax profile does not show much variation with depth below the Cretaceous, which could possibly be the result of cavings in the lower part of the well.

BA SHELL KLUA B-049-F/094-J-09

This well drilled a Lower Cretaceous to Precambrian section. The only source rock interval that appeared to be intersected is the basal Exshaw Formation source rock at 3910 ft. This sample has a TOC content of 1.53% and is of high maturity. PI values are high for most of the well making it hard to determine if there are stained intervals. Tmax values indicate that organic matter is already mature with respect to hydrocarbon generation at the top of the well. There is a trend of increasing Tmax values with increasing depth until the Upper Devonian where organic matter appears to be at the end of the oil window.

PAN AM SHEEP C-086-D/094-J-12

Middle Triassic to Middle Devonian samples were analysed from this well. Tmax values are not useful for determining maturity in this well as all samples are overmature. PI values are high throughout the well, indicating either extensive staining, or more likely, that some form of oil-based drilling mud was used. TOC contents of 1-2% occur in the Triassic section that probably corresponds to the Montney Formation further east. It is possible that the sample from 5860 ft (TOC, 1.46%) could represent the basal Exshaw Formation source rock. The rest of the samples have low TOC contents with some notable exceptions at 3950 ft. and 4750 ft. that also have S2 and Tmax values that also appear to be anomalous suggesting contamination.

JOINT VENTURE NO.1 C-010-E/094-N-07

This well drilled a Middle Triassic to Middle Devonian section. Tmax values are not useful for determining maturity in this well as all samples are overmature. PI values are high for almost all the samples, indicating either extensive staining, or more likely, the use of hydrocarbon drilling additives. The Triassic to Upper Devonian section is very organic lean. There are several samples with elevated TOC contents (>1%) within the Middle Devonian including some with greater than 2%. Source rocks have been previously identified within the Elk Point of northeast British Columbia (e.g. Fowler et al., 2001).

AQUIT ELF JULIA B-014-A/094-O-01

A Lower Cretaceous to Cambrian section was intersected by this well. Some high TOC (>1%) contents occur in the lower part of the 'Bluesky' section, especially over the 1020-1830 ft range. These samples are associated with high HI values (>400 mg HC/g TOC) and Tmax values that suggest early mature Type II organic matter. Thus this section may have significant liquid hydrocarbon potential. The rest of the well is almost entirely organic-lean. The sample at 3570 m which has a TOC content of 1.33% and Hydrogen Index of 248 mg HC/g TOC could be the basal Exshaw Formation source rock. Its Tmax of 448°C suggests it is in the late oil window. A sample at 7570 ft with a TOC content of 1.74% and a very low HI value of 30 mg HC/g TOC could represent a thin overmature Middle Devonian organic-rich interval. Tmax values are early

mature at the top of the well, increasing into the late oil window going down into the Upper Devonian (~ 4000 ft) after which there is no longer any Tmax trend with increasing depth.

IOE PAN AM VISCOUNT A-077-D/094-O-11

This well encountered an Upper Cretaceous to Mississippian section. Note the old “Fort Nelson Formation” nomenclature is used for the uppermost section for which Dunvegan Formation would now be employed.

There are several zones of elevated TOC contents in this well. An extended interval of moderate TOC contents (1-1.75%), and HI (200-310 mg HC/g TOC) and PI values suggesting immature Type III organic matter, occur over the 2270-2640 ft interval within the Lower Cretaceous Lepine Formation. At the base of the Lepine Formation, between 4200ft and 4350 ft. there are samples with TOC contents of 1.11-1.63% and HI values between 372-517 HC/g TOC. The Tmax values are 446-446°C suggesting the samples are mature which is also supported by PI values between 0.08 and 0.19. This suggests the HI values would have originally been higher before the onset of hydrocarbon generation, with the organic matter being Type II. Thus this section could have significant hydrocarbon generation potential depending on what proportion is the source facies. Within the Lower Cretaceous Scatter Formation, from 5430 to 5520 ft, there is an interval with TOC contents between 1.14 and 2.32% with HI values of 235-344 mg HC/g TOC. The Tmax values for these samples (447-454°C) and PI values (0.16-0.24) suggest they are mature and stained. Based on this and assuming that the stained hydrocarbons were generated within this section, the organic matter would likely have been Type II and thus this section also may originally have had significant hydrocarbon potential. The interpretation of significant hydrocarbon potential for these Lower Cretaceous intervals is made cautiously as elsewhere in the Western Canada Sedimentary Basin, the Lower Cretaceous is commonly stained with heavy hydrocarbons thought to have mostly an Exshaw source (e.g. Fowler and Riediger, 2000). It is not always easy to distinguish potential source rocks from stained intervals based simply on Rock-Eval data but in this case Lower Cretaceous source rocks are favoured based on the Tmax values which are higher than those usually observed for stained intervals.

The remaining part of the well is organic-lean. There are some high TOC samples for

samples near the base of the well, at 10210 ft (11.93%) and 10180 ft (5.16%). These samples have HI and Tmax values that seem anomalous for the depth and maturity of the samples and thus contamination is suspected.

There is a good trend of increasing Tmax values with increasing depth over the upper part of the well, down to the top of the “Nordegg-Baldonnel” section. This suggests the uppermost part of the well is immature with respect to hydrocarbon generation and has reached the later stages of the oil window by the lower part of the Upper Cretaceous. Tmax values are scattered over the lower part of the well due to a combination of low organic content and high maturity.

IMPERIAL PAN AM LA BICHE B-055-E/094-O-13

This well drilled an Upper Cretaceous to Carboniferous section. Almost all the samples are organic-lean. There is an extensive interval within the “Sikanni” from 1620 to 2700 ft where most samples have greater than 1-1.5% TOC but despite their low maturity, the samples have low HI values (most less than 200 mg HC/g TOC). The sample with both the highest TOC content and HI is from 1770 ft which has a TOC content of 1.63% and a Hydrogen Index of 292 mg HC/g TOC. This section may have some minor hydrocarbon potential. The rest of the well is essentially organic-lean with no source rock intervals indicated by the data.

Tmax shows a good trend with increasing depth from the Sikanni to the Toad-Grayling and an apparent trend down into the Mattson. It suggests an increase in maturity from immature with respect to hydrocarbon generation in the Upper Cretaceous to overmature in the Permian.

BP ET AL FORTUNE D-061-A/094-O-15

Samples throughout this well show high PI values indicating possibly pervasive staining or the use of some form of oil-based drilling fluid and making conclusions based on these results less certain. At the top of the well there are some pre-Debolt Formation samples with high TOC values, notably at 1530 ft (3.97 %) and 1260 ft (3.76%). The former has a HI of 509 HC/g TOC and the latter a HI of 294 mg HC/g TOC. Tmax values of 426 and 429°C suggest these samples are immature. Other samples in this part of the well have TOC contents greater than 1%, ranging

up to 2.18% with Type III-II organic matter, suggesting this interval could have some hydrocarbon potential if more mature. The samples at 4340 and 4370 ft probably correspond to the basal Exshaw source rock. These have TOC contents of 2.08 and 2.48% and HI values of 234 and 238 HC/g TOC. Tmax values of 444-446°C suggest these samples are in the middle of the oil window. In the lower part of the “Nahanni” section (i.e. 9240-9490 ft) there are a number of samples with TOC contents greater than 2% with the highest being that from 9410 ft with 2.88%. These samples have very low HI values and very high PI values ($S_1 > S_2$). These could be overmature source rocks stained with hydrocarbons generated in close proximity. The Nahanni and other Middle Devonian intervals are reservoirs in this area. More detailed work would be needed to follow this up.

The Tmax profile shows a good trend of increasing with increasing depth until the base of the Exshaw where it becomes more scattered. The data suggests the maturity of the organic matter ranges from immature in the pre-Debolt section, to middle oil window at the base of the Exshaw, to overmature at the bottom of the Nahanni.

CPOG THETLAANDOA D-001-G/094-P-06

This well penetrated a Lower Cretaceous to Middle Devonian section. Within the Lower Cretaceous there is an extended section with TOC contents greater than 1% from 1190 ft to 1750 ft. The best samples are from 1730 ft which has a TOC content of 3.65% and a HI of 395 mg HC/g TOC and from 1550 ft which has a TOC content of 2.23% and a HI of 374 mg HC/g TOC. Most of the remaining samples over this depth range have TOC contents less than 2% and HI values less than 200 mg HC/g TOC. Tmax values suggest the organic matter is immature with respect to hydrocarbon generation. Thus this Lower Cretaceous section could have some hydrocarbon potential.

Most of the rest of the well is organic-lean. The sample from 3380 ft at the base of the “Banff Formation” which has a TOC content of 1.46% and HI of 280 mg HC/g TOC could be a mature basal Exshaw Formation source rock observed in other wells in this area. There are also some organic-rich intervals within the Muskeg section from 6320 to 6390 ft with the best being that from 6390 ft that has a TOC content of 2.46%. It only has a HI of 14 which together with its

high PI value suggests all its hydrocarbon potential has been generated.

Tmax values increase with increasing depth until the Upper Devonian. Organic matter is immature in the Lower Cretaceous, mid-oil window by the base of Mississippian, and overmature in the Middle Devonian.

PAN AM PAULSEN A-041-J/094-P-09

It should be noted that the stratigraphic tops provided for this well for the most part make little sense, and hence should be treated with the utmost caution. In the pre “Banff” section, there is an interval with excellent hydrocarbon potential between 1110 and 1230 ft. It has TOC contents of between 2.34 and 5.28% and Hydrogen Index values between 295 and 536 HC/g TOC. The Tmax values are low and appear to be suppressed compared to other samples. Together with the low PI values, they indicate that the organic matter in these samples is immature. There is another sample at 1470 ft with similar good hydrocarbon potential. The rest of the well is organic-lean with the exception of some Middle Devonian samples at 5320 and 5350 ft (TOC, 1.07 and 1.70%) and 6190 to 6250 ft (TOC, 2.21-3.30%) that have very low HI values due their high maturity but may have generated significant volumes of hydrocarbons sometime in the past.

Tmax values suggest that the pre “Hay River” section (down to ~3510) ranges from immature to early mature with respect to hydrocarbon generation. There is a steep jump in maturity between early mature and overmature between the intervals given as “Livingston” and “Hay River”, which may suggest presence of a significant unconformity.

CNRL ET AL HELMET C-054-J/094-P-15

Samples from an unknown pre-Mississippian unit(s) to Middle Devonian were analysed from this well. The pre-Banff interval from 400-505 m contains samples that mostly have TOC contents between 1 and 2% and HI values in the 100-250 mg HC/g TOC range. However, the sample from 410 m has a TOC content of 3.88% and a HI of 460 mg HC/g TOC. It has a Tmax value considerably suppressed compared to other samples in this interval (421° vs mostly 432-435°C). This could be related to the type of organic matter (i.e. possibly Type IIS) or may

indicate something suspicious about this particular sample. Further analyses would be needed to confirm one or the other.

The sample at 820 m that has a TOC content of 1.27% and a HI of 251 mg HC/g TOC probably corresponds to the basal Exshaw source rock observed in other wells in this area. Its Tmax of 435°C suggests that is early mature.

In the Klua, between 2080 and 2100 are high TOC values (2.11-3.58%) with very low HI values suggesting they could be overmature source rocks. This is supported by their Tmax values of 567-572°C. Thus these units could have had substantially higher TOC contents prior to the onset of hydrocarbon generation, depending on organic matter type and thus may have been source rocks. Similar results for the Klua Formation in this area were reported by Fowler et al. (2001).

Tmax values suggest that the organic matter is marginally mature in the top part of the well although, as noted previously, the organic-rich sample from 410 m has a very low Tmax of 421°C. There appears to be little variation until the base of the Tetchu when any trend in the data is lost. The maturity of the organic-rich Klua samples suggests the Middle Devonian is overmature in this area.

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