GEOLOGICAL SURVEY OF CANADA
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INTRODUCTION

Cuttings and core samples have been analyzed using a Rock-Eval 6 Turbo pyrolysis apparatus in the Calgary organic geochemistry laboratory of the Geological Survey of Canada. The wells typically were sampled on about a 10 metre (30 foot) spacing. Analyses also have been carried out for additional depth intervals for wells included in Geological Survey of Canada Open File Report 1720 (Snowdon, 1988). The original data were measured using a Rock-Eval II/TOC instrument, while the new data were run using a Rock-Eval 6 Turbo.

In addition, Oil Show Analyzer data were generated by Chevron Canada in the late 1980s and early 1990s using samples archived by the GSC for seven Yukon wells. These data were filed with the well history documents in the early 1990s and released after a confidentiality period. The results have been transcribed and included in this data set. The depth intervals for these data are somewhat irregular and generally at a larger interval spacing than the analyses carried in the GSC.

Rock-Eval 6 Turbo results

Beavercrow YT B-16 (54 cuttings samples + 55 RE II unpublished results)

Ellen YT (7 core samples* + 34 cuttings sample + 505 RE II previously published results)

North Hope YT N-53 (193 cuttings samples)

North Parkin YT D-61 (6 core samples* + 215 cuttings samples)

Schaeffer Creek YT O-22 (2 core samples* + 297 cuttings samples)

South Tuttle YT N-05 (44 cuttings samples + 322 RE II previously published results)

Oil Show Analyzer results

Alder YT C-33 (261 samples)

Blackie M-59 (102 samples)

Chance J-19 (46 samples)

East Chance C-18 (52 samples)

Porcupine YT F-72 (80 samples)

Parkin YT D-51 (88 samples)

West Parkin D-54 (65 samples)

The depth units shown in the figures (feet or metres) are those in which the original well was drilled and logged, and in which the samples are currently labelled. The formation tops are those from the GSC Calgary archives supplemented with some from Fraser and Hogue (2007). All formation tops presented herein are provisional and subject to revision.

EXPERIMENTAL

Rock-Eval/TOC analysis provides fast and reliable characterization of the quantity and quality of sedimentary organic matter, as well as its level of thermal maturity. The previously published results (Snowdon, 1988) were generated using a Rock-Eval II instrument equipped with a TOC (total organic carbon) module. The new pyrolysis experiments were conducted using a Rock-Eval 6 Turbo instrument. The data generated by Chevron were run using an Oil Show Analyzer, an instrument essentially similar to a Rock-Eval II but in which no S3 peak is measured and hence no Oxygen Index is available.

The operating parameters for a Rock-Eval II (RE II) are provided in several GSC Open File reports (e.g. Snowdon, 1988). These are generally the default settings for this type of instrumentation and thus similar conditions likely will have been used by Chevron for the Oil Show Analyzer. The operating conditions for a Rock-Eval 6 (RE6) instrument are slightly different in some respects, although the measured or calculated parameters are nominally the same for the two instruments. The RE6 uses nitrogen as a pyrolysis gas rather than helium, resulting in a reduction in thermal gradients within the pyrolysis oven and a higher level of temperature control and precision. The default maximum pyrolysis temperature of a RE6 is 650 ºC rather than 600 ºC in a RE II. Thus the new instrument may yield somewhat higher S2 values especially for samples containing terrigenous (Type III) organic matter at high levels of thermal maturity. The RE6 instrument has infrared detectors that continuously monitor CO and CO_2 production during the pyrolysis and oxidation steps of the analysis, and this provides a much more reliable determination of the S3 (and Oxygen Index = 100*S3/TOC) than the older machine. The RE6 detectors are more sensitive and thus the typical sample size used is 70 mg of rock rather than the 100 mg used in a RE II. The RE6 oxidation oven is programmed to heat to 850 ºC and thus TOC estimates tend to be more accurate than for the older technology, especially for high maturity samples. The temperature measured at the maximum of the S2 peak in a RE II is referred to as Tmax, whereas the equivalent temperature in a RE6 is termed Tpeak. There was an absolute error of about 40 ºC in the RE II instrument that is no longer present in the RE6. Tmax values reported from a RE6 instrument are calculated by subtracting ~40 ºC from the measured Tpeak value. Additional details on the RE6 instrument are available in Behar et al. (2001).

The TOC (total organic carbon) content is used as a proxy for the quantity of organic matter in a sample and this parameter is determined by algorithmically summing the carbon present in the pyrolysis peaks S1, S2 (hydrocarbons) with CO and CO_2 along with the carbon derived from the oxidation of the residual organic matter in the oxidation oven. Thermal decomposition of mineral carbonates to CO_2 are identified separately in the pyrolysis and oxidation steps and summed to yield an estimate of the total inorganic carbon content.

The determination of the quality of organic matter is based upon the calculation of Hydrogen (HI) and Oxygen (OI) indices (HI= 100 x S2/TOC, OI=100 x S3/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. Results from the Oil Show Analyzer do not include the S3 and Oxygen Index parameter (plotted as zero values) and thus Hydrogen Index versus Tmax is commonly used as a surrogate for the pseudo van Krevelen diagram. 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: 440–448 ºC (Type I), 430–455 ºC (Type II) and 430–470 ºC (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.

While the RE6 instrument is much more stable and reliable than the older technology, interpretation of the results must be carried out with care. If TOC is very low (e.g. <0.1%) then all parameters have questionable significance and the experiment suggests no source rock potential. Similarly, if S1 and S2 are low (e.g. <0.2 mg HC/g rock), the analytical error may be large relative to the absolute measured value and the Production Index (PI = S1/(S1+S2)) ratio may be effectively undefined. Also it will be difficult to select a reliable peak top for a very low S2 value and thus the Tpeak (and hence Tmax) will be unreliable. Additional guidelines on the interpretation of Rock-Eval data may be found in Peters (1986), Snowdon (1995) and Sykes and Snowdon (2002).

DATA SET SUMMARIES

Brief comments are provided on the results of the Rock-Eval analyses of samples from each data set. 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 complementary to other GSC Open File Reports of Rock-Eval data for the Yukon and adjacent areas (Feinstein et al., 1988; Fowler and Snowdon, 2001;

Fowler et al., 2003, 2007a, 2007b; Gal et al., 2007; Link et al., 1989; Potter et al., 2000, 2003; Riediger et al., 2004; Snowdon, 1988, 1990; Snowdon and Price, 1994; also see Appendix A).

Beavercrow YT B-16 (54 cuttings samples + 55 RE II unpublished results)

The entire well shows undefined Tmax values (<300 ºC) for both the older, RE II data (>3900 ft, 1189 m) and the RE6 data (740–3830 ft, 226–1167 m). The unusually shaped pyrolysis peaks indicate that the organic matter in all of the samples for this well is dominated by a drilling additive contaminant. It does not appear that any of the analytical results are useful for this well.

Ellen YT C-24 (7 core + 34 cuttings samples + 505 RE II previously published results)

The Ellen C-24 well samples are within the early oil generation window at the surface and increase slightly to about 0.9–1.0 %VRo at about 5400 ft (1646 m) within the Tuttle, the deepest cuttings samples in the previously published Open File Report (Snowdon, 1988). The Burnthill Creek and Fishing Branch along with the uppermost portion of the Whitestone River units show elevated TOC contents, with a few Fishing Branch samples also showing high Hydrogen Index values, indicating the presence of mature, oil prone organic matter. The deepest Fishing Branch samples show a slight Tmax suppression, as do a few organic rich samples in the lower part of the Whitestone River. The high TOC Whitestone River samples also have very high HI values indicating the possible presence of a lacustrine source rock. The Rock-Eval 6 data for the core sample from 3067 ft (935 m) show a slightly higher Tmax (441 ºC) and lower S2, TOC and HI values than the adjacent cuttings samples. Similarly, the core samples from 4214 and 4218 ft (1284 and 1286 m) have slightly lower S2, TOC and HI values than the adjacent cuttings, but a similar Tmax. The deepest core samples (3 analyzed as duplicates) generally show an increase in the level of thermal maturity to beyond the oil generation window. The additional cuttings samples from the section below the data presented in OFR 1720 (Snowdon, 1988) show Tmax values that are generally less consistent with the core data. As these samples were small, derived from "excess bag cuttings" residual after the archive set of vial cuttings was recovered and likely more difficult to clear out the cavings and/or drilling mud, their results are less reliable.

North Hope YT N-53 (193 cuttings samples)

The increasing Tmax trend throughout the N-53 well indicates that thermal maturity progresses from middle of the main phase of oil generation near the surface through to overmature within the Ogilvie Fm. (6300 ft, 1920 m), well above the TD of 14,043 ft (4280 m). The TOC content is below 2% throughout the sampled interval and Hydrogen Index values are low throughout. The low HI values in the Whitestone River Fm. indicate that the organic matter is Type III, whereas the low HI values for deeper units may be the result of more advanced thermal maturity.

North Parkin YT D-61 (6 core + 215 cuttings samples)

The thermal maturity in this well shows a more or less smooth increase extending from marginally mature at the surface (Cody Creek Formation) to the end of the main oil generation window (Ogilvie Formation). TOC contents are generally low, with small increases notable in the Carboniferous (Ford Lake Formation) and Imperial Formation. The Hydrogen Index values are quite low throughout the well indicating that there are no oil prone source rocks in this well.

Schaeffer Creek YT O-22 (2 core + 297 cuttings samples)

The Tmax trend in the O-22 well is similar to that in the Parkin D-61 well, with marginal maturity at the surface (Fishing Branch Formation) increasing to very high thermal maturity in the Ogilvie. Marginal TOC contents in the Parkin and Whitestone River formations are accompanied by relatively low Hydrogen Index values indicating dominance by Type III (terrigenous) organic matter. No oil prone source intervals are identified in this well.

South Tuttle YT N-05 (44 cuttings samples + 322 RE II previously published results)

The newly analyzed samples for the N-05 well (40–1460 ft., 12–445 m) show a rapidly increasing level of thermal maturity starting within the main oil generation phase at the surface (Imperial Fm.) and increasing to overmature, still within this unit. The Production Index discontinuity near 1460 ft (445 m) coincides with change from RE6 data above and RE II data below. This discontinuity is attributable to the slightly different temperature range for the measurement of the S2

peak. The Canol Fm. shows a significant increase in TOC content over the rest of the samples in this well, but the Hydrogen Index is very low, consistent with a very high level of thermal maturity.

Oil Show Analyzer results

Alder YT C-33 (261 samples)

The Alder YT C-33 log shows a very rapid rise in thermal maturity from a relatively high level of about 1% VRo for the shallowest sample at 500 m. The high maturity and rapid increase as a function of depth is consistent with the Production Index (PI) data. The Blackie Fm. (1163–1288 ft) shows a decrease in PI accompanied by a small increase in the S2 yield, TOC and Hydrogen Index. This behaviour is similar to the apparent depression of the PI in the Ford Lake Shale in the Chance M-08 (L-08) well (Snowdon, 1988) that was interpreted to indicate that petroleum had been expelled from the source rock with a commensurate reduction in the S1. Below about 1400 m, the level of thermal maturity appears to be very high. Residual TOC peaks that occur in the upper part of the Ford Lake, Imperial and Canol formations reflect the fact that each of these units once had significant amounts of TOC but are now overmature.

Blackie M-59 (102 samples)

The level of thermal maturity in the Blackie M-59 well is within the early part of the main oil generation window (about 0.7–0.8 %VRo). The interval at 4250–4650 ft (1295–1417 m) in the Blackie Fm. has a few samples with TOC contents above 2% and HI values in the 400–500 mg HC/g TOC range. The HI values indicate the presence of a good oil prone source rock in which much of the potential has not yet been realized. The HI values that exceed 1000 mg HC/g TOC indicate that the reported TOC contents for these samples are erroneous with all of the TOC being derived from the S1+S2 peaks. These results suggest that the sample crucible was dropped during the transfer from the pyrolysis oven to the oxidation oven and that the oxidation step failed altogether during these analyses. In this case the reported TOC is essentially only the TOC present in the S1 and S2 peaks.

Chance J-19 (46 samples)

The maturity of this well is similar to that of the East Chance C-18 well (see below), in the early part of the main oil generation window. Three of the four samples with anomalously high HI values are most likely errors caused by significant underestimates of the TOC content. The sample from 2400 ft (731.5 m) has a Hydrogen Index value of 795 mg HC/g TOC and the samples from 4280 ft (1305 m) and 4510 ft (1375 m) also have high HI values of >900 mg HC/g TOC, inconsistent with the adjacent samples. The HI value of 356 mg HC/g TOC for the 3200 ft (975 m) sample could indicate the presence of a thin interval with better source potential, but the TOC content (0.25%) is 3 to 5 times lower than the adjacent samples and this suggests an analytical error for the TOC in this sample.

East Chance C-18 (52 samples)

The samples from the Chance C-18 well all show a more or less constant Tmax of about 435ºC, equivalent to about 0.7 %VRo. There is a slight increase in PI towards the bottom of the well suggesting the generation of small amounts of volatile hydrocarbons has occurred. The HI values are all less than about 200 with a single exception at 4700 ft (1433 m) that is the result of a TOC analysis error.

Porcupine YT F-72 (80 samples)

All of the samples down to about 6700 ft (2042 m) in the Porcupine YT F-72 well have S2 values that are near zero, precluding the determination of a useful Tmax. The small S1 values throughout the section indicate either a very high level of thermal maturity and/or a small amount of contamination in the samples by a volatile organic contaminant such as diesel fuel or methanol in the drilling mud. Several samples in the Road River Fm. at the bottom of the sampled interval (6700–7388 ft, 2042–2252 m) have relatively high TOC contents, Tmax values that are consistent with the beginning of the oil window and HI values that indicate an oil prone source rock. These results are almost certainly the result of contamination of the samples.

West Parkin YT D-51 (88 samples)

There is no apparent depth trend in the Tmax values which are dominantly between 435 and 440 ºC or at the beginning of the main phase of oil generation. Production Index values are more or less constant and low down to the Hart River Fm. (about 3700 ft, 1128 m) at which depth a few samples show higher PI values indicating the presence of early generated hydrocarbons in that unit and the underlying Chance sandstone member. The increase in TOC to 2–3% and Hydrogen Index to 300–400 mg HC/g TOC in the deepest samples (>4000 ft, 1220 m) could indicate that there is some source potential in the Chance sandstone member. Alternatively, these values could be the result of a small amount of contamination in these samples.

West Parkin D-54 (65 samples)

The selected intervals that have been analyzed in the West Parkin D-54 well contain variable amounts of TOC, with the highest values in the Tuttle, Ford Lake shale and Parkin Fm. The S2, TOC and Hydrogen Index values of the Ford Lake shale are consistent with level of thermal maturity indicated by the Tmax values, that is, near the top of the main phase of oil generation (0.8–0.9 %VRo). The samples below about 1615 m mainly in the Tuttle Fm. show very high S2 values (15–25 mg HC/g TOC), very high Hydrogen Index values (400-700 mg HC/g TOC) and high residual TOC contents (3–5%). The Tuttle Fm. in the Parkin D-61 well shows rather modest TOC and Hydrogen Index values, suggesting that the Tuttle samples in the West Parkin D-54 well are likely contaminated.

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