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INTRODUCTION

Rock-Eval 6/TOC results were obtained for cutting samples from the following 22 boreholes in the Liard Basin area:

Location	Well Authorization No.	Cuttings Interval Sampled	Garbutt, Top (m)	Rad Zone, Top (m)	Lower Garbutt, Top (m)	Underlying unit, Top m
A-02-D/94-O-15	WA3493	1080 - 1380 ft (323 - 421 m)	413.4	463.6	n/a	Bluesky - 467.7
A-34-F/94-O-04	WA10754	1510 - 1810 m; 2005, 2365 m	1507.9	1690.3	1754.4	Chinkeh - 1811.9; Toad - 1849.3
A-50-I/94-O-14	WA13307	1190 - 1235 m; 1260 m	1086.7	1191.7	1218.3	Chinkeh - 1237.4; Toad - 1249.3
A-59-L/94-O-11	WA10746	1725 - 1920 m; 2180 m	1646.6	1739.1	1778.2	Chinkeh - 1813.8; Toad - 1827.9
A-67-D/94-O-06	WA2809	4690 - 4940 ft (1430 - 1506 m)	1261.5	1406.3	1458.9	Toad - 1530.2
A-77-D/94-O-11	WA1290	5390-5600 ft (1643 - 1707 m)	1490.6	1641.6	1671.1	Chinkeh - 1713.7
A-98-D/94-O-13	WA6397	1805 - 1890 m	1652.8	1803.1	1856.9	Toad - 1891.2
B-06-C/94-O-11	WA18890	1360 - 1535 m; 1580 m	1349.6	1464.2	1501	Chinkeh - 1541.2; Toad - 1561.5
B-37-I/94-N-09	WA6396	1955 - 2000 m	1761.3	1923.2	1960.2	Chinkeh - 1999.7
B-43-K/94-O-05	WA5725	1600 - 1855 m; 2000, 2200, 2400 m	1602.1	1767	1808.4	Toad - 1854
B-52-B/94-O-14	WA16198	1105 - 1270 m; 1405 m	1101.6	1222.2	1253.4	Chinkeh - 1272.2; Toad - 1289.0
B-55-E/94-O-13	WA 0442	5010 - 5600 ft (1527 - 1707 m)	1419.6	1549.5	1614.5	Toad - 1648
B-59-I/94-O-11	WA9941	1100 - 1270 m	1080.2	1196.1	n/a	Chinkeh - 1237
B-81-E/94-O-06	WA12611	1475 - 1560 m	1332.3	1467.9	1515	Chinkeh - 1563.4; Toad - 1568.3
B-83-K/94-O-14	WA13773	1220 - 1360 m; 1525 m	1202.3	1303.2	1329.9	Chinkeh - 1361.8; Toad - 1374.6
C-13-H/94-O-04	WA14517	1180 - 1435 m; 1500, 1630 m	1115.9	1258	1325.9	Chinkeh - 1351.6; Toad - 1362.8
C-31-F/94-O-11	WA13262	1630 - 1665 m	1491.3	1616.6	1643	Chinkeh - 1669.6; Toad -1688.4
C-60-E/94-O-14	WA18587	1800-1965 m; 2095, 2305 m	1788.5	1907.1	1925.3	Chinkeh - 1968.4; Toad - 1988.7
C-76-G/94-O-04	WA10755	1695 - 1815 m	1511.5	1674.6	1732.1	Toad - 1815.5
C-86-B/94-O-05	WA10756	1450 - 1745 m; 1905, 2050, 2260 m	1442.5	1645.4	1678.1	Toad - 1743.2
D-28-B/94-O-12	WA24902	1720 - 1935 m; 2055, 2250, 2455 m	1690.1	1853.7	1875.5	Chinkeh - 1933.3; Toad - 1937.6
D-95-I/94-O-04	WA16276	1335 - 1445 m	1184.9	1329	1381.9	Toad - 1451.2

Sampling was focused on the Cretaceous Garbutt Formation particularly the organic rich radioactive zone (Rad Zone) and the Lower Garbutt below the Rad Zone. For 10 of these boreholes a few samples from shale intervals in the Triassic Toad Formation were also analyzed. Depth units sampled (feet or metres) are those in which the original well was drilled and logged, and how the samples are currently labelled. The stratigraphic tops listed above were interpreted from well logs and used by Ferri et al. (2015) in a study of the Garbutt Formation. These tops may differ from those in the BC government database associated with the Rock-Eval data.

Rock-Eval 6/TOC results were also obtained for samples of the Garbutt Formation from the following 10 cores, 5 from the Liard Basin and 5 from east of the Liard Basin:

Location	Well Authorization No.	Interval Sampled	Liard Basin	East of Liard Basin	VR
B-006-C/094-O-11	WA18890	1476.0 -1494.0 m	Y		Y
B-A015-K/094-P-03	WA6477	620.25 - 624.25 m		Y	
B-017-H/094-I-09	WA13960	338.0 - 343.4 m		Y	Y
B-053-B/094-O-14	WA9950	1260 - 1278 m	Y		Y
B-059-I/094-O-11	WA9941	1190.4 - 1208.4 m	Y		
C-013-H/094-O-04	WA14517	1402.2 -1414.2 m	Y		Y
C-069-K/094-O-14	WA12703	1597.3 m	Y		Y
D-033-F/094-P-13	WA6468	298.0 - 321.05 m		Y	
FORT LIARD A-01		1333-1351 m		Y	
FORT LIARD K-32		1322-1338.55 m		Y	

Other previously published Rock-Eval/TOC results for the Garbutt Formation in the Liard area are available from several reports (Potter et al., 2003; Fowler et al., 2007; Walsh and McPhail, 2007; Ferri et al., 2011, 2013; Obermajer et al., 2012; McMechan et al., 2013). Vitrinite reflectance data for five of the sampled cores are available from Reyes et al. (2015).

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), 430º-455ºC (Type II) and 430º-470ºC (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 (Espitalié 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 reliable 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 petroleum source potential. Oxygen Index (OI) 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 0.2 mg HC/g rock. Results can be affected by rock mineral composition. The mineral matrix may either retain hydrocarbon compounds, generally lowering the S1 or S2 peaks, while increasing Tmax, or liberate inorganic CO_2 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 CO_2 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. Additional guidelines on the interpretation of Rock-Eval data may be found in Peters (1986), Snowdon (1995) and Sykes and Snowdon (2002).

RESULTS

Samples analyzed for this study range from immature east of the Liard Basin to immature to peak oil in the northern Liard Basin to peak wet gas in the southern Liard Basin. Ferri et al. (2015) presented a preliminary analysis of the unconventional potential of the Garbutt Formation in the Liard Basin based on the data in this report and the publications listed above. Ardakani et al. (2015) presented a preliminary interpretation of the hydrocarbon potential of the Garbutt Formation using the core samples from the Liard Basin. More substantial interpretations will be published by these authors soon.

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