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Thermal Maturation and Petroleum Source Potential of some Cambrian and Proterozoic Rocks in the Mackenzie Corridor

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Introduction

Unmetamorphosed Proterozoic sediments occur in the subsurface over a large portion of the Mackenzie corridor, District of Mackenzie, NWT (Figure 1). There has been considerable interest lately in the petroleum source potential of these rocks. This study addresses that subject in a preliminary, reconnaissance fashion. In some wells the age of the bottom hole sediments is uncertain: Cambrian (or even younger?) or Proterozoic(?). For such strata the term PIP rocks has been coined (Williams, 1986), meaning pre-identified Phanerozoic.

Samples of cuttings or core of Cambrian, PIP or Proterozoic strata from seventeen exploration wells in the District of Mackenzie, Northwest Territories (Figure 1), have been analyzed for thermal maturity and petroleum source potential using a Rock- Eval/TOC pyrolysis apparatus (Espitalié et al, 1977; Espitalié et al, 1985; Peters, 1986). Approximately 100 mg aliquots of either washed cuttings samples or pulverized core (where available) were analyzed and the results have been listed in Table I along with a brief description of the lithology and interpreted age. Depths have been recorded in feet because the wells were drilled and logged in those units.

Samples from at least two of the wells (Lac Tache C-35 and Tedji Lake K-24) were heavily contaminated with lost circulation material including plastic, wood fibre and other unidentified organic particles. Even after thorough hand washing and flotation, some of the contaminants remained. As a result, the analytical results were not reproducible and do not represent the true organic carbon content and hydrocarbon potential of the sections from which they were recovered.

Samples from other wells were also contaminated to a lesser extent, but the washing procedure was adequate to remove essentially all of the foreign matter. Results for these wells (for example, Caribou N-25, and Iroquois D-40) were quite reproducible, although the Tmax results may indicate the presence of small amounts of organic contamination in some of the samples.

Results

With very few exceptions, all of the samples were found to have very low TOC (total organic carbon) content, that is, less than 0.4% TOC. A few samples exceeded this value but, except for the contaminated wells, the measured TOC was always less than 1.5%. Commensurate with the low TOC, the source potential also tended to be uniformly low, with a few Precambrian aged samples from the Belot Hills M-63 well (3860-4210') indicating a small residual potential and TOC contents between 0.75 and 1.40%.

The quantity of pyrolyzable hydrocarbons (S2 peak) was usually so low that the determination of thermal maturation using the maximum temperature of S2 evolution (Tmax) was unreliable or completely unusable. The few values of Tmax which may truly indicate the level of thermal maturation fell into the 460°C to 470°C range, corresponding to fully mature to overmature and indicating that, although some potential for natural gas generation may still remain in these samples, they are currently beyond the oil generation and preservation stages. So few of the samples yielded reliable Tmax results that no general trends in thermal maturation may be discerned from these data. In general, the Production Index [S1/(S1+S2)] or Transformation Ratios were very high. This may reflect levels of thermal maturity which are beyond the oil window and into the gas generation phase. Alternatively, the PI may be specious due to the very low overall concentration of hydrocarbons in the samples and the presence of organic contaminants including wood and plastic, both of which tend to yield large amounts of hydrocarbon in the S1 peak.

Arrowhead I-46 (core:7108-7420′/2166.5-2262 m)

PIP rocks (pre-Devonian) in this well consist of a distinctive green shale or mudstone; it is variably siliceous, occasionally resembling a chert.

A single sample from this interval (7268′/2215m) contained slightly more TOC (0.20%) than all the other samples which yielded the minimum detectable TOC content (0.01%). The pyrolyzable hydrocarbon content (S2) of 0.13 mg/g of rock may have been sufficient to enable the determination of the only useful Tmax value in this well which was measured at 463°C, that is at the end of the oil window and into the gas generation phase.

Belot Hills M-63 (cuttings: 3460-4210′/1055-1283 m)

In this well the top of the Proterozoic is at 3485′ (1062 m). Samples from 3460′ to 3480′ (1055-1061 m) are of the basal Cambrian Old Fort Island sandstone (the gas reservoir in Tedji Lake K-24). The Proterozoic section in this well consists of an upper dolomite (3485′-3850′/1062-1173 m) and a lower shale (3850′/1173 m to T.D. at 4211′/1283.5 m).

Exceedingly low TOC and S2 values for the dolomitic portion of the Proterozoic precluded the determination of useful Tmax results. Many of the Proterozoic shale samples, however, did contain significant amounts of both organic carbon and pyrolyzable organic matter. The observed Tmax values fell into the 460 to 483°C range, indicating that the level of maturity was beyond the oil window and into the gas generation phase. Several of the S2 peaks exceeded 1mg/g of rock, indicating the presence of at least some residual generative potential.

The sample from 4210′ (1283 m) also had interesting levels of both TOC and pyrolyzable hydrocarbons, but the Tmax value of 385°C indicates the presence of immature material, likely drilling additives or contamination introduced from the sample bag. Microscopic examination of samples immediately above this interval showed no obvious contamination, and the Tmax values above 460°C are too high to have been derived from sawdust or plastic drilling fluid additive contamination.

Blackwater Lake G-52 (cuttings: 5990-6480'/1826-1975 m)

In this well the Cambrian/PIP contact is tentatively placed at 6146' (1873 m). Thus the sample from 5990' (1826 m) has been interpreted as Cambrian, while those from 6150' to 6480' are PIP rocks. All the samples from this well were either fine grained clastics or dolomite.

The TOC contents of all samples from this well are 0.12% or less and thus have no source potential. The level of thermal maturation of these samples cannot be interpreted from the Rock- Eval pyrolysis data. All but one of the Tmax values fell below 400°C, indicating the presence of small amounts of contamination in the samples. The high Production Index [S1/(S1 + S2)] values also suggest that the pyrolyzable hydrocarbons that are observed in samples from this well are not due to syngenetic organic matter.

Caribou N-25 (cuttings: 11,240-11800'/3426-3597 m)

The two uppermost samples from this well (11,240' and 11,260') were Cambrian-Devonian dolomite, while the deeper samples were siltstone and shale of uncertain age, as discussed later.

The TOC content of samples from this well range up to 0.34%, but more than half of them contain less than 0.10%. The pyrolyzable hydrocarbon content of two samples (11,400' and 11,600'/3475 and 3536 m) was substantially above the other samples and may indicate the presence of some petroleum source potential, albeit slight. Twelve of the samples from this well were observed to have Tmax values in the 433 to 442°C range, indicating that this section has not been thermally altered much beyond the beginning of the oil window. The yield of pyrolyzable organic matter for many of these samples was determined as zero, however, indicating that the Tmax results may not be reliable (see discussion).

Cartridge F-72 (core: 2082'-2094'/635-638 m)

All of the samples from this well were PIP sandstones or finer grained clastics generally interpreted as being Proterozoic.

Only one TOC value (2082') was measured at greater than 0.01%, and that value of 0.03% cannot be considered as significant. The S2 concentrations were all very low (<0.30mg/g rock) and thus the Tmax values, which suggest a very high level of thermal maturity for the indigenous organic matter (518°C at 2082'/635 m, 463°C at 2088'/636 m, and 475°C at 2094'/1638 m), are probably not very reliable.

Cli Lake K-54 (core: 8712'-8714'/2655-2656 m)

Only two samples of PIP quartzitic sandstone were analyzed for the Cli Lake well.

The TOC and S2 yields were 0.01% and .01mg/g, respectively, and the measured Tmax values of 255°C are theoretically impossible because the pyrolysis oven is never less than 300°C during the analysis. It must be concluded that these samples contain essentially no organic carbon, have no petroleum source potential, and cannot be used to interpret the level of thermal alteration on the basis of organic parameters.

Goodhope A-40 (cuttings: 4930'-5220'/1503-1591 m)

Three sandstone samples (4930'-5060'/1503-1542 m) at the top of the analyzed interval in this well were from the Old Fort Island Formation of Cambrian age. From 5070' to 5220' (1545 to 1591 m), the samples were Proterozoic dolomite.

The TOC contents are quite low, with all but the first sample falling below 0.10%. The Tmax values were all below 409°C, and thus the observed pyrolyzable hydrocarbon yields have been interpreted as having been derived from traces of low maturity contamination of the cuttings. The relatively high S3 or organic carbon dioxide content of many of these samples may have been derived from the suspected contaminants, or, alternatively, may reflect a small amount of carbonate decomposition at temperatures below the 390°C cutout that was set on the instrument during analysis.

Harris River A-31 (core: 2402'-2407'/732-734 m)

Three core samples from this well were of PIP sandstone.

Although the TOC contents of these samples were very low (0.01%,0.02% and 0.06%), the pyrolyzable hydrocarbon contents (S2) were small but higher than anticipated for the measured TOC. An additional aliquot of the powdered core sample was analyzed using a LECO WR-12 carbon analyzer, which operates using pure oxygen at much higher temperatures than the Rock-Eval oxidation oven. The LECO results (0.11%,0.12%, and 0.18%) and very high Tmax values of the Rock-Eval indicate that these samples are at very high levels of thermal maturity, and that the the residual carbon in the samples was refractory and thus incompletely burned under the oxidation conditions of the Rock-Eval.

The relatively high S1 peak for the sample from 2407' (734 m) indicates the presence of volatile hydrocarbons, and this is inconsistent with the inferred level of thermal maturity and interpreted refractory nature of the kerogen. Contamination of the core by volatile hydrocarbons during storage is a possibility, but no evidence for this occurrence was observed during sampling.

Iroquois D-40 (cuttings: 7050'-8210'/2149-2502 m)

This entire interval consists of Proterozoic shale and siltstone.

Only two of the TOC contents exceeded 0.20%, and all of the S2 hydrocarbon yields are fairly low. The Tmax values are also low, indicating that much of the organic matter present in these samples has been derived from drilling fluid additives such as sawdust or walnut shells.

Iroquois I-11 (cuttings: 6440'-6950'1963-2118 m)

Proterozoic dolomite comprises the entire sampled section in this well.

The organic carbon and pyrolyzable carbon contents of all the samples from this well are very low, as are the measured Tmax values, many of which fall below the operational minimum value of 300°C. The organic content has been interpreted as too low to permit any reliable interpretation of the Rock-Eval pyrolysis parameters.

Lac Tache C-35 (cuttings: 1110'-1640'/338-500 m)

Samples from 1110' to 1340' (338-408 m), inclusive, are Mt. Kindle (Ordovician) dolomite; those below 1420' (433 m) are PIP sandstone.

Samples from this well are characterized by high TOC contents (up to 2.67%) and high to very high S2 yields (up to 6.82 mg/g rock). As noted above however, these samples were heavily contaminated and microscopic examination after washing indicated the presence of particles of woody and fibrous material.

Root River I-60 (core: 7680'-8471'/2341-2582 m)

Samples from this well were all PIP red shale.

The TOC content of the samples from this well were very low, and the pyrolyzable hydrocarbon content (S2) essentially zero. No information concerning the thermal maturity was available from the Tmax values because of the low S2 yields.

Sibbeston Lake G-24 (cuttings:2530'-3410'/771-1039 m)

The PIP rocks in this well consisted of sandstone and green shale.

The TOC contents were 0.03% or less for all of the samples, and the S2 yields were very small. The Tmax results are scattered over a wide range and essentially uninterpretable because of the low low yield of pyrolyzable organic matter.

Stopover K-44 (cuttings: 2870'-3080'/875-939 m)

All of the samples from this well are from a Proterozoic dolomite section with essentially no pyrolyzable organic matter and very low TOC contents (0.10% or less). The relatively high S3 peaks (organic carbon dioxide) probably reflect a small amount of dolomite degradation during pyrolysis.

Tedji Lake K-24 (cuttings: 3700'-3976'/1128-1212 m)

The uppermost two samples (3700' and 3750'/1128 and 1143 m) are Cambrian aged Old Fort Island sandstone, while samples from below this depth are fine clastics of Proterozoic age.

A few of the samples from this well contained appreciable amounts of organic carbon and pyrolyzable organic matter (for example, 3750' (1143 m) contains 0.81% TOC and 0.77mg/g rock S2 yield; 3920' (1195 m) contains 0.36% TOC and 0.40mg/g rock S2 yield), but the low Tmax values suggest that all of these samples have been contaminated to some extent by drilling fluid additives that were not completely removed during washing.

W. Whitefish River H-34 (cuttings: 5400'-5430'/1646-1655 m)

The samples from 5400' and 5410' (1646 and 1649 m) are Cambrian sandstone while the samples from 5420' and 5430' (1652 and 1655 m) are PIP dolomite.

While the TOC and S2 yields are low, $\leq 0.21\%$ and <0.20mg/g rock, respectively, three of the four measured Tmax values fall between 438 and 441°C. Only one of

the Production Index values is high enough to suggest that these results are due to contamination. If these maturation data are valid, then this section must be interpreted as being at a level of thermal maturation near the beginning of the oil generation window.

Willow Lake H-10 (cuttings: 2760'-3140'/841-957 m)

The sampled interval in this well is represented by fine grained PIP clastics (siltstone and shale).

The TOC contents of samples from this well were all below 0.30% but four of the seven samples yielded more than 0.15% TOC and contained sufficient pyrolyzable organic matter (0.25 to 0.62 mg/g rock) to yield reasonably reliable Tmax values which fell into the 414 to 442°C range. While the Tmax results indicate moderate levels of thermal maturity, the high S1 yields and hence high Production Index [S1/(S1 + S2)] values suggest that much of the TOC and S2 yields may have been derived from drilling fluid contaminants and thus that the thermal maturity values interpreted from the Tmax are not highly credible.

Discussion

The extensive attribution of contamination to the analytical results in this study stems from the generally low concentration of both organic carbon and pyrolyzable material in the samples. As a result, very small amounts of wood, plastic or other organic additives which are residual in the samples would be expected to have a major impact on the measured pyrolysis parameters. Similarly, small amounts of caved material from shallower, organic-rich strata could essentially control the parameters measured in organically-lean samples.

Probably the most significant result of this survey is the indication that a Proterozoic shale section has been found to contain up to 1.4% organic carbon at a maturity level beyond the oil window but within the gas generation phase. This shale occurs between 3850' (1173m) and Total Depth of 4211' (1284m) in Mobil Belot Hills M-63 (~67°N, 126°30'W, Figure 1). The shale is hard, black, grey or greenish, slightly dolomitic, contains very fine grained pyrite and traces of other sulfides. This shale has been correlated (Aitken and Pugh, 1984) with unit P1 of the Shaler Group outcrops of the Brock Inlier (Cook and Aitken, 1969). If this correlation is correct, the Belot M-63 shale at T.D. lies above, but probably not far above the Coppermine River basalts (see correlation chart in Williams, 1986).

Belot Hills M-63 is one of several wells drilled in the Colville Hills area in search of Cambrian gas. There are two successful wells to date: Ashland Tedji Lake K-24 (~67°45'N, 126°50'W) and PCI et al Tweed Lake M-47 (~66°55'N, 125°54'W, figure 1). The source of the gas, it has usually been assumed, is from Cambrian shale. However, it has long been recognized that Proterozoic sediments may also contain source beds. While our results tend to confirm a Proterozoic potential, it must be stressed that the analyzed materials were sample cuttings, not core, and therefore undoubtedly contain some caved Cambrian shale. Until core of this horizon is available and tested, a Proterozoic source for Cambrian gas can be said to be probable but not proven.

Other wells pertinent to the Cambrian gas play are A-40, K-44, K- 24 and H-34. Of these, only the results from H-34 may be valid (that is, not due to

contaminants); the Cambrian/PIP contact in this well may lie near the top of the oil window.

PIP rock samples from the southern wells generally contained too little organic carbon to yield information on thermal maturity. The lack of carbon is not surprising as the dominant lithology is a mature siliceous sandstone. The PIP mudrocks in I-46 (~60°45′N, 122°22′W) indicate a maturity beyond the oil window but still within the gas generation phase; this result is in keeping with what is known of the maturity level of Middle Devonian rocks in this area (Macqueen and Powell, 1983; Gunther and Meijer-Drees, 1977).

Caribou N-25, located on the east flank of the Richardson anticlinorium (Figure 1), spuds in the Imperial Formation; other markers (after GKW) are: Road River Formation (Devonian and older), 5212′ (1589 m); undivided Cambrian-Devonian dolomite, 9220′ (2810 m); Slats Creek Formation (Cambrian siltstone and shale), 11,264′ (3433 m); T.D. 11,812′ (3600 m). According to Pugh (1983) the section below 11,264′ is a Proterozoic orthoquartzite. As noted previously, several samples from this lowest interval indicated a low thermal maturity, near the top of the oil window. There is good reason to doubt the validity of these analyses. The present day bottom hole temperature is about 100°C. Also, in the general vicinity of this well, the Upper Devonian-Mississippian Imperial Formation shows maturation levels within and beyond the oil window (see well report, Shell Peel River H-37; see also discussion of outcrops in A.W. Norris, 1985, p.35).

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Table I. Rock-Eval Pyrolysis Results

Imp Sun Arrowhead I-46 (core) 60° 46'N 122° 23'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
7108	.01	301	.00	.01	.07	fine clastics	PIP
7261	.01	503	.03	.03	.01		
7268	.20	463	.10	.13	.02		
7293	.01	321	.01	.00	.03		
7391	.01	382	.03	.02	.02		
7397	.01	363	.03	.01	.01		
7406	.01	395	.01	.02	.03		
7420	.01	380	.12	.07	.20		

Mobil Belot Hills M-63 (cuttings) 67° 02'N 126° 27'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
3460	.20	371	.94	.55	.13	sandstone	Cambrian
3480	.18	380	.92	.43	.16		
3500	.02	301	.22	.04	.09	dolomite	Proterozoic
3540	.01	277	.08	.00	.07		
3580	.01	301	.07	.00	.02		
3630	.01	338	.09	.02	.04		
3680	.01	225	.07	.00	.01		
3720	.03	419	.05	.00	.07		
3770	.01	255	.06	.00	.03		
3820	.01	326	.02	.00	.04		
3860	.22	483	.26	.21	.06	shale	
3890	.74	460	.67	1.14	.03		
3950	.06	301	.06	.00	.01		
3990	.10	504	.10	.15	.11		
4030	.10	372	.06	.03	.05		
4070	.83	468	.37	1.00	.05		
4120	1.40	466	.90	1.72	.01		
4160	1.24	468	.63	1.49	.05		
4190	.48	465	.25	.44	.06		
4210	.74	385	1.45	1.87	.13		

Shell Blackwater Lake G-52 (cuttings) 64° 01'N 122° 55'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
5990	.01	301	.17	.07	.08	dol, f clastics	Cambrian
6150	.06	387	.38	.17	.06		PIP
6170	.02	301	.22	.06	.04		
6230	.04	304	.40	.12	.08		
6250	.05	380	.41	.19	.06		
6270	.12	423	.34	.24	.10		
6320	.09	384	.34	.16	.09		

6330	.05	351	.41	.23	.15
6340	.10	350	.46	.27	.14
6360	.05	365	.33	.16	.09
6370	.05	355	.37	.16	.07
6390	.10	363	.71	.35	.13
6400	.03	365	.34	.15	.06
6410	.06	352	.56	.23	.12
6420	.03	348	.31	.08	.10
6440	.06	353	.56	.18	.15
6450	.03	362	.30	.12	.22
6460	.04	351	.37	.13	.08
6470	.06	366	.58	.18	.13
6480	.03	376	.23	.08	.11

Gulf Mobil Caribou N-25 (cuttings) 66° 15'N 134° 50'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
11240	.01	417	.00	.01	.04	dolomite	Cambrian
11260	.20	436	.03	.18	.04		
11280	.25	226	.03	.00	.11	siltst, shale	Cambrian
11290	.24	271	.07	.00	.08		(Slats)
11300	.11	415	.02	.00	.12		
11320	.20	436	.03	.09	.11		
11340	.17	437	.02	.00	.16		
11360	.12	440	.01	.00	.10		
11390	.09	439	.04	.00	.07		
11400	.34	437	.29	1.46	.10		
11440	.12	437	.03	.11	.08		
11480	.24	353	.26	.14	.05		
11510	.03	438	.01	.01	.06		
11550	.06	442	.03	.00	.07		
11600	.13	438	.10	.65	.04		
11620	.06	411	.03	.22	.05		
11650	.09	297	.06	.01	.04		
11690	.01	301	.01	.00	.01		
11700	.01	358	.01	.00	.01		
11720	.04	394	.01	.00	.03		
11740	.03	223	.00	.01	.01		
11760	.04	261	.04	.00	.05		
11780	.05	435	.03	.00	.02		
11790	.11	433	.07	.38	.06		
11800	.02	387	.01	.00	.05		

Imp Cartridge F-72 (core) 63° 11'N 120° 29'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
2082	.03	518	.10	.30	.08	SS, f clastics	PIP
2088	.01	463	.07	.06	.18		
2090	.01	323	.02	.00	.23		
2093	.01	301	.01	.00	.07		

2094	.01	475	.01	.01	.03		

Gulf Amerada Cli Lake K-54 (core) 62° 03'N 123° 10'W

Depth	TOC	Tmax	87 S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
8712	.01	255	.00	.01	.03	SS, quartzite	PIP
8714	.01	255	.00	.01	.07		

Union Goodhope A-40 (cuttings) 66° 20'N 124° 35'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
4930	.26	391	.66	.97	.44	sandstone	Cambrian
4980	.03	378	.03	.04	.42		(Old Fort I.)
5060	.01	379	.03	.03	.22		
5070	.04	403	.10	.10	.30	dolomite	PIP
5090	.11	378	.22	.37	.26		
5100	.04	375	.04	.06	.26		
5110	.04	377	.08	.11	.26		
5120	.09	380	.19	.36	.22		
5130	.05	391	.06	.14	.24		
5140	.05	409	.04	.10	.42		
5150	.02	362	.04	.06	.24		
5160	.01	370	.05	.05	.17		
5170	.06	369	.13	.18	.09		
5220	.01	378	.05	.07	.29		

Chevron Harris River A-31 (core) 62° 30'N 120° 06'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
2402	.01	548	.05	.13	.01	sandstone	PIP
2405	.02	538	.09	.18	.01		
2407	.06	587	.52	.31	.04		

Mobil Iroquois D-40 (cuttings) 67° 29'N 129° 52'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
7050	.30	385	.86	.41	.33	shale, siltstone	Proterozoic
7080	.12	365	.17	.04	.21		
7110	.10	358	.14	.04	.34		
7180	.09	314	.11	.02	.31		
7290	.13	301	.09	.03	.49		
7310	.09	267	.07	.01	.14		
7350	.10	370	.09	.06	.27		
7370	.11	385	.22	.08	.20		
7470	.11	368	.14	.09	.10		
7520	.31	384	.50	.31	.21		

7590	.17	425	.05	.07	.26
7690	.08	292	.08	.04	.18
7760	.08	401	.08	.12	.13
7820	.08	407	.08	.07	.16
7890	.17	417	.15	.37	.81
7910	.03	301	.07	.01	.18
7980	.13	409	.14	.41	.35
8030	.06	398	.14	.12	.01
8060	.06	356	.23	.26	.17
8120	.17	346	.35	.38	1.15
8150	.03	352	.10	.12	.08
8210	.04	355	.19	.18	.03

Candel Iroquois I-11 (cuttings) 67° 40'N 129° 32'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
6440	.07	342	.14	.07	.07	dolomite	Proterozoic
6480	.22	257	.08	.01	.17		
6520	.08	283	.06	.02	.19		
6580	.05	256	.04	.00	.12		
6660	.11	256	.08	.00	.03		
6700	.15	303	.03	.02	.14		
6750	.07	398	.28	13	.19		
6790	.06	407	.33	.10	.09		
6820	.06	375	.14	.07	.38		
6880	.01	262	.00	.01	.06		
6920	.01	294	.15	.02	.09		
6950	.12	386	.28	.18	.37		

Imp Lac Tache C-35 (cuttings) 63° 44'N 120° 36'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
1110	.74	430	.36	.14	.21	dolomite	Ordovician
1150	.88	427	.79	1.50	1.57		(Mt. Kindle)
1300	1.68	434	1.87	1.93	.67		
1340	.36	429	1.68	.37	.38		
1420	.33	369	1.20	.20	.23	sandstone	PIP
1430	2.67	421	4.45	6.82	2.61		
1450	1.29	433	2.61	3.26	2.06		
1480	1.85	391	5.57	5.79	3.88		
1500	.54	343	1.27	1.20	1.85		
1540	.89	421	2.34	2.50	1.91		
1590	.55	436	3.36	.86	1.22		
1600	1.44	415	11.92	3.20	1.08		
1640	1.60	430	5.42	4.51	1.96		
1680	.17	392	1.14	.27	.62		
1690	.07	321	.68	.02	.37		
1716	3.99	318	20.13	5.03	8.03		

FPC Root River I-60 (core) 62° 39'N 123° 24'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
7680	.31	281	.00	.01	.83	red shale	PIP
7682	.01	303	.00	.01	.02		
7683	.01	305	.01	.00	.09		
7691	.01	303	.01	.00	.04		
8457	.01	305	.00	.01	.11		
8471	.01	469	.01	.02	.01		

Scurry et al Sibbeston Lake G-24 (cuttings) 61° 33'N 122 °34'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
2530	.01	317	.13	.01	.02	SS, green shale	PIP
2620	.01	359	.08	.00	.01		
2840	.01	353	.15	.06	.34		
2950	.02	414	.03	.31	.12		
3040	.03	381	.20	.21	.05		
3100	.02	314	.26	.03	.01		
3130	.01	510	.10	.08	.04		
3200	.01	469	.18	.06	.04		
3300	.01	451	.11	.06	.07		
3410	.02	412	.11	.22	.01		

Union Stopover K-44 (cuttings) 67 33'N 123 38'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
2870	.05	330	.00	.01	.95	dolomite	Proterozoic
2900	.05	214	.00	.01	.61		
2930	.05	257	.00	.01	.53		
2960	.08	243	.00	.01	.97		
2990	.10	254	.00	.01	.64		
3020	.07	215	.00	.01	.59		
3050	.06	274	.00	.01	.48		
3080	.09	438	.00	.01	.43		

Ashland Tedji Lake K-24 (cuttings) 67 44'N 126 50'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
3700	.31	450	.18	.49	.56	sandstone	Cambrian
3750	.81	381	1.32	.77	2.09		
3770	.10	409	.09	.06	.12	fine clastics	Proterozoic
3780	.15	415	.10	.13	.29		
3800	.10	487	.14	.19	.73		
3820	.22	371	.53	.35	1.54		
3840	.08	384	.09	.12	.35		
3860	.05	406	.03	.03	.13		

3880	.13	358	.27	.20	.95
3900	.11	361	.05	.05	.22
3920	.36	376	.41	.40	.90
3940	.09	342	.19	.11	.35
3960	.04	325	.07	.03	.14
3980	.20	421	.21	.16	.82

Arco W. Whitefish River H-34 (cuttings) 65° 33'N 124° 35'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
5400	.13	439	.09	.12	.20	sandstone	Cambrian
5410	.15	441	.05	.19	.05		
5420	.21	438	.24	.17	.13	dolomite	PIP
5430	.06	408	.05	.03	.12		

Husky et al Willow Lake H-10 (cuttings) 62° 49'N 121° 45'W

Depth	TOC	Tmax	S1	S2	S3	Lithology	Age
*****	*****	****	******	******	*****	*********	*******
2760	.25	424	.31	.26	.27	fine clastics	PIP
2770	.28	414	.39	.25	.38		
2880	.03	382	.14	.11	.16		
2950	.17	435	.25	.35	.13		
3000	.06	381	.10	.08	.12		
3040	.27	442	.44	.62	.09		
3140	.06	383	.26	.19	.35		

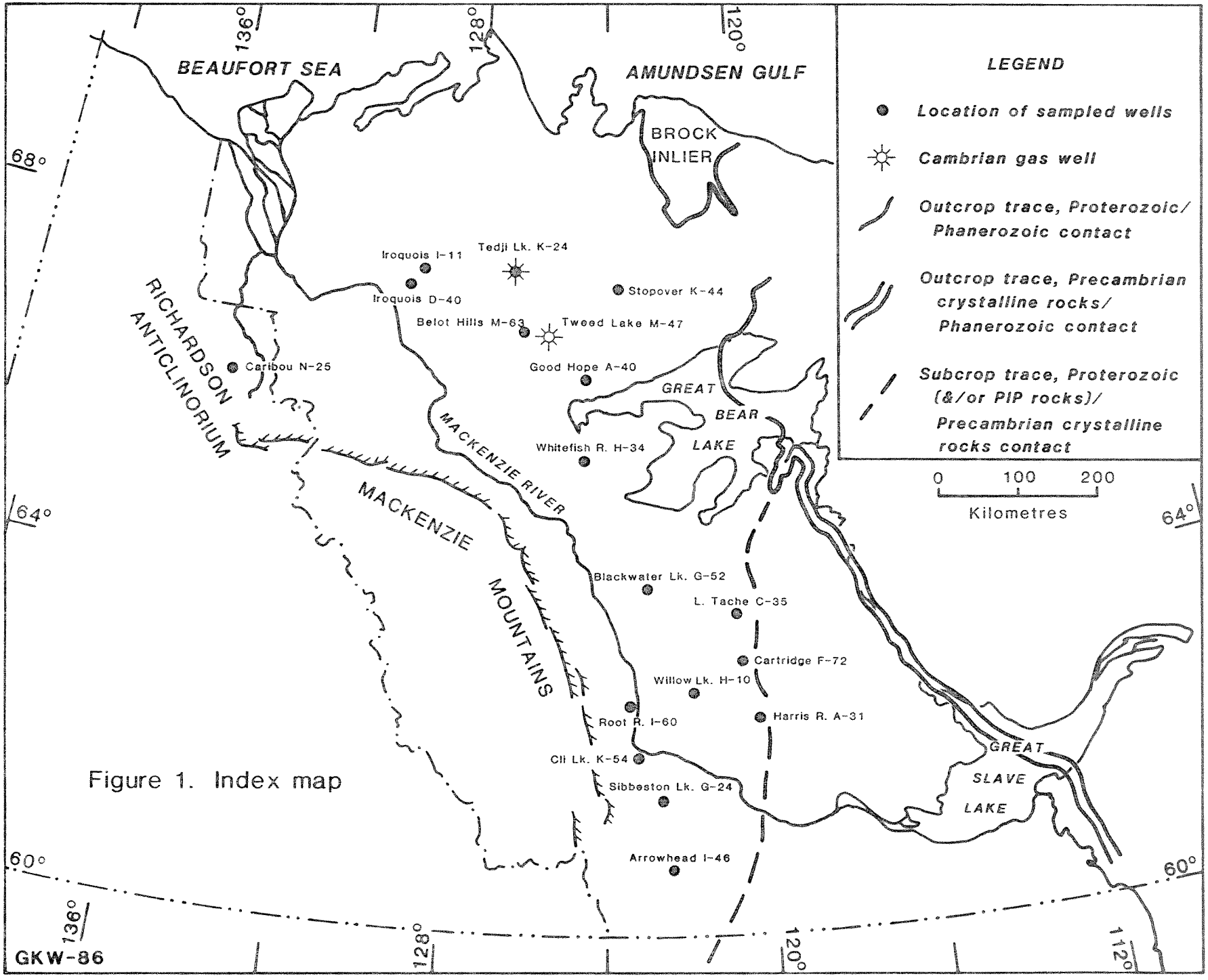

Figure 1. Index map