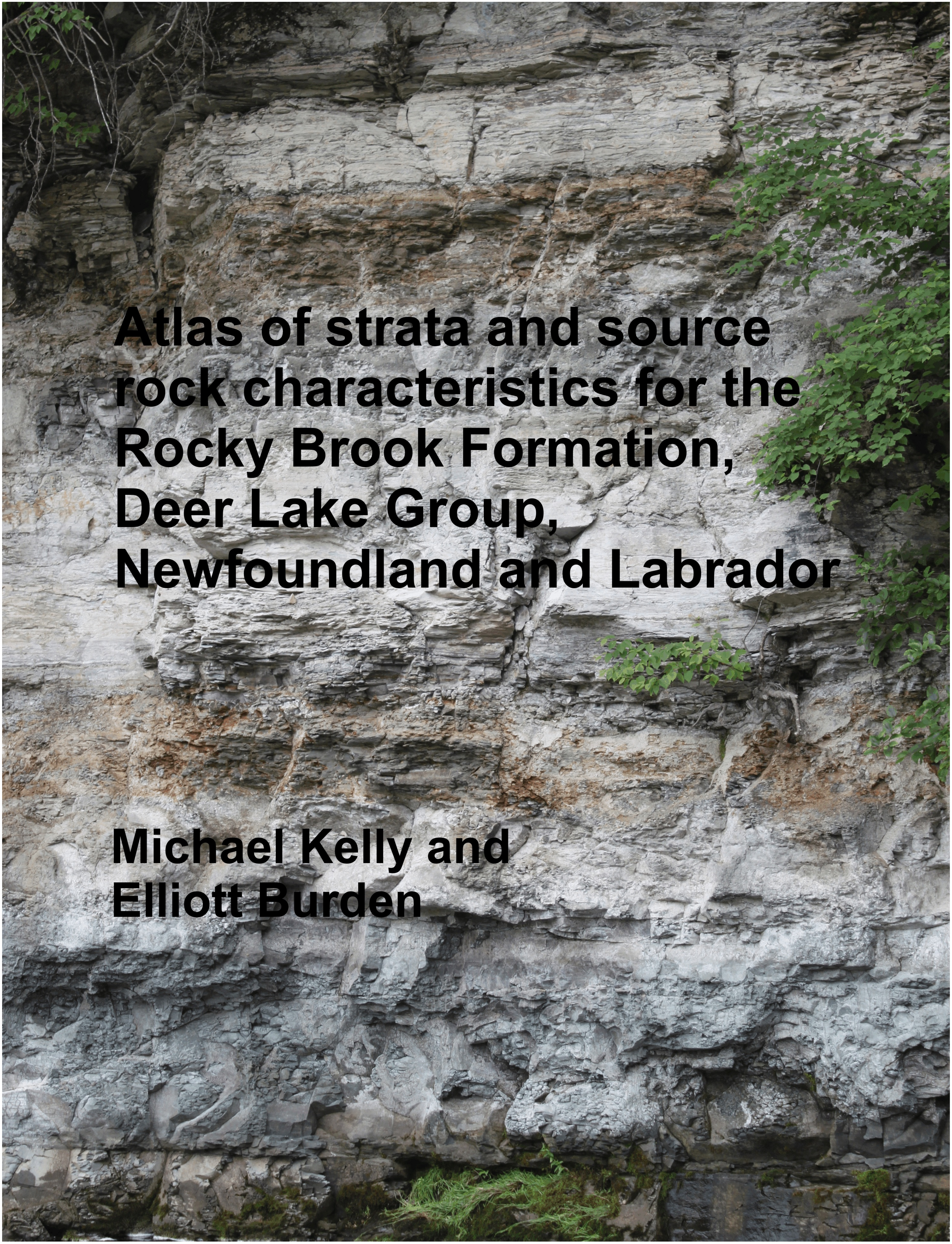

Atlas of strata and source rock characteristics for the Rocky Brook Formation, Deer Lake Group, Newfoundland and Labrador

Michael Kelly and Elliott Burden

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A Report Prepared for the
Province of Newfoundland and Labrador
Petroleum Exploration Enhancement Programme
(PEEP)

Executive Summary

The Rocky Brook Formation of the Deer Lake Group in the Deer Lake basin is thought to be one of the better petroleum source rocks in western Newfoundland. Late Mississippian in age and lacustrine in origin, the Deer Lake Basin is divided into two parts, the Humber Lateral Subbasin in the west and the Howley Lateral Subbasin in the east. Published reports indicate more than 10% TOC in some Type I and Type II source rocks discovered in outcrop and core. To better assess source rock distribution and to learn more about the basin origin and evolution, both key aspects for determining resource exploration strategies, an atlas of core stratigraphy and compilation of earlier reports is presented here.

Most of the physical work was conducted on cores 12H/06/0023, 12H/06/0025, 12H/06/0027, 12H/06/0031, 12H/06/0037, 12H/06/0038, 12H/06/0039, 12H/06/0043 and 12H/06/0045, all stored in the Newfoundland and Labrador Government core and sample library in Pasadena, NL. These cores represent a small part of the materials available from an extensive mineral exploration programme conducted across the entire Deer Lake Basin in the late 1970's. Three other cores, RB-06-130, RB-06-139 and RB-06-140 from the site of an ongoing Altius Minerals exploration project, and a few small outcrops on the Rocky Brook River were also examined.

For the 9 holes identified from government records, 7 cores, totaling 740 m have been photographed, examined for lithology and sedimentary structures and sampled for additional Rock-eval analyses. Two holes (12H/06/43 and 12H/06/45) are extremely deteriorated and no longer useful for detailed logging and analysis. In addition to core logging, government files containing publicly available information on drilling reports, geochemistry and radioactivity were reviewed, with industry core and sample data summarized. For the Altius cores, descriptions and Rock-eval analysis for recently drilled strata offers insight into colour change and degradation that can be expected after 30 or more years in storage.

The Rocky Brook Formation is formally divided into two members. The Squires Park Member is a predominantly greenish grey and dark grey siltstone and shale. Beneath, there lies the Spillway Member, a mix of greenish grey and dark grey siltstone and shale with thick bands of brownish red siltstone and thin bedded sandstone. Drilling reports detail five informal members, the upper grey beds (equivalent to the Squires Park Member), and the underlying brown beds, lower grey beds, mottled beds, and red beds (all equivalent to the Spillway Member).

In our work, the mottled beds and red beds cannot be readily differentiated. So too, when strata are correlated on the Squires Park-Spillway contact, the formation apparently resolve into three discrete cycles each about 150 m thick. In general, more organically enriched sediment, perhaps deposited under meromictic (and shallow?) lacustrine conditions, are separated by layers of somewhat more oxidized and silty strata, perhaps deposited in a polymictic (and deep?) lake. Within these thick cycles there are smaller and similarly constructed cycles generally less than 10 m thick. Conceptually, it is tempting to ascribe these cycles to worldwide orbitally forced glacial events, but neither the age nor the timing for tectonism are sufficiently resolved. By inference and comparison with other studies, thin cycles of alternating source rocks and lean rocks may correspond with half precession cycles approximately 10 ka duration and fit with changes in monsoonal activity identified in equatorial regions. The three thick cycles may be recording a tropical lacustrine record for Mississippian glacial-interglacial events. These sediments appear to represent fluctuating profundal environments in a lake where there is a balance between sediment and water input and tectonic subsidence.

In core, putative Rocky Brook source rocks are laminated and massive dark grey and greyish black shale with a Munsell colour index N4, N3, and N2. Published reports for Rock-eval analysis of samples from these dark beds correspond with organic values ranging from lean <1% to ~2% TOC for N4 shale and thin beds of N3 shale to ~2% to more than 8% TOC for thick N2 and N3 shale . Net to gross ratios for beds of the dark, slightly organic rich strata apparently varies systematically across the region from 0% on the northwestern margin of the basin to greater than 60% in short cores (~30 m long) from the "upper grey beds" in the northeast part of the basin. In total, the richest, thickest and probably most continuous source rocks are thought to occur in two distinctive bands, each probably less than 20 m thick and found in both the lower and the upper grey units. Internally, these bands are formed as relatively thin beds and with some thick beds separated by greenish grey siltstone. From core logs, this apparently covers an area of less than 200 km^2 and centred on the northeast side of this sub-basin. Additional beds may occur in the Howley Subbasin farther east.

Published reports on thermal maturation indicators (spores and vitrinite) show the Rocky Brook Formation of the Deer lake Sub-basin as immature to marginally mature strata (Ro ~0.4 - 0.7). If a search is to continue for a petroleum system involving Rocky Brook source rock, these beds should presently be buried more than 1.5 km. Farther east in the Howley Subbasin, Rocky Brook strata should be more deeply buried.

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Atlas of strata and source rock characteristics for the Rocky Brook Formation, Deer Lake Group, Newfoundland and Labrador

Michael Kelly and Elliott Burden

Introduction

The Deer Lake Basin in western Newfoundland (Figure 1) is a small, narrow, thickly forested, transtensional feature, approximately 100 km long by < 40 km wide. A product of Appalachian mountain building, the basin was formed and deformed during the Carboniferous Alleghenian Orogeny. Sedimentary fill consists of lacustrine, fluvial, and terrestrial strata that may be up to several thousand metres thick (Wright et al., 1996). All along the axis of this fault zone, rocks are exposed along rectilinear NW and NE trending valleys and on elevated ridges that apparently formed as flower structures (Hyde et al., 1988) with Riedel and en-echelon faults in the shear zones (Figure 2 and Appendix 1).

Historically, geological exploration has focused upon the discovery of Carboniferous coal, oil and gas, and uranium. For all of these commodities, organic

Figure 1: General location of the Deer Lake Sub-Basin.

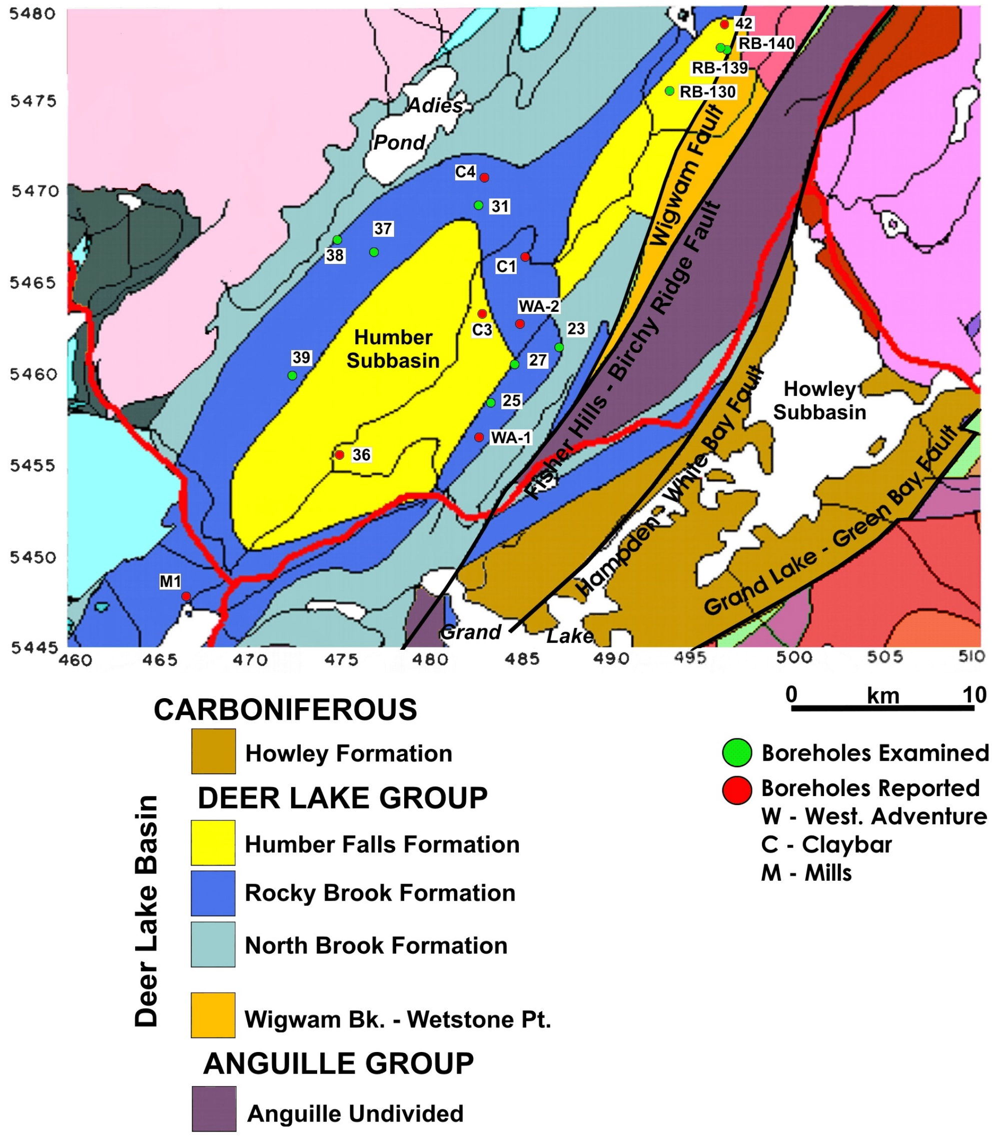


Figure 2: Geology map with UTM NAD27 co-ordinates of the central part of the Deer Lake Basin and showing Carboniferous strata. Map modified slightly from a Provincial Government Department of Natural Resources web site. Major faults, mineral and oil exploration drill holes described or discussed in the text are shown. Numbered green circles are mineral exploration holes drilled in the 1970's; recent Altius Minerals holes have a prefix RB. Red circles are a selection of historic and recent holes reported in this study. The Humber Lateral Subbasin (also sometimes called the Deer Lake Lateral Subbasin), centred upon the Humber Falls Formation, and the Howley Lateral Subbasin, centred upon Sandy Lake, are separated by major faults.

matter from plants and algae plays a significant role in generating fuel and mineral deposits (Batten, 1996; Robbins and Burden, 1996).

The Rocky Brook Formation, the focus for this report, is an organic and sometimes radioactive shale and sandstone succession (Hyde, 1982). Strata are thought to be excellent source rocks, for conventional gas trapped in adjacent sandstones, shale gas, shale oil, and oil shale production. In a practical sense, little is known of the physical distribution of the organic rich strata in the Deer Lake Basin. In particular, little has been said about sedimentary facies and environments controlling Rocky Brook sand/shale ratios and the net to gross volume for these rocks. These are important parameters for understanding whether there is an active petroleum system for conventional and unconventional hydrocarbon plays and in determining how organic matter affects the distribution of uranium mineralization.

To get a sense of the distribution and quality for source rock, 9 historic holes (12H/06/0023, 12H/06/0025, 12H/06/0027, 12H/06/0031, 12H/06/0037, 12H/06/0038, 12H/06/0039, 12H/06/43 and 12H/06/45) and three more recent holes (RB-130, RB-139 and RB-140) are examined for stratigraphy and sedimentology. In total, this amounts to about 1000 m of core, a small fraction of the many holes drilled in the 1970's when a major mineral exploration programme was completed. Stratigraphic coverage for this summary includes top and bottom contacts and 2 long cores covering the entire unit.

Most of the core examined was drilled more than 30 years ago; three other cores reported here come from an active exploration programme being conducted by Altius Minerals. Inasmuch as the older cores and accompanying completion reports are now properly stored at the Department of Natural Resources, A.K. Snelgrove Core Library in Pasadena, NL., and where a small layout facility exists, these rocks have in the past been less carefully protected. Cores from the ongoing Altius programme are in a small warehouse in the field. Completion reports for the Altius holes are not at this time in the public domain.

A significant body of literature is available in Open File reports available on-line from the Government of Newfoundland and Labrador. These show many more details for the Rocky Brook Formation; this includes many Rock-eval, gamma, organic and inorganic geochemistry analyses. For this study, an additional 15 samples (Appendix 2) were taken in cores where limited Rock-eval sampling has taken place and to provide duplicate analytical controls. These new Rock-eval analyses are not yet available.

For this report, Kelly completed core logging and photography and Burden and Kelly completed data analysis and synthesis.

Background

The Rocky Brook Formation is a lacustrine deposit straddling the Visean-Serpukhovian boundary (Figure 3) of the late Mississippian, approximately 326 Ma (Utting and Giles, 2008). As a part of the Deer Lake Group, these beds represent late stage thermal subsidence and sag in a mature strike-slip basin and following a Tournaisian and older episode of transtensional tectonism (Hyde et al., 1988). The thickness of Rocky Brook strata varies according to proximity to the erosional edge. In central areas, Wright et al. (1996) suggest it may reach up to 1000 m.

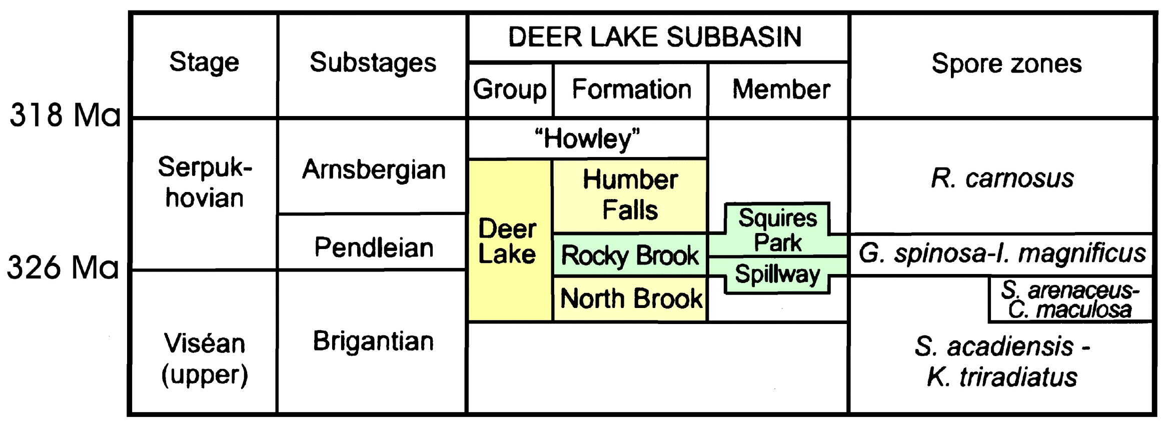


Figure 3: Lithostratigraphy and age relationships for upper Mississippian rocks of the Deer Lake Basin. Figure modified from Utting and Giles (2008).

The formation has two members, the Spillway Member in the lower part and the Squires Park Member in the upper part (Figure 4). The Spillway member is described as red calcareous siltstone and fine-grained sandstone, grey to green, calcareous to dolomitic siltstone and mudstone, grey calcareous dolostone and dolomitic limestone with minor oil shale (Hyde and Ware, 1981). The overlying Squires Park member is grey to green siltstone and mudstone, black mudstone, grey calcareous dolostone, dolomitic limestone, and dolomitic oil shale (Hyde and Ware, 1981). The formation conformably overlies Visean (Brigantian) North Brook Formation, with a gradational basal contact (Hyde and Ware, 1981). In the Humber Valley, where the holes examined for this study were drilled, it is overlain by Serpukhovian (Pendleian-Arnsbergian) Humber Falls

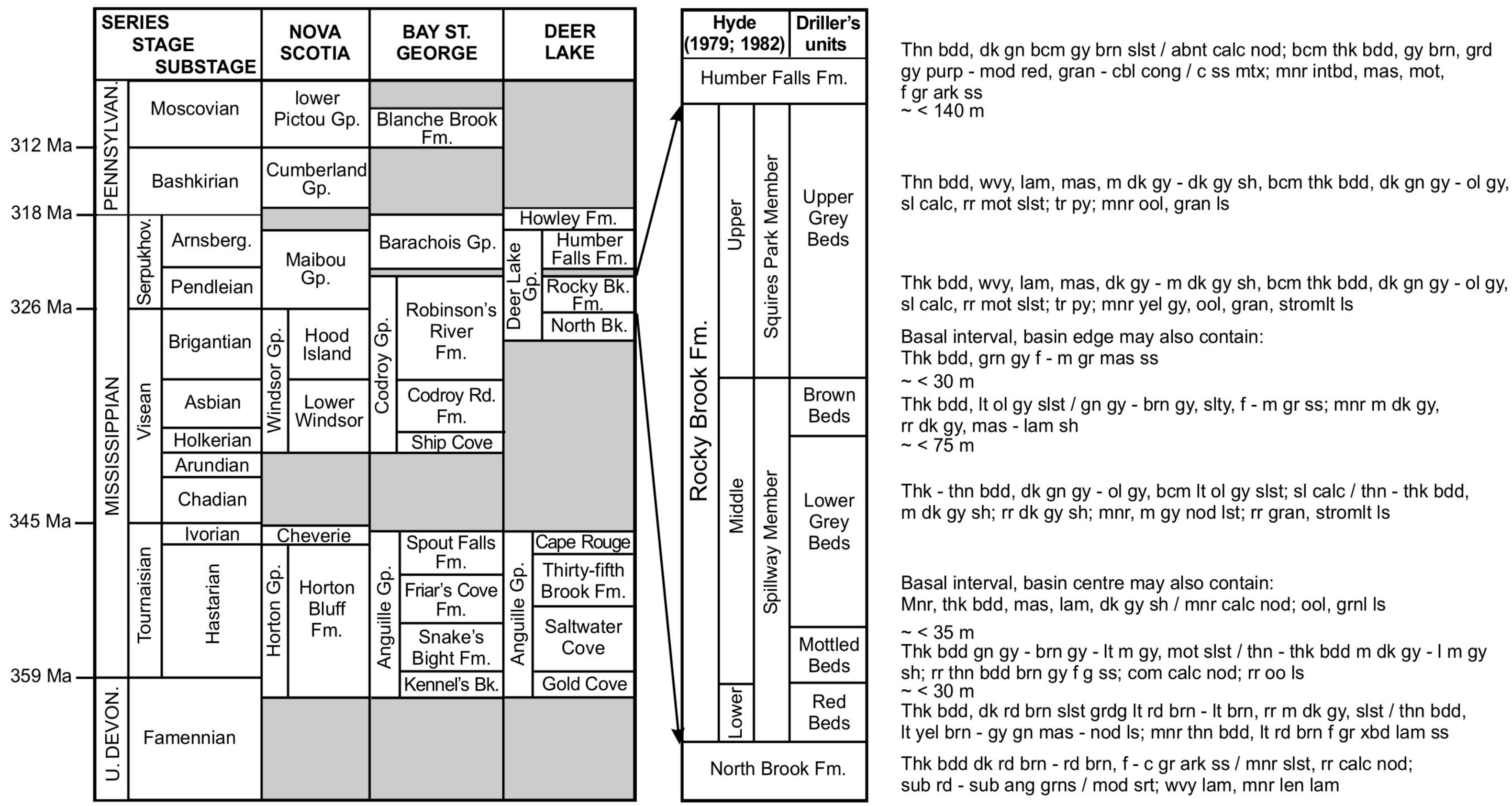


Figure 4: Carboniferous stratigraphy of Nova Scotia and Newfoundland with summary of strata and characteristics for the Deer Lake Group. Figure modelled after Hamblin et al. (1997) with age relationships after Utting and Giles (2008).

Formation (Utting and Giles, 2008). The upper contact with Humber Falls Formation is sharp and possibly disconformable (Hyde and Ware, 1981).

In earlier work, drilling records from exploration activities informally differentiated five units - Red Beds, Mottled Beds, Lower Grey Beds, Brown Beds and at the top, Upper Grey Beds. Hyde (1982) equates the Red Beds, Mottled Beds, Lower Grey Beds, and Brown Beds with the Spillway Member; the Upper Grey Beds are the Squires Park member. Hamblin et al (1997) suggest these coloured beds are to some extent traceable. As will be shown in this study, the Squires Park Member and the adjacent Brown Bed succession are distinct. Beneath this, additional successions of grey and red beds indicate a more complicated history of sedimentation for the Spillway Member. In addition, colour patterns determined with a Munsell Rock Color Chart do not necessarily support the choice for colours used by drillers for their informal stratigraphy. Many of the intervals are shades of grey, brown, green and yellow. They reflect oxidation states and sedimentary facies variations in a complex and evolving lacustrine system. For improved hydrocarbon prospectivity, the geology, structure and facies of this lacustrine system is an area that deserves a more thorough examination.

A significant body of organic and inorganic geochemical work is published (Hyde, 1984a; Gall and Hiscott, 1986; Kalkreuth and Macauley, 1989; Hyde et al., 1988; Hamblin et al., 1997). Hyde et al. (1988) compiled 100 clay mineral analyses for Anguille and Rocky Brook strata, showing Anguille rocks to be better organized more crystalline clays that have been significantly modified through diagenesis. In examining organic material, Kalkreuth and Macauley (1989) indicate the Rocky Brook Formation is dominated by fluorescent liptinite and specifically lamalginite and sporonite. In addition, the fluorescent spectra determined from microscopy of liptonite varies with the thermal maturation of strata. For Rocky Brook Formation Kalkreuth and Macauley (1989) show λ max (the wavelength for the brightest colour) values between 524 and 534 nm for the Squires Park Member and 556 to 642 nm for the Spillway Member. They report these values are very similar to numbers obtained for the immature to marginally mature (Tournaisian) Albert Formation in New Brunswick. For vitrinite, a common part of some samples, 4 separate analytical reports are available. Hyde et al. (1988) indicate vitrinite ranges between 0.59 and 1.07% Ro with a mean of 0.74% Ro. This places Rocky Brook strata well into the oil window. In contrast, Gall and Hiscott (1986), Kalkreuth and Macauley (1989) and Hamblin et al. (1995) show vitrinite between 0.35 and 0.74% Ro, indicating that Squires Park Member is at or above the top of the oil window and Spillway Member is in the oil window but not yet in the zone of peak production. TOC

% and Rock-Eval Analyses for organic enriched outcrop are reported in Hyde (1984a) and Kalkreuth and Macauley (1989). Within the interval they sampled, finely laminated "papery" shale source rocks are rich, immature, Type I kerogen with more massive beds (1 cm or greater) having little overall potential (Kalkreuth and Macauley, 1989). Hamblin et al. (1997) re-examined some outcrop material, logged cores, and completed a suite of detailed geochemical analyses, including GC-MS. With a larger spectrum of samples, a greater appreciation of the stratigraphy, chemistry and distribution of source rock has been determined. More than 60% of the 44 core analyses completed by Hamblin et al. (1995) show TOC values of less than 1% and "with little or no hydrocarbon potential". Nine samples of mudstone (20% of the analyses) have TOC values between 1 and 2%, with Hamblin et al. (1997) suggesting these may have some hydrocarbon-generating potential. Another 9 samples (20% of analyses) have TOC values greater than 2% and are excellent, albeit largely immature, Type II or Type I source rocks. These rich samples apparently occur as relatively thin horizons in both the upper grey and lower grey shale of the Squires Park and Spillway members. They are apparently unrelated to any of the gamma anomalies reported in mineral exploration surveys. Data from the Hamblin et al. (1997) report that are relevant to the cores examined in this study are reproduced in Appendix 3

The challenge identified from these studies lies with determining where thick beds of source rock are located and whether any of these rocks have entered the oil window. A better understanding of sedimentary rocks, facies and depositional environments is required if exploration is to advance in a meaningful way.

Core description method

The 9 holes slated for examination were selected on advice as the longest and best preserved examples of the Rocky Brook Formation housed at the Pasadena Core Repository. In the core lab in Pasadena, two of the holes (12H/06/43 and 12H/06/45) were dropped from the list because of they are extremely fragmented and weathered. For other holes, assessment files, and including drilling logs, were also obtained from the Pasadena Core Repository. These files form a very important source for information, and are extremely helpful, given that many cores are in a degraded state. Gamma ray logs for uranium exploration are also available for many holes. In our reporting here, we only identify locations where gamma radiation is more than 5-times higher than background (~30-60 cps). Other geochemical data shown on our logs and in Appendix 3 are taken from previous work by Hamblin et al. (1997).

There was also some minor fieldwork involved in the project. Some recently drilled core belonging to Altius Resources Inc. was examined and sampled over the course of three days. This core was in much better shape than the 30 year-old core from the library. It provided a better picture of the formation and some insight into the degradation that can occur in time as the organic rich mudstones dry.

For each of the cores described here, the government identification number or an Altius Minerals number is followed with UTM coordinates in NAD 27, Zone 21. This is followed with basic information on depth and azimuth, basic position within the basin and a photo illustration of the entire core. For our written description of the logs, stratigraphic units are described from the bottom up and summarized for basic source rock characteristics. In the graphical presentation, core depth in metres is noted on the left side of each log. Basically, each core is logged for standard properties, colour, lithology, mineralogy, contact relations, sedimentary features, fossils and structures.

The American/Canadian Stratigraphic Lithologic Symbols and Abbreviations chart provide the basis for symbols and short hand text used in these logs. Other symbols used for schematically illustrating sedimentary structures, bedding thickness and cyclical patterns for deposition were created by Burden (Figure 5). The abbreviations and numerical symbols used to describe different colours for sedimentary units are taken from the Geological Society of America, Munsell Color Chart (Anonymous, 1991).

Amongst these fundamental rock properties, colour is frequently cited as a basic guide for the presence of organic material. In particular, dark grey and black rocks are oftentimes considered to be organic rich. For this study, we too use colour as a proxy measure for organic content, and one that may be used as a basic indicator for prospectivity as a shale oil or gas play versus an oil shale development. Here, moderate dark grey rocks (N4) are lean source rocks and dark grey through black rocks (N3 and N2) represent rich source rocks. By measuring the thickness of specifically coloured dark beds, an indicator of source rock volume and distribution is determined.

As a basic measure of the reliability of this proxy colour index for source rock quality, our visual classification of rock colour is plotted against the analytical work of Hamblin et al (1997) to show general relationships (Figure 6). Fundamentally, all moderate dark grey rocks (N4) and all thin bedded dark grey rocks (N3) are lean source rocks with, typically, much less than 2% TOC. In contrast, all of the very dark grey or black shale (N2) and the thicker beds of dark grey shale (N3) contain more than 2% TOC. Within our measured sections, these very dark rocks are much less abundant.

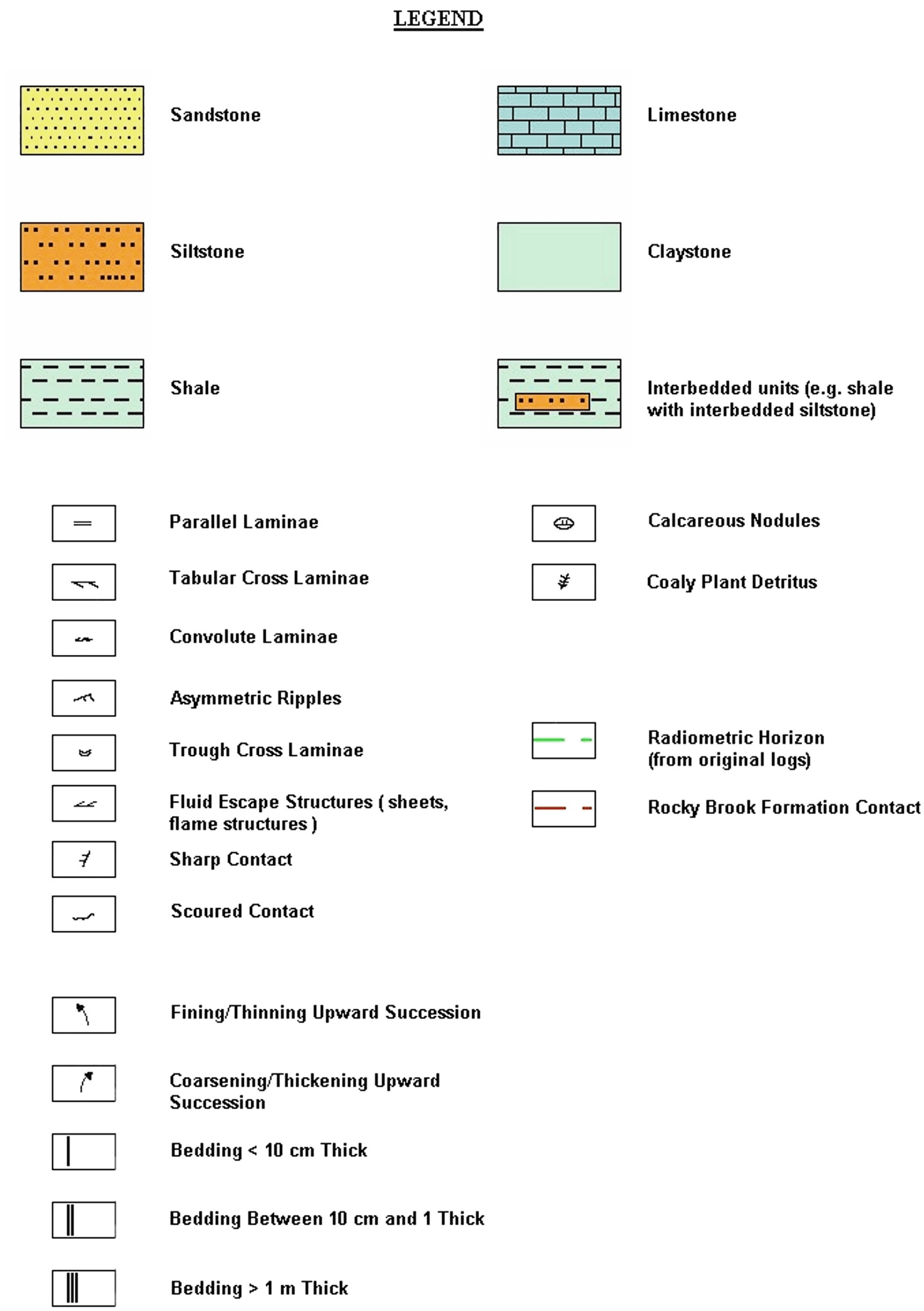


Figure 5: Legend used for core logs.

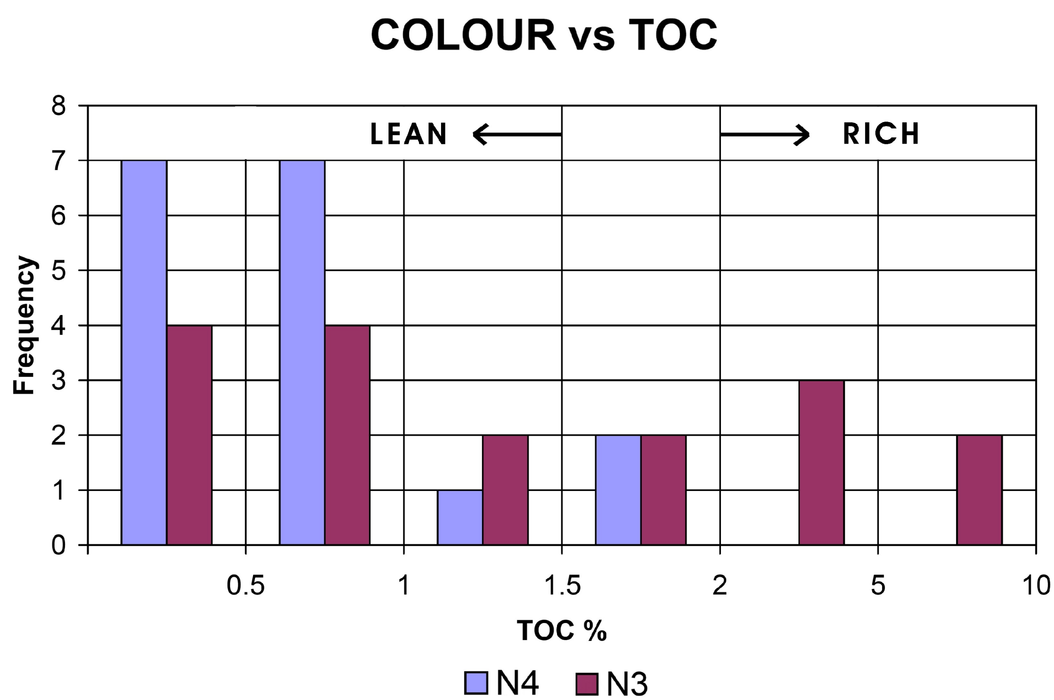


Figure 6: In a plot of 34 geochemical analyses produced by Hamblin et al (1997) and for some of the cores analysed in this investigation, moderate dark grey (N4) shale is always less than 2% TOC, with most samples falling below 1.5 % TOC. Hamblin et al. (1997) consider rocks with more than 2% TOC to be rich source rocks. Organic dark grey and black source rocks (N2 and N3) form a much smaller volume of rock in the Deer Lake Basin.

Acknowledgements

Original logs by J. O'Sullivan, M. Patterson, D. Cook and R. Parker, available as open file reports from the Government of Newfoundland and Labrador, Ministry of Natural Resources web site were instrumental in this project. Stewart Cochrane, Joe Carroll and Russell Bowers, the staff of the Newfoundland and Labrador Department of Mines and Energy, Core Library, Pasadena, NL. were very generous with their time and effort. Many thanks also to Dale O'Reilly and Altius Resources for their help.

Pasadena Core Library - selected core logs and descriptions

12H/06/0023
UTM: 487300 E 5461000 N

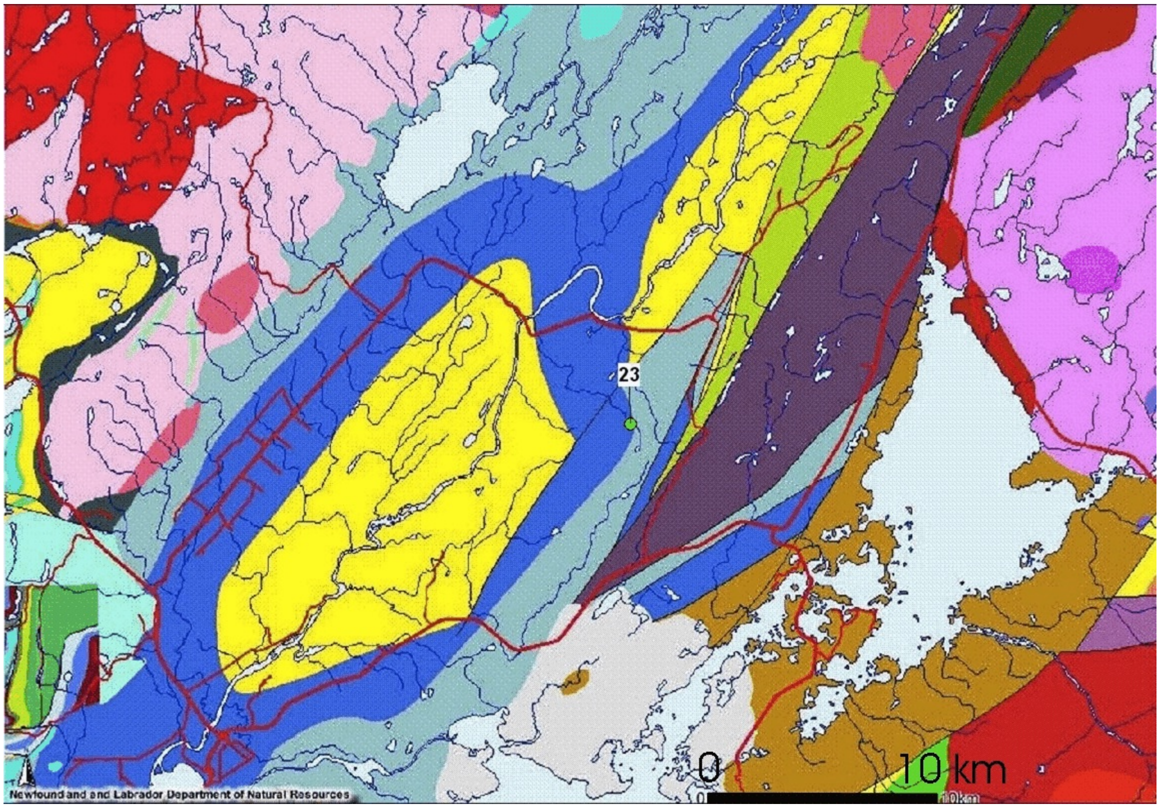


Figure 7: Location of drill-hole 0023 (taken from Newfoundland and Labrador Ministry of Natural Resources web site).

12H/06/0023
Azimuth/Dip: 000/90
Depth: 122.83 m

Hole 12H/06/0023, also known as Westfield Minerals Ltd. DDH 79-53, and GSC Locality C-231307 (Figure 7), is located on a flower structure west of the Fisher Hills - Birchy Ridge Fault Zone. The 122 m core from the Spillway Member consists of a broadly coarsening upward cycle, formed of smaller cycles of shale, or shale interlaminated with siltstone, siltstone, and fine-, medium-grain sandstone (Figure 8).

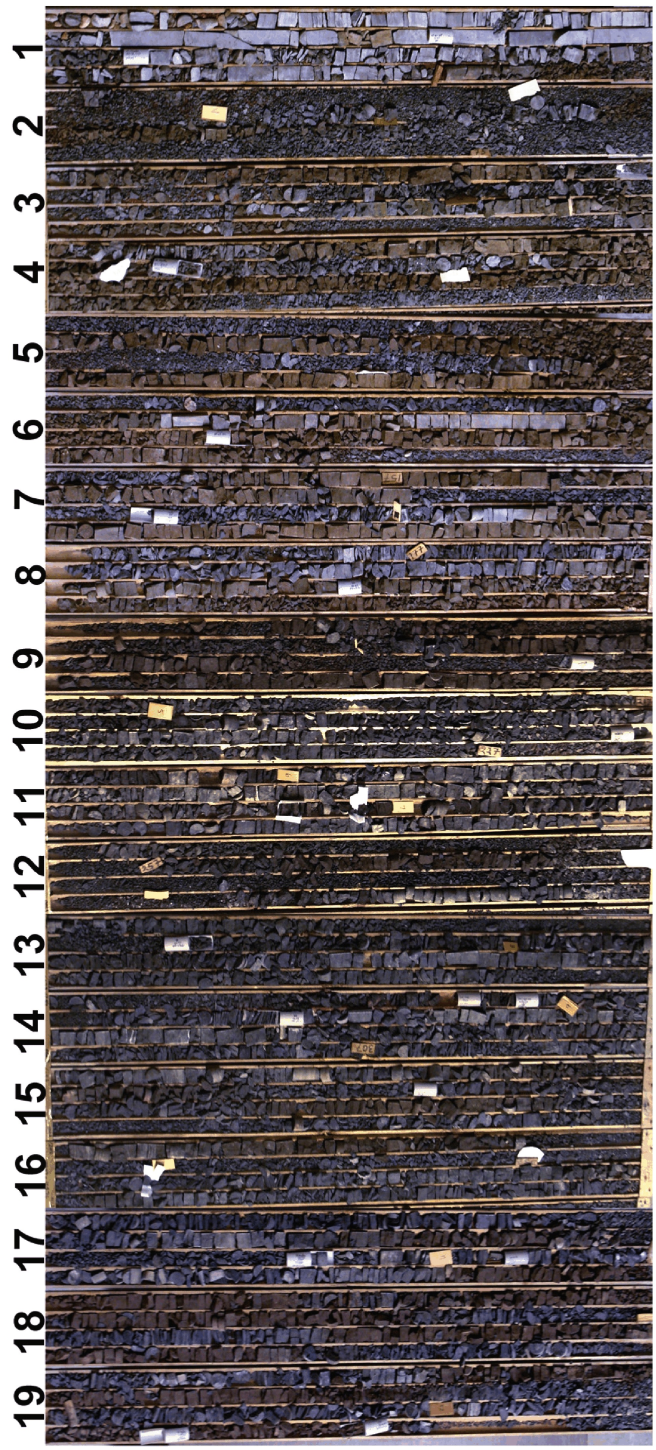


Figure 8: Core 0023 of the Spillway Member consists of 19 boxes of broken and rubbly shale, siltstone and sandstone with colours ranging from greenish grey and brown to yellow-brown and black. A detailed photographic log is contained in the Appendix 4.

Deposition is not always observed in that order.

Starting at the base of this core (Figure 9), the lower 10 m consists of interbeds medium and dark grey shale and medium grey through grey-brown siltstone in sharp contact with one another and gradually coarsening and thickening upward. Shale intervals range in thickness from 40 cm to 3.5 m; interbedded siltstone-shale beds are 1.1 to 2.3 m thick. Beds tend to be laminated over the entire interval in which they occur. Lamination may be planar parallel, or wavy parallel within the silt lenses.

The first thin dark green sandstone appears at 111 m. Between 111 m and 67.8 m there are 11 sharp based coarsening-upward successions, each 2 to 3 m thick and consisting of dark grey shale grading to dark grey-green and grey-brown calcareous siltstone with small calcareous nodules and capped with grey-green and dark green, mostly massive, fine-grained calcareous sandstone. Through this part of the succession there is a tendency for the siltstone beds to become thinner, whereas the dark shale intervals become thicker and pyritic. In addition, and between 85 and 74 m the dip for these sandstone and shale beds increases from 10º to about 30º, flattening again higher in the core.

The first shale-sandstone succession above 67.8 m contains calcareous nodules and the sandstone cap is calcareous, mottled - perhaps bioturbated, and a dark yellow-brown colour. Overlying strata to about 20 m are interbedded grey shale, with yellow, brown and red siltstone and sandstone. Coarsening-upward successions are 4 to 10 m thick, with the thickest sandstone beds located between 55 and 39 m. Mottled textures, wavy lamina, and tabular crossbeds are present in sandstones and siltstones. Internally, some sandstones are fining-upward successions of massive unstructured sandstone overlain by slightly finer-grained sandstone with lamina and crossbeds. All strata across this interval can contain calcareous nodules and thin micritic limestone beds.

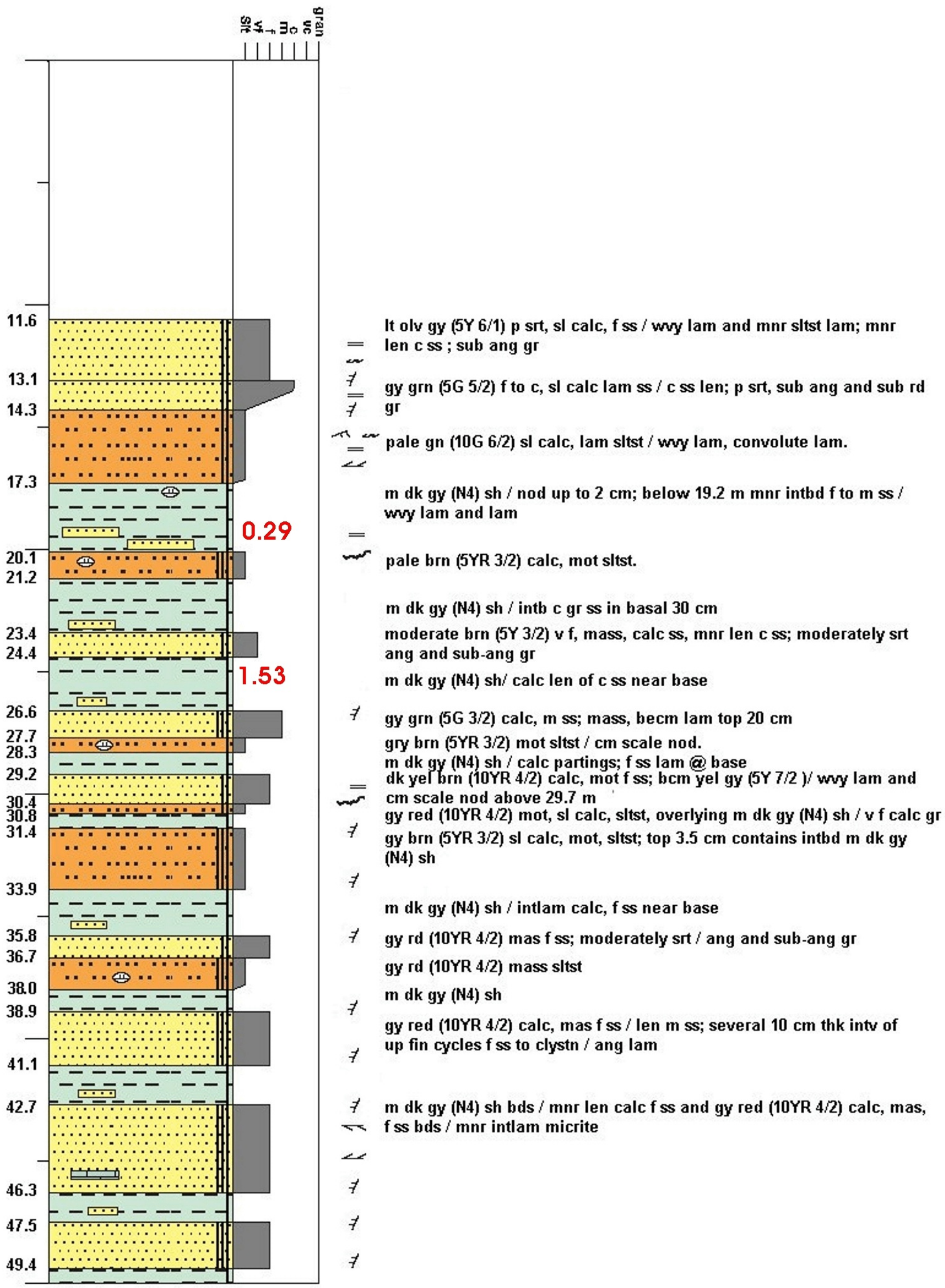
The highest beds in this succession, between 20 and 11 m, occur as a single coarsening-upward cycle of dark grey shale overlain by pale green siltstone and grey-green and olive-grey sandstone. As with strata below, beds are slightly calcareous and with calcite nodules. Sedimentary structures include convolute bedding and flame structures in the siltstones and wavy, parallel and convolute laminae in the fine grain sandstones. Mottled horizons may be bioturbated.

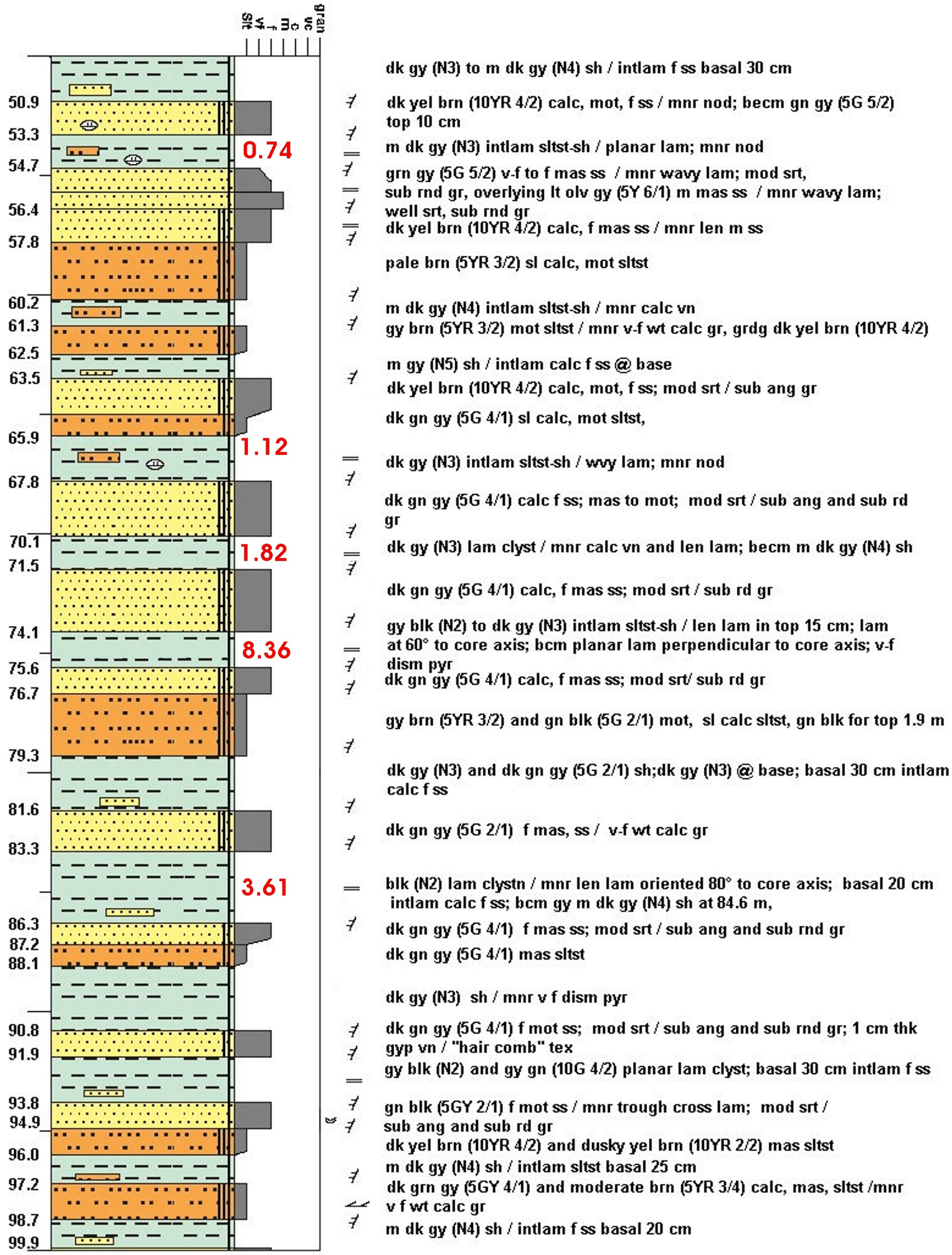
These siltstone-shale beds have been examined for organic geochemistry (Hamblin et al., 1997). Their report shows marginally mature, lean and rich, Type II and Type I source rocks are present in this borehole. High quality source rocks in this core tend to be associated with abundant amorphous material seen in palynology samples

(Hamblin et al., 1997). A significant observation lies with an apparent relationship between rock colour as measured in this study and the Total Organic Carbon (TOC) measured in Hamblin et al (1997), and used here as our proxy for source rock quality. Rich source rocks, that is rocks with more than 2% TOC tend to be dark grey and black in colour, N2 and N3 on the Munsell colour chart. Lean source rocks, that is rocks with about 1% TOC are medium dark grey (N4) in colour.

A net to gross source rock ratio is calculated by dividing the total thickness of the dark organic rich beds (N2, N3, N4) by the total thickness of strata in the hole. With both lean and rich source rock considered, and optimistically considering the organic mudstone beds to be free of lean siltstone interbeds, the net to gross ratio for this part of the Rocky Brook Formation is 44%. If rich source rock is more realistically considered (the N2-N3 colour proxy), the quantity of source rock in this core is about 10% and principally located in beds between 0.5 and 3 m thick and lying between 65 and 95 m, near the bottom of the lower grey unit of the Spillway Member.

The Westfield Minerals core report by Peterson (1979a) indicates no radioactive anomalies and background radiation at 40-75 cps.


slt vf f m c vc gran
11.6
13.1
14.3
17.3
20.1
21.2
23.4
24.4
26.6
27.7
28.3
29.2
30.4
30.8
31.4
33.9
35.8
36.7
38.0
38.9
41.1
42.7
46.3
47.5
49.4
0.29
1.53
lt olv gy (5Y 6/1) p srt, sl calc, f ss / wvy lam and mnr sltst lam; mnr len c ss ; sub ang gr
gy grn (5G 5/2) f to c, sl calc lam ss / c ss len; p srt, sub ang and sub rd gr
pale gn (10G 6/2) sl calc, lam sltst / wvy lam, convolute lam.
m dk gy (N4) sh / nod up to 2 cm; below 19.2 m mnr intbd f to m ss / wvy lam and lam
pale brn (5YR 3/2) calc, mot sltst.
m dk gy (N4) sh / intb c gr ss in basal 30 cm
moderate brn (5Y 3/2) v f, mass, calc ss, mnr len c ss; moderately srt ang and sub-ang gr
m dk gy (N4) sh/ calc len of c ss near base
gy grn (5G 3/2) calc, m ss; mass, bcm lam top 20 cm
gry brn (5YR 3/2) mot sltst / cm scale nod.
m dk gy (N4) sh / calc partings; f ss lam @ base
dk yel brn (10YR 4/2) calc, mot f ss; bcm yel gy (5Y 7/2)/ wvy lam and cm scale nod above 29.7 m
gy red (10YR 4/2) mot, sl calc, sltst, overlying m dk gy (N4) sh / v f calc gr
gy brn (5YR 3/2) sl calc, mot, sltst; top 3.5 cm contains intbd m dk gy (N4) sh
m dk gy (N4) sh / intlam calc, f ss near base
gy rd (10YR 4/2) mas f ss; moderately srt / ang and sub-ang gr
gy rd (10YR 4/2) mass sltst
m dk gy (N4) sh
gy red (10YR 4/2) calc, mas f ss / len m ss; several 10 cm thk intv of up fin cycles f ss to clystn / ang lam
m dk gy (N4) sh bds / mnr len calc f ss and gy red (10YR 4/2) calc, mas, f ss bds / mnr intlam micrite



Slt
vf
f
m
c
vc
gran
dk gy (N3) to m dk gy (N4) sh / intlam f ss basal 30 cm
50.9
dk yel brn (10YR 4/2) calc, mot, f ss / mnr nod; becm gn gy (5G 5/2) top 10 cm
53.3
0.74
m dk gy (N3) intlam sltst-sh / planar lam; mnr nod
54.7
grn gy (5G 5/2) v-f to f mas ss / mnr wavy lam; mod srt, sub rnd gr, overlying lt olv gy (5Y 6/1) m mas ss / mnr wavy lam; well srt, sub rnd gr
56.4
dk yel brn (10YR 4/2) calc, f mas ss / mnr len m ss
57.8
pale brn (5YR 3/2) sl calc, mot sltst
60.2
m dk gy (N4) intlam sltst-sh / mnr calc vn
61.3
gy brn (5YR 3/2) mot sltst / mnr v-f wt calc gr, grdg dk yel brn (10YR 4/2)
62.5
m gy (N5) sh / intlam calc f ss @ base
63.5
dk yel brn (10YR 4/2) calc, mot, f ss; mod srt / sub ang gr
dk gn gy (5G 4/1) sl calc, mot sltst,
65.9
1.12
dk gy (N3) intlam sltst-sh / wvy lam; mnr nod
67.8
dk gn gy (5G 4/1) calc f ss; mas to mot; mod srt / sub ang and sub rd gr
70.1
1.82
dk gy (N3) lam clyst / mnr calc vn and len lam; becm m dk gy (N4) sh
71.5
dk gn gy (5G 4/1) calc, f mas ss; mod srt / sub rd gr
74.1
gy blk (N2) to dk gy (N3) intlam sltst-sh / len lam in top 15 cm; lam at 60° to core axis; bcm planar lam perpendicular to core axis; v-f dism pyr
8.36
75.6
dk gn gy (5G 4/1) calc, f mas ss; mod srt/ sub rd gr
76.7
gy brn (5YR 3/2) and gn blk (5G 2/1) mot, sl calc sltst, gn blk for top 1.9 m
79.3
dk gy (N3) and dk gn gy (5G 2/1) sh;dk gy (N3) @ base; basal 30 cm intlam calc f ss
81.6
dk gn gy (5G 2/1) f mas, ss / v-f wt calc gr
83.3
3.61
blk (N2) lam clystn / mnr len lam oriented 80° to core axis; basal 20 cm intlam calc f ss; bcm gy m dk gy (N4) sh at 84.6 m,
86.3
dk gn gy (5G 4/1) f mas ss; mod srt / sub ang and sub rnd gr
87.2
dk gn gy (5G 4/1) mas sltst
88.1
dk gy (N3) sh / mnr v f dism pyr
90.8
dk gn gy (5G 4/1) f mot ss; mod srt / sub ang and sub rnd gr; 1 cm thk gyp vn / "hair comb" tex
91.9
gy blk (N2) and gy gn (10G 4/2) planar lam clyst; basal 30 cm intlam f ss
93.8
gn blk (5GY 2/1) f mot ss / mnr trough cross lam; mod srt / sub ang and sub rd gr
94.9
dk yel brn (10YR 4/2) and dusky yel brn (10YR 2/2) mas sltst
96.0
m dk gy (N4) sh / intlam sltst basal 25 cm
97.2
dk grn gy (5GY 4/1) and moderate brn (5YR 3/4) calc, mas, sltst /mnr v f wt calc gr
98.7
m dk gy (N4) sh / intlam f ss basal 20 cm
99.9

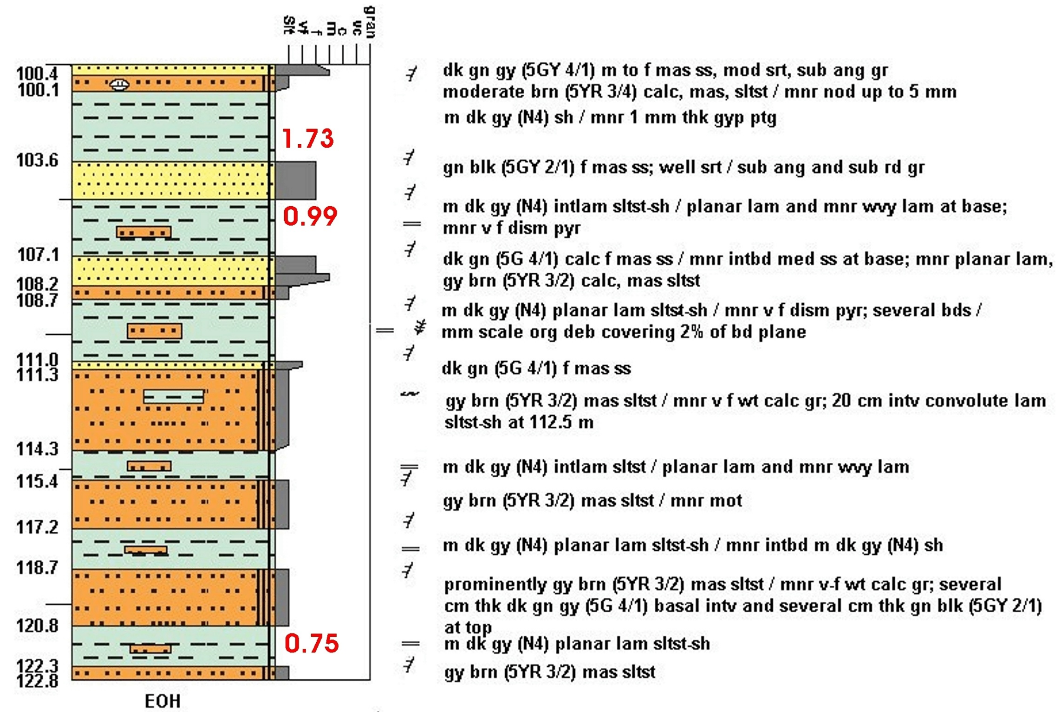


Figure 9: Lithologic log for drill-hole 0023. Red numbers are TOC % from analyses reported in Hamblin et al. (1997)

12H/06/0025

UTM: 483220 E 5457760 N

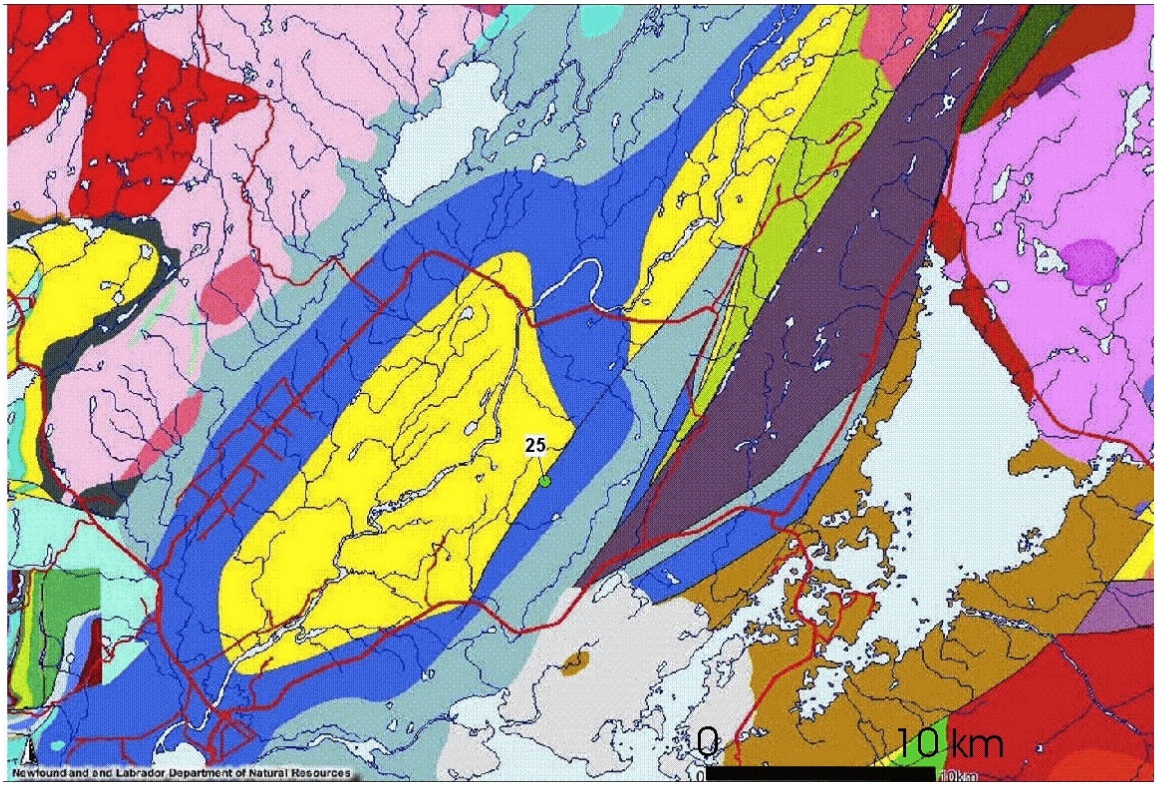


Figure 10: Location of drill-hole 0025 (taken from Newfoundland and Labrador Ministry of Natural Resources website)

12H/06/0025
Azimuth/Dip: 000/90
Depth: 30.5 m

Hole 12H/06/0025, also known as Westfield Minerals Ltd. DDH 79-55 (Figure 10), is located on a flower structure west of the Fisher Hills - Birchy Ridge Fault Zone. It is in close proximity to the hangingwall for a presumed thrust fault defining the western edge of this block. The report by Patterson (1979b) on this 30 m core from the Squires Park Member shows nearly 100% core recovery. Today, the core is now in large part broken and rubbly; some features described by Patterson have deteriorated. In general, the core apparently consists of small cycles of shale, or shale interlaminated with siltstone, and thicker siltstone beds (Figure 11). Traces of pyrite occur throughout.

Figure 11: Core 0025 of the Squires Park Member is today reduced to broken and rubbly shale and siltstone with minor pyrite and calcite.

In detail (Figure 12), the core shows 5 complete cycles, 3 to 6 m thick, and formed as sharp-based, coarsening and thickening upward successions of laminated, dark grey, slightly pyritic shale overlain by dark greenish grey, slightly calcareous siltstone. The top 6 m of core is silty, olive grey, and slightly calcareous shale. Lamina at an angle 70° to 75° to the core axis indicates bedding dips 15° to 20°.

The lower contact between shale and siltstone may be gradational or sharp. If sharp, the base of the siltstone may be a scour surface with small angular shale clasts. The upper contact of siltstone to shale is nearly always sharp and planar. One contact at about 20.5 m is apparently a scour overlain by contorted shale with a very thin limestone bed containing shale clasts.

Internally, the siltstone beds are mostly mottled and have thicknesses from 60 cm to 2.3 m. They generally contain traces of very fine, to fine white, calcareous grains and very fine disseminated pyrite. Both fractions amount to less than 1% of the rock.

There are no organic geochemistry or TOC values to report for this hole. For this short 25 m section of the Squires Park Member, the ratio of potential source rock (dark shale N2, N3, N4) to gross thickness is 47% . For this core, most of the dark shale corresponds with Munsell colours N3 and N2, our proxy for rich source rock potential. Here, this amounts to approximately 12 m of source rock in Squires Park Member beds about 1.5 to 5 m thick.

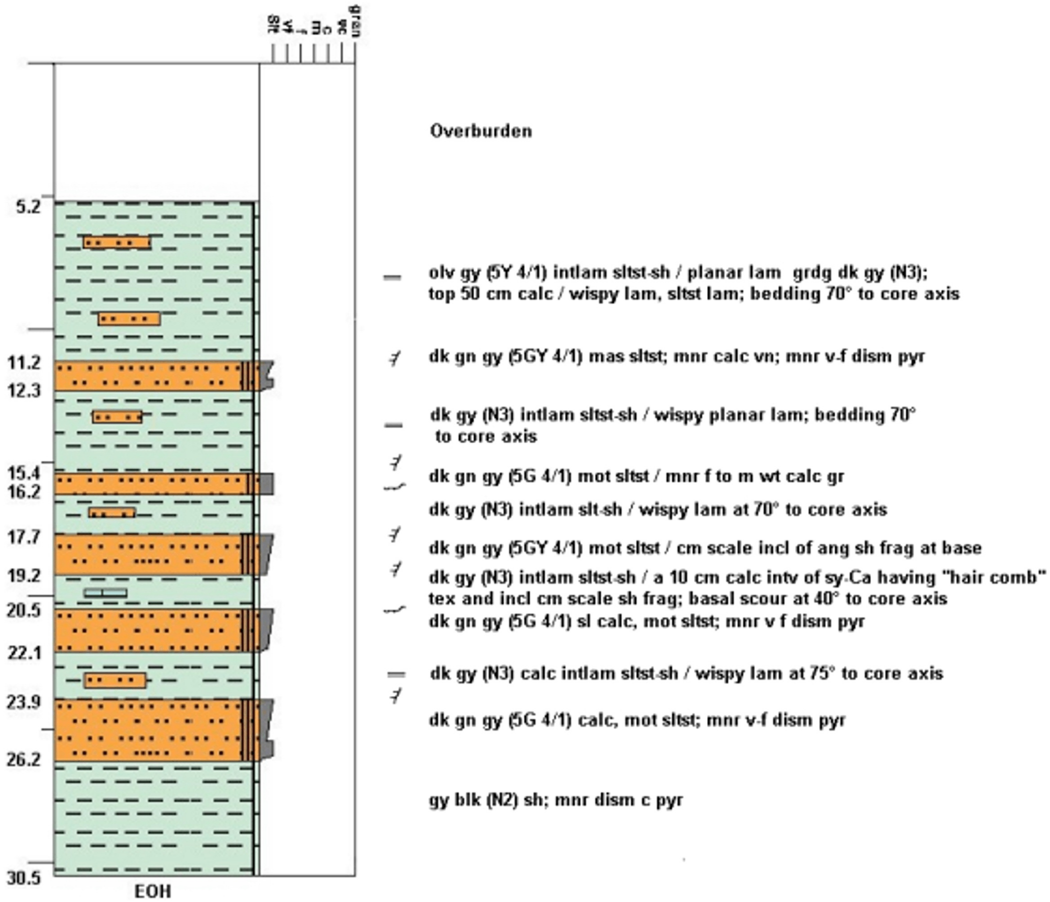


Figure 12: Lithologic log for core 0025 showing shale-siltstone successions in dark grey and greenish grey Squires Park Member strata.

12H/06/0027

UTM: 484700 E 5460000 N

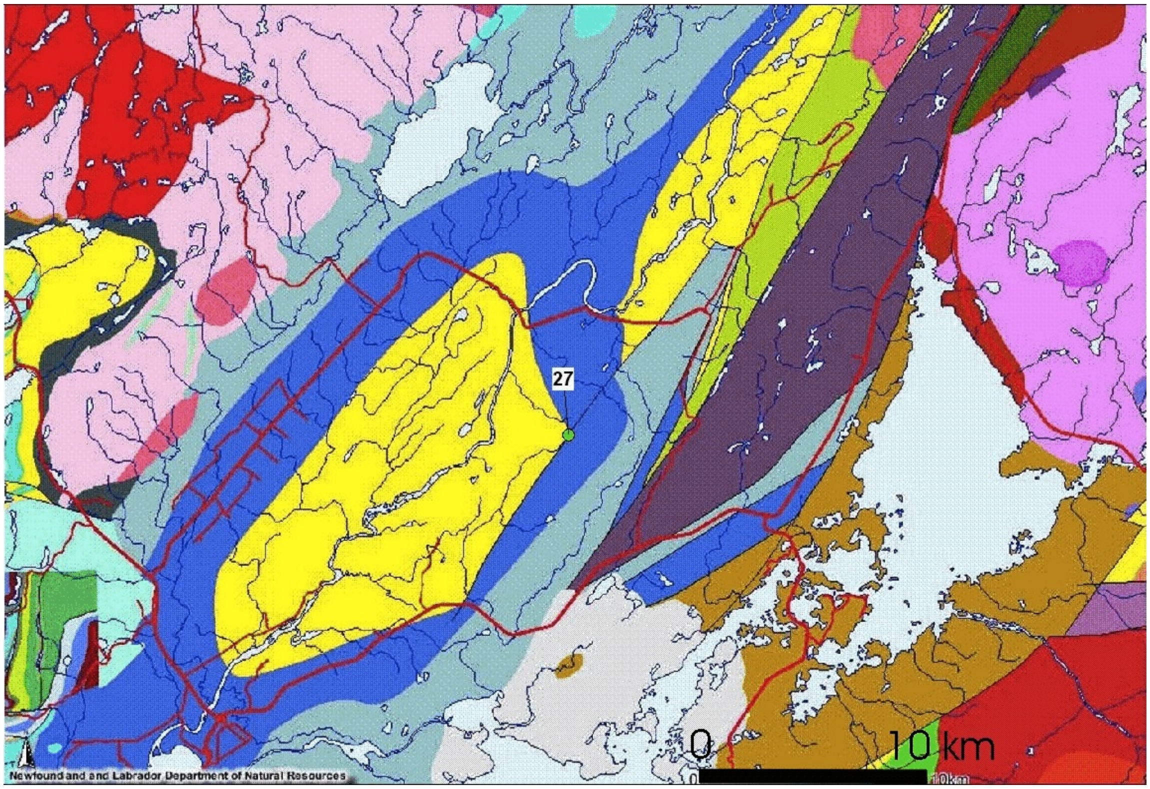


Figure 13: Location of hole 0027 (taken from Newfoundland and Labrador Ministry of Natural Resources website).

12H/06/0027
Azimuth/Dip: 000/90
Depth: 30.5 m

Hole 12H/06/0027, also known as Westfield Minerals Ltd. DDH 79-58 (Figure 13), is located on a flower structure west of the Fisher Hills - Birchy Ridge Fault Zone. As with hole 0025 a few kilometres to the south, it too is in close proximity to the hangingwall for a presumed thrust fault defining the western edge of this block. The core is now in large part broken and rubbly; some interval thicknesses are simply estimates. In general, the core apparently consists of small cycles of shale, or shale interlaminated with siltstone, and thicker siltstone beds (Figure 14). Thin beds of oolitic limestone and limestone coated clasts are present (Figure 15); traces of pyrite occur throughout.

Figure 14: Core 0027 of the Squires Park Member is today reduced to broken and rubbly shale and siltstone with minor pyrite and calcite.

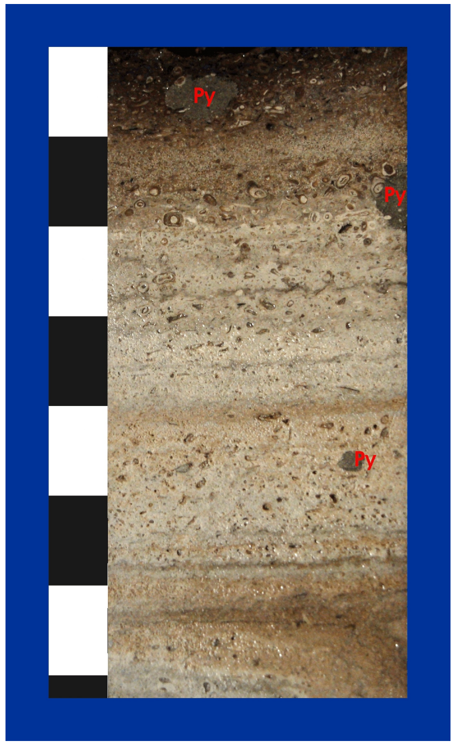


Figure 15: Thin 7.5 cm carbonate interval at about 8.5 m depth. Oolites, other concentrically coated clasts and pyrite (Py) are common.

Core 0027 (Figure 16) is cycles of slightly calcareous dark gray shale, dark gray interbedded siltstone and shale, and greenish-gray siltstone. Within the shaley horizons there are also thin beds of yellowish gray, oolitic packstone and grainstone

The shale and siltstone components for these successions range in thickness from 0.8 to more than 2.0 m. Shale can be parallel bedded, wispy laminated, and wavy and lenticular in places. There are also minor convolute lamina in strata forming at the base of some successions. This lenticular lamination normally occurs above an interval of planar lamination. Lamination is generally oriented at 70°-80° to the core axis, meaning these beds are dipping between 10° and 20°. Siltstones tend to be a mottled and slightly calcareous. Some siltstone beds contain mm scale pyrite nodules.

The oolitic packstone and grainstone beds are distinctive features in this core. Typically, these limestones are 3 cm to 4 cm thick, with one bed being as much as 30 cm. The ooids range from fine to coarse and pisolitic. Most are irregular in shape and multi-banded. These limestone beds tend to contain small pieces of organic debris on some bedding planes. Beds also contain very fine disseminated pyrite as well as mm scale pyrite nodules.

No radiometric anomalies are present in this hole. No hydrocarbon geochemistry and TOC reports are known to exist. The net to gross ratio for hole 0027 is 55% and largely formed from one ~7 m thick, dark (N3), and probably rich organic shale at the base of this core.

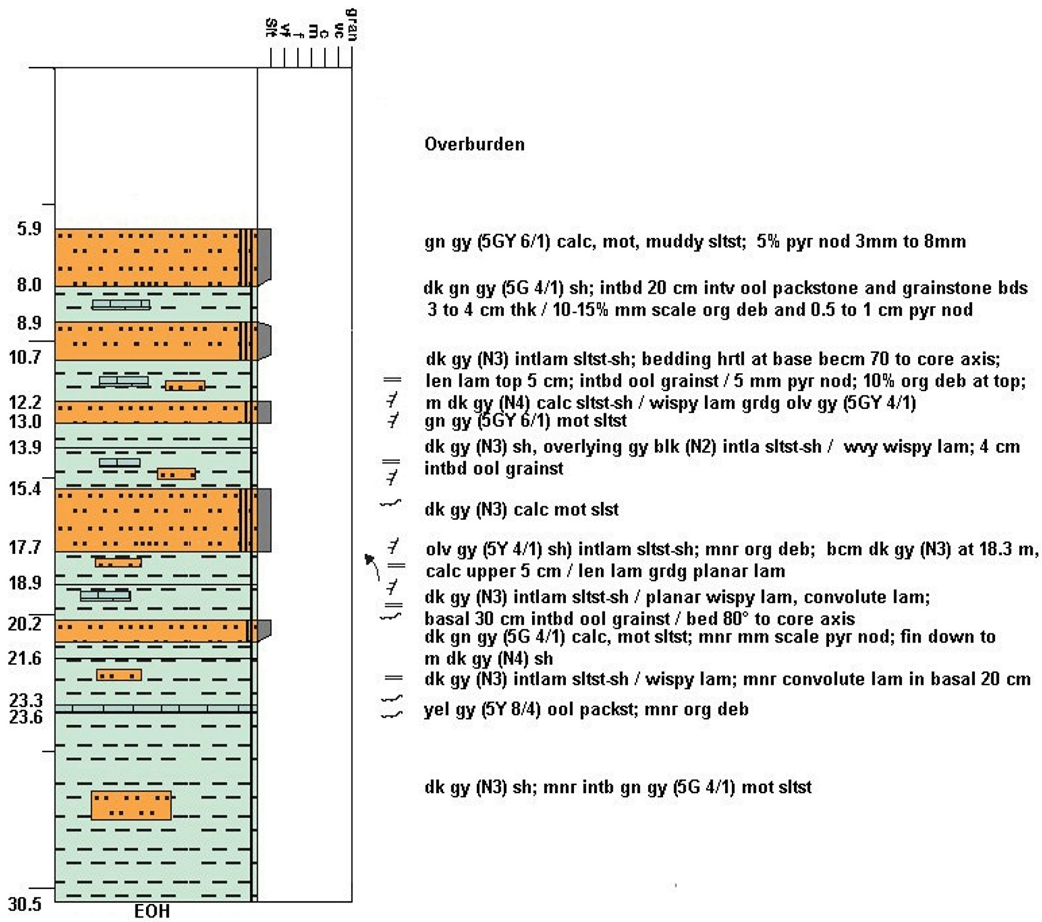


Figure 16: Lithologic log for core 0027 showing shale-siltstone successions in dark grey and greenish grey strata with thin yellow-grey oolitic limestone beds.

12/H6/0031

UTM: 482930 E 5469030 N

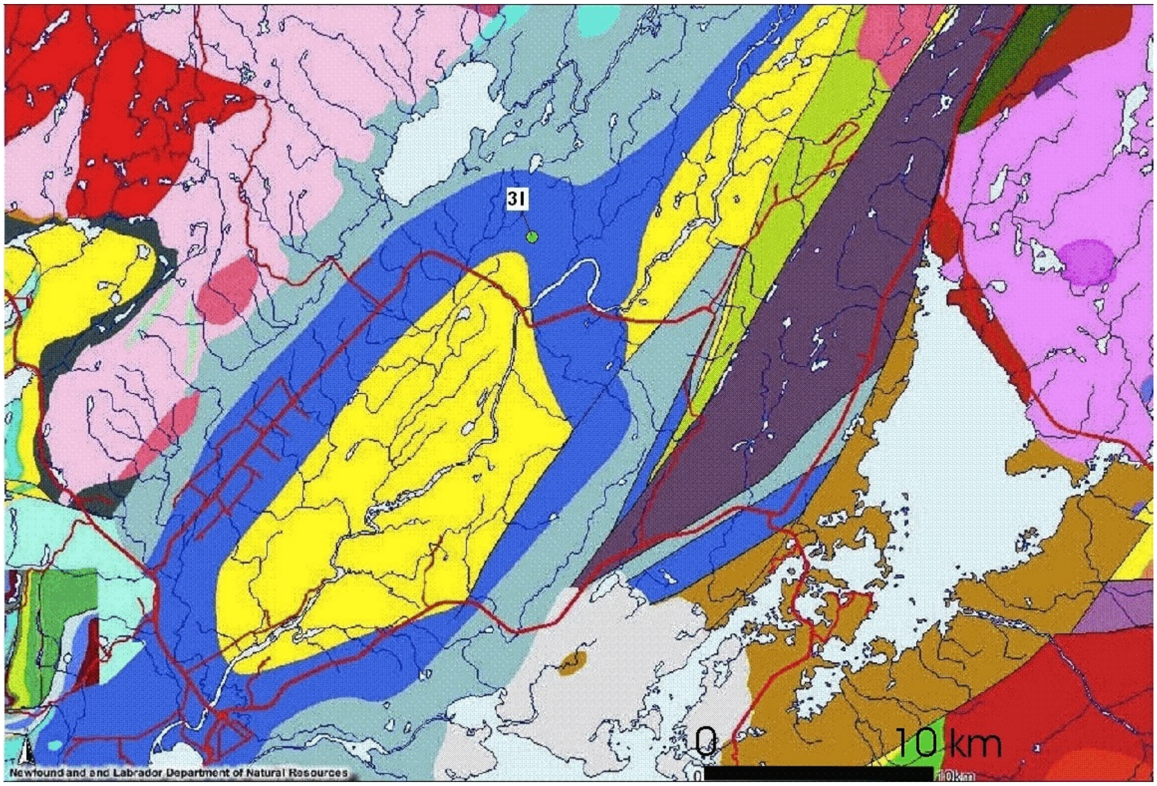


Figure 17: Location of hole 0031 (taken from Newfoundland and Labrador Ministry of Natural Resources website).

12/H6/0031
Azimuth/Dip: 000/90
Depth: 30.5 m

Hole 12H/06/0031, also known as Westfield Minerals Ltd. DDH 79-62 (Figure 17), is located along the central axis of the basin and on the southwest plunging axis of the Humber Syncline. The edge of the Humber Falls Fm. lies a short distance to the south. Humber Falls strata are 248 m thick in borehole DDH 79-67 (12/H06/0036), another 15 km farther south, and near the geographic centre of this basin (Figure 2). The 23 m core (Figure 18) belongs to the Squires Park Member. It consists of sharply bounded and also upward coarsening cycles of dark grey shale with dark grey and dark greenish grey, mottled siltstone with a small amount of oolitic limestone at the top.

Figure 18: Cycles of dark grey shale with dark grey and dark greenish grey, mottled siltstone. Both shale and siltstone may be slightly calcareous.

The shale beds (Figure 19) are dark grey colour (N3) and range in thickness from 50 cm to ~6 m (avg ~1.5 m). Many of these beds may be slightly calcareous and nearly all contain trace quantities of pyrite. The upper contacts between shale and overlying siltstone are commonly sharp; the lower contacts between shale and underlying siltstone can be gradational or sharp.

The dark gray siltstone beds tend to be associated with dark grey shale. Siltstones are planar laminated and 1 to 1.4 m thick. Pyrite, as very fine disseminated crystals or as nodules up to 4 cm thick, also occurs in these beds. A second variety of siltstone is dark greenish gray in colour, generally calcareous and mottled and from 50 cm to 1.8 m thick. In the top half of this hole, these siltstone beds contain calcareous nodules several millimeters in diameter.

The thin oolitic packstone beds in the upper part of this core are in sharp contact with bounding shale. Contact relations suggest a regional dip of less than 10°.

The net source rock thickness to gross thickness for this short core is 62%, the greatest net to gross ratio of all holes examined. Some of the thick, dark grey (N3) shale beds are probably rich in organic matter.

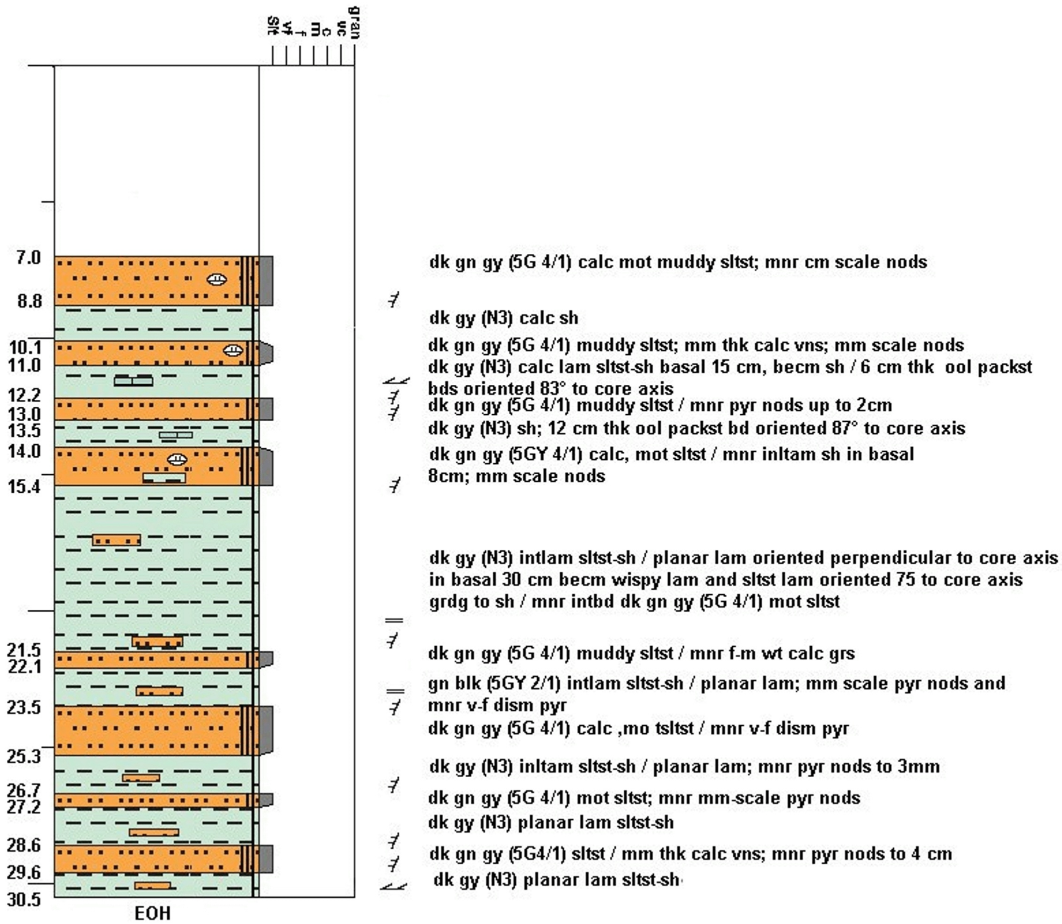


Figure 19: Lithologic log for core 0031 showing shale-siltstone successions in dark grey and greenish grey Squires Park Member strata.

12H6/0037

UTM: 477120 E 5466650 N

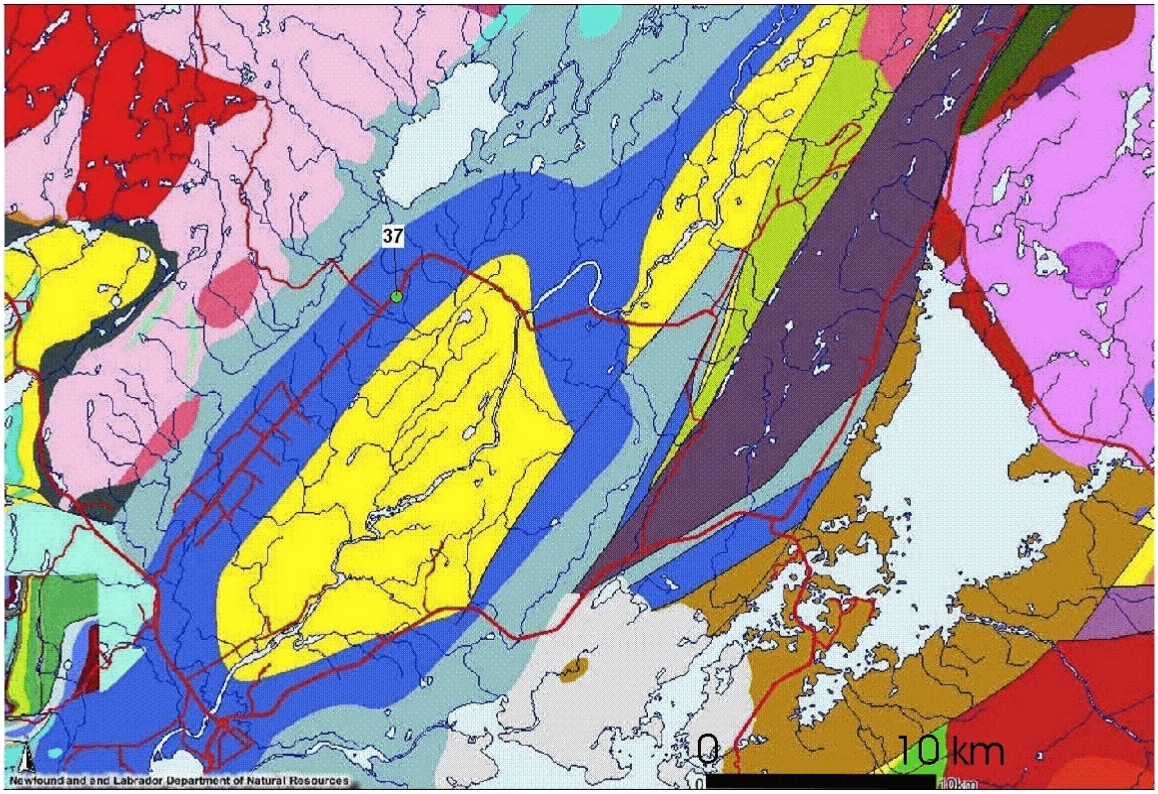


Figure 20: Location of hole 0037 (taken from Newfoundland and Labrador Ministry of Natural Resources website).

12H6/0037
Azimuth/Dip: 000/90
Depth: 269.1 m

Hole 12H/06/0037, also known as Northgate Exploration DDH 79A-003, and GSC Locality C-165010 (Figure 20), is located on the western edge of the basin and on the southeast dipping, northwest limb of the Humber Syncline.

This long core (Figure 21) contains a nearly complete record of the Rocky Brook Formation from its lower contact with red sandstones of the North Brook Formation, through red, grey, and brown beds of the Spillway member, to very high in the grey beds of the Squires Park Member, and where grey green siltstone and thin beds of limestone begin to reappear.

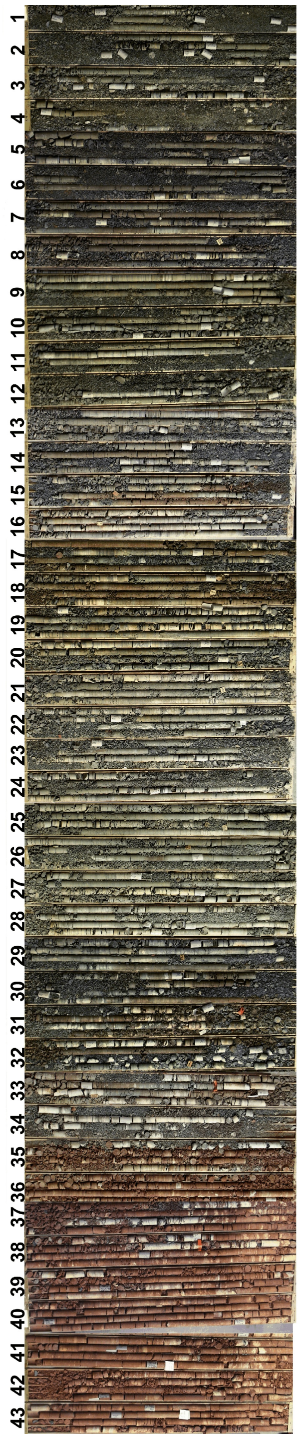


Figure 21: Colour patterns on core 0037 crudely differentiate the reddish coloured Spillway Member (boxes 17-38) from the overlying grey and dark grey Squires Park Member (boxes 1-16). Boxes 39-43 are North Brook Formation sandstones. A detailed photographic log is in the Appendix 4.

In total, this borehole is nearly 270 m in length. The basal 20 m (Box 43 to Box 40) of fine through coarse red sandstone, mottled siltstone and nodular limestone of the North Brook Formation is not included in the accompanying log. The uppermost bed (Box 39) of the North Brook Formation (Figure 22), an 8 m, graded, medium through fine-grained, polylithic, dark red-brown arkosic sandstone with carbonate nodules, is in sharp contact with nearly a metre of pale yellow brown, bedded and nodular limestone.

The interval from 242 m to about 215 m (Box 38 to Box 35) is 3 to 5 m beds of laminated dark red-brown siltstone grading to pale red-brown and pale brown siltstone. Scattered throughout this siltstone are a few, thin (< 10 cm), fine-grained sandstone beds that can be massive, rippled (Figure 23) or planar bedded. Siltstone beds are separated from one another by 0.5 to 1 m intervals of thinly layered and broken interbeds of pale yellow brown and greenish grey nodular limestone and packstone (Figure 24).

Siltstone beds lying between 215 and 180 m (Box 34 to Box 29) are 2 to 7 m thick, greenish grey and brownish grey in colour, and separated from one another by beds of medium dark grey shale and pale grey and orange limestone 1 to 2 m thick. Calcareous nodules are common throughout this interval and the rocks have a mottled appearance (Figure 25).

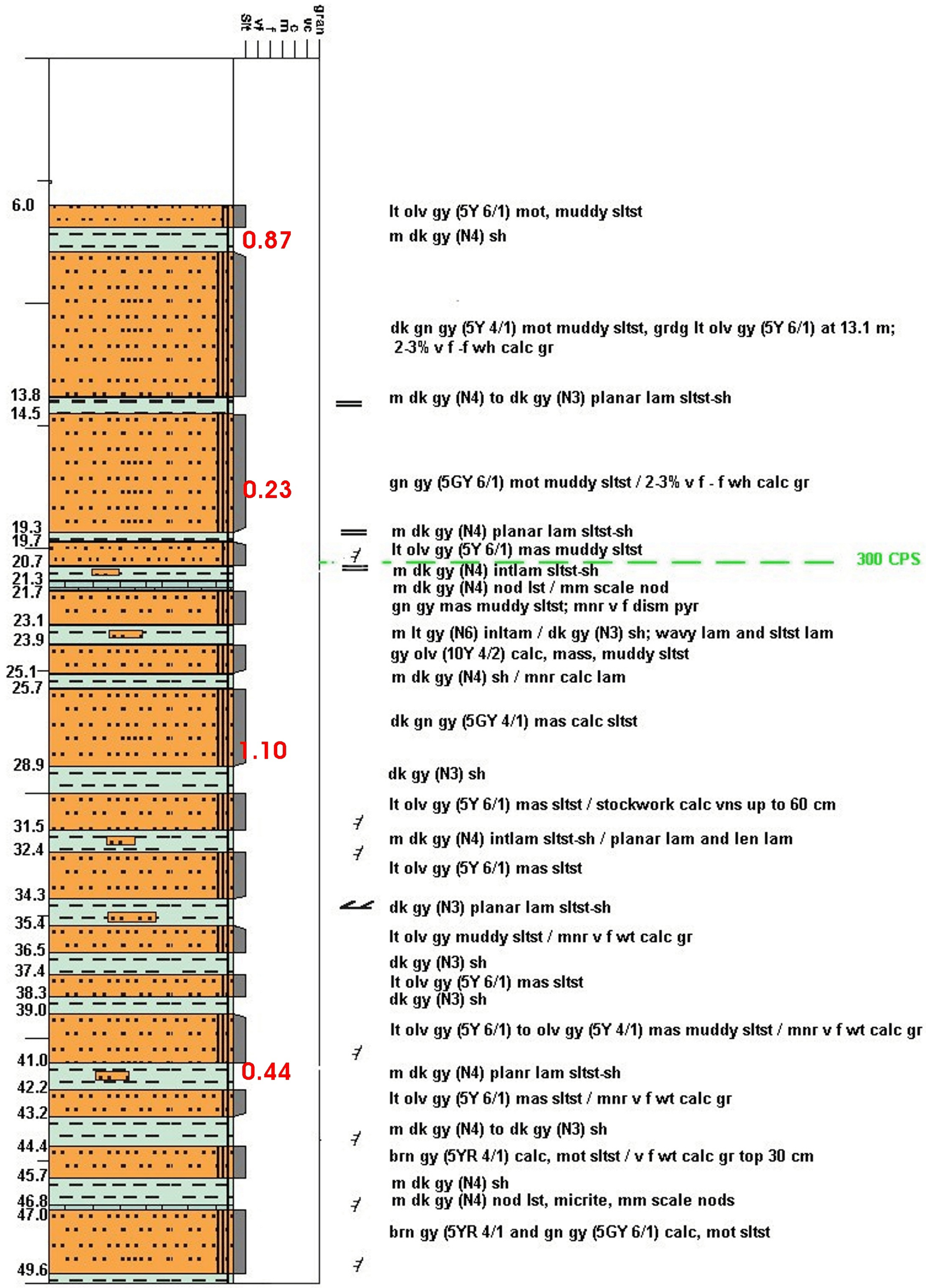
Beginning around 180 m and continuing to about 122 m (Box 29 to Box 20) the section is dominated by interbedded (dark) greenish grey siltstone and medium dark grey shale. Siltstone beds vary from 0.5 to 5 m thickness, with thicker beds tending to be near the top. Shale beds are <1 to about 4 m thick. The thick shale beds are apparently random; the thinner shale beds tend to be clustered between 176 and 142 m. Two prominent medium grey limestone beds occur at about 176 and 179 m. The lower of these two beds is nodular and similar to others found in the lower strata. The upper bed at 176 m is a fining-upward cycle of coarse to fine pelloidal packstone with a sharp, scoured upper contact.

At 122 m there is a distinctive change in colour with siltstone becoming light olive grey. Between 122 m and 83 m (Box 19 and Box 13), the siltstones, typically 1 m to 5 m thick, are light olive grey with a few greenish grey, brownish grey and dark grey beds. Above ~100 m, massive and laminated shale beds, normally about 1 m thick, are medium dark grey and dark grey in colour; below 100 m shale beds are medium dark grey. The highest siltstone bed in this succession contains a thin dark limestone bed at about 85 m and less than 20 cm thick.

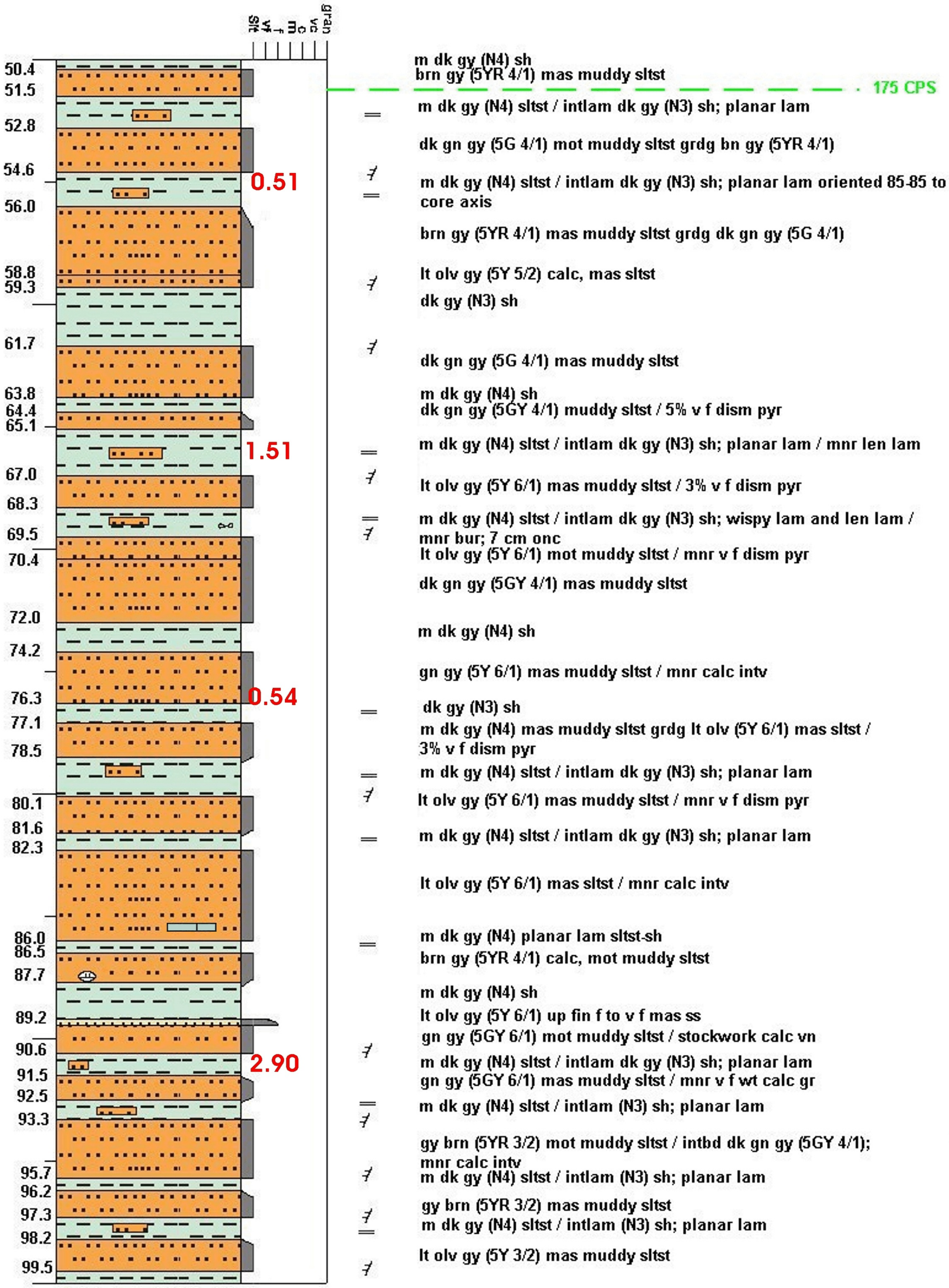
The top 78 m of core (Box 1 to Box 13) is predominantly greenish grey siltstone (infrequently light olive grey) in beds 1 to 3 m thick and separated by dark grey and medium dark grey massive and laminated shale in beds that are normally less than 1 m to about 2 m thick. The thickest siltstone beds lie at the top of this hole. Traces of carbonate are evident throughout this section as mottled horizons, nodules, and thin limestone lamina and algal oncolites (Figure 26).

There are several radiometric horizons reported for this hole by O'Sullivan. They occur at 20.7 m, 51.5 m, and 140 m with radiometric values of 300 cps, 175 cps, and 200 cps respectively. All of these points are near thin limestone beds or indurated and calcite cemented siltstone.

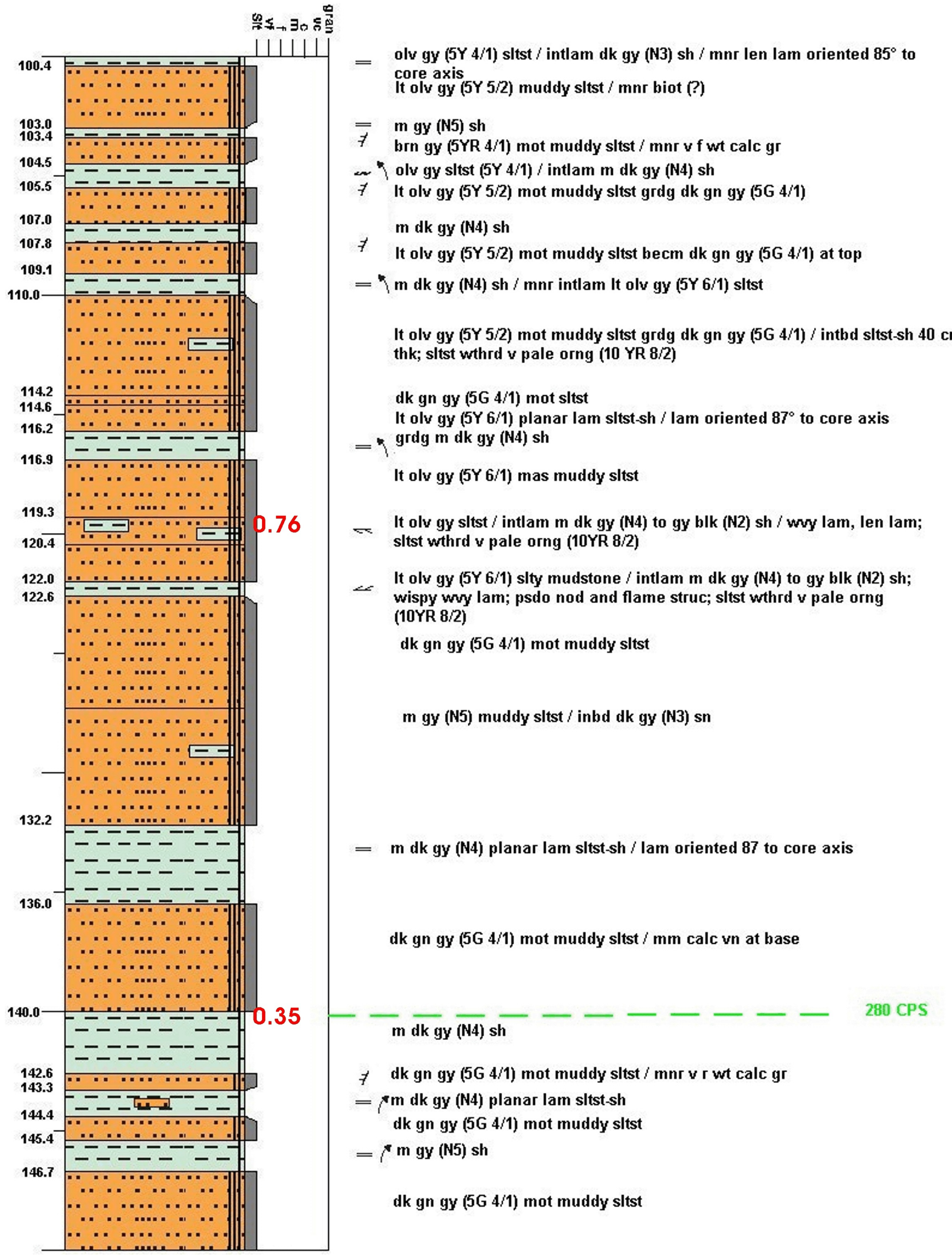
The highest TOC in this core (2.90%) occurs in a siltstone-shale bed between 90.6 m and 91.5 m, the base of the Squires Park member (Hamblin et al. 1997). This bed, and other nearby horizons are also relatively enriched in dispersed amorphous material (Hamblin et al., 1997). Based upon colour characteristics, the net potential source rock thickness to gross thickness for this hole is 27% in beds that are generally less than 1.5 m thick. From colour proxy, the most promising horizons lie scattered between about 60 and 100 m.



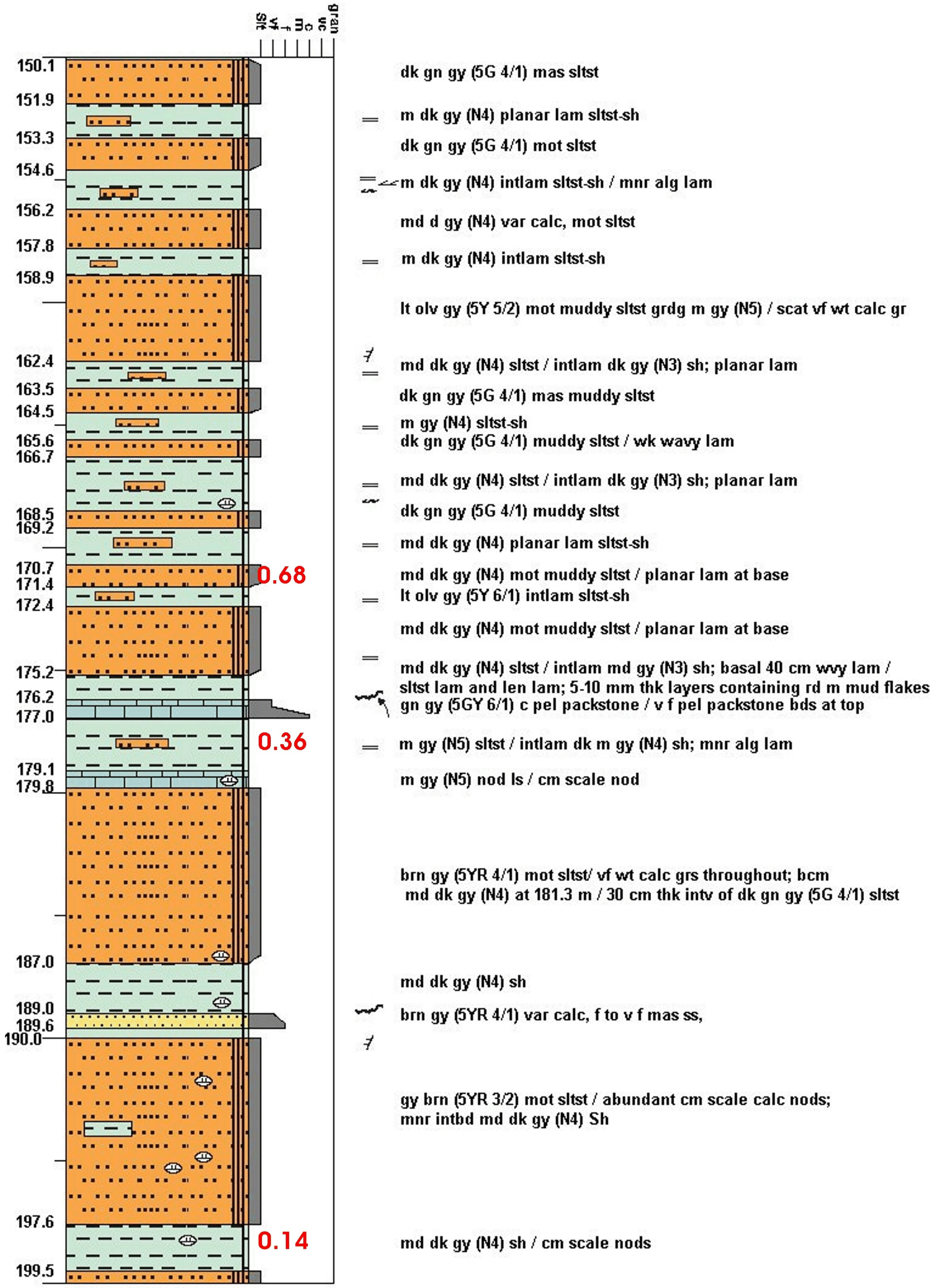
slt
vf
f
m
c
vc
gran
6.0
lt olv gy (5Y 6/1) mot, muddy sltst
0.87
m dk gy (N4) sh
dk gn gy (5Y 4/1) mot muddy sltst, grdg lt olv gy (5Y 6/1) at 13.1 m;
2-3% v f -f wh calc gr
13.8
14.5
m dk gy (N4) to dk gy (N3) planar lam sltst-sh
0.23
gn gy (5GY 6/1) mot muddy sltst / 2-3% v f - f wh calc gr
19.3
19.7
20.7
21.3
21.7
m dk gy (N4) planar lam sltst-sh
lt olv gy (5Y 6/1) mas muddy sltst
300 CPS
m dk gy (N4) intlam sltst-sh
m dk gy (N4) nod lst / mm scale nod
gn gy mas muddy sltst; mnr v f dism pyr
23.1
23.9
m lt gy (N6) inltam / dk gy (N3) sh; wavy lam and sltst lam
gy olv (10Y 4/2) calc, mass, muddy sltst
25.1
25.7
m dk gy (N4) sh / mnr calc lam
dk gn gy (5GY 4/1) mas calc sltst
1.10
28.9
dk gy (N3) sh
lt olv gy (5Y 6/1) mas sltst / stockwork calc vns up to 60 cm
31.5
32.4
m dk gy (N4) intlam sltst-sh / planar lam and len lam
lt olv gy (5Y 6/1) mas sltst
34.3
dk gy (N3) planar lam sltst-sh
35.4
lt olv gy muddy sltst / mnr v f wt calc gr
36.5
37.4
38.3
39.0
dk gy (N3) sh
lt olv gy (5Y 6/1) mas sltst
dk gy (N3) sh
lt olv gy (5Y 6/1) to olv gy (5Y 4/1) mas muddy sltst / mnr v f wt calc gr
41.0
0.44
42.2
43.2
m dk gy (N4) planr lam sltst-sh
lt olv gy (5Y 6/1) mas sltst / mnr v f wt calc gr
m dk gy (N4) to dk gy (N3) sh
44.4
45.7
brn gy (5YR 4/1) calc, mot sltst / v f wt calc gr top 30 cm
46.8
47.0
m dk gy (N4) sh
m dk gy (N4) nod lst, micrite, mm scale nods
brn gy (5YR 4/1 and gn gy (5GY 6/1) calc, mot sltst
49.6



slt vf f m c vc gran
50.4
51.5
52.8
54.6
56.0
58.8
59.3
61.7
63.8
64.4
65.1
67.0
68.3
69.5
70.4
72.0
74.2
76.3
77.1
78.5
80.1
81.6
82.3
86.0
86.5
87.7
89.2
90.6
91.5
92.5
93.3
95.7
96.2
97.3
98.2
99.5
0.51
1.51
0.54
2.90
175 CPS
m dk gy (N4) sh
brn gy (5YR 4/1) mas muddy sltst
m dk gy (N4) sltst / intlam dk gy (N3) sh; planar lam
dk gn gy (5G 4/1) mot muddy sltst grdg bn gy (5YR 4/1)
m dk gy (N4) sltst / intlam dk gy (N3) sh; planar lam oriented 85-85 to core axis
brn gy (5YR 4/1) mas muddy sltst grdg dk gn gy (5G 4/1)
lt olv gy (5Y 5/2) calc, mas sltst
dk gy (N3) sh
dk gn gy (5G 4/1) mas muddy sltst
m dk gy (N4) sh
dk gn gy (5GY 4/1) muddy sltst / 5% v f dism pyr
m dk gy (N4) sltst / intlam dk gy (N3) sh; planar lam / mnr len lam
lt olv gy (5Y 6/1) mas muddy sltst / 3% v f dism pyr
m dk gy (N4) sltst / intlam dk gy (N3) sh; wispy lam and len lam / mnr bur; 7 cm onc
lt olv gy (5Y 6/1) mot muddy sltst / mnr v f dism pyr
dk gn gy (5GY 4/1) mas muddy sltst
m dk gy (N4) sh
gn gy (5Y 6/1) mas muddy sltst / mnr calc intv
dk gy (N3) sh
m dk gy (N4) mas muddy sltst grdg lt olv (5Y 6/1) mas sltst / 3% v f dism pyr
m dk gy (N4) sltst / intlam dk gy (N3) sh; planar lam
lt olv gy (5Y 6/1) mas muddy sltst / mnr v f dism pyr
m dk gy (N4) sltst / intlam dk gy (N3) sh; planar lam
lt olv gy (5Y 6/1) mas sltst / mnr calc intv
m dk gy (N4) planar lam sltst-sh
brn gy (5YR 4/1) calc, mot muddy sltst
m dk gy (N4) sh
lt olv gy (5Y 6/1) up fin f to v f mas ss
gn gy (5GY 6/1) mot muddy sltst / stockwork calc vn
m dk gy (N4) sltst / intlam dk gy (N3) sh; planar lam
gn gy (5GY 6/1) mas muddy sltst / mnr v f wt calc gr
m dk gy (N4) sltst / intlam (N3) sh; planar lam
gy brn (5YR 3/2) mot muddy sltst / intbd dk gn gy (5GY 4/1); mnr calc intv
m dk gy (N4) sltst / intlam (N3) sh; planar lam
gy brn (5YR 3/2) mas muddy sltst
m dk gy (N4) sltst / intlam (N3) sh; planar lam
lt olv gy (5Y 3/2) mas muddy sltst



slt
vf
f
m
c
vc
gran
100.4
olv gy (5Y 4/1) sltst / intlam dk gy (N3) sh / mnr len lam oriented 85° to core axis
lt olv gy (5Y 5/2) muddy sltst / mnr biot (?)
103.0
103.4
m gy (N5) sh
brn gy (5YR 4/1) mot muddy sltst / mnr v f wt calc gr
104.5
olv gy sltst (5Y 4/1) / intlam m dk gy (N4) sh
105.5
lt olv gy (5Y 5/2) mot muddy sltst grdg dk gn gy (5G 4/1)
107.0
m dk gy (N4) sh
107.8
lt olv gy (5Y 5/2) mot muddy sltst becm dk gn gy (5G 4/1) at top
109.1
m dk gy (N4) sh / mnr intlam lt olv gy (5Y 6/1) sltst
110.0
lt olv gy (5Y 5/2) mot muddy sltst grdg dk gn gy (5G 4/1) / intbd sltst-sh 40 cr thk; sltst wthrd v pale orng (10 YR 8/2)
114.2
114.6
dk gn gy (5G 4/1) mot sltst
lt olv gy (5Y 6/1) planar lam sltst-sh / lam oriented 87° to core axis
116.2
grdg m dk gy (N4) sh
116.9
lt olv gy (5Y 6/1) mas muddy sltst
119.3
0.76
lt olv gy sltst / intlam m dk gy (N4) to gy blk (N2) sh / wvy lam, len lam; sltst wthrd v pale orng (10YR 8/2)
120.4
122.0
122.6
lt olv gy (5Y 6/1) slty mudstone / intlam m dk gy (N4) to gy blk (N2) sh; wispy wvy lam; psdo nod and flame struc; sltst wthrd v pale orng (10YR 8/2)
dk gn gy (5G 4/1) mot muddy sltst
m gy (N5) muddy sltst / inbd dk gy (N3) sn
132.2
m dk gy (N4) planar lam sltst-sh / lam oriented 87 to core axis
136.0
dk gn gy (5G 4/1) mot muddy sltst / mm calc vn at base
140.0
0.35
280 CPS
m dk gy (N4) sh
142.6
143.3
dk gn gy (5G 4/1) mot muddy sltst / mnr v r wt calc gr
m dk gy (N4) planar lam sltst-sh
144.4
dk gn gy (5G 4/1) mot muddy sltst
145.4
m gy (N5) sh
146.7
dk gn gy (5G 4/1) mot muddy sltst



slt vf f m c vc gran
150.1
151.9
153.3
154.6
156.2
157.8
158.9
162.4
163.5
164.5
165.6
166.7
168.5
169.2
170.7
171.4
172.4
175.2
176.2
177.0
179.1
179.8
187.0
189.0
189.6
190.0
197.6
199.5
0.68
0.36
0.14
dk gn gy (5G 4/1) mas sltst
m dk gy (N4) planar lam sltst-sh
dk gn gy (5G 4/1) mot sltst
m dk gy (N4) intlam sltst-sh / mnr alg lam
md d gy (N4) var calc, mot sltst
m dk gy (N4) intlam sltst-sh
lt olv gy (5Y 5/2) mot muddy sltst grdg m gy (N5) / scat vf wt calc gr
md dk gy (N4) sltst / intlam dk gy (N3) sh; planar lam
dk gn gy (5G 4/1) mas muddy sltst
m gy (N4) sltst-sh
dk gn gy (5G 4/1) muddy sltst / wk wavy lam
md dk gy (N4) sltst / intlam dk gy (N3) sh; planar lam
dk gn gy (5G 4/1) muddy sltst
md dk gy (N4) planar lam sltst-sh
md dk gy (N4) mot muddy sltst / planar lam at base
lt olv gy (5Y 6/1) intlam sltst-sh
md dk gy (N4) mot muddy sltst / planar lam at base
md dk gy (N4) sltst / intlam md gy (N3) sh; basal 40 cm wvy lam /
sltst lam and len lam; 5-10 mm thk layers containing rd m mud flakes
gn gy (5GY 6/1) c pel packstone / v f pel packstone bds at top
m gy (N5) sltst / intlam dk m gy (N4) sh; mnr alg lam
m gy (N5) nod ls / cm scale nod
brn gy (5YR 4/1) mot sltst/ vf wt calc grs throughout; bcm
md dk gy (N4) at 181.3 m / 30 cm thk intv of dk gn gy (5G 4/1) sltst
md dk gy (N4) sh
brn gy (5YR 4/1) var calc, f to v f mas ss,
gy brn (5YR 3/2) mot sltst / abundant cm scale calc nods;
mnr intbd md dk gy (N4) Sh
md dk gy (N4) sh / cm scale nods

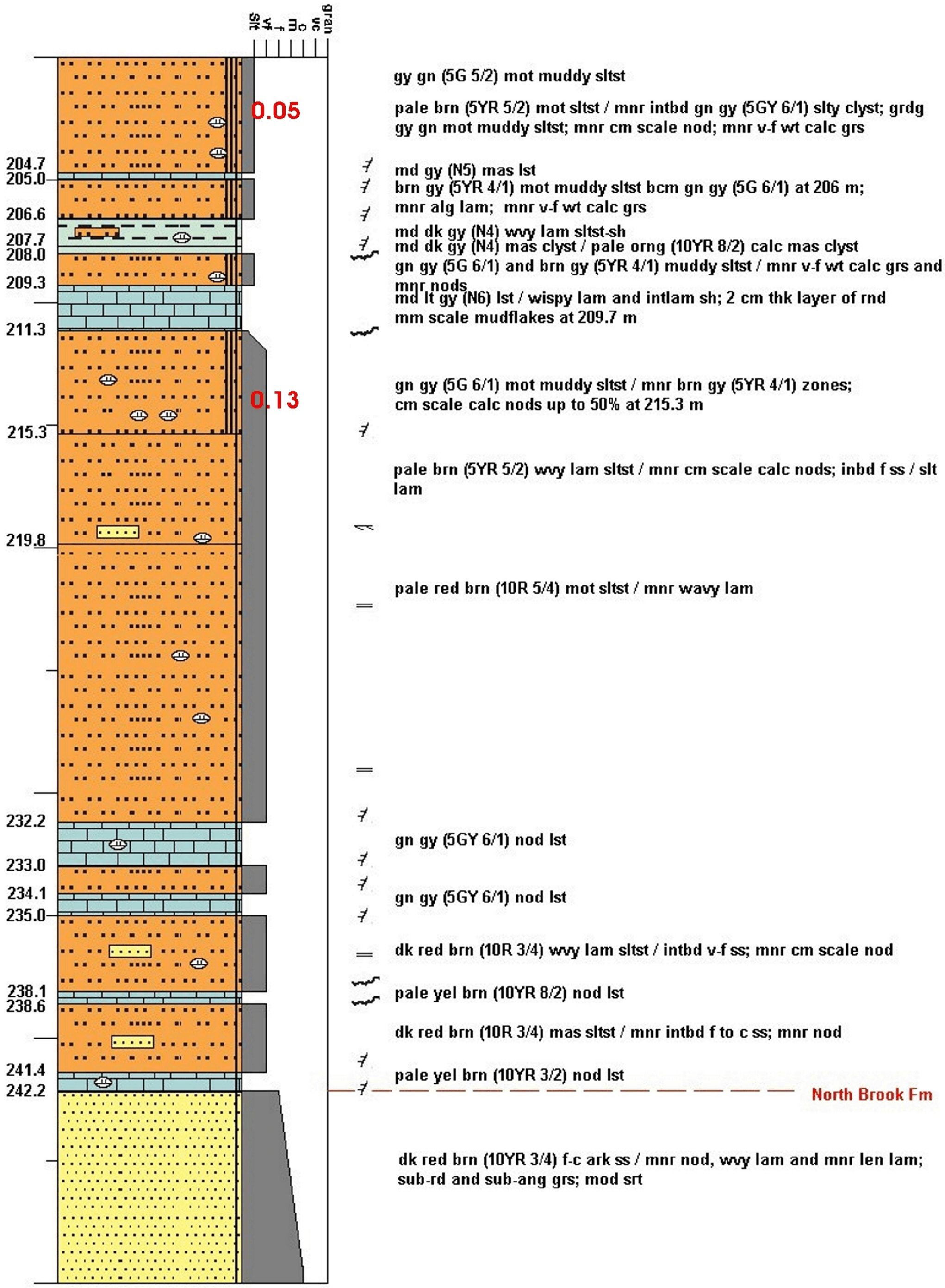
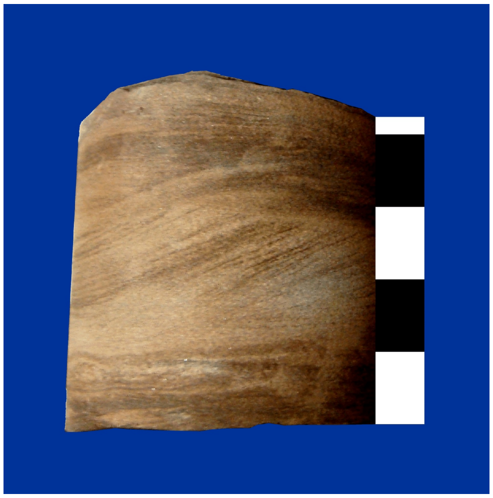


Figure 22: Lithologic log for core 0037 showing a nearly complete section of the Rocky Brook Formation. Red numbers are TOC % from analyses reported in Hamblin et al. (1997).

Figure 23: Thin, rippled, fine-medium grained sandstone in red siltstone (0037 ~219m). Scale bar is 1 cm.



A

B

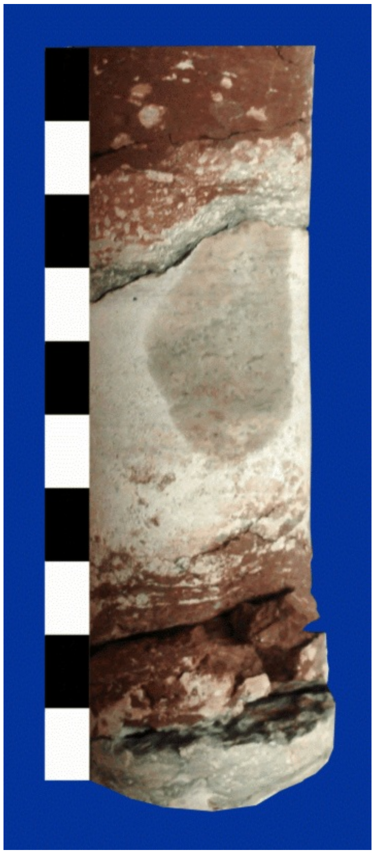


Figure 24: Two thin carbonate horizons near 230 m. In A, the thin beds are stretched, deformed and ruptured. In B, the thicker limestone bed is apparently more resistant to soft sediment deformation.

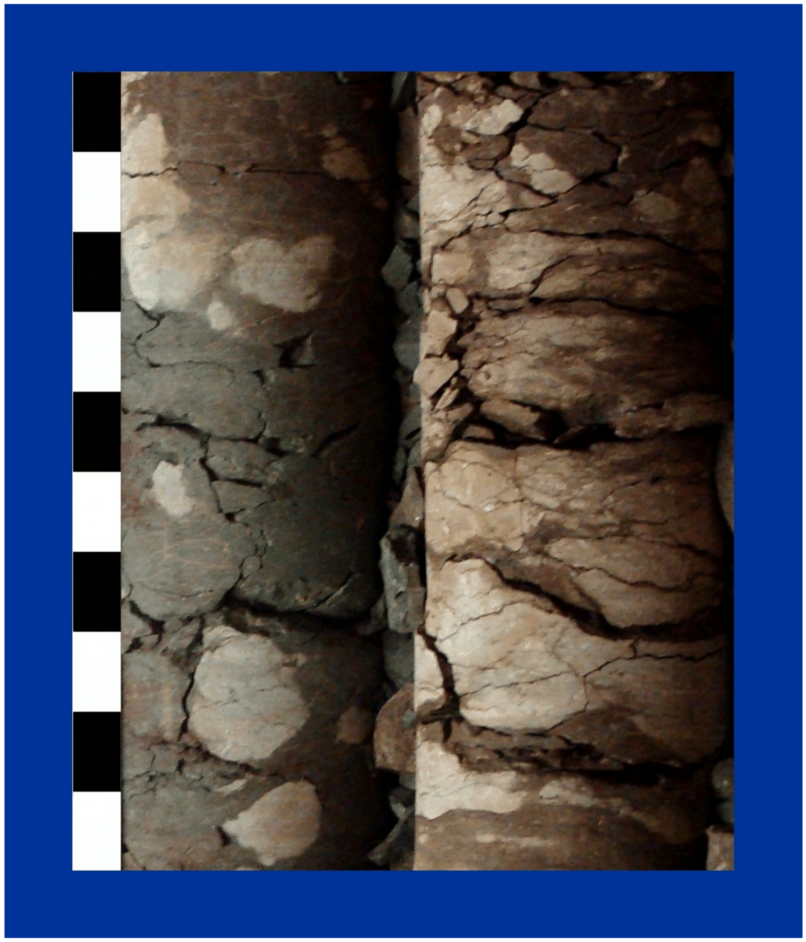
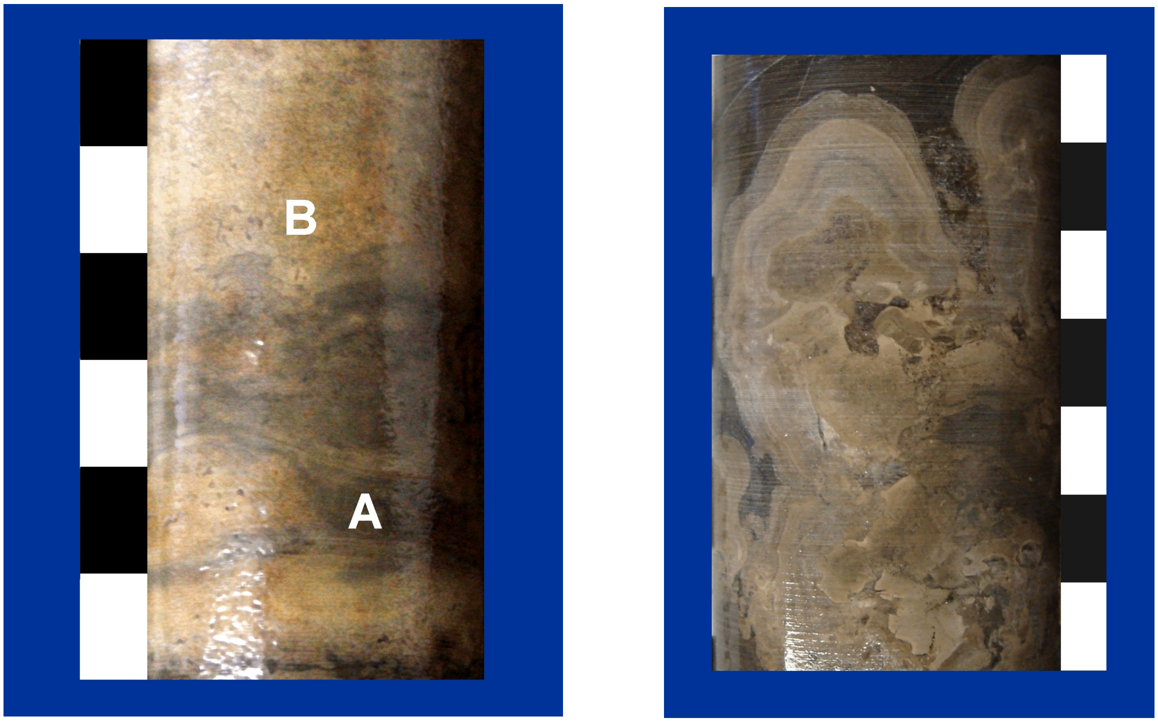


Figure 25: Mottled greyish green and grey brown siltstone with carbonate nodules.
0037- ~195 m.



A B

Figure 26: A. Peloidal and bioclastic packstone with surrounding algal laminae (A) and small vertical burrows to the left of (B). 0037- 47 m

B. Oncolitic stromatolite encasing and probably once using other carbonate clasts as a substrate. 0037 - 44.4 m

12/H6/0038

UTM: 475180 E 5467620 N

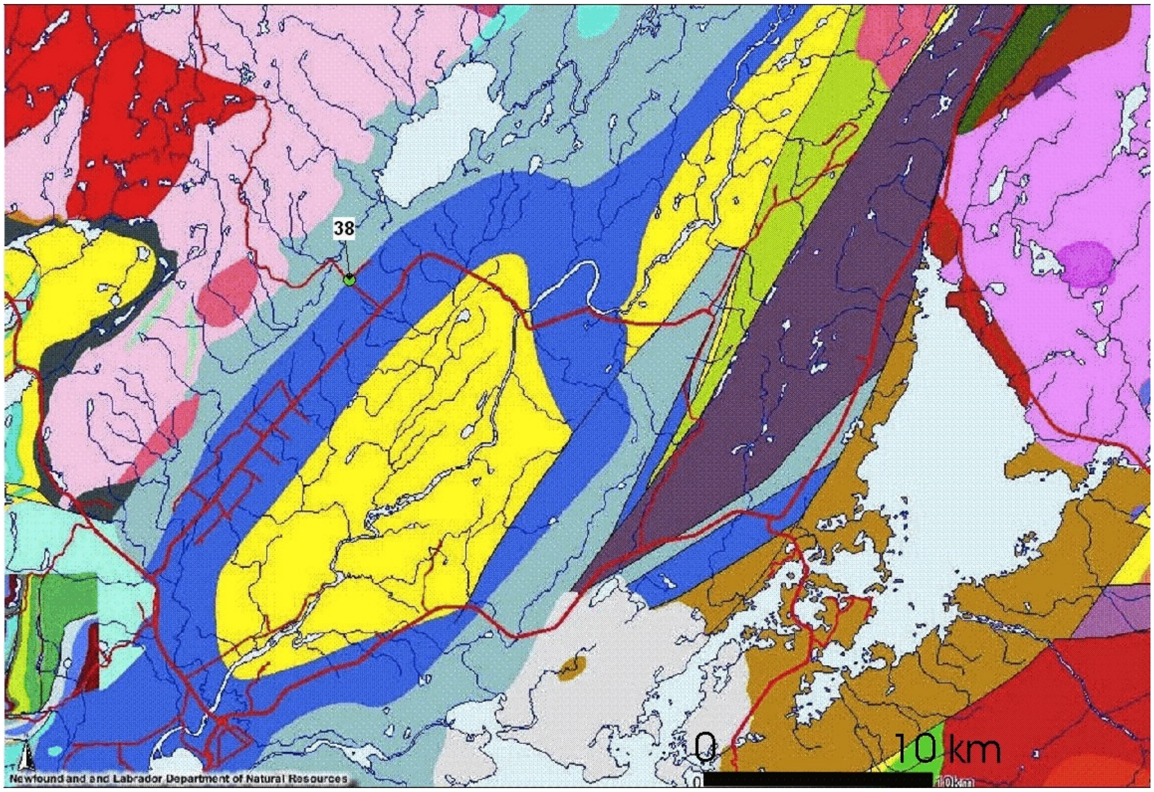


Figure 27: Location of hole 0038 (taken from Newfoundland and Labrador Ministry of Natural Resources website).

12/H6/0038
Azimuth/DIP: 90
DEPTH: 268.2 m

This long core (Figure 27), also known as Westfield Minerals 79-A-004, lies on the western edge of the basin about 5 km west of hole 0037. A site report by Tuach (1979) shows it was drilled as a test for the base Carboniferous contact - it was not reached. The top 55 m (Figure 28) of this core contains a record of the lower part of the Rocky Brook Formation from its basal contact with the red sandstones of the North Brook Formation and through the lowest red coloured siltstone beds. In total, and for this study, this core was examined to about 68 m in order to provide material to show similarities and differences between lower Rocky Brook and upper North Brook rocks.

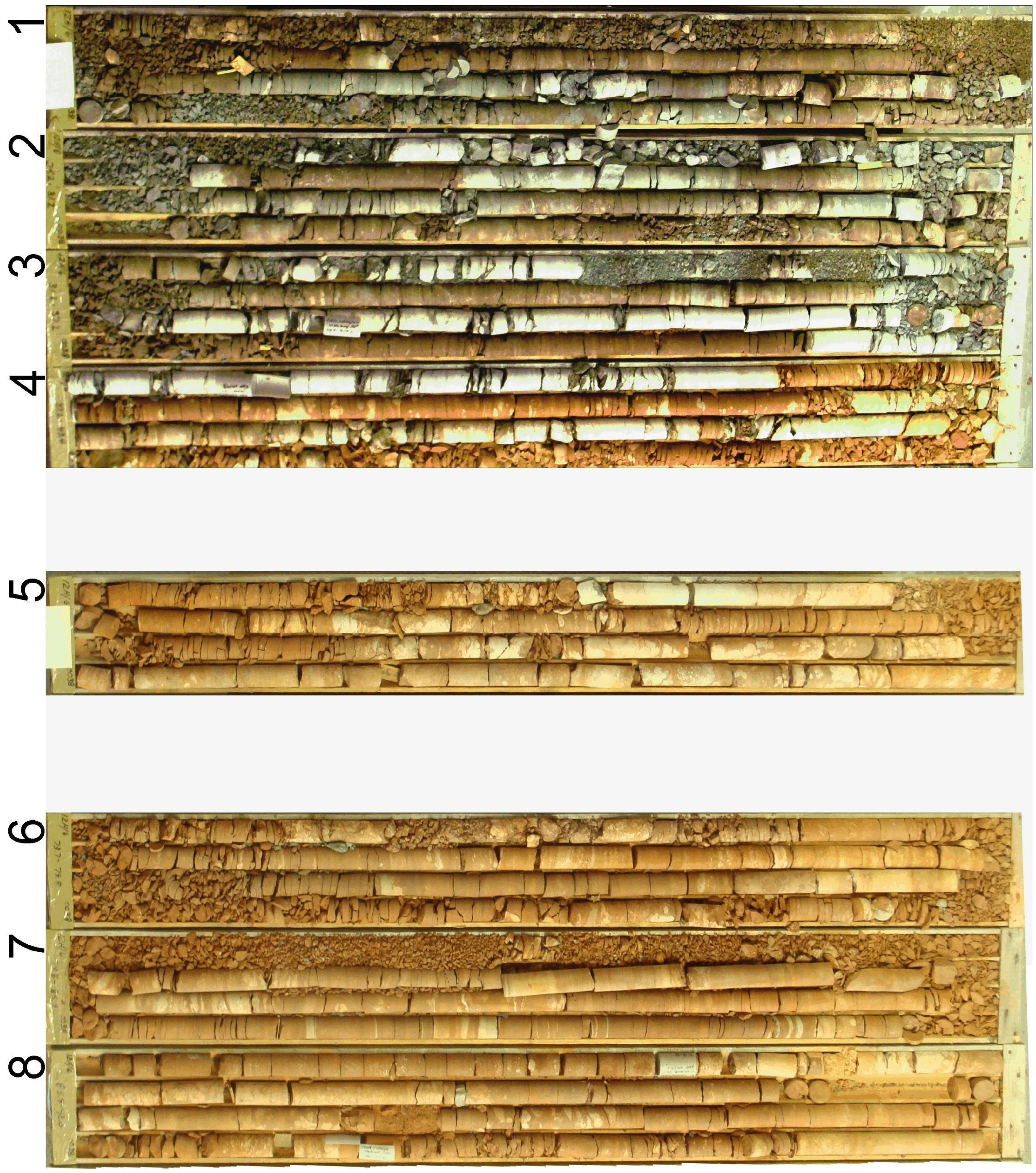


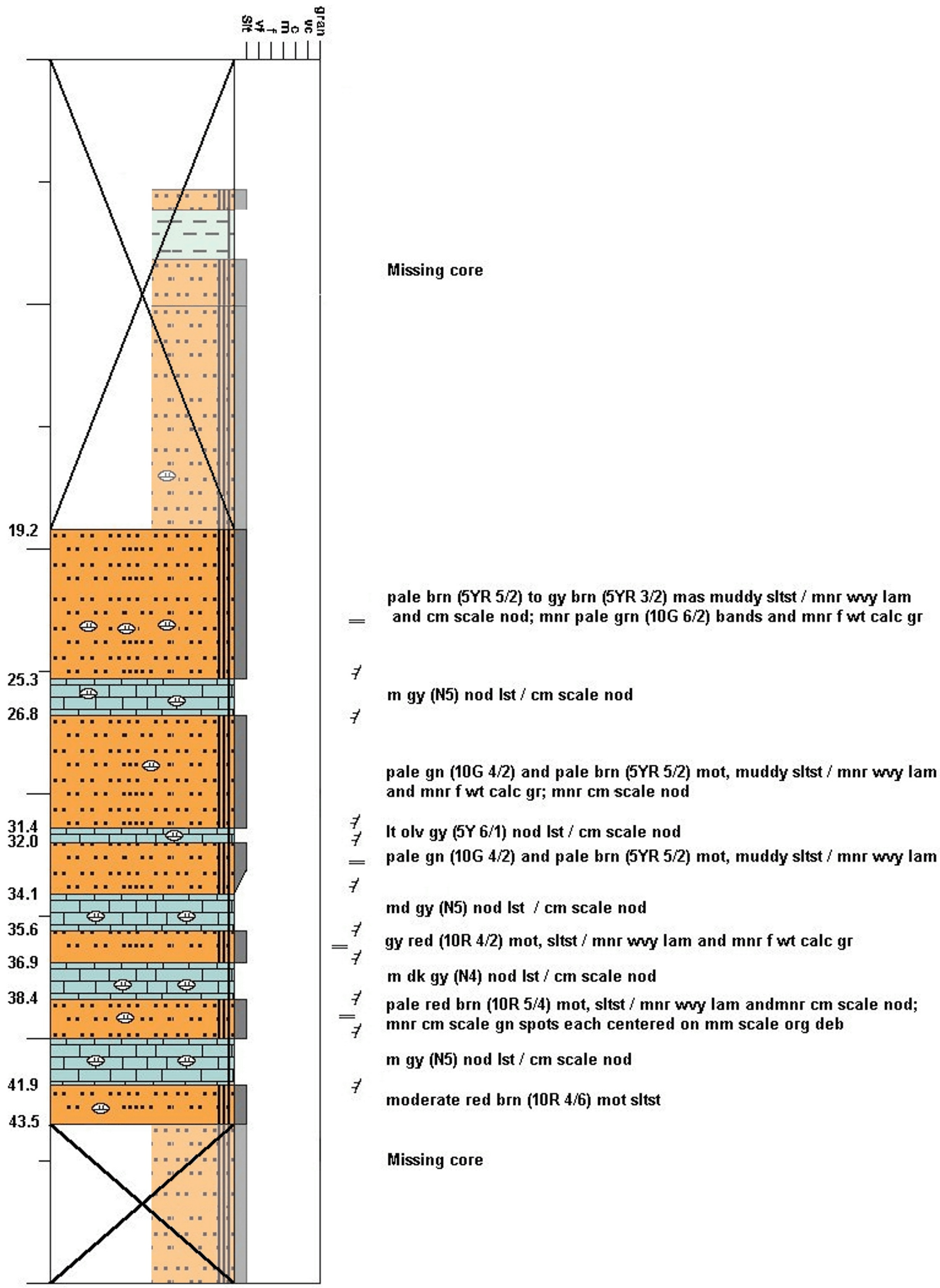
Figure 28: Boxes 1 through 8 of the top of borehole 0038, a long core aimed at sampling the base of the Carboniferous. The space surrounding Box 5 indicates lost or missing core that was described in the original drilling reports.

Strata of the North Brook Formation (Figure 29) from 55 m to a depth of about 140 m (not shown on this log, and where a prominent conglomerate bed occurs) are predominantly medium- and fine-grain sandstones (rarely coarse-grained) that are mostly dark to moderate red brown in colour. Beds are massive, graded and rippled (Figure 30). In a general sense, bedding through this upper part of the North Brook Formation, and to the contact at about 55 m, is presented as a thick, graded succession. Above 140 m, medium- and fine-grained sandstone beds from 4 to 10 m thick, are interbedded with minor 1 to 2 m moderate red brown siltstone beds. At the top of the formation and near 55 m, fine and medium grained sandstones are thinner, 1 to 4 m beds with 1 to 6 m siltstone. Coincident with the increase in siltstone beds, and over this same interval, widely spaced pale brown, white and pale grey limestone beds less than 1 m thick first appear at about 130 m as thin interlaminated limestone and siltstone separating sandstone beds. At about 107 m these limestone beds become more massive and nodular, in part brecciated and with root casts. Above 70 m and on into the overlying Rocky Brook Formation, limestone beds can be massive or nodular, occasionally laminated, and separating siltstone beds.

O'Sullivan (1979) places the contact for the top of the North Brook Formation at the top of a 1 m sandstone bed at about 55 m. This is part of the missing core material and could not be confirmed.

Less than 25 m of lower Rocky Brook Formation is available for viewing. These rocks consist of 1 to 6 m thick beds of pale red, pale brown and pale green laminated, massive, mottled, and occasionally muddy, siltstone with 60 cm to 1.9 m beds of grey and grey green nodular limestone and calcareous concretions.

There are no radiometric anomalies reported from O'Sullivan's survey of this hole. These red oxidized strata indicate little possibility for recovery of organic matter.



slt
vf
f
m
c
vc
gran
Missing core
19.2
pale brn (5YR 5/2) to gy brn (5YR 3/2) mas muddy sltst / mnr wvy lam and cm scale nod; mnr pale grn (10G 6/2) bands and mnr f wt calc gr
25.3
m gy (N5) nod lst / cm scale nod
26.8
pale gn (10G 4/2) and pale brn (5YR 5/2) mot, muddy sltst / mnr wvy lam and mnr f wt calc gr; mnr cm scale nod
31.4
lt olv gy (5Y 6/1) nod lst / cm scale nod
32.0
pale gn (10G 4/2) and pale brn (5YR 5/2) mot, muddy sltst / mnr wvy lam
34.1
md gy (N5) nod lst / cm scale nod
35.6
gy red (10R 4/2) mot, sltst / mnr wvy lam and mnr f wt calc gr
36.9
m dk gy (N4) nod lst / cm scale nod
38.4
pale red brn (10R 5/4) mot, sltst / mnr wvy lam andmnr cm scale nod; mnr cm scale gn spots each centered on mm scale org deb
m gy (N5) nod lst / cm scale nod
41.9
moderate red brn (10R 4/6) mot sltst
43.5
Missing core

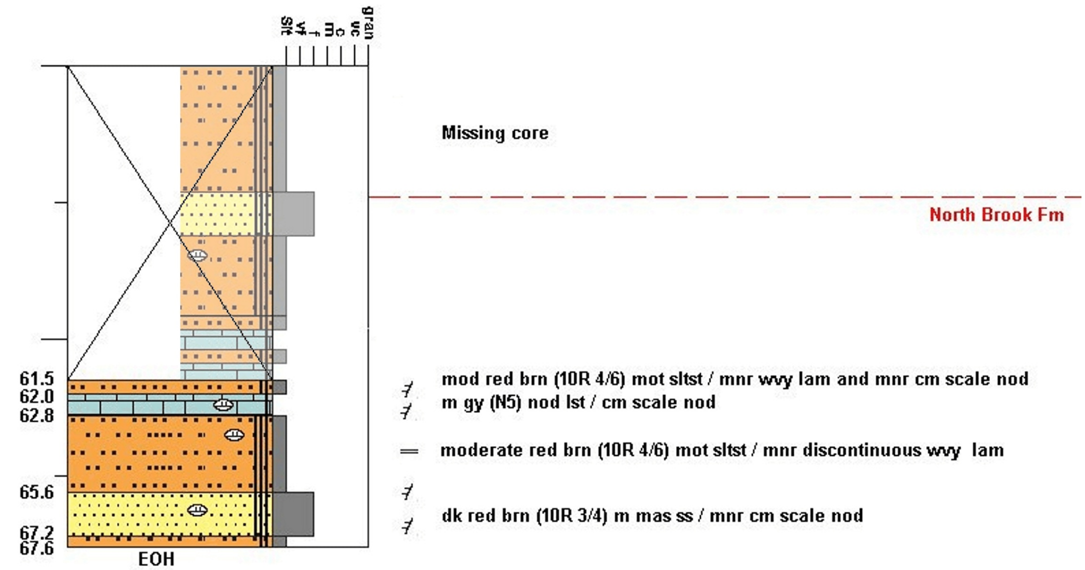


Figure 29: Lithologic log for core 0038 showing red-brown sandstones and siltstones of the top of the North Brook Formation and pale red-brown and grey-brown siltstones of the lower part of the Rocky Brook Formation. Missing intervals described by O'Sullivan (1979a) are schematically illustrated. The entire core, not shown here is 268 m in length.

Figure 30: North Brook Formation red brown sandstone and conglomeratic sandstone from about 77 m. A sharp irregular surface separates fine- and medium-grained, rippled sandstone from a graded bed of coarse-grained and conglomeratic sandstone.

12/H6/0039

UTM: 472100 E 5459410 N

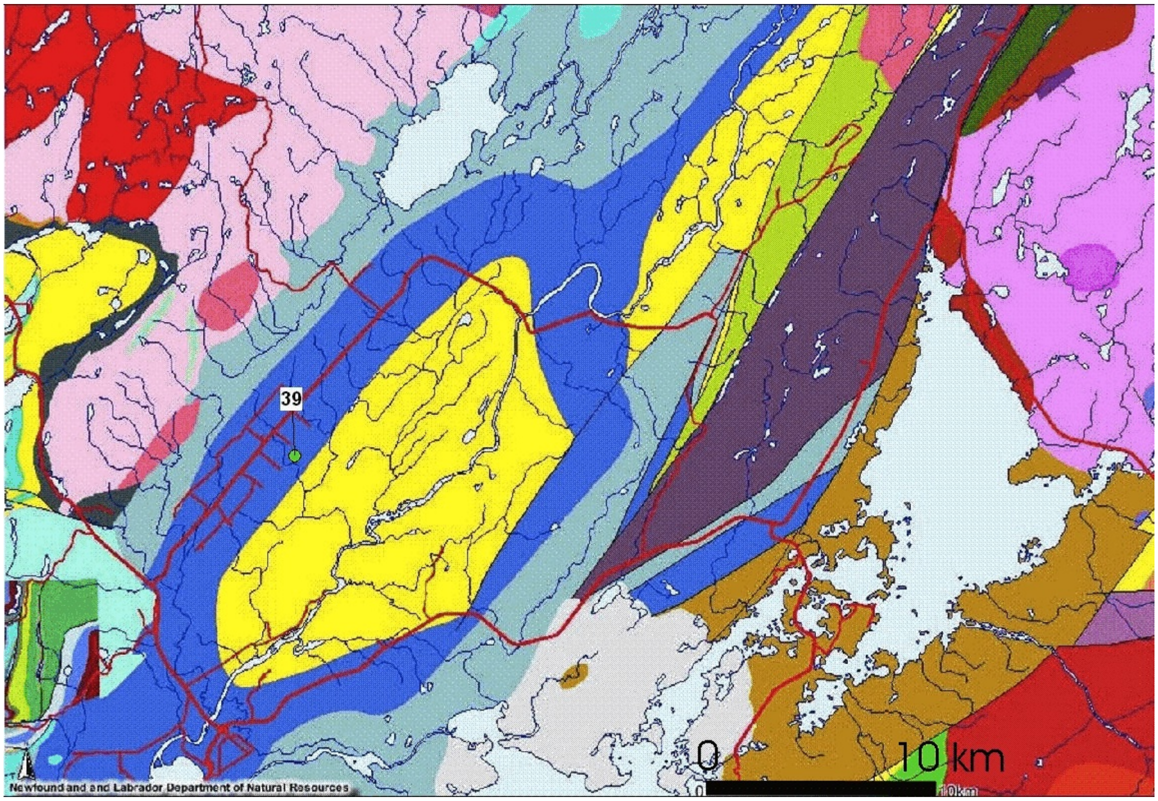


Figure 31: Location of hole 0039 (taken from Newfoundland and Labrador Ministry of Natural Resources website)

12/H6/0039
Azimuth/Dip: 000/90
Depth: 289.5 m

Hole 12H/06/0039, also known as Northgate Exploration DDH 79A-005,is located on the western-central part of the basin and on the southeast dipping, northwest limb of the Humber Syncline (Figure 31). The outcrop in the vicinity of this site and for several kilometres along strike and down dip into the centre of the basin is dipping less than 10º. Five kilometres to the southeast, near the banks of the Humber River, and on the axis of the Humber Syncline, is borehole 12H/06/0036 (Figure 2). Here, the base of the nearly flat lying Humber Falls Formation is at 248 m depth.

This long core (Figure 32) contains a nearly complete record of the Rocky Brook

Figure 32: Colour patterns on core 0039 crudely differentiate the reddish coloured Spillway Member (boxes 21-45) from the overlying grey and dark grey Squires Park Member (boxes 1-20). A detailed photographic log is in the Appendix 4.

Formation from a position high in the Squires Park Member to a point marking a transition to brown or red siltstones in the Spillway member and near the base of the formation. Neither the top nor bottom of the formation was penetrated, therein implying that the Rocky Brook Formation is at least 300 m thick in this area.

With a small zone of missing core considered, the basal 10 m of hole 0039 and up to 269 m (Figure 33) consists of about 10 m of nodular and laminated, light and medium grey siltstone and shale with thin, oxidized, yellow-brown and -orange horizons. Thin beds of oolitic grainstone form some interbeds in the lower part of this light coloured muddy interval. Bedding is dipping about 20º.

Between 269 and about 215 m, the strata occur as massive and laminated, medium (N4) and dark grey (N3) shale in beds up to 7.5 m thick. One bed, at about 230 m contains many small carbonate nodules. Shale beds are in sharp contact with siltstone beds that can be over 6 m thick. Siltstone beds are mottled in appearance and slightly calcareous in composition. They apparently occur as two thickening (and coarsening?) upward successions bounded by a light olive grey shale at about 251 m. The lower succession consists of medium grey and grey brown colour siltstones, whereas the overlying succession contains grey red coloured siltstone.

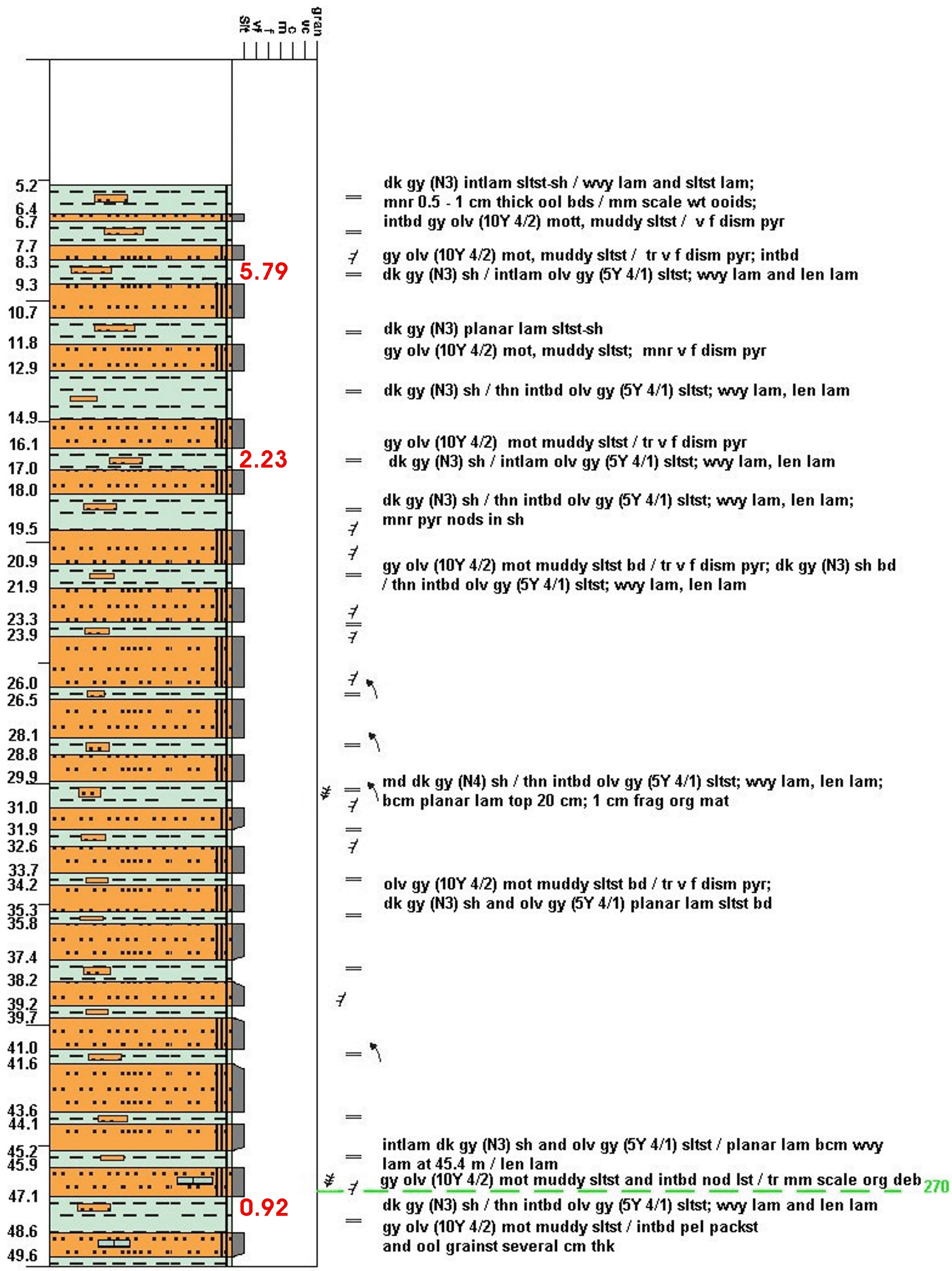
Strata lying between about 215 and 144.8 m are generally darker than the underlying mottled beds. Massive and laminated shale beds, and sometimes with traces of calcite, are always less than 2 m in thickness. They are typically medium dark grey (N4) in colour, with a smaller subset being very dark grey (N3), medium grey and olive grey. Adjacent siltstone beds are frequently in sharp contact with shale. Some siltstone beds can contain traces of disseminated pyrite. These greenish grey and olive grey beds are typically less than 2 m thick, but a few may be as many as 6 m thick. Bedding patterns are suggestive of graded thickening and coarsening upward cycles that may be 10 to 20 m in thickness.

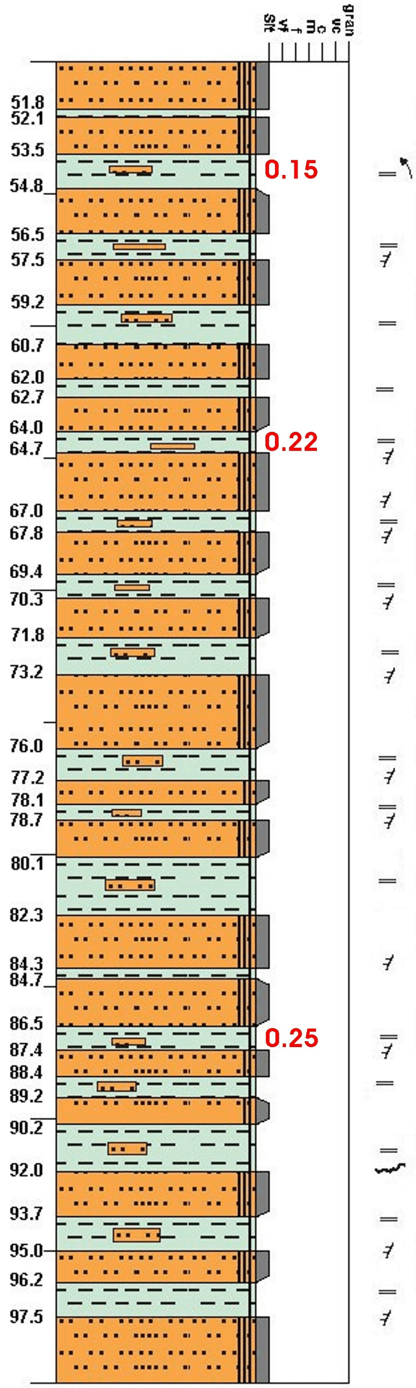
Siltstone beds found between 144.8 m and 123.3 m are mottled and slightly calcareous rocks with a brownish grey colour. Individual siltstones may be as many as 4.4 m thick, but most are between 1 and 2 m thickness. The basal contact is generally transitional with shale; the upper contact is sharp and sometimes obviously scoured. Interbedded massive and laminated shale beds are light grey at the bottom of this part of the succession, becoming dark grey (N3) at the top. Nearly all of these beds are less than 1 m thick. A small piece of degraded wood with a pyrite rim (Figure 34) is one of the few bits of macrofossil debris found in this core.

The top of this core from 123.3 m to 5.2 m is greyish olive, mottled, slightly calcareous siltstone interbedded with medium dark grey shale (N4) grading into dark grey (N3), massive and laminated shale. Siltstone beds vary from about 1 m thickness to just over 3 m. Shale beds are slightly thinner and range from 0.5 m to just over 2 m thickness. Small amounts of disseminated pyrite and tiny coalified plant fragments are present in both siltstone and shale, and particularly in the upper part of this core where more of the dark grey shale beds are found. One of the shale beds at about 91 m contains broken siltstone fragments that have been rolled into a ball (Figure 35). Two thin bands of carbonate grainstone and packstone interbeds and nodules occur at about 46 m and 111 m.   Beds in the upper part of the core dip between 5^{o} and 10^{o}.

There are four slightly radioactive horizons identified by O'Sullivan (1979b) at 47.1, 172.2, 174.0, and 184.9 m; they have values of 270, 850, 300, and 200 CPS respectively. For organic matter, Hamblin et al. (1997) show only two beds of dark grey (N3) siltstone-shale with TOC values that can be considered viable source rocks. These are found at 8.3 m (5.79%) and 9.3 m (2.30%). Nearly all of the other TOC values reported in Hamblin et al. (1997) are less than 1.0% . If amorphous material identified in the Hamblin et al (1997) study is considered alongside the TOC values, the top and bottom of the Squires Park Member may be good candidates for source rock horizons.

In our use of colour as a proxy measure of TOC, and generously considering all of the N3 and darker muddy strata as silt free, as much as 32% of the dark shale beds of the Squires Park Member and 8% of the Spillway Member could be considered potential source rocks. In reality, and considering the overall silty nature of these thin shale beds, the quantity of source rock in hole 0039 is likely very much smaller and confined to the thicker shale horizons at the top and bottom of the Squires Park Member.


slt
vf
f
m
c
vc
gran
5.2
6.4
6.7
7.7
8.3
9.3
10.7
11.8
12.9
14.9
16.1
17.0
18.0
19.5
20.9
21.9
23.3
23.9
26.0
26.5
28.1
28.8
29.9
31.0
31.9
32.6
33.7
34.2
35.3
35.8
37.4
38.2
39.2
39.7
41.0
41.6
43.6
44.1
45.2
45.9
47.1
48.6
49.6
5.79
2.23
0.92
270
dk gy (N3) intlam sltst-sh / wvy lam and sltst lam;
mnr 0.5 - 1 cm thick ool bds / mm scale wt ooids;
intbd gy olv (10Y 4/2) mott, muddy sltst / v f dism pyr
gy olv (10Y 4/2) mot, muddy sltst / tr v f dism pyr; intbd
dk gy (N3) sh / intlam olv gy (5Y 4/1) sltst; wvy lam and len lam
dk gy (N3) planar lam sltst-sh
gy olv (10Y 4/2) mot, muddy sltst; mnr v f dism pyr
dk gy (N3) sh / thn intbd olv gy (5Y 4/1) sltst; wvy lam, len lam
gy olv (10Y 4/2) mot muddy sltst / tr v f dism pyr
dk gy (N3) sh / intlam olv gy (5Y 4/1) sltst; wvy lam, len lam
dk gy (N3) sh / thn intbd olv gy (5Y 4/1) sltst; wvy lam, len lam;
mnr pyr nods in sh
gy olv (10Y 4/2) mot muddy sltst bd / tr v f dism pyr; dk gy (N3) sh bd
/ thn intbd olv gy (5Y 4/1) sltst; wvy lam, len lam
md dk gy (N4) sh / thn intbd olv gy (5Y 4/1) sltst; wvy lam, len lam;
bcm planar lam top 20 cm; 1 cm frag org mat
olv gy (10Y 4/2) mot muddy sltst bd / tr v f dism pyr;
dk gy (N3) sh and olv gy (5Y 4/1) planar lam sltst bd
intlam dk gy (N3) sh and olv gy (5Y 4/1) sltst / planar lam bcm wvy
lam at 45.4 m / len lam
gy olv (10Y 4/2) mot muddy sltst and intbd nod lst / tr mm scale org deb
dk gy (N3) sh / thn intbd olv gy (5Y 4/1) sltst; wvy lam and len lam
gy olv (10Y 4/2) mot muddy sltst / intbd pel packst
and ool grainst several cm thk



gy olv (10Y 4/2) mot, muddy sltst bds and dk gy (N3) planar lam sltst-sh

dk gy (N3) sh / intlam dk gn gy (5GY 4/1) sltst; planar lam and mnr v-f dism pyr in sh

gy olv (10Y 4/2) mot, muddy sltst / mnr v f to f wt calc grs and tr v f dism pyr

gy olv (10Y 4/2) mot, muddy sltst bds / mnr v f to f wt calc grsand tr v f dism pyr and dk gy (N3) planar lam sltst-sh bds

gy olv (10Y 4/2) mot, calc, muddy sltst / mnr v f to f wt calc gr

dk gy (N3) sh / intlam dk gn gy (5GY 4/1) sltst; planar lam

gy olv (10Y 4/2) mot, muddy sltst / mnr v f to f wt calc gr; intv of dk yel brn (10YR 4/2) muddy sltst fm 65.5 to 66.5 m.

gy olv (10Y 4/2) mot, muddy sltst bds / mnr v f to f wt calc gr and dk gy (N3) sh and intbd dk gn gy (5GY 4/1) sltst bds / planar lam

gy olv (10Y 4/2) mot, muddy sltst grdg dk yel brn (10YR 4/2)

dk gy (N3) planar lam sltst-sh

gy olv (10Y 4/2) mot, muddy sltst, grdg dk yel brn (10YR 4/2)

dk gy (N3) sltst-sh / wvy lam and len lam

gy olv (10Y 4/2) mot, muddy sltst bd grdg dk yel brn (10YR 4/2) and dk gy (N3) sltst-sh / wvy lam and len lam

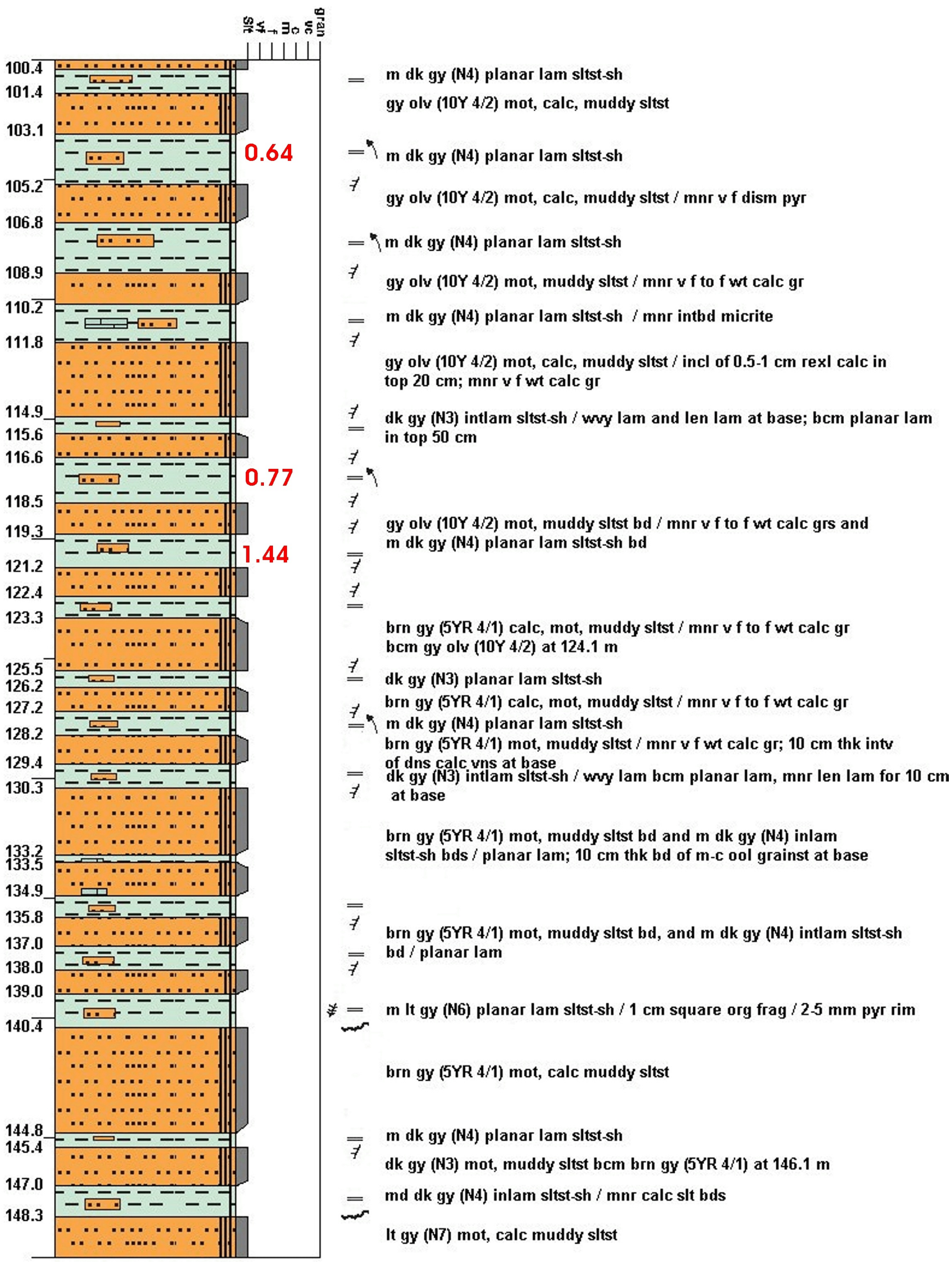
dk gy (N3) sltst-sh bds / wvy lam and len lam oriented 80° to core axis

gy olv (10Y 4/2) mot, muddy sltst / mnr intbd dk yel brn (10YR 4/2) muddy sltst

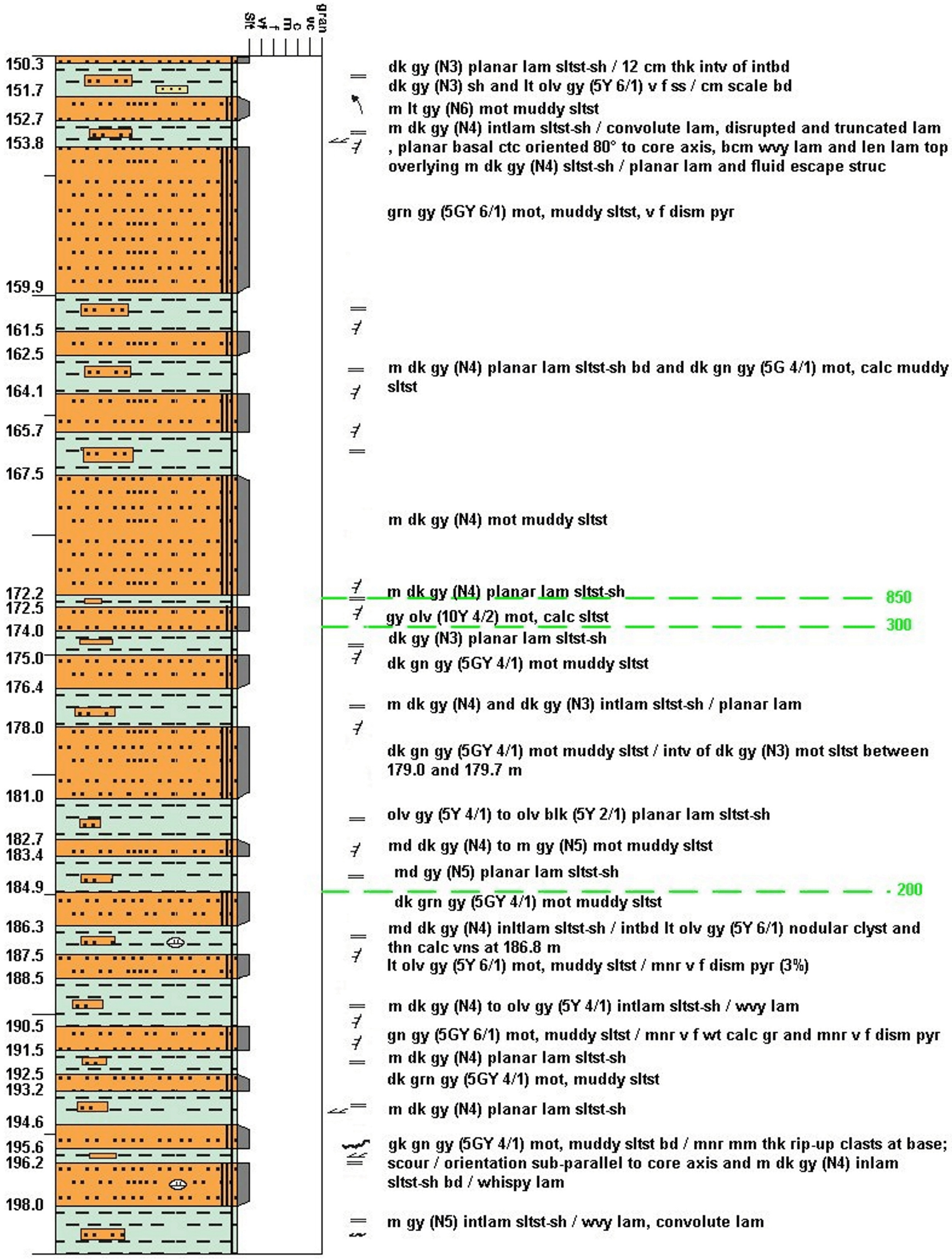
gy olv (10Y 4/2) mot, muddy sltst bds / mnr v f wt calc grs, and dk gy (N3) planar lam sltst-sh bds

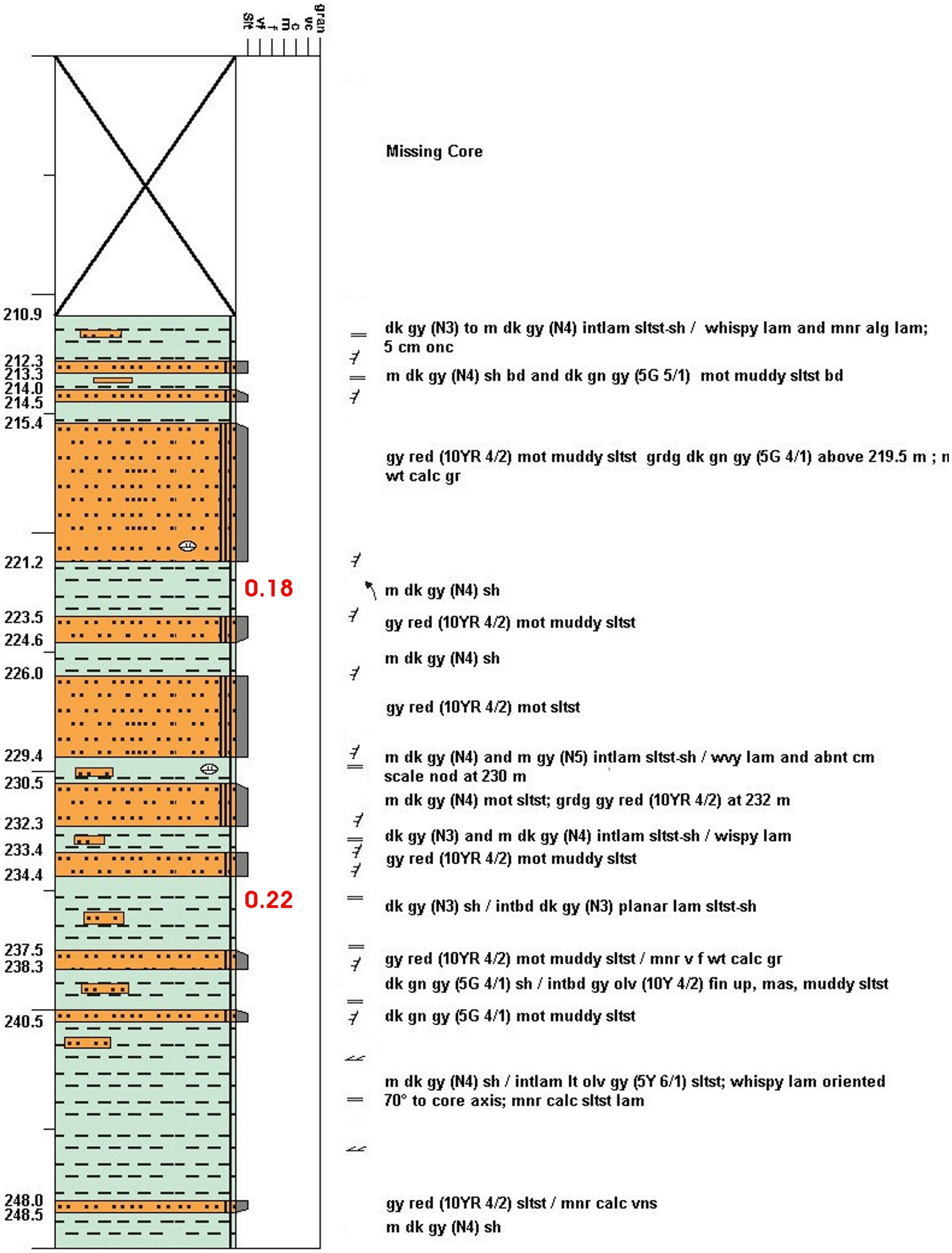
dk gy (N3) sltst-sh / wvy lam and len lam; 3cm thick layer of mm scale mudflakes swirled around each other, resembling "tumbleweed"

gy olv (10Y 4/2) calc mot, muddy sltst bds / mnr v f dism pyr, and dk gy (N3) sltst-sh bds / calc slst; wvy lam and len lam oriented 85° to core axis



slt vf f m c vc gran
100.4
101.4
103.1
105.2
106.8
108.9
110.2
111.8
114.9
115.6
116.6
118.5
119.3
121.2
122.4
123.3
125.5
126.2
127.2
128.2
129.4
130.3
133.2
133.5
134.9
135.8
137.0
138.0
139.0
140.4
144.8
145.4
147.0
148.3
0.64
0.77
1.44
m dk gy (N4) planar lam sltst-sh
gy olv (10Y 4/2) mot, calc, muddy sltst
m dk gy (N4) planar lam sltst-sh
gy olv (10Y 4/2) mot, calc, muddy sltst / mnr v f dism pyr
m dk gy (N4) planar lam sltst-sh
gy olv (10Y 4/2) mot, muddy sltst / mnr v f to f wt calc gr
m dk gy (N4) planar lam sltst-sh / mnr intbd micrite
gy olv (10Y 4/2) mot, calc, muddy sltst / incl of 0.5-1 cm rexl calc in top 20 cm; mnr v f wt calc gr
dk gy (N3) intlam sltst-sh / wvy lam and len lam at base; bcm planar lam in top 50 cm
gy olv (10Y 4/2) mot, muddy sltst bd / mnr v f to f wt calc grs and m dk gy (N4) planar lam sltst-sh bd
brn gy (5YR 4/1) calc, mot, muddy sltst / mnr v f to f wt calc gr bcm gy olv (10Y 4/2) at 124.1 m
dk gy (N3) planar lam sltst-sh
brn gy (5YR 4/1) calc, mot, muddy sltst / mnr v f to f wt calc gr
m dk gy (N4) planar lam sltst-sh
brn gy (5YR 4/1) mot, muddy sltst / mnr v f wt calc gr; 10 cm thk intv of dns calc vns at base
dk gy (N3) intlam sltst-sh / wvy lam bcm planar lam, mnr len lam for 10 cm at base
brn gy (5YR 4/1) mot, muddy sltst bd and m dk gy (N4) inlam sltst-sh bds / planar lam; 10 cm thk bd of m-c ool grainst at base
brn gy (5YR 4/1) mot, muddy sltst bd, and m dk gy (N4) intlam sltst-sh bd / planar lam
m lt gy (N6) planar lam sltst-sh / 1 cm square org frag / 2-5 mm pyr rim
brn gy (5YR 4/1) mot, calc muddy sltst
m dk gy (N4) planar lam sltst-sh
dk gy (N3) mot, muddy sltst bcm brn gy (5YR 4/1) at 146.1 m
md dk gy (N4) inlam sltst-sh / mnr calc slt bds
lt gy (N7) mot, calc muddy sltst


slt vf f m c vc gran
150.3
151.7
152.7
153.8
159.9
161.5
162.5
164.1
165.7
167.5
172.2
172.5
174.0
175.0
176.4
178.0
181.0
182.7
183.4
184.9
186.3
187.5
188.5
190.5
191.5
192.5
193.2
194.6
195.6
196.2
198.0
dk gy (N3) planar lam sltst-sh / 12 cm thk intv of intbd
dk gy (N3) sh and lt olv gy (5Y 6/1) v f ss / cm scale bd
m lt gy (N6) mot muddy sltst
m dk gy (N4) intlam sltst-sh / convolute lam, disrupted and truncated lam
, planar basal ctc oriented 80° to core axis, bcm wvy lam and len lam top
overlying m dk gy (N4) sltst-sh / planar lam and fluid escape struc
grn gy (5GY 6/1) mot, muddy sltst, v f dism pyr
m dk gy (N4) planar lam sltst-sh bd and dk gn gy (5G 4/1) mot, calc muddy sltst
m dk gy (N4) mot muddy sltst
m dk gy (N4) planar lam sltst-sh
850
gy olv (10Y 4/2) mot, calc sltst
300
dk gy (N3) planar lam sltst-sh
dk gn gy (5GY 4/1) mot muddy sltst
m dk gy (N4) and dk gy (N3) intlam sltst-sh / planar lam
dk gn gy (5GY 4/1) mot muddy sltst / intv of dk gy (N3) mot sltst between 179.0 and 179.7 m
olv gy (5Y 4/1) to olv blk (5Y 2/1) planar lam sltst-sh
md dk gy (N4) to m gy (N5) mot muddy sltst
md gy (N5) planar lam sltst-sh
200
dk grn gy (5GY 4/1) mot muddy sltst
md dk gy (N4) inltlam sltst-sh / intbd lt olv gy (5Y 6/1) nodular clyst and thn calc vns at 186.8 m
lt olv gy (5Y 6/1) mot, muddy sltst / mnr v f dism pyr (3%)
m dk gy (N4) to olv gy (5Y 4/1) intlam sltst-sh / wvy lam
gn gy (5GY 6/1) mot, muddy sltst / mnr v f wt calc gr and mnr v f dism pyr
m dk gy (N4) planar lam sltst-sh
dk grn gy (5GY 4/1) mot, muddy sltst
m dk gy (N4) planar lam sltst-sh
gk gn gy (5GY 4/1) mot, muddy sltst bd / mnr mm thk rip-up clasts at base; scour / orientation sub-parallel to core axis and m dk gy (N4) inlam sltst-sh bd / whispy lam
m gy (N5) intlam sltst-sh / wvy lam, convolute lam



slt vf f m c vc gran
Missing Core
210.9
dk gy (N3) to m dk gy (N4) intlam sltst-sh / whispy lam and mnr alg lam; 5 cm onc
212.3
213.3
214.0
214.5
m dk gy (N4) sh bd and dk gn gy (5G 5/1) mot muddy sltst bd
215.4
gy red (10YR 4/2) mot muddy sltst grdg dk gn gy (5G 4/1) above 219.5 m ; n wt calc gr
221.2
0.18
m dk gy (N4) sh
223.5
gy red (10YR 4/2) mot muddy sltst
224.6
m dk gy (N4) sh
226.0
gy red (10YR 4/2) mot sltst
229.4
m dk gy (N4) and m gy (N5) intlam sltst-sh / wvy lam and abnt cm scale nod at 230 m
230.5
m dk gy (N4) mot sltst; grdg gy red (10YR 4/2) at 232 m
232.3
dk gy (N3) and m dk gy (N4) intlam sltst-sh / wispy lam
233.4
gy red (10YR 4/2) mot muddy sltst
234.4
0.22
dk gy (N3) sh / intbd dk gy (N3) planar lam sltst-sh
237.5
238.3
gy red (10YR 4/2) mot muddy sltst / mnr v f wt calc gr
dk gn gy (5G 4/1) sh / intbd gy olv (10Y 4/2) fin up, mas, muddy sltst
240.5
dk gn gy (5G 4/1) mot muddy sltst
m dk gy (N4) sh / intlam lt olv gy (5Y 6/1) sltst; whispy lam oriented 70° to core axis; mnr calc sltst lam
248.0
248.5
gy red (10YR 4/2) sltst / mnr calc vns
m dk gy (N4) sh

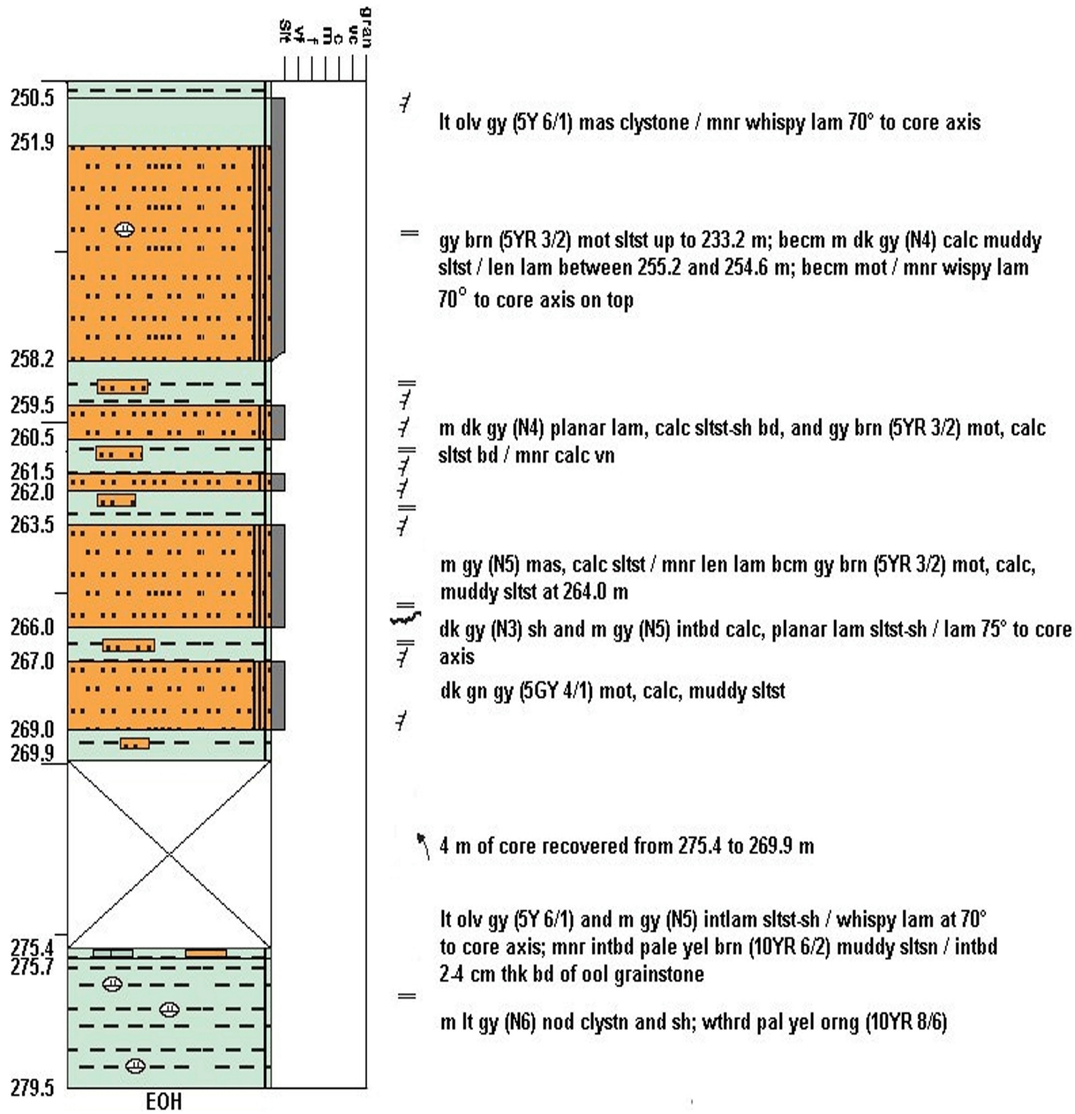


Figure 33: Lithologic log for core 0039 showing the Spillway Member as a succession of grey brown and grey red siltstone, lower greenish grey and dark grey siltstone and shale, and brown grey siltstone. This is overlain by a thick succession of greyish olive siltstone and dark grey shale of the Squires Park Member.

Figure 34: Coalified organic debris with pyrite rim within siltstone-shale

Figure 35: Rolled mud flakes within dark grey shale (0039 at ~91 m).

Altius Resources Core

Three cores, RB-06-130, RB-06-139 and RB-06-140, from an ongoing Altius exploration programme in the vicinity of Birchy Hill Brook and Wigwam Brook were examined on site (Figure 36). Locally, outcrop on river banks and subcrop from drill holes is shallow dipping beds belonging to the Humber Falls Formation. The eastern edge of this area, near holes RB-06-139 and RB-06-140 lies close to the footwall of the Wigwam Fault. In an earlier round of uranium exploration about 100 holes were drilled in this area (Patterson, 1981). Today, in consultation with Altius staff, the new cores selected for analysis all contain intersections with the Rocky Brook Formation. The holes are 93.4 m, 99.92 m and 39.92 m in length; all are at a 45º incline. Four samples were collected for Rock-eval analysis (Appendix 2).

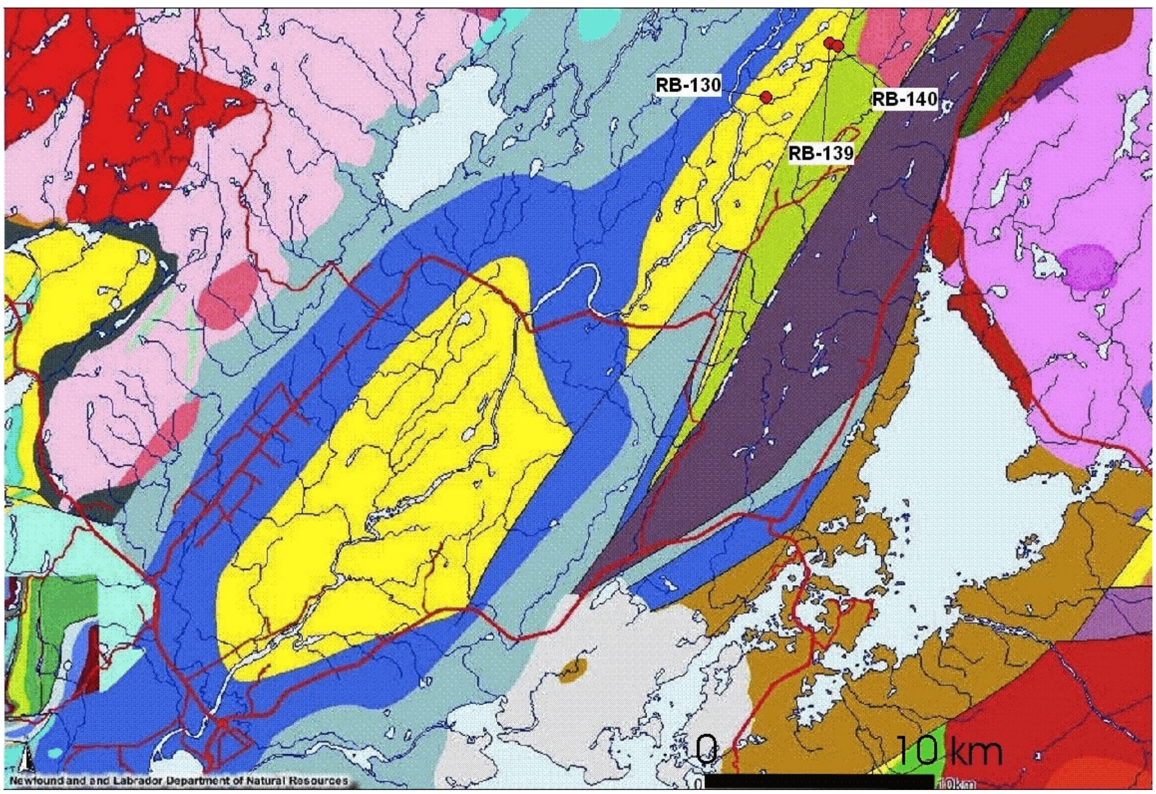


Figure 36: Altius cores RB-130, RB-139 and RB-140 are a part of an ongoing exploration programme on a claim block first drilled in the 1970's.

RB-06-130

UTM: 494391 E 5476118 N

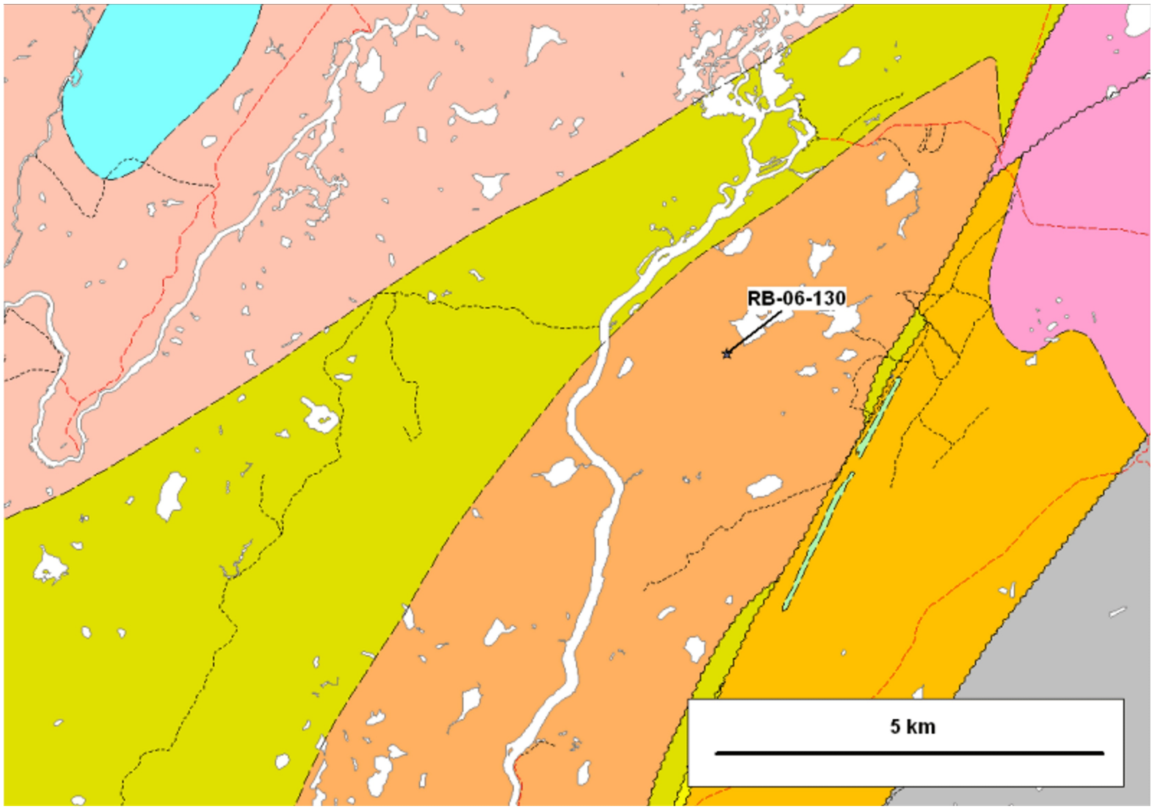


Figure 37: Location of RB-06-130. Map courtesy of Altius Resources Inc

RB-06-130
Azimuth/Dip: 320/45
Depth: 93.4 m

Hole RB-06-130 lies on the southwest end of a small pond in a line of (fault controlled?) ponds extending about 5 km to the northeast (Figure 37). Many of the cores collected across this area and during earlier exploration programmes contain about 50 to 100 m of Humber Falls Formation before entering the Rocky Brook Formation. This drill hole is no different. The upper 50 m for core RB-06-130 is moderate red to grayish orange pink fine- to coarse-grained arkosic sandstone and polymictic pebble conglomerate of the Humber Falls Formation (Figure 38). Below that, there lies dark greenish grey siltstone, dark grey shale and dark grey siltstone-shale of the Rocky Brook

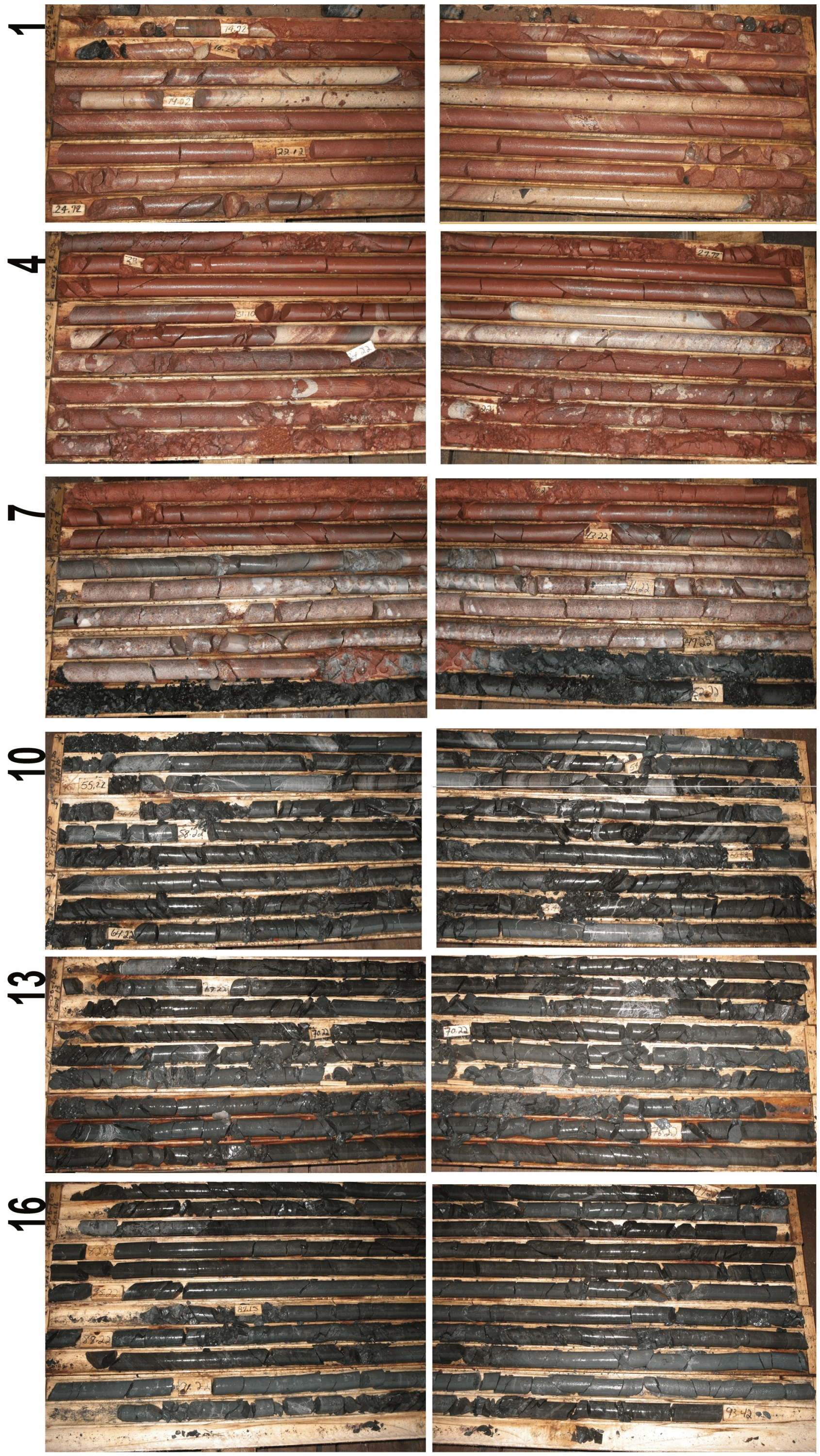


Figure 38: Entire core from RB-06-130. Top and bottom halves separated with some overlap. Photos courtesy of Altius Resources Inc.

Formation. The strata are generally deposited as upward coarsening successions from shale to siltstone.

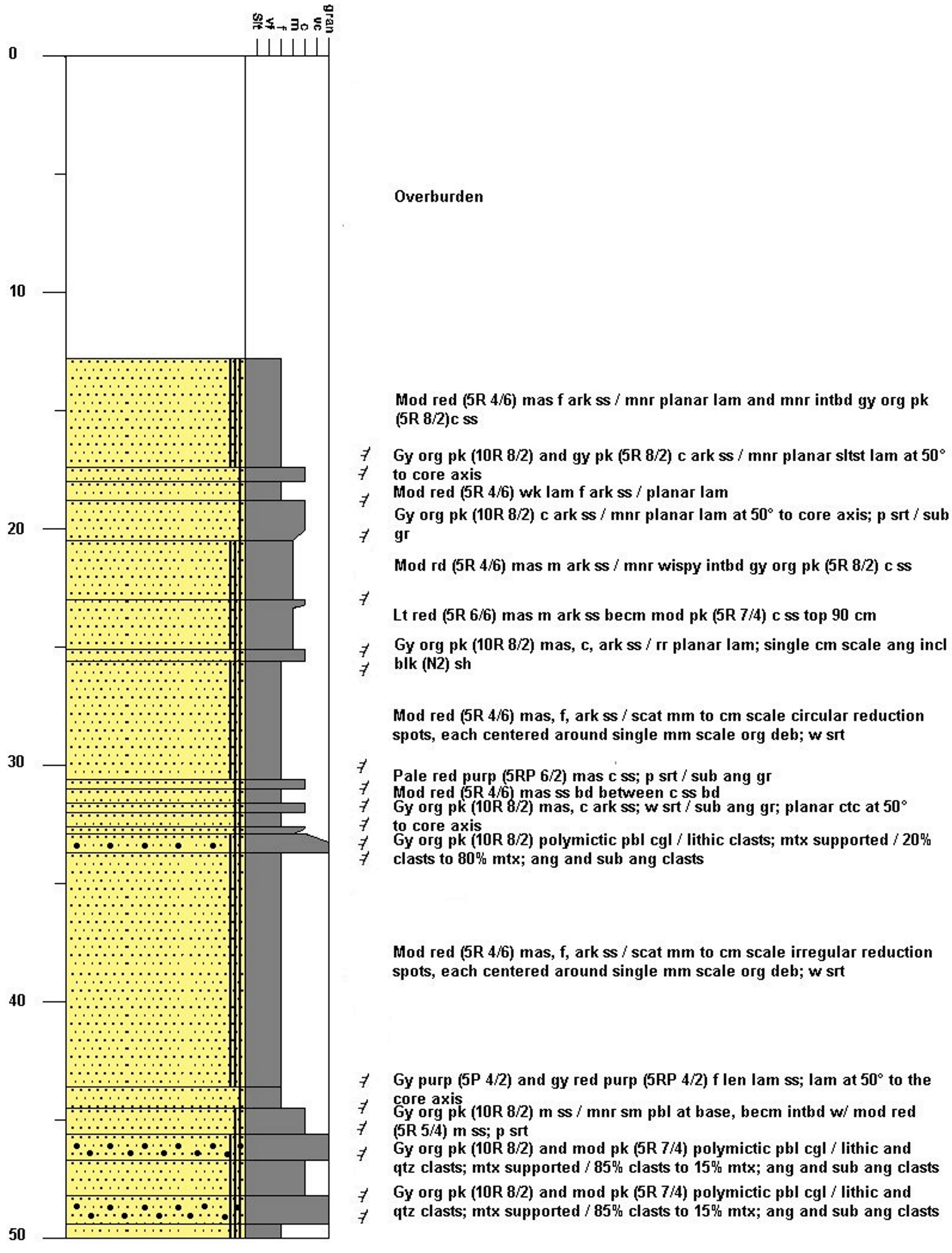
The arkosic sandstone beds are generally massive deposits with thicknesses from around 10 cm to several tens of metres (Figure 39). Some beds contain parallel-planar lamina oriented around 50° to the inclined core axis, and therefore implying nearly flat-lying or (less likely) vertical beds. The polylithic pebble conglomerate is generally thinner than the sandstone, with each bed measuring close to a metre in thickness. The conglomerates are matrix supported and contain rounded clasts that are rounded to sub-angular. The sandstones and conglomerates are well cemented.

The contact between the Humber Falls Formation and the Rocky Brook Formation is sharp and faulted. The two units are separated by about 40 cm of unlithified fault gouge clay with millimetre rock fragments (Figure 39). Across this interval, the clay changes from dark greenish grey to a moderate red colour.

The dark grey (N3) shale beds range in thickness from 40 cm to 4.6 m. Some of them contain beds of round fine- to medium-grained calcareous debris that are 5 mm to 2 cm thick. The bedding is oriented at around 45° to the core axis (Figure 40). One of the uppermost intervals of dark grey shale contains a network of fractures filled with dark greenish grey siltstone, as if the siltstone was injected into the shale. From 50 m to around 67 m the base of each unit generally contains nodular limestone from 10 to 20 cm thick.

Muddy, greenish grey siltstone is nearly always in sharp, if not also scoured contact with dark grey shale. Often slightly calcareous in composition, mottled siltstone beds range in thickness from 3.6 m to 4 m. Many of these beds are prominently laminated in two distinctive ways. Some beds are wavy laminated with siltstone lenses, and minor asymmetric ripples. Other siltstone-shale beds have wispy discontinuous laminae with siltstone lenses. This lamination is oriented between 45° and 50° to the core axis.

There are no anomalous radiometric readings in the original logs provided by Altius Resources. Inasmuch as this core is from a uranium exploration project, there is no data reported for organic carbon content. The net to gross ratio for dark grey shale in the lower 43.4 m of the hole (Rocky Brook Formation) is 44.7% and distributed in 4 thick beds 3 - 4.6 m thick and lying between 50 and 85 m.


Slt
vf
f
m
c
vc
gran
0
10
20
30
40
50
Overburden
Mod red (5R 4/6) mas f ark ss / mnr planar lam and mnr intbd gy org pk (5R 8/2)c ss
Gy org pk (10R 8/2) and gy pk (5R 8/2) c ark ss / mnr planar sltst lam at 50° to core axis
Mod red (5R 4/6) wk lam f ark ss / planar lam
Gy org pk (10R 8/2) c ark ss / mnr planar lam at 50° to core axis; p srt / sub gr
Mod rd (5R 4/6) mas m ark ss / mnr wispy intbd gy org pk (5R 8/2) c ss
Lt red (5R 6/6) mas m ark ss becm mod pk (5R 7/4) c ss top 90 cm
Gy org pk (10R 8/2) mas, c, ark ss / rr planar lam; single cm scale ang incl blk (N2) sh
Mod red (5R 4/6) mas, f, ark ss / scat mm to cm scale circular reduction spots, each centered around single mm scale org deb; w srt
Pale red purp (5RP 6/2) mas c ss; p srt / sub ang gr
Mod red (5R 4/6) mas ss bd between c ss bd
Gy org pk (10R 8/2) mas, c ark ss; w srt / sub ang gr; planar ctc at 50° to core axis
Gy org pk (10R 8/2) polymictic pbl cgl / lithic clasts; mtx supported / 20% clasts to 80% mtx; ang and sub ang clasts
Mod red (5R 4/6) mas, f, ark ss / scat mm to cm scale irregular reduction spots, each centered around single mm scale org deb; w srt
Gy purp (5P 4/2) and gy red purp (5RP 4/2) f len lam ss; lam at 50° to the core axis
Gy org pk (10R 8/2) m ss / mnr sm pbl at base, becm intbd w/ mod red (5R 5/4) m ss; p srt
Gy org pk (10R 8/2) and mod pk (5R 7/4) polymictic pbl cgl / lithic and qtz clasts; mtx supported / 85% clasts to 15% mtx; ang and sub ang clasts
Gy org pk (10R 8/2) and mod pk (5R 7/4) polymictic pbl cgl / lithic and qtz clasts; mtx supported / 85% clasts to 15% mtx; ang and sub ang clasts

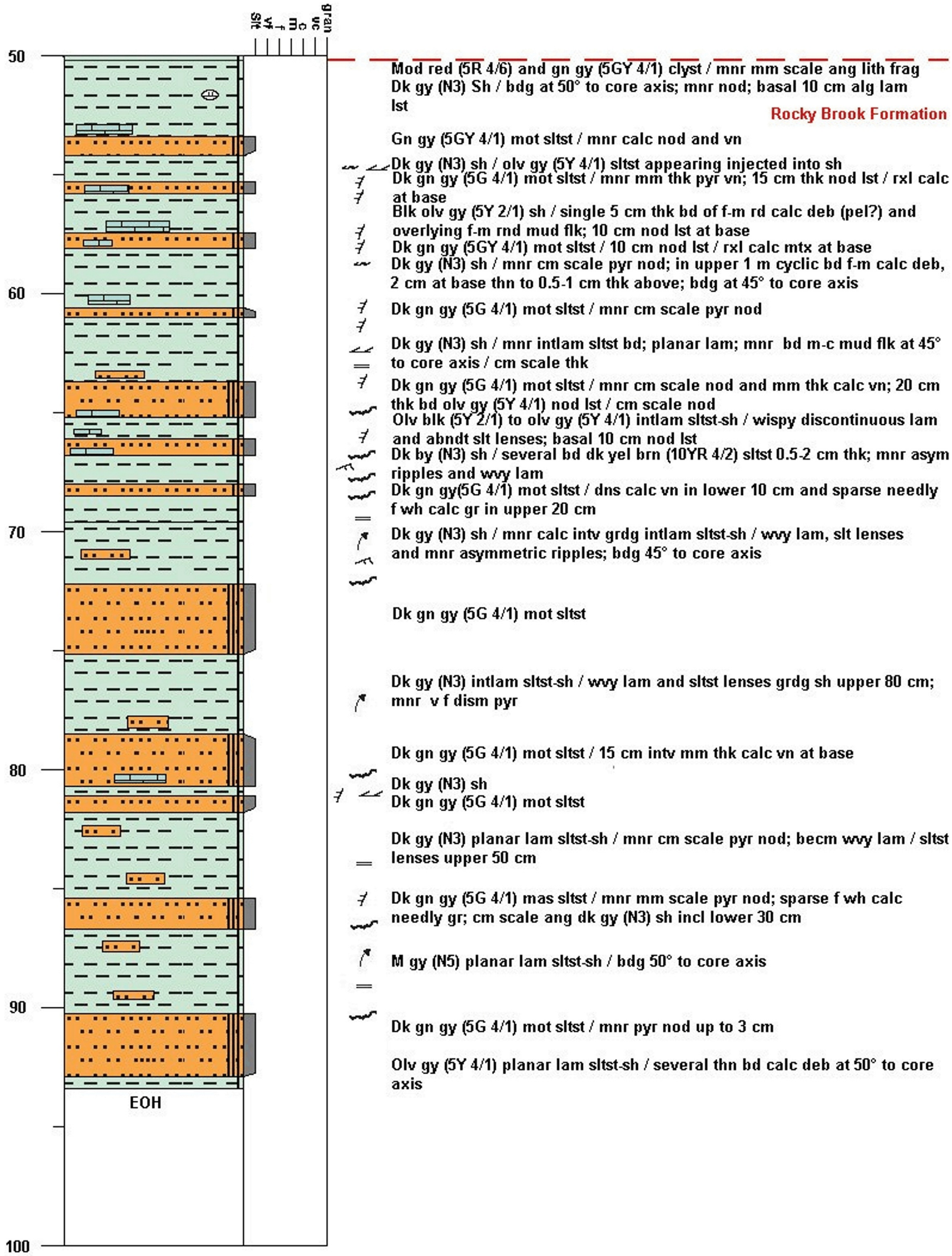


Figure 39: Lithologic log for Altius Minerals core RB-06-130 showing Humber Falls Formation sandstone and conglomerate in fault contact with upper grey shale of the Squires Park Member of the Rocky Brook Formation.

Figure 40: Beds of calcareous debris, mud flakes and oolites forming thin fining-upward successions within dark grey shale (RB 06-130 at ~59 m).

RB-06-139

UTM: 497895 E 5478456 N

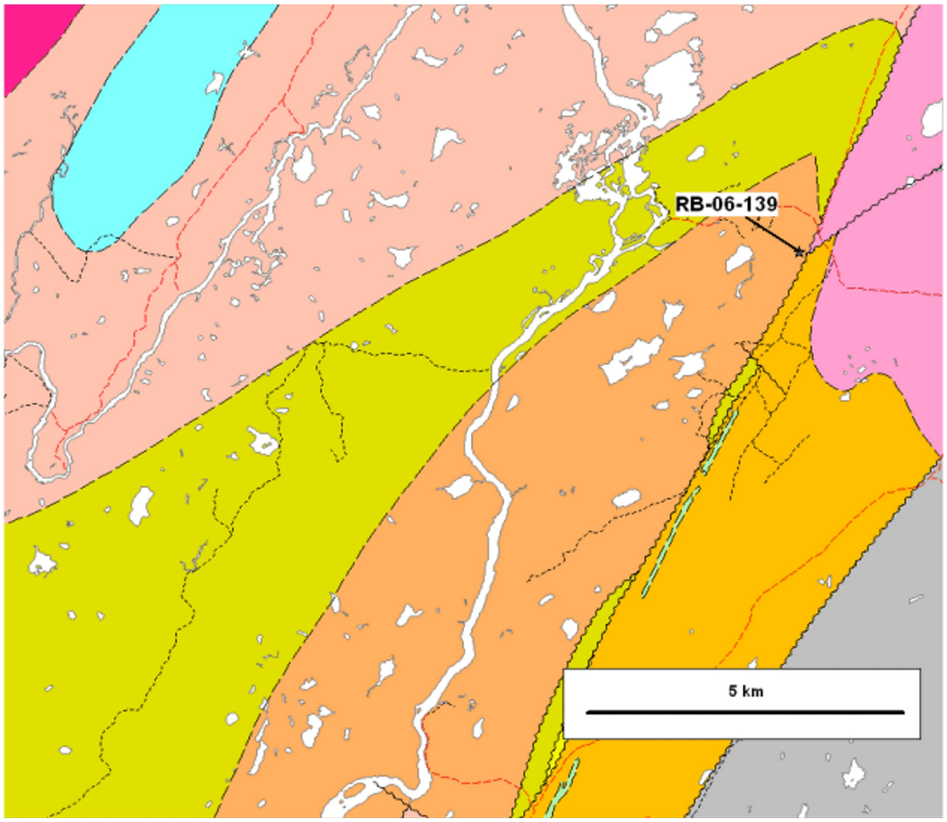


Figure 41: Location of RB-06-139. Map courtesy of Altius Resources Inc.

RB-06-139
Azimuth/Dip: 300/45
Depth: 99.9 m

Hole RB-06-139 is on the hangingwall of the Wigwam Fault, a major, north northeast trending dextral strike-slip fault in the Cabot Fault Zone (Figure 41). As with RB-06-130, this hole contains both Humber Falls Formation and Rocky Brook Formation lithologies. The uppermost 63 m is the Humber Falls Formation (Figure 42). Here, beds from the upper 49 m are erosion based cycles of greyish brown granule to cobble, polymictic conglomerate that generally fine-upward, becoming interbedded greyish brown, fine-grained, massive sandstone beds and greyish brown massive siltstone beds.

Conglomerate beds are matrix supported with sub-rounded to sub-angular clasts

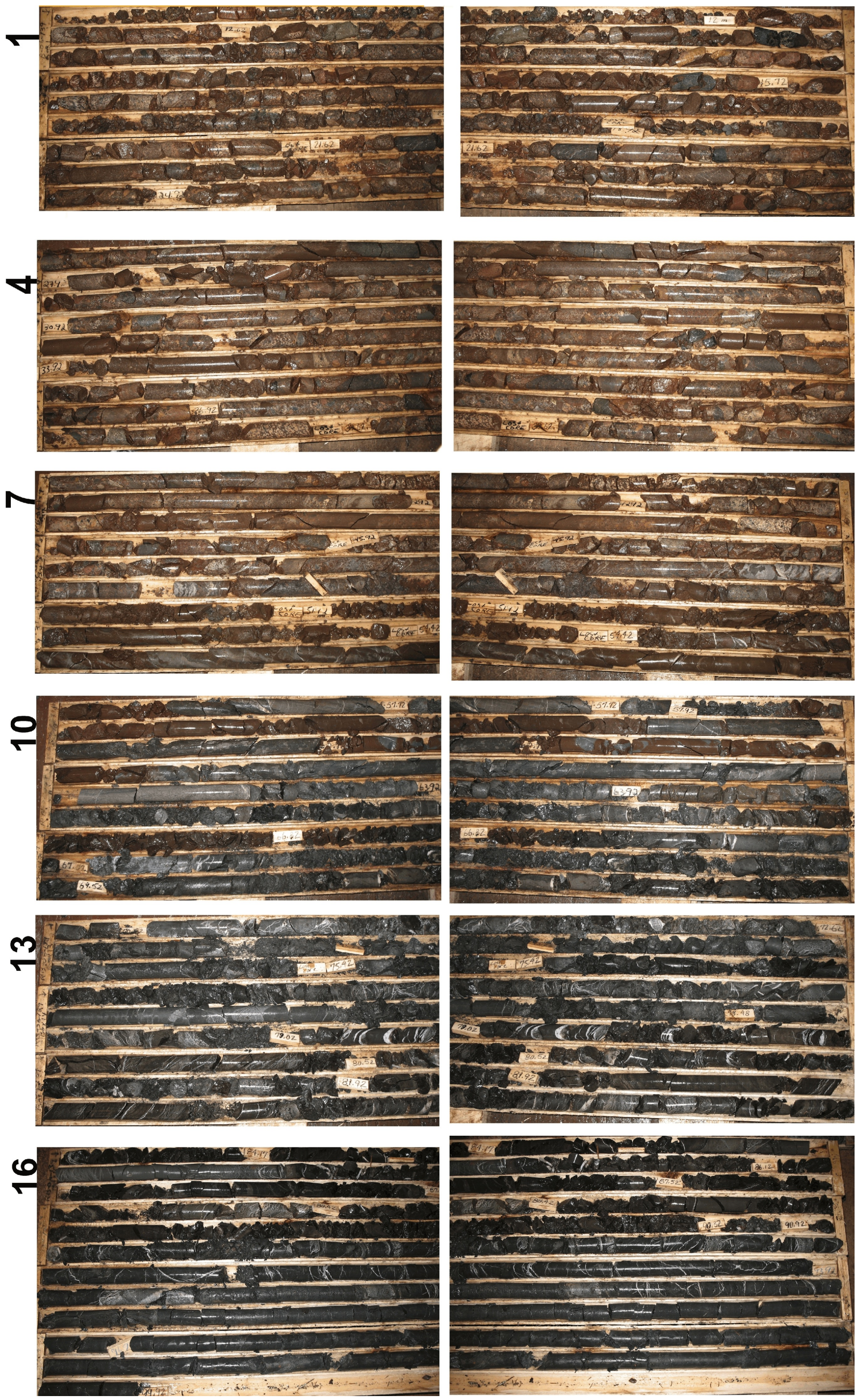


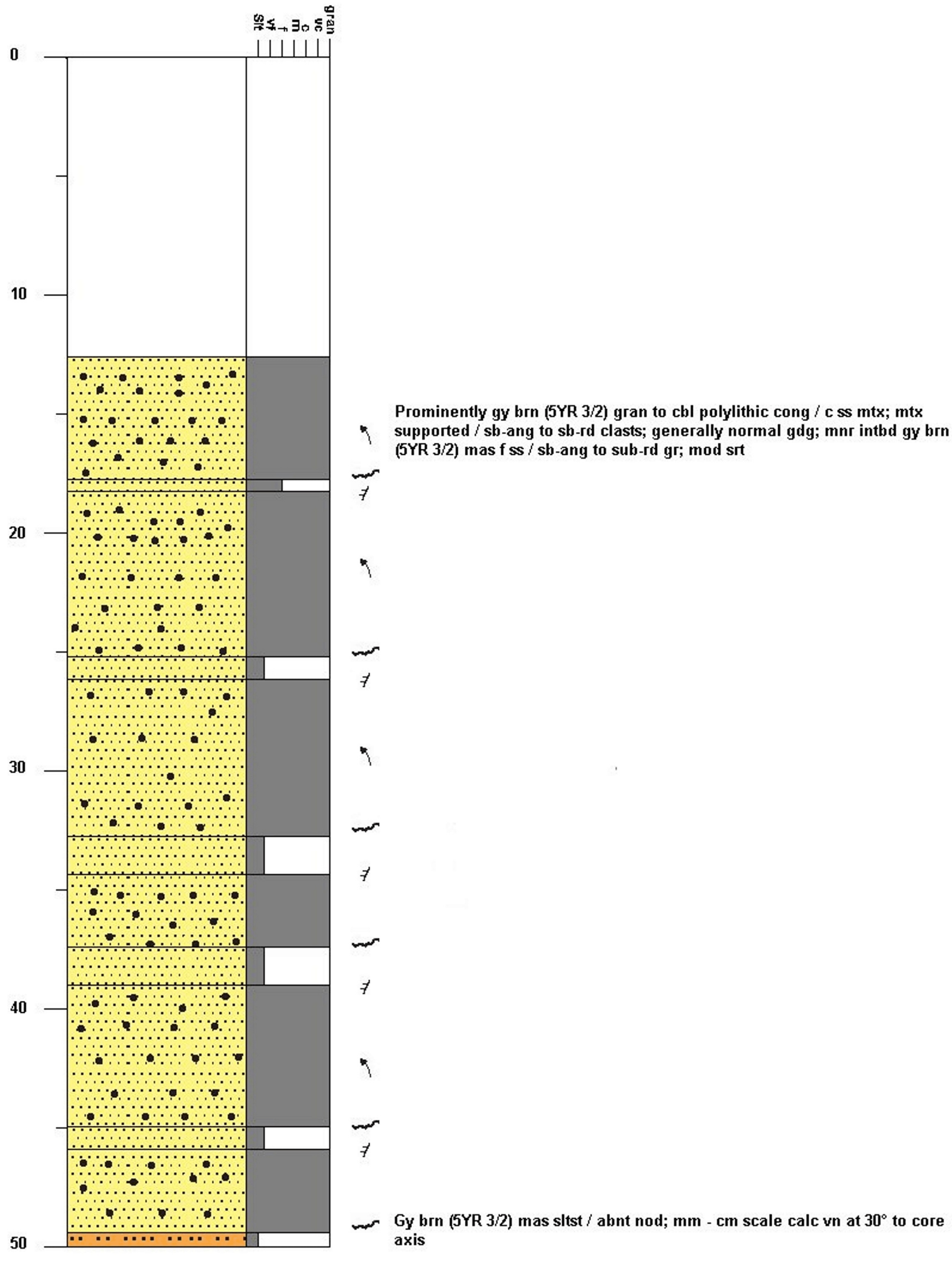
Figure 42: Entire core of RB-06-139 showing the base of the Humber Falls Formation in fault contact with the upper grey shale of the Squires Park member of the Rocky Brook Formation. Top and bottom halves are shown with some overlap. Photos courtesy of Altius Resources Inc.

that generally decrease in size upward (Figure 43). They range in thickness from 3 to 5.9 m. The overlying fine-grained and massive sandstones are in sharp contact with underlying conglomerate. The upper contact of each sandstone bed is eroded, and marks the beginning of the next overlying cycle. Sandstone beds range in thickness from around 50 cm to 2.6 m. They have sub-angular to sub-rounded grains that are moderately sorted. Both the sandstones and conglomerates are well cemented.

The lowest part of the Humber Falls Formation, from about 49 to 63 m is interbedded, medium grey to medium dark grey, fine-grained, massive, siltstone with abundant centimeter scale calcareous nodules and calcareous veins oriented 30° to the core axis. Within the basal massive siltstone are thin beds of medium grey to dark grey fine-grained calcareous sandstone. The sandstone beds range in thickness from approximately 30 cm to 40 cm and are massive. The base of the last, lowest sandstone is underlain with a thin zone of dark grey green unlithified mud. This is considered to be fault gouge and marking the base of the Humber Falls Formation.

Below conglomerates and sandstones there lies greyish black to greenish black shale, medium dark grey siltstone-shale and generally dark greenish grey massive siltstone of the Rocky Brook Formation. The beds of shale are relatively thick, measuring between 70 cm and 10 m. Several shale beds contain minor calcareous veins, and intervals of dense calcareous veins, generally a decimetre to several decimetres thick. There are two muddy siltstone beds, each approximately 5 m thick. The stratigraphically higher bed is dark greenish grey and medium grey. It is wispy laminated with siltstone lenses and rare convolute lamina. The lamina are oriented 30° to the core axis, implying gently dipping or (less likely) nearly vertical beds. There are also several centimetre scale inclusions of angular shale fragments and millimetre scale pyrite nodules. The lower muddy siltstone bed is medium dark grey and planar laminated. The laminae are oriented from 20° to 40° to the core axis. There is also fine disseminated pyrite and minor carbonate veins within the bed. The dark greenish grey to greenish black, massive siltstone beds of the Rocky Brook Formation are 1 to 5.2 m thick. Within the siltstone are minor very fine-grained, white, needle-like calcareous grains, very fine disseminated pyrite, intervals of dense calcareous veins and also rare centimetre scale calcareous nodules.

There were no radiometric anomalies reported in this hole and no data with organic carbon content was found. The net source rock thickness to gross thickness for this short section of dark grey (N2, N3) Rocky Brook shale is about 48%.


slt vf f m c vc gran
0
10
20
30
40
50
Prominently gy brn (5YR 3/2) gran to cbl polylithic cong / c ss mtx; mtx supported / sb-ang to sb-rd clasts; generally normal gdg; mnr intbd gy brn (5YR 3/2) mas f ss / sb-ang to sub-rd gr; mod srt
Gy brn (5YR 3/2) mas sltst / abnt nod; mm - cm scale calc vn at 30° to core axis

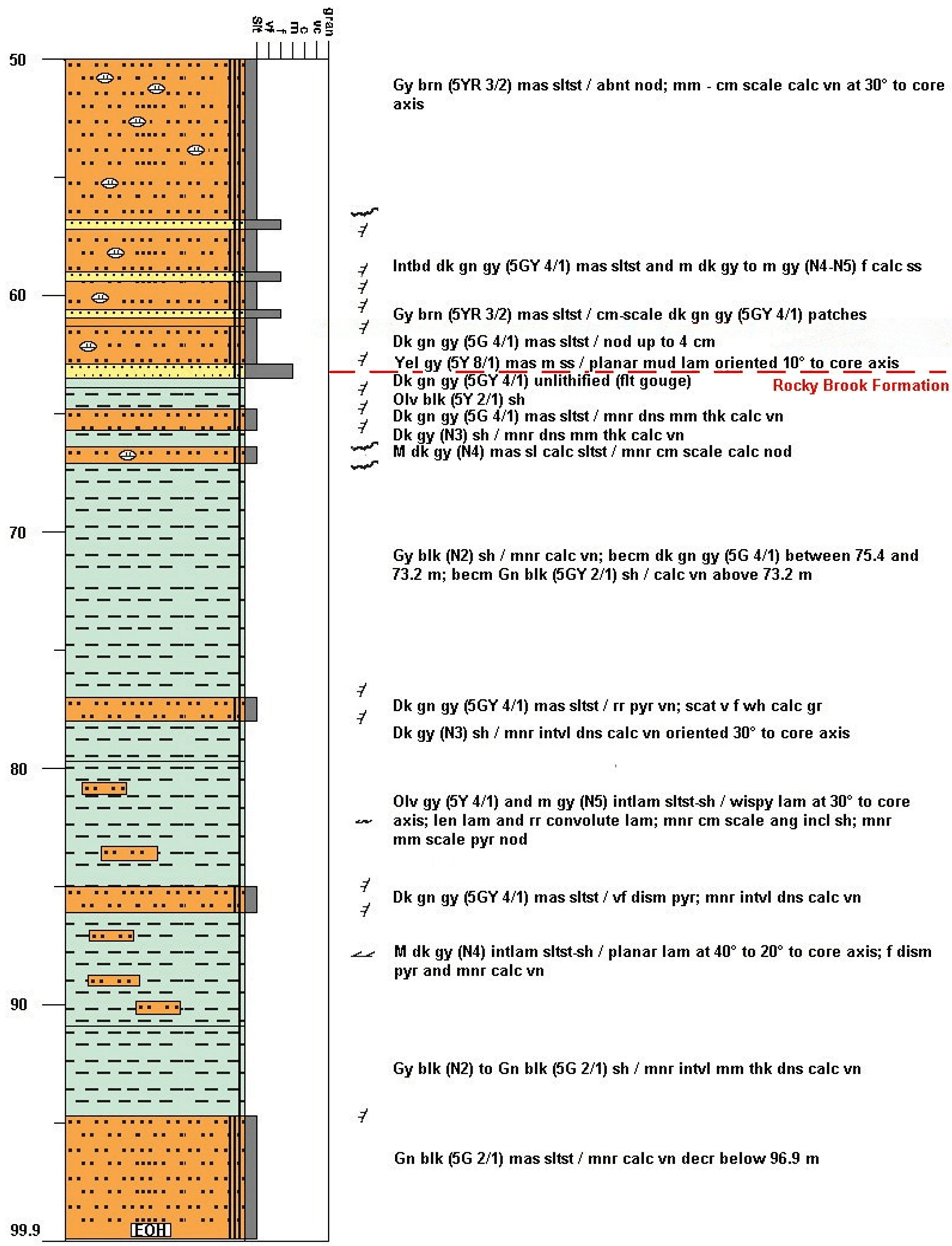


Figure 43: Lithologic log for Altius Minerals core RB-06-139 showing Humber Falls Formation sandstone and conglomerate in fault contact with upper grey shale of the Squires Park Member of the Rocky Brook Formation.

RB-06-140

UTM: 497 813 E 5478498 N

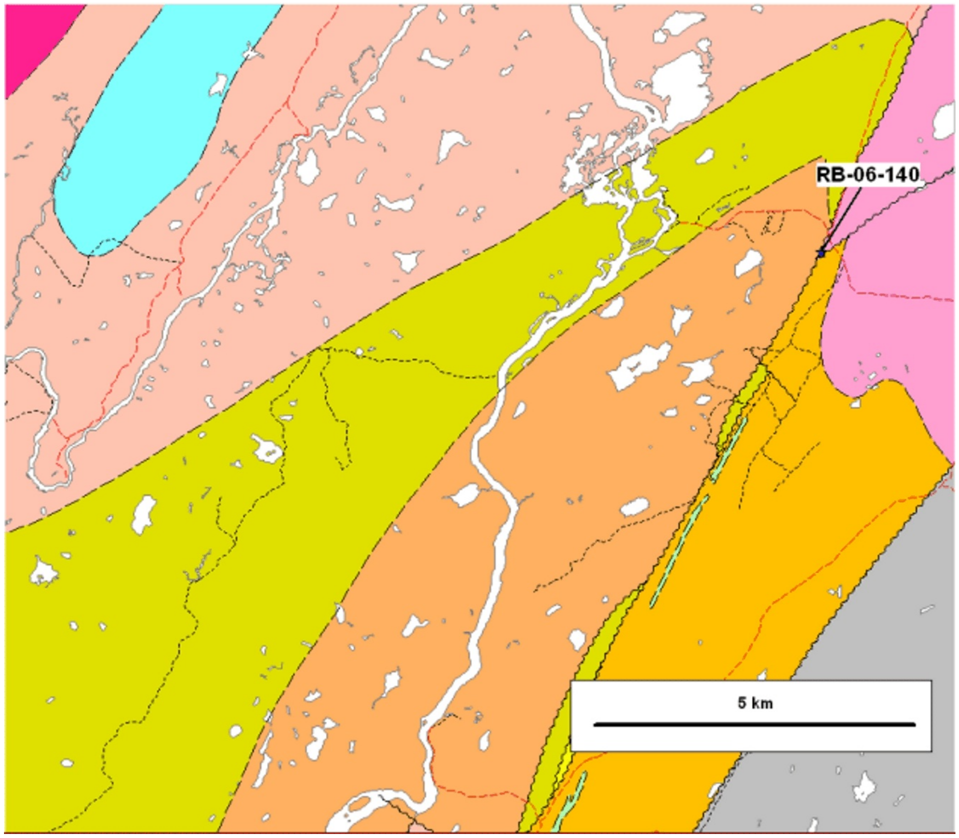


Figure 44: Location of RB-06-140. Map courtesy of Altius Resources Inc.

RB-06-140

Azimuth/Dip: 300/45

Depth: 39.9 m

The shortest of the three Altius Resources cores examined, this hole was drilled very close to RB-06-139 and nearly on top of the Wigwam Fault (Figure 44). Core only shows recovery from the Rocky Brook Formation (Figure 45).

Rocky Brook strata (Figure 46) are olive black and greenish black shale, dark grey and grey black silty shale and dark greenish grey to grayish black mottled silty shale with minor olive grey very fine-grained sandstone at the top. The olive black and

Figure 45: Entire core of RB-06-140. Glacial overburden forms the top 24.9 m of this core. Below, there lies dark grey shale of the Squires Park Member. The top and bottom halves are photographed separately with some overlap. Photos courtesy of Altius Resources Inc.

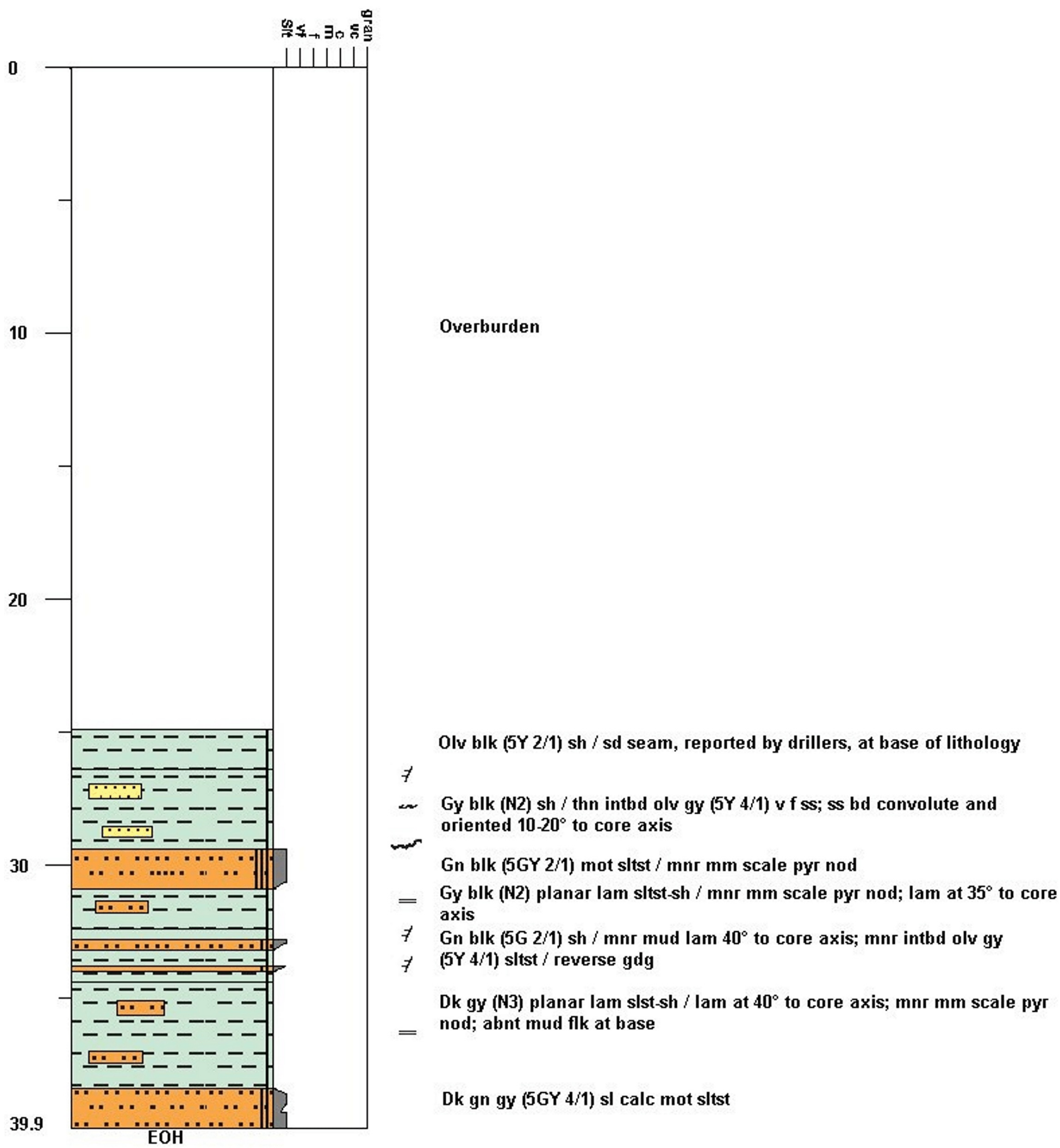


Figure 46: Lithologic log for Altius Minerals core RB-06-140 showing upper grey shale of the Squires Park Member of the Rocky Brook Formation.

greenish black shale ranges in thickness from 2 to 2.5 m. The thickest shale contains some thin convolute beds of olive grey, massive, very fine sandstone. The beds are oriented at 10° to 20° to the core axis, implying either a 25-35º dip for these beds or (less likely) a steep 55-75º dip. The dark grey silty shale beds are 2.5 to 4 m planar laminated deposits with minor millimetre scale pyrite nodules. The bedding is oriented between 35°

and 40° to the core axis, indicating either nearly flat-lying or nearly vertical beds. The beds of mottled siltstone range in thickness from 20 cm to 1.5 m. They generally coarsen upward. There are minor mm scale pyrite nodules in the upper most siltstone interval.

There are no anomalous radiometric values reported on the original log and the organic content is not available. The net to gross ratio of dark grey shale in the 15 m of Rocky Brook Formation core is 69.4%. That number is possibly skewed because the intersection is short.

Discussion

The Rocky Brook Formation is basically a very fine-grained deposit of mostly shale and siltstone with minor, very fine-grained sandstone and thin carbonate beds. Summary analyses reported in Hyde et al. (1988), and Hamblin et al. (1997) show predominantly thermally immature and sometimes organic enriched lacustrine strata deposited in a mature strike-slip basin that was undergoing late stage thermal subsidence. Palynology reported in Hamblin et al (1997) suggest that formation of the Deer Lake Group was a relatively rapid event and the Rocky Brook Formation is contained in one small biozone spanning the latest Visean and earliest Serpukhovian. However, from a regional scale, structural and depositional history analyses of Anguille Group and Deer Lake Group strata hint at a more complex story of basin evolution in this area, and one that is certainly open to reinterpretation as new data come to light.

Structural geology summaries presented in Hyde (1984b), Hyde et al. (1994), Wright et al. (1996) and Hamblin et al (1997) show episodic activity on the main faults that cross this region led to the development of flower structures dividing the basin into two smaller lateral basins, the Humber Lateral Subbasin (also known as the Deer Lake Lateral Subbasin, the focus of this study) and the Howley Lateral Subbasin, around and beneath Sandy Lake. Hyde et al. (1994) suggest that flower structures were actively developing in the Visean and may have formed a barrier dividing this ancient lake. If true, Rocky Brook strata from both lateral basins and on the fault zone should show differences in strata and structure. This might include differences in dip, basic lithology, and sedimentary features (e.g. abundant chaotic beds from active fault scarps). All of the cores examined in this report come from the Humber Lateral Subbasin; none are obviously chaotic. With the exception of core 0023, in an elevated fault block separating the two subbasins, we have no comparative material from the Howley Lateral Subbasin and the main fault zone. Finally, and on a regional scale, it is also clear that structural deformation did not end when the Deer Lake Basin was filled. Gently dipping, through folded, and faulted Deer Lake Group strata, illustrated in Hyde (1982), show that dextral shearing continued long after sedimentation ended. Post Visean movement on new and reactivated faults may have important implications for reservoir geometry, trap integrity, hydrocarbon migration, and the migration of uranium bearing fluids. This detail is a significant area of study and one where new research into the evolution of basin structure and fill is required.

Given our present understanding of available regional data covering the time of Deer Lake Group deposition, it has been suggested that (a) the basin developed an asymmetric profile (Hyde, 1979; Hamblin et al., 1997) thickening to the south and up to the edge of the Grand Lake Fault (Figure 2), and (b) the Rocky Brook formation was deposited quickly during one palynomorph biozone.

Establishing thickness for these rocks, a key component towards determining burial history and petroleum potential, is an ongoing exercise. From mapping, Belt (1969) suggested that the Rocky Brook Formation is 1500 m thick on Grand Lake; Hyde (1981) indicates less than 1000 m of structurally deformed Rocky Brook strata are present.

Until the early 1980's, there were no significant regional geophysical surveys of the area (Miller and Wright, 1984); independent geophysical measures for sediment thickness and crustal structure remained a mystery. Beginning in the late 1970's, Miller and Wright began collecting and reporting on gravity and aeromagnetic surveys. Their work (Figure 47) identified significant differences in crustal composition between the Humber and Howley lateral subbasins and including a substantial thickness of Carboniferous strata beneath Sandy Lake (Miller and Wright, 1984). With Lithoprobe seismic, Waldron and Stockmal (1994) suggest that the base of the Carboniferous correlates with a reflector at about 1 s (approximately 1500 m). Given additional industry seismic, Wright et al. (1996) and Hamblin et al. (1997) suggest that basin asymmetry extends along the entire margin of the Grand Lake-Green Bay Fault (Cabot Fault). In Wright et al. (1996) and Hamblin et al. (1997), and for central and eastern areas of the basin, the Deer Lake Group is said to be as much as 2000 m thick, with the base for the Deer Lake Group lying at close to 4000 m depth in the Howley Subbasin.

In recent years, and with additional drilling, hydrocarbon exploration well Western Adventure #1 (WA1 - Figure 2), drilled in 2001 (Martin, 2001; 2009), shows 284 m of Rocky Brook, and more than 1300 m of North Brook strata in the middle of the basin and before Lower Paleozoic basement was touched. This is in large part similar to

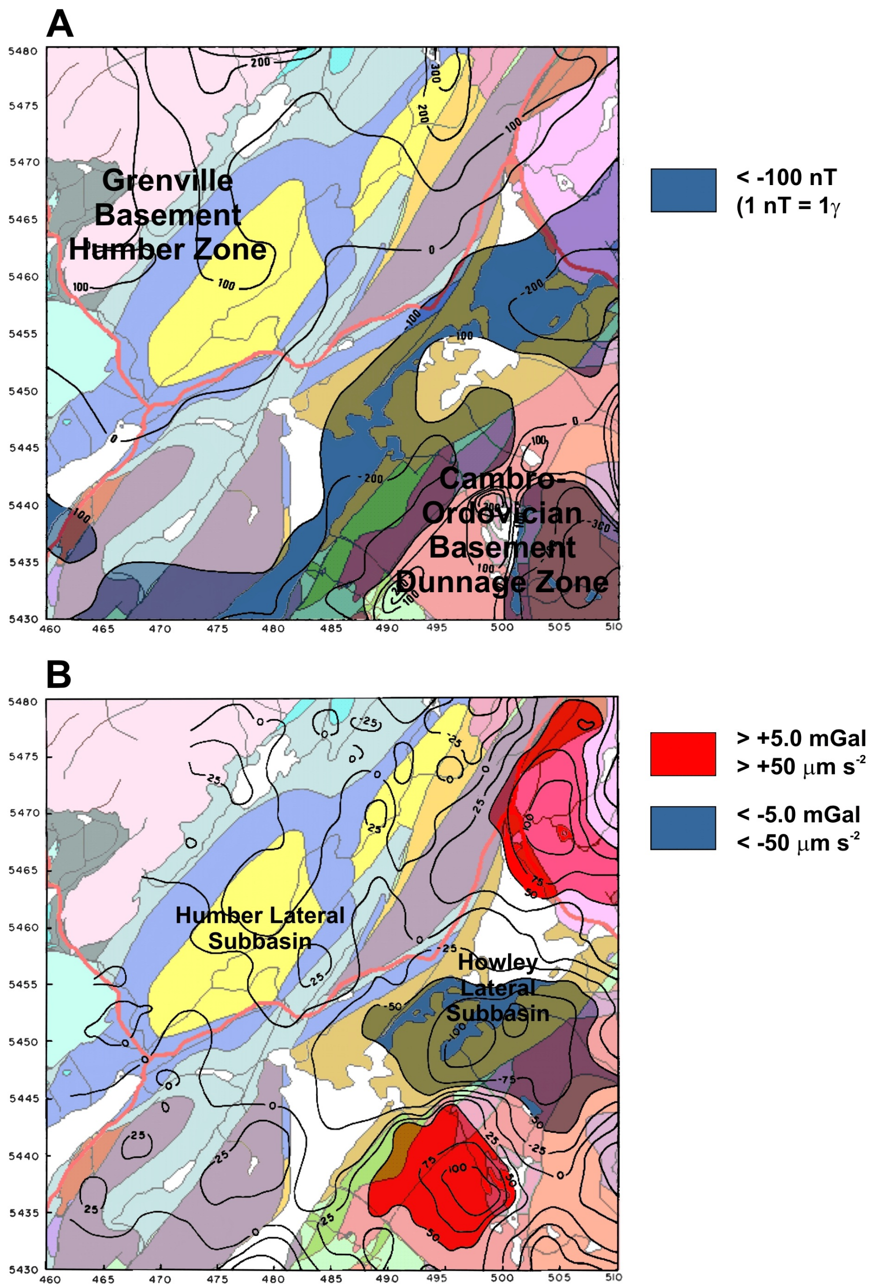


Figure 47: (A) Total field magnetic anomaly map with IGRF removed and lying upon regional geology. The prominent magnetic low corresponds with the suture joining the Humber and Dunnage zones. (B) Residual gravity map showing anomalously low values beneath the Howley Lateral Subbasin. Geophysics from Miller and Wright, 1984; geology from Newfoundland and Labrador Department of Natural Resources web site.

the results reported in Fleming (1970) for Rocky Brook and North Brook strata in the Claybar #3 borehole about 2 km to the west (Figures 2 and 48). In contrast, and nearby, in Western Adventure #2 (WA2 ; Figure 2), Lower Paleozoic carbonate basement was encountered at 761.5 m (Martin, 2002a; 2002b) in a well that initially proposed more than 800 m of North Brook formation below thick Rocky Brook strata. As with Claybar #3, both of the Western Adventure wells detected gas in the older and underlying North Brook Formation. If asymmetry exists in this basin, the generally uniform thickness for Rocky Brook rocks across the region and the overall thin succession of Deer Lake Group strata for Western Adventure #2 shows that the pattern for sedimentation, hydrocarbon generation, migration, faulting and trapping is likely to be more complicated than that suggested by simple tilting and development of a thick sediment wedge adjacent to the Cabot Fault zone.

In the east, apparently thick Deer Lake Group rocks lie upon Anguille Group and Dunnage Zone basement volcanics; in the west, thin Deer Lake Group strata lie upon Cambro-Ordovician platform carbonates (and allochthon?) and Precambrian Grenville basement. Fundamentally, it must be concluded that the Humber and Howley subbasins have very different histories of sedimentation, burial, and tectonism, derived in large part from their distinctive basements. The Humber Lateral Subbasin rests on older, rifted Grenville crust of the Humber Tectonostratigraphic Zone; the Howley Lateral Subbasin rests on younger, allochthonous volcanic crust of the Dunnage Tectonostratigraphic Zone (Figure 49).

It may therefore be no coincidence that Lower Paleozoic basement occurs immediately below relatively thin Deer Lake Group strata in both Western Adventure holes and Claybar #1. With adjacent and surrounding outcrop as an indicator, most of the basement beneath the Humber Lateral Basin could be deformed Cambro-Ordovician platform (and allochthon?), and not affected by events that led to deposition of Anguille strata farther east. This fits gravity and magnetic model presented by Miller and Wright (1983) and showing Precambrian basement and Siluro-Devonian volcanics separating the northwest and southeast parts of the basin.

Thick Anguille Group deposits east of the Deer Lake and Wigwam faults show significant subsidence predates the Deer Lake Group in this area. In addition, regional mapping (Hyde, 1981) confirms that apparently thick Deer Lake Group rocks are in stratigraphic contact with the underlying Anguille Group. Fundamentally, the Humber and Howley lateral basins are very different. One is a broad shallow depression with relatively thin Deer Lake Group rocks resting upon Cambro-Ordovician platform; the

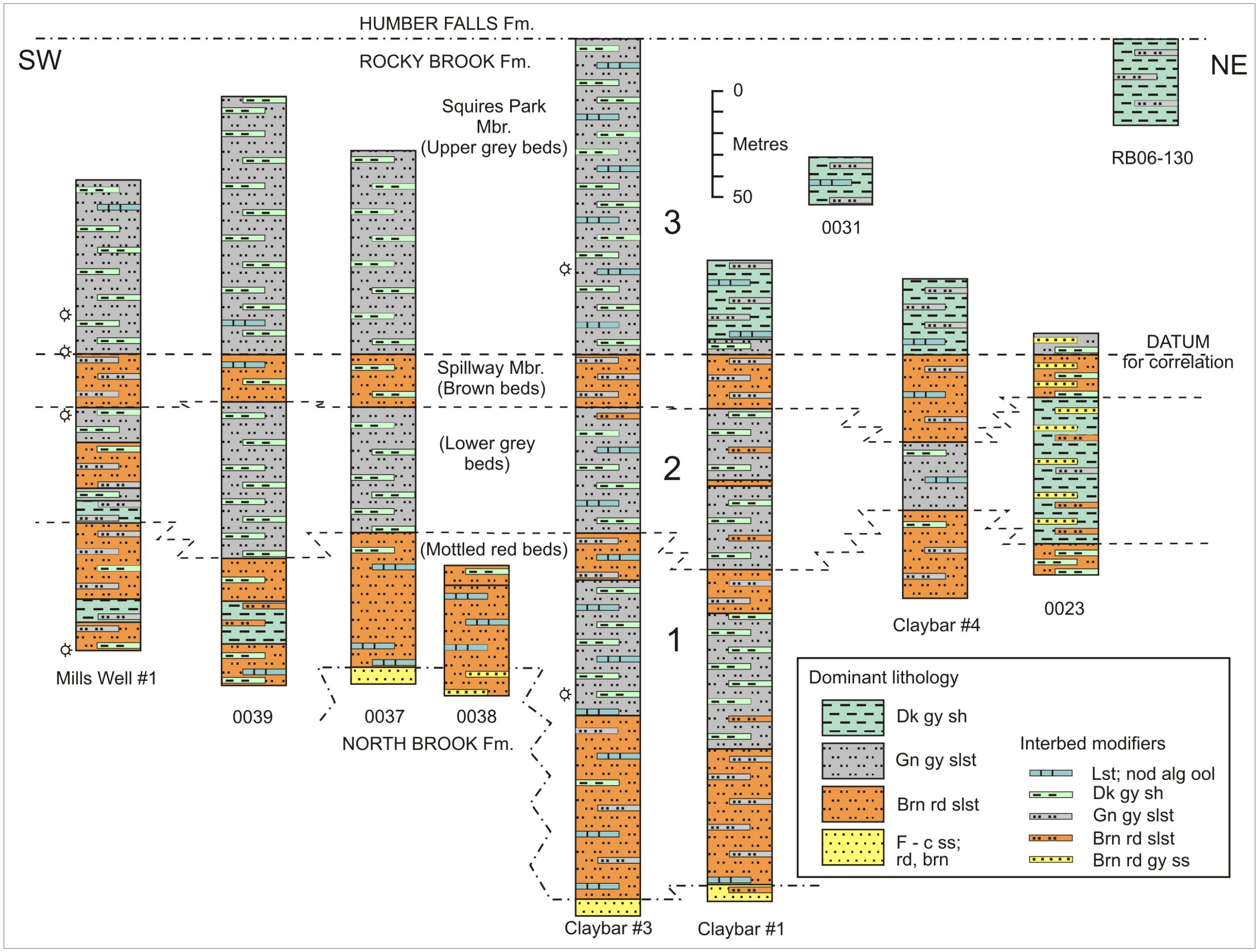


Figure 48: Regional correlation of strata showing 3 cycles of essentially meromictic sedimentation formed in the Rocky Brook Formation as the Deer Lake Basin expanded and contracted. Gas shows are indicated on the old Mills and Claybar cores.

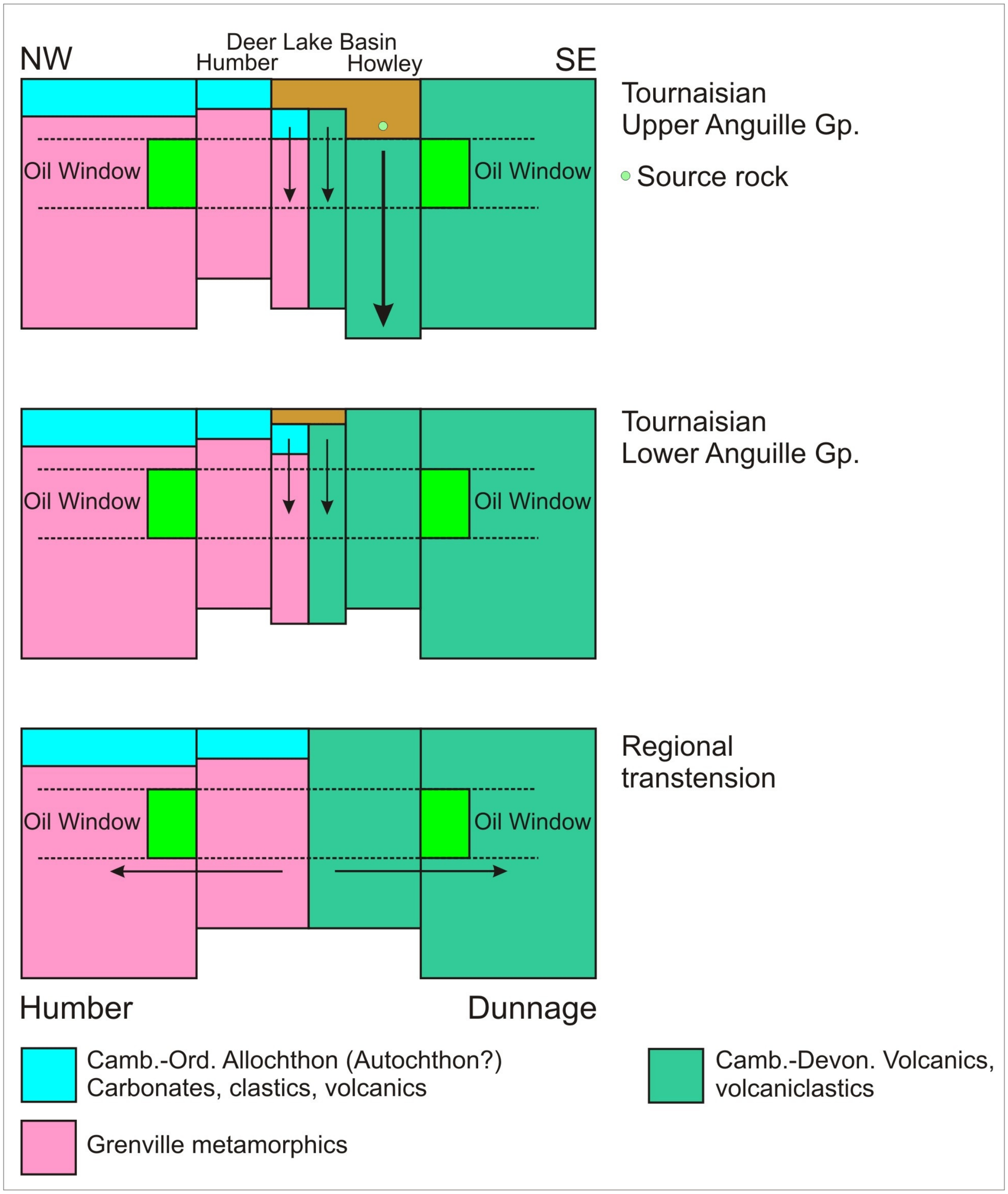


Figure 49a: Schematic box model cross section of Deer Lake Basin basement and fill showing an asymmetric stretching and rifting history. The Howley Subbasin, first appeared in the Tournaisian and expanded eastward. The length of the arrows symbolizes the amount of subsidence.

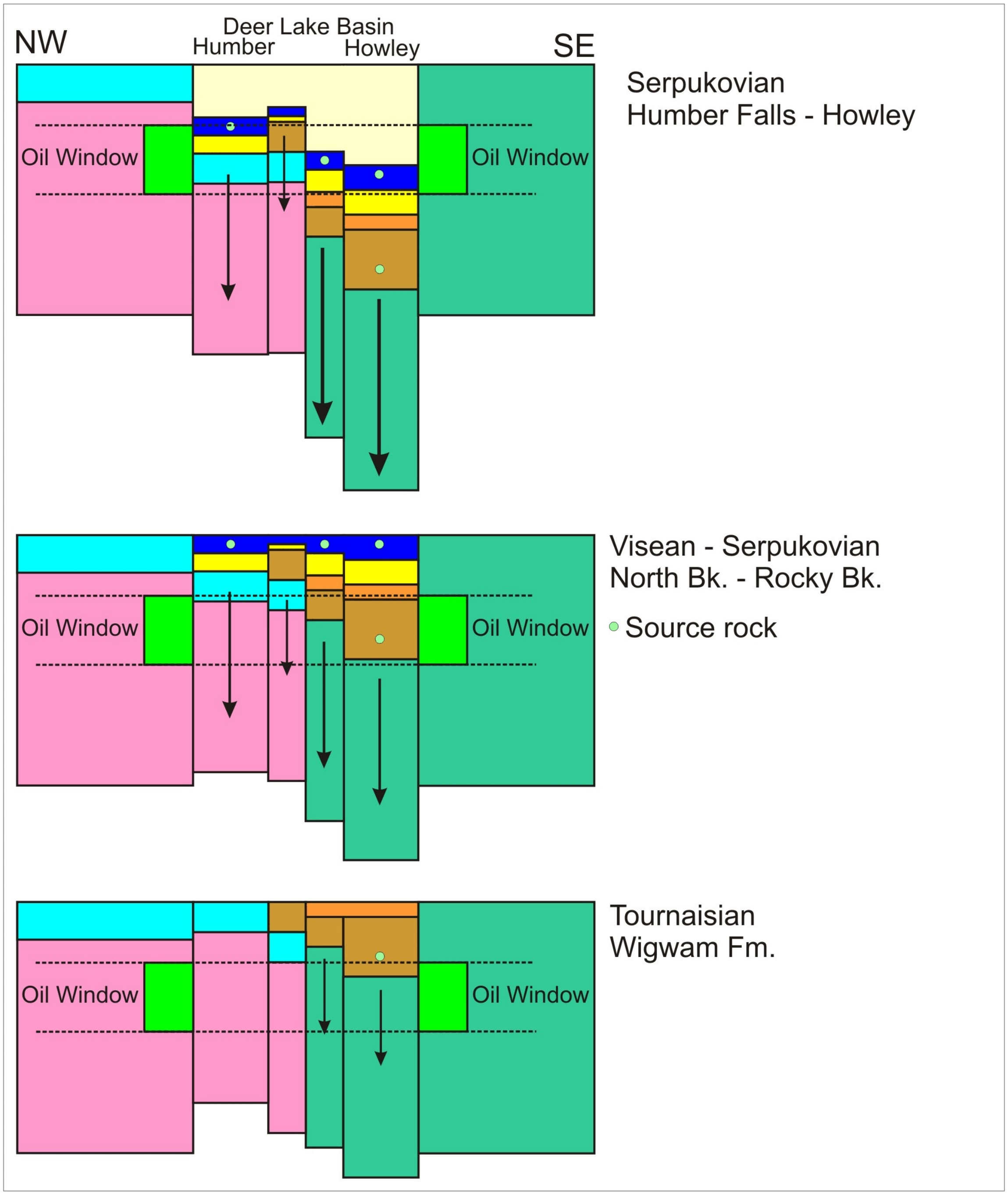


Figure 49b (continued): Subsidence of the Humber Lateral Subbasin did not begin until the Visean when the basin expanded west and onto the Humber Zone. Humber Subbasin fill is not thick and Rocky Brook source rocks barely enter the oil window. Significant subsidence in the Howley Subbasin to the east take Rocky Brook source rocks well into the oil window, whereas Anguille source rocks passed through the oil window.

other is a narrow deep depression filled with several kilometers of Anguille Group, Deer Lake Group, and Howley Formation strata . These basic structural and stratigraphic differences can be used to suggest somewhat different origins and histories for these subbasins. For resource exploration, models erected for generating and trapping hydrocarbons and minerals in the Humber Subbasin will not necessarily apply in the adjacent Howley Subbasin. For instance, there is likely only one Mississippian source rock in the Humber Subbasin, and it is largely immature. In contrast, the Howley Subbasin contains both Anguille and Deer Lake group source rocks lying within and below the oil window (Figure 49).

Rocky Brook sediments, sedimentary facies and interpretations

In order of apparent abundance, the most prominent rock associations in the Rocky Brook Formation are interlaminated and thin bedded grey and greenish grey (mottled) siltstone and shale, massive and mottled grey brown, grey red, brownish grey, reddish brown, and reddish grey siltstone, thick bedded dark grey shale, thin beds of medium and light grey oolitic and oncolitic packstone/grainstone, and a small amount of greenish grey, yellow brown and greyish red fine- and medium-grain sandstone. These 5 lithologies represent components for distinctive and recurring sedimentary facies assemblages. Within this suite of rocks, dark strata are inferred to represent intervals where little oxygen was available to organic enriched sediment; lighter coloured and reddish rocks are inferred to have been deposited under more oxygenated conditions.

In hole 0038, where the base of the Rocky Brook Formation is well displayed, the core shows a thick interval of graded oxidized and red coloured sandstones and siltstones with minor brecciated and rhyzolithic limestones and dolomites at the top of the North Brook Formation. This sandstone dominated North Brook succession grades into massive, mottled and reddish brown, oxidized siltstone with common laminated and oncolitic limestone beds and minor fine-grained sandstone, the lower part of the Mottled red beds in this study (Figure 48). The actual basal contact of the Spillway Member and base of the Rocky Brook Formation, ~55 m in hole 0038 and 242 m in hole 0037 (Figure 48), is arbitrarily defined at the top of the last thick medium-grained sandstone (Hyde, 1984b). In cores 0038 and 0037, this red or brown oxidized siltstone interval is less than 25 m thick before the colours become more subdued and the strata more clay rich.

With outcrop at Junction Brook (Figure 50), Hyde et al. (1994) report a similar sandstone-mudstone succession to our own core analyses. There, they identified three complete and incomplete cyclical deposits, 3 to 8 m thickness and formed as mixed

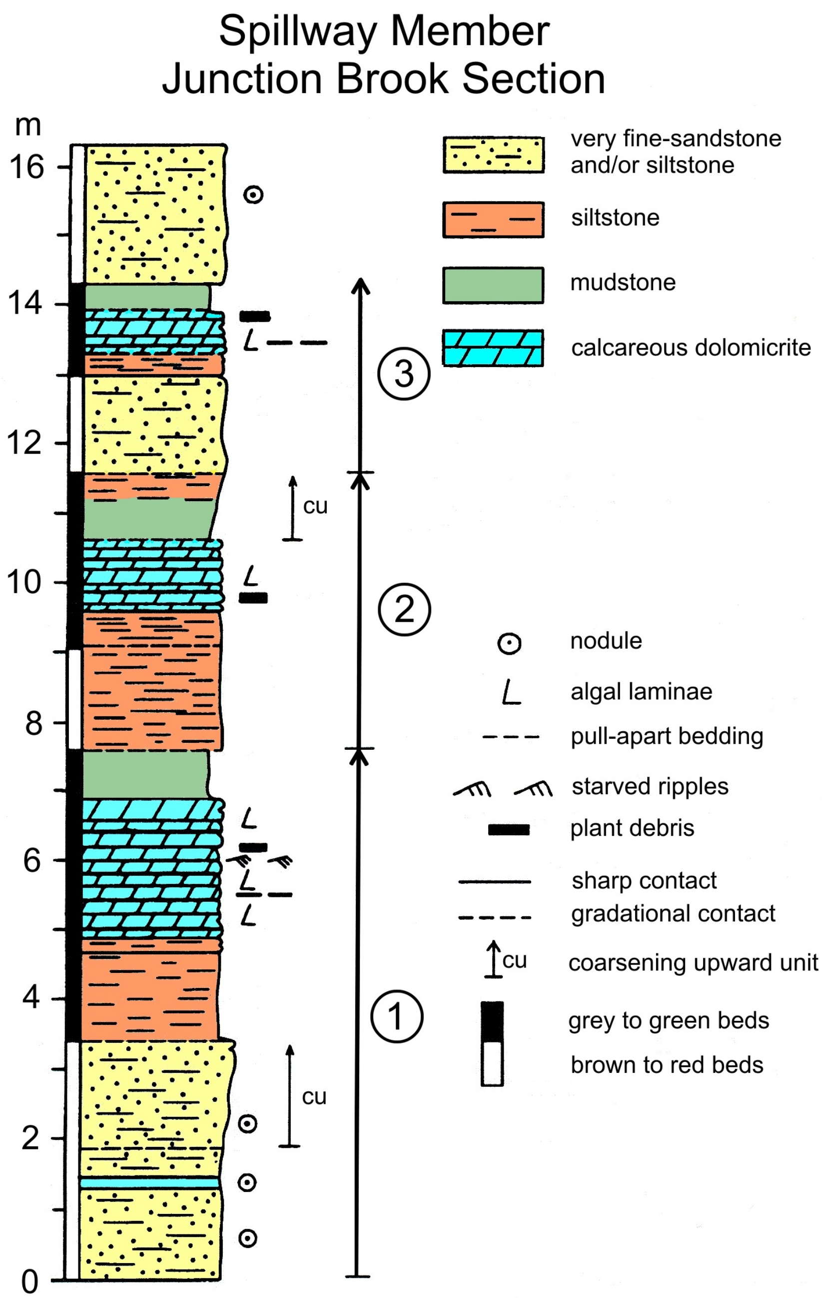


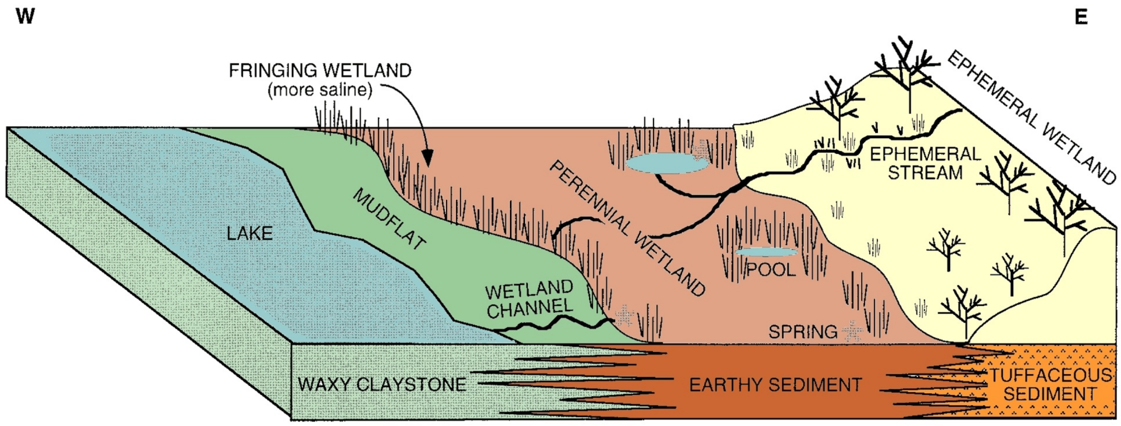
Figure 50: Stratigraphic section from the Mottled red beds from the lower part of the Spillway Member at Junction Brook (modified from Hyde et al. 1994). Three cycles between about 3 and 8 m thick were thought to be terrestrial and lacustrine in origin (Hyde et al., 1994). Here, we believe these are allocycles showing shallow, nearshore and deeper, offshore lacustrine settings.

brown to red coloured, very-fine sandstone and siltstone grading into grey to green siltstone calcareous dolomicrite and mudstone cycles of sandstone, siltstone, limestone, and shale. For these deposits, they propose that the beds developed as soils formed on an inland plain away from the shoreline. Their interbedded calcitic and dolomitic carbonates formed in terrestrial and lacustrine environments, respectively.

Over the last 20 years a relatively large body of new research describing lacustrine and palustrine sediment facies and environments has emerged as ancient lakes become targets for conventional and unconventional hydrocarbon reservoirs . Early and admittedly idealized models for lakes (eg. Picard and High, 1972) have been met with a large body of newer data on the origin and evolution of lakes (eg. Fleet et al., 1988; Katz, 1990). More recently, Liutkus and Ashley (2003) explored semi-arid palustrine deposits on the edge of an underfilled playa lake in Africa. There, they show repeated cycles of green “waxy” clay and friable, beige to light grey and white, earthy soils with slabs of tufa containing rhizoliths and carbonate nodules (Figure 51). In detail, fossil soil and rhizolithic limestones are not similar to beds we have seen in the Mottled red bed succession. In another study, Pietras and Carroll (2006) examined nearshore and terrestrial deposits, showing the littoral zone with common intraclasts, whereas the palustrine setting has mud cracks (Figure 51). This too does not correspond with our Rocky Brook core studies, though it does share similarities with basal Rocky Brook strata located on the western edge of the basin at North Brook and reported by Hyde (1979).

A possible analogue may come from the Cretaceous Rayoso Formation of Argentina (Zavala et al. 2006). In their study, Zavala et al. (2006) postulate hyperpycnal flows in a lake with fluctuating water levels may account for a variety of sandstone and siltstone successions (Figure 52). Density differences in water in the lake and in suspended sediment loads generate stacked subaqueous deposits that may be massive, laminated or cross-bedded. Many of these features occur in the Mottled red beds succession. From sedimentology, the main difference between the Rocky Brook Formation and the Rayoso Formation lies with sandstone-siltstone ratios; the Rocky Brook Formation is a mud dominated succession. Cyclical deposits of red and brown mud and silt may represent times when increased suspended sediment load entered the lake. Pulses of mostly silt and clay may become mixed into the surface waters of the lake where it evenly spreads into the basin according to grain size and settling rates. At other times, denser suspended sediment loads may behave as hyperpycnal flows plunging to the lake bed and travelling far into the centre of the basin. Zavala et al. (2006) suggest

A.



B.

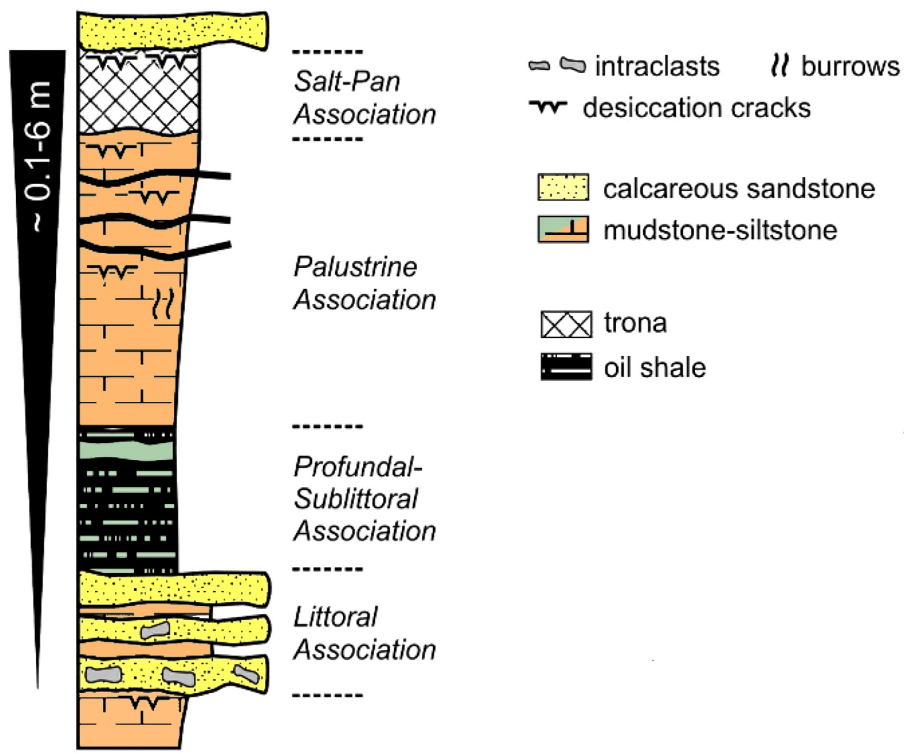


Figure 51: Schematic models of environments (A) and sedimentary strata (B) that may be expected from marsh and littoral areas surrounding an arid, underfilled lake; (A) from Liutkus and Ashley (2003); (B) from Pietras and Carroll (2006).

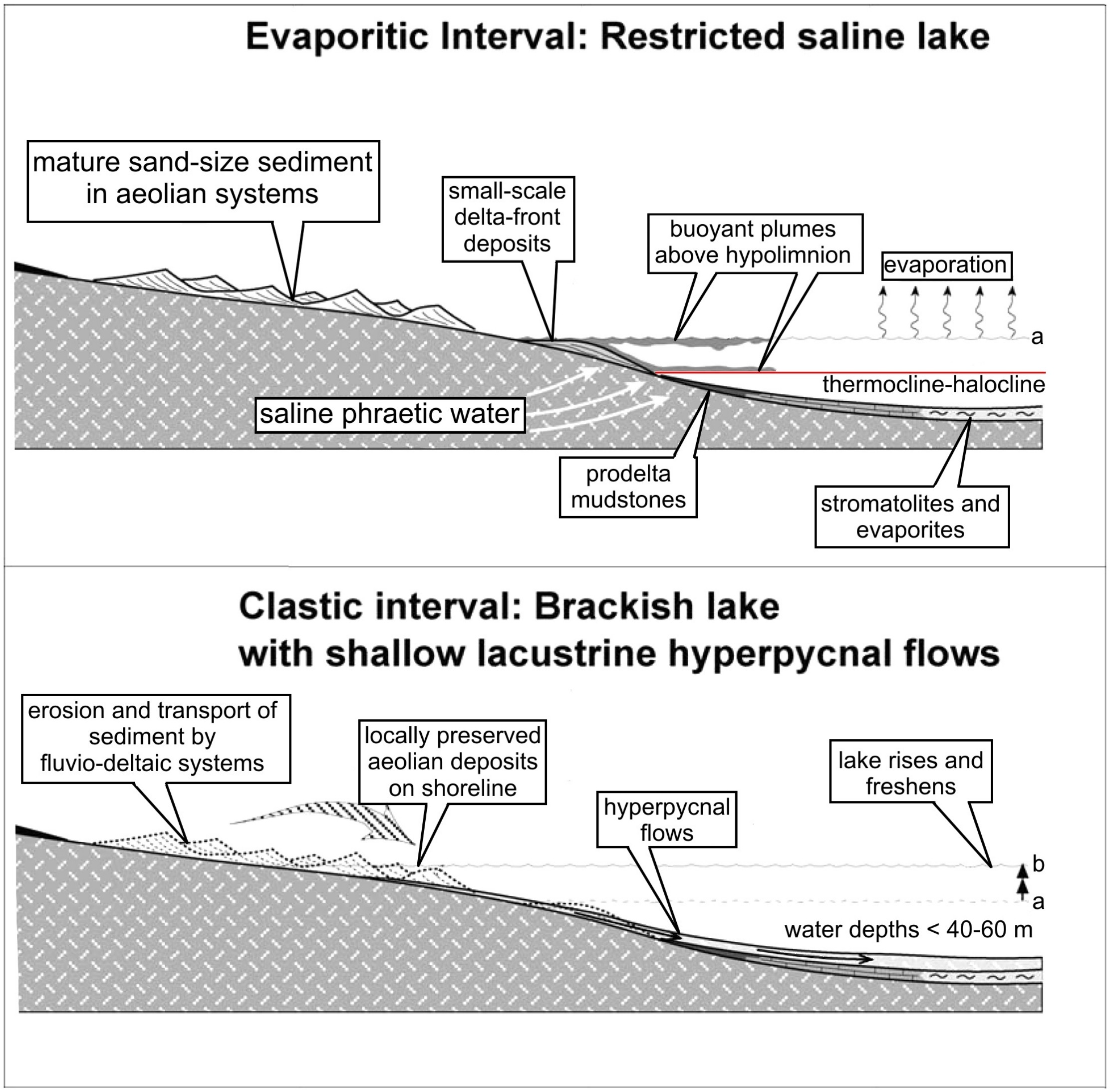


Figure 52: Model for lacustrine sedimentation with hyperpycnal currents carrying sediment far into the basin. Fluctuating water depth and the generation of meromictic conditions in the lake are key components for generating cyclical sedimentary events. Modified from Zavala et al. (2006).

the frequency of hyperpycnal flows on a lake bed is related to water depth and the degree of stratification of the water column.

At present, the exact depositional setting for this part of the Mottled red bed facies is difficult to determine. From structures and strata, we believe this part of the Rocky Brook succession of beds represents a distal alluvial setting, a silty shoreline grading into a shallow, and probably not very productive lake with a littoral zone populated with algal mats and oncolites. Alone, our core analyses and correlations (Figure 48) cannot clearly distinguish whether this is a polymictic (usage here refers to a broadly unstratified and well oxygenated lake and not lithology) and underfilled lake or simply the shoreline facies of a larger stratified, meromictic lake. By incorporating other published logs (Fleming, 1970) into our regional cross section, the Mottled red beds become the shoreline and littoral environments for another large, slightly older, and apparently unreported, meromictic lake system (our #1 cycle of meromictic sedimentation; Figure 48) that expanded across at least part of the Deer Lake Basin at the beginning of Rocky Brook time. This frequently oxidized part of the Mottled red beds interval has little prospect as a hydrocarbon source. Under appropriate structural and stratigraphic circumstances, it may be a reservoir rock.

The facies transition zone from mottled red and reddish brown, basal Rocky Brook strata into a mottled, predominantly grey and grey green siltstone and shale can be as much as 60 m thick, as in core 0039 where a thick zone of interbedded grey, grey green, olive grey and grey red and grey brown siltstone extends to the bottom of this hole. Nearby in hole 0037, this transition is thinner, only about 35 m thick, and characteristically grey brown in colour. This upper transitional part of the Mottled red beds succession was apparently deposited in a lower energy, oxidized and sometimes dysoxic environment; perhaps a relatively deep but also a polymictic or dimictic (seasonally stratified) lacustrine setting that expanded to cover most of the Deer Lake Basin. Longer term cyclical fluctuations in seasonal organic productivity from lacustrine phytoplankton and terrestrial plant detritus, can result in layered sediment that is slightly more organic in composition. The thicker layering of siltstone beds and overall lack of bioturbation suggests that sedimentation rates were fairly high.

In the cores we have examined, overlying grey, grey black and greenish grey siltstone and shale up to about 75 m thick (Lower grey beds) are formed of thin and thick beds up to about 5 m thick (Figure 48). Many of these beds are lighter grey in colour and not prospective source rocks. Other thicker and darker shale beds, such as those reported by Hamblin et al. (1997) for hole 0023, contain significant organic carbon belonging to

Type I and Type II source rocks. Thicker, darker, and organic rich source rocks may have formed in poorly oxygenated or anoxic water at times when meromictic conditions developed in the lake.

Meromictic conditions occur when seasonal or other periodic overturn of the water mass stops. Failure for the lake waters to turn over may be caused by significant and persistent temperature differences between warm surface waters and cold water deep in the basin or density differences between fresh surface water and deep water that may be enriched with, among other things, dissolved humic material, sulfates, and salts. Climate change influencing wind shear and the shape, depth and tectonic configuration of a lake basin are critical to the development of a meromictic state.

Some grey and grey black siltstone and shale from this part of the Spillway Member present an interesting paradox. In core 0023, reported here, and to a lesser extent in Northgate Exploration core DDH 79B-001 (0042 in Figure 2) reported by Hamblin et al. (1997), high TOC values occur in thick grey black siltstone and shale that is interbedded with sandstone beds. These sandstones are for the most part massive, however they also contain minor sedimentary structures such as tabular cross-laminae, convolute laminae, fluid escape structures, and sandstone lenses of generally coarser material than the matrix. Several of these structures point to rapid sedimentation. By simply considering these sandstones as proximal deposits in a lake, one may conclude that these were shallow water delta-front sands formed on or adjacent to one of the elevated flower structures that ultimately separated the Howley and Humber Lateral Basins (Hyde et al. 1994). However, the source for this sand and the mechanism for transport to a muddy lake bed is not well explained, nor is the association of these sands with rich source rocks of presumably deeper water origin.

Another possible origin may arise if one considers similarities of Spillway Member deposits to sand deposits reported by Nelson et al. (1999) in Lake Baikal. In their study, Nelson et al. (1999) show how axial turbidites form parallel to the edge of a ramp margin in Lake Baikal, Russia. The mostly homogenous sandstone beds in core 0023 are apparently thin sheets with sharp upper and lower contacts. Many of these contacts are simply sandstone to dark grey mudstone. In others, underlying siltstone beds may be a part of a coarsening-upward cycle or simply part of the basins normal mudstone-siltstone sucession and randomly covered with a sandstone bed. By following the examples presented in Nelson et al. (1999) and Zavala et al. (2006), the rich source rocks observed in core 0023 and formed in a relatively deep water setting can co-exist with turbidite or hyperpycnal sandstone beds deposited far into the basin.

In addition, and for our Deer Lake core study, we found very little soft sediment deformation, erosion and transport of intraformational sandstone and mudstone. In abundance, intraformational rocks are indicators for penecontemporaneous faulting tied to active basin subsidence (Wetzler et al., 2010). If sandstone beds in core 0023 are hyperpycnal deposits, the main episode of tectonic activity separating the Humber and Howley Lateral Basins occurred sometime after deposition of Humber Falls Formation.

The last and highest stratigraphic unit of the Spillway Member, the Brown beds, marks a return to brownish grey, greyish olive, light grey and dark grey siltstone and shale. The top of the Lower grey beds and the base of the Brown beds is defined by the first appearance of brownish coloured strata. The top of the Brown beds, also known as the top of the Spillway Member and base for the Squires Park Member is the top of the last significant bed of brownish coloured strata. For this study, this boundary also defines the horizontal datum we used for correlation (Figure 48). Across the basin, the siltstone succession in the cores we examined typically measures about 25 m in thickness. Strata occur in sharply bounded thickening and coarsening-upward cycles of grey siltstone and shale grading to thick beds of lighter grey and brownish coloured siltstone. Brownish colouration, probably indicative of oxidation, may indicate sediment progradation into a lake that was becoming shallower and more susceptible to mixing. In core 0042, in the north end of the basin and very near the Altius Minerals core localities (Figure 2), Hamblin et al. (1997) report root casts in nodular limestone beds. In this area, the lake may have become a subareal plain.

The Squires Park Member, and also known as the Upper grey beds, lies immediately above the Brown beds of the top of the Spillway Member (Figure 48). It is a rather uniform succession of about 120 m of predominantly grey, grey green and grey black siltstone and shale. The gradational base is defined by the top of the last brownish coloured bed in the underlying Brown bed succession. The top of the Squires Park Member is always very sharp, and perhaps an erosional unconformity or fault with conglomerate and sandstone of the base of the Humber Falls Formation.

Hyde et al. (1994) report three different oil shale-siltstone facies associations in the Squires Park Member (Figure 53). These facies associations are based upon the presence or absence of allochemical and stromatolitic carbonates and fish fossils interbedded with oil shale and surrounded by grey siltstones. Oil shales with bedded allochems (FA1) are recording the passage of hyperpycnal flows or turbidites across the lake bed. *In situ* stromatolites (FA2), perhaps akin to those identified in core 0037 (Figure 26) indicate quasi-stable conditions on the lake bed allowing sufficient time for

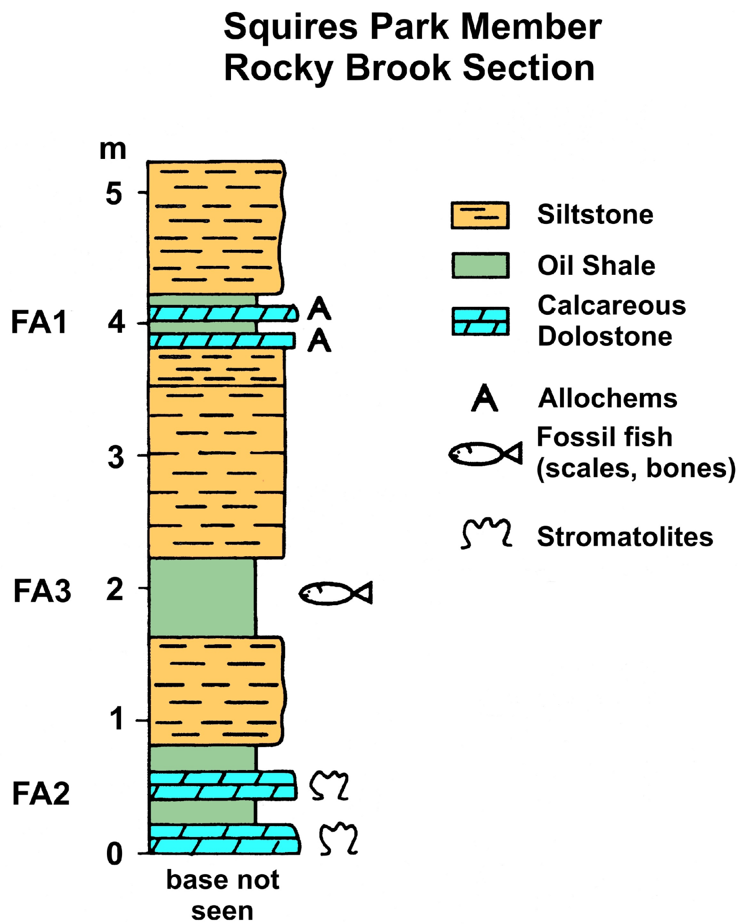


Figure 53: Stylized Facies Associations recorded by Hyde et al. (1994) for oil shale beds of the Squires Park Member; similar successions also occur in the Spillway Member. Rich source rocks are not often found as thick bedded deposits. Allocycles thought to represent a few thousand years are typically only a few metres thick.

cyanobacteria to grow. For oil shale with fish fossils (FA3), vertebrate remains may not be particularly good environment indicators. They are rare, probably randomly located, and clearly not in an environment where they can contribute much new information about the strata. Their state of preservation will offer proxy information on water quality, and particularly whether the environment was oxic, dysoxic or anoxic.

In summary, and based upon the cores we have examined, a broad range of apparently cyclical events are captured in the rock record of the Rocky Brook Formation. Some of these are summarized in Figures 50-53. For these cycles, it is tempting to consider strata as records for wet-dry and oxic-anoxic cycles formed as a result of orbital forcing, Milancovitch Cycles, associated with Mississippian glaciations. However, both Liutkus and Ashley (2003) and Pietras and Carroll (2006) offer advice cautioning against fitting data to a model. In their work, as ours, intramember sedimentary cycles are generally thin, and typically less than 10 m thick. Liutkus and Ashley (2003) and Pietras and Carroll (2006) have radiometric dates indicating that these kinds of cycles are no more than a few thousand years in duration and outside the shortest 19-23 ka precessional periodicity in the Milancovitch cycles. Independently, both Liutkus and Ashley (2003) and Pietras and Carroll (2006) suggest these deposits are allocycles or perhaps parasequences in today's Sequence Stratigraphy nomenclature. Pietras and Carroll (2006) offer a variety of options linked to a background of tectonic and geomorphologic changes to the landscape, but none capture the apparent periodicity of these beds. One possibility examined by Pietras and Carroll (2006) involves a proposal made be Short et al. (1991) and Park et al. (1993) and showing how half precession cycles of approximately 10 ka can develop in lakes formed under alternating dry and monsoonal conditions in equatorial regions. For their work on Eocene Green River Formation strata, Pietras and Carroll (2006) rejected that concept; their study is nowhere near the equator. We cannot say the same thing for the Rocky Brook Formation; the Carboniferous equator cuts across this region.

On a grander scale, a summary of the Spillway and Squires Park members, and based upon the cores examined here, shows two, shallow and deep water lacustrine cyclothems, each perhaps as much as 150 m thick. The Spillway Member cycle is recognized as shallow water, polymictic, oxidized lake beds (Mottled red beds) succeeded by deeper water, oligomictic and meromictic, organic, sometimes reduced, lake beds (Lower grey beds), and capped with a relatively thin succession of shallow water, polymictic, oxidized lake beds (Brown beds). The Squires Park Member cycle is incomplete; there is no clear contact between the Squires Park lacustrine mudstone and overlying Humber Falls fluvial sandstone.

Finally, by expanding this review to include the Claybar core logs (Figure 48) as summarized from Fleming (1970), it is clear that yet another earlier and underlying cycle of lacustrine sedimentation, also characterized by red, grey, black and red siltstone and shale, as much as 150 m thick, developed in other parts of this basin. The three cycles, each with their respective dark, shale beds, simply labelled 1, 2 ,and 3, are schematically illustrated in Figure 48. These successions may be on the same time scale as glacial-interglacial events driven by orbital periodicities.

Carroll and Bohacs (1999) synthesized many earlier studies of modern and ancient lakes to create a ternary model of broad scale facies associations and lakes, identifying Underfilled, Balanced and Overfilled lake models according to changes in tectonic subsidence and climate. In their model, Overfilled Lakes can be dominated by fluvial processes prograding into and rapid infilling a lake basin. Underfilled Lakes are subjected to repeated wet-dry cycles with dominantly aggradational strata containing aeolianites and evaporite minerals. Balanced or Fluctuating-profundal Lakes show distinctive shoaling cycles formed as a combination of prograding fluvial processes balanced against a background of tectonic subsidence and climate change. Strata and sedimentary structures in the Deer Lake Basin indicate that the Rocky Brook Formation lakes that once occupied this area were basically balanced, having slowly changed from an evaporative underfilled state as North Brook sedimentation ended.

Conclusions

Core and outcrop analysis shows the Rocky Brook Formation is a distinctive lacustrine siltstone and organic mudstone succession comprised of mixed reddish, brown, green and grey strata of the Spillway Member, below, and green and grey strata of the Squires Park Member, above. Rocky Brook strata contain many beds containing significant Type I and Type II hydrocarbon source rocks. The richest of these beds are apparently dispersed in two relatively narrow bands in the Squires Park Member and in the lower grey unit of the Spillway Member. Stratigraphy and sedimentology analyses of cores and historical review of the literature shows the Rocky Brook Formation to be a fluctuating profundal lake deposit containing distinctive shoaling cycles and very few indicators for dessication. This is a character of Balanced-fill Lakes where input of water and sediment keeps step with basin subsidence. Shoaling cycles may have their origins as half-precession cycles found in monsoonal equatorial regions. Their composition can vary according to position in the lake. In the critical deeper water regions, meromictic conditions leading to organic enriched strata may develop when water and clastic sediment input are reduced.

Rocky Brook strata conformably rest upon fluvial sandstones and conglomerates of the North Brook Formation. They are in turn unconformably overlain by other fluvial sandstones of the Humber Falls Formation. Collectively, these rocks form the Deer Lake group, a probable middle to late Visean and early Serpukovian succession deposited in a basin (the Deer Lake Basin) centred on an Alleghenian rift on the suture of the Humber and Dunnage tectonostratigraphic zones.

In origin, gravity and magnetic measurements for the Deer Lake Basin show subsidence is controlled by reactivation of Precambrian and Ordovician basement. Deer Lake Group and other strata deposited on Dunnage crust in the east (the Howley Lateral Subbasin) are much thicker and more deeply buried than their correlative beds deposited on Humber crust to the west (the Humber Lateral Subbasin). With shallow burial, Rocky Brook strata in the Humber Subbasin are largely immature and not capable of generating significant hydrocarbons. In contrast, Rocky Brook strata in the Howley Basin are likely to have entered the oil window and produced liquids and gas.

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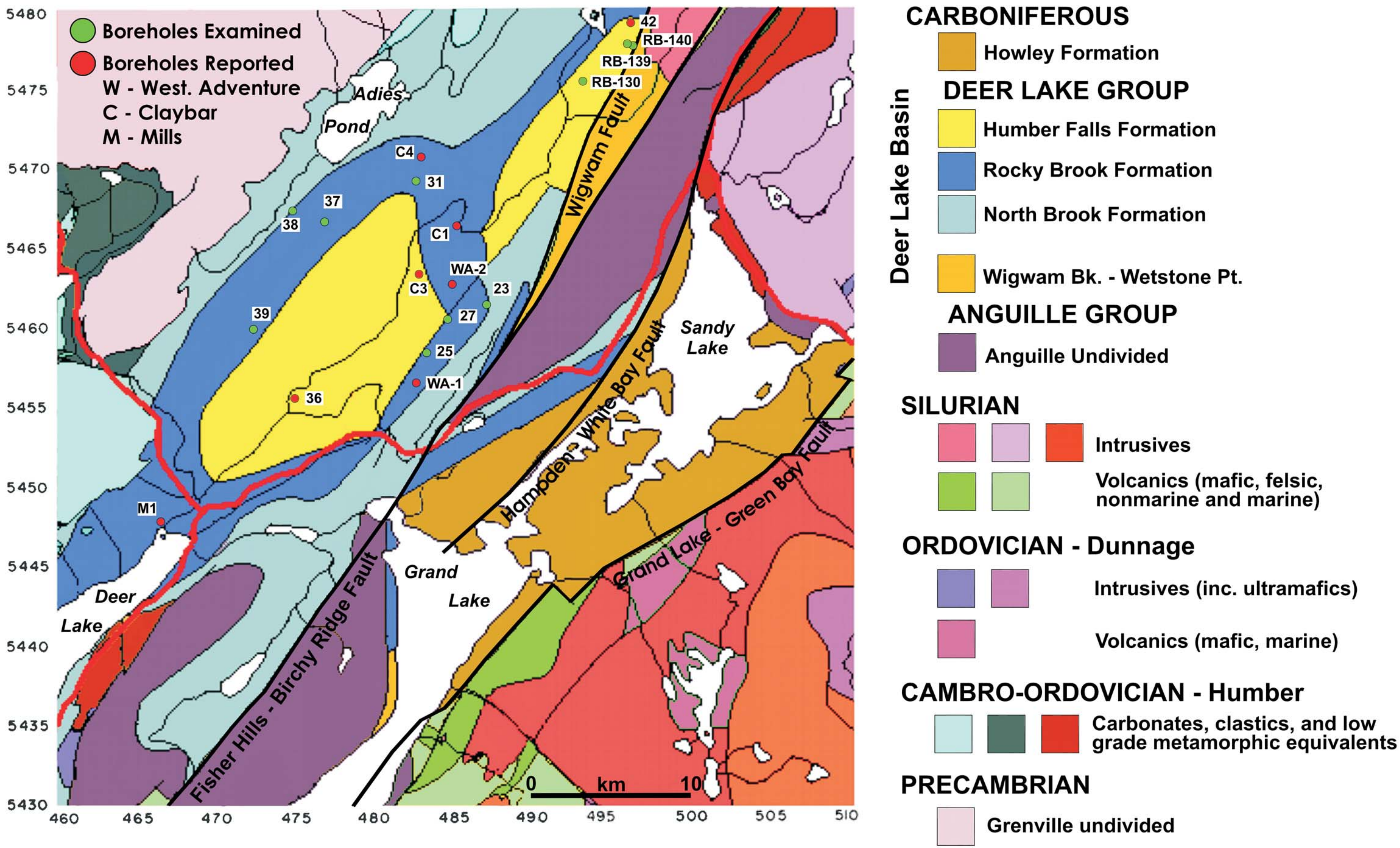
APPENDIX 1

Larger Regional Map



Boreholes Examined
Boreholes Reported
W - West. Adventure
C - Claybar
M - Mills
Adies Pond
Deer Lake
Grand Lake
Sandy Lake
Wigwam Fault
Hampden - White Bay Fault
Fisher Hills - Birchy Ridge Fault
Grand Lake - Green Bay Fault
42
RB-140
RB-139
RB-130
C4
31
37
38
C1
WA-2
C3
23
39
27
25
WA-1
36
M1
0 km 10
5480
5475
5470
5465
5460
5455
5450
5445
5440
5435
5430
460
465
470
475
480
485
490
495
500
505
510
CARBONIFEROUS
Howley Formation
Deer Lake Basin
DEER LAKE GROUP
Humber Falls Formation
Rocky Brook Formation
North Brook Formation
Wigwam Bk. - Wetstone Pt.
ANGUILLE GROUP
Anguille Undivided
SILURIAN
Intrusives
Volcanics (mafic, felsic, nonmarine and marine)
ORDOVICIAN - Dunnage
Intrusives (inc. ultramafics)
Volcanics (mafic, marine)
CAMBRO-ORDOVICIAN - Humber
Carbonates, clastics, and low grade metamorphic equivalents
PRECAMBRIAN
Grenville undivided

APPENDIX 2

Rock Specimens for Rock-eval Analysis

Samples

Table 1 lists locality data for 15 samples collected from the Pasadena core library. Samples were taken as fragments of the core or "pucks" within the specified intervals. Samples represent duplicate analyses from previously published work and as in-fill analyses for strata and for cores where limited data are available.

Table 2 shows all samples taken from core belonging to Altius Resources. Fragments of rock were taken randomly from the specified intervals. In total, 4 samples were taken in this area and where there is no record for TOC and Rock-Eval analyses.

Table 1: Samples taken from the Pasadena Core Library

Sample ID	HOLE ID	FROM (m)	TO (m)	LITHOLOGY
1	12H6/0037	171.4	171.5	Siltstone-Shale
2	12H6/0039	11.7	11.8	Siltstone-Shale
3	12H6/0039	47.9	48.1	Shale
4	12H6/0039	171	172.5	Siltstone
5	12H6/0023	89	89.2	Shale
6	12H6/0023	109.4	110.2	Siltstone-Shale
7	12H6/0025	29.4	29.9	Shale
8	12H6/0031	12	12.1	Shale
9	12H6/0037	20.7	21.3	Siltstone-Shale
10	12H6/0037	41.7	42	Siltstone-Shale
11	12H6/0039	54.1	54.3	Siltstone-Shale
12	12H6/0039	73.5	74	Siltstone
13	12H6/0027	9	9.1	Siltstone
14	12H6/0027	14.7	15	Siltstone-Shale
15	12H6/0027	17.9	18.1	Siltstone-Shale

Table 2: Samples taken from Altius Resources core.

Sample ID	Hole ID	From (m)	To (m)	Lithology
1-AC-RB-140	RB-06-140	36.9	37.6	Siltstone-shale
2-AC-RB-130	RB-06-130	59.7	60	Shale
3-AC-RB-130	RB-06-130	69.8	70.2	Siltstone-Shale
4-AC-RB-130	RB-06-130	85.1	85.4	Shale

APPENDIX 3

Geochemical Analyses Reported In Hamblin *et al.* 1997

	SAMPLE	DEPTH (m)	TOC	S1	S2	S3	S1+S2	PI	HI	OI	TMAX
	SUBSURFACE SAMPLES										
Core 0023	92-2A	19.2	0.12	0.01	0.01	0.17	0.02	0.50	8	142	
	92-2B	19.5	0.29	0.00	0.05	0.33	0.05	0.00	17	114	
	92-2C	25.26	1.53	0.18	6.03	0.78	6.21	0.03	394	51	434
	92-2D	53.9	0.74	0.05	0.45	0.62	0.50	0.10	61	84	
	92-2E	66.4	1.12	0.13	4.39	0.51	4.52	0.03	392	46	440
	92-2F	71.3	1.82	0.43	8.43	0.47	8.86	0.05	463	26	434
	92-2G	74.8	8.36	2.35	67.76	0.75	70.11	0.03	811	9	441
	92-2H	85.0	3.61	0.71	25.68	0.60	26.39	0.03	711	17	441
	92-2I	84.9	3.35	0.98	20.65	0.88	21.63	0.05	616	26	437
	92-2J	103.3	1.73	0.29	5.72	0.77	6.01	0.05	331	45	434
	92-2K	104.4	0.99	0.10	0.62	0.73	0.72	0.14	63	74	431
	92-2L	121.6	0.75	0.07	0.51	0.54	0.58	0.12	68	72	426
Core 0039	92-3A	8.7	5.79	2.62	47.82	0.62	50.44	0.07	826	11	442
	92-3B	17.0	2.23	0.98	12.73	1.01	13.71	0.07	571	45	430
	92-3C	47.5	0.92	0.14	3.01	0.46	3.15	0.04	327	50	438
	92-3C	54.4	0.15	0.00	0.02	0.17	0.02	0.00	13	113	
	92-3E	64.3	0.22	0.01	0.02	0.35	0.03	0.33	9	159	
	92-3F	86.9	0.25	0.01	0.01	0.32	0.02	0.50	4	126	
	92-3G	104.1	0.64	0.09	1.50	0.42	01.59	0.06	234	66	439
	92-3H	117.6	0.77	0.10	0.69	0.51	0.79	0.13	90	66	434
	92-3I	121.0	1.44	0.38	4.80	0.81	5.18	0.07	333	56	432
	92-3J	222.6	0.18	0.02	0.03	0.44	0.05	0.40	17	244	
	92-3K	235.7	0.22	0.01	0.03	0.47	0.04	0.25	14	214	
Core 0037	88-5A	7.8	0.87	0.07	2.08	0.20	2.15	0.03	239	23	432
	88-5B	17.0	0.23	0.00	0.04	0.16	0.04	0.00	17	70	
	88-5C	27.5	1.10	0.19	3.92	0.19	4.11	0.05	356	17	438
	88-5D	41.0	0.44	0.03	0.42	0.22	0.45	0.07	95	50	433
	88-5E	54.8	0.51	0.04	0.42	0.22	0.46	0.09	82	43	436
	88-5F	66.3	1.51	0.33	6.74	0.25	7.07	0.05	446	17	442
	88-5G	76.1	0.54	0.04	0.96	0.19	1.00	0.04	178	35	435
	88-5H	91.3	2.90	0.55	15.81	0.39	16.36	0.03	545	13	436
	88-5I	119.8	0.76	0.08	1.70	0.11	1.78	0.04	224	14	437
	88-5J	140.2	0.35	0.00	0.30	0.20	0.30	0.00	86	57	441
	88-5K	171.0	0.68	0.07	2.05	0.21	2.12	0.03	301	31	442
	88-5L	178.0	0.36	0.05	.81	0.15	0.86	0.06	225	42	439
	88-5M	198.6	0.14	0.01	0.03	0.14	0.04	0.25	21	100	
	88-5N	202.0	0.05	0.00	0.00	0.01	0.00	0.00	0	20	
	88-5O	214.0	0.13	0.00	0.06	0.06	0.06	0.00	46	46	
Core 0042	92-4A	103.9	1.06	0.18	2.49	0.46	2.67	0.07	235	43	427
	92-4B	30.0	3.70	1.67	24.54	1.10	26.21	0.06	663	30	436
	92-4C	55.5	2.08	0.57	11.64	0.91	12.21	0.05	560	44	438
	92-4D	96.5	0.65	0.08	0.66	0.34	0.74	0.11	102	52	429
	92-4E	115.8	1.22	0.13	3.99	0.43	4.12	0.03	327	35	440
	92-4F	134.1	0.11	0.01	0.07	0.38	0.08	0.13	64	345	
	92-4G	170.0	0.38	0.04	0.10	0.47	0.14	0.29	26	124	
	92-4H	165.7	4.59	0.62	26.88	1.56	27.50	0.02	586	34	426
	OUTCROP SAMPLES										
STRATOTYPE LOCALITY	92-1A		0.41	0.01	0.51	0.21	0.52	0.02	124	8	433
	92-1B		0.32	0.01	0.42	0.21	0.43	0.02	131	8	436
	92-1C		0.01	0.00	0.00	0.02	0.00	0.00	0	8	
	92-1D		0.43	0.03	0.71	0.19	0.74	0.04	165	8	435
	94-14		5.97	0.08	51.25	0.89	51.33	0.00	858	8	440
	RB2		13.63	0.48	125.95	1.58	126.43	0.00	924	8	444
	RB3		8.22	0.16	67.42	0.73	67.58	0.00	820	8	446
	RB7		14.93	2.85	140.20	1.30	143.05	0.02	939	8	449
	RB9		9.80	0.33	90.65	1.20	90.98	0.00	925	8	447

Rock-Eval/TOC data for Rocky Brook shales including standard measured and derived Rock-Eval parameters (Espitalie *et al.*, 1985). Annotation is as follows: **TOC** = total organic carbon as per cent by weight of whole rock; **S1** = hydrocarbons evolved at 300°C (mg hydrocarbon/g rock); **S2** = hydrocarbons evolved during heating at 25°C/min between 300°C and 600°C (mg hydrocarbon/g of rock); **S3** = organic carbon dioxide evolved at 300°C and up to 390°C (mg CO_2/g rock) ; **PI** = Production Index (S1/S1+S2); **HI** = Hydrogen Index (100 x (S2/TOC)); **OI** = Oxygen Index (100 x (S3/TOC); **Tmax** = temperature (°C) at top of S2 peak. Where no Tmax values are given, S2 peak was too small for a reliable value.

Geochemical data on bitumen and Rocky Brook Formation rock extracts.

	Sample	Lab No.	Ext Yld.[1]	HC Yld.[2]	% HC[3]	% R+A[4]	Sat/ Arom[5]	pr/ ph[6]	pr/ nC17[7]	C29 S/R[8]	27[9]	28[9]	29[9]	hop αβ/βα[10]	29/ 30[11]	Ts Tm[12]	Gam/ Hop[13]	Hop/ ster[14]	β-car[15]
	Subsurface samples																		
Core0023	92-2C	8115	262.3	14.5	7.4	81.1	2.89	2.15	0.13	0.15	17	28	54	1.68	0.58	0.06	10.82	13.72	
	92-2F	8116	165.3	33.2	20.1	76.4	3.35	1.25	0.61	0.15	17	28	54	4.84	0.4	0.46	4.67	13.72	
	92-2G	8117	65.8	26.9	41.0	56.2	3.02	1.19	0.42	0.22	16	30	54	4.14	0.37	0.49	11.72	13.72	*
	92-2H	8118	135.8	24.1	17.7	77.8	3.02	1.17	0.27	0.21	18	38	44	3.82	0.44	0.53	10.74	13.72	
	92-2I	8119	184.5	48.2	26.1	69.1	2.95	1.2	0.44	0.25	19	36	45	4.55	0.43	0.54	11.33	13.72	
Core0039	92-3A	8120	161.6	52.4	32.5	66.9	2.22	0.74	0.64	0.22	22	31	47	3.49	0.31	0.37	29.80	13.72	**
	92-3B	8122	344.3	60.1	17.5	79.2	2.07	1.09	0.54	0.26	26	34	40	2.44	0.42	0.41	22.52	13.72	
	92-3I	8123	213.6	46.0	21.5	77.4	2.71	1.32	0.75	0.24	20	24	56	4.55	0.41	0.53	9.33	13.72	
Core0042	92-4B	8124	288.7	70.5	24.4	71.6	2.44	0.82	0.57	0.24	11	32	57	4.58	0.36	0.35	14.57	13.72	**
	92-4C	8125	260.0	49.4	19.0	73.0	1.92	1.07	0.49	0.26	20	24	56	4.19	0.3	0.5	17.88	13.72	*
	92-4E	8126	377.3	41.0	10.9	83.8	3.19	1.41	0.16	0.26	32	18	50	3.79	0.69	0.64	30.41	13.72	
	92-4H	8127	126.0	8.8	7.0	91.7	1.06	1.63	0.4	0.46	21	30	49	7.42	0.62	0.5	7.09	13.72	
	Bitumen samples																		
Rocky Bk Fm	94-3A	8310	190.7	67.8	35.6	57.5	2.63	1.98	0.43	0.71	17	24	59	4.93	0.86	0.49	5.41		***
	94-4A	8311	282.8	103.2	36.5	55.1	1.07	2.17	0.7					4.51	0.79		8.40		**
	94-4B	8312	285.0	84.7	29.7	51.8	0.64	1.64	0.49					4.93	0.89	0.47	5.59		***
Howley Fm	94-8A	8313	1237.9	610.0	47.0	50.4	1.53	0.83	0.55	0.59	14	29	57	4.31	0.6	0.38	5.96	16.02	***
	94-8B	8314	1338.1	691.8	51.7	46.2	1.16	0.65	0.53	0.59	15	29	56	4.19	0.6	0.25	5.30	13.72	***
	Outcrop samples																		
Rocky Bk Fm	94-14	8368	85.2	23.1	28.0	57.2	2.41	0.9	0.33	0.2	17	35	48	4.58	0.65	0.4	2.82	2.52	*
	RB2	8364	54.0	23.1	42.8	46.8	2.86	0.94	0.3	0.22	17	35	48	4.41	0.7	0.49	10.64	2.85	*
	RB3	8365	42.9	11.7	27.4	64.8	1.38	2.19	0.23	0.3	24	22	54	3.94	0.59	0.47	4.93	16.89	
	RB7	8366	52.0	25.1	48.3	44.6	5.90	1.63	0.23	0.2	15	37	48	4.24	0.71	0.33	4.12	5.52	*
	RB9	8367	96.4	40.4	41.9	48.2	2.15	0.78	0.6	0.21	19	33	48	3.48	0.55	0.29	5.48	2.68	**

[1]Extract Yield (mg/g OrgC)
[3]%Hydrocarbons in extract
[4]%Resins+asphaltenes in extract
[5]Saturate/Aromatic hydrocarbons
[6]Pristane/phytane
[7]Pristane/n-heptadecane
[8]5α(H),14α(H),17α(H)20S/5α(H),14α(H),17α(H)20R-C_{29}steranes
[9]normalized proportion of C_{27}:C_{28}:C_{29}5α(H),14α(H),17α(H)20R steranes
[10]17α(H),21βhopane/17β(H),21α(H)-moretane
[11]C29/C30 17α(H)-hopane
[12]18α(H)-trisnorhopane/17α(H)-trisnorhopane
[13]Gammercerane/17α(H)-hopane x 100
[14]17α(H)-hopane/C_{29}5α(H), 14α(H), 17(H)20R sterane
[15]Relative abundance of β-carotane in SFGCs (***high, *low)

APPENDIX 4

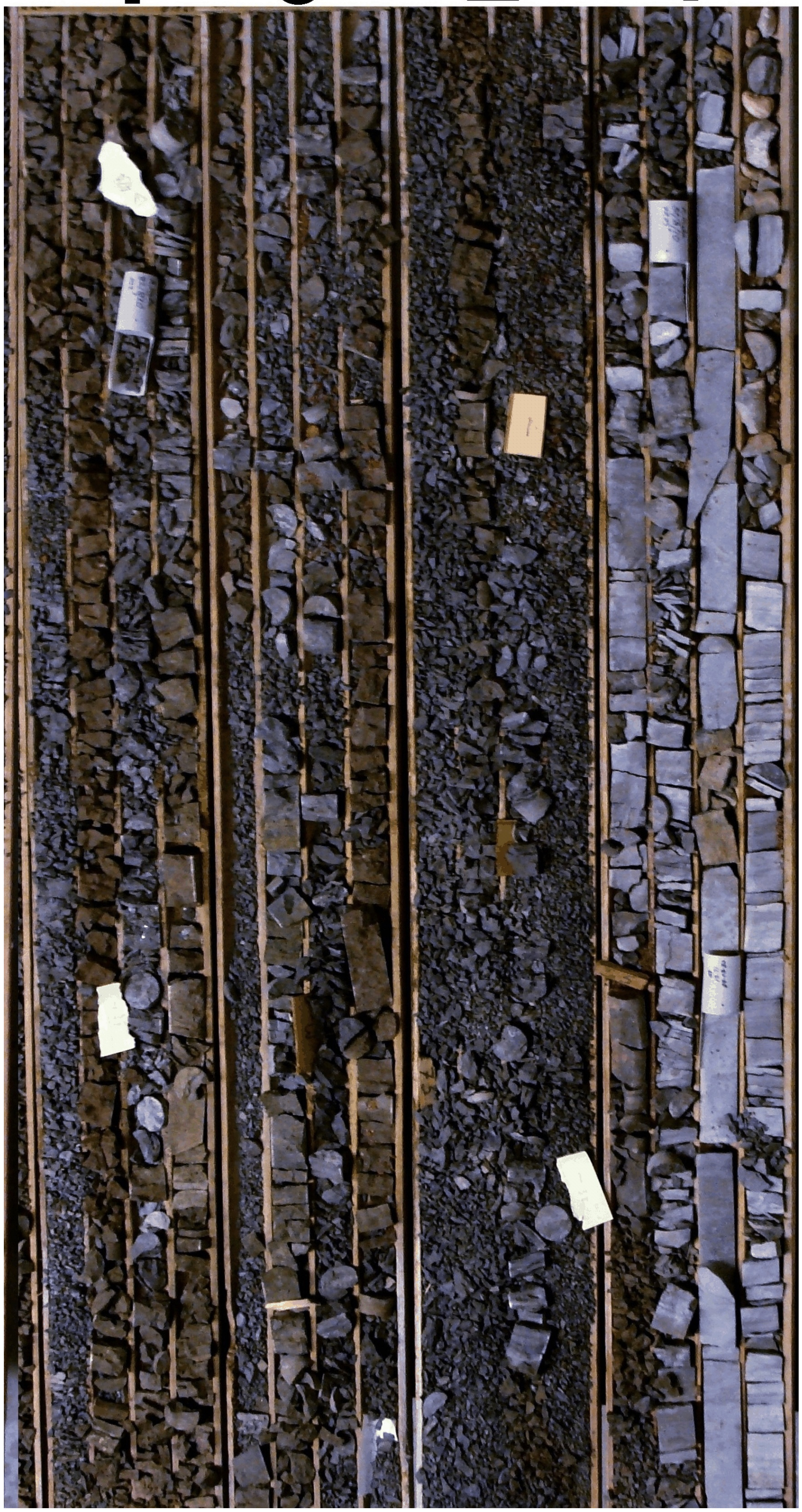
Detailed Long Core Photographs

NOTE: Colour for many of these images is not exact; photos for old cores were produced under imperfect lighting conditions at the Government core library. In referencing the apparent colours seen on these images, one should first consult the log report and determinations made with Munsel colour chips.

Core 0023

4 3 2 1

Top



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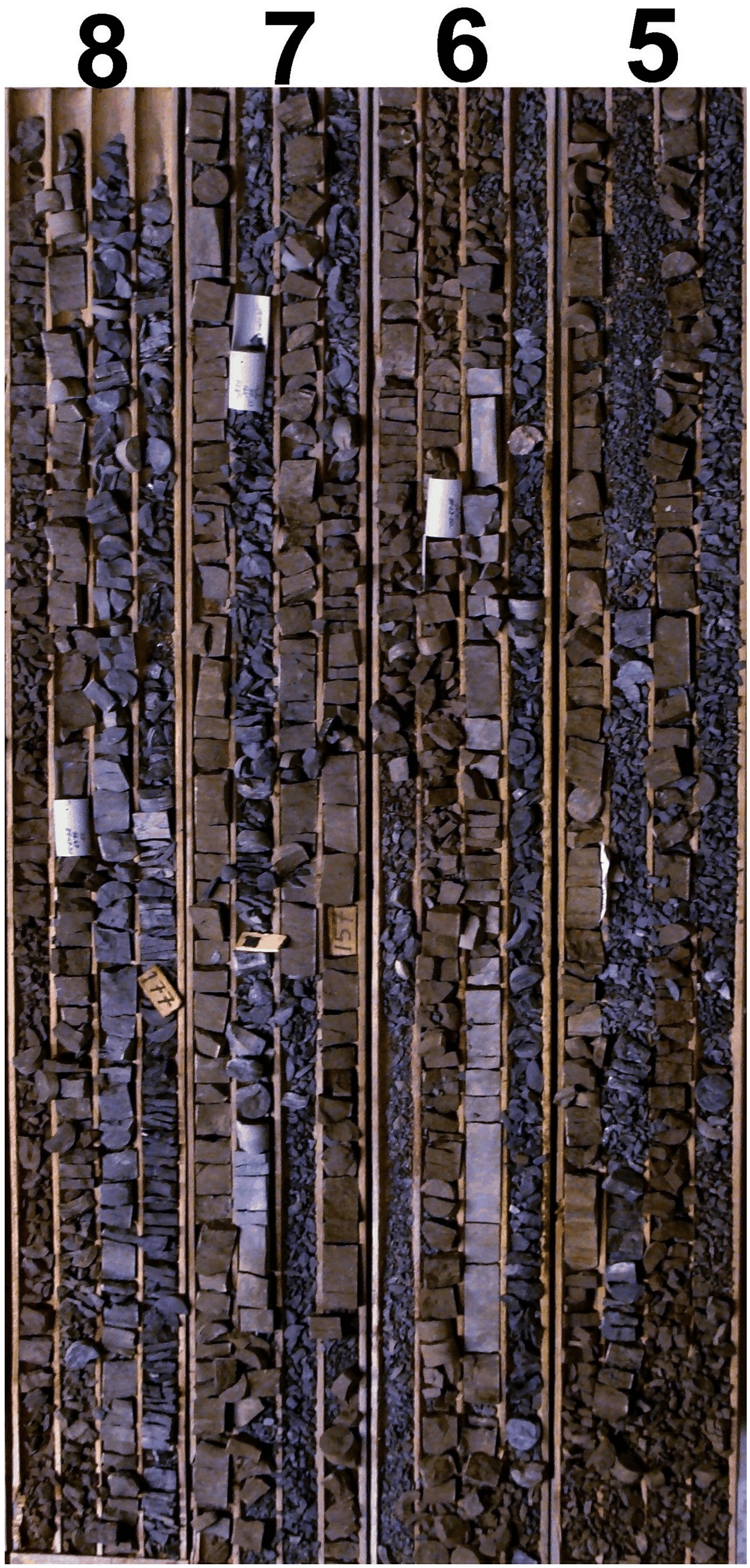

Core 0023

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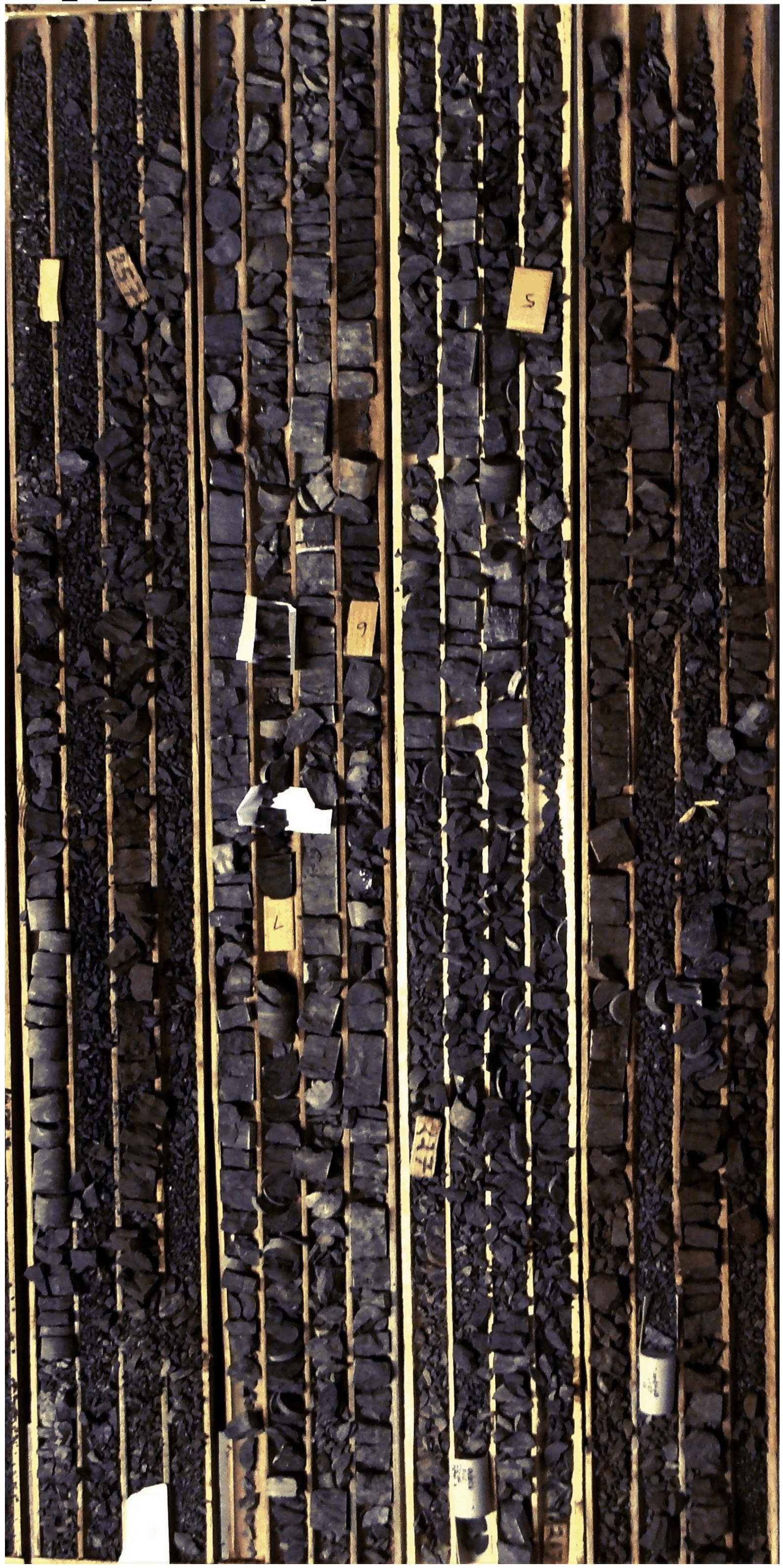

Core 0023

Core 0023

19 18 17

Bottom

Core 0037

Top

Core 0037

Core 0037

Core 0037

Core 0037

Core 0037

Core 0037

Core 0037

Core 0037

Bottom

Core 0039

Top

Core 0039

Core 0039

Core 0039

Core 0039

Core 0039

Core 0039

Core 0039

Core 0039

Core 0039

Core 0039

Core 0039

Bottom

Core Altius RB130

Top

Core Altius RB130

Core Altius RB130

RB130 7

Core Altius RB130

Core Altius RB130

RB130 13

Core Altius RB130

RB130 16

Bottom

Core Altius RB139

RB139 1

Top

Core Altius RB139

RB139 4

Core Altius RB139

Core Altius RB139

Core Altius RB139

RB139 13

Core Altius RB139

RB139 **16**