EUB/AGS Earth Sciences Report 2004-01

Sequence Stratigraphy and Its Use for Uranium Exploration in the Western Athabasca Basin of Alberta and Saskatchewan

Alberta Energy and Utilities Board

Alberta Geological Survey

EUB/AGS Earth Sciences Report 2004-01

Sequence Stratigraphy and Its Use for Uranium Exploration in the Western Athabasca Basin of Alberta and Saskatchewan

Brent Collier[1]

[1]Formerly of Alberta Geological Survey (see page ii for permanent address)

May 2005

ISBN 0-7785-1495-1

When using information from this publication in other publications or presentations, due acknowledgment should be given to the EUB/AGS. The following reference format is recommended:

Collier, B. (2005): Sequence stratigraphy and its use for uranium exploration in the western Athabasca Basin of Alberta and Saskatchewan; Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2004-01.

Author address:
Brent Collier
Box 631
Gull Lake, Saskatchewan
S0N 1A0
E-mail: brent_n_collier@hotmail.com

Published May 2005 by:
Alberta Energy and Utilities Board
Alberta Geological Survey
4th Floor, Twin Atria Building
4999 – 98th Avenue
Edmonton, Alberta
T6B 2X3
Canada

Tel: (780) 422-3767 (Information Sales)
Fax: (780) 422-1918
E-mail: EUB.AGS-Infosales@gov.ab.ca

Website: www.ags.gov.ab.ca

Contents

Appendices

Tables

Figures

Acknowledgments

The author thanks Reg Olson, Dinu Pană, Darrel Long, Charlie Jefferson, Paul Ramaekers and Gary Yeo for insightful reviews and/or discussions of this paper. The support provided by Rob Natyshen and Tim Berezniuk at the Mineral Core Research Facility (MCRF) of the Alberta Geological Survey in Edmonton is greatly appreciated. Also, a special thanks is required for the staff at the Subsurface Geological Laboratory at Saskatchewan Industry and Resources in Regina. Last, the author thanks Bob Davie at RnD Technical for his quick and thorough edit of this report.

Foreword

Throughout the course of the EXTECH IV uranium subproject 4a (Jefferson and Delaney, 2000), a variety of stratigraphic studies were conducted in the Athabasca Basin of Alberta. Ramaekers (2004) conducted a comprehensive regional study of Alberta; Kupsch and Catuneanu (in press) provided a localized stratigraphy and geochemical clay alteration study of the Maybelle River prospect; and Post (2004) carried out a detailed stratigraphic study over the Maybelle River and Net Lake trends. Due to the differing scales of each subproject, each author approached division of the Athabasca Group somewhat differently, although each employed a variation of Ramaekers' earlier studies (1979, 1980, 1981, 1990).

Although this report is a regional study similar in scale to that of Ramaekers (2004), it based on a different view that links bulk changes in lithology to grain-size trends, since lithological variations seem to always accompany changes in grain-size. Grain-size trends are an easy and consistent means of dividing the strata, as they can readily be recognized over large distances. Although lithological characteristics are similar within sequences, there are slight lateral variations in lithology that occur throughout the basin. By using this method for division, it is easier to extrapolate and compare these lithological changes from one part of the basin to another, especially through the use of selected parameters from metre-by-metre lithologs. This report relates grain-size trends to concepts of sequence stratigraphy and proposed as revised set of well-defined stratigraphic units.

The report contains metre-by-metre stratigraphic sections constructed for each drillcore, a third of which are compiled from data of the EXTECH IV project (Yeo et al., 2001, 2002a; Collier, 2002; Kupsch and Catuneanu (in press); Post, 2004; Ramaekers, 2004). The remaining drillcores were either studied anew, or relogged to acquire additional information. This information is used to make detailed correlations throughout the western Athabasca Basin in Alberta and Saskatchewan. Graphic logs give a good basis for the stratigraphic divisions because they allow the reader to visually assess the author's rationale for making stratigraphic picks.

Abstract

Eighty-nine cores were logged on a metre-by-metre basis in the western Athabasca Basin of Alberta and Saskatchewan. Seven third-order sequences, ranging from several tens to hundreds of metres in thickness, were positively identified. These include from base to top: the Fair Point, Shea Creek, Lower Manitou Falls, Upper Manitou Falls, Lower Wolverine Point, Upper Wolverine Point and Locker Lake–Otherside sequences. Above the Fair Point Sequence, a highly erosive boundary containing localized paleosols separates two unique depositional basins. The older Jackfish Basin consists entirely of coarser fluvial clastic sediments of the Fair Point Sequence. The overlying William River Basin consists of the relatively finer-grained and dominantly fluvial clastics of all of the remaining sequences.

The basal Shea Creek, Lower Manitou Falls and Upper Manitou Falls sequences are entirely fluvial and were probably restricted to near the present-day margins of the Athabasca Basin. Their general coarsening-upward stacking pattern and limited lateral distribution suggest a normal regression under relatively low change in rates of accommodation. In contrast, the overlying Lower and Upper Wolverine Point sequences were probably more widespread beyond the present-day margins of the Athabasca Basin. This fining-upward succession represents deposition under relatively higher change in rates of accommodation, as deposits retrograded from entirely fluvial to fluvial-lacustrine. The uppermost Locker Lake–Otherside sequence, although not complete, represents a late normal regression where relative change in rates of accommodation are overtaken by rates of sediment supply. Changes in sequence thickness and basal lithology appear to be linked to faulting within the basin. If such is the case then this can be used to predict where fault zones occur in the western Athabasca Basin, and indicate potential uranium mineralized zones.

1 Introduction

The western third of the ca. 1700 Ma Athabasca Basin is located in northeastern Alberta and northwestern Saskatchewan, roughly between latitudes 57.2° and 59.6°N and longitudes 103.5° and 111.5°W (Figure 1). It is generally confined between the northern shores of Lake Athabasca (on the north and northwest), the Athabasca River (on the west and southwest), and the Richardson River (on the south). The southern portion of the basin is only 80 km north of the Athabasca Oil Sands. The majority of the basin lies in Saskatchewan, extending east to Wollaston Lake, 100 km from the Manitoba border. The basin encompasses a surface area of approximately 80 000 km^2. Of this, the Alberta portion accounts for 8000 km^2, or approximately 10%.

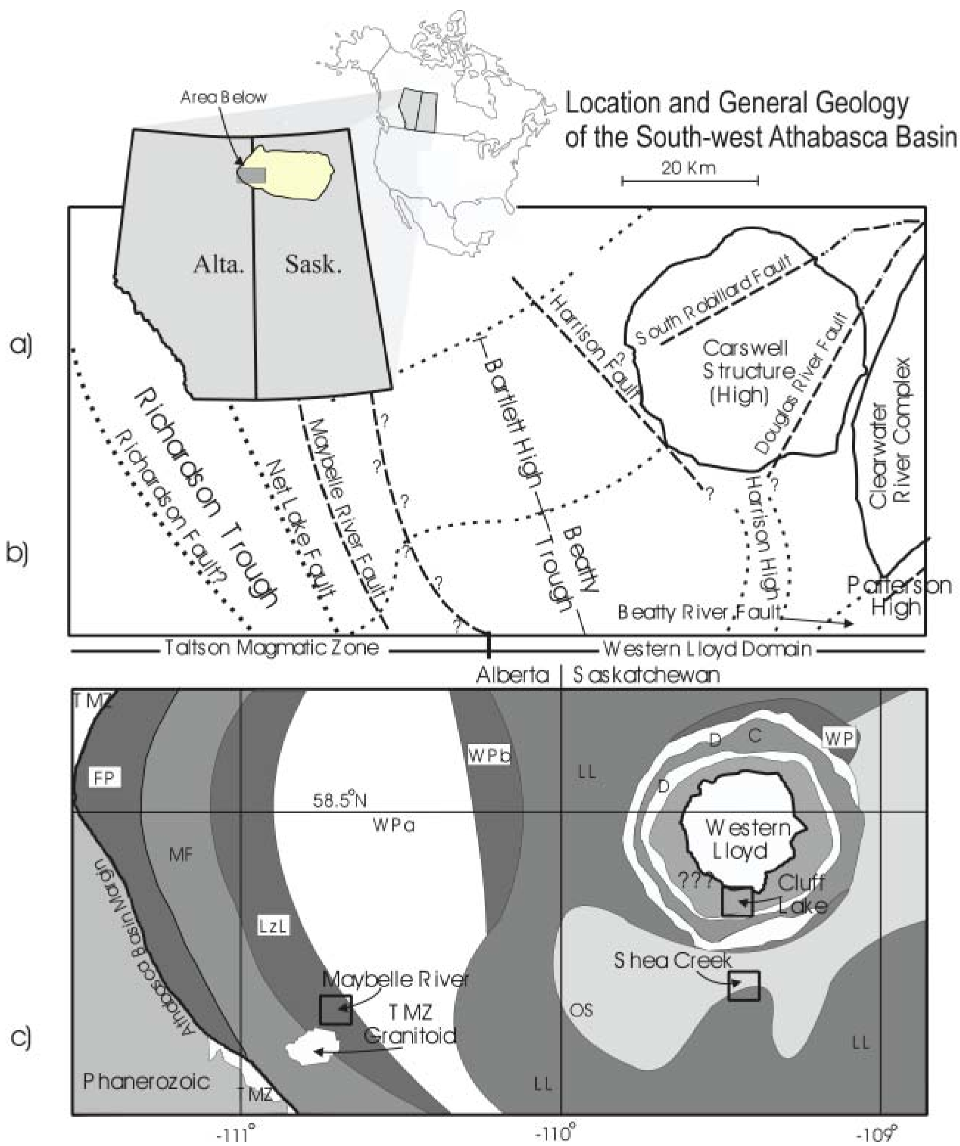


Figure 1. a) Location of Athabasca Basin. b) Basement and structural divisions in the southwestern Athabasca Basin (revised from Ramaekers, 2004). Dashed lines indicate faults and dotted lines represent inflection points between basement highs and lows. c) Athabasca Group stratigraphy of the southwestern Athabasca Basin (after Ramaekers, 2004). Lithostratigraphic formations are indicated by the following abbreviations: FP, Fair Point; MF, Manitou Falls; LzL, Lazenby Lake; WP, Wolverine Point; LL, Locker Lake; OS, Otherside; D, Douglas; C, Carswell; TMZ, Taltson Magmatic Zone. Note that a revised version of this subcrop map is presented later in this report.

At present the largest high-grade uranium deposits are found along the eastern rim of the Athabasca Basin. In the western part of the basin, uranium orebodies have been mined within the Carswell meteorite impact structure, at Cluff Lake, Saskatchewan. As well, south of Cluff Lake, mineralized zones have been found at approximately 700 m depth at Shea Creek (Figure 1c). In Alberta, the first notable occurrence of uranium mineralization was found at Maybelle River, where grades of 21% U_3O_8 were intercepted over a 5 m interval (drillcore MR-39; see Orr, 1989).

The unconformity-related uranium mineralization of the Athabasca Basin is either basement hosted, sandstone hosted or a combination of the two (e.g., Hoeve and Sibbald, 1978). It is concentrated in dilation zones associated with faults, and often associated with graphitic basement (e.g., Ramaekers, 2004). The sandstone hosted deposits are almost always restricted to the basal sections of the Athabasca Group. It is unclear whether certain formations are more susceptible to mineralization than others. Regardless, some units acted as aquifers or aquitards that either directly delivered metalliferous or diagenetic fluids to sites of mineralization or suppressed the migration of potential remobilizing fluids. Concepts of basinal fluid flow in the Athabasca Group have been discussed by Kyser (2000).

Alberta is a favourable area for exploration because many splays off major fault systems run along the western margin of the basin (e.g. Ramaekers, 2004). Two interesting zones parallel the Net Lake and Maybelle River faults, oriented roughly north-northwest (Post and Kupsch, work in progress). Since mineralization has already been discovered at Maybelle River, it is currently the most prospective area for exploration. The basement unconformity at Maybelle River is relatively shallow, ranging between 0 and 250 m in depth, making the area of particular economic interest because open-pit exploitation costs would be relatively low compared to those of the deep mines, such as at McArthur River, where the orebody is more than 500 m deep.

2 General Geology of the Study Area

The Athabasca Basin lies unconformably above the Rae and Hearne provinces, which form the core of the Churchill Structural Province (Stockwell, 1961). The Rae and Hearne are separated by the enigmatic Snowbird Tectonic Zone, a crustal-scale discontinuity that has been modelled both as a suture (Hoffman, 1988) and as an intracontinental strike-slip shear zone (Hanmer et al., 1994). The basement rocks beneath the western part of the Athabasca Basin in Saskatchewan lie within the Lloyd Domain of the Rae Province (Figure 1). This includes a supracrustal package dominated by metasedimentary rocks of the Careen Lake Group (Scott, 1985), a younger suite of ca. 1.985–1.968 Ga granitoid orthogneiss (Stern et al., 2003), and weakly deformed ca. 1.93–1.91 anatectic granite bodies (Brouand et al., 2003). The two magmatic suites are essentially contemporaneous with intrusive rocks found in the Taltson Magmatic Zone (Bostock et al., 1987; McDonough et al., 2000), which dominate the basement of the Alberta portion of the Athabasca Basin. The Lloyd Domain can be traced into northeastern Alberta based on its aeromagnetic signature, which comprises an alternating pattern of highs and lows (Geological Survey of Canada, 1987). It is likely that the Lloyd Domain grades into more granitoid-rich rocks of the Taltson Magmatic Zone, although no drillcores are available to confirm this. In Saskatchewan, the Lloyd Domain is overprinted by the north-trending Clearwater aeromagnetic high, inferred to comprise mainly ca. 1.843 Ga granite intrusives of the Clearwater Domain (Stern et al., 2003), which subdivides the Lloyd Domain into eastern and western parts. The origin of these granite bodies is poorly understood.

Structures in the western Athabasca Basin (Figure 1b) have largely been described in terms of basement topographic lows (troughs) and highs, based largely on mapped and inferred faults from outcrops and aeromagnetic maps (Ramaekers, 2004). The majority of the drillcores examined in this study are centred in and around a basement topographic low found in the southwestern portion of the Athabasca Basin, referred to as the Beatty Trough. The Beatty Trough is bounded to the southeast by the Beatty River Fault, which is easily identified on aeromagnetic maps (Card, 2001). South of the Beatty River Fault is a basement topographic high that extends from the southwestern rim of the Athabasca Basin in Alberta across the basin into Saskatchewan. This is referred to here as a portion of the Patterson High. The Beatty Trough is bounded to the north by the Bartlett High, a structure that trends east-northeast across the western basin. The Bartlett High is probably associated with movements along the South Robillard Fault, which can be traced across the northwestern portion of the Carswell Structure in Saskatchewan (Ramaekers, 2004). A more southerly trending fault, the Douglas River Fault, can be traced along the southeastern portion of the Carswell Structure and may be a splay of the same fault zone (Ramaekers, 2004). Southeast of the Patterson High, another basement low is identified in the western Saskatchewan portion of the Athabasca Basin and is here referred to as the Mirror Sub-basin. North of the Bartlett High, a major basement low extends all the way to the northern margin of the Athabasca Basin in Alberta and is referred to as the Jackfish Sub-basin (Ramaekers, 2004).

A series of more northerly trending faults, such as the Maybelle and Net Lake faults, have been interpreted as splays off the Charles Lake Shear Zone (Ramaekers, 2004). These crosscut all of the east-northeast trending structures. In the Maybelle River area, movements along these faults have created further relief over the Bartlett High. As a result, a large Taltson granitoid body subcrops in the area (Post, 2004). West of Maybelle River there is a basement topographic low referred to as the Richardson Trough (Ramaekers, 2004) that appears to be associated with movement along the north-northwest trending Richardson Fault. A similarly trending basement topographic high segments the Beatty Trough south of the Carswell Structure, as recognized by Yeo (pers. comm., 2003) in Saskatchewan. This high appears to extend from Shea Creek and toward the southern margin of the basin. It appears to be parallel to the north- to northwest-trending Harrison Fault and is here referred to as the Harrison High.

The ca. 1700 Ma Athabasca Group consists of approximately 2.1 km of predominantly fluviatile sandstone (Figure 1c), which has been divided into eight formations by Ramaekers (2004). Some of these formations have been further subdivided into members, designated by a lower-case letter suffix. Lithostratigraphic divisions are based on changes in the size and/or abundance of pebbles, clay intraclasts, conglomerate and mudstone. The Fair Point Formation (FP) is confined to the Jackfish Sub-Basin in the northwestern portion of the Athabasca Basin (Ramaekers, 2004) and pinches out to the south over the Bartlett High. This is overlain by the Manitou Falls Formation (MF), which is the basal formation for the rest of the Athabasca Basin. The Lazenby Lake (LzL) and Wolverine Point (WP) formations are widespread over large portions of the central and western basin. The Locker Lake (LL) and Otherside (OF) formations are limited to the central portion of the basin. The Douglas (DF) and Carswell (CF) formations are restricted to the Carswell meteorite impact structure in the western Saskatchewan portion of the Athabasca Basin. Radiometric dating of breccia units associated with this structure have yielded a lower age limit of 356 Ma (Bell, 1985).

3 Previous Work on the Athabasca Group

The stratigraphy of the Athabasca Basin was largely developed by Ramaekers (1979, 1980, 1981, 1990, 2004). Although the formation-scale divisions are formalized throughout the Athabasca Basin, the member scheme is still informal because there is not yet enough information available regarding their areal extent and lithological variation (Ramaekers, 2004). Ramaekers' (1990) original classification was developed from regional outcrop mapping and logging of selected drillcores throughout the basin. To date, the Manitou Falls Formation (MF) has been the most extensively studied unit. In the eastern basin, its members (MFa–d) are regionally extensive and widely accepted. In the western basin, the lithostratigraphic requirements for most of these members are rarely met, making the entire package an equivalent of the clean sandstone member, MFc. Table 1 compares the previous classification schemes in the western Athabasca Basin, with reference to the revised classification scheme introduced later in this paper. See text below for explanation of the subunits and the correlations between authors.

Table 1. Comparison between the lithostratigraphic and sequence-stratigraphic classifications of previous authors in the western Athabasca Basin. Note that the previous division between the Lazenby Lake and Wolverine Point formations is difficult to compare in this table because many previous authors have been relatively inconsistent with this subdivision, compared to other subdivisions, and because the boundary has been redefined in the current study.

<table>
<tr><th colspan="2">Sequences</th><th colspan="4">Lithostratigraphy</th></tr>
<tr><th>Collier (this study)</th><th>Ramaekers (2004)</th><th>Ramaekers (2004)</th><th>Wilson (1985)</th><th>Post and Kupsch (work in progress)</th><th>Yeo et al. (2001)</th></tr>
<tr><td>not present</td><td rowspan="6">Locker Lake–Carswell</td><td>Carswell</td><td>not present</td><td>not present</td><td>not present</td></tr>
<tr><td>not studied</td><td>Douglas</td><td>not present</td><td>not present</td><td>Douglas</td></tr>
<tr><td rowspan="4">Locker Lake–Otherside</td><td>Otherside</td><td>Otherside</td><td>not present</td><td>Otherside</td></tr>
<tr><td>Locker Lake c</td><td rowspan="3">Locker Lake</td><td>not present</td><td>Locker Lake c</td></tr>
<tr><td>Locker Lake b</td><td>not present</td><td>Locker Lake b</td></tr>
<tr><td>Locker Lake a</td><td>not present</td><td>Locker Lake a</td></tr>
<tr><td rowspan="3">Upper Wolverine Point</td><td rowspan="5">Lazenby Lake–Wolverine Point</td><td>Wolverine Point c</td><td rowspan="2">Wolverine Point Upper</td><td>not present</td><td>Wolverine Point c</td></tr>
<tr><td>Wolverine Point b</td><td>not present</td><td>Wolverine Point b</td></tr>
<tr><td rowspan="2">Wolverine Point a</td><td>Wolverine Point Lower</td><td>not present</td><td>Wolverine Point a</td></tr>
<tr><td rowspan="2">Lower Wolverine Point</td><td rowspan="7">Manitou Falls</td><td rowspan="2">Lazenby Lake</td><td rowspan="2">Wolverine Point–Lazenby Lake</td></tr>
<tr><td>Lazenby Lake</td></tr>
<tr><td rowspan="2">Upper Manitou Falls</td><td rowspan="5">Manitou Falls</td><td rowspan="2">Manitou Falls c/c’</td><td>Manitou Falls d</td><td>Manitou Falls d</td></tr>
<tr><td rowspan="2">Manitou Falls c</td><td rowspan="2">Manitou Falls c</td></tr>
<tr><td rowspan="2">Lower Manitou Falls</td><td rowspan="2">Manitou Falls c/a?</td></tr>
<tr><td>not present</td><td>Manitou Falls b</td></tr>
<tr><td>Shea Creek</td><td>Manitou Falls c”</td><td>not present</td><td>Manitou Falls a</td></tr>
<tr><td rowspan="3">Fair Point</td><td rowspan="3">Fair Point</td><td>Fair Point c</td><td rowspan="3">Fair Point</td><td>Fair Point Upper</td><td>Fair Point c</td></tr>
<tr><td>Fair Point b</td><td rowspan="2">Fair Point Lower</td><td>not present</td></tr>
<tr><td>Fair Point a</td><td>not present</td></tr>
</table>

Wilson (1985) conducted the first comprehensive study of the Athabasca Group in Alberta. He did not use Ramaekers’ member classification in this part of the basin and suggested that the Lazenby Lake Formation was absent in Alberta. This is understandable because during Wilson’s study there were very few drillcores available that intersected the Lazenby Lake Formation. Those that did were to the north of the Net Lake and Maybelle River trends, where the characteristic pebbly Lazenby Lake Formation is difficult to distinguish. This is probably the reason why Wilson classified Ramaekers’ (1990) Lazenby Lake Formation as part of the Manitou Falls Formation. Wilson’s (1985) Wolverine Point Formation included upper and lower members. The upper member is comparable to Ramaekers’ Wolverine Point ‘b’ (WPb) and ‘c’ (WPc) members. The lower member consists of a thin unit (<100 m) of granule- and pebble-bearing sandstone with minor mudstone. This unit correlates, in part, with Ramaekers’ (2004) Wolverine Point ‘a’ member (WPa).

One of the main goals of the EXTECH IV stratigraphy subproject (2000–2003) was to help clarify correlations in the western Athabasca Basin and attempt to resolve the apparent ‘border fault’ between the bedrock geology maps of Alberta (Wilson, 1985) and Saskatchewan (Ramaekers, 1990). Studies in the western Saskatchewan portion of the basin (Collier et al., 2001; Yeo et al., 2001, 2002a) indicated that possible equivalents of the eastern Manitou Falls members of Ramaekers (1990) were probably present throughout the western basin, as similar distinct lithofacies could be mapped across the area. Direct lithostratigraphic correlations were difficult to employ, however, as the criteria for the subdivision had to be changed in this portion of the basin to account for the lack of significant pebble and clay-intraclast proportions that are typical of their inferred eastern counterparts, MFb and d. The basal member, MFa, had never been studied in detail, thus making it difficult to identify, as the brief description by Ramaekers (1990) suggested that it would be difficult to distinguish from his MFc member. In the Shea Creek area, south of the Carswell Structure, a sedimentologically distinct succession was identified at the base of the Manitou Falls Formation and described as the Shea Creek unit (Collier, 2002). Similar sandstone units in this stratigraphic position were classified as MFa in a regional study in western Saskatchewan (Yeo et al., 2001), and a variant of MFc, Manitou Falls ‘c’ double prime (MFc”) in Alberta (Ramaekers, 2004), accounting for an inconsistency in nomenclature between authors. Ramaekers also designated another variant of MFc to the Jackfish Sub-basin referred to as Manitou Falls ‘c’ prime (MFc’).

There also has been confusion among authors regarding the distinction between the Lazenby Lake and Wolverine Point formations. Some studies considered the Lazenby Lake only as a pebbly sandstone (Ramaekers, 1990; Collier et al., 2001; Collier, 2002), whereas others have included the overlying clean mudstone-deficient sandstone (Yeo et al., 2001; Ramaekers, 2004). In this study, the Lazenby Lake Formation is considered only as pebbly sandstone. This unit is commonly less than 50 m thick in the western Athabasca Basin.

The first sequence-stratigraphy approach was proposed by Ramaekers et al. (2001), and later elaborated on by Yeo et al. (2002a). Ramaekers (2004) later attempted to link the four sequences (Fair Point, Manitou Falls, Lazenby Lake–Wolverine Point and Locker Lake–Carswell) to tectonism within the Athabasca Basin region.

4 Data Collection

Fifty-two drillcores were logged from the Alberta portion of the Athabasca Basin, and seven were logged from southern portion of the basin in Saskatchewan. An additional thirty-seven metre-by-metre logs were then created from log spreadsheets of the EXTECH IV project (*from* Yeo et al., 2001, 2002a; Collier, 2002; Kupsch and Catuneanu (in press); Ramaekers, 2004; Post, 2004). Drillcore information is summarized in Table 2. Eight lithological parameters were quantified for each interval by measuring crossbedded, low-angle or flat-bedded, and deformed bedded intervals, as well as maximum and mean grain sizes, thickness of pebbly-conglomeratic and fine-grained interbeds, percentages of clay rip-up, and thickness of sedimentary structures. Fracture and fault counts were also taken. Parameters that were difficult to quantify (i.e., clay mineral content, silicification and colour patterns) were only indicated in the remarks column where distinct changes occurred.

5 Stratigraphy

5.1 Sequence Stratigraphy in the Athabasca Basin

Sequence stratigraphy has primarily been used as an exploration tool for hydrocarbons in Phanerozoic

Table 2. Drillcore used in this study. Total thickness of drillcore used in this study is indicated at the bottom of the table.

	ID	Prov.	Logged by	Project	Drilled to basement	Depth to EOH or basement (m)
1	ALX-1	SK	Yeo & Hunter	EXTECH IV	x	721
2	AS-02	SK	Collier	This project		502
3	BR-09	SK	Yeo & Hunter	EXTECH IV	x	152
4	BR-18	SK	Yeo & Hunter	EXTECH IV	x	342
5	CAR-114	SK	Collier & Urban	EXTECH IV	x	1224
6	CAR-257	SK	Collier	This project		278
7	CAR-301	SK	Yeo & Hunter	EXTECH IV		460
8	CAR-651	SK	Yeo & Hunter	EXTECH IV		205
9	CLU1-78	SK	Collier	This project		86
10	CLU18-79	SK	Collier	This project	x	218
11	CLU9-79	SK	Collier	This project	x	114
12	CSP-6-1	SK	Collier	This project	x	374
13	DGS-04	SK	Yeo & Hunter	EXTECH IV		1101
14	DGS-07	SK	Collier & Urban	EXTECH IV	x	746
15	ERC-1	SK	Collier & Shumay	EXTECH IV	x	797
16	ERC-4	SK	Yeo & Hunter	EXTECH IV	x	752
17	FC-005	AB	Ramaekers & Jefferson	EXTECH IV	x	823
18	FC-007	AB	Collier	This project		1255
19	FC-008	AB	Collier	This project		1161
20	FC-009	AB	Ramaekers	EXTECH IV		360
21	FC-014	AB	Collier	This project		242
22	FC-015	AB	Collier	This project	x	220
23	FC-016	AB	Collier	This project		184
24	FC-017	AB	Collier	This project		228
25	FC-027	AB	Collier	This project	x	267
26	FC-028	AB	Collier	This project		307
27	FC-029	AB	Collier	This project		206
28	FC-030	AB	Collier	This project	x	259
29	FC-031	AB	Collier	This project	x	81
30	FC-032	AB	Collier	This project	x	99
31	FC-034	AB	Collier	This project		118
32	FC-035	AB	Collier	This project	x	132
33	FC-036	AB	Collier	This project	x	52
34	FC-037	AB	Collier	This project		174
35	FC-038	AB	Collier	This project	x	35
36	FC-039	AB	Collier	This project	x	173
37	FC-041	AB	Collier	This project	x	88
38	FC-043	AB	Collier	This project	x	148
39	FC-044	AB	Collier	This project	x	85
40	FC-045	AB	Collier	This project	x	109
41	FC-046	AB	Collier	This project	x	112
42	FC-047	AB	Collier	This project	x	88
43	FC-048	AB	Collier	This project	x	136
44	FC-052	AB	Collier	EXTECH IV		245
45	FC-056	AB	Collier	This project	x	35
46	FC-064	AB	Collier	This project	x	21
47	FC-071	AB	Collier	This project	x	206

	ID	Prov.	Logged by	project	Drilled to basement	Depth to EOH or basement (m)
48	FC-072	AB	Collier	This project	x	193
49	FC-075	AB	Collier	This project	x	154
50	HAR-04	SK	Collier	This project	x	274
51	HK-12	Sk	Yeo & Hunter	EXTECH IV	x	571
52	MR-02	AB	Collier	This project	x	79
53	MR-03	AB	Collier	This project	x	88
54	MR-04	AB	Collier	This project	x	121
55	MR-05	AB	Collier	This project	x	84
56	MR-06	AB	Collier	This project	x	57
57	MR-07	AB	Post	EXTECH IV	x	100
58	MR-10	AB	Post	EXTECH IV	x	150
59	MR-12	AB	Post	EXTECH IV	x	116
60	MR-13	AB	Collier	This project	x	80
61	MR-14	AB	Collier	This project	x	102
62	MR-15	AB	Collier	This project	x	56
63	MR-17	AB	Collier	This project	x	76
64	MR-18	AB	Collier	This project	x	79
65	MR-20	AB	Collier	This project	x	177
66	MR-34	AB	Kupsch	EXTECH IV	x	202
67	MR-35	AB	Collier	EXTECH IV	x	239
68	MR-36	AB	Post	EXTECH IV	x	279
69	MR-37	AB	Post	EXTECH IV	x	308
70	MR-64	AB	Post	EXTECH IV	x	118
71	MR-65	AB	Collier	This project	x	425
72	MR-66	AB	Collier	EXTECH IV	x	375
73	MR-68	AB	Collier	This project	x	380
74	MR-69	AB	Collier	This project	x	417
75	MR-70	AB	Post	EXTECH IV	x	339
76	MR-74x	AB	Collier	This project	x	104
77	MR-76	AB	Post	EXTECH IV	x	71
78	MR-78	AB	Collier	This project	x	60
79	MR-79	AB	Collier	This project	x	183
80	MR-81	AB	Post	EXTECH IV	x	174
81	MR-83	AB	Collier	This project	x	126
82	MR-84	AB	Post	EXTECH IV	x	338
83	MT-01	AB	Collier & Ickert	This project	x	328
84	MT-02	AB	Collier & Ickert	This project	x	230
85	SHE-1B	SK	Yeo & Hunter	EXTECH IV	x	406
86	SHE-6	SK	Collier & Kline	EXTECH IV	x	693
87	SHE-22	SK	Collier & Shumay	EXTECH IV	x	741
88	SHE-45	SK	Shumay	EXTECH IV	x	735
89	SYL-1	SK	Yeo & Hunter	EXTECH IV	x	726
			Total section:	EXTECH IV:		14609
				This project:		11666
						26275

basins. Sloss (1963) first introduced the concept that sea-level changes directly influenced stratigraphy by matching large-scale transgressive-regressive events across the North American Craton. Mitchum et al. (1977) later defined a sequence as "…a relatively conformable, genetically related succession of strata bound by unconformities or their correlative conformities". The building blocks of sequences are called *systems tracts*, which are characteristic stratigraphic responses to changes in rates of accommodation. In the marine environment, lithological changes are influenced by changes in the position of the coastline and are therefore related to relative sea level.

Although there have been fewer applications of sequence stratigraphy to nonmarine systems, they have been widely discussed (Posamentier et al., 1988; Posamentier and Vail, 1988; Shanley and McCabe, 1994; Miall, 1997). In such cases, the farther the basin is from the ocean, the less effect relative sea level or base level has on sedimentation (i.e., influence on river grade). In such cases, stratigraphic responses to the dynamics of the basin can be referenced solely by changes in the creation or destruction of accommodation space. Such changes are affected by the interrelation of many variables, such as eustatic sea level, regional tectonism and subsidence. In addition to these, sediment flux, paleogeography and climate also affect sedimentary patterns.

Traditionally, Precambrian basins have been mapped using principles of lithostratigraphy, given the relative homogeneity of the infill and the limited exposure within many of these basins. More recently, sequence stratigraphy has been used to revolutionize the understanding of Precambrian deposits (e.g., Krapez, 1996, 1997; Rainbird et al., 2003a). Krapez (1997) stated that "although lithostratigraphy provides a descriptive framework for terrain-scale geology, the technique is not genetically based, that is stratigraphic divisions are not tied to the depositional [and] tectonic meaning of the rocks". Throughout the Earth's history, there is no evidence for changes in the manner in which basins develop and evolve; sequence-stratigraphic principles should therefore apply to the Precambrian as well.

Similar to Phanerozoic models, Krapez (1996) suggested that sequences should be assigned in a hierarchical order, emphasizing their duration and genetic meaning: First-order sequences are linked to supercontinental cycles, which have an estimated periodicity of 183–364 m.y. Second-order sequences are defined as reflecting individual depositional basins or their tectonic stages, with a time span of 22–45 m.y. Third-order sequences represent basin-filling rhythms; these are highly influenced by regional-scale tectonics and interplate stresses, with periods of 1–11 m.y. Climate is thought to strongly influence higher order sequences (e.g., fourth-order, fifth-order, etc.). These age ranges should be used with caution, as there is little geochronological evidence at present to support them.

5.2 Athabasca Basin

The fill of the Athabasca Basin consists of predominantly braided fluvial deposits (Ramaekers, 2004). Because Precambrian systems were barren of vegetation, the closest modern analogues are dry-land rivers. In these systems, flow competency and stream energy dissipate downstream as a result of water infiltration into the underlying unconsolidated alluvium (Tooth, 2000).

The seeming overall homogeneity of the Athabasca Group and the general character of Precambrian rivers make sequence boundaries difficult to recognize in drillcore. Therefore, in this study, the term 'unconformity' is only used where an unconformable boundary has been directly and unequivocally observed in drillcore. Unconformities, though rarely observed, are usually recognized by massive basal gravel lags between formational-scale sequences (Figure 2). These lags are often associated with mudstone and clay-intraclast horizons, which may make feasible sequence stratigraphic picks where gravel lags are absent. The term 'conformity' is used where boundaries between discrete lithological

Figure 2. Massive conglomerate lag above the unconformity between the Upper Manitou Falls and Lower Wolverine Point sequences, at a depth of 186 m in drillcore FC-052, east of Maybelle River; lag is 15 cm thick; arrow indicates stratigraphic younging direction.

units have been picked on lithologs, even though an unconformity may have gone unrecognized. A combination of maximum grain size, mean grain size and coarse material (granules-pebbles and conglomerate) is used to infer these sequence boundaries. Grain-size trends appear to work best for estimating the location of sequence boundaries, as they are closely associated with unconformities where identified and are widely recognized across the western Athabasca Basin.

Each sequence is described in terms of up to three systems tracts, as outlined in Table 3. It is important to note that the nomenclature for systems tracts has been defined for marine-influenced systems, related to changes in relative sea level (e.g., Posamentier and Vail, 1988; Catuneanu, 2002). These terms should therefore be redefined for cratonic basins, such as the Athabasca Basin, where there is no evidence of marine influence on the succession, with the exception of the uppermost Douglas and Carswell formations. Relative sea-level change is ultimately driven by changes in the rates of creation or destruction of accommodation space. Just like marine-influenced systems, nonmarine systems should have similar characteristic stratigraphic responses to changes in accommodation rates. A revised nomenclature has not been proposed, as it would only add more jargon to an already complex field in which there is no standardization imposed by the North American Code of Stratigraphic Nomenclature.

A complete sequence consists of an initial coarsening-upward lowstand systems tract (LST); a middle, fining-upward transgressive systems tract (TST); and an upper, slightly coarsening-upward highstand systems tract (HST). All components are not always present for each sequence, because the LSTs appear to be confined to the centre of depositional troughs and the HSTs may have low preservation potential in the nonmarine environment (Miall, 1997). In distal sections (i.e., farther downstream or above topographic highs), sequences are only identified as fining-upward packages of the TST. Systems tracts

Table 3. Subsurface expression and genetic meanings of systems tracts for formation-scale sequences in the southwestern Athabasca Basin.

Stage	Systems Tracts	Signature	Subsurface Expression	Genetic Meaning
6	Highstand systems tract (HST)	Uniform to- slightly coarsening	Aggradation and progradation	Relative low rate of change in accommodation results in a late normal regression, where the locus of sedimentation shifts downstream (low preservation potential); only identified in the Upper Wolverine Point Sequence
5	Maximum flooding surface (MFS)	Discontinuities and correlative in-tract conformities	Overlies the thick mudstone unit (Upper Wolverine Point Sequence), separates retrograding strata from aggrading/prograding strata	Surface at which the change in rate of accommodation is once again overtaken by sediment influx (late-stage basin-filling); only identified in the Upper Wolverine Point Sequence
4	Transgressive systems tract (TST)	Fining-upward and/or no trends	Retrogradation	Relative high change in rate of accommodation shifts the locus of deposition upstream
3	Maximum regressive surface (MRS)	Discontinuities and correlative in-tract conformities	Underlies clay clasts and granule horizons, overlies mudstone and/or separates prograding strata from retrograding strata	Surface at which the change in rate of accommodation overtakes rates of sediment influx
2	Lowstand systems tract (LST)	Coarsening-upward	Progradation	Normal regression may occur in place of, or after, forced regression and shifts the locus of sedimentation downstream
1	Sequence boundary	Unconformity or correlative conformity	Underlies massive basal conglomerate and/or separates over-all upward-fining sequences	Low rates of accommodation or uplift creates a subaerial unconformity (forced regression); in more distal reaches of the fluvial system, these may be linked to correlative conformities

(Figure 3) are separated by minor disconformities and/or conformities, referred to as the maximum regression surface and the maximum flooding surface (e.g., Catuneanu, 2002). In the Athabasca Group, these commonly overlie mudstone and/or underlie clay rip-up and one-clast-thick granule-pebble horizons.

5.3 Facies Associations

Distinctive sets of facies associations are linked to each stratigraphic sequence in the western Athabasca Basin. Although lithofacies are not necessarily genetically based, they are usually laterally extensive and provide the framework for regional-scale correlations. As such, the sequences of this study, although defined by sequence boundaries and systems tracts, are described in terms of lithofacies and their changes throughout the southwestern Athabasca Basin. This provides a valuable link to the previously defined lithostratigraphy of Ramaekers (2004). As more information becomes available for the Athabasca Basin, more refined in-tract stratigraphic divisions could be implemented.

Twenty-eight facies associations are defined in this paper. These are briefly described throughout each

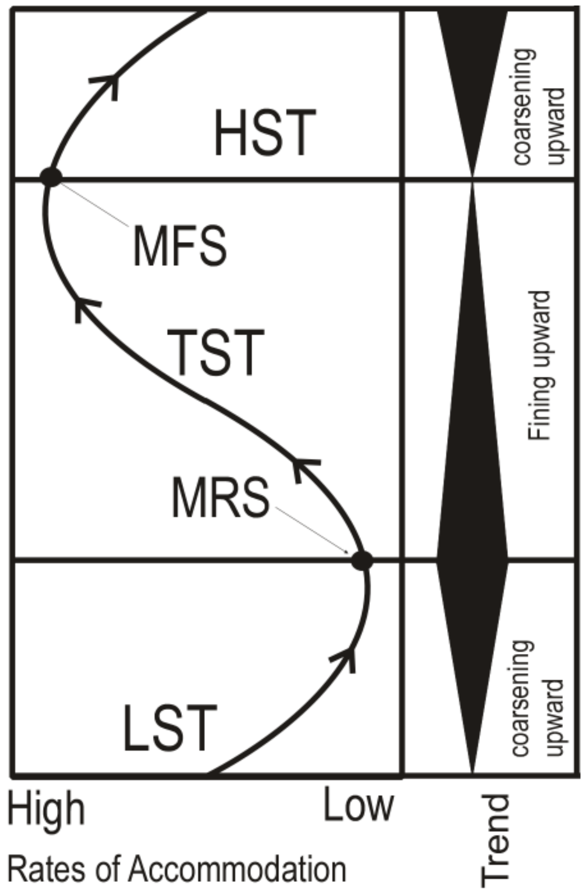


Figure 3. Systems tracts for sequences in the southwestern Athabasca Basin. The basal lowstand systems tract (LST) generally coarsens upward to represent early progradation while relative changes in rate of accommodation are low. The overlying transgressive systems tract (TST) is a fining-upward succession that represents retrogradation while relative changes in rate of accommodation are high. The highstand systems tract (HST) is rarely preserved, but generally coarsens to represent a late-stage basin-filling package that occurs when relative changes in rate of accommodation are overtaken by sediment influx. Systems tracts are separated by in-tract conformities. The maximum regressive surface (MRS) separates the LST and TST. The maximum flooding surface separates the TST and HST.

stratigraphic sequence and are summarized in Table 4. Note that although similar facies associations may occur throughout different sequences, they have been described and labelled separately for each sequence.

The sedimentary rocks that directly overlie the basement, contain a variety of lithologies, none of which can be traced with confidence between drillcores. These lithological changes are probably linked to local paleotopography. In some cases, it is convenient to force correlation between basal units because they share common characteristics (e.g., conglomerate, red mudstone layers). As a result, in this study, these are considered to be part of the overlying sequence because they probably represent partial, if not complete reworking of basement and/or earlier sedimentary deposits during initial stages of the sequence.

5.4 Stratigraphic Sequences

Seven formational-scale sequences (Table 4) were identified during this study. These sequences are interpreted as basin-filling rhythms or third-order sequences (Krapez, 1996, 1997). Such sequences are strongly influenced by intraplate stresses and basin-scale tectonics (Krapez, 1997). Depositional-

Table 4. Facies associations and their relationships to the stratigraphic sequences of this study.

Stratigraphic Sequence	Facies Association	Brief Lithological Description
Locker Lake–Otherside	FA 7-3	Clean fine-grained sandstone
	FA 7-2	Granule-bearing medium-grained sandstone
	FA 7-1	Pebbly medium-grained sandstone with minor conglomerate
Upper Wolverine Point	FA 6-5	Clay-rich medium-grained sandstone
	FA 6-4	Mudstone (abundant sandstone)
	FA 6-3	Fine-grained sandstone (abundant mudstone)
	FA 6-2	Fine-grained sandstone (little or no mudstone)
	FA 6-1	Granule- or pebble-bearing medium-grained sandstone
Lower Wolverine Point	FA-5-5	Clay intraclast–rich medium-grained sandstone
	FA-5-4	Granule-rich medium-grained sandstone
	FA 5-3	Fine to medium-grained sandstone (little or no mudstone)
	FA 5-2	Fine to medium-grained sandstone (common mudstone)
	FA 5-1	Pebbly medium-grained sandstone
Upper Manitou Falls	FA 4-5	Clay intraclast–rich (1%) fine to medium-grained sandstone
	FA 4-4	Clean medium-grained sandstone (frequent clay clasts)
	FA 4-3	Clean medium-grained sandstone (few or no clay clasts)
	FA 4-2	Granule/pebble-bearing medium-grained sandstone
	FA 4-1	Conglomeratic medium-grained sandstone
	FA 4-0	Basal rock types (above basement)
Lower Manitou Falls	FA 3-2	Clean medium-grained sandstone (few or no clay clasts)
	FA 3-1	Pebbly to conglomeratic medium-grained sandstone
	FA 3-0	Basal rock types (above basement)
Shea Creek	FA 2-2	Low-angle crossbedded sandstone
	FA 2-1	Trough crossbedded sandstone
	FA 2-0	Basal rock types (above basement)
Fair Point	FA 1-2	Pebbly medium to coarse-grainedsandstone
	FA 1-1	Conglomeratic coarse sandstone and conglomerate
	FA 1-0	Basal rock types (above basement)

trough development due to movements along interbasin fault zones seems to be a major factor for lithostratigraphic variation within the sequences, as the orientation of depositional troughs seems to parallel that of fault zones (as interpreted from Ramaekers, 2004). This indicates that regional tectonics played a major role in sedimentation. Nevertheless, changes in sequence thickness are usually slight from trough to limb, suggesting that the main control on accommodation rate within the Athabasca Basin was regional subsidence and/or other external controls, which are poorly understood at this time. The distributions of the third-order sequences in this study are largely tied into the structural interpretations of Ramaekers (2004), which are shown in Figure 4. These interpretations should be considered as preliminary as the AGS is currently assembling data that may result in significant revisions to this structural map in the future (D. Pana and R.A. Olson, pers. comm.).

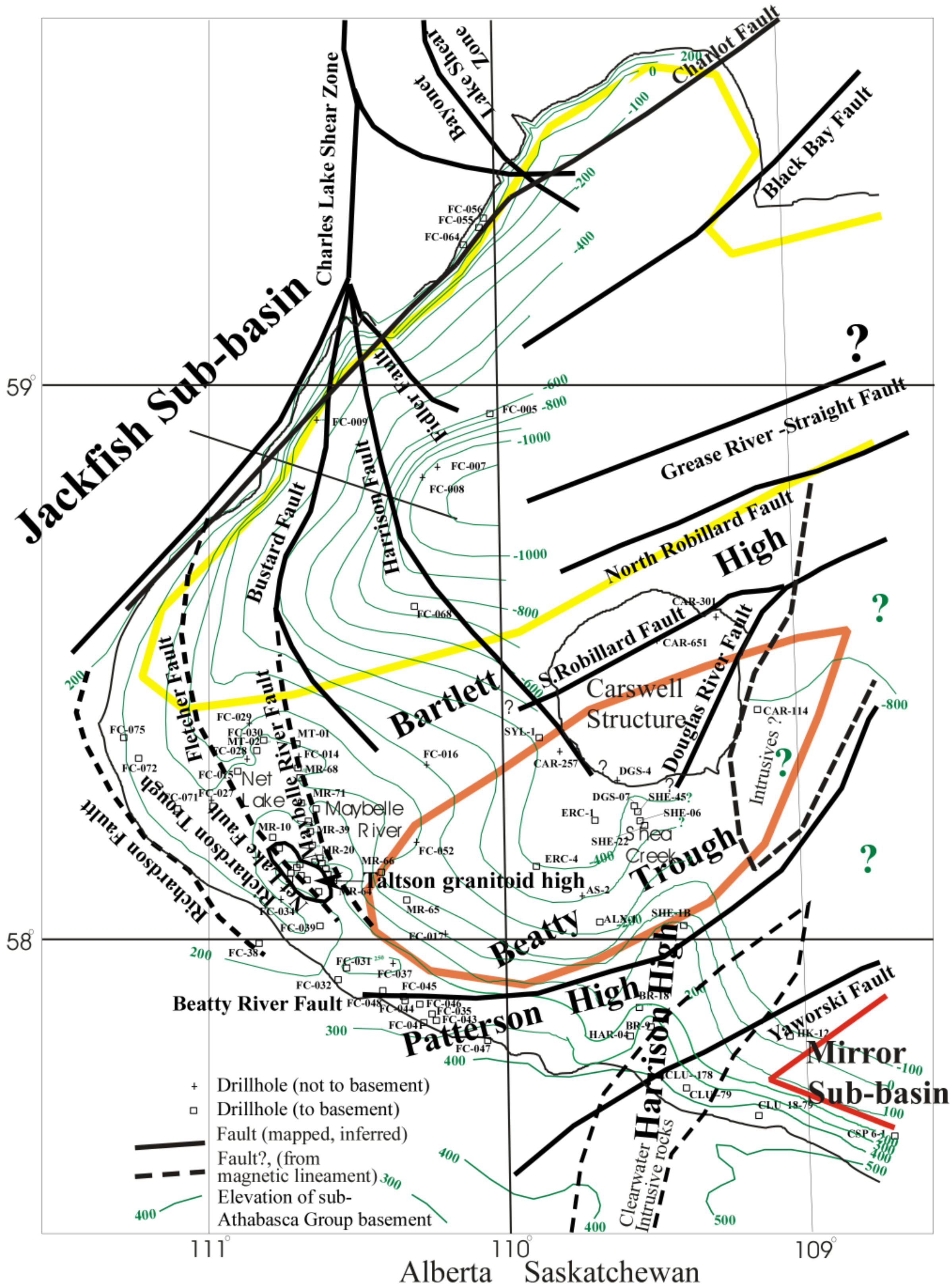


Figure 4. Basement topography and fault zones in the western Athabasca Basin (*revised from* Ramaekers, 2004). Contours are spaced at 100 m.

Included in the appendices are a table of sequence-top depths and thicknesses (Appendix 1), metre-by-metre lithologs for the eighty-nine drillcores (Appendix 2) and isopach maps for all the sequences (Appendix 3). The facies associations and stratigraphic sequences are indicated on each litholog. In the text, sequence thicknesses are only considered from cores where the measured sequence is preserved below other Athabasca Group sequences and not where they have been eroded at the subcrop surface. The revised subcrop map for the Alberta and western Saskatchewan portion of the Athabasca Basin (Figure 5) is based on the results of this core study, as well as outcrop maps of Ramaekers (1990, 2004). Cross-sections for stratigraphic fences on Figure 5 are shown on Figure 6. Log correlations between individual drillcores along these fences are shown on Figures 7 and 8. A detailed description for each sequence follows. Note that all references to mapped and inferred faults are from Ramaekers (2004).

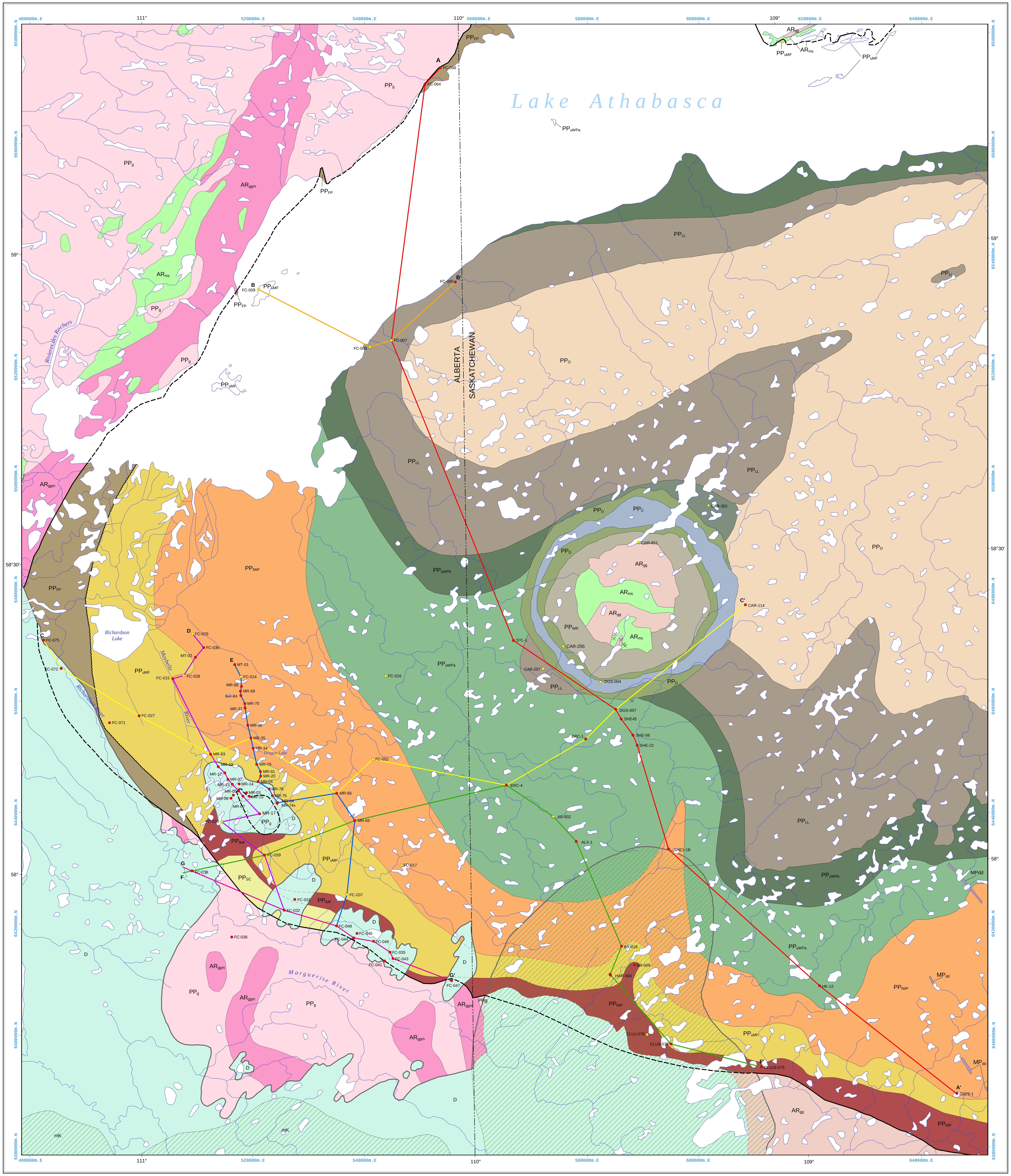
5.4.1 Fair Point Sequence

The Fair Point Sequence is the oldest succession in the Athabasca Basin. It is distinguished from the overlying sequences by its 'coarser' sand grade, very abundant interstitial clay, unique lithic clasts and poorly defined sedimentary structures. Its basal facies association (FA 1-0) varies in thickness from 0 to 30 m. It comprises medium- to coarse-grained sandstone with localized basal lag conglomerate and red mudstone interbeds. This is often overlain by conglomeratic sandstone (FA 1-1) that in places is up to several hundred metres thick (e.g., in drillcores FC-005 and FC-007). However, some drillcores completely lack conglomerate (e.g., in drillcore FC-009). The most characteristic lithofacies is pebbly sandstone (FA 1-2), which is most common toward the top of the sequence. A thin, dense, massive, red hematized argillite (e.g., in drillcores FC-071 and MR-69) locally marks the top of the sequence and is interpreted as a saprolite; it contains horizons of oncolites, first recognized in Alberta by Ickert (2003) that are similar to those found in Saskatchewan by Yeo et al. (2001). Paleocurrents from scarce outcrops of the Fair Point Sequence indicate drainage to the northwest (Ramaekers, 2004).

The northwestern margin of the Athabasca Basin in Alberta subcrops as the Fair Point Sequence. It thins in the southern basin over the Bartlett High (Figure 4). Along the Maybelle River and Net Lake trends, it pinches out to the south over the Taltson granitoid basement high. The Fair Point Sequence generally thickens toward and into Saskatchewan (e.g., in drillcores FC-007, SYL-1), suggesting that it is widespread north of the Carswell Structure. The southeastern margin appears to be truncated, in part, by the Beatty Trough (e.g., in drillcore SYL-1). The presence of basal Fair Point rocks in the Douglas River and Shea Creek area suggests that outliers of the Fair Point Sequence may also occupy local basement topographic lows within the Beatty Trough. The Fair Point Sequence reaches a maximum thickness of 300 m in Alberta (in drillcore FC-007), just south of Lake Athabasca

5.4.2 Shea Creek Sequence

The Shea Creek Sequence has been described by Ramaekers (2004) as a variation of part of the Manitou Falls 'c' member, called MFc" (i.e., MFc double prime). Nevertheless, it is geologically divisible from the rest of the overlying Manitou Falls on the basis of grain-size and sedimentary structures (Collier, 2002). The Shea Creek Sequence overlies the Fair Point Sequence west of the Carswell Structure (in drillcore SYL-1). Elsewhere, it directly overlies basement in the Beatty Trough. As opposed to the overlying rippled and compound bedforms of the Manitou Falls, the Shea Creek has units that are dominated by simple trough crossbeds and low-angle crossbeds. The basal facies association (FA 2-0) locally comprises a thin lag of pebble-bearing sandstone with subordinate conglomerate. Like all basal facies associations, these may contain red mudstone interbeds. This basal unit is usually overlain by simple trough-crossbedded sandstone (FA 2-1). Low-angle crossbedded sandstone (FA 2-2) dominates toward the top of the sequence. Paleocurrent directions, measured in inclined drillcores at Shea Creek, indicate an easterly



Scale 1:250 000

15 0 15 30 kilometres

5 0 5 10 15 miles

Projection: UTM Zone 12
Datum: NAD83

Collar location of examined drillhole

- Drilled to basement
- Not drilled to basement
- Drillhole identifier MR-69

Uranium deposit

Sections

- A - A'
- B - B'
- C - C'
- D - D'
- E - E'
- F - F'
- G - G'

Geological contact (defined, inferred)

Athabasca basin erosional edge (defined, inferred)

Western Canada Sedimentary Basin erosional edge

Mappable unconformity within Athabasca Group

Note: Except for the crystalline basement, geological contacts and unconformities are shown as dashed lines where overlain by younger strata.

UTM, zone 12 grid 450000m.E

River

Lake

MIDDLE CRETACEOUS

mK — Mainly clastic sedimentary rocks

DEVONIAN

D — Mainly carbonate and evaporite sedimentary rocks

PALEOPROTEROZOIC

ATHABASCA GROUP

POINTS LAKE SUBGROUP

PP_C — *CARSWELL FORMATION*

PP_D — *DOUGLAS FORMATION*

WILLIAM RIVER SUBGROUP

PP_O, PP_{LL} — *OTHERSIDE - LOCKER LAKE SEQUENCE: OTHERSIDE FORMATION* (PP_O); *LOCKER LAKE FORMATION* (PP_{LL})

PP_{uWPb}, PP_{uWPa}, PP_{uWP} — *UPPER WOLVERINE POINT SEQUENCE* (PP_{uWPb}) 'b' member; (PP_{uWPa}) 'a' member; (PP_{uWP}) undifferentiated

PP_{lWP} — *LOWER WOLVERINE POINT SEQUENCE*

PP_{uMF} — *UPPER MANITOU FALLS SEQUENCE*

PP_{lMF} — *LOWER MANITOU FALLS SEQUENCE*

PP_{SC} — *SHEA CREEK SEQUENCE*

PP_{FP} — *FAIR POINT SEQUENCE*

PP_{WR} — *WILLIAM RIVER SUBGROUP, UNDIFFERENTIATED*

MESOPROTEROZOIC

MP_{dd} — Mackenzie diabase dyke or sill

ARCHEAN AND PALEOPROTEROZOIC

PP_g — Granitoid rock, variably foliated (Paleoproterozoic)

AR_{ggm} — Granitoid gneiss, variably sheared and retrogressed (high- to low-grade mylonite)

AR_{ms} — High-grade metasedimentary rocks

AR_{gg} — Granitoid gneiss (Archean)

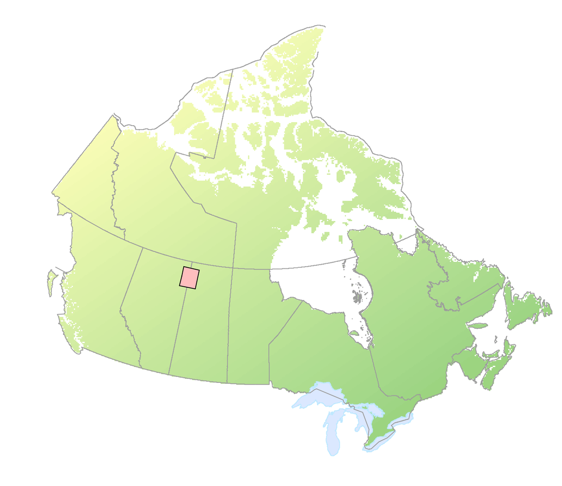


Figure 5: Sequence stratigraphy subdivisions of the western Athabasca Group

B.Collier, 2005

Earth Sciences Report 2004-01

Bedrock geology surrounding the Athabasca basin adapted by D. Pana from Geological Map of Alberta (Hamilton et al., 1999), and Geological map of Saskatchewan (Macdonald and Slimmon, 1999).

Digital base data provided by:
GeoGratis, Natural Resources Canada

Copies of this report may be obtained from:

Information Sales Office
Alberta Geological Survey

Telephone (780) 422-3767
Website: www.ags.gov.ab.ca

Head office website: www.eub.gov.ab.ca

Alberta Energy and Utilities Board

Alberta Geological Survey

Figure 6 - Cross-sections used to construct the fences of this study (see Figure 5 for locations)

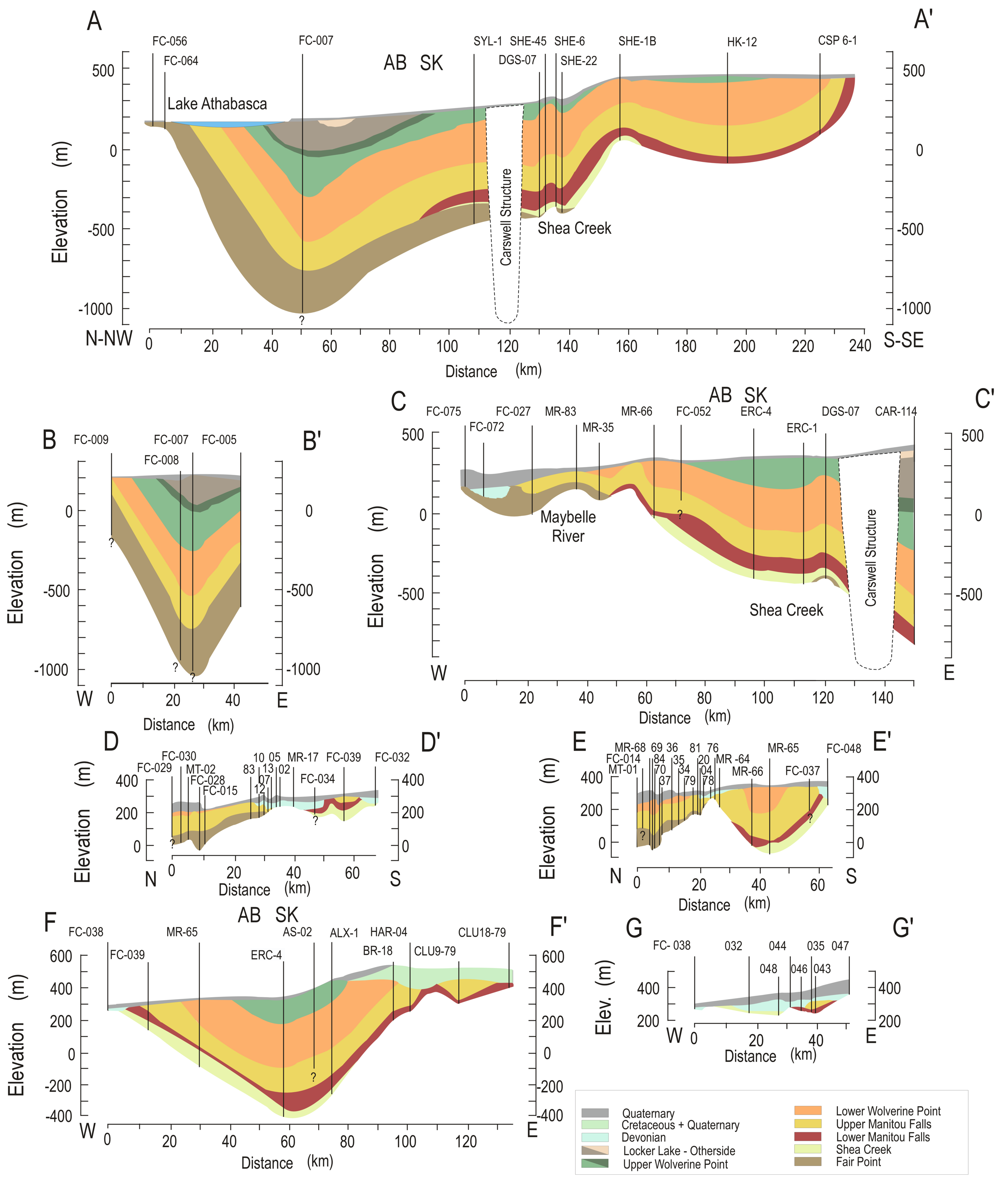
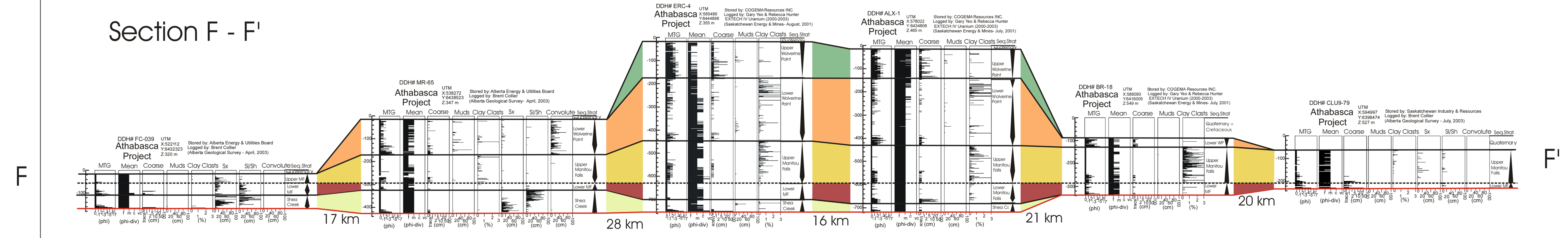


Figure 7 - Litholog correlations for fences A-A', B-B', and C-C'

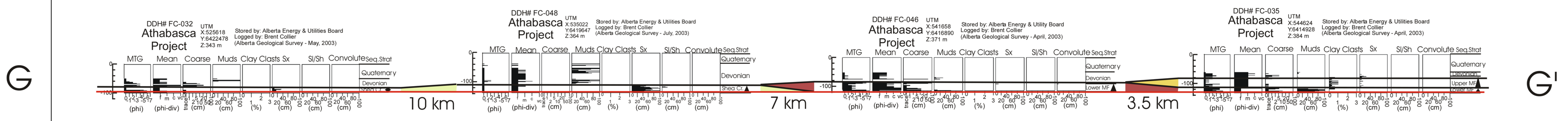
Section D - D'

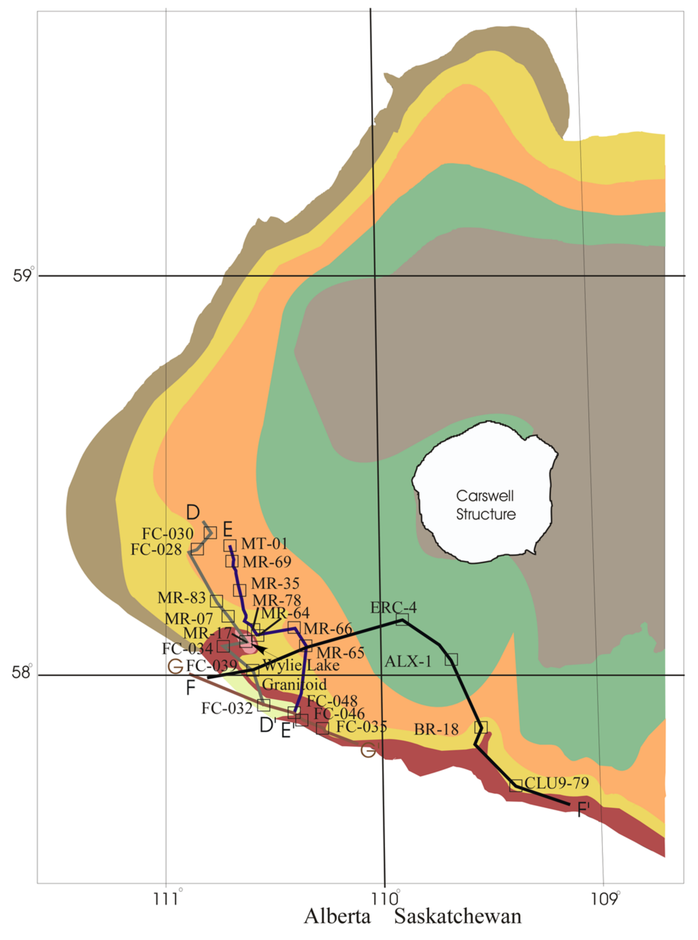
Section E - E'

Section F - F'



Section G - G'





Locker Lake - Otherside
Upper Wolverine Point
Lower Wolverine Point
Upper Manitou Falls
Lower Manitou Falls
Shea Creek
Fair Point

paleoflow direction (Collier, 2003). These are relatively consistent with measurements taken from an inclined drillcore in the southern Alberta portion of the basin (in drillcore FC-048, Ramaekers, 2004).

The Shea Creek Sequence appears to be confined to the Beatty Trough in the southwestern portion of the Athabasca Basin. It thins toward the northern margin (in drillcore SYL-1) and southern margin (drillcore SHE-1b) of the trough; it is absent east of the Carswell Structure (in drillcore CAR-114). It reaches a maximum thickness of 97 m in Alberta (in drillcore MR-65). It only subcrops in Alberta toward the southwestern margin of the Beatty Trough (in drillcore FC-048). The Shea Creek Sequence is continuous over the Harrison High (in drillcore SHE-1b) and thus predates its development.

5.4.3 Lower Manitou Falls Sequence

The Lower Manitou Falls Sequence is thickest and most distinctive in the Beatty Trough, where it has been previously described as the Manitou Falls 'c' member (MFc) by Ramaekers (2004). Beyond the Beatty Trough margins, correlations become problematic, because it is difficult to distinguish from the overlying Upper Manitou Falls Sequence (i.e., both sequences contain similar rock types). The Lower Manitou Falls Sequence directly overlies the Shea Creek Sequence throughout most of the Beatty Trough and often overlies basement along and beyond the trough margins. Above basement, the distinctive basal assemblage of Lower Manitou Falls (FA-3-0) is most notable along the southern margin of the basin in Alberta, where it has previously been referred as the Manitou Falls 'a' member (MFa) by Ramaekers (2004). Here, it comprises pebbly sandstone and local pebble and cobble conglomerate. Both sandstone and conglomerate may be supported by mud matrix and is commonly interbedded with thin to thick interbeds of red mudstone.

Toward the southern margin in Saskatchewan, the basal sandstone is only slightly pebbly to conglomeratic and lacks mudstone. Where Lower Manitou Falls overlies the Shea Creek Sequence within the Beatty Trough, slightly pebbly to conglomeratic sandstone units (FA 3-1) are found at the base. These may contain thick sections of conglomerate over localized areas (e.g., in drillcore ERC-1). In Alberta and above the Patterson High in Saskatchewan, pebbly sandstone is thin to absent, and the uppermost, clean, fine- to medium-grained sandstone (FA 3-2) facies dominates. This locally contains abundant flat-laminated interbeds (<20%), and generally lacks the clay clasts and thin green mudstone that are more typical of the overlying Upper Manitou Falls Sequence. There are presently no paleocurrent directions available for the Lower Manitou Falls Sequence.

The Lower Manitou Falls Sequence reaches a maximum thickness of 99 m east of the Carswell Structure (in drillcore CAR-114), where it directly overlies basement. It thins to the west into Alberta, as well as south of the Beatty Trough over the Patterson High. There are insufficient drillcores available to establish the northern limit of Lower Manitou Falls in Saskatchewan, but it remains relatively thick toward the northern margin of the Beatty Trough (in drillcore SYL-1), although the sequence appears to pinch out to the north over the Bartlett High in Alberta. The Lower Manitou Falls Sequence is continuous over the Harrison High, and thus predates its development.

5.4.4 Upper Manitou Falls Sequence

The majority of the Upper Manitou Falls sequence in the western Athabasca Basin has been previously mapped as the Manitou Falls 'c' member (MFc and MFc') by Ramaekers (2004). It is distinguished from the overlying Lower Wolverine Point Sequence by its paucity of deformed bedding structures and lack of thick mudstone beds (i.e., >20 cm). The sequence locally overlies basement north of the Taltson granitoid high, south of the Maybelle River and Net Lake trends where a thin, pebbly to conglomeratic lag is present (FA 4-0). To the north, over the Bartlett High in Alberta, the Upper Manitou Falls directly overlies the Fair Point Sequence. In this area, Fair Point pebbles and boulders are usually reworked into the basal succession. Southeast of the Bartlett High, the Upper Manitou Falls Sequence overlies Lower Manitou Falls.

In Saskatchewan, the stratigraphically lowest lithofacies assemblage coarsens to the east along the southern margin of the Athabasca Basin, where it fits the description of Ramaekers' (1990) Manitou Falls 'b' member, containing more than 2% conglomerate (FA 4-1). In this report this area is described as the Mirror Sub-basin. Its relationship to the Cree Sub-basin in the eastern Athabasca Basin is poorly understood. In the Beatty Trough, the basal sandstone lacks significant conglomerate, although it still contains granules and small pebbles (FA 4-2). This lithofacies thins or disappears into Alberta and toward the southern margin of the Beatty Trough in Saskatchewan. It is thickest and coarsest south of Lake Athabasca near the centre of the Jackfish Sub-basin (135 m in drillcore FC-007), where it has been previously designated as the Manitou Falls c prime member (MFc') by Ramaekers (2004), which makes up the entire sequence in that area. Clean, fine- to medium-grained sandstone is dominant over the Bartlett and Patterson highs. Over the Beatty Trough, these cap the Upper Manitou Falls Sequence. These 'finer-grained' sandstones may lack clay clasts (FA 4-3) or contain small but frequent clay clasts (FA 4-4). Over the Mirror Sub-basin (e.g., in drillcore CSP-6-1), an 80 m section that contains 1% clay-clast intraclasts (FA 4-5) may correlate with Ramaekers' (1990) intraclast-rich Manitou Falls 'd' member. This section also contains approximately 25% flat-laminated interbeds, which are not typical of Upper Manitou Falls elsewhere in the western Athabasca Basin. The Upper Manitou Falls Sequence may correlate in part with most of the Manitou Falls Formation in the eastern Athabasca Basin. Paleocurrent directions for Manitou Falls Formation taken from outcrop in the eastern basin, indicate drainage to the west and northwest (Ramaekers, 2004).

In this study, the Upper Manitou Falls Sequence reaches a thickness of approximately 200 m in the Beatty Trough and over the Jackfish Sub-basin, but probably thickens more to the east. It is thickest southeast of the Patterson High, where it reaches 233 m (e.g., in drillcore CSP-6-1); this is the easternmost core that was studied as part of this project work. In Alberta, the Upper Manitou Falls thins to a 100 m in the Maybelle River area, over the Bartlett High. Upper Manitou Falls is continuous over the Harrison High, which indicates that it developed at a later stage. Table 5 shows the relationship of the early stratigraphic sequences in the western Athabasca Basin to the main depositional centres, with respect to lithostratigraphic units of Ramaekers (2004).

Table 5. Litho-stratigraphic units versus sequences for the earliest strata in the western Athabasca Basin in relation to the three major depositional centres.

<table>
<tr><th>Depocentre</th><td>Jackfish Basin</td><td rowspan="8">Bartlett High</td><td>Beatty Trough</td><td rowspan="8">Patterson High</td><td>Mirror Sub-Basin</td></tr>
<tr><th rowspan="3">Sequences</th><td rowspan="2">Upper Manitou Falls</td><td>Upper Manitou Falls</td><td>Upper Manitou Falls</td></tr>
<tr><td>Lower Manitou Falls</td><td rowspan="2">Lower Manitou Falls</td></tr>
<tr><td>Fair Point</td><td>Shea Creek</td></tr>
<tr><th rowspan="4">Lithostratigraphic units (after Ramaekers, 2004)</th><td rowspan="2">Manitou Falls c'</td><td>Manitou Falls c</td><td>Manitou Falls d</td></tr>
<tr><td>Manitou Falls c'</td><td>Manitou Falls c</td></tr>
<tr><td rowspan="2">Fair Point Formation</td><td>Manitou Falls a?</td><td>Manitou Falls b</td></tr>
<tr><td>Manitou Falls c"</td><td>Manitou Falls a</td></tr>
</table>

5.4.5 Lower Wolverine Point Sequence

The Lower Wolverine Point Sequence has most commonly been classified as the Lazenby Lake Formation (LzL) and part of the Wolverine Point 'a' member (WPa; Table 1). In this study the Lazenby Lake Formation is defined as the basal, thin, pebbly layer at the base of the Lower Wolverine Point Sequence. The remainder of the sequence is classified as part of the Wolverine Point 'a' member. The Lower Wolverine Point Sequence is typically more mudstone and clay rich relative to the underlying Upper Manitou Falls Sequence.

A basal unconformity is locally observed in the southwestern Athabasca Basin in Alberta, distinguished by a massive basal conglomerate up to 30 cm thick. The unconformity is less distinctive to the north and east. A uniform apron (approximately 50 m) of pebbly sandstone (FA 5-1) is found at the base of the sequence. This sandstone contains quartzite pebbles up to 20 mm in diameter. Pebble abundance and size decrease toward the north, to where this lithofacies generally thins or disappears south of Lake Athabasca (e.g., in drillcore FC-005). The Lower Wolverine Point Sequence is dominated by fine- to medium-grained sandstone. This contains up to 20% deformed bedding structures in the southwestern Athabasca Basin; these are less common to indistinguishable in the north. The succession contains both mudstone-common intervals (FA 5-2) and mudstone-deficient intervals (FA 5-3). The upper half of the sequence is slightly coarser, containing thin granule-rich (FA 5-4) and clay intraclast–rich (FA 5-5) horizons, possibly indicating a slight change in climatic regime. The clay intraclasts are typically more abundant and larger than those of the Upper Manitou Falls Sequence. Outcrop measurements near the south-central margin of the basin (near drillcore CSP-6-1) indicate northwest-trending paleocurrents. Note that this area has previously been interpreted as subcropping Manitou Falls Formation (Ramaekers, 2004).

The Lower Wolverine Point Sequence is relatively uniform in thickness in most drillcores at approximately 285 m. It reaches a maximum of 315 m thick in the Shea Creek area (in drillcore SHE-45). It thins toward the northern part of the Athabasca Basin, where it is 200 m thick (in drillcore FC-005). The basal pebbly layer is continuous and uniform in thickness over the Harrison High, suggesting that it developed at a later stage.

5.4.6 Upper Wolverine Point Sequence

The Upper Wolverine Point Sequence is distinguished by its uppermost mudstone- and clay-rich sandstone, which previously has been described by Ramaekers (2004) as the Wolverine Point 'b' (WPb) and 'c' (WPc) members. Where these are eroded, the underlying sandstone may be difficult to differentiate from that of the underlying Lower Wolverine Point Sequence or overlying Locker Lake–Otherside Sequence. At present, the Upper Wolverine Point Sequence is confidently identified only in cores that contain the complete section. These cores are limited to those just south of Lake Athabasca in Alberta (e.g., in drillcores FC-005, FC-007 and FC-008), just east of the Carswell Structure (e.g., in drillcore CAR-114) and within the Carswell Structure (e.g., in drillcores CAR-301, CAR-255 and DGS-04). The less distinctive lower sandstone has previously been described as part of the Wolverine Point 'a' member (WPa) of Ramaekers (2004) and the Wolverine Point Lower Member of Wilson (1985). This lithofacies (FA 6-1) comprises medium-grained sandstone with scattered granules and pebbles; it can be up to 130 m thick. Pebbles are usually less than 8 mm, but may become larger to the south (up to 16 mm), where instances of deformed bedding structure become more common. This granually-pebbly lithofacies is overlain by fine-grained sandstone that either contains abundant mudstone (FA 6-2) or little to no mudstone (FA 6-3). Near the top of the sequence, there is a large accumulation of interbedded mudstone and sandstone (FA 6-4). The mudstone contains minor reworked tuff, which originally was noted by Ramaekers (1990). The interbedded sandstone units are typically planar or low-angle crossbedded.

The sequence is capped by clay-rich medium-grained sandstone (FA 6-5). The Upper Wolverine Point Sequence, like the Lower Wolverine Point, is 315 m thick in the Carswell area. It thins dramatically to 145 m toward the northern margin of the Athabasca Basin (in drillcore FC-005). The Upper Wolverine Point Sequence is probably widespread throughout all thick sections of the western Athabasca Basin.

Maps from Ramaekers (2004) indicate that much if not all of the Wolverine Point Formation has been completely eroded throughout much of the Beatty Trough. This suggestion is based on the fact that pebbly sandstone that subcrop southwest of the Carswell Structure, are interpreted as Locker Lake Formation where they directly overlie the Lazenby Lake Formation (i.e. which is considered as the Lower Wolverine Point Sequence in this area from this study). This study reconsiders the uppermost pebbly sandstones (e.g., drillcores , ERC-1, ERC-4, ALX-1 and AS-02) as part of the basal Upper Wolverine Point Sequence (FA 6-1) for the following reasons:

- Although not as coarse, similar granule- and pebble-bearing sandstone (FA-6-1) occupies the same stratigraphic position to the north and east (e.g., see drillcores SYL-1, HK-012, SHE-45 and CAR-114).
- Complete removal or nondeposition of the Upper Wolverine Point Sequence in this area would require approximately 300 m of uplift (i.e., the total thickness of the Upper Wolverine Point). In fact, the area represents a basement topographic low, not a high.
- There is no sign in drillcore from this area of the major unconformity that would be expected from the inferred relative uplift.
- Paleocurrents are north trending, similar to those in outcrops to the east that are perceived to be the Upper Wolverine Point Sequence.
- East of where these pebbly sandstones subcrop, there is a high developed (Harrison High) that trends in the same direction as the paleocurrents, thus providing a possible mechanism for trough development in the area.

5.4.7 Locker Lake–Otherside Sequence

The Locker Lake–Otherside Sequence comprises the Locker Lake and Otherside formations of Ramaekers (2004). The basal Locker Lake Formation is distinguished as a thick pebbly unit with scattered large clasts. The overlying pebble-free sandstone of the Otherside Formation is lithologically similar to those of the Upper and Lower Wolverine Point sequences. Outside the Carswell Structure, the thickest sections of the Locker Lake–Otherside Sequence in this study are preserved over the Jackfish and Mirror sub-basins. Here, the basal pebbly sandstone (FA 7-1) contains minor conglomerate interbeds, with clasts commonly larger than 16 mm, and abundant deformed bedding structures. Where complete, this unit is up to 260 m thick (e.g., in drillcore CAR-114). It is overlain by a thin remnant succession of granule-bearing (FA 7-2) and/or granule-free (FA 7-3) sandstones. Paleocurrent measurements from outcrops of the Otherside Formation suggest a return to more westerly trending paleocurrents (Ramaekers, 2004).

Although eroded, the Locker Lake–Otherside Sequence reaches a maximum of 305 m outside the Carswell Structure (e.g., in drillcore CAR-114). It is approximately 230 m thick in drillcore DGS-04b (logged by G. Yeo and included in this study) from the southern part of the Carswell Structure. In this core, the Locker Lake–Otherside Sequence is overlain by Douglas Formation. Because this section has been disturbed by the meteorite impact, it is difficult to give an original thickness for this area and difficult to assess the contact with the Douglas Formation (Yeo, pers. comm., 2003). The Locker Lake–Otherside Sequence is widespread throughout the thickest sections of the Athabasca Basin and forms the subcrop over much of the Mirror and Jackfish sub-basins.

5.5 Formations of the Carswell Structure (Points Lake Group)

The Carswell and Douglas formations were not studied in this project; however, there is a metre-by-metre log is available for drillcore DGS-4b, from the southern part of the Carswell Structure (logged by G. Yeo). The Douglas Formation is inferred to be lacustrine and contains thick mudstone units and interbedded, very fine to fine-grained sandstone (Ramaekers, 1990). The Carswell Formation comprises dolomite of lacustrine or marine origin. Only estimates of the thickness of the Douglas and Carswell formations are available because of they are disturbed by the meteorite impact. Minimum thickness of the Douglas Formation is estimated at approximately 200 m (Ramaekers, 1990). The Carswell Formation is estimated at 400–500 m thick (Hendry and Wheatley, 1985).

The bases of both the Douglas and Carswell formations are poorly exposed. Where available, these are difficult to study because they are faulted (Hendrey and Wheatley, 1985). Ramaekers (1990) suggested that the boundaries are conformable, as there appears to be a gradation or an interbedding of rock types across or near the inferred contacts.

Rhenium-osmium isotopic analysis of organic-rich mudstone of the Douglas Formation recently yielded a preliminary age of approximately 1500 Ma (R.A. Creaser, per. comm., 2004). The Douglas Formation may therefore be significantly younger than the underlying Athabasca Group, as dating of zircons of igneous origin from an Upper Wolverine Point Sequence tuff recently yielded an age 1644 ± 13 Ma (Rainbird et al., 2003b). This suggests that there may be a hiatus of more than 100 m.y. between deposition of the Upper Wolverine Point Sequence and Douglas Formation. From the cores examined in this study, it is unlikely that a major hiatus occurred at the base of the Locker Lake Formation, because the sequence boundary appears conformable in drillcore and the underlying Upper Wolverine Point mudstone and clay-rich sandstone units (WPb and WPc of Ramaekers, 2004) are completely intact. Also, the lithofacies of the Locker Lake and Otherside Formations are nearly identical to those of much of the Lower and Upper Wolverine Point sequences, suggesting that they were probably deposited under similar conditions and therefore probably temporally related. It likely that in places an unconformity may be present in the sandy formation below the Douglas Formation mudstone, because there may be reworking of the underlying sandstone at the contact. This reworked sandstone may fit the lithological criteria of the Locker Lake and Otherside formations.

The age of the Carswell Formation is very poorly constrained. Hendry and Wheatley (1985) suggested an upper limit of 1200–1300 Ma, based on K-Ar dating of diagenetic clay minerals thought to be associated with a similar hydrothermal event that caused syndepositional deformation of the Carswell Formation dolostone. Once again, this age is in strong contrast to those of the Wolverine Point and Douglas formations. Therefore, lumping of the Locker Lake, Otherside, Douglas and Carswell formations into a single depositional sequence, as done by Ramaekers et al. (2001), is too preliminary and warrants further study.

5.6 Devonian

Devonian clastic rocks are distinguished from the underlying Athabasca Group by their carbonate cement. They have been previously referred to as possible equivalents of the Laloche Sandstone and Methy Dolomite of the Elk Point Group (Ramaekers, 2004). The basal unconformity is usually overlain by a thin lag of Athabasca clast conglomerate. Locally, massive conglomeratic sandstone is found above the unconformity. This is overlain by sandstone, muddy sandstone and fossiliferous silty mudstone. These contain small intervals of massive carbonate. Although only a remnant of the succession remains, the Devonian clastic rocks reach a maximum thickness of 70 m near the southwestern rim of the Athabasca Basin (e.g., in drillcore FC-048).

Devonian clastic rocks are concentrated in two main areas in this study, both of which are associated with basement highs: 1) the Patterson High in Alberta, and 2) the Wylie Lake granitoid high south of the Maybelle River and Net Lake trends. Devonian clastic rocks were also encountered along the western rim of the Athabasca Basin (in drillcore FC-072).

5.7 Cretaceous

Uncemented terrigenous clastic rocks are only found above the Harrison High in the southwestern Saskatchewan portion of the Athabasca Basin. These have been interpreted by Ramaekers (1990) as possible Mannville Group equivalents. The clastic rocks consist of crossbedded, silty fine sand; shaly to gummy mud; and coaly beds. The thickest and most impressive drillcore studied was HAR-04, which is approximately 80 m thick (stored at the Subsurface Geological Laboratory of Saskatchewan Industry and Resources in Regina).

Since noncoring tricone bits are usually used until the more competent Devonian and Athabasca Group sandstone are reached, the Cretaceous clastic rocks may be more widespread than currently perceived, as they would rarely be cored (Ramaekers, 1990).

5.8 Pleistocene

No cores containing Pleistocene glacial and periglacial deposits were examined during this study. The surface- to- bedrock picks from the drillcores indicate that Pleistocene deposits may be thickest along the western rim of the Athabasca Basin in Alberta (95 m in drillcore FC-075).

6 Diagenesis and Postdepositional Characteristics

Diagenetic characteristics were difficult to quantify during the EXTECH IV project and therefore not analyzed in detail due to the scale of this study and the limited time available.

6.1 Interstitial Clay Minerals

The only readily observable changes in clay content were in the Fair Point Sequence (15 to 20%) and the Upper Wolverine Point Sequence (5 to 15%); the remaining Athabasca Group contains 1 to 5% clay.

6.2 Faults and Fractures

Faults and fractures were migration pathways for diagenetic and epigenetic fluids. The nature of the alteration in and around faulted and fractured zones largely depends on the wallrock permeability and other characteristics, as well as the fluid geochemistry. Alteration types include 1) silicification or desilicification; 2) hematization or bleaching; 3) increased clay content; and 4) fracture/fault fillings such as drusy quartz, limonite, calcite, siderite, phosphate minerals, diagenetic clay minerals, pyrite and other sulphide minerals, and hydrocarbons.

6.3 Silicification

Most of the Athabasca Group is moderately silicified, due to secondary quartz overgrowths and suturing of grain-to-grain contacts, as observed in thin section (Collier, 2003). Small intervals of intense silicification are often concentrated at the basal contacts of the Lower Wolverine Point and Locker Lake–Otherside sequences. Areas of weak silicification are often associated with increased grain size and hematization. Desilicification is often associated with fault zones. In the study area, the basal Fair Point and Shea Creek sequences are generally weakly silicified compared to the overlying sandstone units.

6.4 Hematization

Many episodes of hematization are apparent throughout the Athabasca Group. Intense staining usually accompanies mudstone (early?) and coarser sandstone (later).

6.5 Porosity and Permeability

The majority of the Athabasca Group has a low porosity and permeability, due to compaction and diagenesis, except along fault zones. The basal Shea Creek sequence is relatively porous and permeable, as it is consistently less silicified. Coarser portions of the Lower and Upper Manitou Falls sequences may also have a higher porosity and permeability due to desilicification. Prior to extensive compaction and diagenesis, the porosity and permeability of the Athabasca Group was probably considerably higher.

6.6 Hydrocarbons

Due to the dominantly low porosity of the Athabasca Group, hydrocarbons are usually confined to fault and fracture zones that provide pathways for hydrocarbon infiltration into the basement. Hydrocarbons found during this study ranged from minor staining to heavy tarry bitumen. Hydrocarbons rarely infiltrate laterally into the formation; however, there can be some infiltration into porous sections of the Shea Creek, Lower Manitou Falls and Upper Manitou Falls sequences. In drillcore FC-039, along the southwestern margin of the basin, there are 10–20 m thick zones that are saturated with oil. During drilling, these were described as “dead oil-stained” (Laanela, 1978).

7 Discussion

7.1 Development of Depositional Centres in the Western Athabasca Basin

Detailed stratigraphy and sedimentology provide insight into the tectonic evolution of a region and the structural controls on a sedimentary basin. Although there is little geological information in many parts of the Athabasca Basin, sufficient evidence is available from drillcore to help locate the major depositional centres for the sequences of this study. Small deposition centres have previously been described as distinctive troughs (i.e., Beatty Trough), whereas larger depositional centres also use the term ‘trough’ but attach it to the development of sub-basin (i.e., trough of Jackfish Sub-basin; as interpreted from Ramaekers, 2004). All of these depositional centres generally coincide with present day basement topographic lows that appear to be bound by fault zones.

At the onset of sequence development, while accommodation rates were low, sedimentation was probably confined to the bases of depositional troughs. Higher energy ‘coarser’ sediments, such as pebbly sandstone and conglomerate, are thicker and better defined at the centres of these troughs and are interpreted as lowstand systems tract deposits (LSTs). A good example of these deposits is within the Beatty Trough, which appears to be the dominant depositional centre for the Shea Creek, Lower Manitou Falls and Upper Manitou Falls Sequences (i.e., all three sequences are thickest within the Beatty Trough). The Shea Creek Sequence is exclusively confined to the Beatty Trough where no LST deposits are identified. For the Lower Manitou Falls and Upper Manitou Falls sequences, the LST deposits are thickest and coarsest within the centre of the trough and appear to thin and/or disappear toward the trough margins. The increased thickness for both sequences within the Beatty Trough is approximately the same as thickness of their LSTs. On the other hand, the transgressive systems tracts (TSTs) for both sequences are approximately the same thickness both inside and outside of the Beatty Trough. This suggests that at early stages of sequence development, deposition was segmented by topographic highs which were later subdued. As such, adjacent fault movements appear to strongly affect stratigraphic signatures, however, these probably did not create the bulk of the accommodation space in the Athabasca Basin.

To summarize, depositional sequence analysis can be a valuable tool for locating fault zones in that:

- thinning or thickening of a sequences may occur over or adjacent to fault zones;
- rapid changes in the basal lithofacies type and thickness may occur across fault zones (i.e. LSTs are present within the troughs and absent over the paleotopographic highs); and
- many of the present-day basement lows and highs can be linked to depositional sequences and are bound by faults that were active at different stages of development of the Athabasca Basin

7.2 Interpretation of the Distribution and Development of the Sequences

The sequences of this study are described below in terms of seven geological events. The corresponding sequence isopach maps are available in Appendix 3.

7.2.1 Development and Erosion of the Jackfish Sub-Basin

Deposition of Fair Point Sequence occurred within the Jackfish Sub-basin, as well as to the south, over the area that later developed into the Bartlett High. The original sub-basin was probably bounded to the southeast by the South Robillard Fault and to the northwest by the Charlot Fault (Ramaekers, 2004). Toward the centre of the sub-basin, the Fair Point Sequence reaches a maximum thickness of 300 m (e.g., in drillcore FC-005) where the entire section consists of coarse conglomeratic sandstone. These are interpreted as being deposited within the depositional trough of the Jackfish Sub-basin. The conglomeratic sandstone thins and disappears toward the margins of the Jackfish Sub-basin. The presence of conglomeratic sandstones over the south and central portions of the Bartlett High, near Maybelle River, indicates that a second depocentre developed to the south of the Jackfish Sub-basin. However, this conglomeratic sandstone unit is only 50 m thick, suggesting that it was probably less significant of a depocentre than that of the Jackfish Sub-basin. Toward the north section of the Bartlett High, an east-west succession of drillcores that completely lack conglomeratic units (e.g., in MT-01, MT-02, FC-029, FC-030 and SYL-1), segments the two depocentres. This area was probably a paleotopographic high during deposition of the Fair Point Sequence, suggesting that part of the relief of the Bartlett High was probably generated during this time. Figure 9 and Figure 10 trace the conglomeratic sandstone of the Bartlett High depocentre, northward across the inferred east-west paleotopographic high, along two north-south oriented transects along the Maybelle River and Net Lake trends.

The upper Fair Point boundary is the only unconformity that can be consistently identified in drillcore. The sharp lithological contrast with overlying sandstone, local saprolite horizons and large reworked

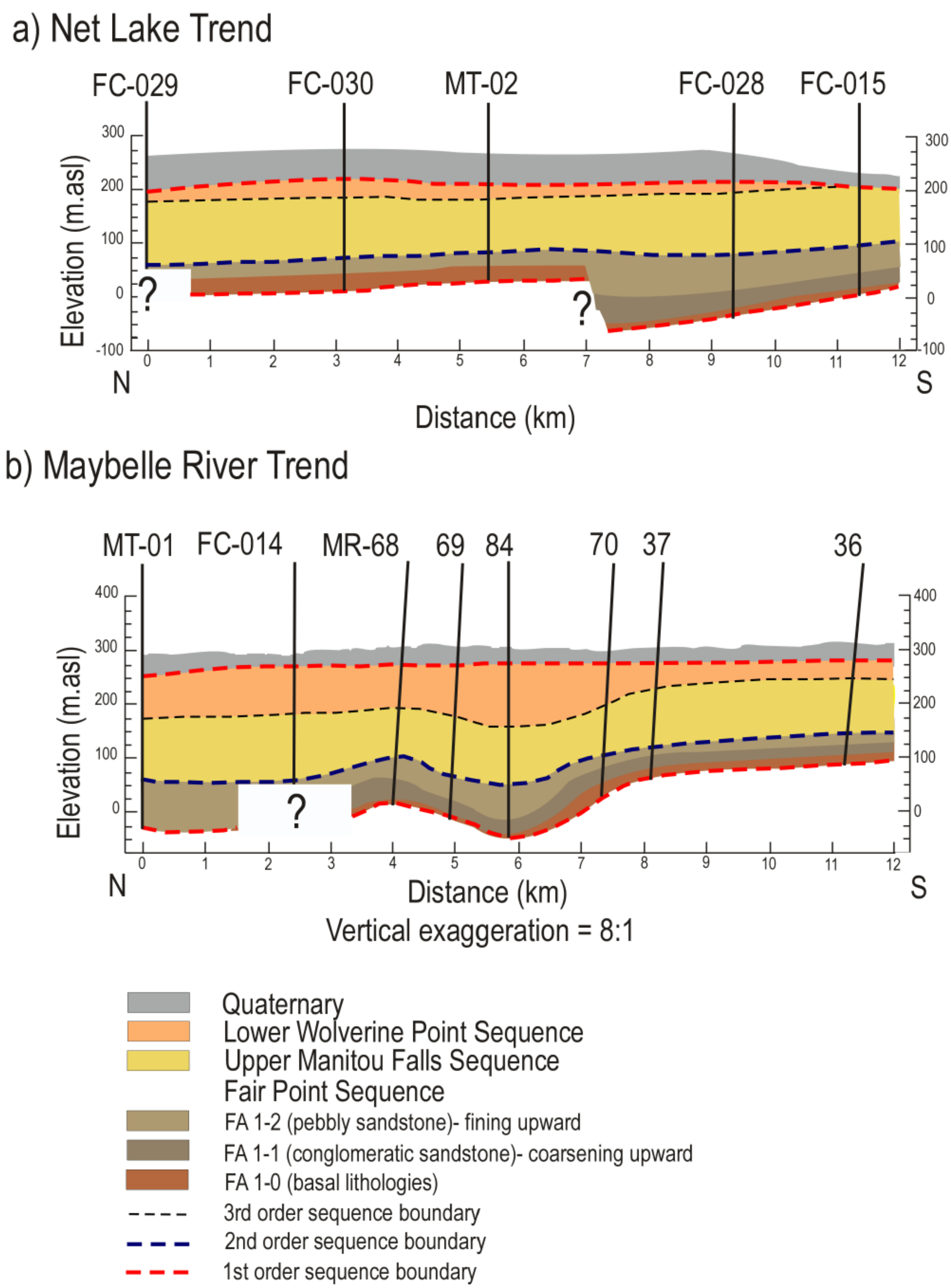


Figure 9. Evidence for a lineament indicates a paleohigh during sedimentation of the Fair Point Sequence, possibly a result of faulting (see Figure 10 for location of fences): a) no evidence for displacement of upper sequences at Net Lake suggests a possible blind fault; b) conglomeratic lithofacies disappears to the north, although there is no distinguishable offset of the Fair Point Sequence.

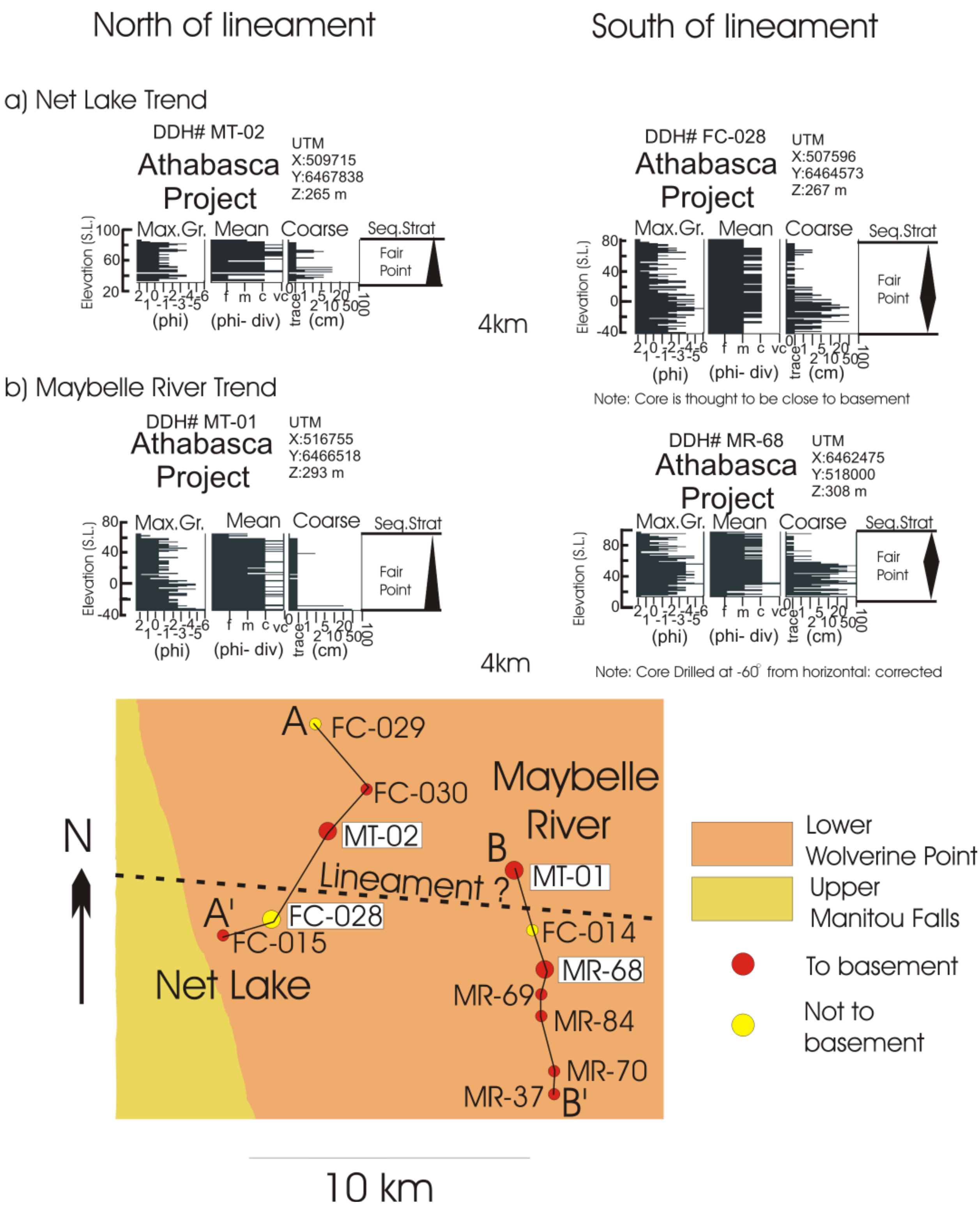


Figure 10. Comparison of basal Fair Point Sequence rock types across a possible lineation between the Maybelle River and Net Lake trends. See Appendix 2 for descriptions of lithologs.

clasts above the contact indicate a significant erosional unconformity. This is confirmed by examining the isopach map for the Fair Point Sequence (see Appendix 3). The irregular isopach pattern in the Maybelle and Net Lake areas is probably due to erosion, possibly due to movement along the Maybelle and Net Lake faults themselves.

7.2.2 Development of the Beatty Trough

The Shea Creek Sequence only overlies the Fair Point Sequence west of the Carswell Structure (e.g., in drillcore SYL-1). Deposition of the Shea Creek Sequence essentially was limited to the Beatty Trough and was probably associated with normal movement along the South Robillard and Beatty River faults. Deposits may have originally extended farther southwest of the present margin of the Athabasca Basin, since paleocurrents indicate a source area in that direction.

7.2.3 Deepening of the Beatty Trough

The Lower Manitou Falls Sequence defines the southern margin of the western Athabasca Basin. It is thickest within the Beatty Trough and thins over the Patterson High and into the area that later developed as the Mirror Sub-Basin. The Lower Manitou Falls Sequence pinches out to the north over the Bartlett High in Alberta and is completely absent over the Jackfish Sub-basin, suggesting that this area was probably inactive during this time. There is not enough drillcore information to indicate the northerly extent of the sequence in Saskatchewan. The distal nature and limited thickness of the Lower Manitou Falls Sequence in the western Athabasca Basin indicates that the original depositional limit probably did not extend much beyond the present-day margins in the western Athabasca Basin. The Lower Manitou Falls Sequence coarsens to the east, suggesting that the locus of sedimentation was located further east.

7.2.4 Deepening of the Beatty Trough, Development of the Mirror Sub-Basin and Reactivation of the Jackfish Sub-Basin

The Upper Manitou Falls Sequence is the first sequence to span the entire western Athabasca Basin. Like the Lower Manitou Falls Sequence, the Upper Manitou Falls Sequence is relatively thick within the Beatty Trough and thins and fines toward and over the adjacent Bartlett and Patterson highs.

South of the Patterson High, the Upper Manitou Falls Sequence thickens and resembles the Manitou Falls Formation of the eastern Athabasca Basin, as all four of Ramaekers' members (MFa-d) can be identified. This area overlies the Mirror Sub-Basin and may be associated with movement along the Yaworski Fault. The relationship between these deposits and those of the Manitou Falls Formation in the eastern Athabasca Basin is poorly understood (i.e. the relationship between the Mirror Sub-basin, as described in this study, with the Cree Sub-basin of the eastern Athabasca Basin, is not well defined).

The Upper Manitou Falls Sequence is thick in the centre of the Jackfish Sub-basin to resemble the basal granule- and pebble-bearing sandstone (LST) found at the base of the sequence in the centre of the Beatty Trough. However, absence of the overlying 'finer' rock types in the Jackfish Sub-basin (i.e. TST deposits), which are diagnostic in the Mirror Sub-basin and Beatty Trough, indicates that Upper Manitou Falls may have been eroded over the Jackfish Sub-basin. Erosion may be related to relative uplift before deposition of the subsequent Lower Wolverine Point Sequence. This idea is consistent with sedimentary patterns for the Lower Wolverine Point Sequence in the area, which indicate that a paleotopographic high was present at the onset of deposition. Considerable thinning of the Upper Manitou Falls Sequence between drillcores FC-005 and FC-007 suggests that the Fidler Fault, which runs between these drillcores, may have been one of these active faults that resulted in this inferred relative uplift.

7.2.5 Active Tectonism in the Southern Athabasca Basin

Deposition of the Lower Wolverine Point Sequence does not appear to be affected by the earlier Bartlett and Patterson highs, because the thin basal pebbly unit (LST) can be recognized across these areas. The thickness and pebble content of this basal unit, however, decreases to the north toward the Jackfish Sub-Basin; frequency of deformed bedding structures, interpreted as seismites, also decreases to the north. In the central Jackfish Sub-basin, the complete lack of pebbly sandstone at the base of the sequence (e.g., in drillcores FC-005, FC-007 and FC-008) indicates that this area may have occupied a paleotopographic high during early sedimentation of the sequence. This is consistent with the interpretation in the previous section that indicates erosion of the Upper Manitou Falls Sequence in this area due to relative uplift. Just like in the Upper Manitou Falls Sequence, a rapid decrease in thickness of the Lower Wolverine Point Sequence between drillcores FC-007 and FC-005 may have been related to movement along Fidler Fault prior to deposition of the Lower Wolverine Point Sequence; the relatively small number of seismic indicators, suggests that this fault was probably not syndepositional. In the southern portion of the Athabasca Basin deformed bedding structures make up as much as 20% of the strata (e.g., in drillcore SHE-6, CSP-6-1), suggesting that these areas were relatively more tectonically active during sedimentation. At present, there are insufficient data to speculate on the thickness relationships of the Lower Wolverine Point Sequence to the east, west or south. Analysis of drillcores near the south-central margin of the Athabasca Basin suggests that most of the area previously defined as Manitou Falls Formation in subcrop, (Ramaekers, 2004), is actually the Lower Wolverine Point Sequence.

7.2.6 Deepening of the Athabasca Basin (Development of the Harrison Trough?)

Complete sections of the Wolverine Point Sequence were only encountered north and east of the Carswell Structure, where the uppermost mudstone was identified (i.e., WPb of Ramaekers, 2004). As with the Lower Wolverine Point Sequence, dramatic thinning in the central Jackfish Sub-Basin between drillcores FC-007 and FC-005 suggests that the Fidler Fault may have been active during this time.

Above the Harrison High (i.e., Shea Creek, Douglas and Carswell areas), the basal sandstone of the Upper Wolverine Point Sequence is generally finer grained and contains minor granules and small pebbles with no visible basal unconformity with the Lower Wolverine Point Sequence. West of the Harrison High, the basal sandstone coarsens and thickens to resemble that of the overlying Locker Lake- Otherside Sequence. Here, basal pebbly lags often mark an unconformity. In this area, the northerly paleocurrents of the Upper Wolverine Point Sequence are consistent with the trend of the Harrison Fault, suggesting that movement along the Harrison Fault may have resulted in the formation of a depositional trough to the east during early deposition of the Upper Wolverine Point Sequence.

7.2.7 Further Deepening of the Athabasca Basin

Very few cores containing the Locker Lake–Otherside Sequence were studied, making interpretations difficult. However, there is a dramatic thinning between drillcore CAR-114, were the sequence is incomplete at 305 m thickness, and drillcore DGS-4b, where the sequence is interpreted to be completely preserved below the Douglas Formation. A respective thinning of the basal pebbly sandstones from drillcore CAR-114 (260 m) to drillcore DGS-4b (60 m), also indicates that the area surrounding drillcore DGS-4b may have been a topographic high during deposition. It is important to note that drillcore DGS-4b has been disturbed, as it was drilled within the Carswell Structure. The Locker Lake-Otherside sequence is widespread east of the Harrison Fault, overlying thick sections of the Jackfish and Mirror sub-basins.

7.3 A Depositional Basin-Scale Model

There is strong evidence from this study to suggest that the Fair Point Sequence should be considered as belonging to a depositional basin that is independent from that of the remainder of the Athabasca Group (i.e., part of its own second-order sequence of Krapez, 1996, 1997), the Jackfish Basin. The lateral limit of the Jackfish Basin spans that of the entire Fair Point Sequence, which overlies the structural Jackfish Sub-basin and extends over most of the Bartlett High. The unique lithology of the Fair Point Sequence suggests a different source area and paleoenvironment from the overlying strata. The distribution of the Jackfish Basin suggests a different tectonic regime than the remainder of the Athabasca Group (Ramaekers, 2004; Post, 2004). The well-pronounced unconformity above the Fair Point Sequence can be pinpointed in every drillcore examined. This suggests that there was a major erosive episode after development of the Jackfish Basin, as well as a hiatus long enough to develop saprolite horizons (Figure 11). The complex isopach pattern of the Fair Point Sequence in the Maybelle River and Net Lake areas is probably related to erosion.

The overlying six sequences record sedimentation in a different and more extensive depositional basin (or second-order sequence) separate from that of the Fair Point Sequence (Figure 12). This depositional basin will be referred to as the William River Basin. The William River Basin is segmented by a number present day basement highs, where the thickest sections are preserved over the adjacent basement lows: the Cree Sub-Basin, Mirror Sub-Basin, Jackfish Sub-Basin and Beatty Trough (of Ramaekers, 2004). The basal Shea Creek, Lower Manitou Falls and Upper Manitou Falls sequences are more constrained to the present-day boundaries of the western Athabasca Basin. Lithofacies within these sequences are generally more variable and stratigraphic patterns (systems tracts) seem to be affected strongly by relatively more localized interbasinal faults than the overlying sequences. The Shea Creek, Lower Manitou Falls and Upper Manitou Falls sequence can collectively be thought of as the lowstand systems tract (LST) for the William River Basin. Mean grain sizes for these sequences generally increase upward and lateral distribution broadens upwards, suggesting an early regression under relatively low accommodation rates. The overlying Lower and Upper Wolverine Point sequences are considered to have originally been more laterally extensive than the underlying sequences. This package retrogrades upward from completely fluvial to fluvial-lacustrine. This fining-upward succession represents the transgressive systems tract (TST). The uppermost Locker Lake–Otherside Sequence returns to fluvial conditions. This late normal regression represents the highstand systems tract (HST); the top of which was probably eroded.

The boundary between the Upper Manitou Falls and Lower Wolverine Point sequences marks a maximum regression surface for the William River Basin marking the boundary between the LST and TST. This may account for the frequent recognition of an unconformity at the contact, as well as the consistency and thickness of the overlying pebbly sandstone above the contact in the southwestern Athabasca Basin. This widespread sheet of pebbles represents extensive reworking of basement from source areas more widespread than that of the LST sequences. The maximum flooding surface is placed between the Upper Manitou Falls and Locker Lake–Otherside sequences and marks the boundary between the TST and HST. Across the boundary, large pebbles have been transported into the William River Basin, representing a late normal regression.

7.4 Correlation with the Eastern Athabasca Basin

At present, basin-wide correlations are speculative because the central part of the Athabasca Basin is virtually unexplored. Where core is available along the north-central and south-central rim of the basin, subdivision of the strata is controversial. The largest problem is that both the Manitou Falls 'd' member in the eastern basin and the Lazenby Lake and Wolverine Point Formations in the western basin contain a)

b)

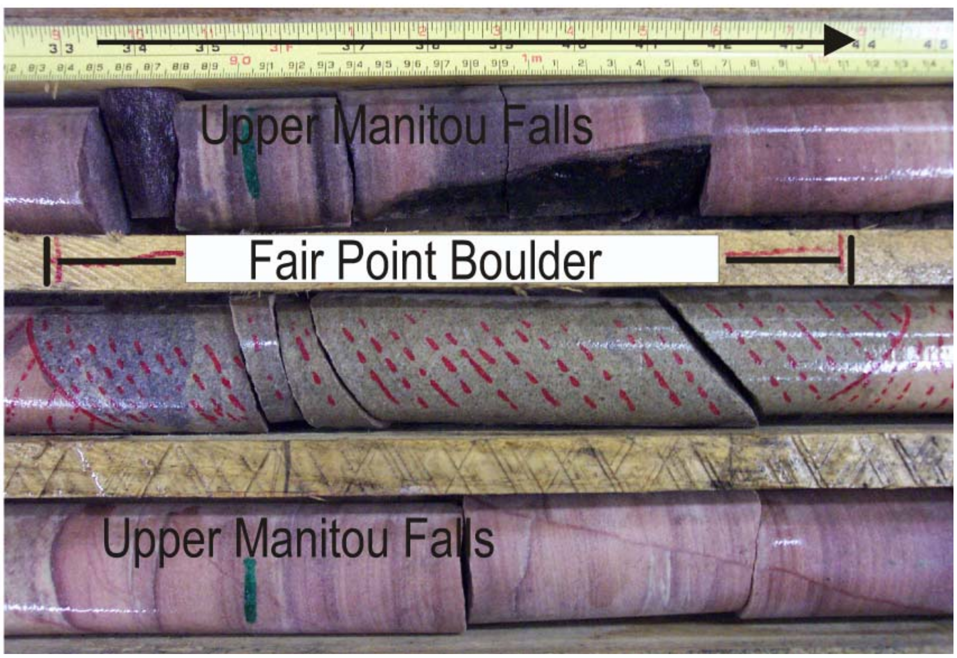


Figure 11. Unconformity above the Fair Point Sequence: a) red saprolite between the Fair Point (Jackfish Basin) and Upper Manitou Falls (part of the William River Basin) sequences, at a depth of 110 m in drillcore FC-071; core boxes are 70 cm long; b) Fair Point boulder reworked into the base of the Upper Manitou Falls Sequence, at a depth of 232 m in drillcore MT-02, north of Net Lake trend; boulder is 12 cm wide.

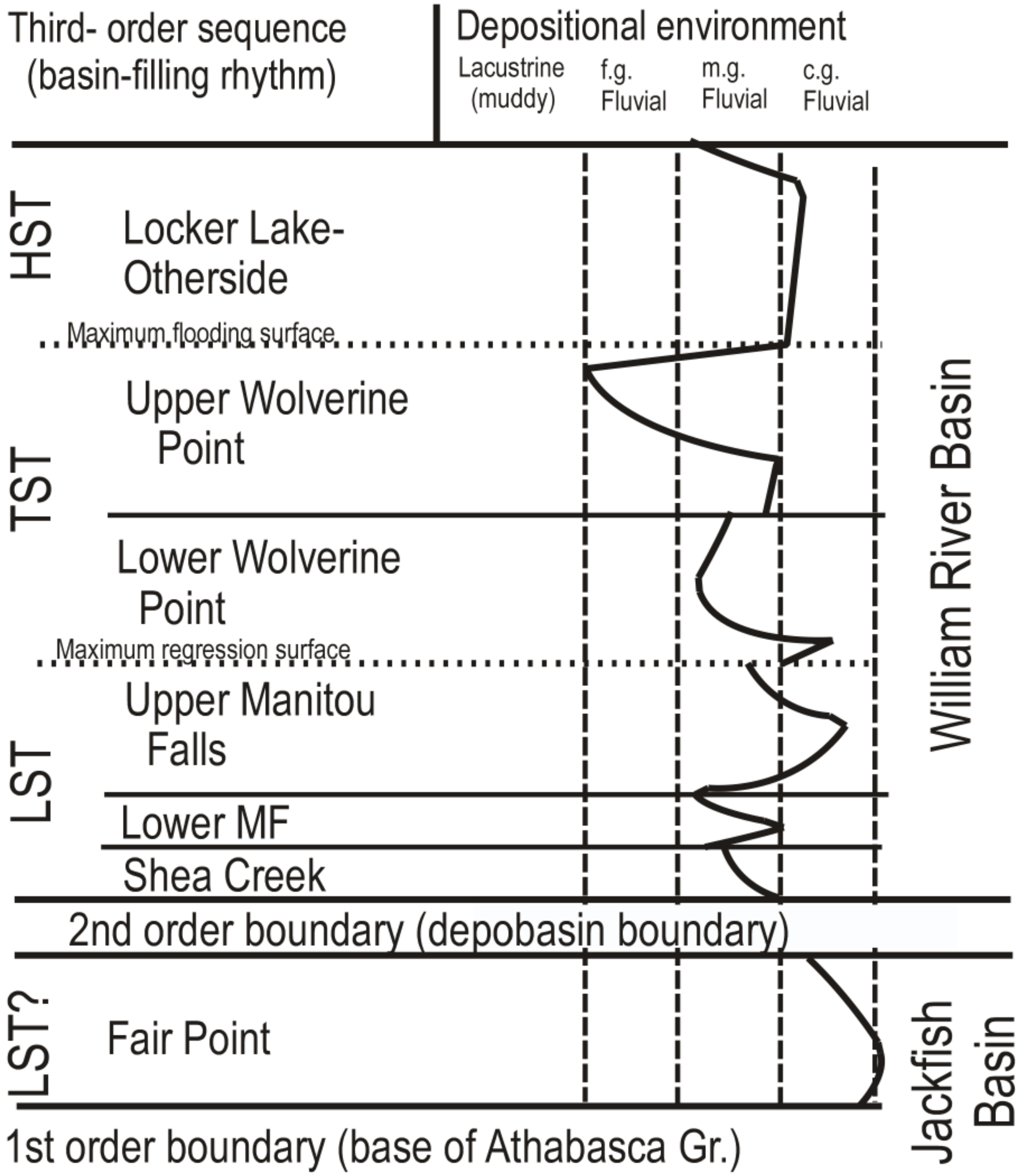


Figure 12. Generalized stacking patterns for formational-scale sequence (third-order sequences or basin-filling rhythms) in the western Athabasca Basin. Rhythms are represented by the dominant depositional environment. For the William River Basin, note the stacking patterns of basin-filling rhythms to form the systems tracts for the depositional basin (second-order sequence). Abbreviations: f.g., fine grained; m.g., medium grained; c.g., coarse grained.

abundant layers rich in clay intraclasts, by which MFd is defined. If these units are indecipherable in the eastern Athabasca Basin, this may account for a large part of the increased thickness of the Manitou Falls Formation in the east, compared to that of the western Athabasca basin. In the future, detailed sequence-stratigraphic studies of the central and eastern parts of the basin should help resolve this problem.

7.5 Correlation with Other Proterozoic Basins

Understanding the original lateral distribution of the sequences is important when comparing or attempting direct correlations with other Proterozoic basins. Thinning relationships within the Shea Creek, Lower Manitou Falls and Upper Manitou Falls sequences suggest that they were relatively closely constrained to the present margins of the Athabasca Basin. During this time, the more localized segmentation of the Athabasca Basin by topographic highs resulted in rapid lateral facies changes than in the overlying sequences. This would probably make the lithological equivalents of the sequences difficult to recognize outside the Athabasca Basin. Direct correlations with other Proterozoic basins are more likely within the thicker and more widely distributed transgressive sequences such as the Lower Wolverine Point, Upper Wolverine Point and Locker Lake–Otherside sequences. Of coarse, geochronology is the best tool for correlating between basins.

7.6 Economic Potential and Future Work

Much of the Alberta portion of the Athabasca Basin is still virtually unexplored. Exploration continues along the Maybelle River uraniferous zone, but there is little or no activity elsewhere at this time. There has been very little exploration in the Beatty Trough. This is surprising, considering the number of major uranium occurrences in the western Athabasca Basin in Saskatchewan that are associated with the Beatty Trough. The intersection of north-northwest faults, such as the Maybelle River, Net Lake, and Harrison Faults, with the east-northeast fault zones, such as those that define the Beatty Trough (i.e., South Robillard and Beatty River faults), could be good targets for exploration. The east-northeast-trending lineament, identified in this study north of Maybelle River area, may be an interesting prospect (see Figure 9 and 10). The intersection of the Maybelle and Net Lake faults with this lineament may be favourable for uranium mineralization. All of these prospective zones are associated with basement highs, making them good economic targets, as drilling costs would be minimal.

8 Conclusions

1) Seven third-order stratigraphic sequences were identified in the western Athabasca Basin in Alberta and Saskatchewan. Sequences are defined by *systems tracts* and are bounded by unconformities and their correlative conformities.

2) The Fair Point Sequence has a unique lithology and distribution that suggests a different paleoenvironment and tectonic regime than the rest of the Athabasca Group. The consistent identification of the upper unconformity of the Fair Point Sequence, which is overlain by large reworked Fair Point boulders and local paleosols, helps support the development of a separate depositional basin (part of its own second-order sequence), the Jackfish Basin.

3) Three additional sequences have been identified in Alberta compared to that of Ramaekers (2004). The Shea Creek, Lower Manitou Falls and Upper Manitou Falls sequences were originally included within the single Manitou Falls Sequence (of Ramaekers, 2004). The Lazenby Lake and Wolverine Point formations have been divided into two sequences: the Lower Wolverine Point and Upper Wolverine Point sequences. The Locker Lake–Otherside Sequence has been separated from the

Locker Lake-Carswell Sequence (of Ramaekers, 2004), as the lower contacts and age constraints of the Douglas and Carswell formations are poorly understood at this time.

4) Similarities in lithology and general lack of unconformities between the overlying sequences suggest that they are all part of the same depositional basin (second-order sequence). The lower sequences (Shea Creek, Lower Manitou Falls and Upper Manitou Falls) generally thicken and coarsen upward. These entirely fluvial sequences seem to be areally restricted to relatively close to the margins of the present-day Athabasca Basin. These represent the lowstand systems tract (LST) and are strongly related to regional tectonics associated with basinward regression. The overlying Lower Wolverine Point and Upper Wolverine Point sequences generally fine upward; these represent the transgressive systems tract (TST) and generally retrograde from fluvial to fluvial-lacustrine. The original lateral extent of this succession was probably widespread past the margins of the present-day Athabasca Basin. The Locker Lake–Otherside Sequence is entirely fluvial and represents a late normal regression, the highstand systems tract (HST), which brought large basement pebbles up to 32 mm into the William River Basin.

5) Pebbly sandstone that subcrops southwest of the Carswell Structure, formerly classified as Locker Lake Formation, is here redefined as the basal part of the Upper Wolverine Point Sequence. It is suggested these pebbly sandstones were deposited in a north-northwest oriented depositional trough formed by the movement along the Harrison Fault. This better explains the present position of the basement underlying this area, which resides in a topographic low. It better explains the lack of evidence for erosion in the area (e.g., no readily recognizable basal unconformity and continuity in thickness of underlying sequence). And it provides a direct linkage to outcrop paleocurrent data, which indicates north-northwest drainage which is subparallel to the Harrison Fault.

6) Major fault zones seem to coincide with present-day lows and highs in basement topography, which can be linked to the development of depositional troughs during sedimentation of the Athabasca Group. Overall sequence thickness and rapid lateral changes can be used as criteria to predict the location of faults in the western Athabasca Basin. For example, an east-west lineament that cuts across the northern part of the Maybelle River and Net Lake trends appears to be related to a paleohigh that, in turn, may be linked to a fault zone.

7) Detailed sequence-stratigraphic analysis through the central and eastern portions of the Athabasca Basin is needed in order to confidently correlate strata with those of the western part of the basin.

8) Favourable targets for uranium mineralization are along north-northwest oriented fault zones such as the Maybelle River, Net Lake and Harrison faults. Exploration should be centred around the areas where these intercept east-northeast-trending fault systems, such as the North Robillard, South Robillard, and Beatty River faults, as well as the newly discovered east-west lineament (fault?) to the north of Maybelle River. All of these areas overlie basement topographic highs, which would make good economic targets because drilling costs would be minimized.

9 References

Bell, K. (1985): Geochronology of the Carswell area, northern Saskatchewan; *in* The Carswell Structure Uranium Deposits, Saskatchewan, R. Laine, D. Alonso and M. Svab (ed.), Geological Association of Canada, Special Paper 29, p. 33–46.

Bostock, H.H., van Breemen, O. and Loveridge, W.D. (1987): Proterozoic geochronology in the Taltson Magmatic Zone, N.W.T.; *in* Radiogenic age and Isotopic Studies: Report 1, Geological Survey of Canada, Paper 87-2, p. 73–80.

Brouand, M., Cuney, M. and Deloule, E. (2003): Eastern extension of the Taltson orogenic belt and eastern provenance of Athabasca sandstone: IMS 1270 ion microprobe U/Pb dating of zircon from concealed basement plutonic rocks and from overlying sandstone, northwestern Saskatchewan, Canada (abstract); Uranium Geochemistry 2003 Conference, Nancy, France, April 2003, Program and Abstracts, p. 91–94.

Card, C.D. (2001): Basement rocks to the western Athabasca Basin in Saskatchewan; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 321–333.

Catuneanu, O. (2002): Sequence stratigraphy of clastic systems: concepts, merits, and pitfalls; Geological Society of Africa, Presidential Review No. 1, Journal of African Earth Sciences, v. 35, p. 1–43.

Collier, B. (2002): Detailed stratigraphy and facies analysis of the Paleoproterozoic Athabasca Group along the Shea Creek–Douglas River transect, northern Saskatchewan; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, CD-ROM, Paper D-10, 16 p.

Collier, B. (2003): Detailed stratigraphy of the Paleoproterozoic Athabasca Group along the Shea Creek–Douglas River trend and its relationship to the regional stratigraphy of the western Athabasca Basin, Canada; M. Sc. thesis; Laurentian University, Sudbury, Ontario.

Collier, B., Yeo, G., Long, D., Koning, E. and Robbins, J. (2001): Preliminary report on the stratigraphy of the William River Subgroup in the vicinity of Shea Creek, southwestern Athabasca Basin, Saskatchewan; *in* Summary of Investigations 2001, Volume 1, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.1, p. 266–271.

Geological Survey of Canada (1987): Magnetic anomaly map of Canada (fifth edition); Geological Survey of Canada, Map 1255A, 1:5 000 000.

Hanmer, S., Parrish, R., Williams, M. and Kopf, C. (1994): Striding-Athabasca mylonite zone: complex Archean deep-crustal deformation in the east Athabasca mylonite triangle, northern Saskatchewan; Canadian Journal of Earth Sciences, v. 31, p. 1287–1300.

Hendry, H.E. and Wheatley, K.L. (1985): The Carswell Formation, northern Saskatchewan: stratigraphy, sedimentology and structure; *in* The Carswell Structure Uranium Deposits, Saskatchewan, R. Laine, D. Alonso and M. Svab (ed.), Geological Association of Canada, Special Paper 29, 230 p.

Hoeve, J. and Sibbald, T. (1978): On the genesis of Rabbit Lake and other unconformity-type uranium deposits in northern Saskatchewan, Canada; Economic Geology, v. 73, p. 1450–1473.

Hoffman, P.F. (1988): United plates of America, the birth of a craton: Early Proterozoic assembly and growth of Laurentia; Annual Reviews of Earth Planetary Science, v. 16, p. 543–603.

Ickert, Ryan (2003). The stratigraphy, sedimentology, and preliminary micropaleontology of the Late Paleoproterozoic Fair Point Formation, Athabasca Basin; B.Sc. thesis, University of Alberta.

Jefferson, C.W. and Delaney, G.D. (2000): EXTECH IV – Athabasca Uranium Multidisciplinary Study – overview; *in* Summary of Investigations 2000, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2000-4.2, p. 99–103.

Krapez, B. (1996): Sequence stratigraphic concepts applied to the identification of basin-filling rhythms in Precambrian successions; Australian Journal of Earth Sciences, v. 43, no. 4, p. 355–380.

Krapez, B. (1997): Sequence-stratigraphic concepts applied to the identification of depositional basins and global tectonic cycles; Australian Journal of Earth Sciences, v. 44, no. 1, p. 1–36.

Kupsch, B.G. and Catuneanu, O. (in press): Preliminary results from a study of the geology and alteration at the Maybelle River uranium zone, Athabasca Basin, Alberta, EXTECH IV; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, CD-ROM, Paper D-11, 8 p.

Kyser, K. (2000): Controls on fluids and basins; Chapter 1 *in* Fluids and Basin Evolution, K. Kyser (ed.), Mineralogical Association of Canada, Short Course Vol. 28, p. 1–16.

Laanela, H. (1978): Assessment report, north of Permit 216, Eldorado Nuclear Limited; Alberta Energy and Utilities Board, EUB/AGS Assessment File 19780005, 3 p.

McDonough, M.R., McNicoll, V.J., Schetselaar, E.M. and Grover, T.W. (2000): Geochronological and kinematic constraints on crustal shortening and escape in a two-sided oblique-slip collisional and magmatic orogen, Paleoproterozoic Taltson magmatic zone, northeastern Alberta; Canadian Journal of Earth Sciences, v. 37, p. 1549–1573.

Miall, A.D. (1997): The Geology of Stratigraphic Sequences; Springer, Berlin, Germany, 433 p.

Mitchum, R.M., Jr., Vail, P.R. and Thompson, S., III (1977): Seismic stratigraphy and global changes of sea level, part 2, the depositional sequence as a basic unit for stratigraphic analysis; *in* Seismic Stratigraphy – Applications to Hydrocarbon Exploration, C.E. Payton (ed.), American Association of Petroleum Geologists, Memoir 26, p. 53–62.

Orr, R.G. (1989): Assessment report for mineral exploration permits 6884120001-2, 6884120001, 6886050002-1 and 68887090002, July 1986 to December 1988; Alberta Energy and Utilities Board, EUB/AGS Assessment File 19890003.

Posamentier, H.W. and Vail, P.R. (1988): Eustatic controls on clastic deposition, II – sequence and systems tract models; *in* Sea Level Changes – An Integrated Approach, C.K. Wilgus, B.S. Hastings, H.W. Posamentier, C.A. Ross, J.C. Van Wagoner and C.G.St.C. Kendall (ed.), Society of Economic Palaeontologists and Mineralogists, Special Publication 42, p. 125–154.

Posamentier, H.W., Jervey, M.T. and Vail, P.R. (1988): Eustatic controls on clastic deposition, I – conceptual framework; *in* Sea Level Changes – An Integrated Approach, C.K. Wilgus, B.S. Hastings, H.W. Posamentier, C.A. Ross, J.C. Van Wagoner and C.G.St.C. Kendall, (ed.), Society of Economic Palaeontologists and Mineralogists, Special Publication 42, p. 109–124.

Post, R.T. (2004): Stratigraphy and Sedimentology of the Athabasca Group in the Net Lake–Maybelle River area, northeastern Alberta; Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2003-01, 103 p.

Rainbird, R.H., Hadlari, T., Aspler, L.B., Donaldson, J.A., LeCheminant, A.N. and Peterson, T.D. (2003a): Sequence stratigraphy and evolution of the Paleoproterozoic intracontinental Baker Lake and Thelon basins, western Churchill Province, Nunavut, Canada; Precambrian Research, v. 125, p. 21–53.

Rainbird, R.H., Rayner, N. and Stern, R.A. (2003b): SHRIMP U-Pb geochronology of apatite cements and zircon-bearing tuff clasts in sandstones from the Athabasca Group, Athabasca Basin, northern Saskatchewan and Alberta (abstract); Saskatchewan Geological Survey, Open House 2003 Abstract Volume, p. 6.

Ramaekers, P. (1979): Stratigraphy of the Athabasca Basin; *in* Summary of Investigations 1979, Saskatchewan Geological Survey; Saskatchewan Mineral Resources, Miscellaneous Report 79-10, p. 154–160.

Ramaekers, P. (1980): Stratigraphy and tectonic history of the Athabasca Group (Helikian) of northern Saskatchewan; *in* Summary of Investigations 1980, Saskatchewan Geological Survey, Saskatchewan Mineral Resources, Miscellaneous Report 80-4, p. 99–106.

Ramaekers, P. (1981): Hudsonian and Helikian basins of the Athabasca region, northern Saskatchewan; *in* Proterozoic Basins of Canada, F.H.A. Campbell (ed), Geological Survey of Canada, Paper 81-10, p. 219–234.

Ramaekers, P. (1990): The geology of the Athabasca Group (Helikian) in northern Saskatchewan; Saskatchewan Energy and Mines, Report 195, 49 p.

Ramaekers, P. (2004): Development, stratigraphy and summary diagenetic history of the Athabasca Basin, early Proterozoic of Alberta, and its relation to uranium potential; Alberta Energy and Utilities Board, EUB/AGS Special Report 62. 85 p.

Ramaekers, P., Yeo, G. and Jefferson, C.W. (2001): Preliminary overview of regional stratigraphy in the Late Paleoproterozoic Athabasca Basin, Saskatchewan and Alberta; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 240–251.

Scott, B.P. (1985): Geology of the upper Clearwater River area; Saskatchewan Energy and Mines, Open File Report 85-2, 26 p.

Shanley, K.W. and McCabe P.J. (1994): Perspectives on the sequences stratigraphy of continental strata; American Association of Petroleum Geologists Bulletin, v. 78, p. 544–568.

Sloss, L.L. (1963): Sequences in the cratonic interior of North America; Geological Society of America Bulletin. v. 74, p. 93–113.

Stern, R.A., Card C.D., Pana, D. and Rayner, N. (2003): SHRIMP U-Pb ages of granitoid basement rocks of the southwestern part of the Athabasca Basin, Saskatchewan and Alberta; Radiogenic Age and Isotopic Studies: Report 16, Geological Survey of Canada, Current Research 2003-F3, 20 p.

Stockwell, C.H. (1961): Structural provinces, orogenies, and time classification of rocks of the Canadian Precambrian Shield; *in* Age Determinations by the Geological Survey of Canada, J.A. Lowden (ed.), Geological Survey of Canada, Paper 61-17, p. 108–118.

Tooth, S. (2000): Process, form and change in dryland rivers: a review of recent research; Earth Science Reviews, v. 51, p. 67–107.

Wilson, J.A. (1985): Geology of the Athabasca Group in Alberta; Alberta Research Council, Alberta Geological Survey, Bulletin 49, 78 p.

Yeo, G., Collier, B., Ramaekers, P., Koning, E., Robbins, J. and Jiricka, D. (2001): Stratigraphy of the Athabasca Group in the southwestern Athabasca Basin, Saskatchewan (NTS 74F and 74K); *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 252–265.

Yeo, G., Jefferson, C.W. and Ramaekers, P. (2002a): A preliminary comparison of Manitou Falls Formation stratigraphy in four Athabasca Basin deposystems; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, CD-ROM, Paper D-7, 14 p.

Yeo, G., Percival, J., Jefferson, C.W., Bernier, S. and Hunt, P. (2002b): Clay oncoids and crypto-microbial laminites from the Late Paleoproterozoic Manitou Falls Formation, Athabasca Basin, Saskatchewan; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, CD-ROM, Paper D-9, 9 p.

Appendix 1 – Sequence Tops and Thicknesses

Appendix 1 -Sequence Tops and Thickness

Sequence Stratigraphic Tops																			Sequence Thickness (Corrected)									
DDH	Prov	X	Y	Z	Inc.	Quar.	Qu+Cret	Dev.	LL-OS	UP-WP	L-WP	UP-MF	L-MF	SC	FP	Base.	or EOH		Quar.	Qu+Cret	Dev.	LL-OS	UP-WP	L-WP	UP-MF	L-MF	SC	FP
ALX-1	SK	578022	6434806	465	-90	0	N/P	N/P	N/P	15.4	146	433	598	683	N/P	721	N/A		15.4	N/P	N/P	N/P	130.5	287	165	85	38	N/P
AS-2	SK	573914	6439262	410	-90	0	N/P	N/P	N/P	8.5	151	428	N/A	N/A	N/A	N/A	502		8.5	N/P	N/P	N/P	142.5	277	74	N/A	N/A	N/A
BR-09	SK	588301	6412525	540	-90	N/A	0	N/P	N/P	N/P	N/P	N/P	110	N/P	N/P	152	N/A		N/A	110	N/P	N/P	N/P	N/P	N/P	42	N/P	N/P
BR-18	SK	586090	6416005	549	-90	N/A	0	N/P	N/P	N/P	94	131	285	N/P	N/P	342	N/A		N/A	94	N/P	N/P	N/P	37	154	57	N/P	N/P
CAR-114	SK	608000	6477000	425	-90	0	N/P	N/P	31	336	650	930	1125	N/P	N/P	1224	N/A		31	N/P	N/P	305	314	280	195	99	N/P	N/P
CAR-257	SK	572092	6465784	???	-90	0	N/P	N/P	15	116	N/A	N/A	N/A	N/A	N/A	N/A	278.2		15	N/P	N/P	101	162.2	N/A	N/A	N/A	N/A	N/A
CAR-301	SK	601620	6494770	350	-90	0	N/P	N/P	N/P	20.9	N/A	N/A	N/A	N/A	N/A	N/A	459.8		20.9	N/P	N/P	N/P	???	N/A	N/A	N/A	N/A	N/A
CAR-651	SK	589161	6488210	353	-52	0	N/P	N/P	N/A	N/A	N/A	N/A	N/A	151	52.8	20.8	197		23.8	N/P	N/P	17.5m-Basement(at top)				N/A	22	20.5
CLU1-78	SK	590726	6400161	550	-90	N/A	0	N/P	N/P	N/P	N/P	N/P	78.5	N/A	N/A	0	86		N/A	78.5	N/P	N/P	N/P	N/P	N/P	7.5	N/A	N/A
CLU9-79	SK	594997	6398474	527	-90	N/A	0	N/P	N/P	N/P	N/P	61	203	N/P	N/P	218	N/A		N/A	61	N/P	N/P	N/P	N/P	142	15	N/P	N/P
CLU18-79	SK	611234	6394341	518	-90	N/A	0	N/P	N/P	N/P	N/P	N/P	95.5	N/P	N/P	114.3	N/A		N/A	95.5	N/P	N/P	N/P	N/P	N/P	18.8	N/P	N/P
CSP6-1	SK	646309	6389609	518	-90	0	N/P	N/P	N/P	N/P	22	97	330	N/P	N/P	373.6	N/A		22	N/P	N/P	N/P	N/P	75	233	43.7	N/P	N/P
DGS-04b	SK	582440	6463400	337	-90	0	Douglas @ 4 m		370	602	913	N/A	N/A	N/A	N/A	N/A	1101		4	N/P	N/P	232	311	188	N/A	N/A	N/A	N/A
DGS-07	SK	585043.9	6458513.5	354.7	-90	0	N/P	N/P	N/P	10	109	411	583	676	733	746	N/A		10	N/P	N/P	N/P	99	302	172	93	57	13
ERC-1	SK	579704.7	6453172.9	363.8	-90	0	N/P	N/P	N/P	12.5	186	473	641	729	N/P	797	N/A		12.5	N/P	N/P	N/P	173.5	287	168	88	68	N/P
ERC-4	SK	565489	6444898	355	-90	0	N/P	N/P	N/P	18.7	177	448	602	699	N/P	752	N/A		18.7	N/P	N/P	N/P	158.2	271	154	97	53	N/P
FC-005	AB	556327.6	6535165.8	220	-90	0	N/P	N/P	30.5	71.9	217	418.1	N/P	N/P	531	823.4	N/A		30.5	N/P	N/P	41.4	145.1	201.1	112.9	N/P	N/P	292.4
FC-007	AB	544851.9	6524699.4	230	-90	0	N/P	N/P	3.7	200	490	774	N/P	N/P	956	N/A	1255		3.7	N/P	N/P	196.3	290	284	182	N/P	N/P	299
FC-008	AB	541000.9	6523524.5	225	-90	0	N/P	N/P	32.6	160	440	710	N/P	N/P	900	N/A	1161		32.6	N/P	N/P	127.4	280	270	190	N/P	N/P	261
FC-009	AB	521044.6	6533824.6	213	-90	0	N/P	N/P	N/P	N/P	N/P	3	N/P	N/P	103	N/A	360		3	N/P	N/P	N/P	N/P	N/P	100	N/P	N/P	257
FC-014	AB	517853.0	6464344.8	390	-90	0	N/P	N/P	N/P	N/P	35	113	N/P	N/P	224	N/A	242		35	N/P	N/P	N/P	N/P	78	111	N/P	N/P	18
FC-015	AB	505654.7	6463987.8	226	-90	0	N/P	N/P	N/P	N/P	12	19.7	N/P	N/P	131.4	219.6	N/A		12	N/P	N/P	N/P	N/P	17.7	111.6	N/P	N/P	88.2
FC-016	AB	543846.2	6464498.5	305	-90	0	N/P	N/P	N/P	47	109	N/A	N/A	N/A	N/A	N/A	184		47	N/P	N/P	N/P	62	75	N/A	N/A	N/A	N/A
FC-017	AB	546647.4	6430523.1	366	-90	0	N/P	N/P	N/P	N/P	35	105	N/A	N/A	N/A	N/A	228		35	N/P	N/P	N/P	N/P	70	123	N/A	N/A	N/A
FC-027	AB	499614.5	6457348.4	274	-90	0	N/P	N/P	N/P	N/P	N/P	58.5	N/P	N/P	138.2	267.3	N/A		58.5	N/P	N/P	N/P	N/P	N/P	79.7	N/P	N/P	129.0
FC-028	AB	507595.7	6464573.4	267	-90	0	N/P	N/P	N/P	N/P	57	73	N/P	N/P	188	N/A	307		57	N/P	N/P	N/P	N/P	N	115	N/P	N/P	119
FC-029	AB	509195.6	6472024.0	259	-90	0	N/P	N/P	N/P	N/P	64	83	N/P	N/P	201	N/A	206.3		64	N/P	N/P	N/P	N/P	19	118	N/P	N/P	5.3
FC-030	AB	511183.6	6469573.3	274	-90	0	N/P	N/P	N/P	N/P	60	89	N/P	N/P	204	258.8	N/A		60	N/P	N/P	N/P	N/P	29	115	N/P	N/P	54.8
FC-031	AB	527537.8	6424395.2	342	-90	0	N/P	31.8	N/P	N/P	N/P	N/P	78	N/P	N/P	80.5	N/A		31.8	N/P	46.2	N/P	N/P	N/P	N/P	2.5	N/P	N/P
FC-032	AB	525617.8	6422478.1	343	-90	0	N/P	49.1	N/P	N/P	N/P	N/P	N/P	80.8	N/P	98.6	N/A		49.1	N/P	31.7	N/P	N/P	N/P	N/P	N/P	17.8	N/P
FC-034	AB	514426.0	6438309.1	308	-90	0	N/P	36.9	N/P	N/P	N/P	N/P	81.7	N/A	N/A	N/A	118		36.9	N/P	44.8	N/P	N/P	N/P	N/P	36.2	N/A	N/A
FC-035	AB	544623.6	6414927.9	384	-90	0	N/P	60	N/P	N/P	N/P	67	119	N/P	N/P	132	N/A		60	N/P	7	N/P	N/P	N/P	52	13	N/P	N/P
FC-036	AB	516224.7	6417638.3	338	-90	0	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	52	N/A		52	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P
FC-037	AB	536891.4	6425274.6	366	-90	0	N/P	N/P	N/P	N/P	N/P	33.5	N/A	N/A	N/A	N/A	174		33.5	N/P	N/P	N/P	N/P	N/P	130.5	N/A	N/A	N/A
FC-038	AB	509095.5	6429518.5	302	-90	0	N/P	26.5	N/P	N/P	N/P	N/P	N/P	N/P	N/P	34.7	N/A		26.5	N/P	8.2	N/P	N/P	N/P	N/P	N/P	N/P	N/P
FC-039	AB	522112.3	6432322.8	320	-90	0	N/P	N/P	N/P	N/P	N/P	16	54	118	N/P	173	N/A		16	N/P	N/P	N/P	N/P	N/P	38	64	55	N/P
FC-041	AB	543624.7	6413354.3	379	-90	0	N/P	36	N/P	N/P	N/P	N/P	53	N/P	N/P	88	N/A		36	N/P	17	N/P	N/P	N/P	N/P	35	N/P	N/P
FC-043	AB	545156.8	6413799.0	393	-86	0	N/P	54.9	N/P	N/P	N/P	79	120	N/P	N/P	148	N/A		54.7	N/P	24	N/P	N/P	N/P	40.9	27.9	N/P	N/P
FC-044	AB	538110.2	6417486.8	365	-90	0	N/P	53	N/P	N/P	N/P	N/P	81	N/P	N/P	85	N/A		53	N/P	28	N/P	N/P	N/P	N/P	4	N/P	N/P
FC-045	AB	538701.6	6418301.6	366	-90	0	N/P	34	N/P	N/P	N/P	N/P	100.4	N/P	N/P	109.3	N/A		34	N/P	66.4	N/P	N/P	N/P	N/P	8.8	N/P	N/P
FC-046	AB	541657.8	6416888.8	371	-90	0	N/P	47	N/P	N/P	N/P	N/P	88.5	N/P	N/P	112	N/A		47	N/P	41.5	N/P	N/P	N/P	N/P	23.5	N/P	N/P
FC-047	AB	555658.3	6409824.0	444	-87	0	N/P	86	N/P	N/P	N/P	N/P	N/P	N/P	N/P	88	N/A		85.8	N/P	2	N/P	N/P	N/P	N/P	N/P	N/P	N/P
FC-048	AB	535021.7	6419646.8	364	-72	0	N/P	37	N/P	N/P	N/P	N/P	N/P	111.1	N/P	135.8	N/A		35.1	N/P	70.5	N/P	N/P	N/P	N/P	N/P	23.5	N/P
FC-052	AB	541521.7	6449548.4	332	-90	0	N/P	N/P	N/P	N/P	16	182	N/A	N/A	N/A	N/A	245		16	N/P	N/P	N/P	N/P	166	63	N/A	N/A	N/A
		NAD [83]																										
N/P= Not Present; N/A= Not Available/ Applicable																												

Sequence Stratigraphic Tops																			Sequence Thickness (Corrected)									
DDH	Prov	X	Y	Z	Inc.	Quar.	Qu+Cret	Dev.	LL-OS	UP-WP	L-WP	UP-MF	L-MF	SC	FP	Base.	or EOH		Quar.	Qu+Cret	Dev.	LL-OS	UP-WP	L-WP	UP-MF	L-MF	SC	FP
FC-056	AB	553644.0	6573590.6	225	-90	0	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	10	34.8	N/A		10	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	24.8
FC-064	AB	550896.7	6570694.1	216	-90	0	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	7	21.2	N/A		7	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	14.2
FC-071	AB	494314.1	6456085.9	274	-90	0	N/P	N/P	N/P	N/P	N/P	61.2	N/P	N/P	108.3	206	N/A		61.2	N/P	N/P	N/P	N/P	N/P	47.1	N/P	N/P	97.6
FC-072	AB	485628.7	6465823.1	247	-90	0	N/P	90.5	N/P	N/P	N/P	N/P	N/P	N/P	125	192.6	N/A		90.5	N/P	34.5	N/P	N/P	N/P	N/P	N/P	N/P	67.6
FC-075	AB	482480.9	6470899.5	269	-90	0	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	93.9	153.5	N/A		93.9	N/P	N/P	N/P	N/P	N/P	N/P	N/P	N/P	59.6
HAR-04	SK	584159	6410813	530	-90	N/A	0	N/P	N/P	N/P	N/P	144.6	245	N/P	N/P	273.5	N/A		N/A	145	N/P	N/P	N/P	N/P	100.4	28.5	N/P	N/P
HK-012	SK	621676	6408904	525	-90	0	N/P	N/P	N/P	11.6	54.6	340.6	538	N/P	N/P	571.1	N/A		11.6	N/P	N/P	N/P	43	286	197.4	33.1	N/P	N/P
MR-02	AB	518239.3	6442919.8	305	-60	0	N/P	33.5	N/P	N/P	N/P	N/P	N/P	N/P	N/P	79	N/A		29.0	N/P	39.4	N/P	N/P	N/P	N/P	N/P	N/P	N/P
MR-03	AB	518869.9	6443552.5	305	-60	0	N/P	36.7	N/P	N/P	N/P	47.5	N/P	N/P	N/P	88.4	N/A		31.7	N/P	9.3	N/P	N/P	N/P	35.5	N/P	N/P	N/P
MR-04	AB	520948.1	6445531.5	308	-60	0	N/P	39.9	N/P	N/P	N/P	52	N/P	N/P	101.4	121.4	N/A		34.5	N/P	10.4	N/P	N/P	N/P	42.8	N/P	N/P	17.4
MR-05	AB	517483.2	6443856.4	310	-60	0	N/P	50	N/P	N/P	N/P	N/P	N/P	N/P	N/P	84.3	N/A		43.3	N/P	29.6	N/P	N/P	N/P	N/P	N/P	N/P	N/P
MR-06	AB	516096.5	6442560.5	300	-60	0	N/P	36.7	N/P	N/P	N/P	N/P	38.8	N/P	N/P	57	N/A		31.7	N/P	1.8	N/P	N/P	N/P	N/P	15.7	N/P	N/P
MR-07	AB	515560.2	6445925.8	290	-60	0	N/P	33	N/P	N/P	N/P	80	N/P	N/P	N/P	100.4	N/A		28.5	N/P	40.7	N/P	N/P	N/P	17.6	N/P	N/P	N/P
MR-10	AB	513810.7	6448210.8	300	-60	0	N/P	46.7	N/P	N/P	N/P	66.7	N/P	N/P	106	150	N/A		40.4	N/P	17.3	N/P	N/P	N/P	34.0	N/P	N/P	38.1
MR-12	AB	514983.9	6447089.7	312	-90	0	N/P	32	N/P	N/P	N/P	62	N/P	N/P	100.1	116	N/A		32	N/P	30	N/P	N/P	N/P	38.1	N/P	N/P	15.8
MR-13	AB	516343.0	6445041.8	292	-60	0	N/P	35	N/P	N/P	N/P	70	N/P	N/P	N/P	80	N/A		30.3	N/P	30.3	N/P	N/P	N/P	8.6	N/P	N/P	N/P
MR-14	AB	517561.2	6445108.6	305	-65	0	N/P	62.6	N/P	N/P	N/P	66.9	88.9	N/P	N/P	101.6	N/A		56.7	N/P	3.9	N/P	N/P	N/P	19.9	N/P	N/P	11.5
MR-15	AB	519352.2	6442910.1	300	-60	0	N/P	39.6	N/P	N/P	N/P	44	N/P	N/P	52.9	55.6	N/A		34.2	N/P	3.8	N/P	N/P	N/P	7.7	N/P	N/P	2.2
MR-17	AB	521231.3	6439749.0	303	-60	0	N/P	36.5	N/P	N/P	N/P	N/P	N/P	N/P	N/P	76.4	N/A		31.6	N/P	34.6	N/P	N/P	N/P	N/P	N/P	N/P	N/P
MR-18	AB	516526.3	6443093.6	303	-90	0	N/P	33.7	N/P	N/P	N/P	61.1	71	N/P	N/P	78.6	N/A		33.7	N/P	27.4	N/P	N/P	N/P	9.9	7.6	N/P	N/P
MR-20	AB	521407.9	6446515.9	312	-60	0	N/P	33.7	N/P	N/P	N/P	63.2	N/P	N/P	168.1	177	N/A		29.1	N/P	25.5	N/P	N/P	N/P	90.8	N/P	N/P	7.7
MR-34	AB	520053.2	6451509.8	305	-70	0	N/P	N/P	N/P	N/P	34	60	N/P	N/P	176	202	N/A		31.9	N/P	N/P	N/P	N/P	24.4	109	N/P	N/P	24.4
MR-35	AB	519648.3	6453344.1	300	-60	0	N/P	N/P	N/P	N/P	24	70	N/P	N/P	192	239	N/A		20.7	N/P	N/P	N/P	N/P	39.8	105.6	N/P	N/P	40.7
MR-36	AB	519104.3	6455632.2	308	-60	0	N/P	N/P	N/P	N/P	47	87	N/P	N/P	208.8	279.2	N/A		40.7	N/P	N/P	N/P	N/P	34.6	105.5	N/P	N/P	60.9
MR-37	AB	518620.9	6458735.5	305	-60	0	N/P	N/P	N/P	N/P	68	94	N/P	N/P	232	308.4	N/A		58.8	N/P	N/P	N/P	N/P	22.5	119.5	N/P	N/P	66.1
MR-64	AB	524438.6	6441738.4	328	-60	0	N/P	28	N/P	N/P	N/P	42	N/P	N/P	N/P	118	N/A		24.2	N/P	12.1	N/P	N/P	N/P	65.8	N/P	N/P	N/P
MR-65	AB	538272.2	6438523.2	347	-90	0	N/P	N/P	N/P	N/P	14	170	305	328	N/P	424.8	N/A		14	N/P	N/P	N/P	N/P	156	145	13	96.8	N/P
MR-66	AB	535031.7	6443429.0	350	-90	0	N/P	N/P	N/P	N/P	18	172	331	354	N/P	375	N/A		18	N/P	N/P	N/P	N/P	154	159	23	21	N/P
MR-68	AB	517972.4	6462619.6	308	-60	0	N/P	N/P	N/P	N/P	80	147.4	N/P	N/P	274.4	379.6	N/A		69.2	N/P	N/P	N/P	N/P	58.3	110	N/P	N/P	91
MR-69	AB	517804.1	6461749.3	308	-60	0	N/P	N/P	N/P	N/P	61.3	174.2	N/P	N/P	311.3	417	N/A		53.0	N/P	N/P	N/P	N/P	97.7	118.7	N/P	N/P	91.5
MR-70	AB	518573.3	6459516.8	297	-60	0	N/P	N/P	N/P	N/P	78	113	N/P	N/P	245.6	339.3	N/A		73.2	N/P	N/P	N/P	N/P	32.8	124.6	N/P	N/P	88
MR-74x	AB	524344.6	6441628.9	321.6	-90	0	N/P	N/P	N/P	N/P	N/P	40.5	N/P	N/P	N/P	103.7	N/A		40.5	N/P	N/P	N/P	N/P	N/P	63.2	N/P	N/P	N/P
MR-76	AB	523534.1	6443005.9	317	-60	0	N/P	20	N/P	N/P	N/P	37.5	N/P	N/P	N/P	71.3	N/A		17.3	N/P	15.1	N/P	N/P	N/P	29.2	N/P	N/P	N/P
MR-78	AB	522953.0	6444192.6	315	-60	0	N/P	28.8	N/P	N/P	N/P	N/P	53	N/P	N/P	59.5	N/A		24.9	N/P	20.9	N/P	N/P	N/P	N/P	5.6	N/P	N/P
MR-79	AB	520684.2	6448626.0	310	-60	0	N/P	N/P	N/P	N/P	30	35	N/P	N/P	144.4	182.7	N/A		25.9	N/P	N/P	N/P	N/P	4.3	94.7	N/P	N/P	33.1
MR-81	AB	521368.9	6447328.0	315	-60	0	N/P	N/P	N/P	N/P	N/P	36.6	N/P	N/P	148.4	173.9	N/A		31.6	N/P	N/P	N/P	N/P	N/P	96.8	N/P	N/P	22.0
MR-83	AB	512446.9	6450452.4	288	-90	0	N/P	N/P	N/P	N/P	N/P	22	N/P	N/P	84.1	125.9	N/A		22	N/P	N/P	N/P	N/P	N/P	62.1	N/P	N/P	41.8
MR-84	AB	517857.5	6460964.5	297	-90	0	N/P	N/P	N/P	N/P	39	133	N/P	N/P	253.6	338	N/A		39	N/P	N/P	N/P	N/P	94	120.6	N/P	N/P	84.4
MT-01	AB	516755.0	6466517.6	293	-90	0	N/P	N/P	N/P	N/P	70.1	123	N/P	N/P	228.4	327.6	N/A		70.1	N/P	N/P	N/P	N/P	52.9	105.4	N/P	N/P	99.2
MT-02	AB	509714.9	6467837.8	265	-90	0	N/P	N/P	N/P	N/P	58	84	N/P	N/P	177.4	229.7	N/A		58	N/P	N/P	N/P	N/P	26	93.4	N/P	N/P	52.2
SHE-1B	SK	594588	6433458	506	-90	0	N/P	N/P	N/P	N/P	18.9	166	333	377	N/P	406	N/A		18.9	N/P	N/P	N/P	N/P	147.1	167	44	29	N/P
SHE-6	SK	588240	6453900	380	-90	0	N/P	N/P	N/P	10	66	364	543	623	N/P	693	N/A		10	N/P	N/P	N/P	56	298	179	80	70	N/P
SHE-22	SK	588960	6452040	372	-90	0	N/P	N/P	N/P	61	95	396	580	647	719	741	N/A		61	N/P	N/P	N/P	34	301	184	67	72	22
SHE-45	SK	586037.7	6456785.7	373.0	-90	0	N/P	N/P	N/P	37	51	366	570	647	N/P	735	N/A		37	N/P	N/P	N/P	14	315	204	77	88	N/P
SYL-1	SK	566716	6470859	305	-90	0	N/P	N/P	N/P	12.1	66	342	514	589	609	726	N/A		12.1	N/P	N/P	N/P	53.9	276	172	75	20	117
		NAD 83																										

N/P= Not Present; N/A= Not Available/ Applicable

Appendix 2 – Lithologs

Stratigraphic Divisions of this Study

Stratigraphic sequence	Facies association	Brief lithological description
Locker Lake–Otherside	FA 7-3	Clean fine-grained sandstone
	FA 7-2	Granule-bearing medium-grained sandstone
	FA 7-1	Pebbly medium-grained sandstone with minor conglomerate
Upper Wolverine Point	FA 6-5	Clay-rich medium-grained sandstone
	FA 6-4	Mudstone (abundant sandstone)
	FA 6-3	Fine-grained sandstone (abundant mudstone)
	FA 6-2	Fine-grained sandstone (little or no mudstone)
	FA 6-1	Granule- or pebble-bearing medium-grained sandstone
Lower Wolverine Point	FA-5-5	Clay intraclast–rich medium-grained sandstone
	FA-5-4	Granule-rich medium-grained sandstone
	FA 5-3	Fine to medium-grained sandstone (little or no mudstone)
	FA 5-2	Fine to medium-grained sandstone (common mudstone)
	FA 5-1	Pebbly medium-grained sandstone
Upper Manitou Falls	FA 4-5	Clay intraclast–rich (1%) fine to medium-grained sandstone
	FA 4-4	Clean medium-grained sandstone (frequent clay clasts)
	FA 4-3	Clean medium-grained sandstone (few or no clay clasts)
	FA 4-2	Granule/pebble-bearing medium-grained sandstone
	FA 4-1	Conglomeratic medium-grained sandstone
	FA 4-0	Basal rock types (above basement)
Lower Manitou Falls	FA 3-2	Clean medium-grained sandstone (few or no clay clasts)
	FA 3-1	Pebbly to conglomeratic medium-grained sandstone
	FA 3-0	Basal rock types (above basement)
Shea Creek	FA 2-2	Low-angle crossbedded sandstone
	FA 2-1	Trough crossbedded sandstone
	FA 2-0	Basal rock types (above basement)
Fair Point	FA 1-2	Pebbly medium to coarse-grained sandstone
	FA 1-1	Conglomeratic coarse-grained sandstone and conglomerate
	FA 1-0	Basal rock types (above basement)

Reference table for the seven sequence of this study with facies associations and inferred lithostratigraphic equivalents. Note: Lithostratigraphic units are large based upon interpretations of works of Ramaekers, 2003.

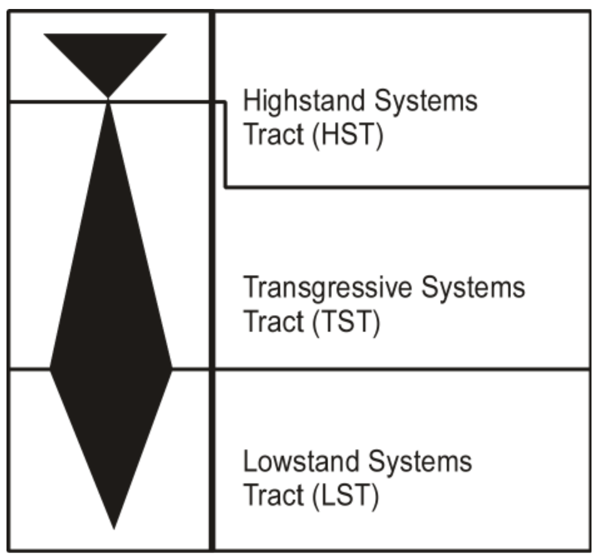
Protocol for logs compiled in this study

Parameter	Brief Description	Plot scale
MTG	Maximum elongation of largest grain	Log (base 2) = phi
Mean	Average grain-size	Log (base 2) = phi
Coarse	Material > 2 mm [trace = rare scattered clasts; G1= one-clast-thick layers; #s= measured thickness of conglomerate beds (clasts exceed 30%)]	Approx. Log (base 2)
Muds	Measured thickness of muddy siltstone, muddy sandstone, silty mudstone, sandy mudstone, mudstone, siltstone and very-fine sandstone	Linear
Clay Intraclast	Surface area percent of clay intraclasts (without rotating core)	Linear (1-3%)
Sx	Measured thickness of combined cross-bedded structures >5cm thick	Linear
Sl/Sh	Measured thickness of combined low angle cross-bedded/ flat-bedded structures	Linear
Convolute	Measured thickness of combined convoluted or overturned intervals	Linear

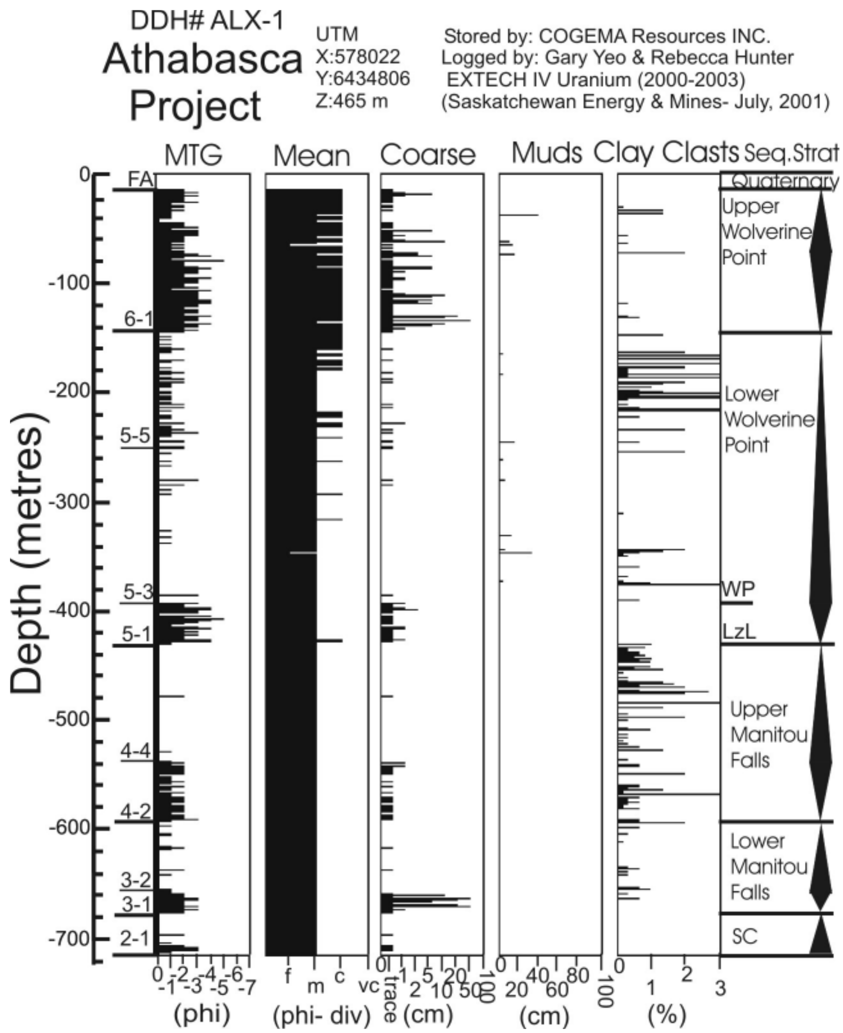
Udden-Wentworth grain-size division (of this study)

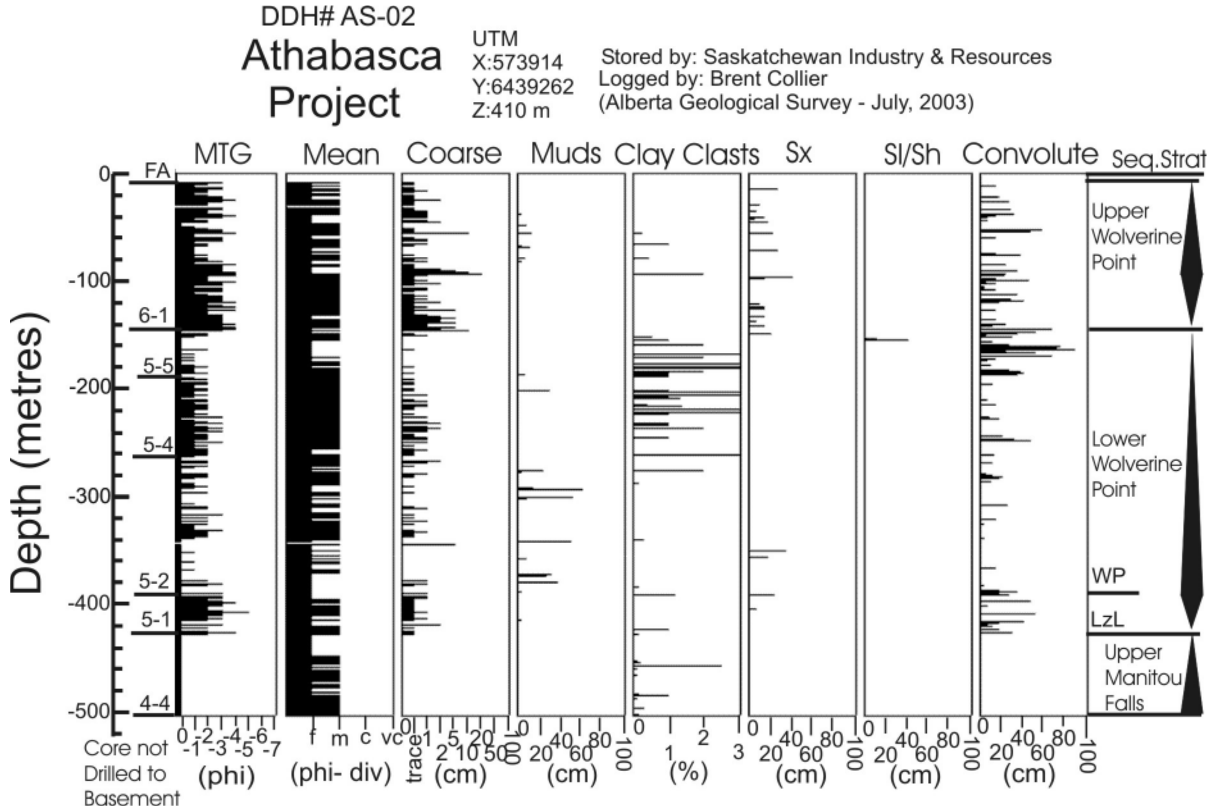
phi	(mm)	Class Terms	abbrev.
-7	128	cobble	cb
-6	64	very large pebble	vlp
-5	32	large pebble	lp
-4	16	medium pebble	mp
-3	8	small pebble	sp
-2	4	granule	g
-1	2	very coarse sand	vc
0	1	coarse sand	c

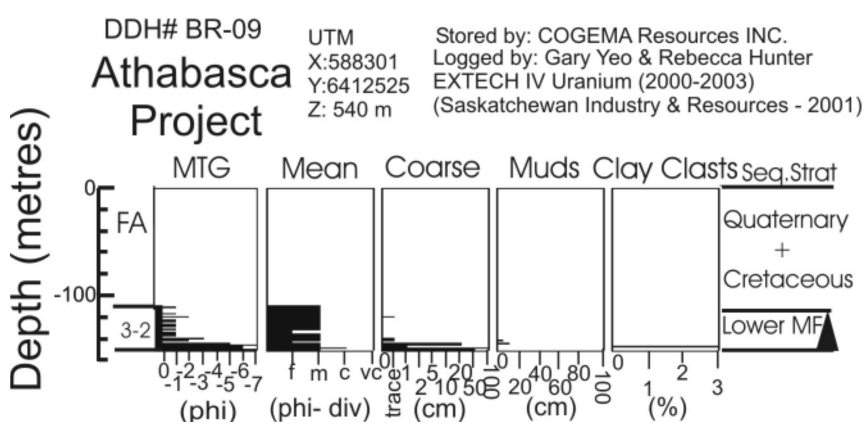
Table indicates the upper limit of each successive class.

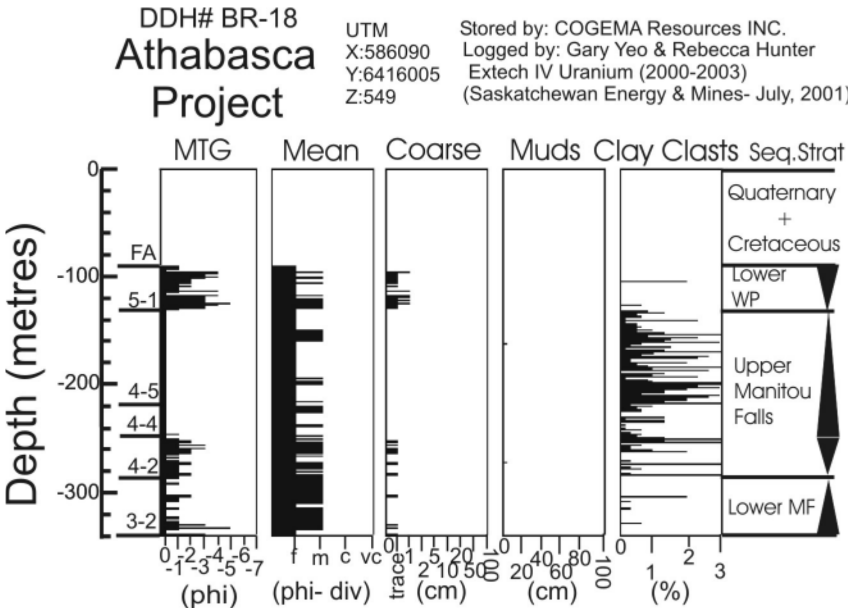


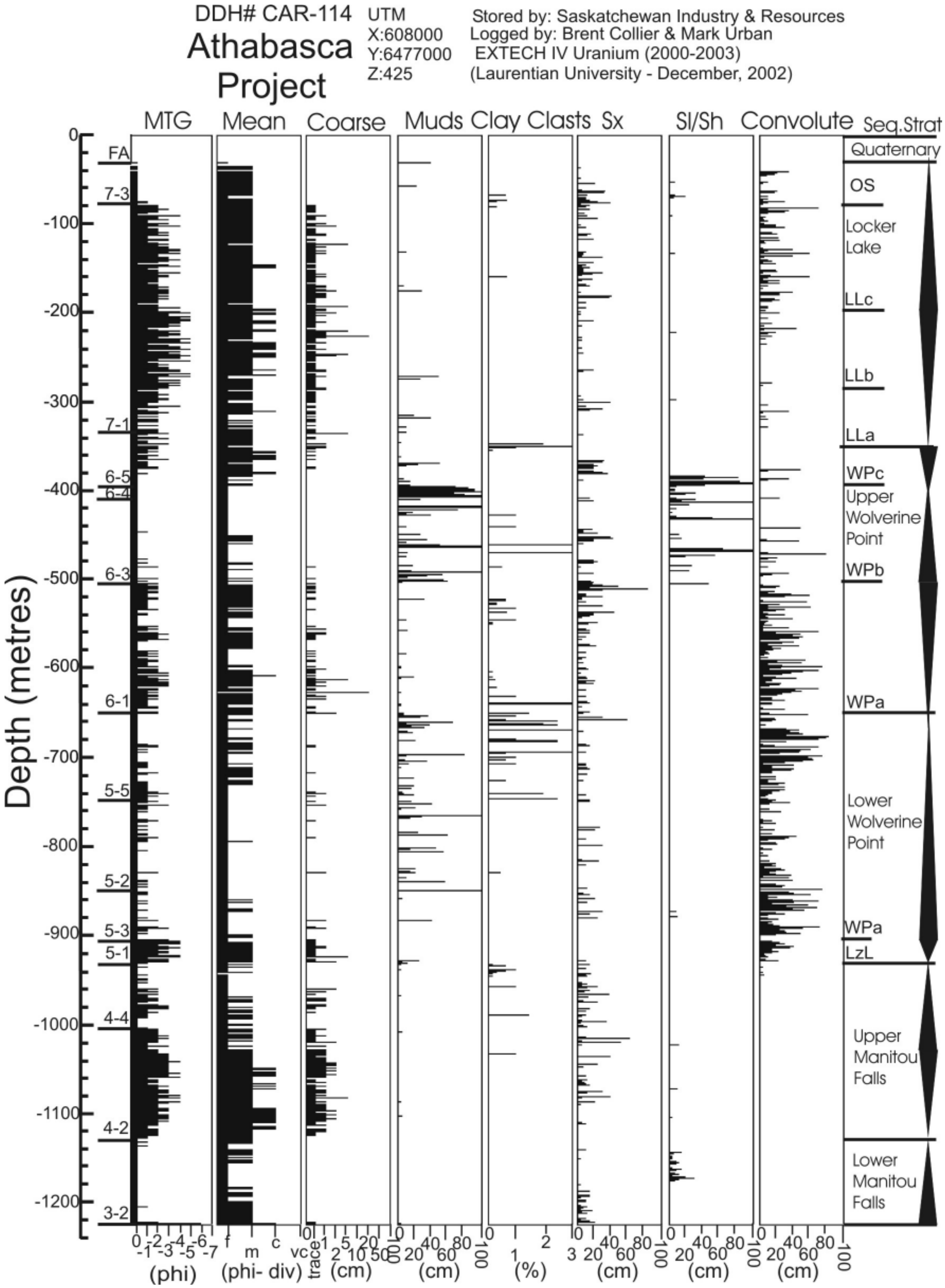
System tract divisions for lithologs.


DDH# ALX-1
Athabasca Project
UTM
X:578022
Y:6434806
Z:465 m
Stored by: COGEMA Resources INC.
Logged by: Gary Yeo & Rebecca Hunter
EXTECH IV Uranium (2000-2003)
(Saskatchewan Energy & Mines- July, 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
6-1
5-5
5-3
5-1
4-4
4-2
3-2
3-1
2-1
Quaternary
Upper Wolverine Point
Lower Wolverine Point
WP
LzL
Upper Manitou Falls
Lower Manitou Falls
SC
(phi)
(phi- div)
trace
(cm)
(cm)
(%)

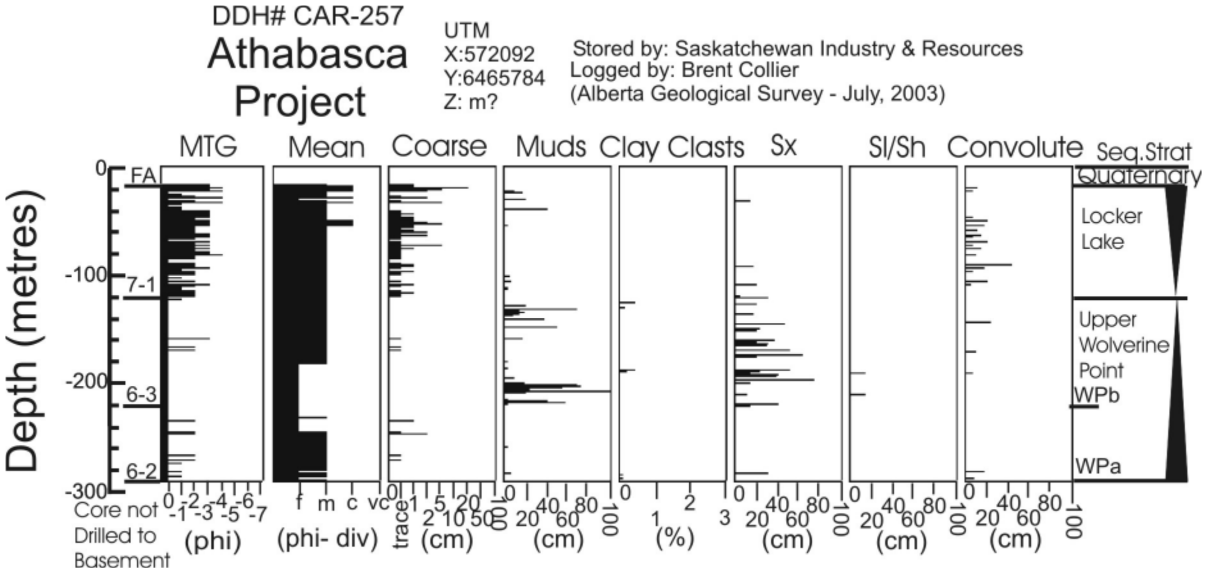

DDH# AS-02
Athabasca Project
UTM
X:573914
Y:6439262
Z:410 m
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
FA
6-1
5-5
5-4
5-2
5-1
4-4
Upper Wolverine Point
Lower Wolverine Point
WP
LzL
Upper Manitou Falls
Core not Drilled to Basement
(phi)
(phi- div)
(cm)
(%)

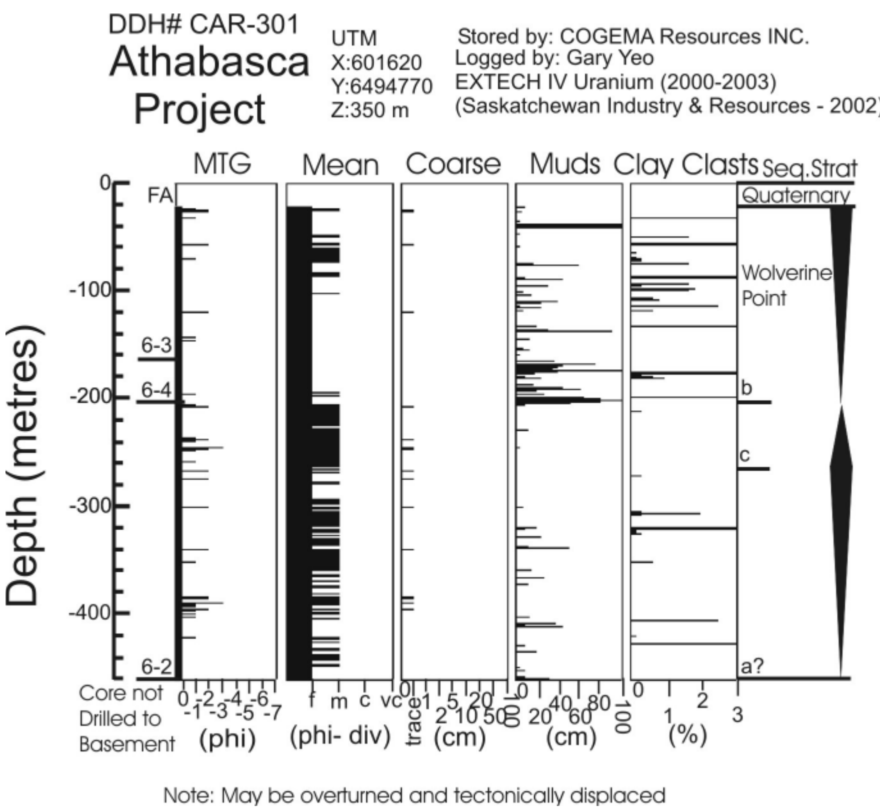

DDH# BR-09
Athabasca Project
UTM
X:588301
Y:6412525
Z: 540 m
Stored by: COGEMA Resources INC.
Logged by: Gary Yeo & Rebecca Hunter
EXTECH IV Uranium (2000-2003)
(Saskatchewan Industry & Resources - 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
3-2
Quaternary + Cretaceous
Lower MF
(phi)
(phi- div)
(cm)
(%)

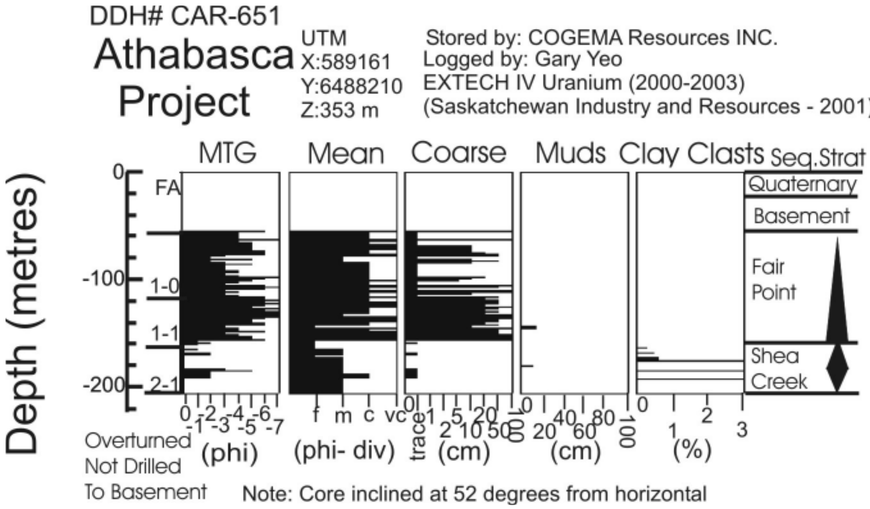

DDH# BR-18
Athabasca Project
UTM
X:586090
Y:6416005
Z:549
Stored by: COGEMA Resources INC.
Logged by: Gary Yeo & Rebecca Hunter
Extech IV Uranium (2000-2003)
(Saskatchewan Energy & Mines- July, 2001)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
FA
5-1
4-5
4-4
4-2
3-2
Quaternary + Cretaceous
Lower WP
Upper Manitou Falls
Lower MF
(phi)
(phi- div)
(cm)
(cm)
(%)
trace

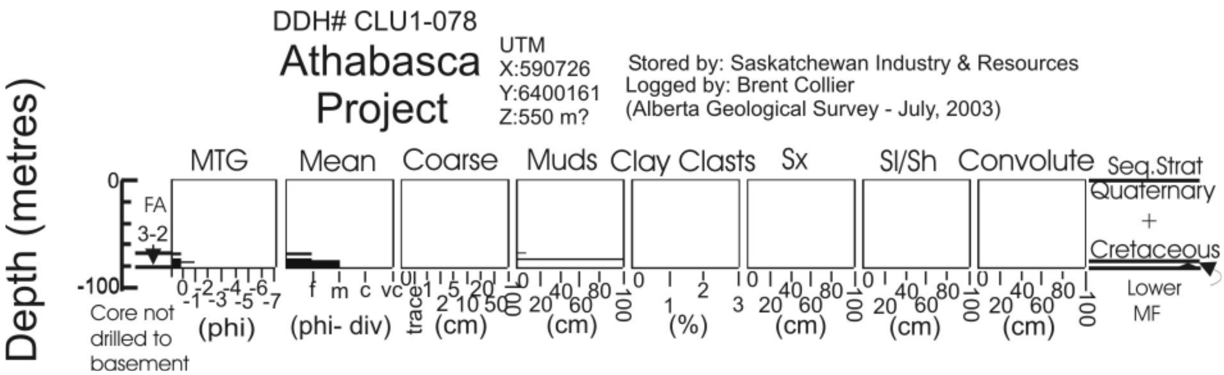


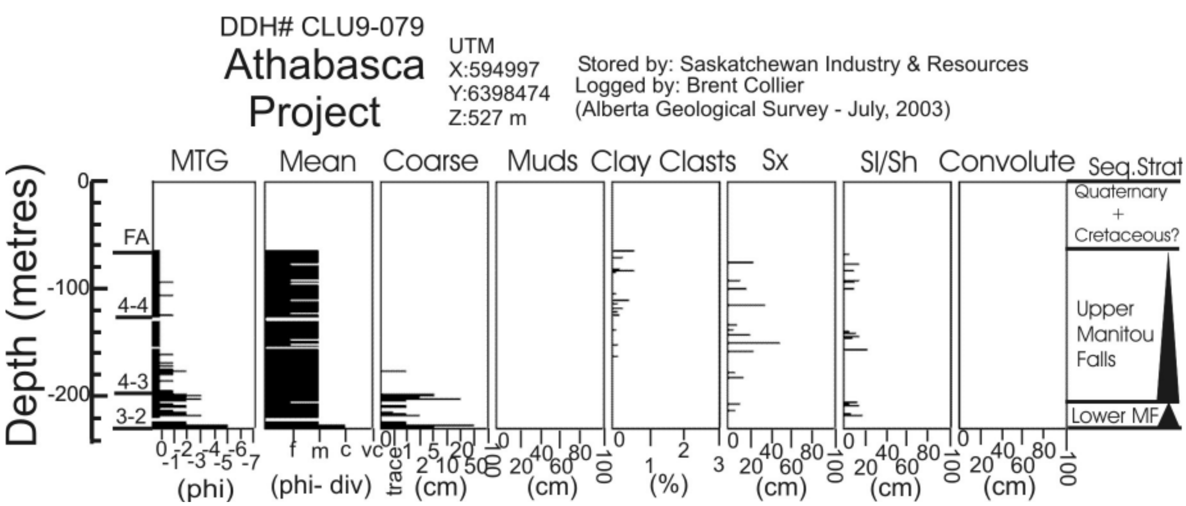
DDH# CAR-114
Athabasca Project
UTM
X:608000
Y:6477000
Z:425
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier & Mark Urban
EXTECH IV Uranium (2000-2003)
(Laurentian University - December, 2002)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
(phi)
(phi- div)
(cm)
(%)
Quaternary
OS
Locker Lake
LLc
LLb
LLa
WPc
Upper Wolverine Point
WPb
WPa
Lower Wolverine Point
WPa
LzL
Upper Manitou Falls
Lower Manitou Falls
FA
7-3
7-1
6-5
6-4
6-3
6-1
5-5
5-2
5-3
5-1
4-4
4-2
3-2

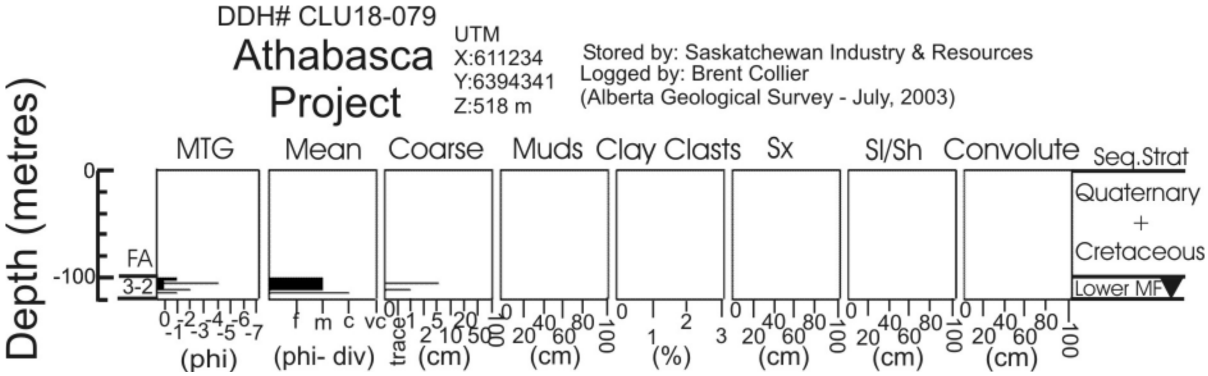

DDH# CAR-257
Athabasca Project
UTM
X:572092
Y:6465784
Z: m?
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Locker Lake
Upper Wolverine Point
WPb
WPa
Depth (metres)
FA
7-1
6-3
6-2
Core not Drilled to Basement
(phi)
(phi- div)
f m c vc
trace
(cm)
(%)

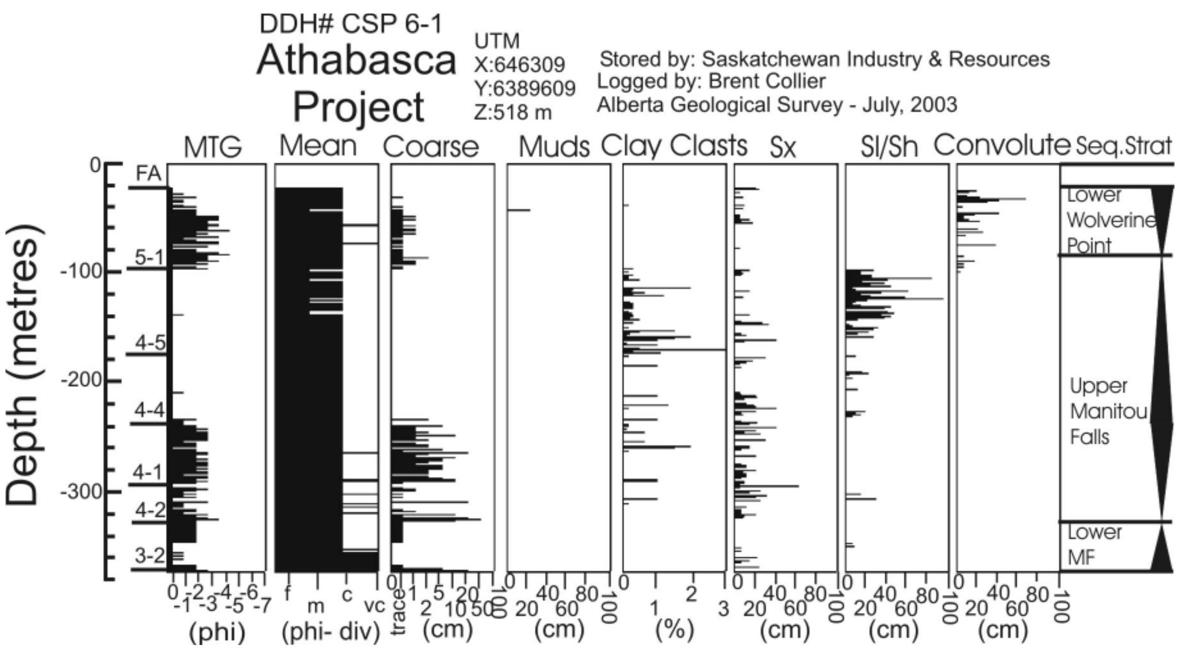

DDH# CAR-301
Athabasca Project
UTM
X:601620
Y:6494770
Z:350 m
Stored by: COGEMA Resources INC.
Logged by: Gary Yeo
EXTECH IV Uranium (2000-2003)
(Saskatchewan Industry & Resources - 2002)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Quaternary
Wolverine Point
b
c
a?
Depth (metres)
FA
6-3
6-4
6-2
Core not Drilled to Basement
(phi)
(phi- div)
f m c vc
trace
(cm)
(%)
Note: May be overturned and tectonically displaced

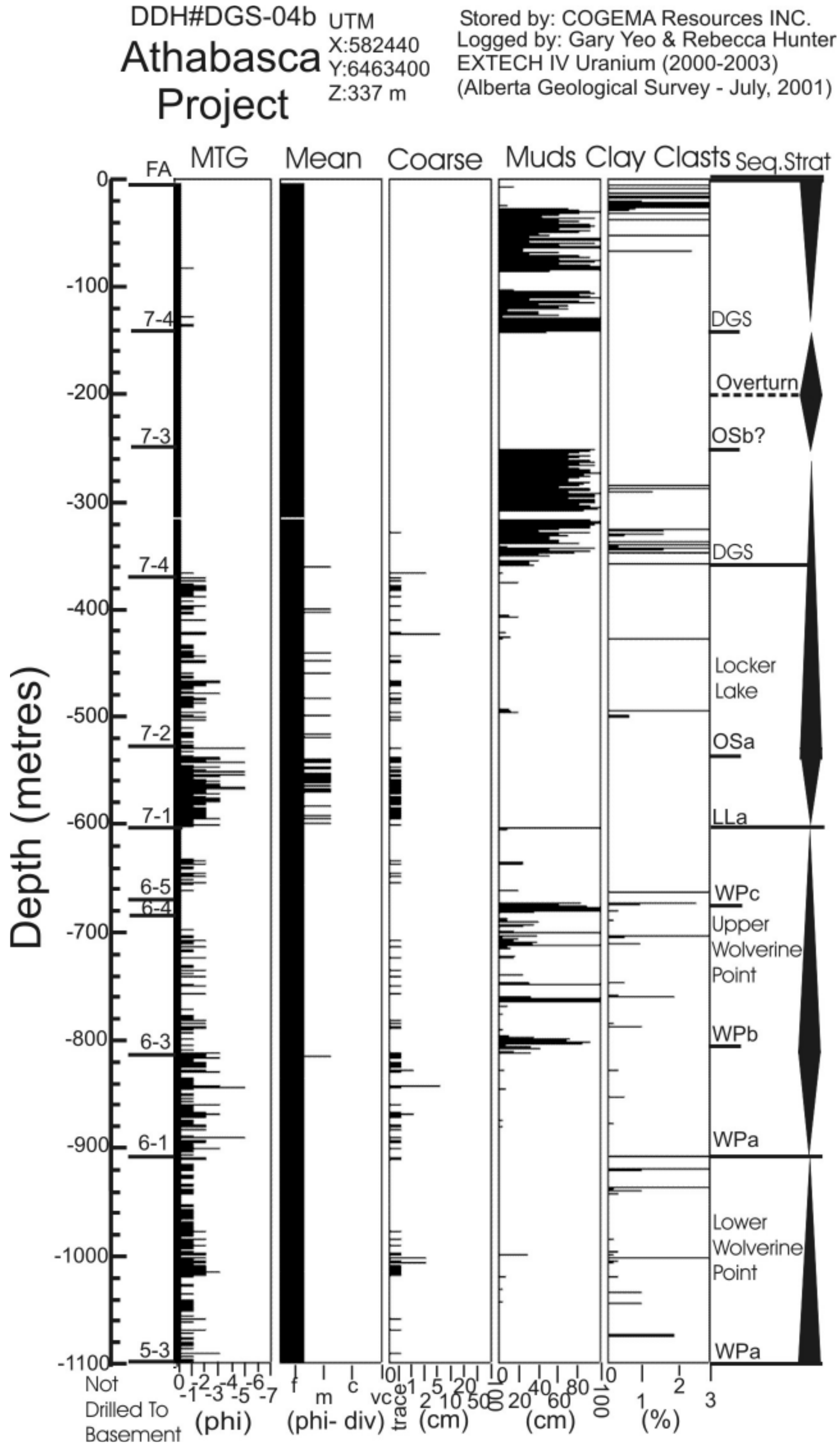

DDH# CAR-651
Athabasca Project
UTM
X:589161
Y:6488210
Z:353 m
Stored by: COGEMA Resources INC.
Logged by: Gary Yeo
EXTECH IV Uranium (2000-2003)
(Saskatchewan Industry and Resources - 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
1-0
1-1
2-1
Quaternary
Basement
Fair Point
Shea Creek
(phi)
(phi- div)
(cm)
(cm)
(%)
Overturned
Not Drilled
To Basement
Note: Core inclined at 52 degrees from horizontal

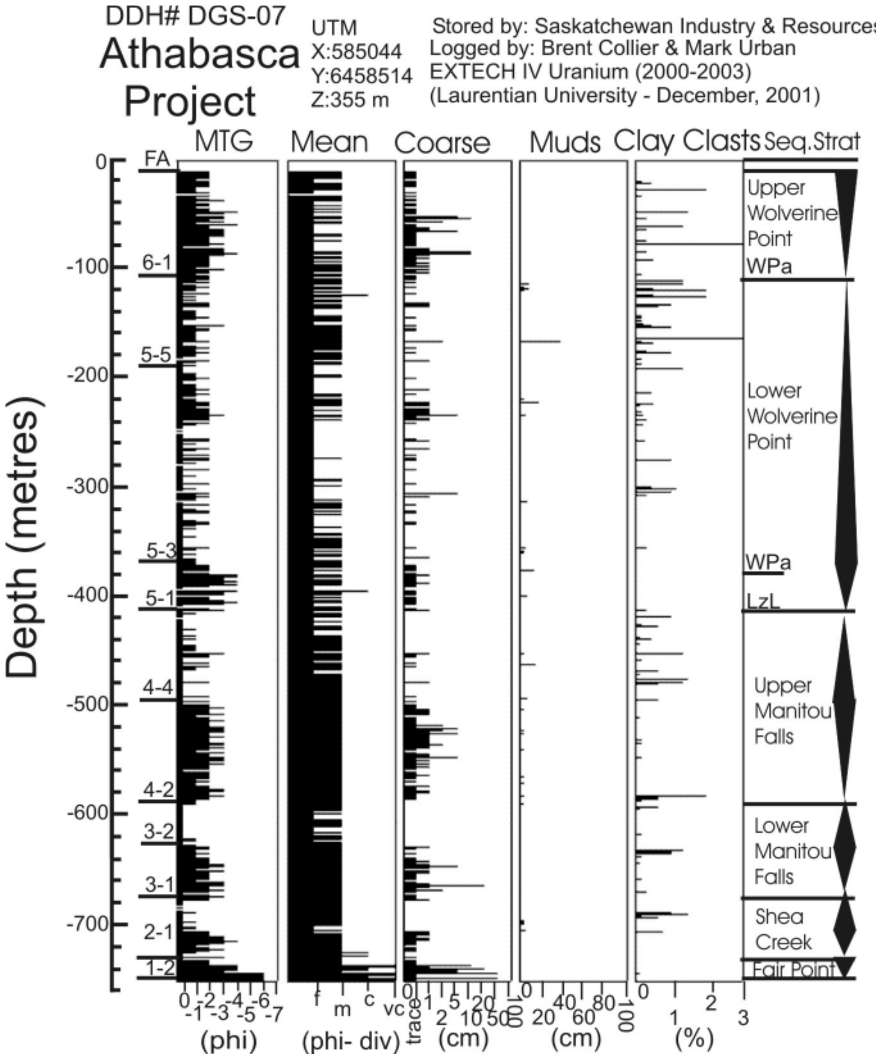

DDH# CLU1-078
Athabasca Project
UTM
X:590726
Y:6400161
Z:550 m?
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
FA
3-2
Quaternary
+
Cretaceous
Lower MF
Core not drilled to basement
(phi)
(phi- div)
(cm)
(cm)
(%)
(cm)
(cm)
(cm)

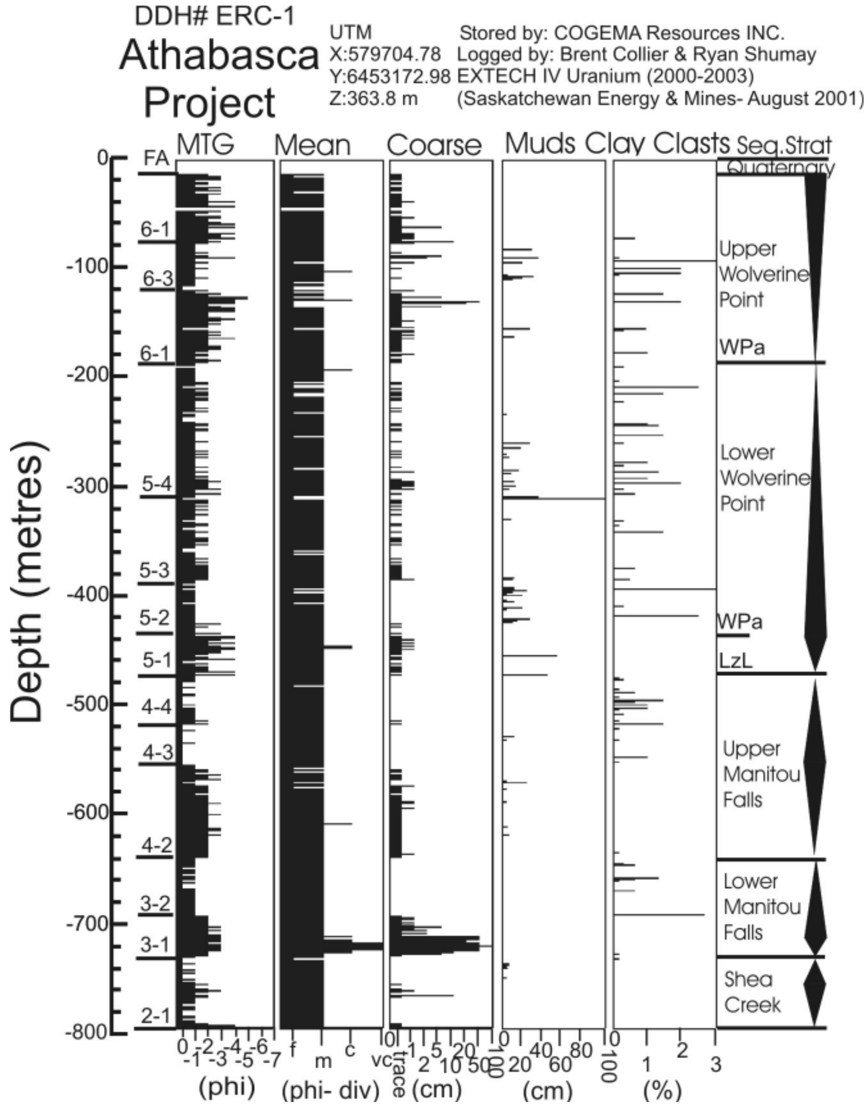

DDH# CLU9-079
Athabasca Project
UTM
X:594997
Y:6398474
Z:527 m
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
FA
4-4
4-3
3-2
Quaternary
+
Cretaceous?
Upper Manitou Falls
Lower MF
(phi)
(phi- div)
(cm)
(cm)
(%)
(cm)
(cm)
(cm)

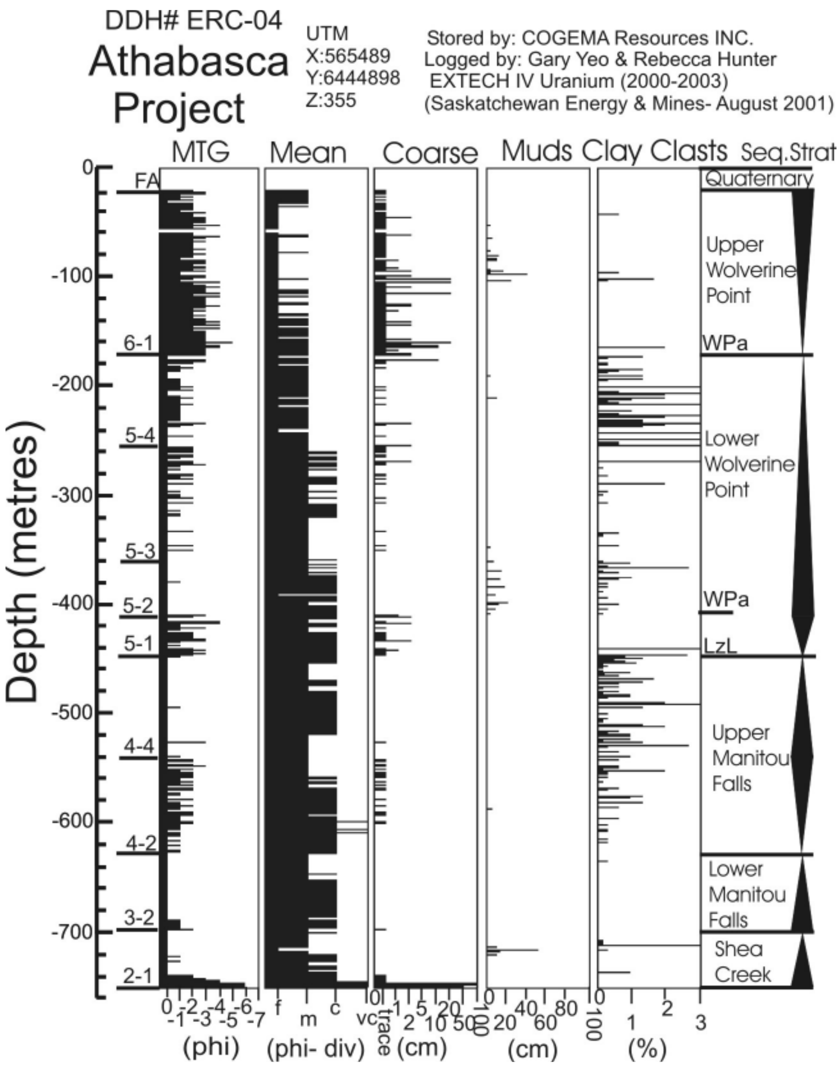

DDH# CLU18-079
Athabasca Project
UTM
X:611234
Y:6394341
Z:518 m
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
FA
3-2
Quaternary + Cretaceous
Lower MF
(phi)
(phi- div)
trace
(cm)
(%)

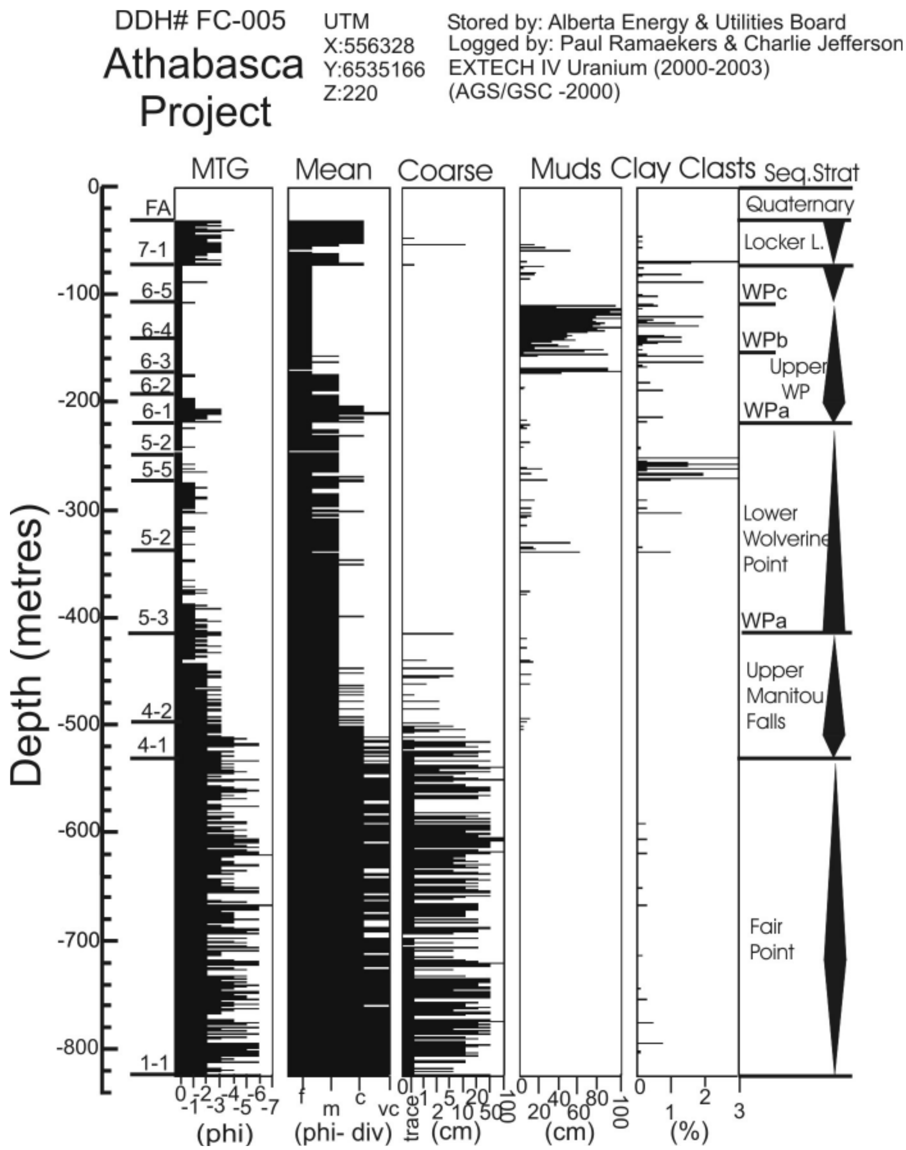

DDH# CSP 6-1
Athabasca Project
UTM
X:646309
Y:6389609
Z:518 m
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier
Alberta Geological Survey - July, 2003
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
FA
5-1
4-5
4-4
4-1
4-2
3-2
Lower Wolverine Point
Upper Manitou Falls
Lower MF
(phi)
(phi- div)
trace
(cm)
(%)

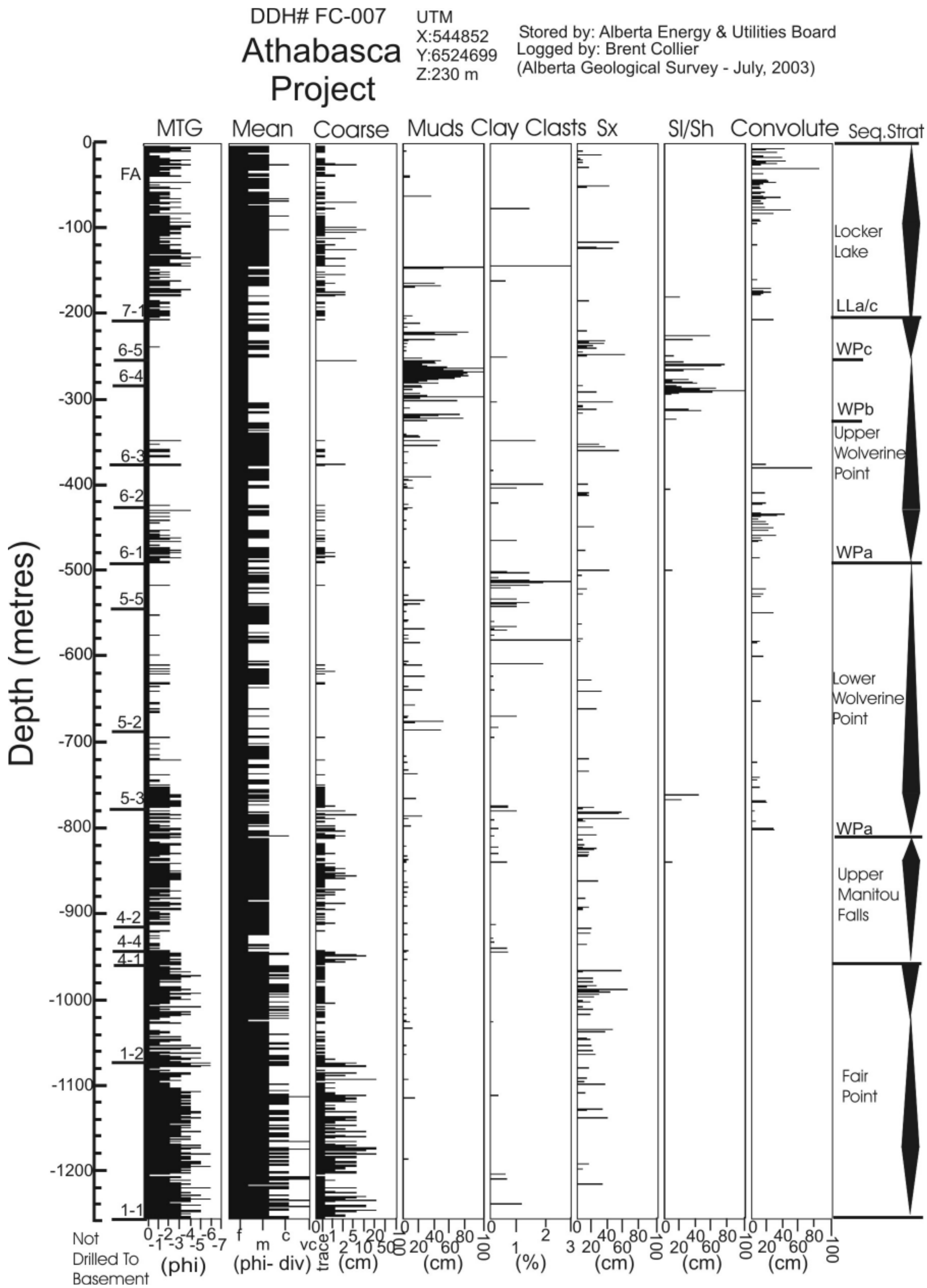

DDH#DGS-04b
Athabasca Project
UTM
X:582440
Y:6463400
Z:337 m
Stored by: COGEMA Resources INC.
Logged by: Gary Yeo & Rebecca Hunter
EXTECH IV Uranium (2000-2003)
(Alberta Geological Survey - July, 2001)
FA
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
7-4
7-3
7-4
7-2
7-1
6-5
6-4
6-3
6-1
5-3
DGS
Overturn
OSb?
DGS
Locker Lake
OSa
LLa
WPc
Upper Wolverine Point
WPb
WPa
Lower Wolverine Point
WPa
Not Drilled To Basement
(phi)
(phi- div)
(cm)
(cm)
(%)


DDH# DGS-07
Athabasca Project
UTM
X:585044
Y:6458514
Z:355 m
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier & Mark Urban
EXTECH IV Uranium (2000-2003)
(Laurentian University - December, 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
6-1
5-5
5-3
5-1
4-4
4-2
3-2
3-1
2-1
1-2
Upper Wolverine Point
WPa
Lower Wolverine Point
WPa
LzL
Upper Manitou Falls
Lower Manitou Falls
Shea Creek
Fair Point
(phi)
(phi- div)
(cm)
(cm)
(%)
trace
f
m
c
vc

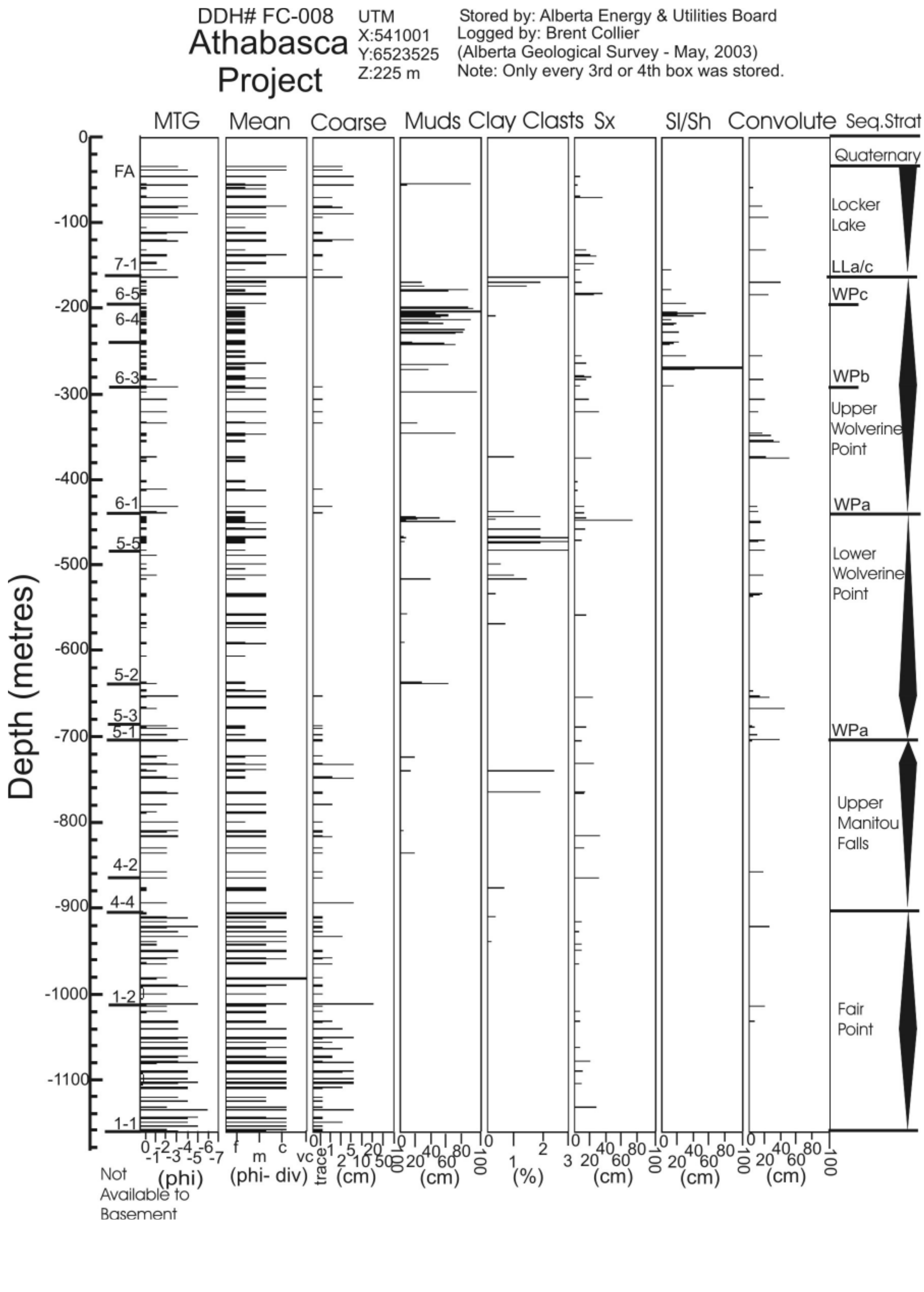

DDH# ERC-1
Athabasca Project
UTM
X:579704.78
Y:6453172.98
Z:363.8 m
Stored by: COGEMA Resources INC.
Logged by: Brent Collier & Ryan Shumay
EXTECH IV Uranium (2000-2003)
(Saskatchewan Energy & Mines- August 2001)
Depth (metres)
FA
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Quaternary
Upper Wolverine Point
WPa
Lower Wolverine Point
WPa
LzL
Upper Manitou Falls
Lower Manitou Falls
Shea Creek
(phi)
(phi- div)
trace
(cm)
(cm)
(%)


DDH# ERC-04
Athabasca Project
UTM
X:565489
Y:6444898
Z:355
Stored by: COGEMA Resources INC.
Logged by: Gary Yeo & Rebecca Hunter
EXTECH IV Uranium (2000-2003)
(Saskatchewan Energy & Mines- August 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
0
-100
-200
-300
-400
-500
-600
-700
FA
6-1
5-4
5-3
5-2
5-1
4-4
4-2
3-2
2-1
Quaternary
Upper Wolverine Point
WPa
Lower Wolverine Point
WPa
LzL
Upper Manitou Falls
Lower Manitou Falls
Shea Creek
0 -2 -4 -6
-1 -3 -5 -7
(phi)
f m c vc
(phi- div)
0 1 5 20 100
trace 2 10 50
(cm)
0 40 80
20 60 100
(cm)
0 1 2 3
(%)

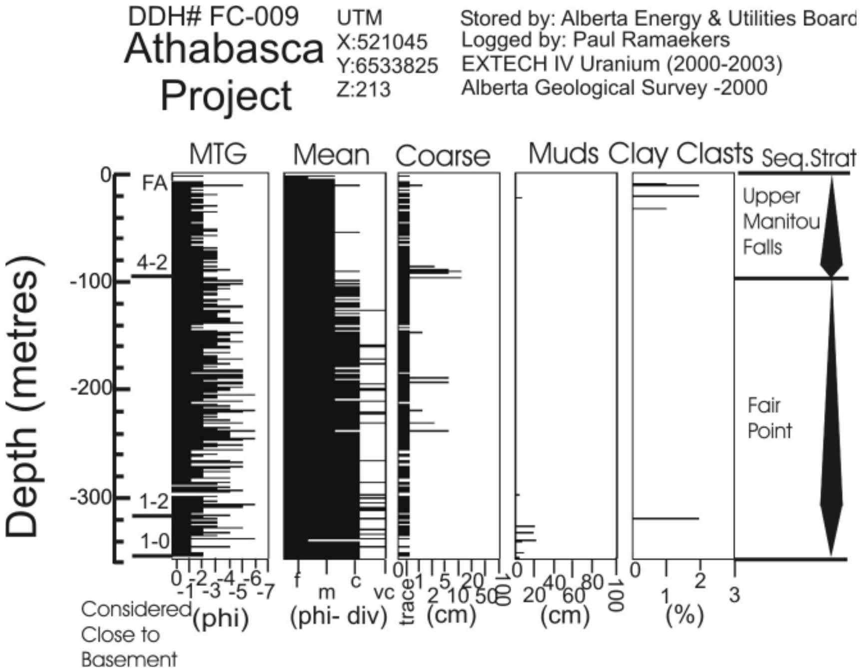

DDH# FC-005
Athabasca Project
UTM
X:556328
Y:6535166
Z:220
Stored by: Alberta Energy & Utilities Board
Logged by: Paul Ramaekers & Charlie Jefferson
EXTECH IV Uranium (2000-2003)
(AGS/GSC -2000)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
7-1
6-5
6-4
6-3
6-2
6-1
5-2
5-5
5-2
5-3
4-2
4-1
1-1
Quaternary
Locker L.
WPc
WPb
Upper WP
WPa
Lower Wolverine Point
WPa
Upper Manitou Falls
Fair Point
(phi)
(phi- div)
trace
(cm)
(cm)
(%)

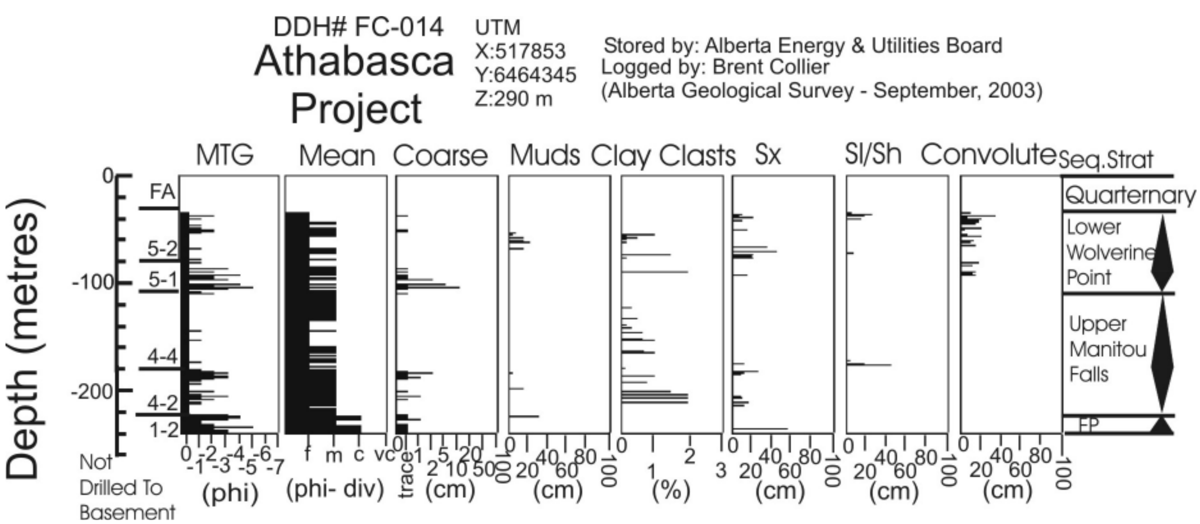


DDH# FC-007
Athabasca Project
UTM
X:544852
Y:6524699
Z:230 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
FA
7-1
6-5
6-4
6-3
6-2
6-1
5-5
5-2
5-3
4-2
4-4
4-1
1-2
1-1
Locker Lake
LLa/c
WPc
WPb
Upper Wolverine Point
WPa
Lower Wolverine Point
WPa
Upper Manitou Falls
Fair Point
Not Drilled To Basement
(phi)
(phi- div)
(cm)
(cm)
(%)
(cm)
(cm)
(cm)



DDH# FC-008
Athabasca Project
UTM
X:541001
Y:6523525
Z:225 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
Note: Only every 3rd or 4th box was stored.
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
Quaternary
Locker Lake
LLa/c
WPc
WPb
Upper Wolverine Point
WPa
Lower Wolverine Point
WPa
Upper Manitou Falls
Fair Point
FA
7-1
6-5
6-4
6-3
6-1
5-5
5-2
5-3
5-1
4-2
4-4
1-2
1-1
(phi)
(phi- div)
(cm)
(%)
Not Available to Basement


DDH# FC-009
Athabasca Project
UTM
X:521045
Y:6533825
Z:213
Stored by: Alberta Energy & Utilities Board
Logged by: Paul Ramaekers
EXTECH IV Uranium (2000-2003)
Alberta Geological Survey -2000
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
4-2
1-2
1-0
Upper Manitou Falls
Fair Point
Considered Close to Basement
(phi)
(phi- div)
trace
(cm)
(cm)
(%)

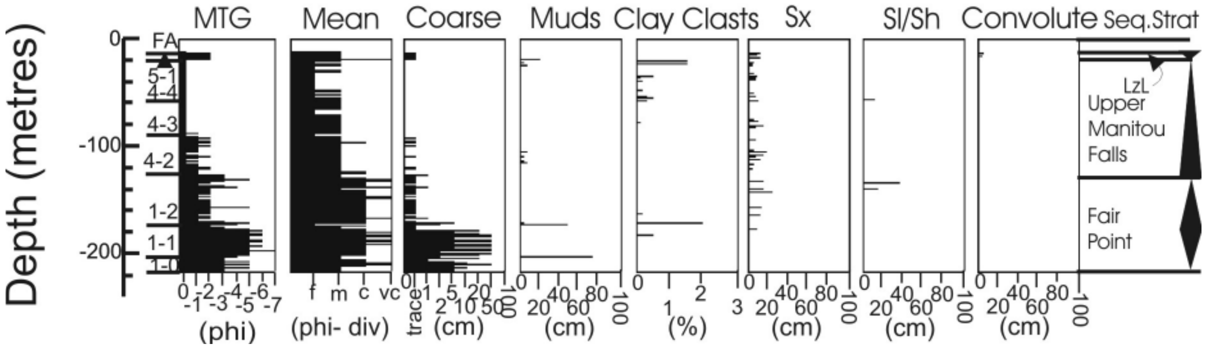

DDH# FC-014
Athabasca Project
UTM
X:517853
Y:6464345
Z:290 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - September, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
FA
5-2
5-1
4-4
4-2
1-2
Quarternary
Lower Wolverine Point
Upper Manitou Falls
FP
Not Drilled To Basement
(phi)
(phi- div)
trace
(cm)
(cm)
(%)
(cm)
(cm)
(cm)

DDH# FC-015

Athabasca Project

UTM
X:505655
Y:6463988
Z:226 m

Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)

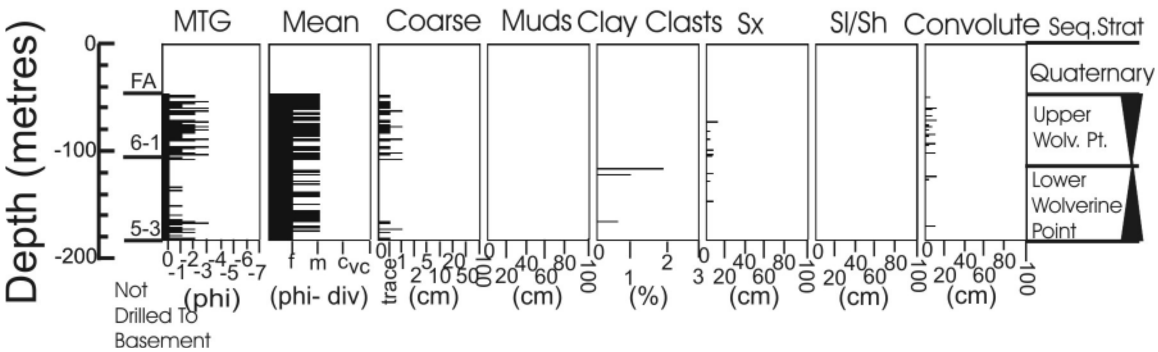


DDH# FC-016

Athabasca Project

UTM
X:543846
Y:6464499
Z:305 m

Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)
Note: Only 10 to 30 cm sections were taken from each metre interval.

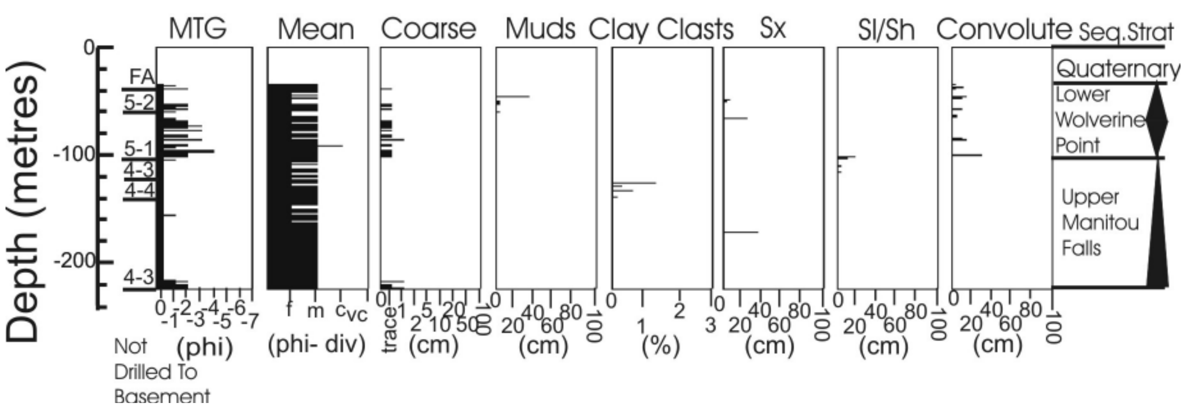


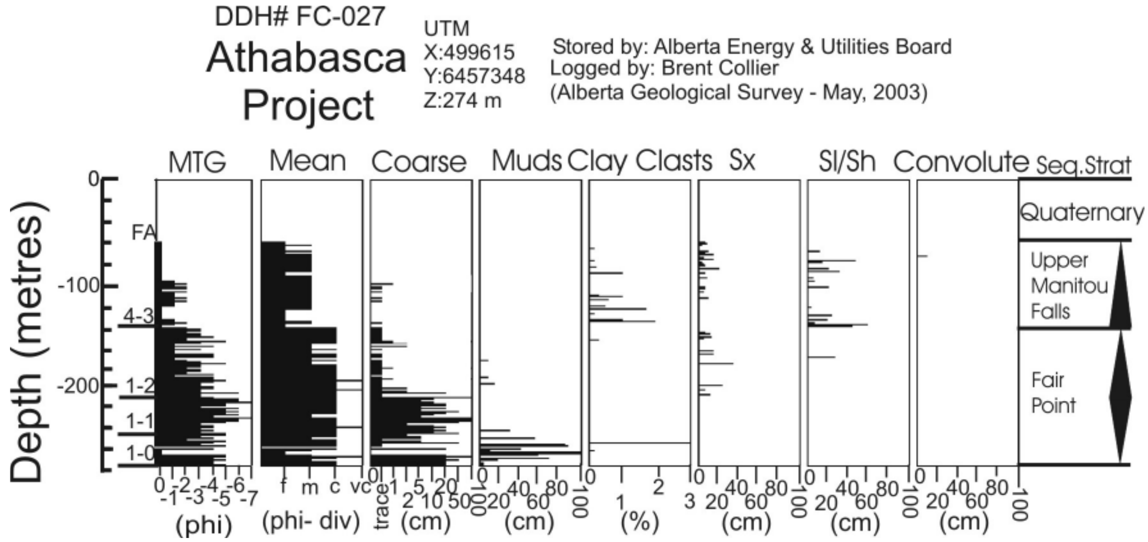
DDH# FC-017

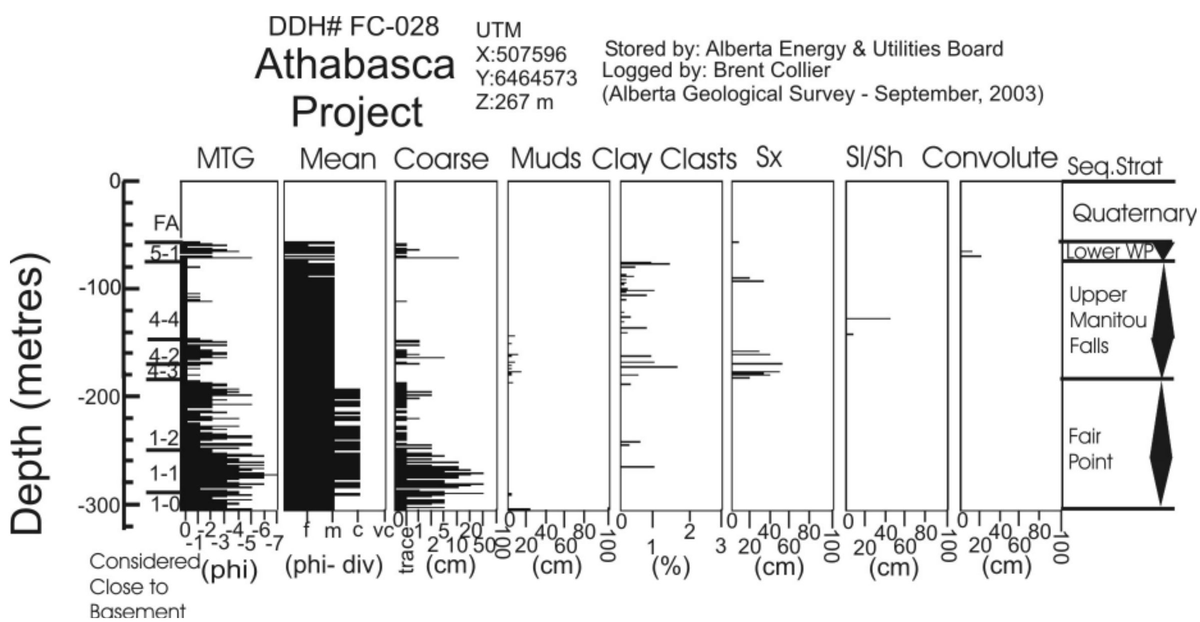
Athabasca Project

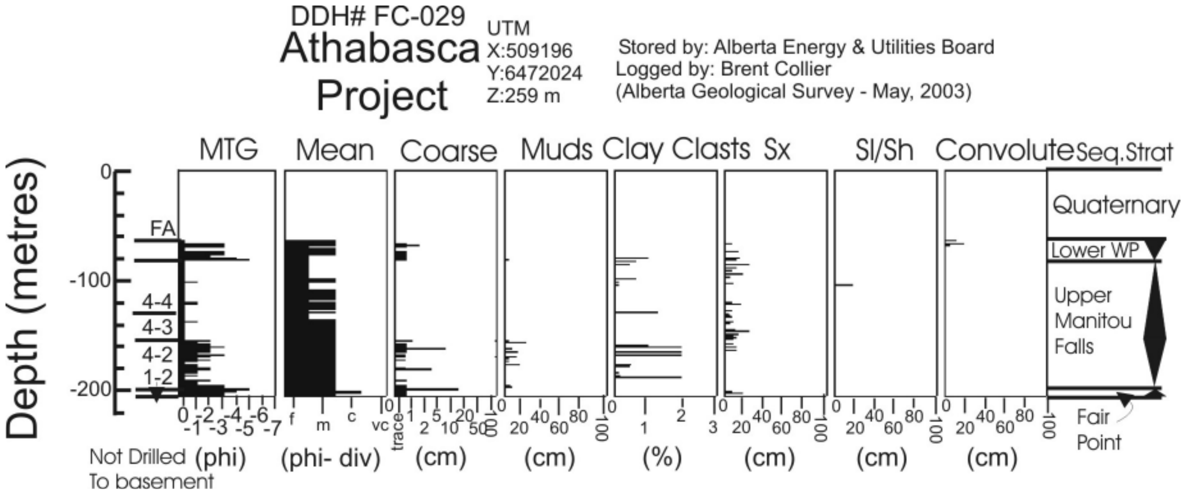
UTM
X:546647
Y:6430523
Z:366 m

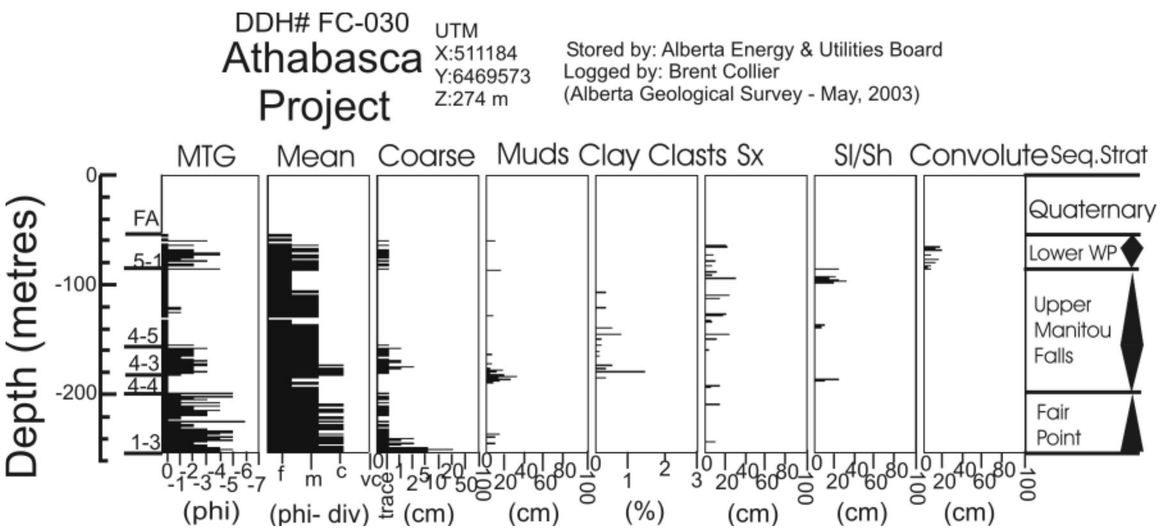
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)
Note: Only 10 to 30 cm sections were chosen from each metre interval.

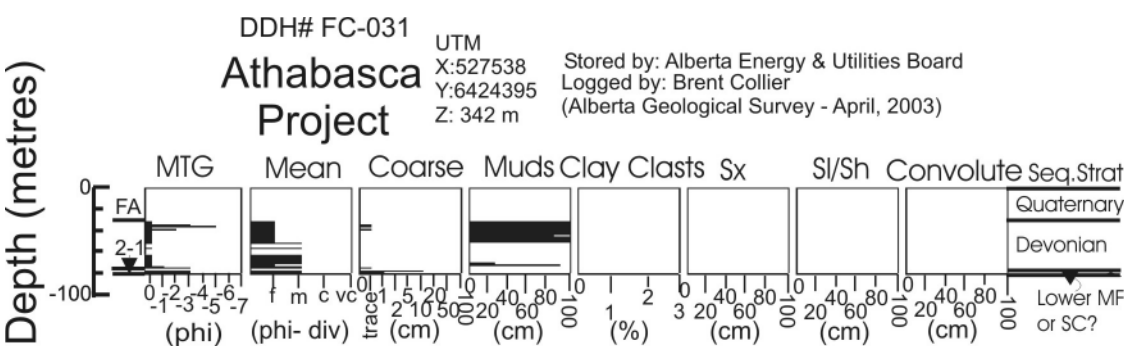


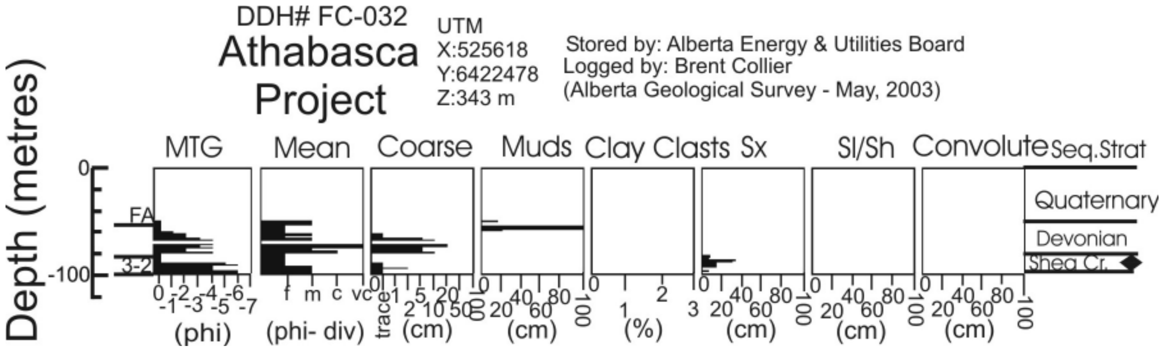

DDH# FC-027
Athabasca Project
UTM
X:499615
Y:6457348
Z:274 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
Quaternary
Upper Manitou Falls
Fair Point
FA
4-3
1-2
1-1
1-0
(phi)
(phi- div)
trace
(cm)
(%)

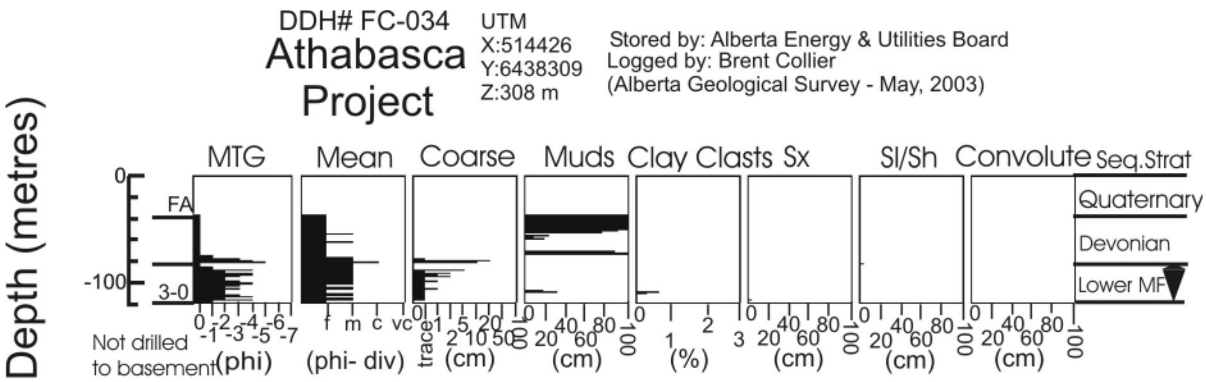

DDH# FC-028
Athabasca Project
UTM
X:507596
Y:6464573
Z:267 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - September, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
Quaternary
Lower WP
Upper Manitou Falls
Fair Point
FA
5-1
4-4
4-2
4-3
1-2
1-1
1-0
Considered Close to Basement
(phi)
(phi- div)
trace
(cm)
(%)

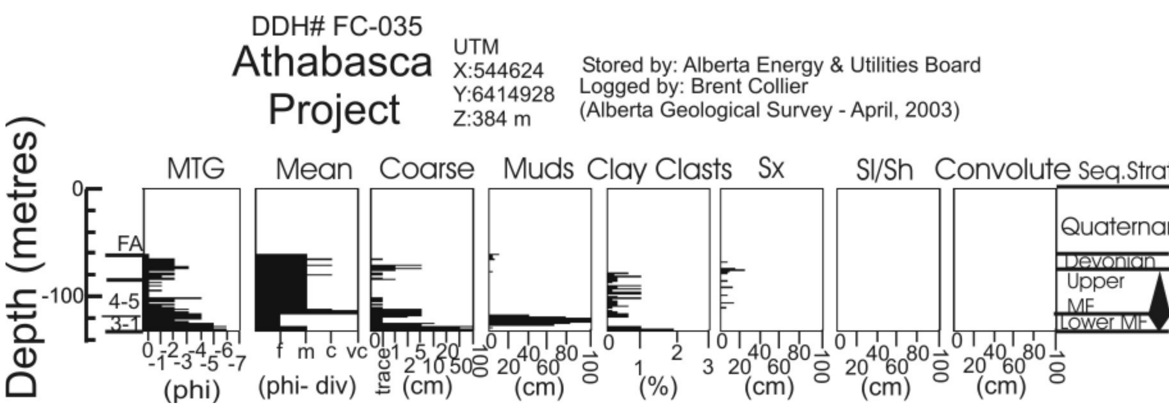

DDH# FC-029
Athabasca Project
UTM
X:509196
Y:6472024
Z:259 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Lower WP
Upper Manitou Falls
Fair Point
FA
4-4
4-3
4-2
1-2
Not Drilled To basement
(phi)
(phi- div)
(cm)
(%)

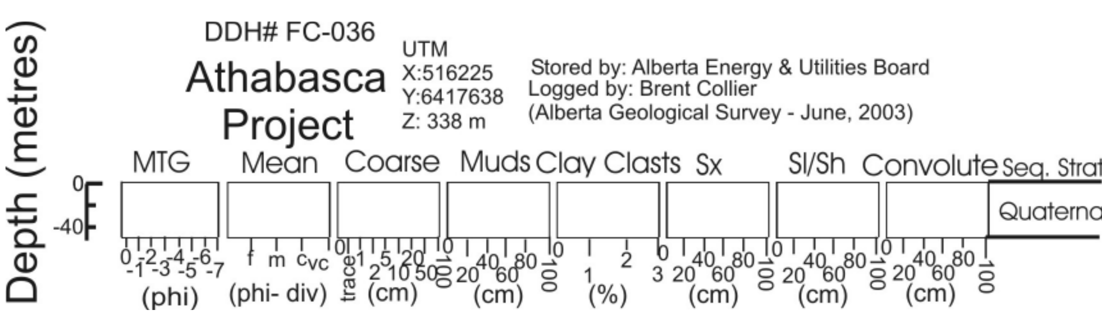

DDH# FC-030
Athabasca Project
UTM
X:511184
Y:6469573
Z:274 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Lower WP
Upper Manitou Falls
Fair Point
FA
5-1
4-5
4-3
4-4
1-3
(phi)
(phi- div)
(cm)
(%)


DDH# FC-031
Athabasca Project
UTM
X:527538
Y:6424395
Z: 342 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Devonian
Lower MF or SC?
FA
2-1
(phi)
(phi- div)
(cm)
(%)


DDH# FC-032
Athabasca Project
UTM
X:525618
Y:6422478
Z:343 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Devonian
Shea Cr.
FA
3-2
(phi)
(phi- div)
trace
(cm)
(%)


DDH# FC-034
Athabasca Project
UTM
X:514426
Y:6438309
Z:308 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Devonian
Lower MF
FA
3-0
Not drilled to basement
(phi)
(phi- div)
trace
(cm)
(%)

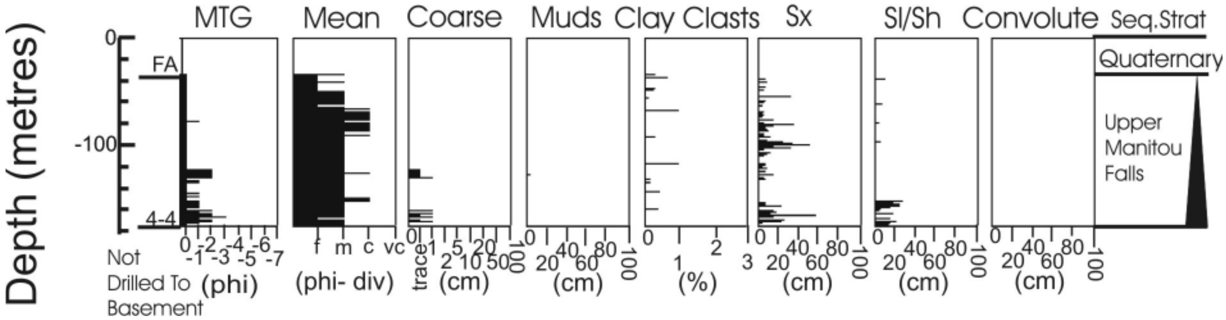

DDH# FC-035
Athabasca Project
UTM
X:544624
Y:6414928
Z:384 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Devonian
Upper MF
Lower MF
FA
4-5
3-1
(phi)
(phi- div)
trace
(cm)
(%)


DDH# FC-036
Athabasca Project
UTM
X:516225
Y:6417638
Z: 338 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - June, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq. Strat.
Quaternary
(phi)
(phi- div)
trace
(cm)
(%)

DDH# FC-037
Athabasca Project

UTM
X:536891
Y:6425275
Z:366 m

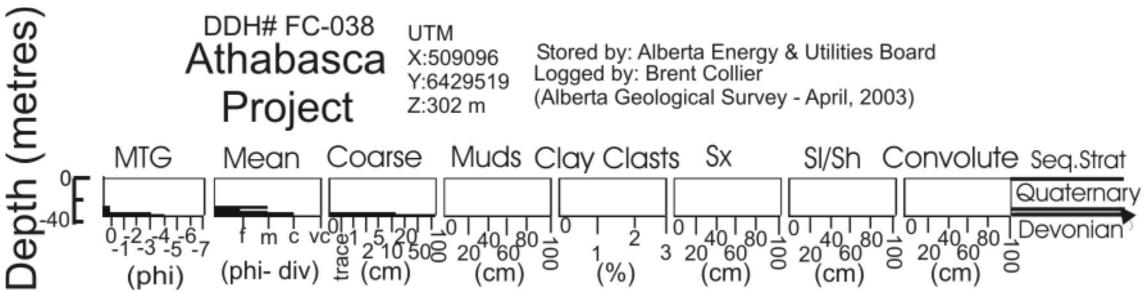
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)



DDH# FC-038
Athabasca Project

UTM
X:509096
Y:6429519
Z:302 m

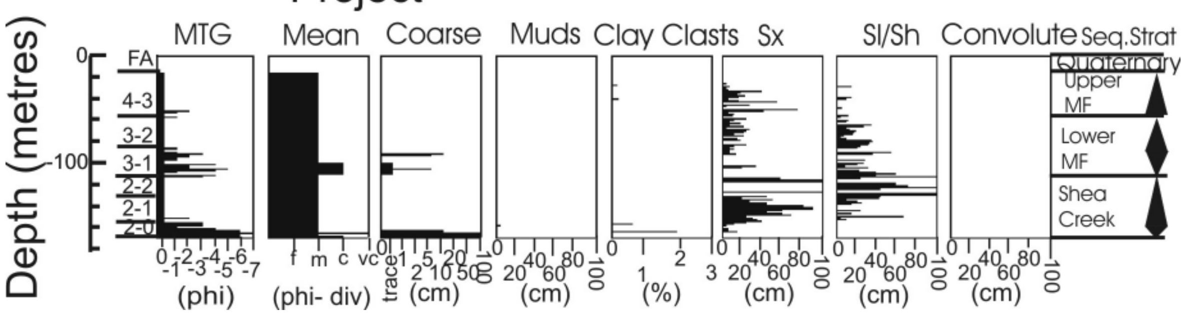
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)



DDH# FC-039
Athabasca Project

UTM
X:522112
Y:6432323
Z:320 m

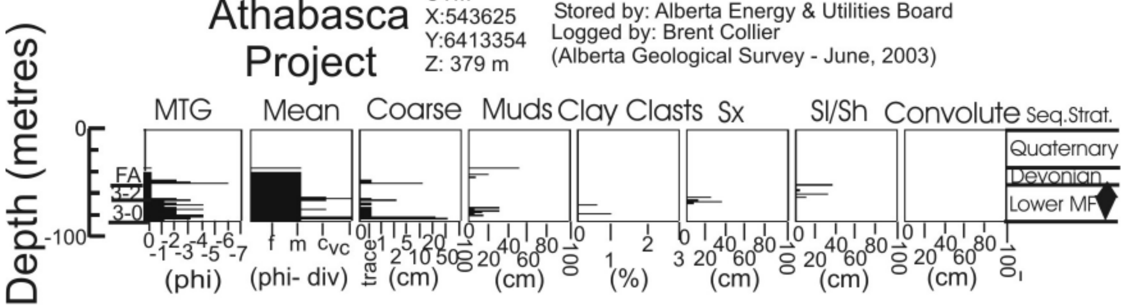
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)

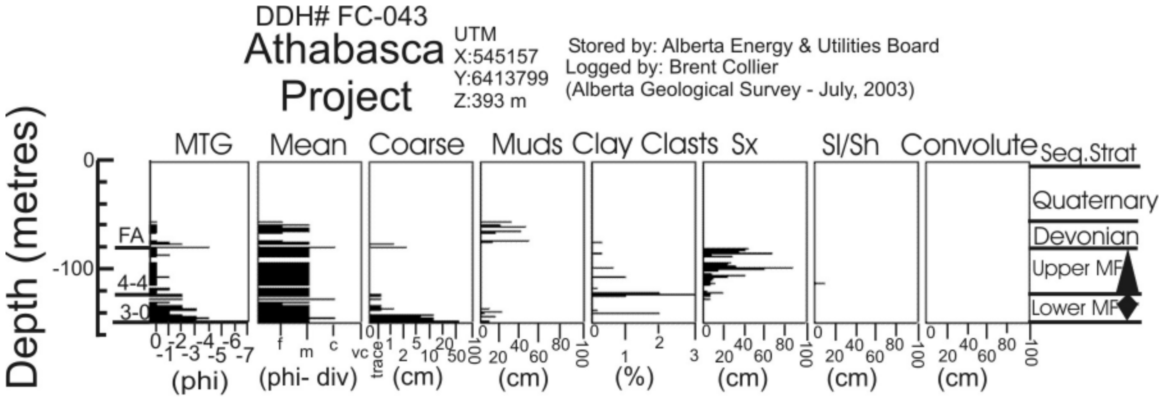


DDH# FC-041
Athabasca Project

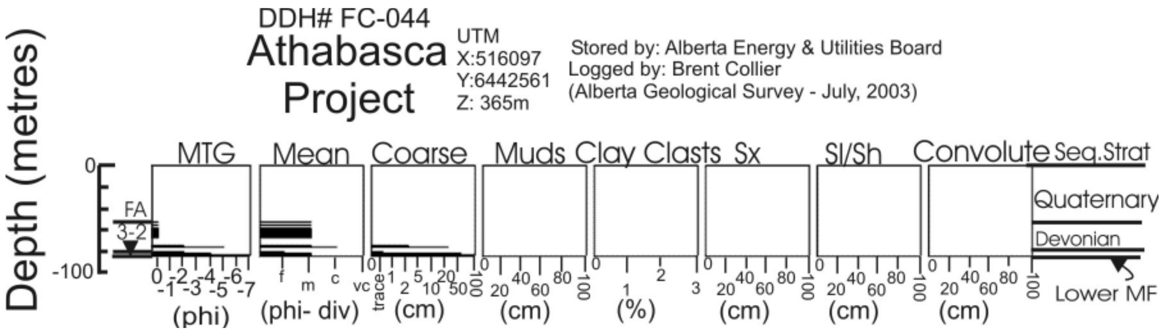
UTM
X:543625
Y:6413354
Z: 379 m

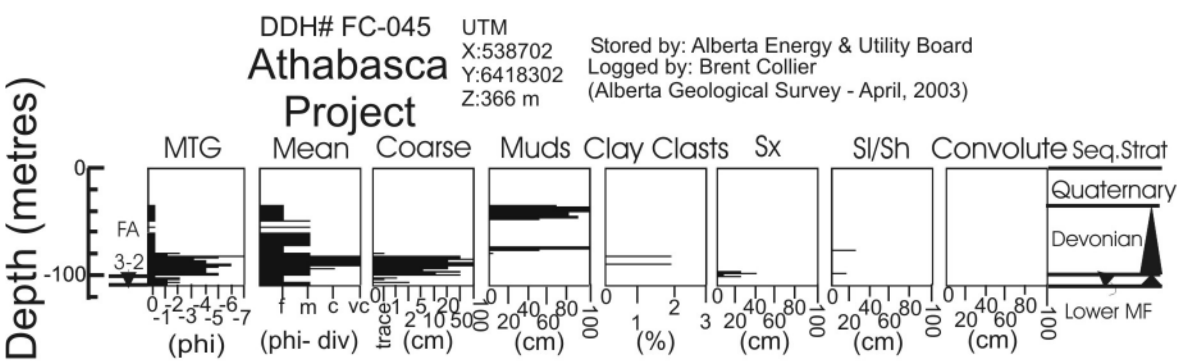
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - June, 2003)

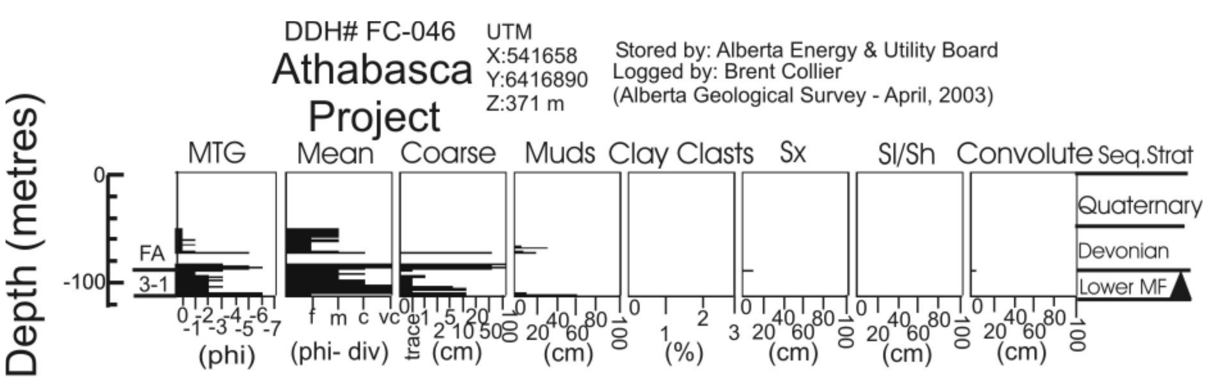


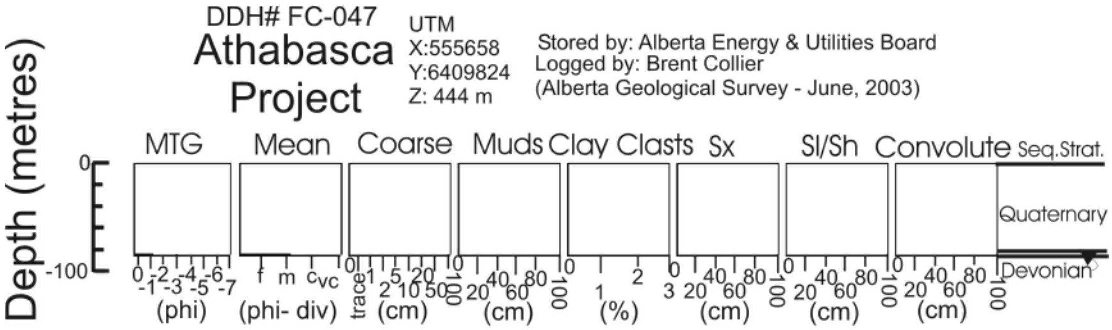


Note: Core inclined at 86 degrees from horizontal

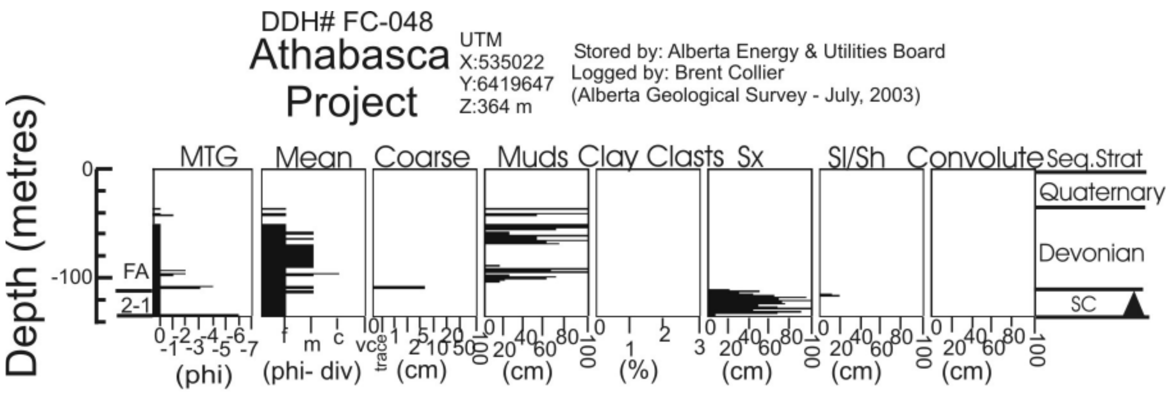




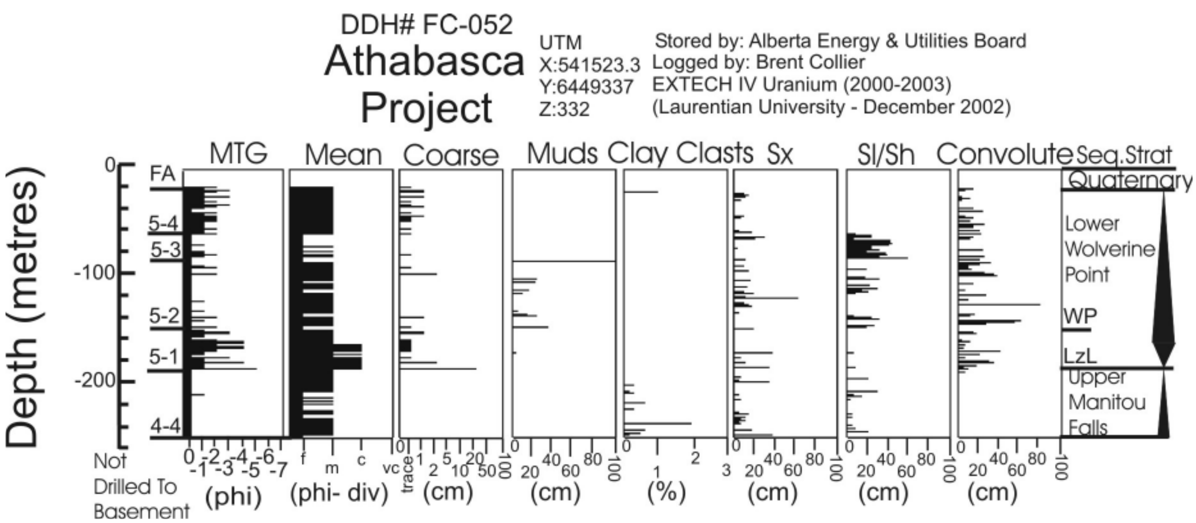


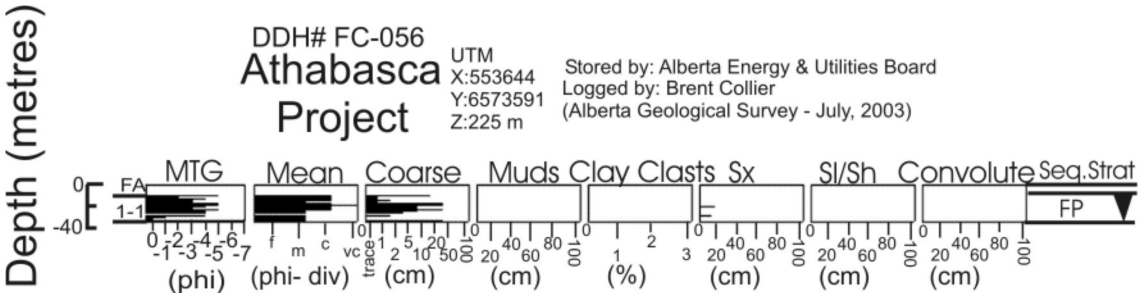


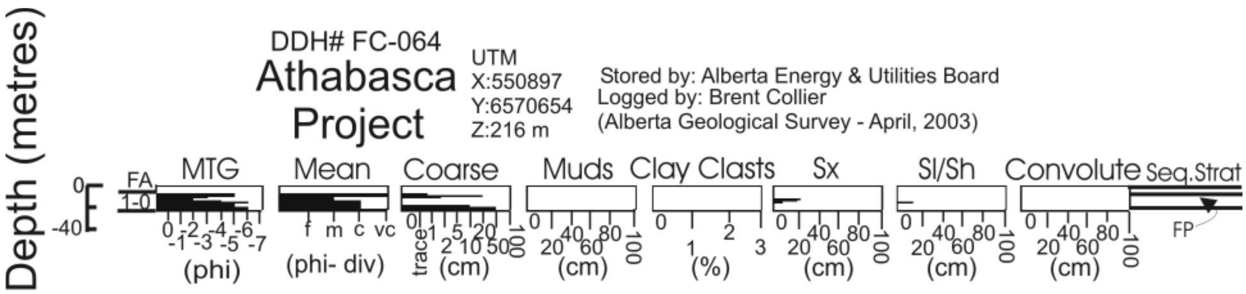
Note: Core inclined at 87 degrees from horizontal

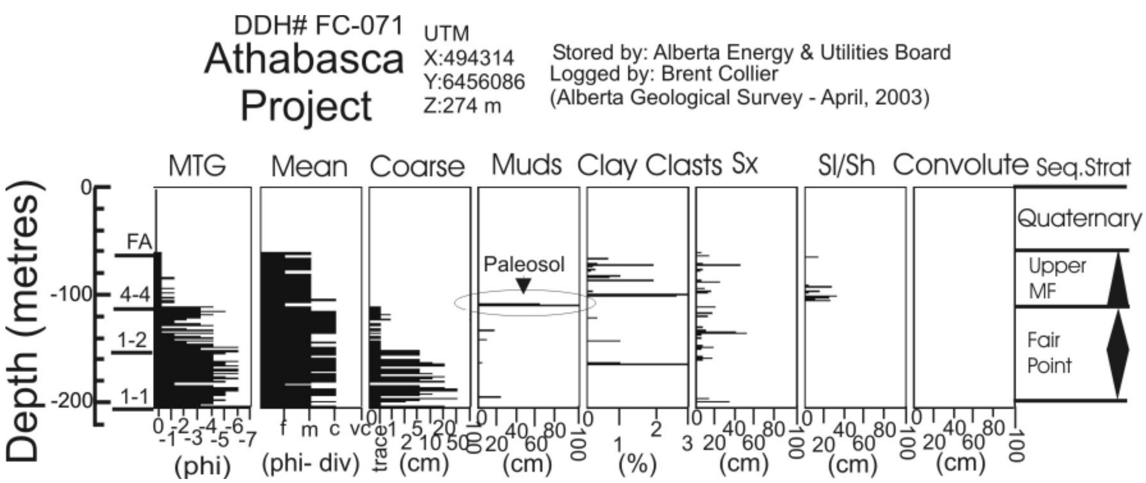


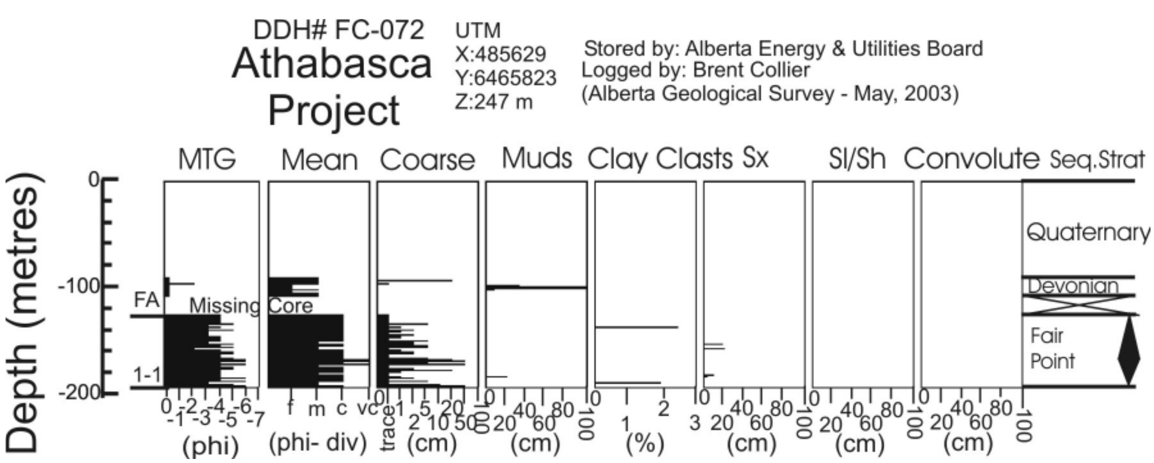
Note: Core inclined at 72 degrees from horizontal

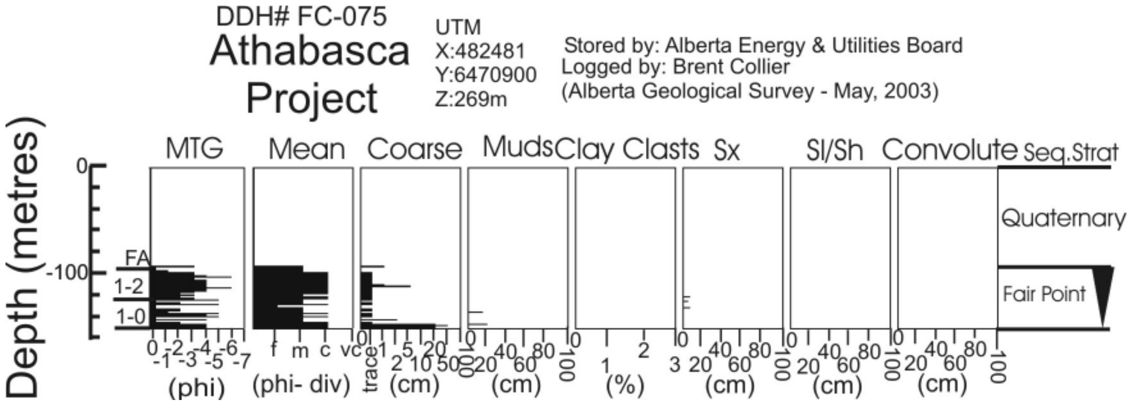


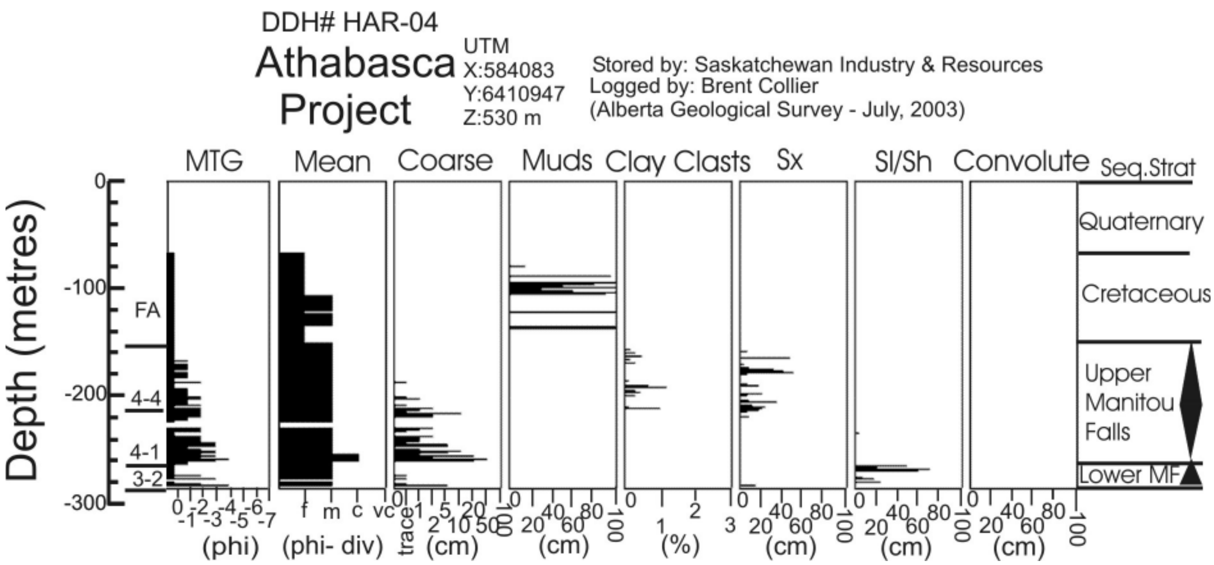

DDH# FC-056
Athabasca Project
UTM X:553644 Y:6573591 Z:225 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
FA
1-1
FP
(phi)
(phi- div)
(cm)
(%)

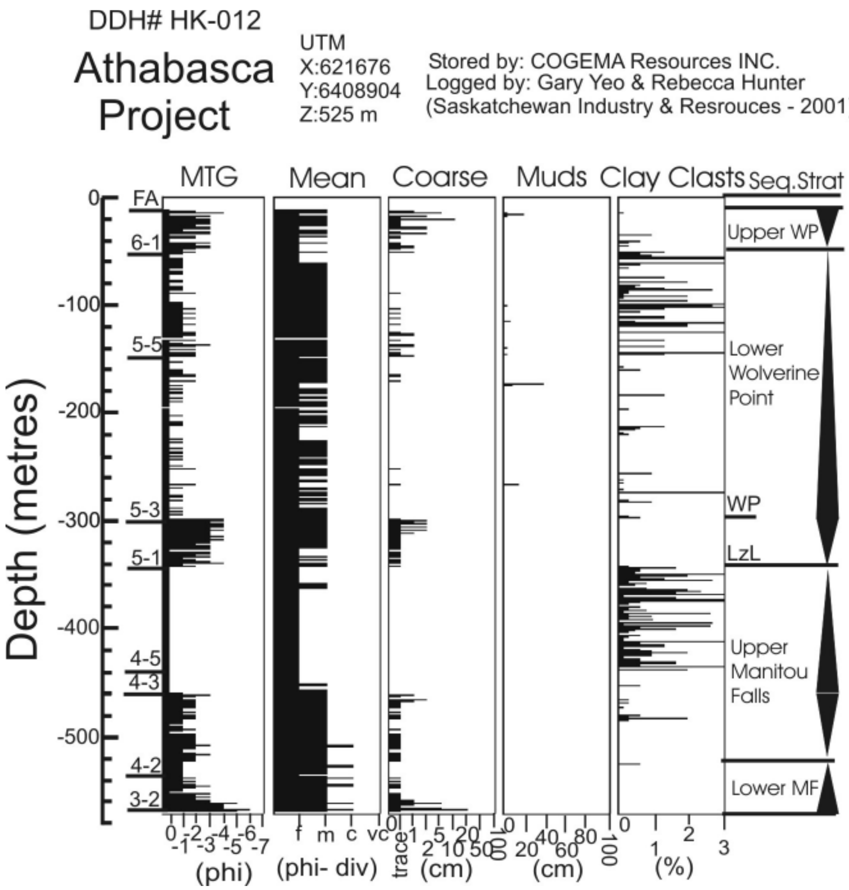

DDH# FC-064
Athabasca Project
UTM X:550897 Y:6570654 Z:216 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
FA
1-0
FP
(phi)
(phi- div)
(cm)
(%)

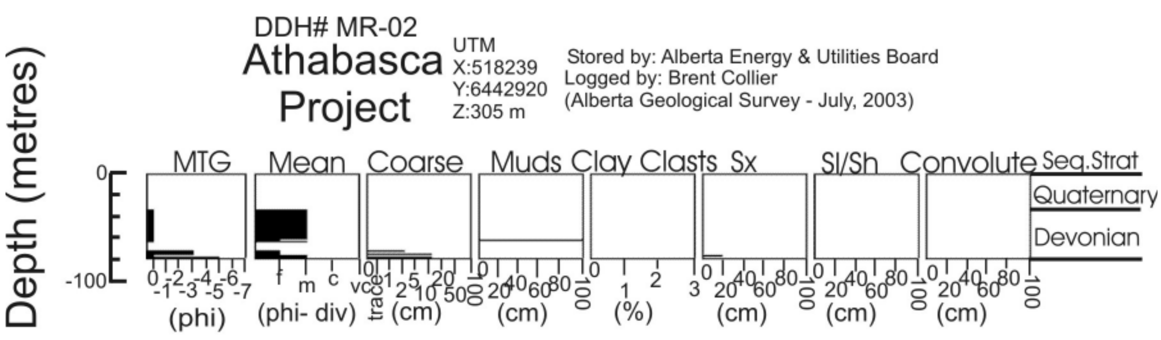

DDH# FC-071
Athabasca Project
UTM X:494314 Y:6456086 Z:274 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
FA
4-4
1-2
1-1
Paleosol
Quaternary
Upper MF
Fair Point
(phi)
(phi- div)
(cm)
(%)


DDH# FC-072
Athabasca Project
UTM X:485629 Y:6465823 Z:247 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
FA
Missing Core
1-1
Quaternary
Devonian
Fair Point
(phi)
(phi- div)
(cm)
(%)

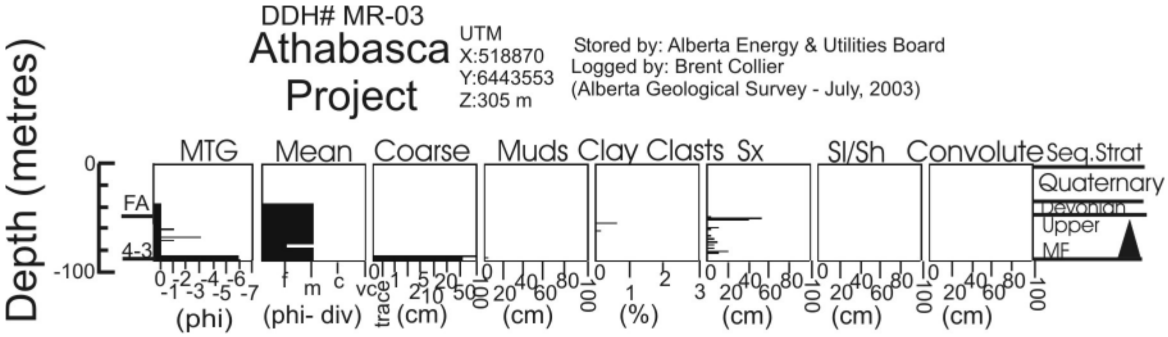

DDH# FC-075
Athabasca Project
UTM
X:482481
Y:6470900
Z:269m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Fair Point
FA
1-2
1-0
(phi)
(phi- div)
trace
(cm)
(%)


DDH# HAR-04
Athabasca Project
UTM
X:584083
Y:6410947
Z:530 m
Stored by: Saskatchewan Industry & Resources
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Cretaceous
Upper Manitou Falls
Lower MF
FA
4-4
4-1
3-2
(phi)
(phi- div)
trace
(cm)
(%)

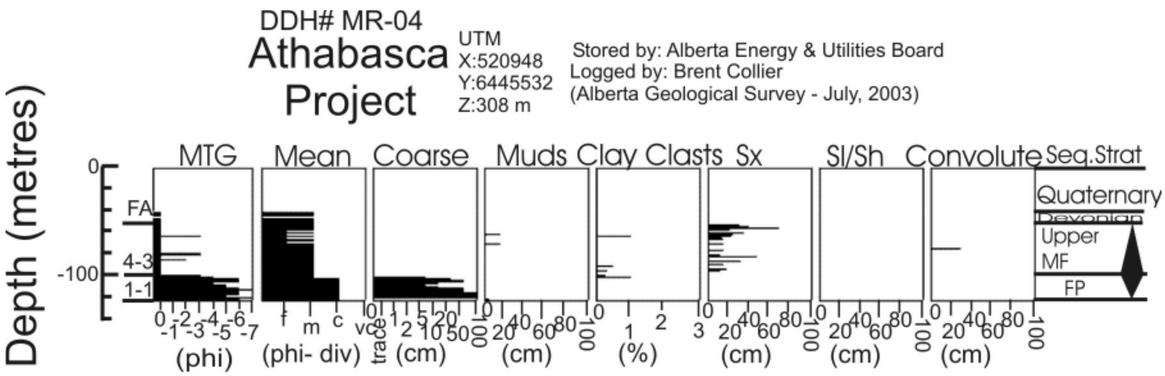




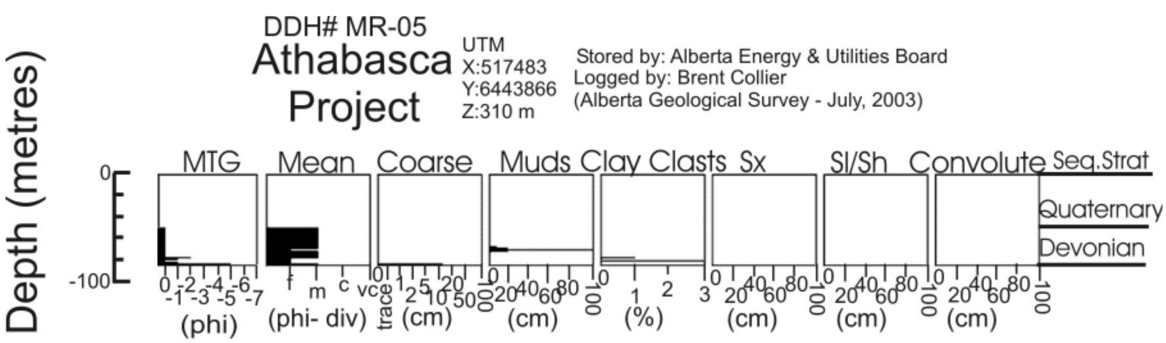
Note: Core inclined at 60 degrees from horizontal



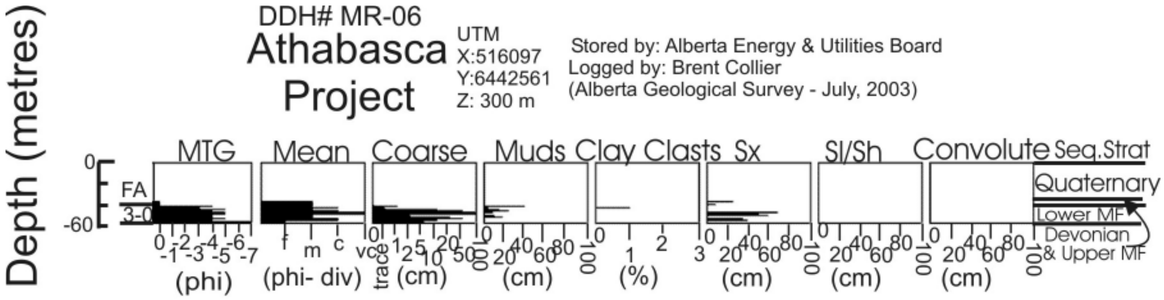
Note: Core inclined at 60 degrees from horizontal



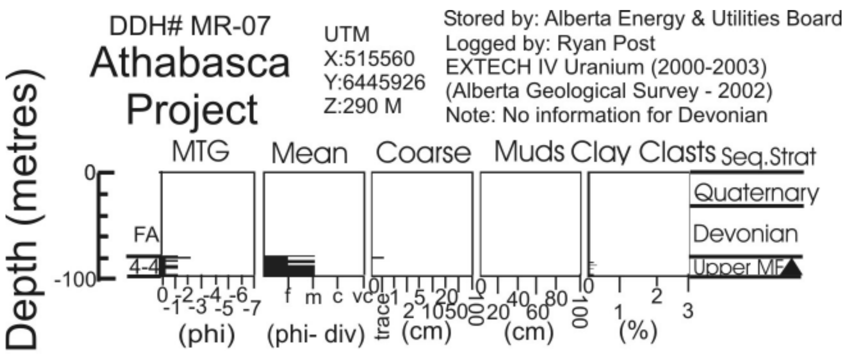
Note: Core inclined at 60 degrees from horizontal



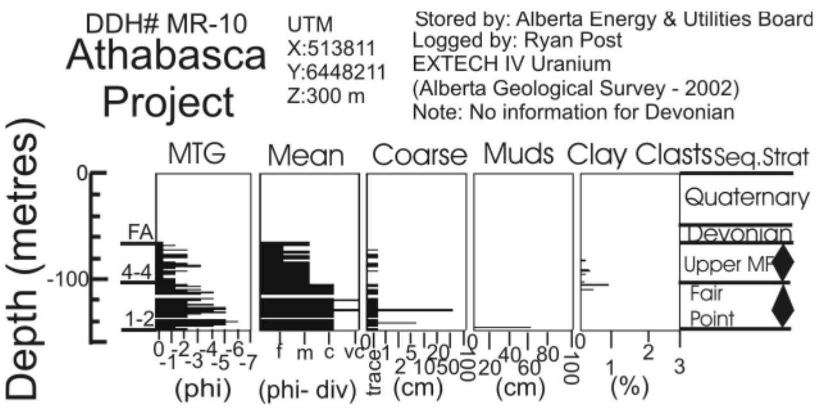
Note: Core inclined at 60 degrees from horizontal



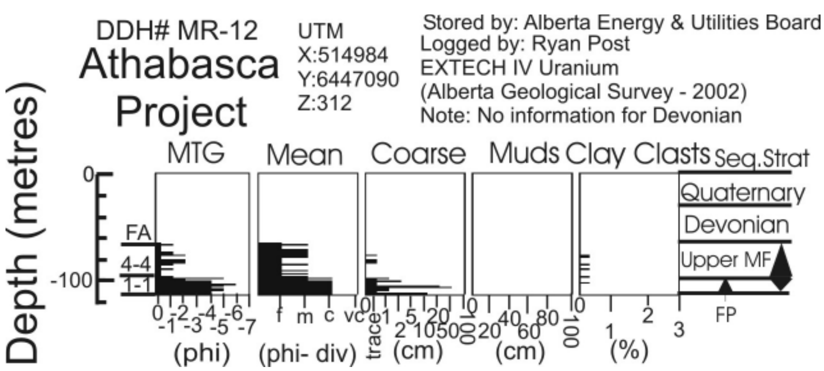
Note: Core inclined at 60 degrees from horizontal

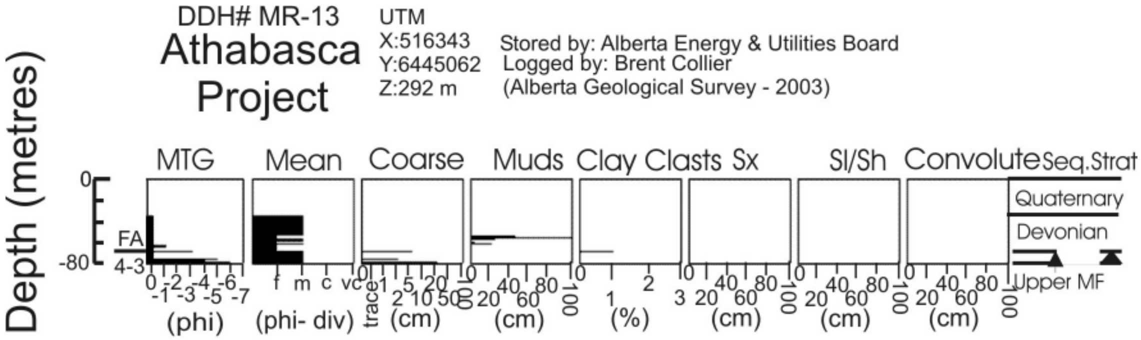


Note: Core inclined at 60 degrees from horizontal

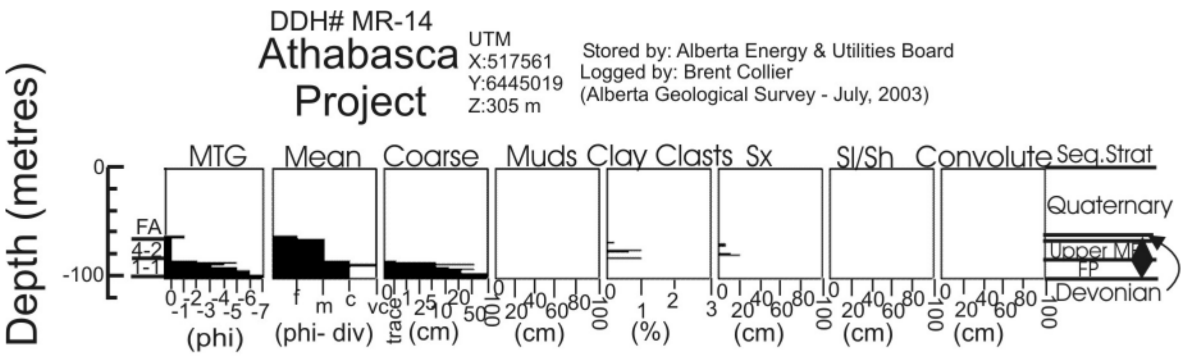


Note: Core inclined at 60 degrees from horizontal

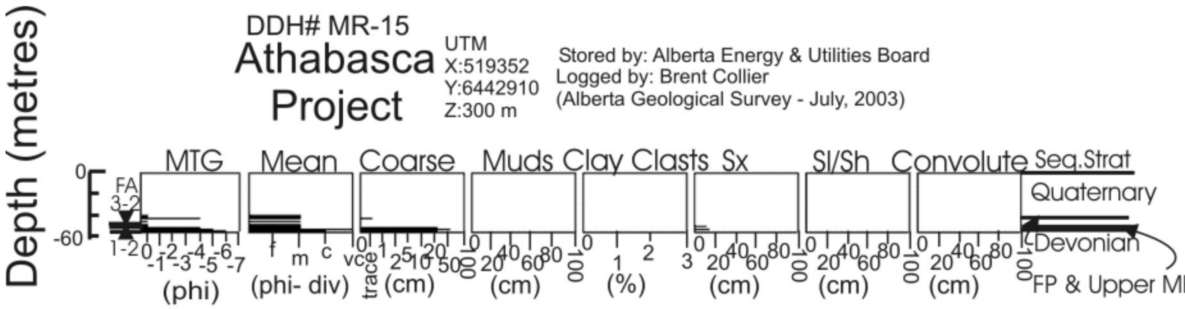




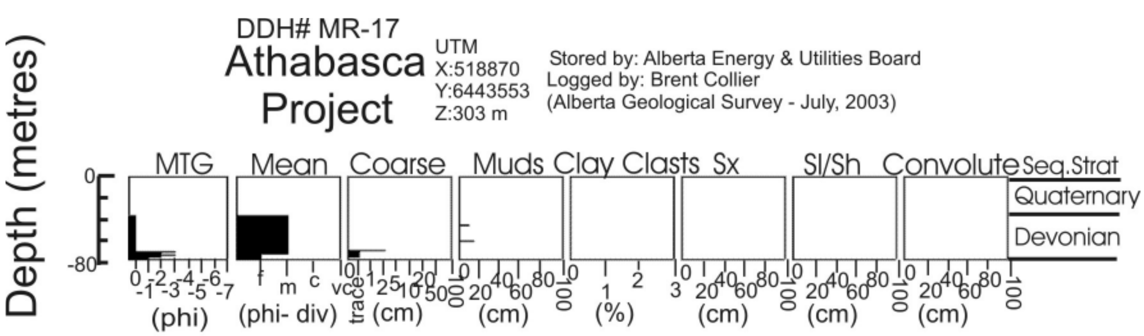
Note: Core inclined at 60 degrees from horizontal



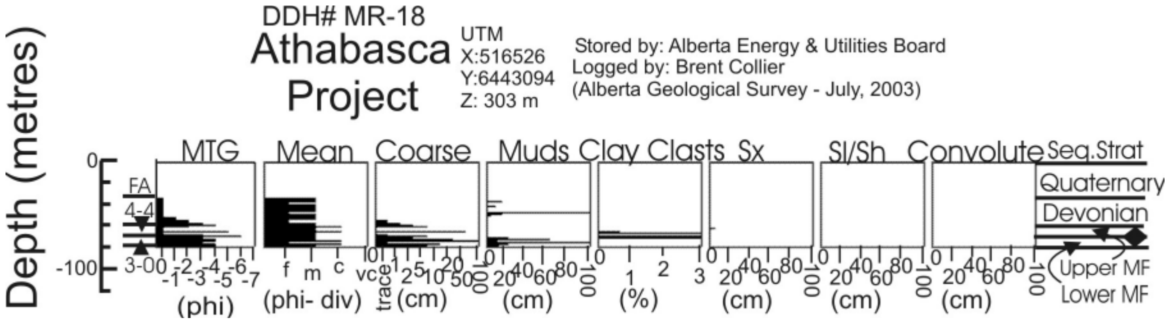
Note: Core inclined at 65 degrees from horizontal

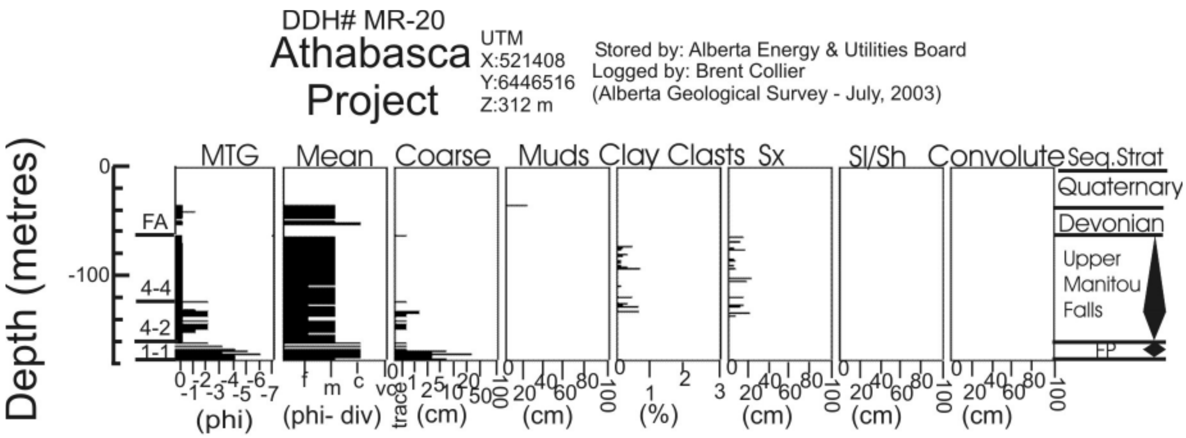


Note: Core inclined at 60 degrees from horizontal

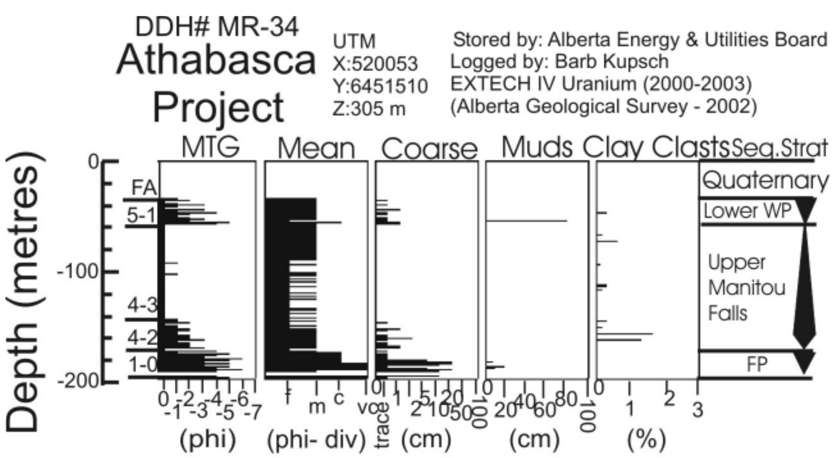


Note: Core inclined at 60 degrees from horizontal

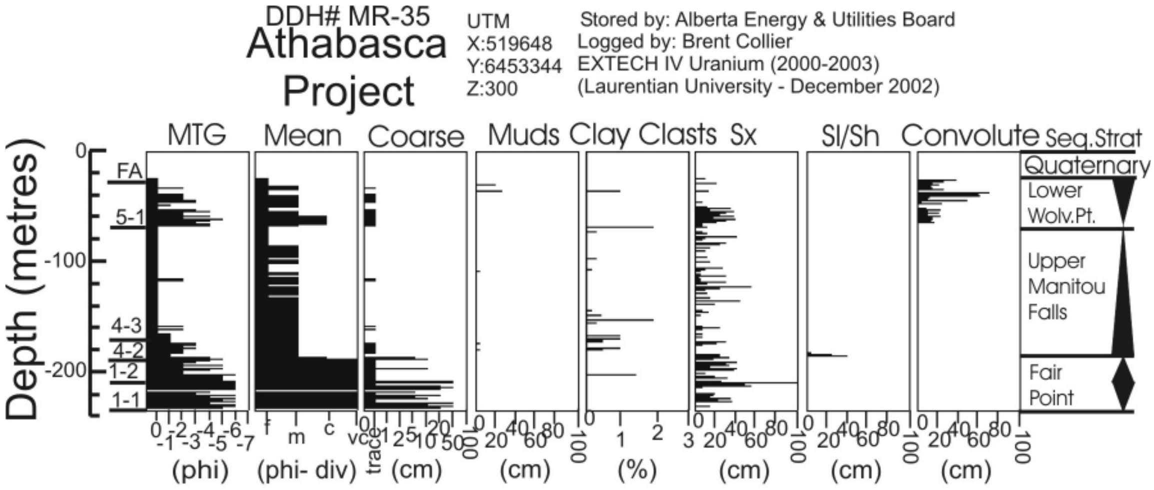




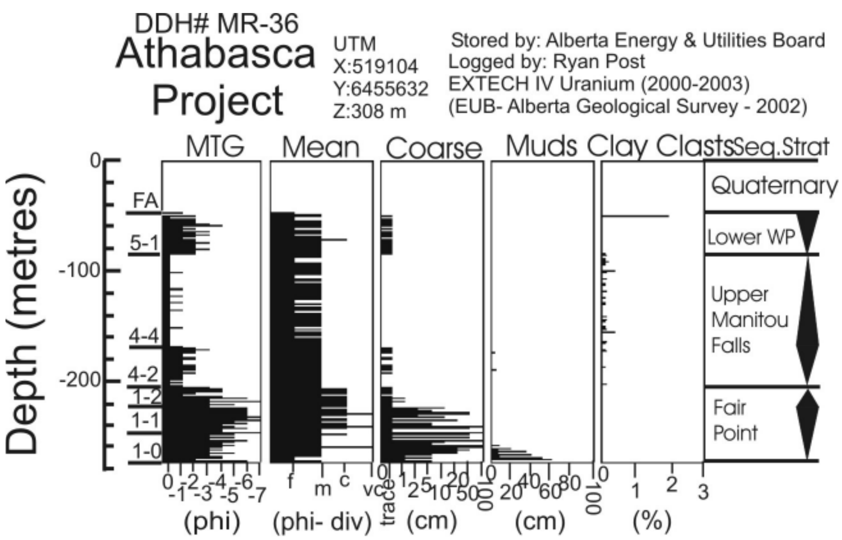
Note: Core inclined at 60 degrees from horizontal



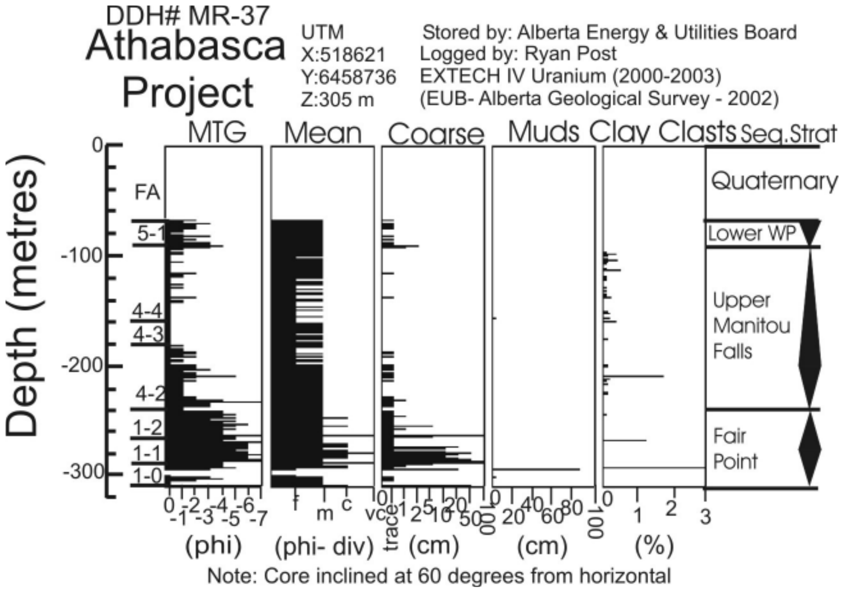
Note: Core inclined at 70 degrees from horizontal

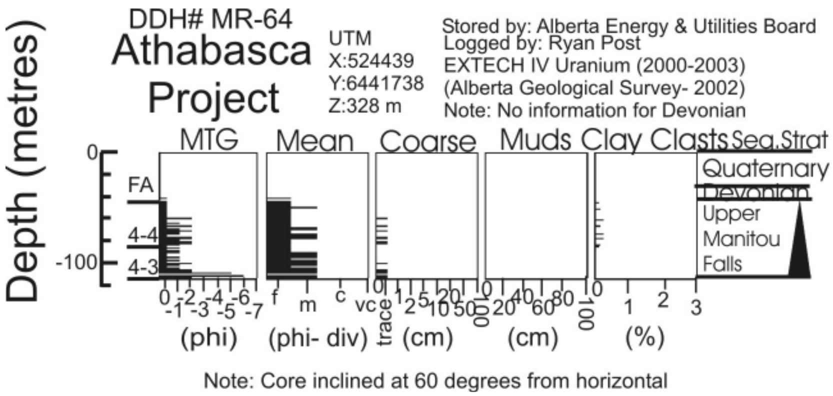


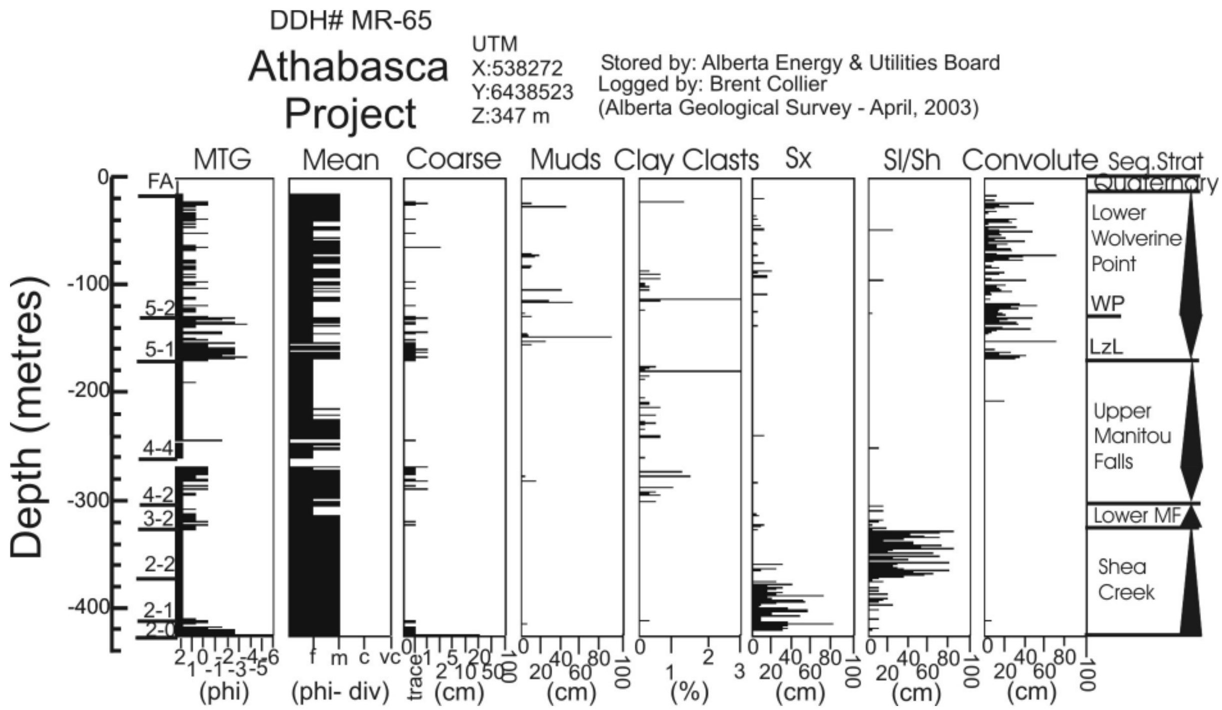
Note: Core inclined at 60 degrees from horizontal

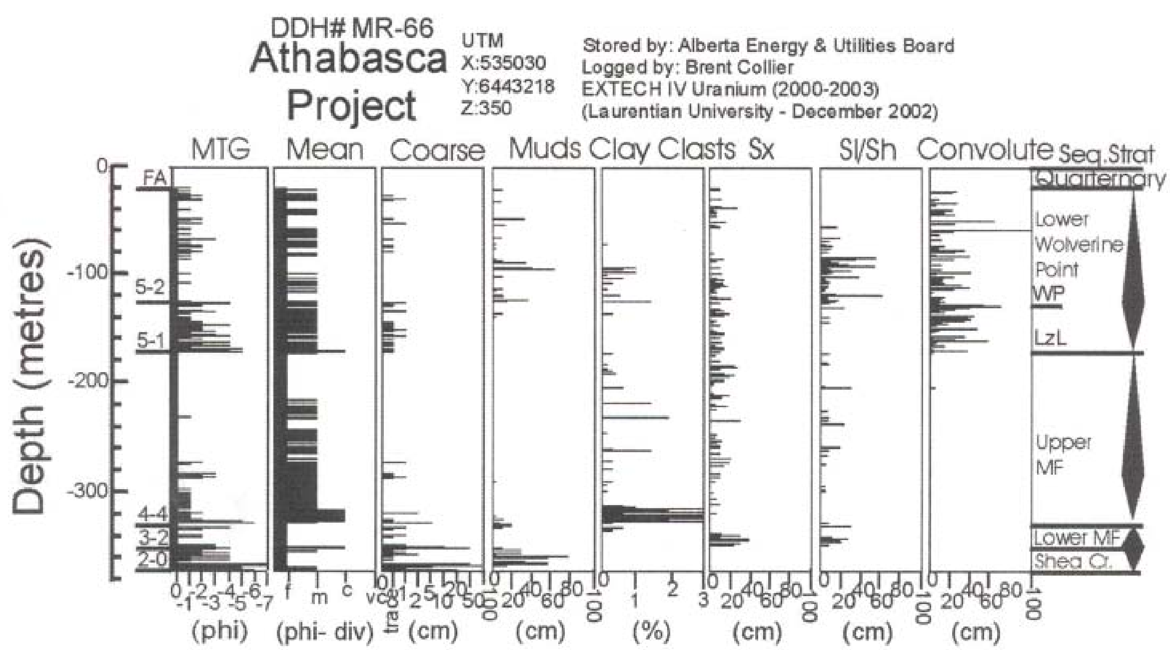


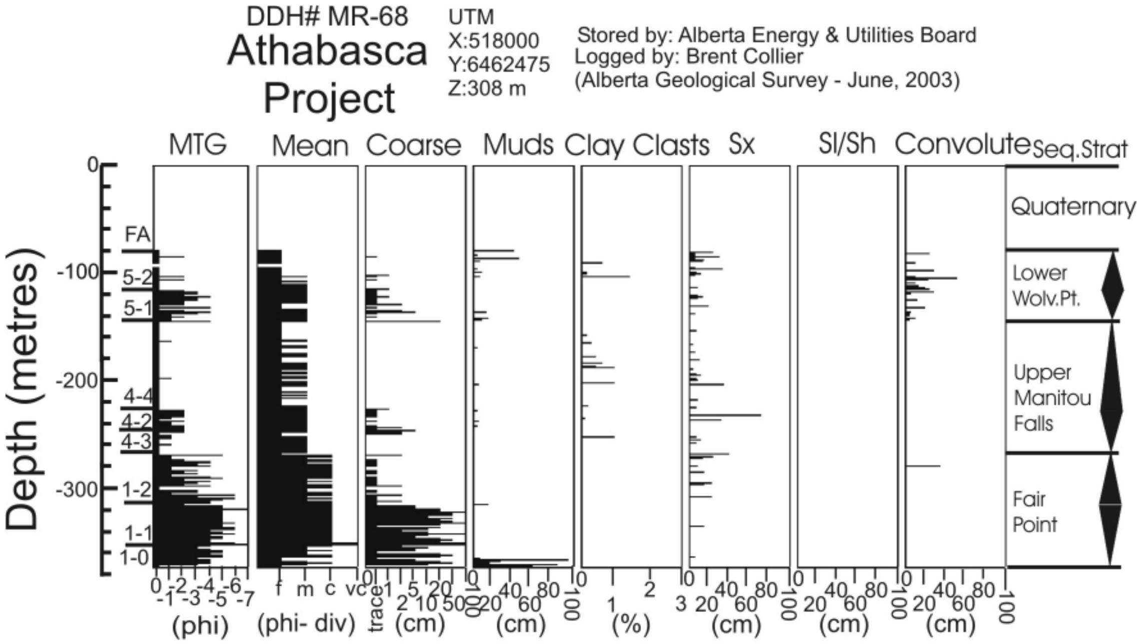
Note: Core inclined at 60 degrees from horizontal


DDH# MR-37
Athabasca Project
UTM
X:518621
Y:6458736
Z:305 m
Stored by: Alberta Energy & Utilities Board
Logged by: Ryan Post
EXTECH IV Uranium (2000-2003)
(EUB- Alberta Geological Survey - 2002)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
Quaternary
Lower WP
Upper Manitou Falls
Fair Point
FA
5-1
4-4
4-3
4-2
1-2
1-1
1-0
(phi)
(phi- div)
(cm)
(cm)
(%)
Note: Core inclined at 60 degrees from horizontal

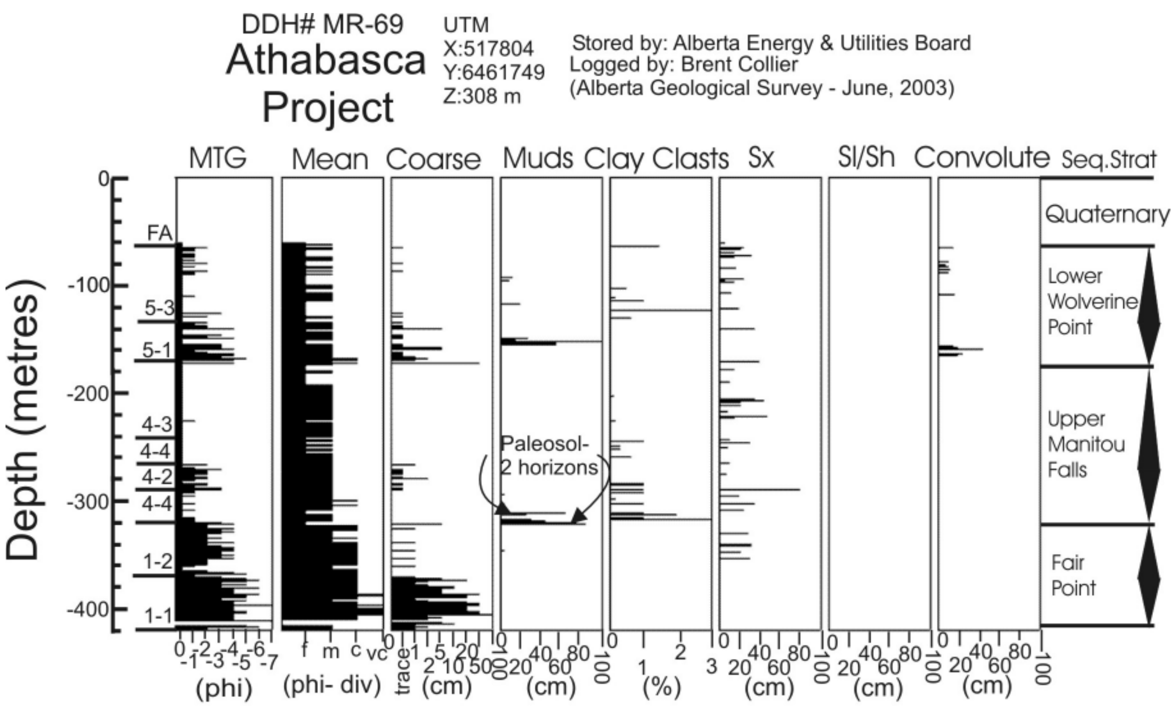

DDH# MR-64
Athabasca Project
UTM
X:524439
Y:6441738
Z:328 m
Stored by: Alberta Energy & Utilities Board
Logged by: Ryan Post
EXTECH IV Uranium (2000-2003)
(Alberta Geological Survey- 2002)
Note: No information for Devonian
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
Quaternary
Devonian
Upper Manitou Falls
FA
4-4
4-3
(phi)
(phi- div)
(cm)
(cm)
(%)
Note: Core inclined at 60 degrees from horizontal


DDH# MR-65
Athabasca Project
UTM
X:538272
Y:6438523
Z:347 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - April, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
FA
5-2
5-1
4-4
4-2
3-2
2-2
2-1
2-0
Quaternary
Lower Wolverine Point
WP
LzL
Upper Manitou Falls
Lower MF
Shea Creek
(phi)
(phi- div)
(cm)
(%)

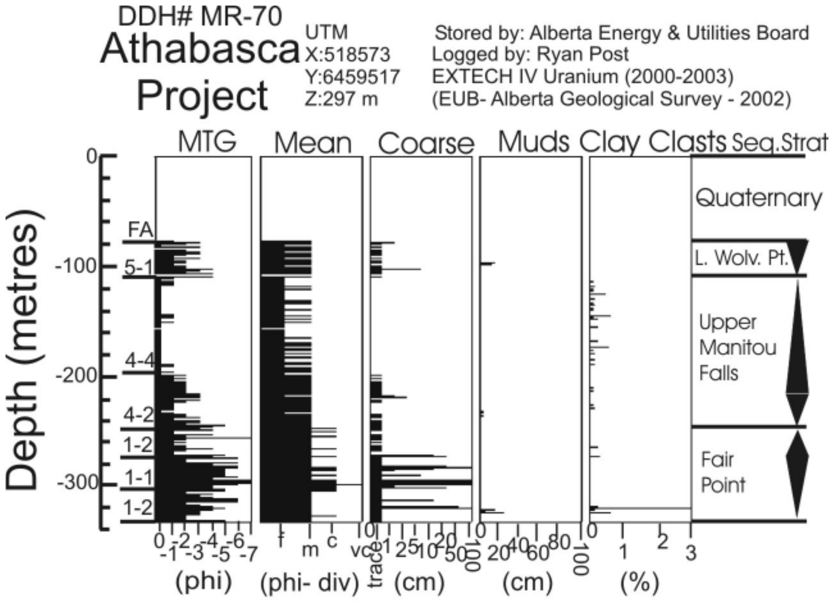

DDH# MR-66
Athabasca Project
UTM
X:535030
Y:6443218
Z:350
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
EXTECH IV Uranium (2000-2003)
(Laurentian University - December 2002)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
FA
5-2
5-1
4-4
3-2
2-0
Quaternary
Lower Wolverine Point
WP
LzL
Upper MF
Lower MF
Shea Cr.
(phi)
(phi- div)
(cm)
(%)



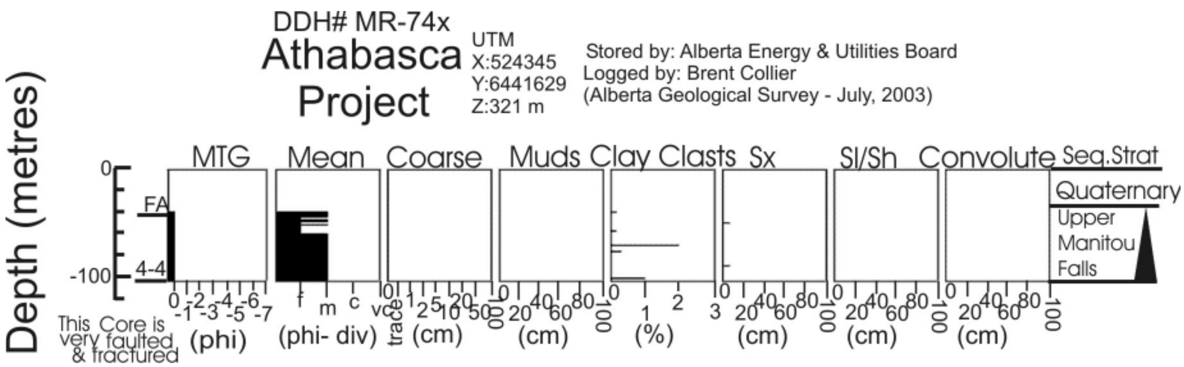
Note: Core inclined at 60 degrees from horizontal

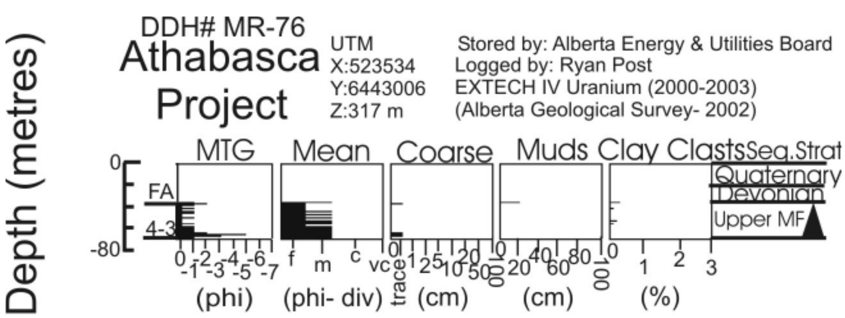


Note: Core inclined at 60 degrees from horizontal

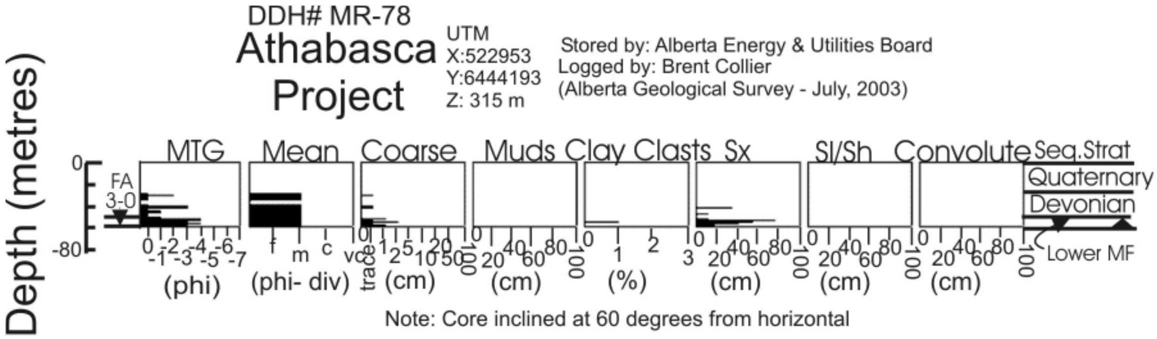


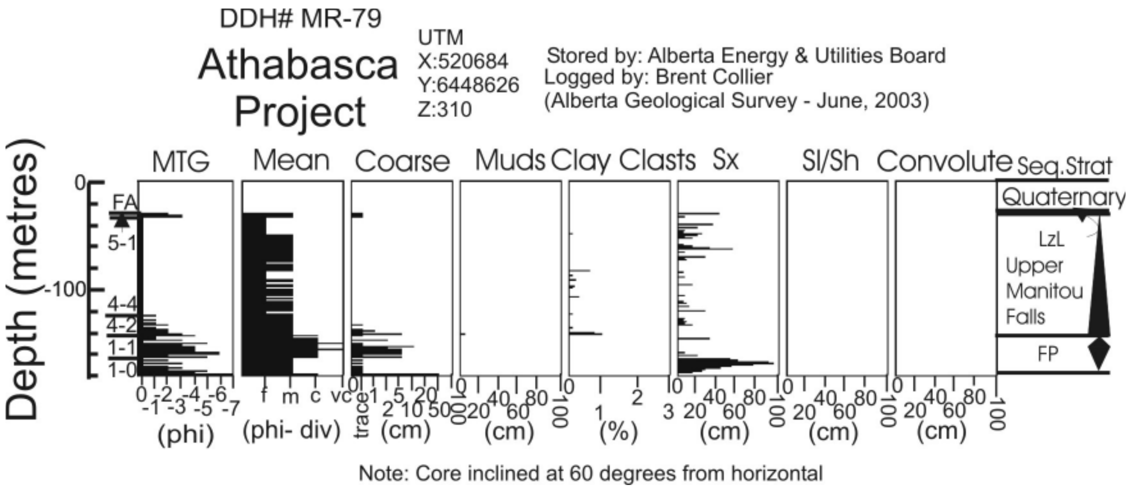
Note: Core inclined at 70 degrees from horizontal

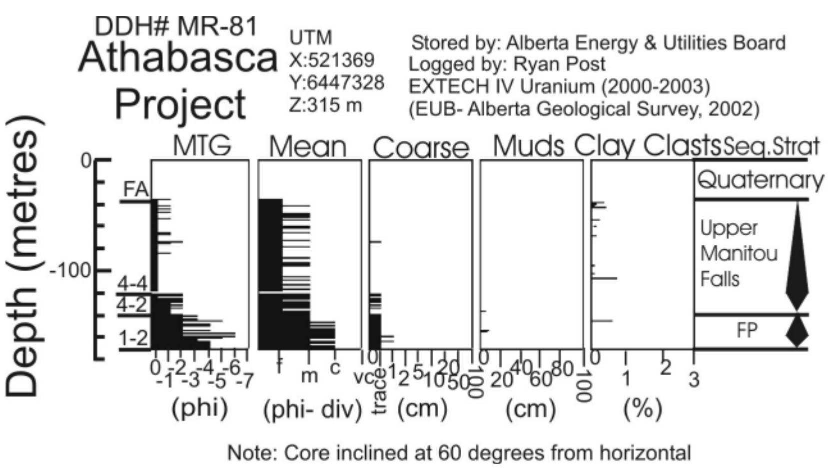


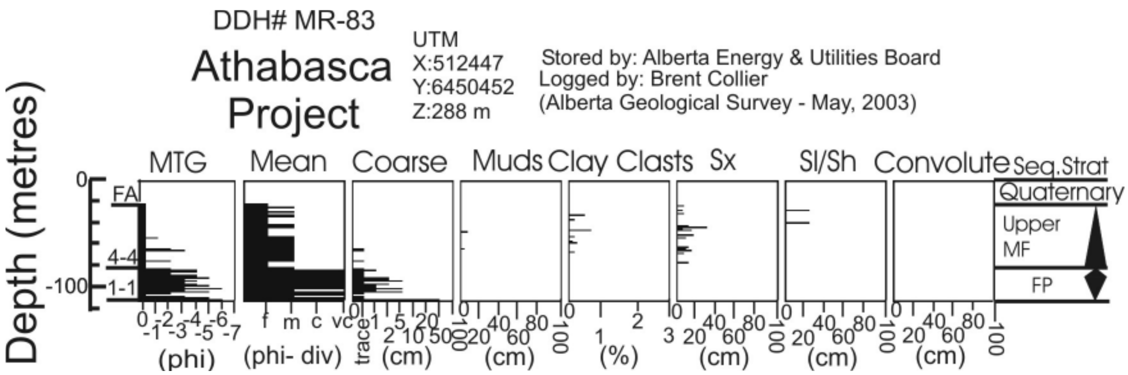


Note: Core inclined at 60 degrees from horizontal

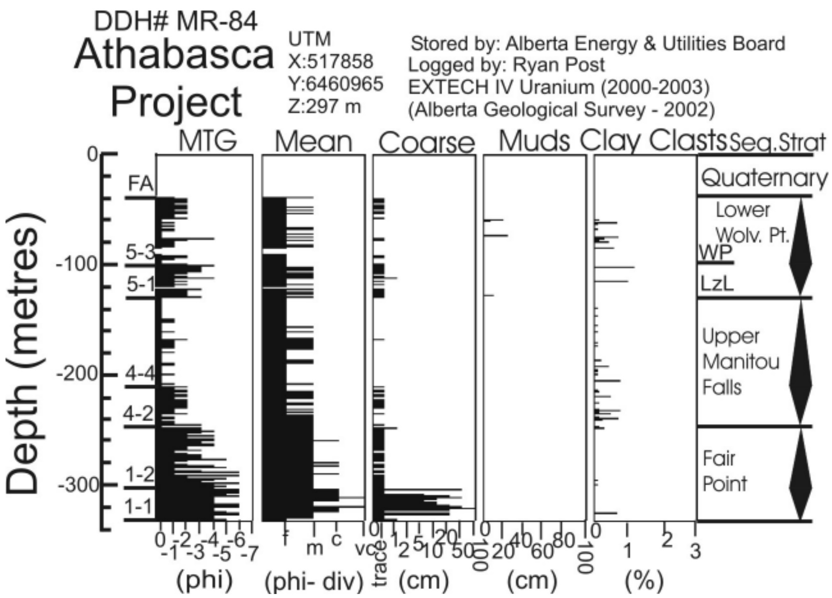

DDH# MR-78
Athabasca Project
UTM
X:522953
Y:6444193
Z: 315 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - July, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
FA
3-0
Quaternary
Devonian
Lower MF
(phi)
(phi- div)
trace
(cm)
(%)
Note: Core inclined at 60 degrees from horizontal


DDH# MR-79
Athabasca Project
UTM
X:520684
Y:6448626
Z:310
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - June, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
FA
5-1
4-4
4-2
1-1
1-0
Quaternary
LzL
Upper Manitou Falls
FP
(phi)
(phi- div)
trace
(cm)
(%)
Note: Core inclined at 60 degrees from horizontal

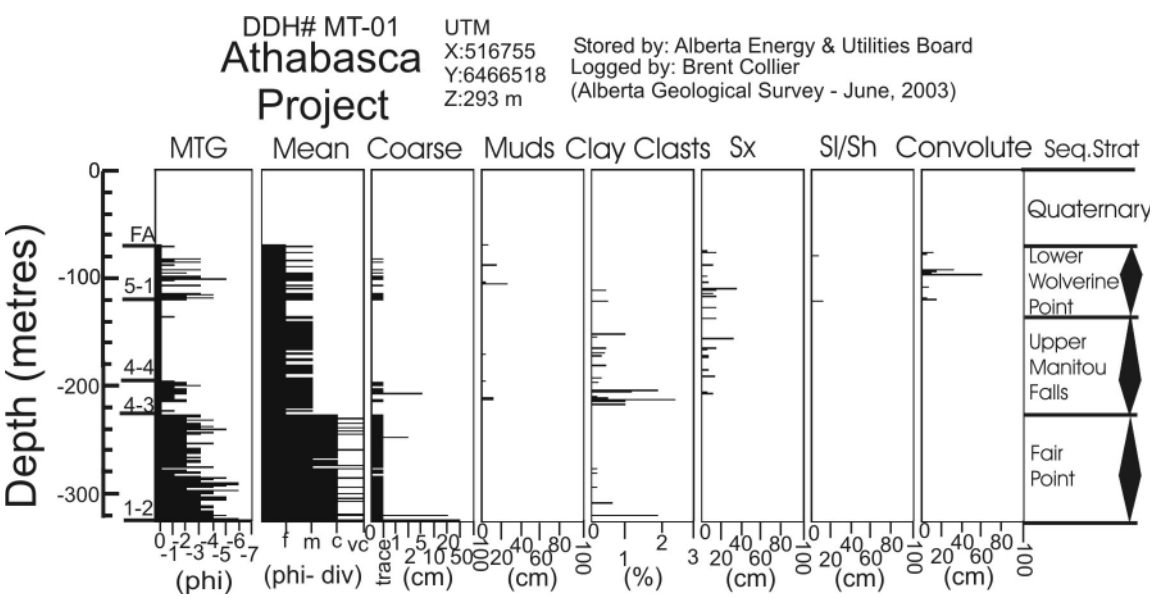

DDH# MR-81
Athabasca Project
UTM
X:521369
Y:6447328
Z:315 m
Stored by: Alberta Energy & Utilities Board
Logged by: Ryan Post
EXTECH IV Uranium (2000-2003)
(EUB- Alberta Geological Survey, 2002)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
FA
4-4
4-2
1-2
Quaternary
Upper Manitou Falls
FP
(phi)
(phi- div)
trace
(cm)
(%)
Note: Core inclined at 60 degrees from horizontal



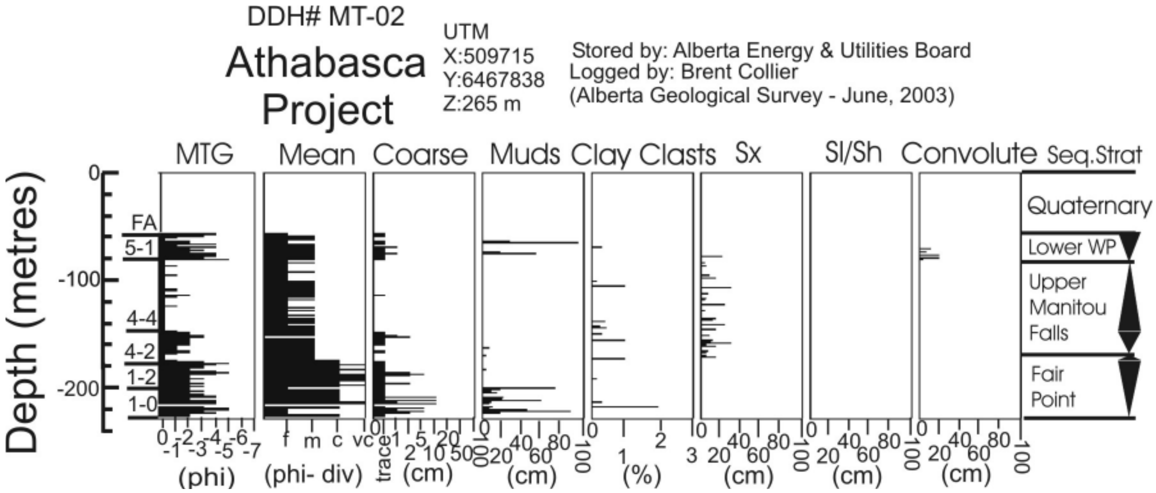
DDH# MR-83
Athabasca Project
UTM
X:512447
Y:6450452
Z:288 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - May, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Upper MF
FP
FA
4-4
1-1
(phi)
(phi- div)
(cm)
(%)

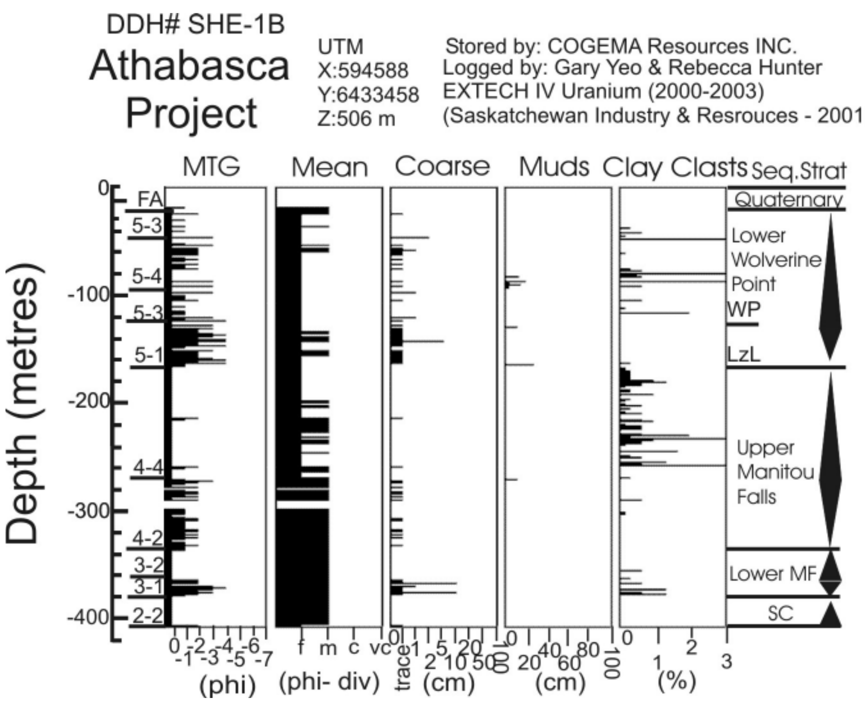


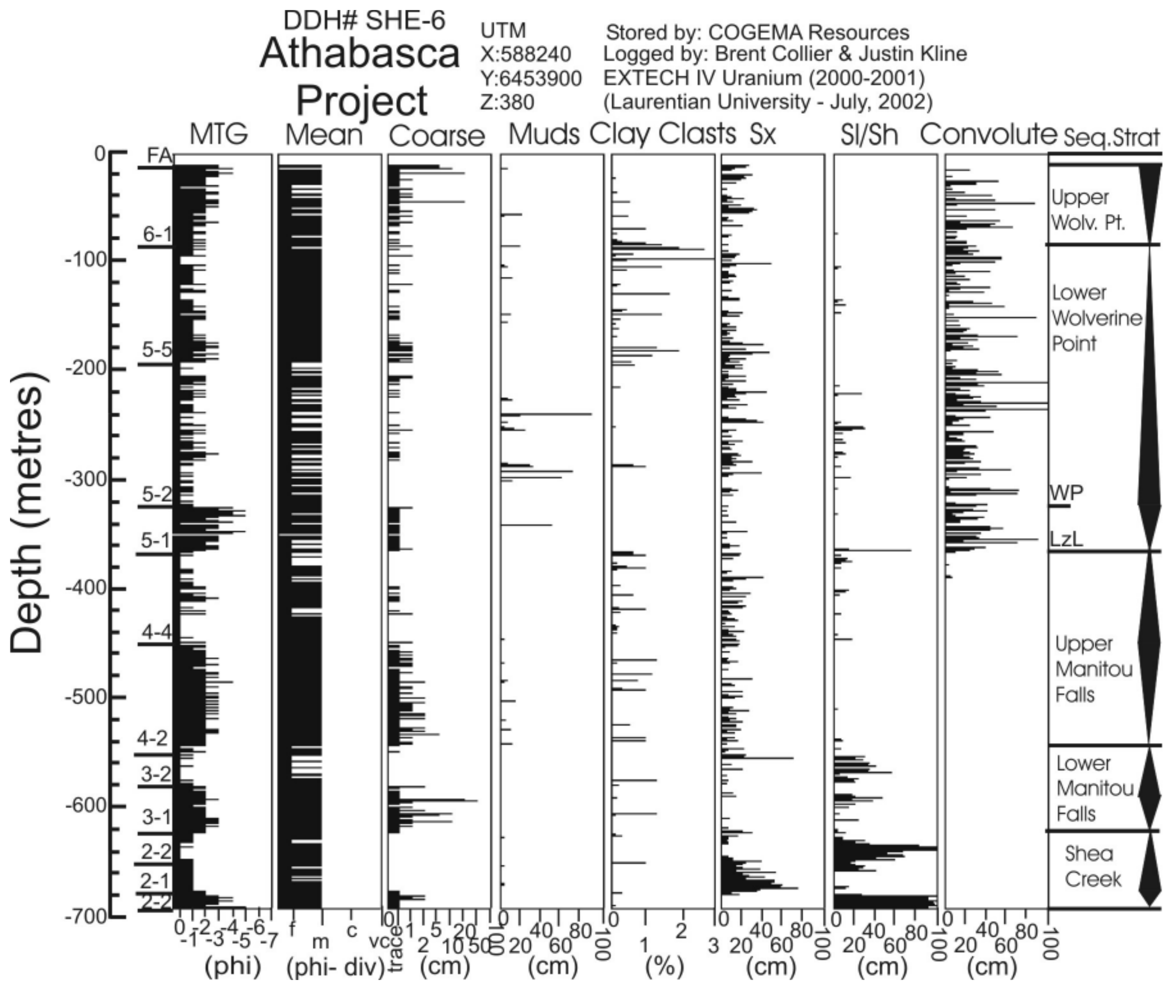
DDH# MR-84
Athabasca Project
UTM
X:517858
Y:6460965
Z:297 m
Stored by: Alberta Energy & Utilities Board
Logged by: Ryan Post
EXTECH IV Uranium (2000-2003)
(Alberta Geological Survey - 2002)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Quaternary
Lower Wolv. Pt.
WP
LzL
Upper Manitou Falls
Fair Point
FA
5-3
5-1
4-4
4-2
1-2
1-1
(phi)
(phi- div)
(cm)
(%)



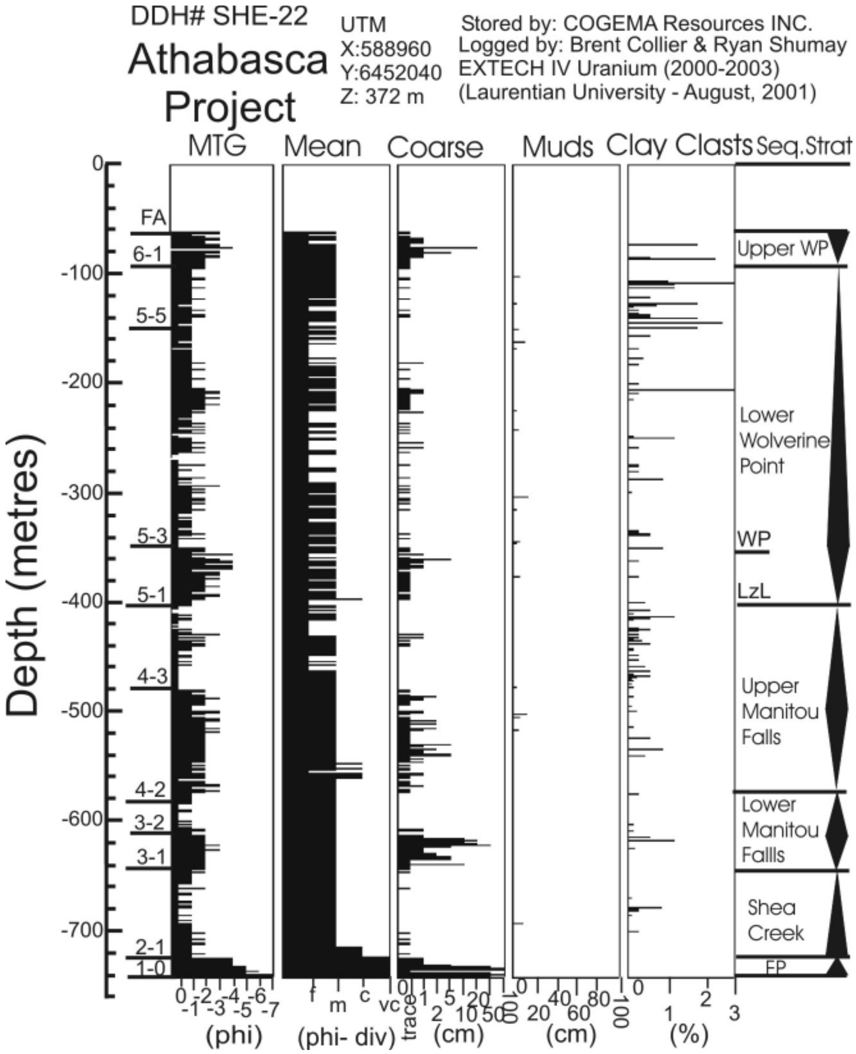
DDH# MT-01
Athabasca Project
UTM
X:516755
Y:6466518
Z:293 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - June, 2003)
Depth (metres)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Quaternary
Lower Wolverine Point
Upper Manitou Falls
Fair Point
FA
5-1
4-4
4-3
1-2
(phi)
(phi- div)
(cm)
(%)

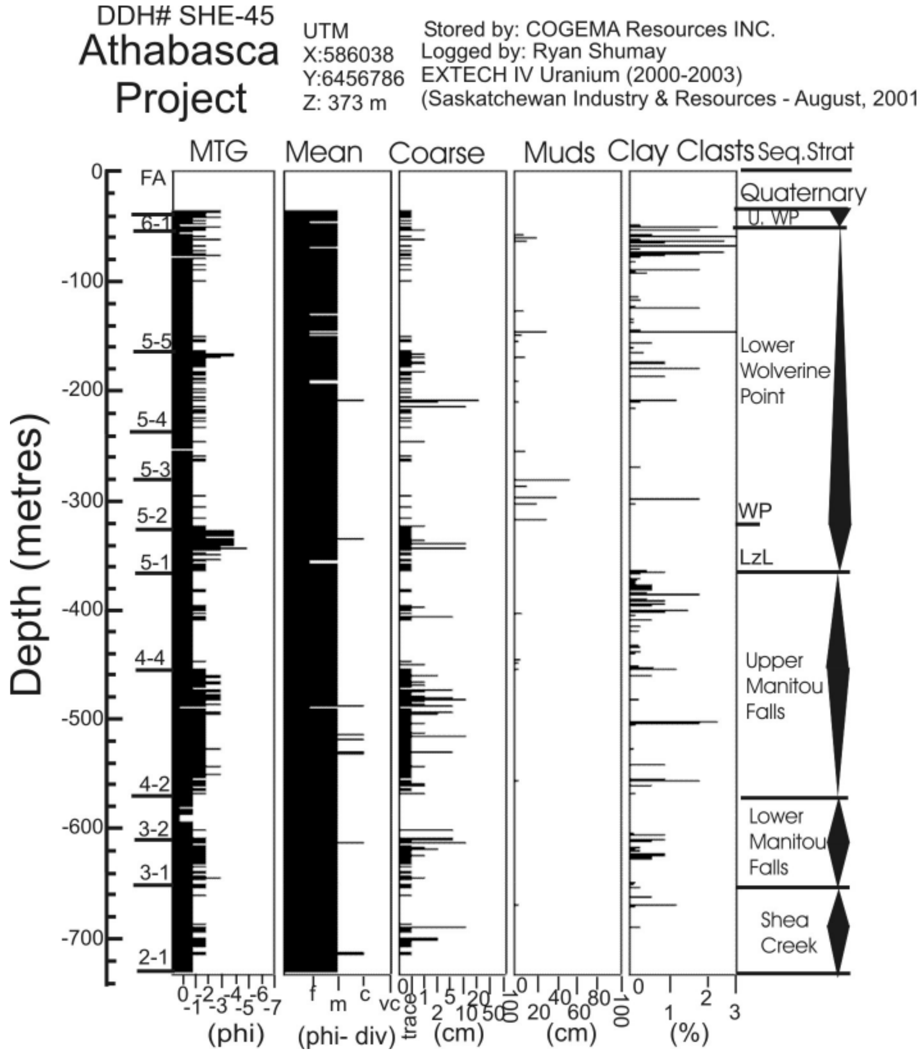

DDH# MT-02
Athabasca Project
UTM
X:509715
Y:6467838
Z:265 m
Stored by: Alberta Energy & Utilities Board
Logged by: Brent Collier
(Alberta Geological Survey - June, 2003)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
Quaternary
Lower WP
Upper Manitou Falls
Fair Point
FA
5-1
4-4
4-2
1-2
1-0
(phi)
(phi- div)
(cm)
(%)

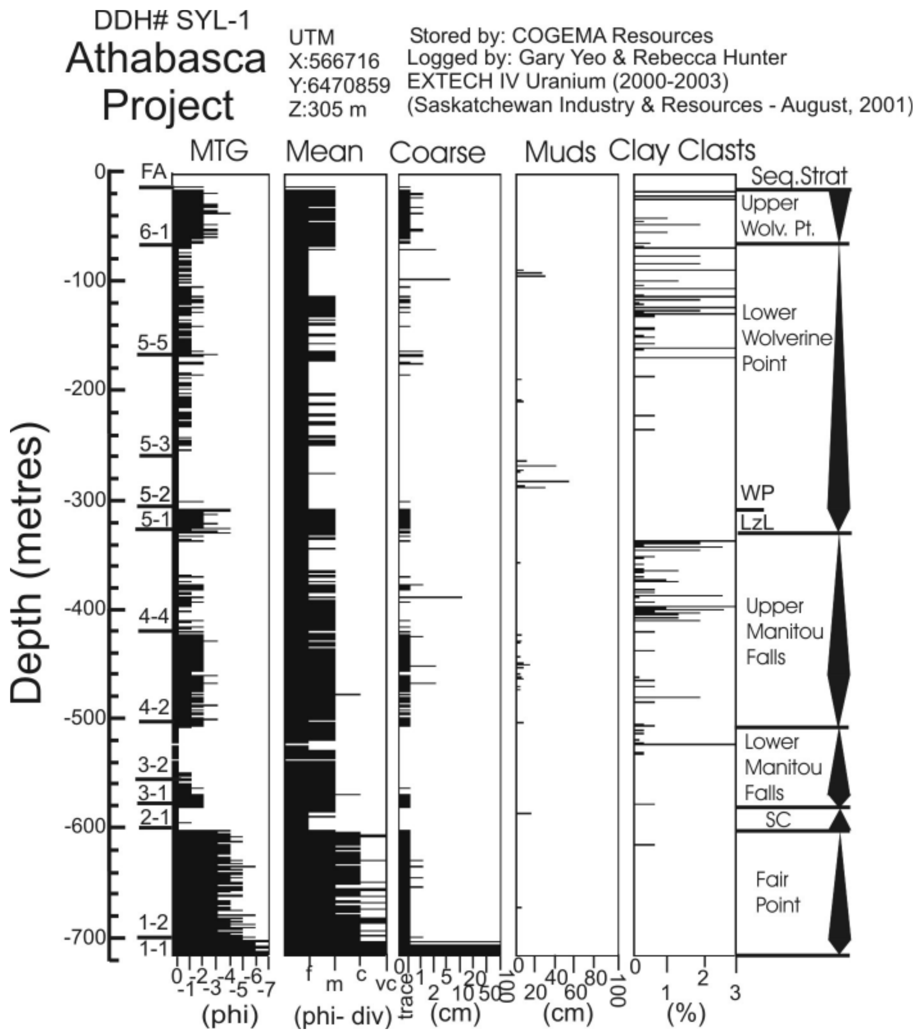

DDH# SHE-1B
Athabasca Project
UTM
X:594588
Y:6433458
Z:506 m
Stored by: COGEMA Resources INC.
Logged by: Gary Yeo & Rebecca Hunter
EXTECH IV Uranium (2000-2003)
(Saskatchewan Industry & Resrouces - 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
Quaternary
Lower Wolverine Point
WP
LzL
Upper Manitou Falls
Lower MF
SC
FA
5-3
5-4
5-1
4-4
4-2
3-2
3-1
2-2
(phi)
(phi- div)
(cm)
(%)



DDH# SHE-6
Athabasca Project
UTM
X:588240
Y:6453900
Z:380
Stored by: COGEMA Resources
Logged by: Brent Collier & Justin Kline
EXTECH IV Uranium (2000-2001)
(Laurentian University - July, 2002)
MTG
Mean
Coarse
Muds
Clay Clasts
Sx
Sl/Sh
Convolute
Seq.Strat
Depth (metres)
FA
6-1
5-5
5-2
5-1
4-4
4-2
3-2
3-1
2-2
2-1
2-2
(phi)
(phi- div)
trace
(cm)
(cm)
(%)
(cm)
(cm)
(cm)
Upper Wolv. Pt.
Lower Wolverine Point
WP
LzL
Upper Manitou Falls
Lower Manitou Falls
Shea Creek

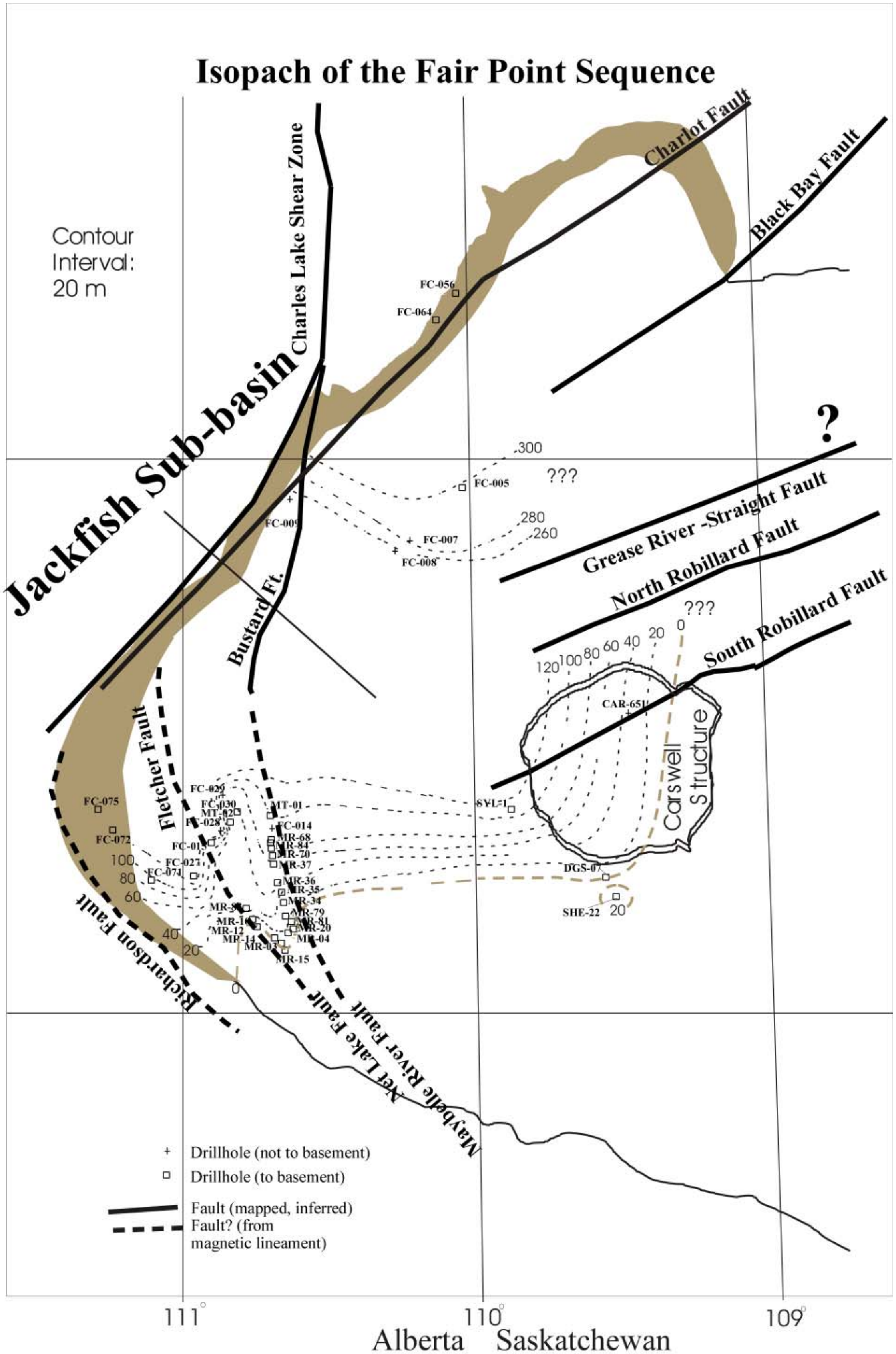

DDH# SHE-22
Athabasca Project
UTM
X:588960
Y:6452040
Z: 372 m
Stored by: COGEMA Resources INC.
Logged by: Brent Collier & Ryan Shumay
EXTECH IV Uranium (2000-2003)
(Laurentian University - August, 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
6-1
5-5
5-3
5-1
4-3
4-2
3-2
3-1
2-1
1-0
Upper WP
Lower Wolverine Point
WP
LzL
Upper Manitou Falls
Lower Manitou Fallls
Shea Creek
FP
(phi)
(phi- div)
trace
(cm)
(cm)
(%)


DDH# SHE-45
Athabasca Project
UTM
X:586038
Y:6456786
Z: 373 m
Stored by: COGEMA Resources INC.
Logged by: Ryan Shumay
EXTECH IV Uranium (2000-2003)
(Saskatchewan Industry & Resources - August, 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
6-1
5-5
5-4
5-3
5-2
5-1
4-4
4-2
3-2
3-1
2-1
Quaternary
U. WP
Lower Wolverine Point
WP
LzL
Upper Manitou Falls
Lower Manitou Falls
Shea Creek
(phi)
(phi- div)
(cm)
(cm)
(%)

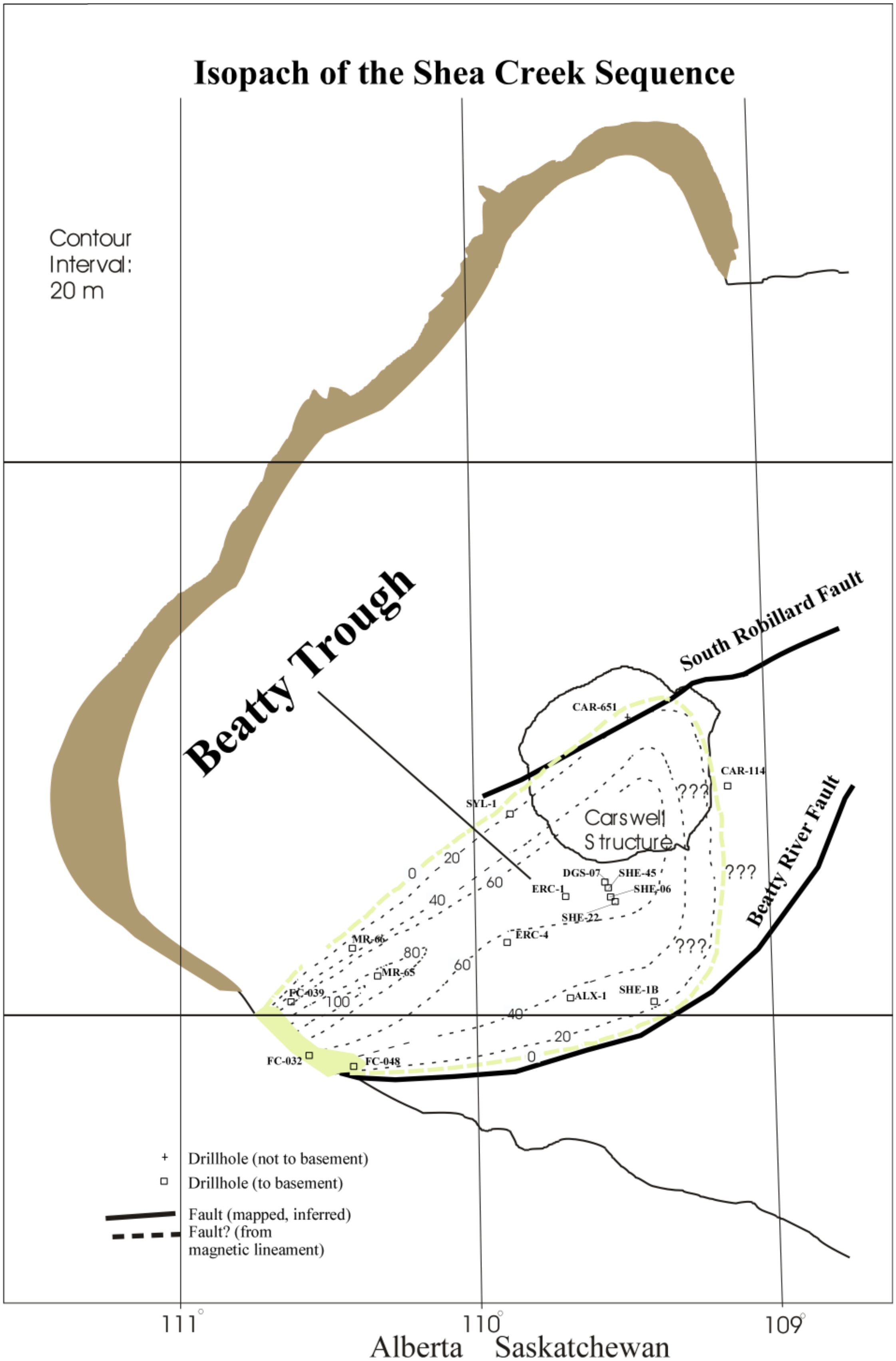

DDH# SYL-1
Athabasca Project
UTM
X:566716
Y:6470859
Z:305 m
Stored by: COGEMA Resources
Logged by: Gary Yeo & Rebecca Hunter
EXTECH IV Uranium (2000-2003)
(Saskatchewan Industry & Resources - August, 2001)
MTG
Mean
Coarse
Muds
Clay Clasts
Seq.Strat
Depth (metres)
FA
6-1
5-5
5-3
5-2
5-1
4-4
4-2
3-2
3-1
2-1
1-2
1-1
Upper Wolv. Pt.
Lower Wolverine Point
WP
LzL
Upper Manitou Falls
Lower Manitou Falls
SC
Fair Point
(phi)
(phi- div)
(cm)
(cm)
(%)
trace

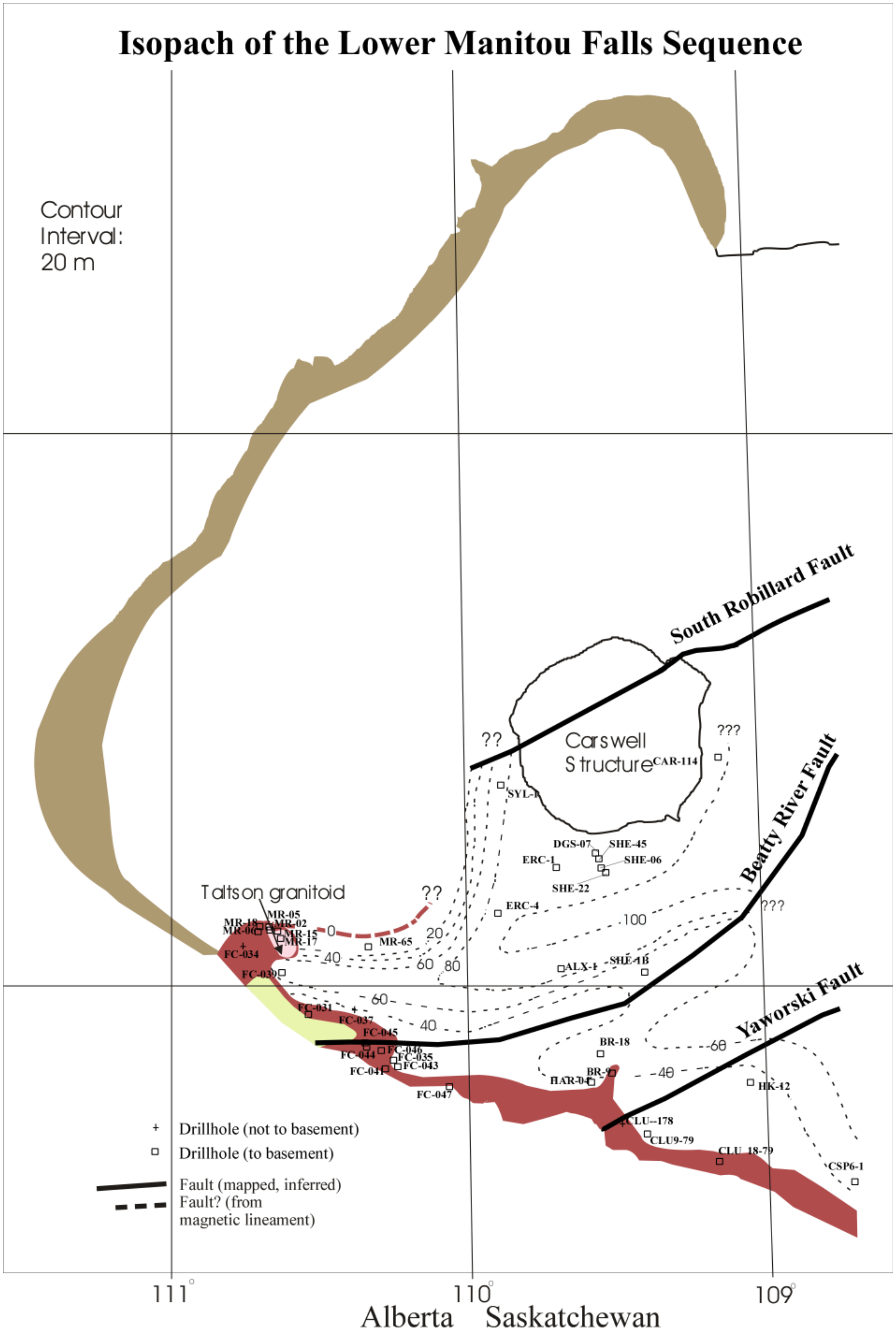
Appendix 3 - Isopach Maps

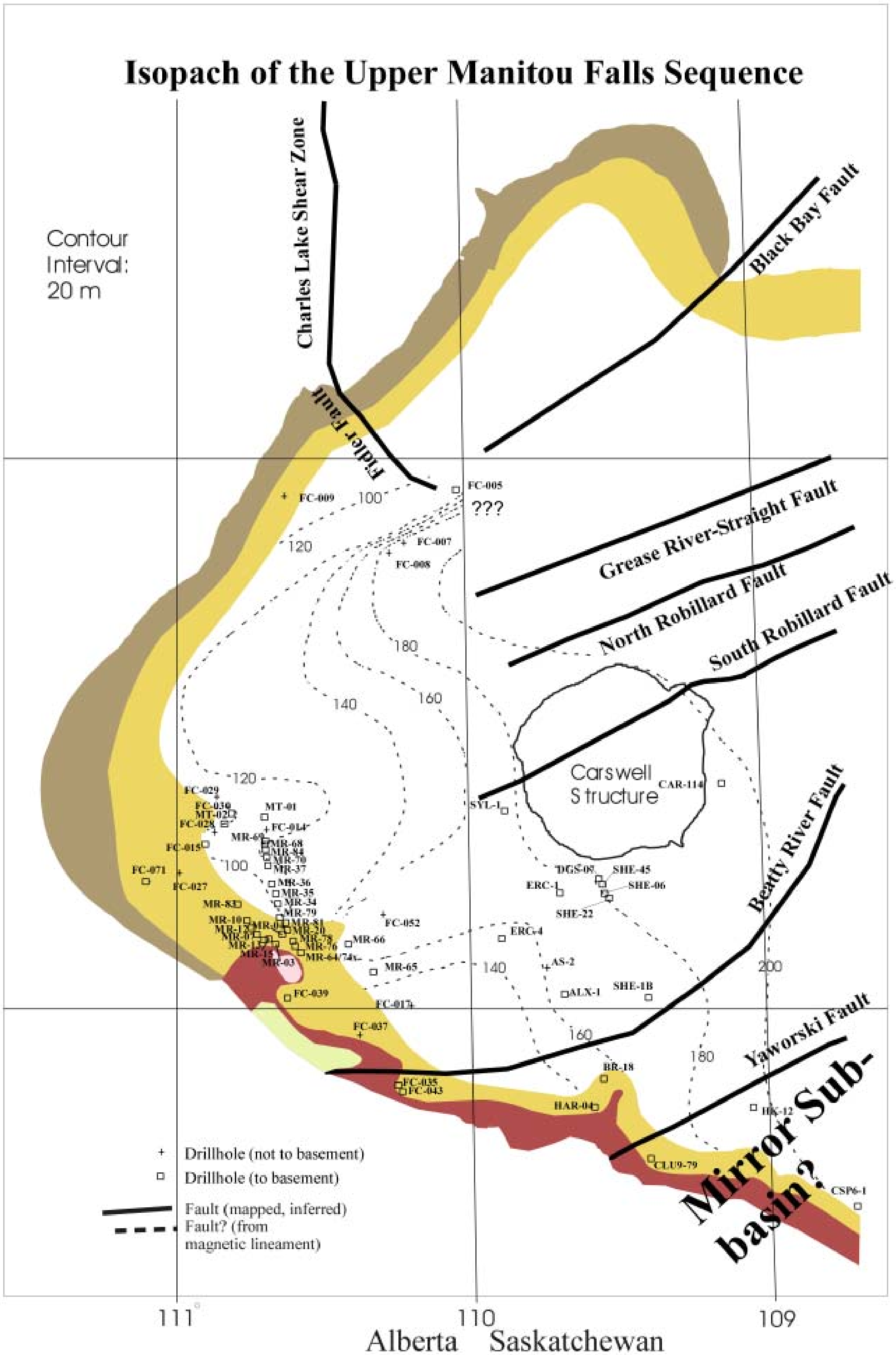
Note: all mapped and inferred faults are interpreted from Figure 4 (revised from Ramaekers, 2004).



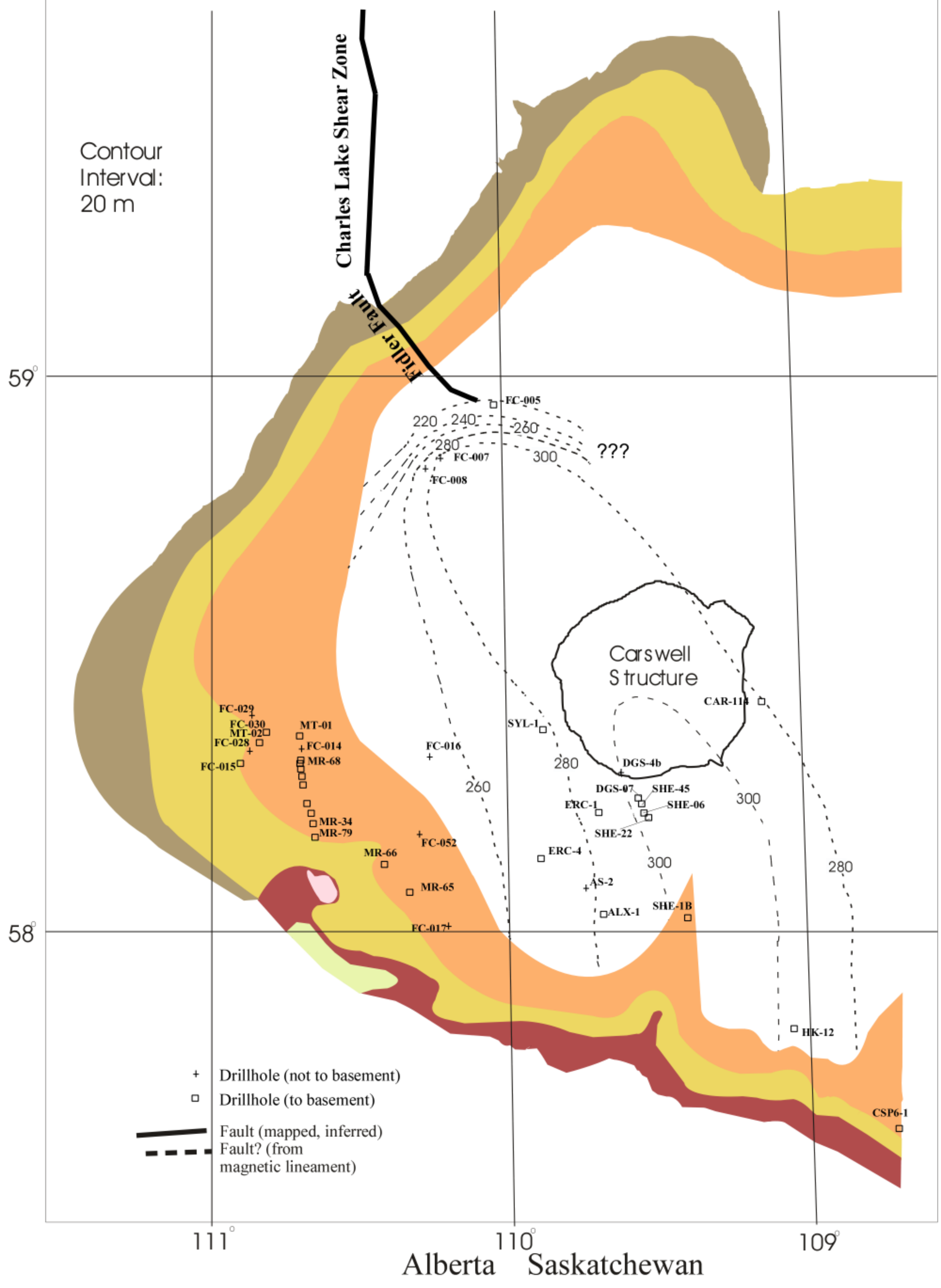
Isopach of the Fair Point Sequence
Contour Interval: 20 m
Charles Lake Shear Zone
Charlot Fault
Black Bay Fault
Jackfish Sub-basin
Grease River -Straight Fault
North Robillard Fault
South Robillard Fault
Bustard Ft.
Fletcher Fault
Richardson Fault
Net Lake Fault
Maybelle River Fault
Carswell Structure
???
?
FC-056
FC-064
FC-005
FC-009
FC-007
FC-008
CAR-651
SYL-1
DGS-07
SHE-22
FC-075
FC-072
FC-029
FC-030
MT-02
FC-028
MT-01
FC-014
MR-68
MR-84
MR-70
MR-37
MR-36
MR-35
MR-34
MR-79
MR-81
MR-20
MR-04
MR-15
MR-03
MR-14
MR-12
FC-027
FC-074
300
280
260
120
100
80
60
40
20
0
59°
58°
111°
110°
109°
Alberta
Saskatchewan
Drillhole (not to basement)
Drillhole (to basement)
Fault (mapped, inferred)
Fault? (from magnetic lineament)

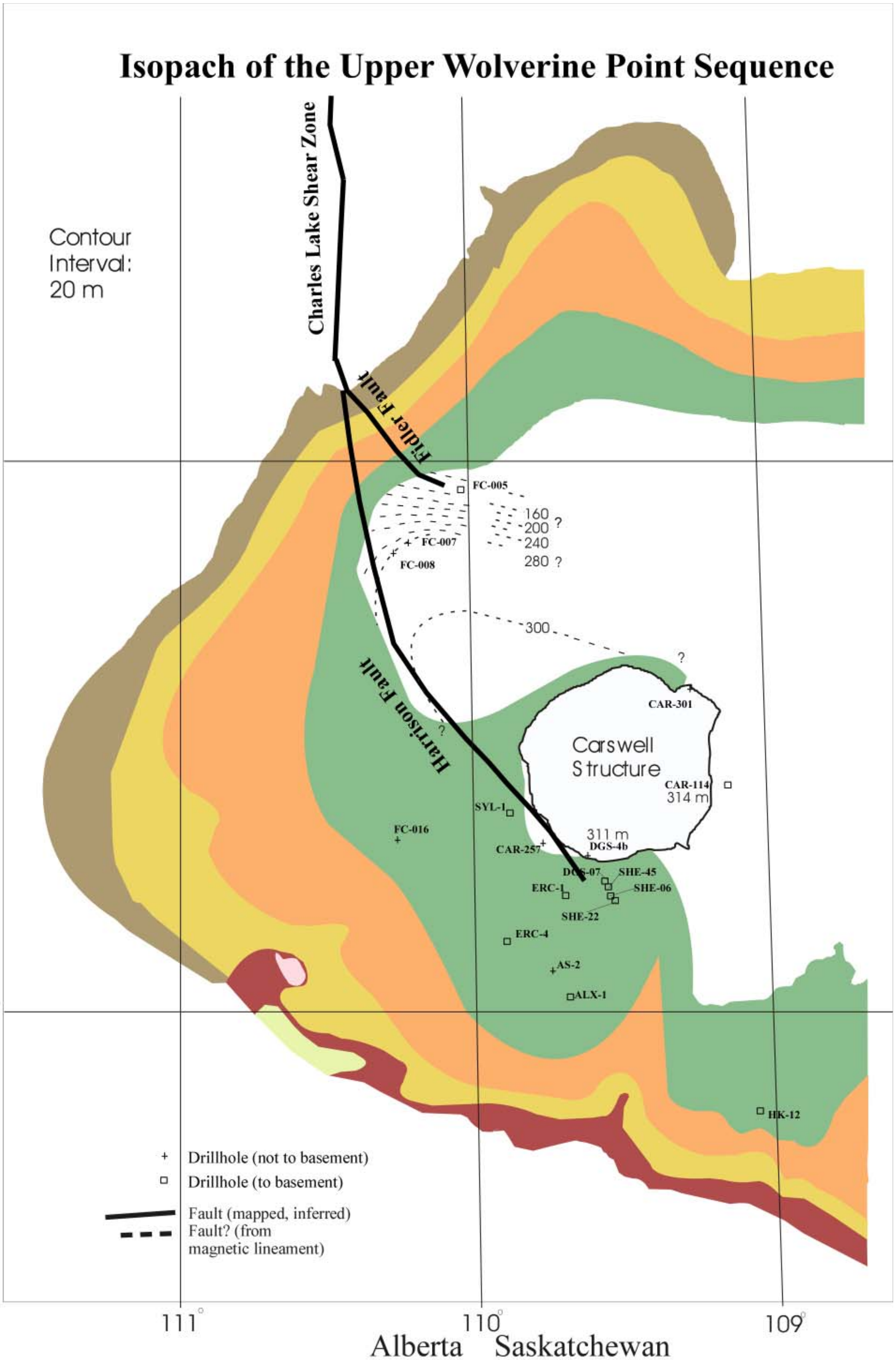

Isopach of the Shea Creek Sequence
Contour Interval: 20 m
59°
58°
111°
110°
109°
Alberta
Saskatchewan
Beatty Trough
South Robillard Fault
Beatty River Fault
Carswell Structure
CAR-651
CAR-114
SYL-1
DGS-07
SHE-45
SHE-06
ERC-1
SHE-22
ERC-4
MR-66
MR-65
FC-039
ALX-1
SHE-1B
FC-032
FC-048
???
0
20
40
60
80
100
Drillhole (not to basement)
Drillhole (to basement)
Fault (mapped, inferred)
Fault? (from magnetic lineament)


Isopach of the Lower Manitou Falls Sequence
Contour Interval: 20 m
59°
58°
111°
110°
109°
Alberta
Saskatchewan
South Robillard Fault
Beatty River Fault
Yaworski Fault
Carswell Structure
Taltson granitoid
Drillhole (not to basement)
Drillhole (to basement)
Fault (mapped, inferred)
Fault? (from magnetic lineament)

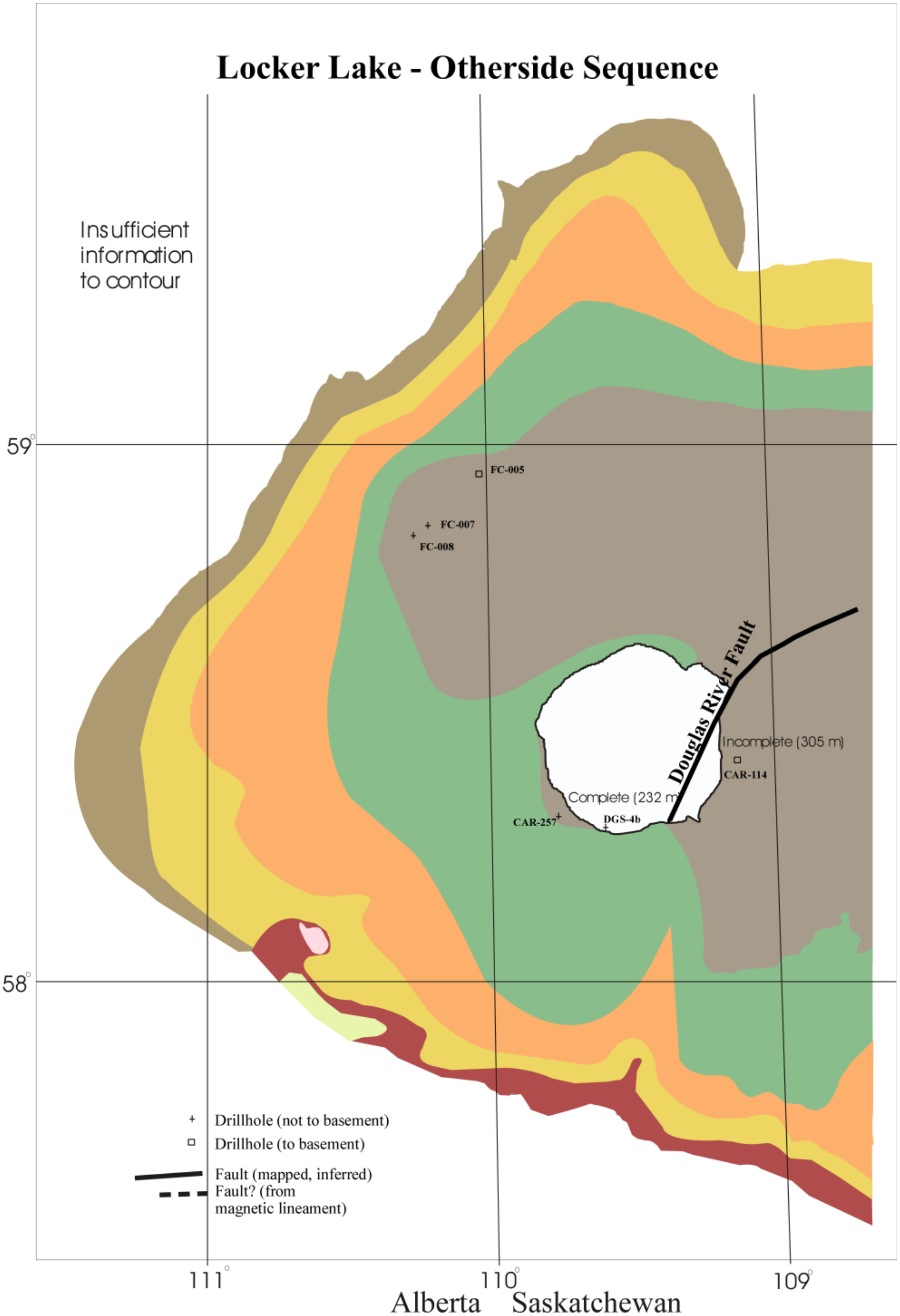

Isopach of the Upper Manitou Falls Sequence
Contour Interval: 20 m
Charles Lake Shear Zone
Fidler Fault
Black Bay Fault
Grease River-Straight Fault
North Robillard Fault
South Robillard Fault
Carswell Structure
Beatty River Fault
Yaworski Fault
Mirror Sub-basin?
???
100
120
140
160
180
200
FC-005
FC-009
FC-007
FC-008
CAR-114
SYL-1
ERC-1
ERC-4
SHE-45
SHE-06
SHE-22
SHE-18
AS-2
ALX-1
MR-65
MR-66
FC-052
FC-039
FC-037
FC-035
FC-043
BR-18
HAR-04
CLU9-79
CSP6-1
FC-071
FC-027
FC-015
MT-01
Drillhole (not to basement)
Drillhole (to basement)
Fault (mapped, inferred)
Fault? (from magnetic lineament)
59°
58°
111°
110
109
Alberta
Saskatchewan

Isopach of the Lower Wolverine Point Sequence





Isopach of the Upper Wolverine Point Sequence
Contour Interval: 20 m
Charles Lake Shear Zone
Fidler Fault
Harrison Fault
FC-005
160
200
240
280
300
FC-007
FC-008
Carswell Structure
CAR-301
CAR-114
314 m
311 m
DGS-4b
SYL-1
FC-016
CAR-257
DGS-07
SHE-45
SHE-06
ERC-1
SHE-22
ERC-4
AS-2
ALX-1
HK-12
59°
58°
111°
110°
109°
Drillhole (not to basement)
Drillhole (to basement)
Fault (mapped, inferred)
Fault? (from magnetic lineament)
Alberta
Saskatchewan


Locker Lake - Otherside Sequence
Insufficient information to contour
59°
58°
FC-005
FC-007
FC-008
Douglas River Fault
Incomplete (305 m)
CAR-114
Complete (232 m)
CAR-257
DGS-4b
Drillhole (not to basement)
Drillhole (to basement)
Fault (mapped, inferred)
Fault? (from magnetic lineament)
111°
110°
109°
Alberta
Saskatchewan