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Stratigraphy and Sedimentology of the Athabasca Group in the Net Lake-Maybelle River Area, Northeastern Alberta

Alberta Energy and Utilities Board
Alberta Geological Survey

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Stratigraphy and Sedimentology of the Athabasca Group in the Net Lake–Maybelle River Area, Northeastern Alberta

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Abstract

The stratigraphy and sedimentology of the unconformity-bounded Fair Point, Manitou Falls and Lazenby Lake formations of the Athabasca Group were examined in the Maybelle River–Net Lake area of northeastern Alberta. The lowermost Fair Point Formation is subdivided into two members: the lower and upper Fair Point Formation. The lower Fair Point Formation consists of locally occurring, massive to planar-laminated siltstone units, interbedded with and overlain by matrix- and clast-supported pebble conglomerate and pebbly sandstone. It is conformably overlain by massive and crudely crossbedded, coarse-grained sandstone of the upper Fair Point Formation. Deposition of the Fair Point Formation commenced with shallow lacustrine sedimentation in fault-controlled paleovalleys that were subsequently infilled with locally derived pebble conglomerate. These valleys are overlain by progradational alluvial-plain deposits. The overlying Manitou Falls Formation consists of a basal, crossbedded, medium- to coarse-grained sandstone unit and an upper, ripple-laminated to crossbedded, medium-grained sandstone unit. These are assigned to the Manitou Falls 'c' and 'd' members, respectively. Deposition of the Manitou Falls Formation occurred in relatively low velocity, perennial, braided river system tracts that are traceable across the basin. The uppermost Lazenby Lake Formation is incompletely preserved within the study area. This unit consists of massive and ripple-laminated, pebble-bearing sandstone with convolute bedding. Initial sedimentation of the Fair Point Formation was fault controlled and probably affected by extensional tectonics related to regional thermal activity that postdated the Trans-Hudson Orogeny. The sedimentological characteristics and distribution of the overlying Manitou Falls and Lazenby Lake formations suggest a significant change in the regional tectonic regime. The exact mechanism is unclear, but may be related to late-stage post–Trans-Hudson Orogeny intrusions or the effects of dynamic loading combined with regional, thermally induced subsidence.

1 Introduction

The EXTECH IV uranium project is a government-university-industry co-operative program aimed at enhancing the four-dimensional geoscience knowledge of the Athabasca Basin and developing new exploration methods for deep uranium deposits. This study is part of subproject 4, which addresses the regional and detailed stratigraphy of the Athabasca Basin (*see* Jefferson and Delaney, 2000), a globally important source of uranium. A high-grade uraniferous zone, containing 21% U_3O_8, was recently intersected across a 5 m interval in drillhole MR-39 at Maybelle River, Alberta (e.g., Kupsch and Catuneanu, 2002). Discovery of this mineralization has led to renewed efforts to better understand the stratigraphy of the Alberta portion of the Athabasca Basin.

This project builds on a regional stratigraphic study by Ramaekers (2003, 2004) and a localized stratigraphic-alteration study by Kupsch and Catuneanu (2002). The study area is situated around two north-northwest structural trends, the Maybelle River trend and the Net Lake trend. The main goals of this study were to 1) examine and reassess the regional stratigraphy in these areas, 2) study the regional diagenesis in the area, and 3) place the stratigraphy of the Net Lake–Maybelle River area into the context of a depositional and tectonostratigraphic model for the western Athabasca Basin.

1.1 Location of Study Area

The ca. 1700 Ma Athabasca Basin is located in northern Saskatchewan and northeastern Alberta (Figure 1). The basin encompasses a surface area of 80 000 km^2, of which Alberta only contains approximately 10%. The study area is located in the Fort Chipewyan 1:250 000 map sheet (NTS 74L), between latitudes 58^o08' and 58^o13'N and longitudes 110^o60' and 110^o76'W, encompassing an area of approximately 60 km^2.

1.2 Methodology

Twenty-six cores were logged in the summer of 2002 at the Alberta Geological Survey Mineral Core Research Facility (MCRF) in Edmonton. Cores were logged in accordance with the methodology developed for the EXTECH IV subproject 4 (*see* Yeo et al., 2001b; Ramaekers, 2003). Thirty-seven parameters were examined on a metre-by-metre basis for each drillcore. Table 1 contains a complete list of the parameters (Jefferson et al., 2001) and the drillhole information is compiled in Appendix 1.

Data were collected on Palm® hand-held computer devices and downloaded daily into an Access® database, where they could be modified for use in other programs (e.g., Excel®, Rockware®, Logplot®). Several key parameters used later to compile lithologs included maximum grain size, percentage of grains over 2 mm, intraclast aggregate thickness, percentage of conglomerate, percentage of fines and percentage of matrix clay. Alteration characteristics, including silicification, friability, tectonic structure, accessory minerals and replacement structures, were also compiled into similar-style logs.

1.3 Previous Work

A summary of studies completed in the Athabasca Basin prior to 1980 is provided in Ramaekers (1990). Ramaekers (1978, 1979, 1980, 1981) carried out the first comprehensive study on the Athabasca Group, based on scarce outcrop and regional drillcore studies. Wilson (1985) completed the first regional stratigraphic study in the Alberta portion of the Athabasca Basin. A review of the mineralization and alteration history of the Athabasca Basin was later compiled by Quirt (1997). The EXTECH IV uranium study provided a plethora of recent publications on the Athabasca Basin, including regional stratigraphic studies in Saskatchewan (Yeo et al., 2001a, 2002) and Alberta (Ramaekers, 2003, 2004); stratigraphic

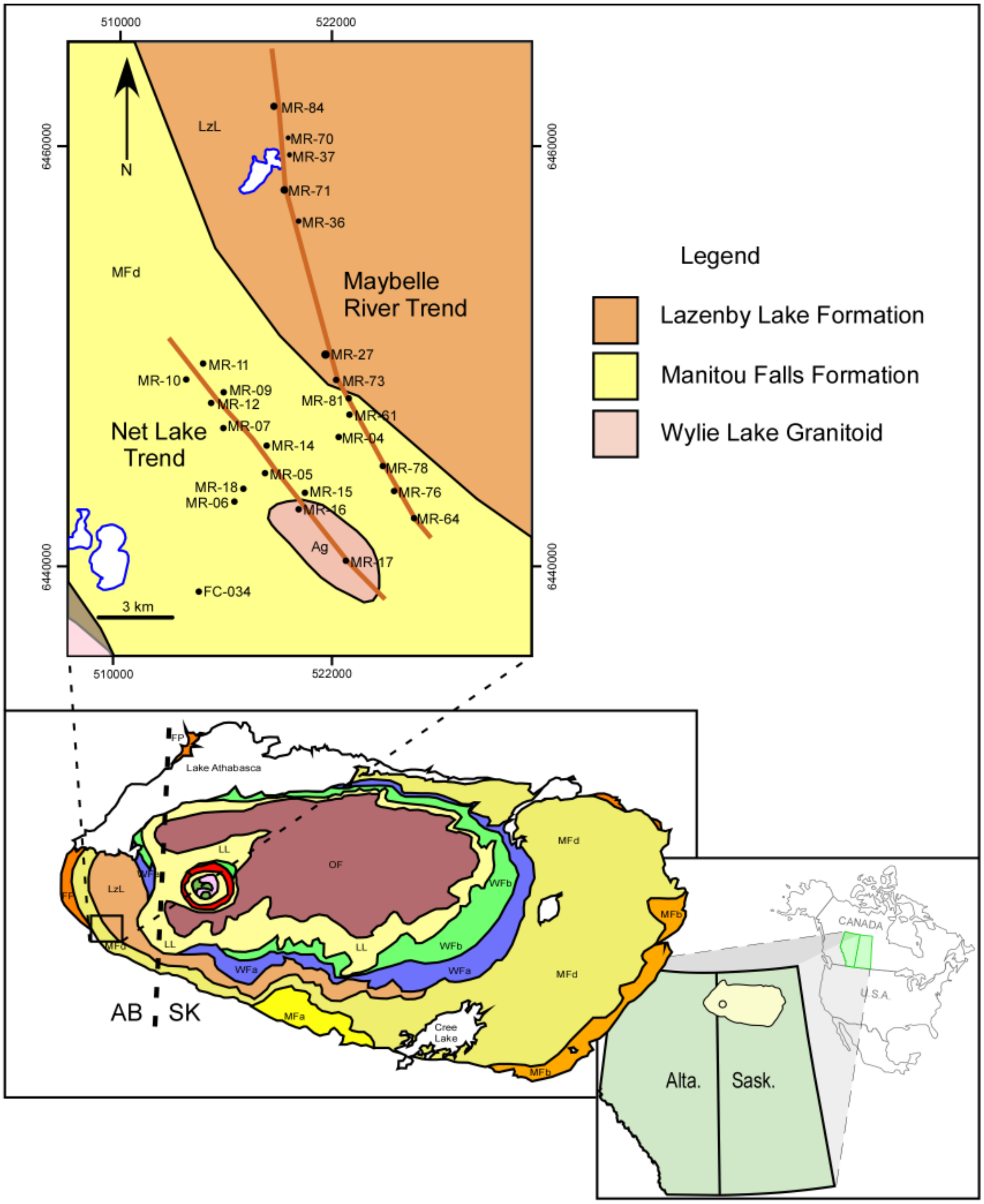


Figure 1. Location of the study area in relation to the Maybelle River and Net Lake trends, and of the logged drillcores (subcrop geology *modified from* Ramaekers et al., 2001).

Table 1. Parameters used for logging cores from the Athabasca Group (*modified from* Jefferson et al., 2001).

Parameter	Variables
DepthFrom	Number (m), equal to the previous "Depth to" value
DepthTo	Number (m)
%CoreRecovery	Number (%)
MatrixClay	n, not visible; t, trace; tm, mostly trace, less moderate; mt, mostly moderate, less trace; m, minor to moderate; a, abundant
CLR_Darkness	w, white; p, very pale to pale; m, moderate to dark; d, dark
CLR_Colour	Bk, black; Bn, brown; BR, black-red; C, cream; Gn, green; Gy, grey; M, maroon (brick); O, orange; P, pink; Pu, purple; R, red (bright); W, white; Y, yellow; YG, yellow-grey; n, no colour alteration
CLR_Pattern	B, bedding related; F, fracture related; G, grain-size related; Ld, Liesegang dark grey; Lg, Liesegang medium grey; Lr, Leisegang, bright to pale red; M, mottled, pale on dark or reverse; Pdp, patchy, dark background, pale patches; Ppd, patchy, pale background, dark patches; Sd, spot, dark; Sp, spot, pale; Srw, spot, outside dark or red, inside pale; D, dots, speckled, usually specular hematite; U, uniform
Friability	C, competent, hard to break; e, competent, breaks easily; f, friable; v, very friable; u, unconsolidated; h, hard, mudstone only (fingernail does not scratch); s, soft, mudstone only (fingernail gouges)
Silicification	n, none; w, weak; m, moderate (sparkles); s, strong, tombstone
TGS_10% (fine tail)	B, boulder (>256 mm); cl, cobble, large (128–256 mm); cs, cobble small (64–128 mm); pebble, very large (32–64 mm); pebble, large (16–32 mm); pebble, medium (8–16 mm); pebble, small (4–8 mm); granule (2–4 mm); vc, very coarse sand; c, coarse sand, m, medium sand; f, fine sand; vf, very fine sand, s, silt; y, clay
TGS_largest (medium tail)	B, boulder (>256 mm); cl, cobble, large (128–256 mm); cs, cobble small (64–128 mm); pebble, very large (32–64 mm); pebble, large (16–32 mm); pebble, medium (8–16 mm); pebble, small (4–8 mm); granule (2–4 mm); vc, very coarse sand; c, coarse sand; m, medium sand; f, fine sand; vf, very fine sand; s, silt; y, clay
TGS_90% (coarse tail)	B, boulder (>256 mm); cl, cobble, large (128–256 mm); cs, cobble small (64–128 mm); pebble, very large (32–64 mm); pebble, large (16–32 mm); pebble, medium (8–16 mm); pebble, small (4 8 mm); granule (2–4 mm); vc, very coarse sand; c, coarse sand; m, medium sand; f, fine sand; vf, very fine sand; s, silt; y, clay
TGS_MTG	Number (mm), maximum transported grain size (in mm measured along the c-axis)
TGS_%>2mm	Number (%), volume % of grains greater than 2 mm in diameter
TGS_%M	Number (mm), % of mud in interval
TGS_%F	Number (mm), % of fines (silts and very fine grained sand) in interval
TGS_%Cong>2cm	Number (mm), % of conglomerate (as defined by >30% of clasts greater than 2 mm in diameter in a beds >2 cm thick) in interval
Intraclast Aggregate type	W, wads [large, thick, subequidimensional (>15mmx>3mm)]; d, dollars [large, thin (>15mmx<3mm)]; p, penny [small, thin (3-15mm x <3mm)]; g, grain [small, equidimensional (<3mm x <3mm)]; b, bank (layer of intraclasts, clast or matrix support); n, none
Intraclast aggregate thickness	Number (%), sum of cross-section thickness of all intraclasts measured individually

Parameter	Variables
Accessory Mineral Colour	Bk, black; Bn, brown; BR, black-red; C, cream; Gn, green; Gy, grey; M, maroon (brick); O, orange; P, pink; Pu, purple; R, red (bright); W, white; Y, yellow; YG, yellow-grey; n, no colour alteration
Accessory Mineral Distribution	D, disseminated; l, laminated; n, none
Tectonic Fractures/m	Number of fractures per m
Primary Sedimentary Structures- structure Size Class	G, granule and larger (>30% coarser material); P, pebbly sand (<30% coarse material, interbedded); S, sand, medium to coarse; F, sand, fine and very fine; M, mud (silt and clay)
Primary Sedimentary Structures_ Bed Form	t, crossbedded, trough; p, crossbedded, planar; xc, crossbedded, condensed; x, crossbedded, high angle, not specific; l, crossbedded, low angle (lower case L); I, horizontal laminated intraformational conglomerate (clay pebbles); 1, horizontal laminated 1 layer thick granule or coarser (the #1); h, horizontally laminated, uniform; ?, indistinct bedforms; m, massive appearance
Secondary Sedimentary Structures	Pc, pedogenic carbonate, calcrete; pp, pedogenic, pisoliths; ps, pedogenic silcretes; sy, syneresis cracks; m, sand-filled mudcracks; d, clastic dikes; l, load clasts; b, ball and pillow; s, steepened and overturned single sedimentary structure; s2, steepened and overturned multiple sedimentary units; c, convolute bedding; u, understeepened, quartz dissolution?; sl, slump, sedimentary fault; r, scour; n, none
Hydrocarbon_type	P, pyrobitumen; t, tar; h, heavy oil; l, light oil; o, odour only; n, none
Hydrocarbon_ Distribution	B, buttons; f, along fractures; -, intergranular, saturated; n, none
Hydrocarbon %	Number
Tectonic structure_ type	Ft, fault, unspecified; fd, fault, dip-slip; fs, fault, strike-slip; fr, fracture, no movement; bx, breccia, br, breccia, milled (fault conglomerate); bc, breccia, crackle; su, sandy gouge, uncemented; sc, sandy gouge, cemented; b, bedding plane; n, not determined
Tectonic structure_ angle to core axis	Number (<^{o})
Tectonic structure_ cement/fill	A, apatite; c, calcite; d, dolomite; s, siderite; h, hematite (only if saturated); l, limonite; m, marcasite; py, pyrite; pi, pitchblende; td, dravite; y, clay; g, gouge; sc, gouge, sandy cemented; su, gouge, sandy uncemented; qc, chalcedony; qd, quartz, drusy; qo, quartz, overgrowths; o, other; n, none
Tectonic structure_ thickness	Number (cm)
Replacement type	B, botryoidal; ps, pseudomorphing; ms, massive; mn, manto, stratabound; v, vuggy; pa, patchy; d, disseminated; l, lining of voids; fi, replace rock within fault zone; fo, replace fault zone and wall rock
Replacement cement/fill	A, apatite; c, calcite; d, dolomite; s, siderite; h, hematite (only if saturated); l, limonite; m, marcasite; py, pyrite; pi, pitchblende; td, dravite; y, clay; g, gouge; sc, gouge, sandy cemented; su, gouge, sandy uncemented; qc, chalcedony; qd, quartz, drusy; qo, quartz, overgrowths; o, other; n, none
Replacement thickness	Number (mm)
Remarks	
Pictures	

studies over detailed transects in areas of known mineralization (Figure 2; Collier and Yeo, 2001; Long, 2001; Bernier, 2002; Collier, 2002; Kupsch and Catuneanu, 2002); and clay alteration studies (e.g., Percival et al., 2002). Ramaekers et al. (2001) made the first attempt to apply sequence stratigraphy to the Athabasca Group. This was later built upon in other publications (Collier, 2002; Yeo et al., 2002; Ramaekers and Catuneanu, 2003; Ramaekers, 2004).

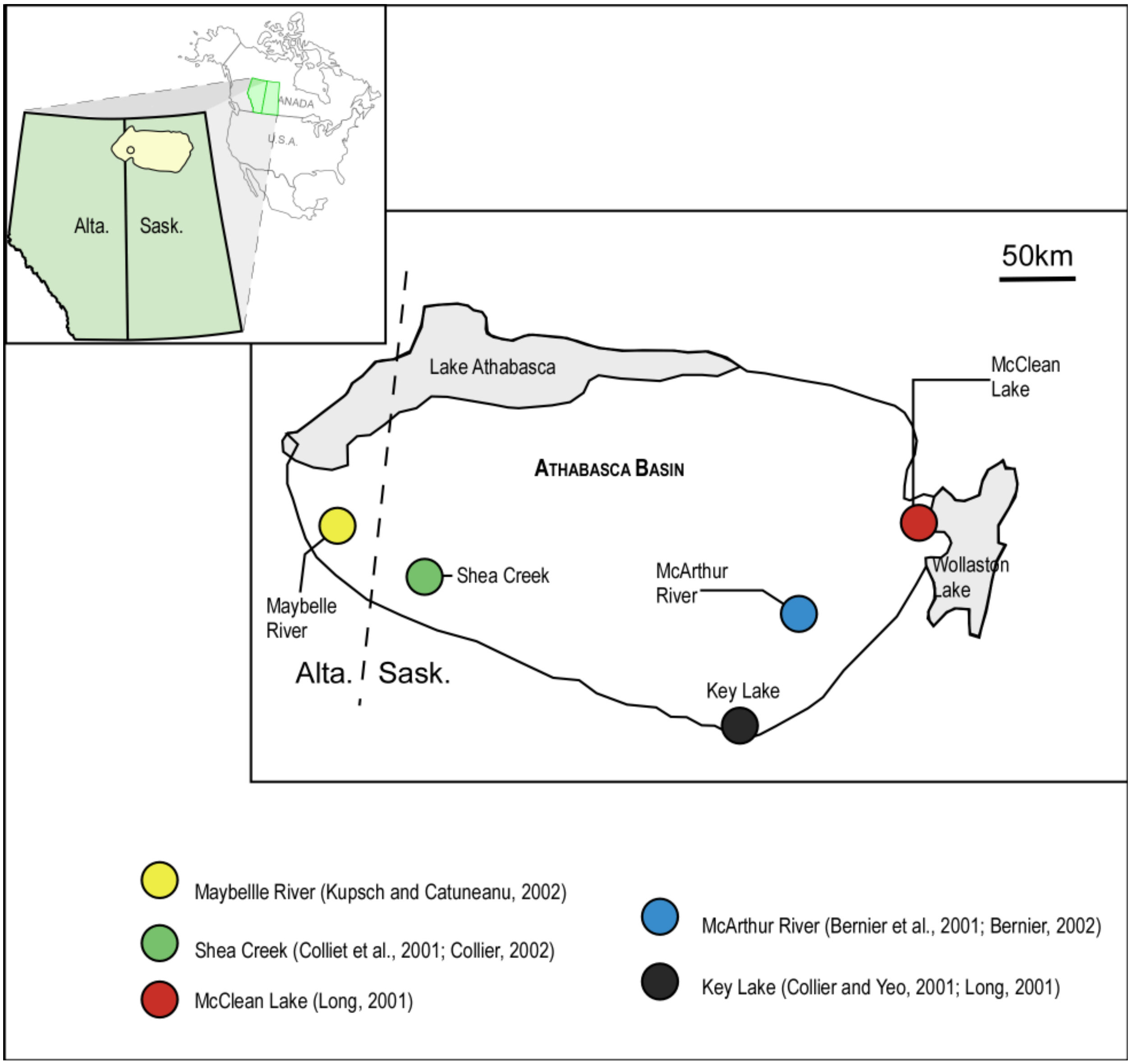


Figure 2. Location of detailed stratigraphic and sedimentological studies carried out under the EXTECH IV uranium project.

2 Overview of the Regional Geology

2.1 Basement Lithology

The crystalline basement underlying the Athabasca Basin consists of various lithotectonic assemblages of western Laurentia. The westernmost portion of the basin is underlain by the north-trending Taltson

Magmatic Zone (TMZ), which represents the southern segment of the Taltson-Thelon Orogen, the 1.98–1.89 Ga weld between the Archean Slave and Churchill provinces (e.g., McDonough et al., 2000; McNicoll et al., 2000). Basement rock types include ca. 1.97 Ga granitoid and variously retrogressed granulite-facies metamorphic rocks (Stern et al., 2003; Pană et al., in press). To the south and east, basement rocks belonging to the Lloyd Domain have a very distinct aeromagnetic pattern. The Lloyd Domain includes massive to foliated granite to granodiorite and granitoid gneiss, with subordinate massive to weakly foliated granite and metabasite (Card, 2001). East, in Saskatchewan, the Lloyd Domain extends to the Clearwater Domain. The eastern Athabasca Basin extends over portions of the Trans-Hudson Orogen, which represents the 1.9–1.8 Ga weld of the Churchill Province to the Superior Province (e.g., Card, 2001).

At the Athabasca Group-basement contact, there is a zone of extensive regolith alteration, ranging in thickness from 5.5 to 47 m, in which hostrock textures are commonly preserved (Wilson, 1986). The alteration pattern is delineated by an upper clay-rich bleached zone, followed by red (hematitic) and green (chloritic) zones. Zone thickness is variable between drillholes, with polyphase alteration commonly overprinting the zonation pattern.

2.2 Athabasca Group

The current model for the stratigraphy of the Athabasca Group was developed by Ramaekers (1978, 1979, 1980, 1981, 1990, 2004). He recognized eight lithostratigraphic formations within the Athabasca Basin, which have been further subdivided into members, designated with a letter suffix (Table 2). Some of these, in turn, have been further subdivided into submembers. The formations have been categorized into two subgroups: the William River Subgroup, comprising mainly fluviatile sandstone; and the Points Lake Subgroup, comprising mudstone, sandstone and dolomite of lacustrine and/or marine origin (Ramaekers, 1990). Type sections for these formations have been outlined by Ramaekers (1990).

2.2.1 Fair Point Formation

The Fair Point Formation (Ramaekers, 1979) forms the base of the William River Subgroup and is restricted to the northwestern portion of the Athabasca Basin, mostly in Alberta. It typically rests unconformably on high-grade crystalline rocks of the Taltson Magmatic Zone (Pană et al., in press.). North of Lake Athabasca, it unconformably overlies greenschist-grade metasedimentary rocks of the Martin Group (e.g., Ramaekers et al., 2001).

The clay-rich Fair Point Formation has been subdivided into three informal members: FPa, FPb and FPc (e.g., Ramaekers, 2004). The lowermost ‘a’ member is characterized by pebbly sandstone containing abundant red siltstone interbeds and subordinate conglomerate. The overlying ‘b’ member is characterized by massive to bedded conglomerate and pebble-bearing coarse-grained sandstone with clasts up to 50 mm in diameter. The uppermost ‘c’ member comprises pebbly sandstone that is deficient in conglomerate. Pebbles are typically well-rounded quartz clasts with minor, more angular clasts of mafic and felsic basement rocks (Wilson, 1985; Ramaekers, 1990). The Fair Point Formation reaches a maximum thickness of 310 m in the northern Alberta portion of the Athabasca Basin. It has also been identified in Saskatchewan, within and surrounding the Carswell Structure (Pacquet and McNamara, 1985; Yeo et al., 2001a).

Table 2. Stratigraphic summary of the Athabasca Group, northern Saskatchewan and northeastern Alberta (*modified from* Ramaekers et al., 2001)

Sub-group	Formation	Member	Lithology
Points Lake	Carswell	CF	Dolostone; stromatolites, ooids, and synsedimentary breccia common
	Douglas	DF	Very fine grained sandstone, siltstone; black, red, and green mudstone; load casts, mud and syneresis cracks common
William River	Otherside	OFb	Fine-grained sandstone; MTG <2 mm; clay intraclasts
		OFa	Fine-grained sandstone with granules and pebbles <8 mm; clay intraclasts
	Locker Lake	LLc	Fine-grained to coarse pebbly sandstone; minor silt and mudstone; MTG 8–16 mm
		LLb	Fine-grained to coarse pebbly sandstone; minor silt and mudstone; MTG >16 mm; horizontal and low-angle crossbedding
		LLa	Fine-grained to coarse pebbly sandstone; minor silt and mudstone; MTG 2–16 mm
	UNCONFORMITY		
	Wolverine Point	WPc	Very well sorted, clay-rich, fine- to medium-grained sandstone; minor siltstone and mudstone
		WPb3	Very fine to medium-grained sandstone, mudstone thicker than 20 cm, tuffaceous relicts; small intraclasts in thin beds
		WPb2	Very well sorted, clay-rich, fine- to medium-grained sandstone, minor siltstone, and mudstone
		WPb1	Very fine to medium-grained sandstone, mudstone thicker than 20 cm, tuffaceous relicts; small intraclasts in thin beds
		WPa2	Very fine to coarse-grained sandstone
		WPa1	Very fine to coarse-grained sandstone, minor thin siltstone and mudstone
	Lazenby Lake	LzL	Basal thin conglomerate, pebbly and coarse- to fine-grained sandstone
	Manitou Falls	MFd	Fine- to medium-grained sandstone; clay intraclasts >2% of rock
		MFd'	Fine- to coarse-grained sandstone and pebbly sandstone; intraclasts >2% (only in northern portions of the basin)
		MFc	Medium- to coarse-grained and pebbly sandstone; clay intraclasts <2% of rock
		MFc'	Medium- to coarse-grained and pebbly sandstone with minor siltstone and mudstone; intraclasts <2% (only in northern portions of the basin)
		MFb	Pebbly to coarse-grained sandstone, pebbly sandstone, conglomerate
		MFa2	Medium- to coarse-grained sandstone, pebbly sandstone, conglomerate
		MFa1	Fine- to coarse-grained sandstone with disseminated pebbles, mudstone; horizontal and low-angle crossbedding common
	UNCONFORMITY		
	Fair Point	FPc	Pebbly sandstone, sandstone; MTG <50 mm; horizontal and low-angle crossbedding common
		FPb2	Pebbly sandstone, sandstone, thin conglomerate; MTG >50 mm; horizontal and low-angle crossbedding common
		FPb1	Conglomerate and sandstone; horizontal and low-angle crossbedding common
		FPa	Conglomerate, pebbly sandstone, sandstone, siltstone; horizontal and low-angle crossbedding common
	Basal lag		Disseminated or bedded pebbles to boulders in sandstone

Abbreviation: MTG, maximum transported grain size

2.2.2 Manitou Falls Formation

The Manitou Falls Formation extends throughout the entire Athabasca Basin. It directly overlies crystalline basement throughout the majority of the basin, and unconformably overlies the Fair Point Formation in the northwest part of the basin. There is a sharp change in lithological characteristics, such as matrix clay, sedimentary structure and mean grain size, across the Fair Point–Manitou Falls unconformity (Kupsch and Catuneanu, 2002). The Manitou Falls Formation is informally subdivided into four members: MFa, MFb, MFc and MFd (e.g., Ramaekers, 2004). These members are widely recognized in the eastern portion of the Athabasca Basin (e.g., Yeo et al., 2000). The dominant member in the western part of the basin is the 'c' member. It is defined as clean sandstone that lacks the conglomerate interbeds of the underlying 'b' member, as well as the abundant clay intraclasts of the overlying 'd' member (Ramaekers, 1990). The lowermost Manitou Falls 'a' member is poorly defined at present. It has been recognized as a red mudstone–bearing unit at the base of the Athabasca Group in the southern part of the Alberta portion of the basin (Ramaekers, 2004). In Alberta, the Manitou Falls Formation is thickest in the southern portion of the basin, as it reaches a maximum of 300 m in drillhole ERC-04 on the Saskatchewan side of the boundary (*see* Yeo et al., 2001a).

2.2.3 Lazenby Lake Formation

The Lazenby Lake Formation is exposed throughout the western and central portions of the Athabasca Basin (Ramaekers, 1990). The base is marked by a disconformity, across which there is a contrast in lithology with the underlying Manitou Falls Formation (Yeo et al., 2001a). The Lazenby Lake Formation is characterized as a pebbly medium-grained sandstone with common overturned bedding (Yeo et al., 2001a; Kupsch and Catuneanu, 2002). It reaches a maximum thickness of 200 m in Alberta (Ramaekers, 2004).

2.2.4 Wolverine Point Formation

The Wolverine Point Formation is widespread throughout the central portion of the Athabasca Basin. It comprises relatively mudstone-rich sandstone and mudstone (Ramaekers, 1990) and conformably overlies the Lazenby Lake Formation, the stratigraphic boundary being placed where mudstone starts to become abundant (Ramaekers, 2004). In places, the two formations are probably coeval (Ramaekers et al., 2001).

The Wolverine Point Formation has been divided into three informal members: WPa, WPb and WPc (Ramaekers, 2004). The 'a' member comprises relatively finer grained sandstone with regular siltstone interbeds that range in thickness from 5 to 20 cm (Ramaekers, 1990). The 'b' member is relatively more clay rich and contains thicker and more abundant mudstone interbeds. These mudstone interbeds dominate the succession towards the top, where they contain reworked tuffaceous material (Ramaekers, 1990). The 'c' member comprises a thin succession of coarser clay-rich sandstone found at the top of the formation (Ramaekers, 2004). In Alberta, the Wolverine Point Formation reaches a thickness of approximately 500 m south of Lake Athabasca (Ramaekers, 2004).

2.2.5 Locker Lake Formation

The Locker Lake Formation forms the uppermost stratigraphic unit throughout much of the south-central Athabasca Basin (Yeo et al., 2001a). It is characterized by pebbly, medium- to coarse-grained sandstone that contains subordinate thin conglomerate interbeds (Ramaekers, 1990; Ramaekers et al., 2001; Yeo et al., 2001a). The Locker Lake Formation disconformably overlies the Wolverine Point Formation, the base of which is often marked by an influx of unmetamorphosed sandstone intraclasts over 8mm in diameter (Ramaekers, 1990).

The Locker Lake Formation has been subdivided into three informal members based on maximum grain-size characteristics: LLa, LLb and LLc. The ‘a’ and ‘c’ members typically contain clasts <6 mm, whereas the interstitial ‘b’ member contains clasts >16 mm. (Ramaekers, 2004). In Alberta, the Locker Lake Formation reaches a maximum thickness of 200 m where it subcrops south of Lake Athabasca (Ramaekers, 2004).

2.2.6 Otherside Formation

The Otherside Formation is the uppermost formation of the William River Subgroup. It subcrops throughout much of the central Athabasca Basin and is generally distinguished from the conformably underlying Locker Lake Formation by its lack of pebbles >8 mm (Ramaekers, 1990). The Otherside Formation consists of two informal members (Ramaekers, 2004): OFa and OFb. The ‘a’ member comprises fine- to coarse-grained sandstone containing isolated granules and small pebbles. The ‘b’ member is characterized as granule-free, fine- to coarse-grained sandstone with common siltstone interbeds. The Otherside Formation is less than 50 m thick in Alberta where it subcrops south of Lake Athabasca (Ramaekers, 2004).

2.2.7 Points Lake Subgroup

The Points Lake Subgroup overlies the fluvial-dominated formations of the William River Subgroup but is only preserved within the 356 Ma (Bell, 1985) Carswell meteorite structure, located in the west-central part of the basin, approximately 25 km east of the Saskatchewan border. Its basal contact is poorly exposed due to the impact (Ramaekers, 1990). The Points Lake Subgroup comprises two formations: the Douglas and the Carswell. The Douglas Formation is dominated by thick mudstone and siltstone with fine sandstone interbeds, and is estimated to be 200 m thick (Ramaekers, 1990). The Carswell Formation is dominated by algal-laminated and stromatolitic dolomites, and is estimated to be 400–500 m thick (Hendry and Wheatley, 1985).

2.3 Structural Features of the Western Athabasca Basin

There are two dominant orientations to faults in the western Athabasca Basin (*see* Figure 3), all faults appearing to be related to pre–Athabasca Basin shear zones. The first set of faults, including the Beatty River, Robillard, Grease River, Black Bay and Charlot faults, trends in a roughly east-northeast direction. The second set, which includes the Richardson, Maybelle River and Net Lake faults, trends roughly north-northwest; these are interpreted as splays off the Charles Lake Shear Zone (Ramaekers, 2004). The structural pattern of the basin appears to be largely related to indentation tectonics of the Slave-Churchill collision, the Churchill-Superior collision and other associated orogenic events leading to the development of Laurentia (Ross, 2002). Only the western and northwestern margins of the Athabasca Basin appear to be bounded by major faults (Ramaekers, 2004). It is unclear what tectonic processes initiated and, more importantly, absorbed subsidence following fault development.

An early depositional model suggested that the Athabasca Group was deposited in three northeasterly-trending, subparallel sub-basins separated by regional highs associated with Hudsonian-age faults (Ramaekers, 1990). The boundaries of these sub-basins have subsequently changed and new smaller sub-basins, or troughs, have been identified. In Alberta, structural features have largely been discussed in terms of such basement topographic lows and related highs (Ramaekers, 2004). These lows and highs appear to be related to fault movements that were syndepositional and postdepositional to the Athabasca Group (note that, in Figure 3, basement topographic lows are shaded). Two major basement lows in the Alberta portion of the Athabasca Basin are the Jackfish Sub-Basin and the Beatty Trough. These are separated by the Bartlett High (Ramaekers, 2004), over which the Maybelle River and Net Lake areas lie.

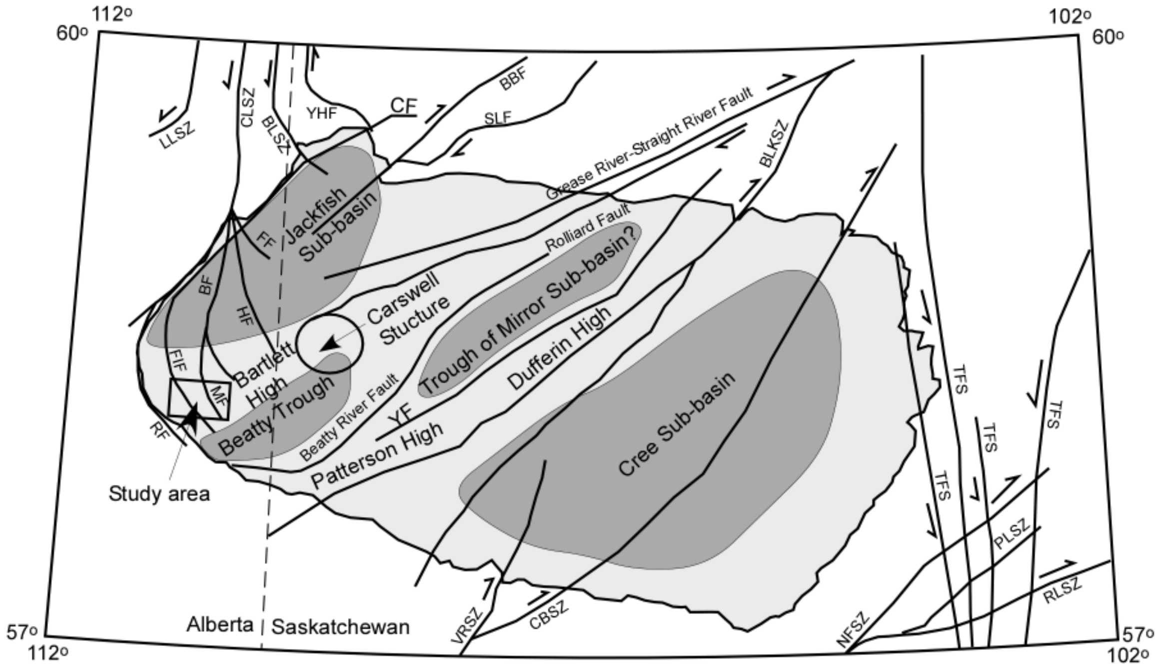


Figure 3. Faults and other structures of the Athabasca Basin (revised from Ramaekers, 2004). Study area is outlined in black. Basement lows are shaded. Key structural trends: BF, Bustard Fault; BBF, Black Bay Fault; BLKSZ, Black Lake Shear Zone; BLSZ, Bayonete Lake Shear Zone; CBSZ, Cable Bay Shear Zone; CF, Charlot Fault; CLSZ, Charles Lake Shear Zone; FF, Fidler Fault; FIF, Fletcher Fault; HF, Harrison Fault; LLSZ, Leland Lake Shear Zone; MF, Maybelle River Fault; NFSZ, Needle Falls Shear Zone; PLSZ, Parker Lake Shear Zone; RF, Richardson Fault; RLSZ, Reilly Lake Shear Zone; SLF, St. Louis Fault; TFS, Tabbernor Fault Systems; VRSZ, Virgin River Shear Zone; YF, Yaworski Fault; YHF, Yastsore Hill Fault. Note that the Maybelle River Fault is a splay of the Bustard Fault and the Net Lake Fault is the southern extension of the Fletcher Fault.

The Jackfish Sub-Basin is confined to the northwestern portion of the Athabasca Basin and defines the basin margin. The western and northwestern margins of the sub-basin appear to be bounded by the Charlot Fault and splays off the Charles Lake Shear Zone (Ramaekers, 2004), and it extends to the southeast toward the North Robillard Fault Zone. The Jackfish Sub-Basin was the major site of deposition for the Fair Point Formation; although the depositional basin for the Fair Point originally extended over the Bartlett High, since the Fair Point Formation can be traced to the South Robillard Fault zone. The current expression of the Jackfish Sub-Basin is therefore somewhat related to fault movement that postdates the Fair Point Formation.

The Beatty Trough is confined to the area between the South Robillard Fault and the Beatty River Fault (Ramaekers, 2004). This area contains the thickest succession of the Manitou Falls Formation in the Alberta portion of the Athabasca Basin (Ramaekers, 2004). South of the Beatty River Fault is a basement topographic high that extends to the southwestern margin of the basin. This is referred to as the Patterson High (Ramaekers, 2004).

3 Stratigraphy of the Southwest Athabasca Basin in Northeastern Alberta

Twenty-six diamond-drill holes were chosen along the Net Lake and Maybelle River faults. The basement is relatively shallow in the study area, making it of particular economic interest (Figure 4). Drillholes ranged from several tens to hundreds of metres in depth, the deepest being the most basinward, containing nearly 300 m of Athabasca Group (drillhole MR-84). In general, the Athabasca Group thins to zero edge along the southern margin of the study area and is thinner in the Net Lake area than in the Maybelle River area. Broader scale observations were recorded for the underlying basement and overlying Paleozoic rocks. Cross-sections and isopach plots for all of the stratigraphic units of this study are available in Appendix 2.

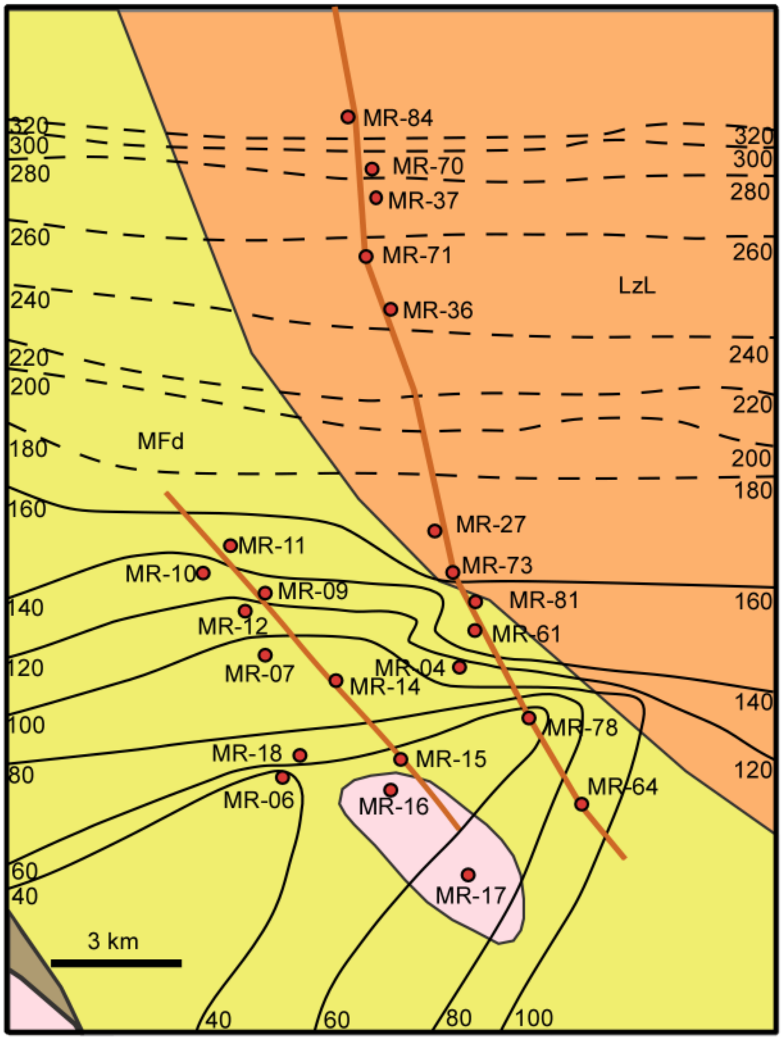


Figure 4. Depth to basement in the study area. Contour interval is 20 metres. Net Lake (left) and Maybelle River (right) trends are superimposed as orange lines. The southern area has abundant drillcore information, so contouring is more confident, as indicated by the solid contours. There is little information north of drillhole MR-27, so contouring is less confident, as indicated by the dashed contours.

The use of Ramaekers' (2004) lithostratigraphic scheme may not be the best means of subdividing the strata in the study area. To facilitate identification of units and members within the Athabasca Group in Alberta, the units have been subdivided into lithofacies associations or sets of lithofacies associations. Subdividing the strata in terms of facies gives a more realistic genetic meaning to these units, as opposed to division by arbitrary lithological picks. Table 3 summarizes the basic facies (*after* Miall, 1996) identified within the revised lithostratigraphic units outlined in the following section.

Table 3. Facies (*after* Miall, 1996) identified in the study area and their relation to the revised lithostratigraphic units along the Net Lake and Maybelle River trends.

	Facies	Names	Grain size	Sorting	Bed thickness	Bed contacts	Interpretation	Units[1]
Conglomerate and pebbly sandstone	Gmm (Pm)	Matrix-supported massive gravel	Granules and pebbles in a medium- to coarse-grained sand matrix	Poorly to extremely poorly sorted	Thinly to thickly bedded	Crude, nonerosive to slightly erosive and transitional	Noncohesive sediment gravity flows	FPl
	Gmc	Clast-supported massive gravel						
	Gi (Pi)	Indistinctly bedded gravel						
	Gh (Ph)	Crudely stratified gravel to pebbly sandstone			Thinly to medium bedded		Crude longitudinal bar forms	FPl, FPu (rare)
	G1	Granule to pebble layer, one granule thick	Granules to pebbles (fine to coarse matrix)	Poorly to moderately poorly sorted	Thickly laminated to very thinly bedded	Sharp	Lag deposits	FP, LzL
Sandstone	Sr	Rippled sandstone	Medium-grained sand	Moderately to well sorted, normal graded where apparent	Very thinly to thinly bedded (<5 cm thick)	Sharp, erosive, minor scour surfaces (change in grain size)	Ripples	MFc, MFd, LzL
	Sxc	Crossbedded sandstone	Medium- to coarse-grained sandstone		Thinly to medium bedded		Dune forms	FPl, FPu,
	Sm	Massive sandstone		Moderately to well sorted			Upper flow regime macroforms	FPl, FPu, MFc, MFd, LzL
	Sl	Low angle cross-beds		Moderately to well sorted		Crudely defined to sharp, erosive, minor scour surfaces (change in grain size)	Dune forms	FPl, FPu, MFc
	Sh	Horizontal beds		Moderately to well sorted	Thickly laminated to medium bedded	Sharp to crudely defined	Upper flow regime simple bar and macroforms	FPl, MFc, MFd, LzL
Fines	Fm	Massive siltstone and/or mudstone	Silt and very fine sand, minor sand, granules, and pebbles	Dependent on abundance of sand and granules	Thinly to medium bedded	Sharp	Lacustrine	FPl
	Fh	Horizontal, interbedded with sandstone, granule to pebbly conglomerate		Moderately to poorly sorted	Thickly laminated to thinly bedded	Sharp	Lacustrine, waning flood deposit to eddy deposit	FPl, MFc

[1] see Table 2 for explanation of abbreviations

Forty thin sections were chosen from selected drillcores for petrographic analysis. These were used to analyze mineralogy, sorting, rounding, fabric and clay content, which are difficult to describe in hand specimen. Point counts were also done on many of the thin sections. Petrographic data and lithologs are presented in Appendices 3 and 4, respectively.

3.1 Basement

The basement in the study area consists of a midcrustal, 1.963 Ga Wylie Lake suite (Figure 5; McDonough and McNicoll, 1997). Wilson (1986) divided the suite into lithological units. The most predominant unit is the Wylie Lake granitoid, a mesocratic, red to dark grey, medium-grained intrusive rock. Crystals are generally equigranular with localized zones of pegmatite. The granitoid is moderately foliated, with more intense foliation closer to shear zones, where mylonitic textures predominate. The dominant mineralogy is quartz, plagioclase, biotite and possibly hornblende. Compositionally, the Wylie Lake granitoid is granodiorite to tonalite (Wilson, 1986).

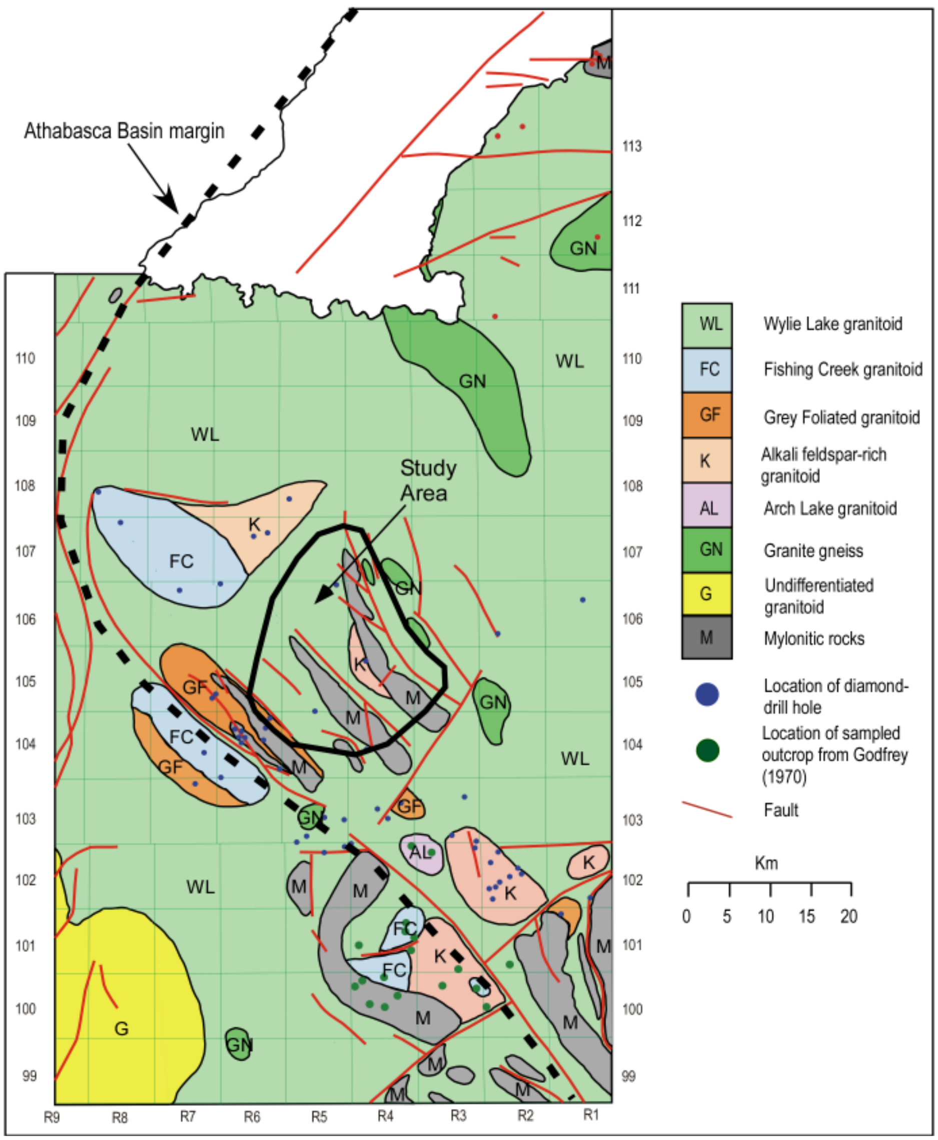


Figure 5. Basement geology of the western Athabasca Basin (revised from Wilson, 1986). Study area is outlined in black. Note that the major fault zones at Net Lake and Maybelle River parallel the mylonite zones (shear zones) of the basement.

The other prominent basement unit observed in the study area is the grey foliated granitoid of Wilson (1986). This granitoid is distinguished by its light to medium grey colour (e.g., drillhole MR-07). Texturally, it ranges from massive to well foliated. It is typically medium grained with localized pegmatite. The unit is dominated by quartz, plagioclase and alkali feldspar, with minor biotite and possibly clinopyroxene. Accessory minerals include minor almandine garnet and pyrite. The alkali feldspar–rich granitoid suite of Wilson (1986) was not positively identified in this study.

Mylonite zones generally coincide with later regional faults. In these zones, graphite and pyrite are typically common (e.g., drillholes MR-12, -64 and -81) and may be associated with fault-movement indicators. Intensely fractured, granitic augen are common within fault zones. Chlorite alteration is predominant in the mylonite zones. Ultra- to protomylonite textures are developed distal to the fault zones. Fault movements form rare dip-slip indicators (e.g., drillhole MR-81). Fractures infilled with calcite are commonly associated with the mylonite.

In this study, the thickness of the alteration zone beneath the Athabasca Group unconformity ranges from zero (e.g., drillhole MR-78), marked by fresh basement, to more than 60 m of intense digenesis (in drillholes MR-16 and -17). Identification of individual red-green zones is not apparent in the majority of holes due to subsequent polyphase alteration. As a result, it is not possible to correlate individual horizons along the Maybelle and Net Lake trends. Nevertheless, it is interesting that there is good zonation within the paleoweathered horizon surrounding the uraniferous zone at Maybelle River.

3.2 Stratigraphic Examination of the Fair Point Formation

The Fair Point Formation is widespread throughout the study area but is absent toward the south, along the southern margin of the Bartlett High (e.g., drillholes MR-07, -16, -17, -64, -76 and -78). In the study area, it thickens to the north from 0 to approximately 80 m (e.g., drillholes MR-70 and -84). The Fair Point Formation is a fining-upward sequence overprinted by five smaller-scale, fining-upward cycles traced across the study area. Cycles are typically 5–10 m thick, except for the uppermost cycle, which is 10–50 m thick. Cyclical sedimentation in the Fair Point Formation may be a result of local, intrabasinal change in depositional subenvironment (Jo et al., 1997). The overall fining-upward Fair Point succession is probably associated with allogenic processes, such as climate and tectonic regime (Ridgeway and DeCelles, 1993).

The Fair Point Formation is best distinguished by pebbles and by the abundant interstitial clay that constitute up to 12% by volume. The dominant pebble lithology is white quartz, although minor sandstone, siltstone and quartzofeldspathic basement clasts are also common. Subordinate regolith clasts are locally found at the base.

In Figure 6, the Fair Point Formation subdivision of Ramaekers (2003) is compared to the revised classification of this study. Due to lack of regional continuity in the study area, Ramaekers' (2004) Fair Point 'a' member has been grouped with the overlying Fair Point 'b' member to form a new lithological unit, referred to as the lower Fair Point Formation (FPl). Alternatively, it comprises two lithofacies associations similar to Ramaekers' members LA-1 and LA-2, respectively. The upper Fair Point Formation (FPu) is considered broadly equivalent to Ramaekers' (2004) Fair Point 'c' member. It consists of one lithofacies association, LA-3.

3.2.1 Lithofacies Association 1: Siltstone

Lithofacies association 1 is found locally above the basement unconformity up to 15 m thick. It is generally equivalent to Ramaekers' (2004) Fair Point 'a' member, best developed in drillhole

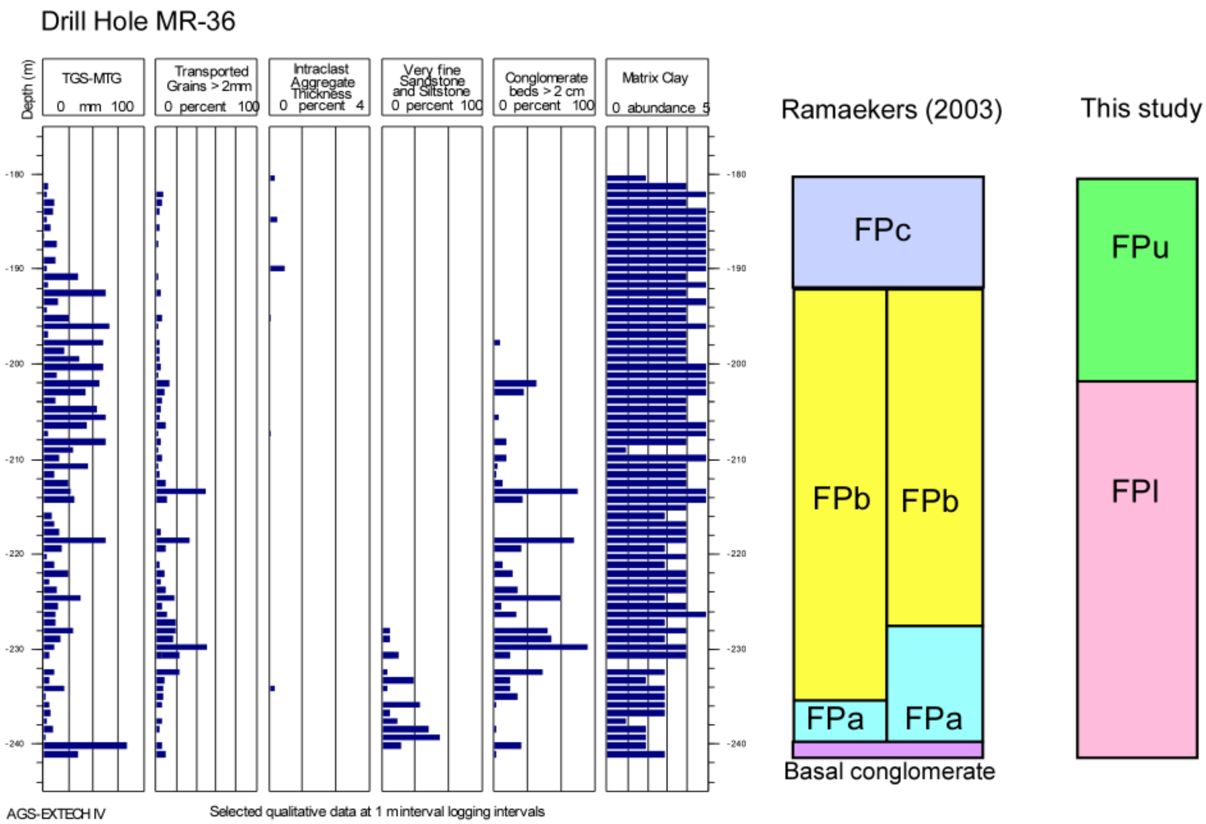


Figure 6. Quantitative metre-by-metre litholog for drillhole MR-36 (see Table 1 for descriptions of parameters). Ramaekers' (2003) regional classification is compared to the revised subdivision of this study. In Ramaekers' scheme, the break between FPa and FPb is unclear because siltstone typical of FPa is interbedded with conglomerate typical of FPb. The upper boundary with FPc is arbitrarily placed at the last 50 mm pebble, irrespective of primary sedimentary structure. The classification of this study is respective of sedimentary structure, dividing the Fair Point into two members. The lower Fair Point Formation is defined as siltstone and conglomerate-bearing sandstone. The upper Fair Point Formation is defined as predominantly massive pebbly sandstone with minor thin conglomerate interbeds at the base.

MR-36 (also in drillholes MR-06, -18 and -37). It comprises red, massive to planar-laminated siltstone (Figure 7a; lithofacies Fm and Fh of Miall, 1996), interbedded with poorly sorted, massive and planar-bedded, medium- to coarse-grained sandstone. Massive siltstone interbeds are more common toward the basal unconformity and occasionally display signs of soft-sediment deformation. Up-section siltstone units become interbedded with and are gradually replaced by thin- to- medium beds of clast-supported conglomerate and pebble-bearing sandstone. Localized matrix-supported conglomerate may be sand or silt supported.

This lithofacies is interpreted as having been deposited in a shallow-lake environment. Quiet-water sedimentation is supported by the predominance of siltstone and massive to flat-bedded sandstone. Lack of syndepositional pyrite or siderite supports deposition in an oxidizing environment (Platt and Wright, 1991). Lack of abundant carbonate and evaporate, and the presence of syneresis cracks indicate that the lake was not extremely alkaline (Allan and Warren, 1993; Sanz-Rubio et al., 1999). The interbedding and gradual replacement of siltstone with conglomerate indicates periodic, high-energy fluvial discharge into the system.

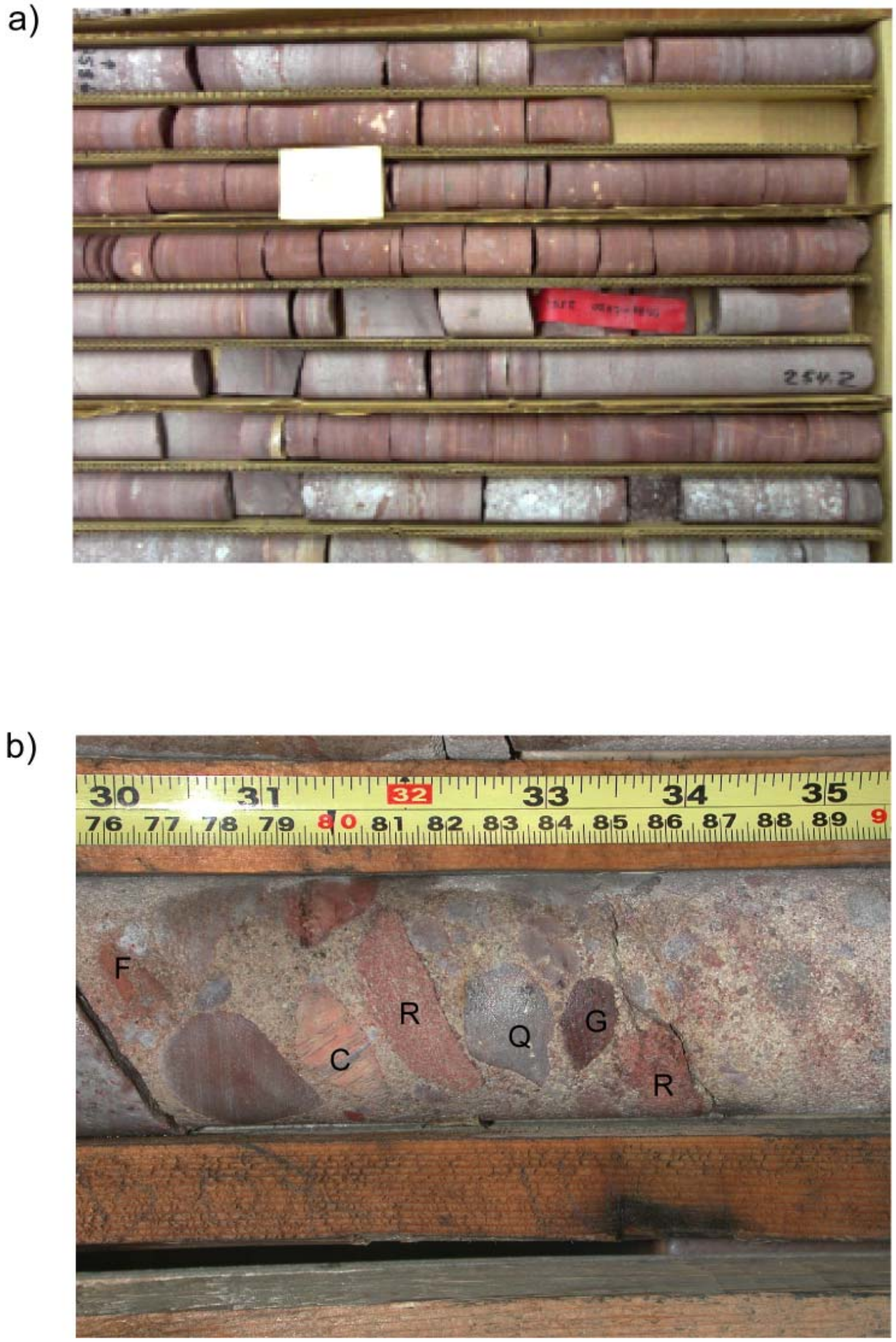


Figure 7. Photos of the lower Fair Point Formation: a) red, massive and planar-laminated siltstone interbedded with pebble conglomerate, typical of the lowermost siltstone facies (LA-1), from a depth of 254 m in drillhole FC-027, located approximately 20 km northwest of the study area (photo courtesy of Brent Collier); width of the photo represents 1 m; b) matrix- and clast-supported conglomerate typical of the conglomeratic lithofacies (LA-2), from a depth of 111.85 m in drillhole MR-04; clasts include altered clayey pebbles (C), resedimented Fair Point sandstone (F), regolith (R), granitoid (G) and quartz (Q).

3.2.2 Lithofacies Association 2: Pebble Conglomerate and Pebbly Sandstone

Lithofacies association 2 is commonly interbedded with the underlying red siltstone–rich lithofacies (LA-1). It is broadly equivalent to Ramaekers' Fair Point 'b' member and is best developed toward the northern part of the Maybelle River trend, where it reaches a maximum of 45 m thickness in drillhole MR-84. It is absent in the southern sections of the Maybelle River and Net lake areas (drillholes MR-14, 27, 73 and 81). The lithofacies is characterized by bleached to red-stained, poorly sorted, granule to pebble conglomerate (facies Gmm, Gmc, Gh and Gi of Miall, 1996), and pebbly sandstone (facies Pm, Pi and Ph). Thin to thick massive and crudely cross-bedded interbeds of matrix- and clast- supported conglomerate (Figure 7b; facies Gmm and Gmc) and common. The clasts are dominated by white quartz with subordinate quartzofeldspathic gneiss and granitoid pebbles present. These are generally subangular to subrounded and locally exceed 80 mm in diameter. Minor medium- to coarse-grained massive sandstone is interbedded throughout this facies and increases in abundance upsection. Interstitial clay is rich within the lithofacies, constituting 12% by volume.

This lithofacies is interpreted as having been deposited by noncohesive sediment gravity flows. Sediment gravity flows are defined as a mixture of sedimentary particles, entrained water and air that moves rapidly downslope under the force of gravity (Lowe, 1982; Blair and McPherson, 1994; Grant, 1997; Blair, 1999). The abundant floating pebble clasts are typical of this cohesionless character. The general paucity of silt and mud within the matrix indicates that the conglomeratic slurry did not behave as a cohesive, viscous, Bingham fluid. This lithofacies does not appear to have been deposited in a bedload-dominated fluvial system, as it lacks the consistent grading and clast imbrication typical of traction-style deposits (Bridge, 1993). Influx of pebbly sandstone interbeds may reflect changes in the hydraulic regime, related to flow velocity.

3.2.3 Lithofacies Association 3: Massive Sandstone

Lithofacies association 3 is gradational with the underlying pebbly and conglomeratic lithofacies (LA-2) where the latter is present. It broadly corresponds to Ramaekers' (2004) Fair Point 'c' member. It reaches a maximum thickness of 80 m in the Maybelle River area (e.g., drillhole MR-84; also found in drillholes MR-04, -09, -10, -11, -12, -14, -15, -18, -27, -36, -37, -61, -71, -73, -81 and -84). Where the lower Fair Point Formation is absent, this fining-upward lithofacies directly overlies basement (e.g., drillhole MR-27) and is considered to be coeval to the underlying lithofacies. It is characterized by moderately sorted, massive to crudely crossbedded, medium- to very coarse grained sandstone (Figure 8a), and is interbedded with minor, thin, pebble conglomerate and pebbly sandstone (predominantly facies Sm and Sxc). Conglomerate interbeds are typically concentrated at the base of the succession. The clast composition is similar to that of LA-2. Minor red-stained siltstone beds, typically less than 5 cm thick, occur periodically throughout the lithofacies.

Sandstone of the upper Fair Point Formation was deposited as hyperconcentrated flows, based on the lack of definable bedding, paucity of fines and consistent sand texture (Lowe, 1982; Costa, 1988; Blair and McPherson, 1994). Such systems contain sediment-rich, fluidized flows with limited cohesion (Costa, 1988). Grains appear to have been transported by grain-to-grain interaction, effectively raising system pore pressure and resulting in slurry movement. Fluvial morphological elements associated with this type of bedding regime are rarely preserved but may include crudely defined, low-angle, longitudinal bar forms and shallow, wide channels. Bar-form morphology is inferred to be relatively similar to that of the underlying conglomeratic unit. The lack of definable bedding may reflect postdepositional reworking in a relatively high-energy fluvial environment. Local conglomerate and pebbly sandstone lenses are interpreted as lag deposits. The depositional plane was probably at a relatively low gradient with respect to the underlying conglomeratic lithofacies.

a)

b)

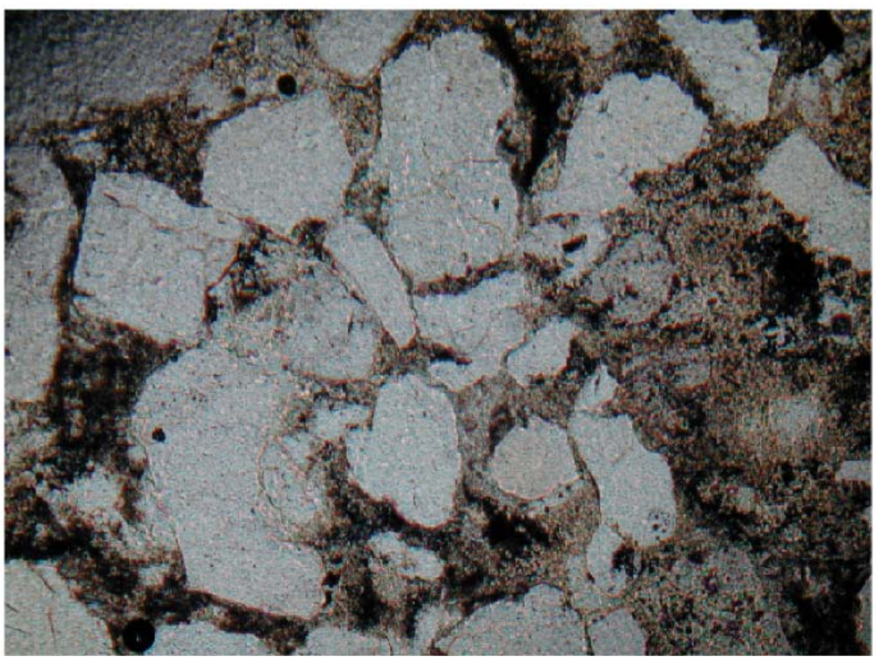


Figure 8. Photos of the upper Fair Point Formation: a) pebble-bearing, clay-rich, massive sandstone from a depth of 153.1 m in drillhole MR-81; note the subrounded clay-altered regolith clast; b) photomicrograph in plane-polarized light; note the abundant hematite clay and angular quartz clasts; width of photo represents approximately 5 mm.

a)

b)

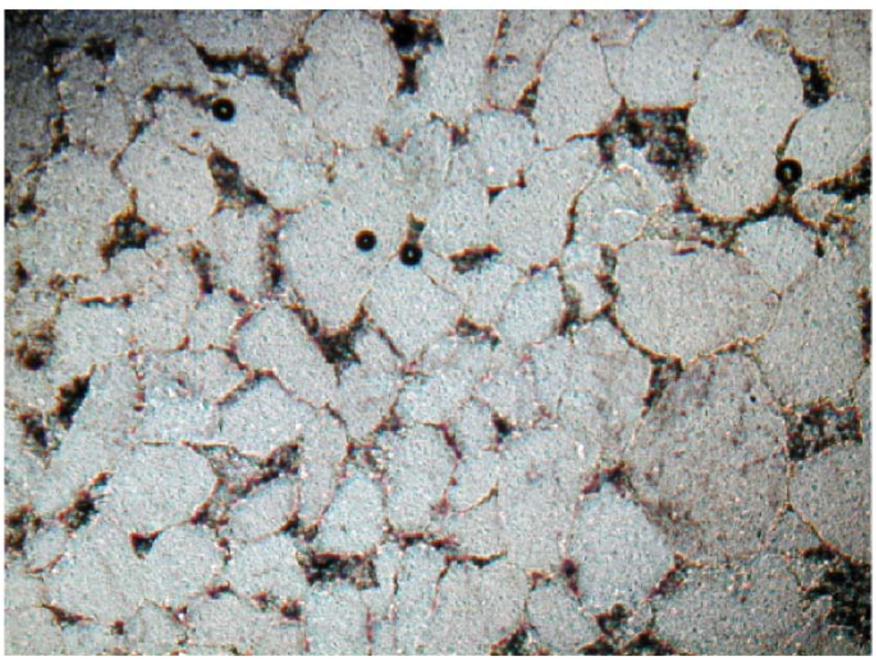


Figure 9. Photos of the Manitou Falls Formation: a) clay-poor, rippled and crossbedded, medium- to coarse-grained sandstone located directly above the basement unconformity (MFc), from a depth of 69.9 m in drillhole MR-76; b) photomicrograph, in plane-polarized light, of typical Manitou Falls Formation, from a depth of 93.5 m in drillhole MR-07; width of photo represents approximately 5 mm.

percentage of matrix clay is significantly less than that of the Fair Point Formation. White, sliver-like clay clasts are typically rare. Hematite staining is commonly associated with larger grain sizes.

The bedding style supports deposition via traction currents with hydraulic conditions dominated by bedload transport. Extrapolated through grain size and sedimentary structure, the dominant bedforms were dunes. These were probably deposited within wide, shallow channels. Flow velocity in such channels would have been approximately 1 m/s (e.g., Ashley, 1990). The abundance of granules and small pebbles within this lithofacies implies that the fluvial velocity prevented the formation of ripples (Ashley, 1990; Miall, 1996). Massive bed forms may be related to upper flow regime conditions associated with sheet floods.

3.3.2 Lithofacies Association 5: Intraclast-Bearing, Rippled, Medium-Grained Sandstone

This clay-poor lithofacies is the equivalent of Ramaekers' (1990) Manitou Falls 'd' member. It locally overlies the coarse-grained lithofacies (LA-4) or, where LA-4 is absent, directly overlies the Fair Point Formation. It is characterized by well sorted, ripple- and crossbedded, medium-grained sandstone (facies Sr with subordinate Sh, Sm and Sxc of Miall, 1996). Bedding is dominated by sets of thin ripple crosslaminae less than 5 cm thick. Massive beds are local and generally decrease in abundance upsection. Minor siltstone lenses are commonly less than 5 cm thick. Bed sets are normal graded. The maximum grain size rarely exceeds 2 mm. Small, white, sliver-like clay intraclasts have a patchy distribution throughout the facies. These generally increase in abundance upsection but rarely exceed 1.5% by volume. No regional variation in intraclasts abundance is apparent.

The dominance of ripple lamination and fine grain size of this lithofacies reflects low-velocity fluvial discharge on a low-gradient braid plain. Flow velocities in such channels would have been approximately 1 m/s (Miall, 1996). The resultant bed and channel forms probably consisted of low-angle ripple and dune forms. Based on the thickness of the bed sets, channel depth was probably less than 1 m. Massive beds may reflect upper flow regime conditions (e.g., Bridge, 1993) or, alternatively, insufficient sorting by burst-sweep processes. The presence of flow end members (ripples and massive bedding) supports the idea that flow velocity had a wide range (Ashley, 1990).

The prevalent clay intraclasts appear to be locally derived. The source of these intraclasts was probably semiconsolidated fines, deposited in quiet-water eddies off the main channel(s) or in standing pools during low-stage channel abandonment (Miall, 1996). Intraclast rip-up and subsequent deposition indicates frequent channel migration.

3.3.3 Petrography of the Manitou Falls Formation

The mineralogy of the Manitou Falls Formation is 99% quartz (Figure 9b). Grains are typically subrounded and moderately sorted, and display undulatory extinction. Trace patches of epitaxial clay were probably derived from feldspar minerals. Siltstone and fine-grained sandstone intraclasts are rare, as are grains of zircon and tourmaline. Grain-to-grain contacts are commonly concavo-convex and are typically sutured. The samples generally exhibit low porosity with minor interstitial, amoeba-shaped voids (<0.5 mm in diameter).

Interstitial clay, probably consisting of kaolinite and illite, may represent diagenetically altered mud. Hematite is found throughout the formation, usually as rims on quartz grains. Silica is the dominant cement, mostly found as overgrowths on quartz grains. Muscovite is present as thin disseminated laths in solution seams or microstylolites. Calcite cement was observed in trace quantities.

3.4 Stratigraphic Examination of the Lazenby Lake Formation

The Lazenby Lake Formation is distinguished by its pebble content and abundant overturned bedding. It subcrops towards the northern limit of the Maybelle River Fault in the study area (e.g., drillholes MR-27, -36, -37, -70, -71, -73 and -84), where it reaches approximately 30 m in thickness. It is completely eroded in the Net Lake area. The unconformity with the underlying Manitou Falls Formation is a marked by an increase in massive fines, a change in grain size and a decrease in abundance of clay intraclasts. Only one lithofacies association, LA-6, was identified in the study area.

3.4.1 Lithofacies Association 6: Pebble-and Granule-Bearing, Rippled and Massive Sandstone

Lithofacies association 6 consists of clay-poor, granule- to pebble-bearing, fine- to medium-grained sandstone (facies Sr, Sm and G1 of Miall, 1996). It is typically rippled and crossbedded, with minor fine- to medium-grained interbeds of massive sandstone. Overturned and convolute bedding are pervasive (Figure 10a). Minor quartz granules and small pebbles are present throughout the formation, constituting 1–2% by volume. Pebbles are locally as large as 27 mm (e.g., drillhole MR-73). They are either found as floating clasts or are concentrated as one-clast-thick layers on bedding planes (G1 layers). The maximum grain size in the Lazenby Lake Formation exhibits an overall fining-upward trend. Clay content is similar to that of the Manitou Falls Formation at approximately 2 % by volume. Ubiquitous hematite staining frequently overprints and cross-cuts sedimentary structures.

The predominance of ripple laminae supports deposition from traction current–dominated, low-velocity, braided fluvial systems. The massive beds may represent high-flow conditions. Alternatively, they may indicate low-flow or stagnant-flow conditions, where a decrease in velocity and associated shear strength resulted in the massive deposition of sand (e.g., Martin and Turner, 1998). Convolute bedding has been attributed to frictional drag over water-saturated sediment during high-energy flows (Collier, 2002). The minor but consistent presence of quartz granules and pebbles has been interpreted as lag deposits within the channel or on the upstream face of bar forms.

3.4.2 Petrography of the Lazenby Lake Formation

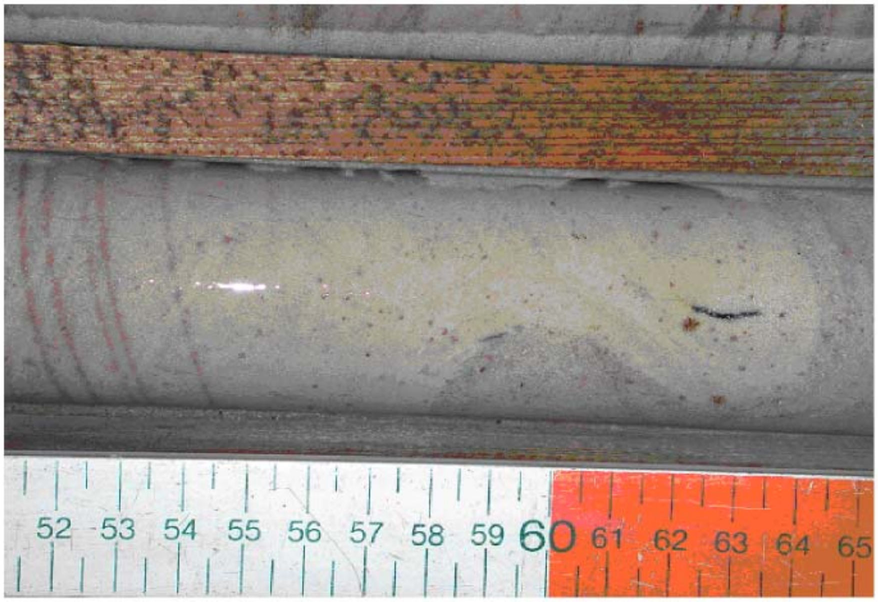
Microscopically, the Lazenby Lake Formation is very similar to the Manitou Falls Formation. It is texturally massive and comprises 99% quartz grains. Grain-to-grain contacts are typically concavo-convex and sutured. All grains exhibit undulose extinctions. Minor to trace amounts of optically independent epitaxial clay probably represent diagenetically altered feldspars. No definitive lithic fragments were observed.

The matrix consists of minor disseminated patches of kaolinite and illite clay. Hematite is found throughout the Lazenby Lake Formation, both rimming framework grains and as interstitial, anhedral masses (Figure 10b). Quartz overgrowths are found throughout the formation. Zircon and tourmaline are found in trace quantities and muscovite is present as thin disseminated laths along solution seams and microstylolites.

3.5 Paleozoic

In the southwestern corner of the study area, quartz arenites with calcareous cement and carbonate rocks unconformably overlie the Athabasca Group. These were only encountered in drillcore FC-034, where crinoid and brachiopod fossils were readily observed. A review of these strata was presented by Ramaekers (2004).

a)



b)

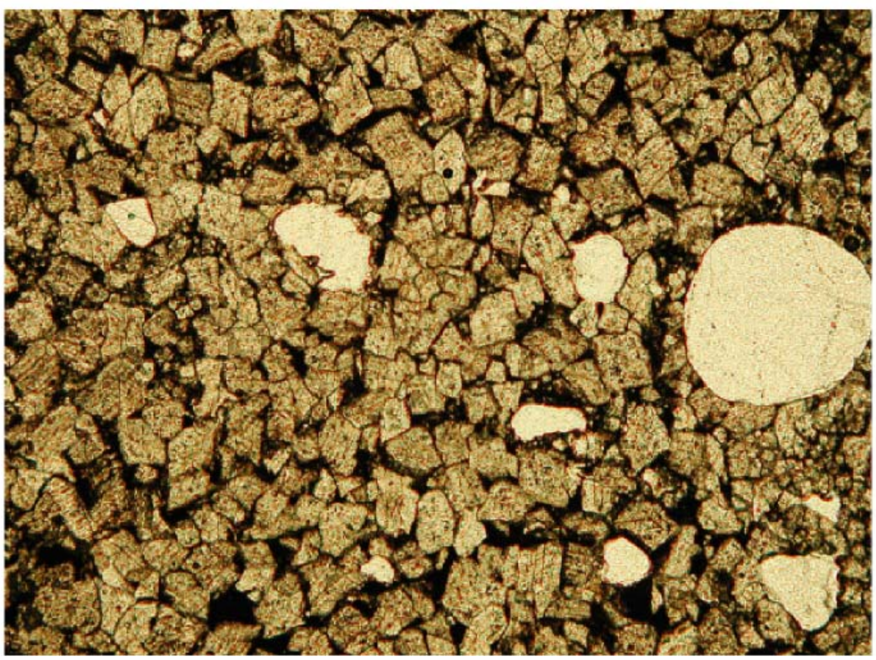


Figure 10. Photos of the Lazenby Lake Formation: a) overturned bedding, from a depth of 109.6 m in drillhole MR-84; b) photomicrograph, in plane polarized light, of extensively hematite stained (brown), moderately sorted sandstone from drillhole MR-71; note the large, rounded quartzite granule on the right; width of photo represents approximately 5 mm.

3.2.4 Petrography of the Fair Point Formation

Quartz predominates throughout this package (Figure 8b). There is no evidence of fresh feldspar, although lithic fragments are common. All clasts are typically poorly sorted and subrounded. Grain-to-grain contacts are usually concavo-convex and are commonly sutured. Fracturing of quartz grains occurs locally. Lithic fragments consist of igneous, metamorphic and sedimentary varieties. The most common types are clay-altered, massive to weakly foliated granite and quartzite clasts; altered to fresh gneissic clasts; and siltstone clasts. Trace minerals clasts include small (<1 mm in diameter), subhedral to anhedral zircon and tourmaline. Zircons have also been found as well-rounded inclusions in quartz. Tourmaline grains typically exhibit frayed authigenic overgrowths or 'suns' (Wilson, 1985). Micaceous solution seams and/or microstylolites are also apparent and are oriented subparallel to bedding. Subordinate amounts of fine-grained carbonate were observed throughout the formation.

Approximately 12% clay is found interstitial to the sandstone matrix. This is probably epitaxial cement rather than depositional mud; however, this is uncertain due to the intense diagenesis. If it is epitaxial cement, then the original labile minerals were probably feldspar, suggesting that the sandstone was originally subarenite or sublitharenite. Kaolinite and illite are the predominant clay minerals throughout the Fair Point Formation. It is unclear whether the groundmass of structureless kaolinite represents original clay, as suggested by Wilson (1985).

As with the clay minerals, distinguishing primary cement in the Fair Point Formation is problematic due to multigenerational diagenetic alteration. Secondary silica cement forms as quartz overgrowths on sand grains. Hematite is ubiquitous and may vary considerably in form and quantity. It is commonly found as fine rims around detrital quartz grains beneath the secondary quartz overgrowths; alternatively, it may be scattered throughout the matrix.

3.3 Stratigraphic Examination of the Manitou Falls Formation

The Manitou Falls Formation in the study area is characterized by clay-poor (< 2%), moderately sorted, ripple- to crossbedded, medium-grained sandstone (Figure 9a). Where the underlying Fair Point Formation is absent (e.g., drillholes MR-07, -64, -76 and -78), the Manitou Falls directly overlies basement. The stratigraphic thickness of the Manitou Falls Formation increases northward from a zero edge, where it subcrops along the southeastern margin of the study area (e.g., drillholes MR-16 and -17), to a thickness of 100–120 m in drillholes MR-70, -71 and –84, where it is completely preserved beneath the Lazenby Lake Formation).

The majority of the Manitou Falls Formation in the western basin has previously been classified as the Manitou Falls 'c' member (e.g., Ramaekers, 2004). This study reclassified this succession as lateral equivalents of both Ramaekers' (1990) clean sandstone member (MFc) and clay intraclast–rich member (MFd). These are defined by the two lithofacies associations LA-3 and LA-4, respectively.

3.3.1 Lithofacies Association 4: Crossbedded, Medium- to Coarse-Grained Sandstone

Lithofacies association 4 corresponds to Ramaekers' (1990) Manitou Falls 'c' member. It is locally present throughout the study area (e.g., drillholes MR-10, -11, -15, -37, -61, -64, -70, -73, -76, -78, -81 and -84) and is commonly less than 10 m thick. It is characterized as a moderately to poorly sorted, medium- to coarse-grained sandstone containing granules and small pebbles (of facies Sr, Sxc, Sm and G1 of Miall, 1996). Crossbedding is the dominant sedimentary structure. Subordinate massive sandstone interbeds are locally up to 70 cm thick (drillhole MR-73). Minor, light orange, fine grained sandstone and siltstone lenses are interspersed throughout this lithofacies and are generally less than 2 cm thick. The

4 Diagenesis and Other Postdepositional Characteristics

Alteration features recorded on a detailed scale include silicification, friability and fractures. Tectonic and mineral-replacement features were only recorded where apparent. Logs displaying this alteration data are provided in Appendix 5. Hydrocarbon staining is pervasive throughout the Athabasca Group in the study area, derived from the nearby Athabasca Oil Sands of the McMurray Formation (Wilson et al., 2002).

Silicification is represented by drusy quartz along fractures or complete silicification of drillcore (Figure 11a). Stratigraphically, the relatively clay-poor Manitou Falls and Lazenby Lake formations are moderately silicified. On the other hand, the clay-rich Fair Point Formation is relatively weakly silicified. Local zones of intense silicification in lower sections of the Manitou Falls Formation were observed in holes along the Maybelle River trend, specifically proximal to the mineralized zone (e.g., drillholes MR-27, -36 and -73). Otherwise, there is no recognizable variation in silicification within the study area. Likewise, the overall succession is competent, with no regional variation in friability. Weak stratigraphic variation in friability is only apparent when comparing the Manitou Falls–Lazenby Lake succession with the Fair Point Formation, where the high clay content seems to make the drillcore more friable.

The most prominent tectonic features observed in core are oriented fractures and faults, and breccia. Both low-angle reverse faults and high-angle normal faults were identified, but the majority of faults lack movement indicators. Clay, pyrite and drusy quartz commonly infill faults and fractures. Infilling by pyrite and euhedral quartz occur predominantly in the Manitou Falls and Lazenby Lake formations. Infilling by clay is most prominent in the Fair Point Formation, where it is locally associated with breccia. In some places, clay gouge can be on the order of several tens of centimetres thick (Figure 11b). No major stratigraphic variation in fracture abundance is apparent in the study area. Stratigraphically, the Fair Point, Manitou Falls and Lazenby Lake formations average 3, 4 and 2.8 fractures/m, respectively. Fracture counts must be interpreted with caution, however, as some are related to recent breakage during core extraction and related activities.

Based on examination of alteration characteristics, the lack of significant change is probably due to the very localized nature of uranium deposits in the Athabasca Basin. These are limited in distribution by their structural controls, typically being less than 1 km long and a few metres wide and deep. As well, the corresponding alteration halo of known deposits is generally less than 2 km in diameter. Hence, the study area of Kupsch and Catuneanu (2002) theoretically may encompass the entire alteration halo.

Postmineralization pyrobitumen (Wilson et al., 2002) is present in core throughout the study area, with no apparent regional variation in distribution. Stratigraphically, the low-maturity hydrocarbons (Wilson et al., 2002) are in the form of sticky tar and hard pyrobitumen. These occur in greater abundance within the Manitou Falls and Lazenby Lake formations than in the Fair Point Formation. Hydrocarbons are also present in the overlying Paleozoic calcarenite and, in places, within the basement. Hydrocarbon habit ranges from fracture controlled to minor hydrocarbon buttons. Some zones are completely saturated, with spots and pervasive staining generally limited to the Manitou Falls and Lazenby Lake formations. It is postulated that hydrocarbon abundance and habit is related to: depth of strata, grain size, clay content, tectonic structures and changes in lithology (such as the Fair Point-Manitou Falls unconformity).

a)

b)

Figure 11. Photos of diagenetic features: a) drusy quartz along a fault, from a depth of 113 m in drillhole MR-09; b) clay gouge in the Fair Point Formation, from a depth of 263.9 m in drillhole MR-71.

5 Discussion

5.1 Depositional Model

5.1.1 Fair Point Formation

Initial deposition of the Athabasca Group occurred in small, shallow lakes in which the siltstone lithofacies of the lower Fair Point Formation was deposited. It is postulated that these lakes were confined to fault-controlled, linear paleovalleys. Lack of lithofacies continuity suggests that the surface area of the lakes was areally limited to less than a few kilometres. The thickest deposits coincide with coalescing fault splays (e.g., drillhole MR-36). Generation of accommodation space resulted in rapid infilling of the lacustrine systems by prograding deposits of interbedded conglomerate and massive to crudely crossbedded fluviatile sandstone.

The sedimentary style of the conglomerate interbeds reflects relatively infrequent and high-volume hyperconcentrated flows on a moderate slope in an alluvial-plain setting. The absence of laterally continuous, thick, coarsening-upward gravel sheets indicates that conglomerates were not deposited in alluvial fans (Blair and McPherson, 1994). Also, the lack of traction-style deposits suggests that these conglomerates were not deposited in a typical braided river system. Tangentially, the steepest slopes (i.e., the thickest conglomerate beds) correspond to areas where faults coalesced.

Overlying, conglomerate-rich sediments were deposited in transverse fluvial systems prograded out of slightly elevated, fault-controlled depositional basins (less than 20–25 km long). The Net Lake and Maybelle River faults probably influenced the depositional conduits. Prolonged erosion of the elevated hinterlands led to active backstepping and subsequent basin enlargement, indicated by the overall fining-upward profile of the Fair Point Formation. Deposition probably occurred as prograding sedimentary tongues off regional topographic highs that were later subdued.

Cyclicity in the Fair Point Formation may be a result of local, intrabasinal change in depositional subenvironment (Jo et al., 1997). The overall fining-upward Fair Point succession is probably associated with allogenic processes, such as climate and tectonic regime (Ridgeway and DeCelles, 1993).

5.1.2 Manitou Falls Formation

A dramatic change in fluvial style occurred across the Fair Point–Manitou Falls unconformity. The Manitou Falls Formation was deposited in a perennially low-gradient system, constructive, braided fluvial system, with slopes substantially lower than those of the Fair Point Formation. The locally occurring, coarser basal unit (MFc) may reflect possible infilling of eroded paleovalleys, which developed during the depositional quiescence prior to deposition of the Manitou Falls. Complete erosion of the Manitou Falls in the southern part of the study area (e.g., drillholes MR-16 and -17) is probably related to late or post-Athabasca uplift along the Maybelle River and Net Lake faults. The catchment basin for the Manitou Falls, as reflected by sedimentology and provenance, was many orders of magnitude larger then that of the Fair Point Formation. This is supported by the lateral extensivity of the Manitou Falls Formation throughout the Athabasca Basin.

5.1.3 Lazenby Lake Formation

The incomplete Lazenby Lake Formation was deposited in a fluvial environment similar to that of the Manitou Falls Formation. Flow was probably perennial, characterized by low-velocity discharge with frequent high-discharge events. The source of pebbles and granules in the Lazenby Lake Formation was distal. There is no evidence for bulk erosion of the underlying Manitou Falls Formation. Similar to the Manitou Falls Formation, deposition of the Lazenby Lake probably occurred in a series of low-relief fluvial tongues prograding off distal regional paleohighs.

5.2 Source Area

The large clast size, angularity and lithological diversity of the Fair Point Formation suggest a relatively proximal source area. A peak of 1.9 Ga detrital zircons is similar to the age of the underlying Taltson Magmatic Zone basement (Rainbird et al., 2002). A second peak of 2.6 Ga probably represent zircons derived from nearby Archaen granitoids, some of which may have been introduced into the Proterozoic basement as a result of crustal scale melting. Some of these zircons may be recycled from the underlying Martin Group, which crops out on the north shores of Lake Athabasca (Ramaekers, 2004). The deficiency of fine-grained interbeds in the majority of the Fair Point Formation suggests that sediment generated from granitic or gneissic basement, underwent minimal chemical weathering but intense mechanical weathering (Blair and McPherson, 1994).

Although there are no ages for the Manitou Falls Formation in Alberta, the dominant westerly paleocurrents indicate a source from the east (Ramaekers, 1990). Detrital zircons from the Manitou Falls Formation in the eastern Athabasca Basin are dominated by 1.83 Ga ages, characteristic of the Trans-Hudson Orogen (Rainbird et al., 2002). The presence of minor zircon and tourmaline throughout Manitou Falls indicates a plutonic source (Morton and Hallsworth, 1999). The overall provenance of the Manitou Falls Formation probably reflects a composite source terrain, with the strata representing an extremely large, low angle alluvial plain prograding from distal uplifted paleohighs associated with the Trans-Hudson Orogen (Yeo et al., 2002).

Based on limited paleocurrent data (Ramaekers, 1990), a change in source is inferred across the Lazenby Lake–Manitou Falls disconformity, although similar mineralogical composition and textural attributes (e.g., grain size) of the accessory minerals in the two formations support a similar plutonic source area. Ages were obtained from xenotime overgrowths on zircons in the correlative Wolverine Point Formation, suggesting a minimum age of 1.66 Ga for the Lazenby Lake Formation (Rainbird et al., 2002).

5.3 Tectonostratigraphic Model

Intracratonic basins are large, circular to ovoid, and are flanked or segmented by basement-cored arches (e.g. Howell and van der Pluijm, 1999; Aspler and Chiarenzelli, 1997; Aspler et al., 2001). Basin fill is broadly symmetrical, with intrabasinal asymmetries related to the migration of depocentres and syndepositional arching from allogenic processes, resulting in the superimposition of successive processes during basin evolution (Loup and Wildi, 1994). Subsidence in intracratonic basins is driven by tectonomagmatic processes (Leighton, 1996). Tectonic stress within a stable craton interior, relative to the plate margins, may arise from distal plate-boundary processes, up to 2000 km away, which are sufficient to cause crustal instabilities (Quinlan, 1987; van der Pluijm et al., 1997; Cloetingh et al., 1999). Intraplate crustal attenuation via mantle-driven processes can be related to lithospheric thinning during the emplacement of anorogenic intrusions (Nunn, 1994; Klein, 1995). Initial intracratonic basin–forming processes are problematic, since lengths of basin faults are an order of magnitude too small relative to the extension suggested by crustal thickness and subsidence (Loup and Wildi, 1994). The magnitude of subsidence in intracratonic basins cannot be strictly accounted for by sediment and water loading (DeRito et al., 1983). Numerous mechanisms have been proposed for basin initiation, and the processes that drive renewed subsidence, arching and tilting are controversial (e.g., Leighton, 1996; Howell and van der Pluijm, 1999). It is noted that climate would also affect sedimentation on a secondary level.

It is suggested here that the subsidence of the Athabasca Group was influenced by polyphase, multi-axial stress regimes, as represented by multiple unconformity surfaces, marking a protracted depositional history (*refer to* Figures 12 and 13 throughout the following discussion). The formations investigated in this study are all parts of different sequences, since they are all separated by unconformities (e.g., Yeo et al., 2002; Ramaekers, 2004).

5.3.1 Sequence 1: Fair Point Sequence

Deposition of the Fair Point Formation corresponds to initial, short-term, rapid subsidence. Fault-controlled deposition of the conglomerate and siltstone of the lower Fair Point Formation was probably related to small-scale footwall uplift of pre-existing highs formed by wrench tectonics (Ramaekers, 2004). This may be related to similar tectonics associated with deposition of the Martin Group (Ramaekers, 2004). The mechanism for initial subsidence may be related to the 1.75 Ga, southwest-trending band of plutonism, subparallel to the Trans Hudson Orogen, that is found throughout the Churchill Province (Peterson et al., 2002). Associated plutonic provinces may include the 1.7 Ga Nueltin granitoid and comagmatic Pitz rhyolite (200 km northeast of the Athabasca Basin; e.g., Peterson and van Breemen, 1999); unnamed 1.76 Ga plutons beneath the Athabasca Basin (e.g., Krogh and Clark, 1987); and the Swift Current anorogenic granitoid plutons (600 km south of the Athabasca Basin; Collerson et al., 1988). Emplacement of the Nueltin anorogenic granitoid and temporally associated plutonic bodies resulted from delamination of the lithospheric mantle, which caused local crustal extension along with passive mantle upwelling (Peterson et al., 2002). This could have triggered viscoelastic relaxation of the lower crust, as well as localized and regional lithospheric stretching (Klein, 1995). Initial stretching may have been accommodated in the faults, and quickly replaced by thermal subsidence.

Rapid conversion in subsidence regime is marked by deposition of the northward-thickening upper Fair Point Formation. This is probably related to ‘basin-wide’ thermal subsidence, in contrast to the lower Fair Point Formation, which was deposited during short-term, localized fault movements. The age of the Fair Point is unclear because the age of formation of the Athabasca Basin is poorly constrained (between 1.75–1.7 Ga), based on the occurrence of rare Pitz volcanic clasts and U-Pb dating of fracture-filled apatite in the Fair Point Formation (Cumming et al., 1987). The general lack of syndepositional volcanic rocks indicates that downwelling, related to second-order mantle convection cells (cold spots), was not a dominant mechanism.

5.3.2 Sequence 2: Manitou Falls Sequence

A major basin reorganization event corresponds to the development of the Fair Point–Manitou Falls unconformity, across which there is a change in tectonic regime. The length of time represented by this unconformity is unclear but considered to be on the order of 1–10 m.y. The regional subsidence regime of the Manitou Falls Formation was probably similar to that of the Fair Point Formation, with the basal, fault-controlled, conglomerate-bearing Manitou Falls Formation in the eastern Athabasca Basin (MFa and MFb of Ramaekers, 1990) corresponding to a short-lived, high-subsidence regime. This was followed by a protracted low-subsidence regime, resulting in deposition of the relatively finer and more distal Manitou Falls units (MFc and MFd). It is apparent that the basin underwent regional westward-directed tilting, as indicated by changes in paleocurrent directions (Ramaekers, 1990). In the study area, there is no evidence to suggest that localized syndepositional fault movement occurred during sedimentation of the Manitou Falls Formation. Nevertheless, the local distribution of the coarser, basal, Manitou Falls ‘c’ member suggests that localized fault movement probably predated the Manitou Falls Formation.

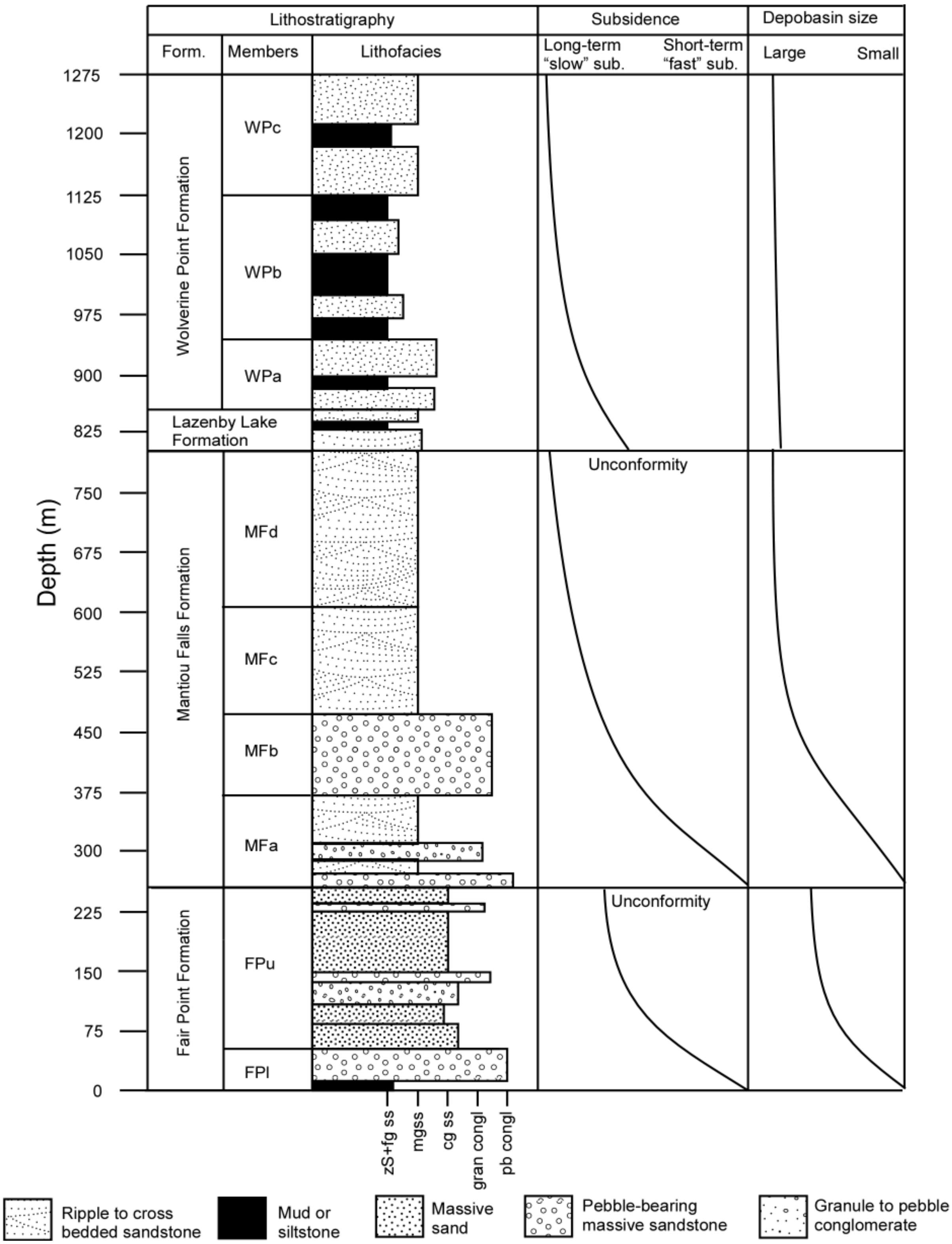


Figure 12. Correlation between lithostratigraphy, subsidence and depositional-basin size for the Athabasca Group. Lithological units and associated thicknesses are compiled from authors of the EXTECH project. Change in subsidence rates relative to basin size reflects change from localized, fault-controlled subsidence to regional thermal subsidence.

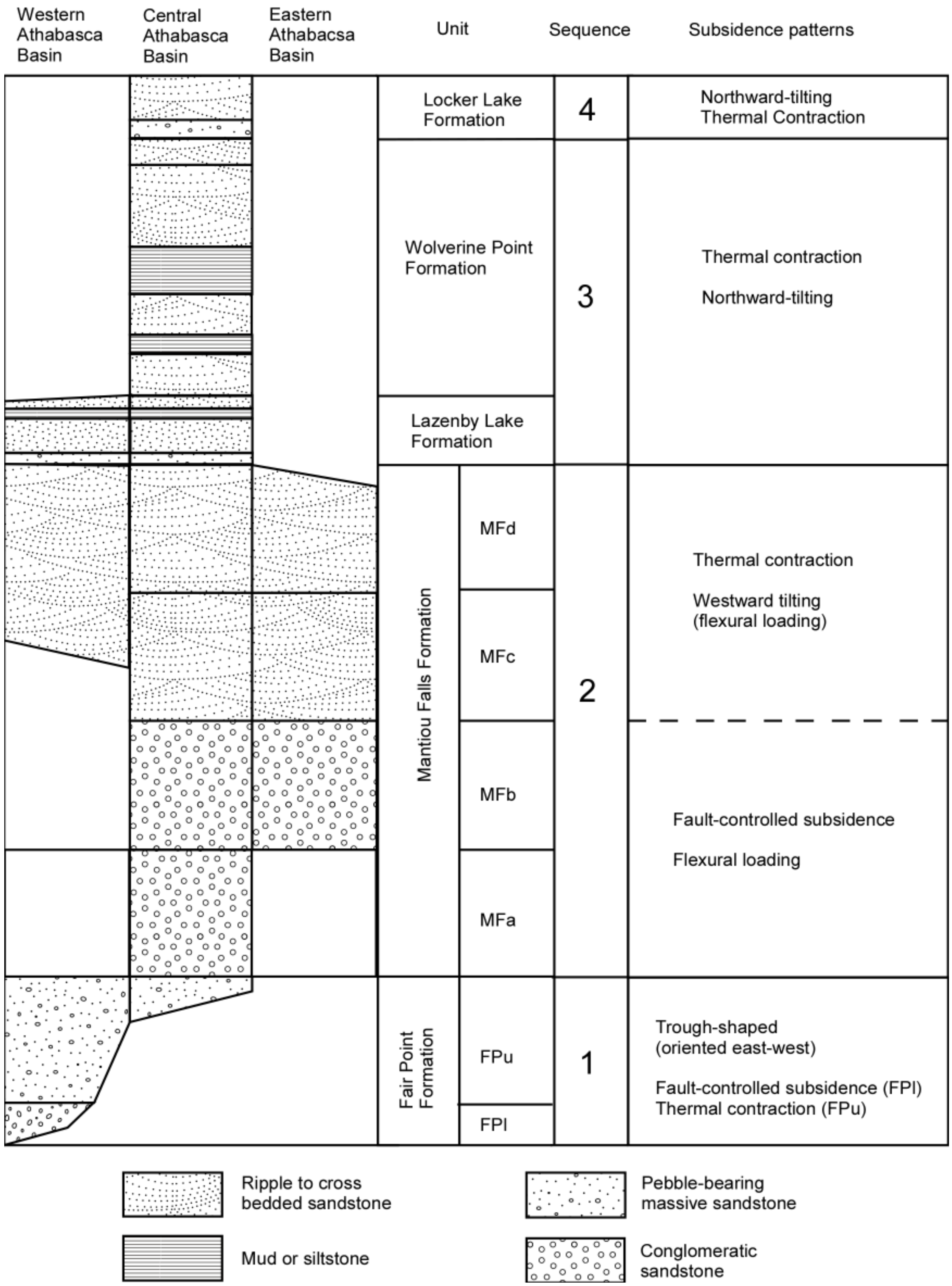


Figure 13. Stratigraphic column for strata of the entire Athabasca Basin, showing stratigraphic extent of the sequences, unconformities and inferred subsidence patterns. Data for Saskatchewan obtained from Bernier (2002) and Collier et al. (2001).

5.3.3 Sequence 3: Lazenby Lake–Wolverine Point Sequence

The driving mechanism for the development of the Manitou Falls-Lazenby Lake unconformity is unclear. It is possible that it may be related to the emplacement of distant granitoid intrusions that resulted in uplift of the Thompson Belt to the east (ca. 1.726–1.720 Ga; Machado, 1990). However recently, deposition of the Lazenby Lake-Wolverine Point sequence has been postulated to have occurred around 1.66 Ga (Rainbird et al., 2002) based on xenotime overgrowths on detrital zircons that are interpreted to be of early diagenesis.

The production of accommodation space for this basinward thickening sequence is suggestive of thermal subsidence regime. Subsidence was probably related to dynamic loading of the northward-convergent Central Plains Orogeny to the south (1780–1680 Ma; Dahl et al., 1999). It is unlikely that dynamic loading from the Yavapai Orogeny (1.79–1.69 Ga; Karlstrom and Bowring, 1988) and/or the Mazatzal Orogeny (1.71–1.62 Ga; Karlstrom and Bowring, 1987) influenced deposition of the Lazenby Lake–Wolverine Point sequence, as claimed by Ramaekers (2004), since the Athabasca Basin is too far removed from these orogenic fronts.

5.4 Stratigraphy as an Exploration Guide

Unconformity-hosted uranium mineralization requires the development of a steady-state redox front near or at the unconformity, with fluid interaction governed ultimately by porosity and permeability of the sedimentary strata and basement rocks. The occurrence of relatively impermeable, fault-controlled siltstone close to the unconformity could limit fluid interaction and hinder the development of the required redox front for mineralization.

The tectonostratigraphic position of the siltstone near or at fault intersections indicates that these locations, even though structurally favourable for exploration, are not necessarily lithostratigraphically favourable for exploration. Proximal to the uraniferous zone at Maybelle River (drillhole MR-39), the basal Fair Point Formation in most holes is largely deficient in siltstone and conglomerate. The similarity in matrix grain size between the conglomerate and the massive sand suggests that both rock types are favourable for mineralization. Because the original depositional slope probably controlled the fluvial architecture, this may be used to locate syndepositional faults.

6 Conclusions

6.1 Stratigraphic Revision of the Lower Athabasca Group

In the Maybelle River and Net Lake areas, the Fair Point Formation has been subdivided into lower and upper members. The lower Fair Point Formation consists of Ramaekers' (2003, 2004) Fair Point 'a' and 'b' members. It comprises siltstone and conglomerate-dominated lithofacies, interbedded with minor massive sandstone. The upper Fair Point Formation is dominated by massive to crudely crossbedded, medium- to coarse-grained sandstone with minor isolated conglomerate lenses. It broadly correlates to Ramaekers' (2003, 2004) Fair Point 'c' member. Conglomerate of the lower Fair Point Formation and the massive sandstone of the upper Fair Point Formation are probably coeval.

The majority of the Manitou Falls Formation in the study area, previously defined as Ramaekers' (1990) Manitou Falls 'c' member, has been reassigned to the Manitou Falls 'd' member. Only a thin succession of Manitou Falls 'c' is locally found at the base of the Manitou Falls Formation. No stratigraphic revision was necessary for the Lazenby Lake Formation.

6.2 Depositional and Tectonic Implications

Local lacustrine siltstone sedimentation of the lower Fair Point Formation was probably confined to fault-controlled paleovalleys, with the thickest deposits directly overlying coalescing fault splays. Renewed extensional tectonic activity resulted in the deposition of syntectonic conglomerate on alluvial plains, with the thickest conglomerate deposits also corresponding to coalescing faults. The upsection change to interbedded sandstone and conglomerate reflects enlargement of the catchment basin and the associated change in slope. The extensiveness of the upper Fair Point Formation sandstone supports a wide distribution for the Jackfish Sub-Basin, with fault-controlled paleohigh development possibly related to reactivation of Martin Group tectonics.

Deposits of the Manitou Falls 'c' and 'd' members in the study area are probably part of a basin-wide, low-gradient, perennial braided river system that originated from the distal Trans-Hudson Orogen located to the east. The unconformity separating the Fair Point Formation from the Manitou Falls Formation represents a significant time hiatus, as well as a change in the basin-scale tectonic regime. The depositional environment of the disconformably overlying Lazenby Lake Formation is marked by a perennial fluvial system similar to that of the Manitou Falls Formation.

Basin initiation was related to mantle-driven processes, with the subsidence regime being influenced by multi-axial forcing and subsidence-generation that were possibly related to Nueltin granitoid intrusions and the Pitz rhyolite of the Thelon Basin.

6.3 Economic Geology Implications

1) Alteration and other postdepositional characteristics may be important on a very localized scale. The area of this study was too regional to show any significant findings.

2) The basal siltstone in the lower Fair Point Formation may act as an impermeable barrier or aquitard to uranium mineralizing fluids. Its local presence may therefore be unfavourable to mineralization.

3) The alteration of the uranium prospect at Maybelle River indicates that the Maybelle River Fault is favourable and prospective for an important uranium deposit. In contrast, the prospectively of the Net Lake Fault is poorly known, although Ramaekers (2004) suggested that the local alteration along the trend makes it prospective.

7 References

Allan, T. and Warren. A. (1993): Deserts: the encroaching wilderness; Oxford University Press, New York, New York, 176 p.

Ashley, G.M. (1990): Classification of large-scale subaqueous bedforms: a new look at an old problem; Journal of Sedimentary Petrology, v. 60, p. 160–172.

Aspler, L.B. and Chiarenzelli, J.R. (1997): Initiation of ~2.45-2.1 Ga intracratonic basin sedimentation of the Hurwitz Group, Keewatin Hinterland, Northwest Territories, Canada; Precambrian Research, v. 81, p. 265-297.

Aspler, L.B., Wisotzek, I.E., Chiarenzelli, J.R., Losonzy, M.F. Cousens, B.L. McNicholl, V.J. and David, W.J. (2001): Paleoproterozoic intracratonic processes, from breakup of Kenorland to assembly of Laurentia: Hurwitz Basin, Nunavut, Canada; Sedimentary Geology, v. 141-142, p. 287-318.

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.

Bernier, S. (2002): Stratigraphy of the Manitou Falls Formation along the McArthur River high-resolution seismic survey B-B', Athabasca Basin, Saskatchewan; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, CR-ROM, Paper D-8, 11 p.

Bernier, S., Jefferson, C.W. and Drever, G.L. (2001): Stratigraphy of the Manitou Falls Formation in the vicinity of the McArthur River uranium deposit, Athabasca Basin, Saskatchewan: preliminary observations; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 291–296.

Blair, T.C. (1999): Cause of dominance by sheetflood versus debris slow processes on two adjoining alluvial fans, Death Valley, California; Sedimentology, v. 46, p. 1015–1028.

Blair, T.C. and McPherson, J.G. (1994): Alluvial fans and their natural distinction from rivers based on morphology, hydraulic processes, sedimentary processes, and facies assemblages; Journal of Sedimentary Research, v. 64, no. 3, p. 450–489.

Bridge, J.S. (1993): The interaction between channel geometry, water flow, sediment transport, and deposition in braided rivers; *in* Braided Rivers, J.L. Best and C.S. Bristow (ed.), Geological Society, Special Publication 75, p. 13–71.

Card, C.D. (2001): Basement rocks of 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.

Cloetingh, S., Burov, E. and Poliakov, A. (1999): Lithosphere folding: primary response to compression (from central Asia to Paris basin); Tectonics, v. 18, p. 1064–1083.

Collerson, K.D., Van Schmus, W.R., Lewry, J.F. and Bickford, M.E. (1988): Buried Precambrian basement in south-central Saskatchewan: provisional results from Sm-Nd models and U-Pb zircon geochronology; *in* Summary of Investigations 1988, Saskatchewan Geological Survey, Miscellaneous Report 88-4, p. 168–171.

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, CR-ROM, Paper D-10, 16 p.

Collier, B. and Yeo, G. (2001): Stratigraphy of the Paleoproterozoic Manitou Falls B Member in the Deilmann Pit, Key Lake, Saskatchewan; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 297–305.

Collier, B., Yeo, G., Long, D., Robbins, J. and Koning, E. (2001): Preliminary report of the stratigraphy of the Athabasca Group in the vicinity of the Shea Creek Project, southwestern Athabasca Basin, Saskatchewan; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 266–271.

Costa, J.E. (1988): Rheologic, geomorphic, and sedimentologic differentiation of water floods, hyperconcentrated flows, and debris flows; *in* Flood Geomorphology, V.R. Baker, R.C. Kochel and P.C. Patton (ed.), John Wiley and Sons, Ltd., Chichester, United Kingdom, 528 p.

Cumming, G.L., Krstic, D. and Wilson, J.A. (1987): Age of the Athabasca Group, northern Alberta; Geological Association of Canada–Mineralogical Association of Canada–Canadian Geophysical Union, Joint Annual Meeting, Program with Abstracts, v. 12, p. 35.

Dahl, P.S., Holm, D.K., Gardner, E.T., Hubacher, F.A. and Foland, K.A. (1999): New constraints on the timing of Early Proterozoic tectonism in the Black Hills (South Dakota), with implications for docking of the Wyoming Province with Laurentia; Geological Society of America Bulletin, v. 111, p. 1335–1349.

DeRito, R.F., Cozzarelli, F.A. and Hodge, D.S. (1983): Mechanism of subsidence of ancient cratonic rift basins; Tectonophysics, v. 94, p. 141–168.

Grant, G.E. (1997): Critical flow constrains flow hydraulics in mobile-bed streams: a new hypothesis; Water Resources Research, v. 33, p. 349–358.

Hayward, A. (1985): Coastal alluvial fans (fan deltas) of the Gulf of Aqaba (Gulf of Elat), Red Sea; Sedimentary Geology, v. 43, p. 241–260.

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. Lainé, D. Alonso and M. Svab M (ed.), Geological Association of Canada, Special Paper 29, p. 87–103.

Howell, P.D. and van der Pluijm, B.A. (1999): Structural sequences and styles of subsidence in the Michigan Basin; Geological Survey of America Bulletin, v. 111, p. 974–991.

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.

Jefferson, C.W., Percival, J.B., Bernier, S., Cutts, C., Drever, G., Jiricka, D., Long., D., McHardy, S., Quirt, D., Ramaekers, P., Wasyliuk, K. and Yeo, G.M. (2001): Lithostratigraphy and mineralogy in the eastern Athabasca Basin, northern Saskatchewan – progress in year 2 of EXTECH IV; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 272–290.

Jo, H.R., Rhee, C.W. and Chough, S.K. (1997): Distinctive characteristics of a stream-dominated alluvial fan deposit: Sanghori area, Kyongsang Basin (Early Cretaceous), SE Korea; Sedimentary Geology, v. 110, p. 51–79.

Karlstrom, K.E. and Bowring, S.A. (1988): Early Proterozoic assembly of tectonostratigraphic terrains in southwestern North America; Journal of Geology, v. 96, p. 561–576.

Klein, G.D. (1995): Intracratonic basins; *in* Tectonics of Sedimentary Basins, C.J. Busby and R.V. Ingersoll (ed.), Blackwell Scientific Publications, Oxford, United Kingdom, p. 459–478.

Krogh, T.E. and Clark, L.A. (1987): Zircon dating of sub-Athabasca granitoid rocks, Saskatchewan; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Program with Abstracts, v. 12, p. 64.

Kupsch, B.G. and Catuneanu, O. (2002): 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, CR-ROM, Paper D-11, 8 p.

Leighton, M.W. (1996): Interior cratonic basins: a record of regional tectonic influences; *in* Basins and Basement of Eastern North America, B.A. van der Pluijm, and P.A. Catacosinos (ed.), Geological Society of America, Special Paper 308, p. 77–93.

Long, D.G.F. (2001): Architecture of Late Paleoproterozoic fluvial strata of the Manitou Falls Formation at McClean Lake and Key Lake, eastern Athabasca Basin, northern Saskatchewan; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 306-313.

Loup, B. and Wildi, W. (1994): Subsidence analysis in the Paris Basin: a key to northwest European intracontinental basins; Basin Research, v. 6, p. 159-177.

Lowe, D.R. (1982): Sediment gravity flows: II. depositional models with special reference to the deposits of high-density turbidity currents; Journal of Sedimentary Research, v. 52, p. 279–297.

Machado, N. (1990): Timing of collisional events in the Trans-Hudson Orogen: evidence from U-Pb geochronology of the New Quebec Orogen, the Thompson Belt, and the Reindeer Zone (Manitoba and Saskatchewan); *in* The Early Proterozoic Trans-Hudson Orogen of North America, J.F. Lewry and M.R. Stauffer (ed.), Geological Association of Canada, Special Paper 37, p. 433–441.

Martin, C.A.L. and Turner, B.R. (1998): Origins of massive-type sandstones in braided river systems; Earth-Science Reviews, v. 44, p. 15–38.

McDonough, M.R. and McNicoll, V.J. (1997): U-Pb age constraints on the timing of deposition of the Waugh Lake and Burntwood (Athabasca) groups, southern Taltson magmatic zone, northeastern Alberta; *in* Radiogenic Age and Isotopic Studies: Report 10, Geological Survey of Canada, Current Research 1997F, p. 101–110.

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 collision and magmatic orogen, Paleoproterozoic Taltson magmatic zone, northeastern Alberta; Canadian Journal of Earth Sciences, v. 37, p. 1549–1573.

McNicoll, V.J., Thériault, R.J. and McDonough, M.R. (2000): Taltson basement gneisses: U-Pb and Nd isotopic constrains on the basement to the Paleoproterozoic Taltson magmatic zone, northeastern Alberta; Canadian Journal of Earth Sciences, v. 37, p. 1575–1596.

Miall, A.D. (1996): The Geology of Fluvial Deposits; Springer-Verlag, Inc., Berlin, Germany, 582 p.

Morton, A.C. and Hallsworth, C.R. (1999): Process controlling the composition of heavy mineral assemblages in sandstones; Sedimentary Geology, v. 124, p. 3–29.

Nunn, J.A. (1994): Free thermal convection beneath intracratonic basins: thermal and subsidence effects; Basin Research, v. 6, p. 115–130.

Pacquet, A. and McNamara, S. (1985): The study of the basal Athabasca succession in the D, E, L, F and S areas of the Carswell Structure; *in* The Carswell Structure Uranium Deposits, Saskatchewan, R. Lainé, D. Alonso and M. Svab (ed.), Geological Association of Canada, Special Paper 29, p. 81–86.

Pană, D.I., Creaser, R.A., Muehlenbachs, K. and Wheatley, K. (in press): Basement geology in the Alberta portion of the Athabasca Basin, with emphasis on the Maybelle River area; in EXTECH IV Athabasca Uranium Multidisciplinary Study, Northern Saskatchewan and Alberta, Jefferson, C.W. and Delaney, G. (ed.), Saskatchewan Geological Society, Mineral Deposits Division of GAC and Geological Survey of Canada, Special Volume.

Percival, J.B., Wasyliuk, K., Reif, T., Bernier, S., Drever, G. and Perkins, C.T. (2002): Mineralogical aspects of three drillcores along the McArthur River transect using a portable infrared spectrometer; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, CD-ROM, Paper D-14, 15 p.

Peterson, T.D. and van Breemen, O. (1999): Review and progress report of Proterozoic granitoid rocks of the western Churchill Province, Northwest Territories (Nunavut); *in* Current Research 1999-C, Geological Survey of Canada, p. 199–127.

Peterson, T.D., van Breemen, O., Sandeman, H. and Cousens, B. (2002): Proterozoic (1.85–1.75 Ga) igneous suites of the western Churchill Province: granitoid and ultrapotassic magmatism in a reworked Archean hinterland; Precambrian Research, v. 119, p. 73–100.

Platt, N.H. and Wright, V.P. (1991): Lacustrine carbonates: facies models, facies distributions and hydrocarbon aspects; *in* Lacustrine Facies Analysis, P. Anadón, L. Cabrera, and K. Kelts (ed.), International Association of Sedimentologists, Special Publication 13, Blackwell Scientific Publications, Oxford, United Kingdom, p. 57–74.

Quinlan, G. (1987): Models of subsidence mechanisms in intracratonic basins, and their applicability to North America examples; *in* Sedimentary Basins and Basin-Forming Mechanisms, C. Beaumont, and A.J. Tankard (ed.), Canadian Society of Petroleum Geologists Memoir, v. 12, p. 463–481.

Quirt, D. (1997): Metallogenetic model; *in* Geochemistry, Host-Rock Alteration, Mineralization, and Uranium Metallogenesis of the Wollaston EAGLE Project Area, Annesesley, Shi, and D. Quirt (ed.), Saskatchewan Research Council, p. 1–41.

Rainbird, R.H., Stern, R.H. and Jefferson, C.W. (2002): Summary of detrital zircon geochronology of the Athabasca Group, northern Saskatchewan and Alberta; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, CR-ROM, Paper D-17, 3 p.

Ramaekers, P. (1978): Reconnaissance geology of the interior Athabasca Basin; *in* Summary of Investigations 1978, Saskatchewan Geological Survey, Saskatchewan Department of Mineral Resources, Miscellaneous Report 78-10, p. 133–135.

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. (2003): Phases 1 to 4, EXTECH IV study of the Early Proterozoic Athabasca Group, northeastern Alberta; Alberta Energy and Utilities Board, EUB/AGS Special Report 61, 29 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. and Catuneanu, O. (in press): Development of sequences of the Athabasca Basin, Early Proterozoic, Saskatchewan and Alberta, Canada; *in* Tempos and Events in Precambrian Time, P.G. Eriksson, W. Altermann, D. Nelson, W.U. Mueller, O. Catuneanu and K. Strand (ed.), Elsevier Publishing Co. Amsterdam, Netherlands, Developments in Precambrian Geology.

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.

Ridgeway, K.D. and DeCelles, P.G. (1993): Stream-dominated alluvial fan and lacustrine depositional systems in Cenozoic strike-slip basins, Denali fault systems, Yukon Territory; Sedimentology, v. 40, p. 645–666.

Ross, G.M. (2002): Evolution of Precambrian continental lithosphere in western Canada: results from LITHOPROBE studies in Alberta and beyond; Canadian Journal of Earth Sciences, v. 39, p. 413–437.

Sanz-Rubio, E., Hoyos, M., Calvo, J.P. and Rouchy, J.M. (1999): Nodular anhydrite growth controlled by pedogenic structures in evaporate lake formations; Sedimentary Geology, v. 125, p. 195–203.

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

van der Pluijm, B.A., Craddock, J.P., Graham, B.R. and Harris, J.H. (1997): Paleostress in cratonic North America: implications for deformation of continental interiors; Science, v. 277, p. 794–796.

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

Wilson, J.A. (1986): Geology of the basement beneath the Athabasca Basin in Alberta; Alberta Research Council, EUB/AGS Bulletin 55, 61 p.

Wilson, N.S.F., Stasiuk, L.D. and Fowler, M.G. (2002): Post-mineralization origin of organic matter in Athabasca unconformity uranium deposits, Saskatchewan; *in* Summary of Investigations 2002, Volume 2, Saskatchewan Geological Survey, Saskatchewan Industry and Resources, Miscellaneous Report 2002-4.2, CR-ROM, Paper D-6, 6 p.

Yeo, G., Collier, B., Ramaekers, P., Koning, E., Robbins, J. and Jiricka, D. (2001a): 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., Percival, J.B., McHardy, S., Munholland, P., Collier, B., Gaze, A. and Williamson, C. (2000): Practical stratigraphy and flashy sedimentology in the Paleoproterozoic Manitou Falls Formation, eastern Athabasca Basin, Saskatchewan – an EXTECH IV progress report; *in* Summary of Investigations 2000, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Misc. Rep. 2000-4.2, p. 123–129.

Yeo, G., Jefferson, C.W. and Ramaekers, P. (2002): 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, CR-ROM, Paper D-7, 14 p.

Yeo, G., Jefferson, C.W., Ramaekers, P. and Tong, K. (2001b): From Palm to plot: core logging in the EXTECH IV Athabasca Basin stratigraphy subproject; *in* Summary of Investigations 2001, Volume 2, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 2001-4.2, p. 314–320.

Appendix 1 – Location, Stratigraphy and Drillhole Information for the Logged Cores

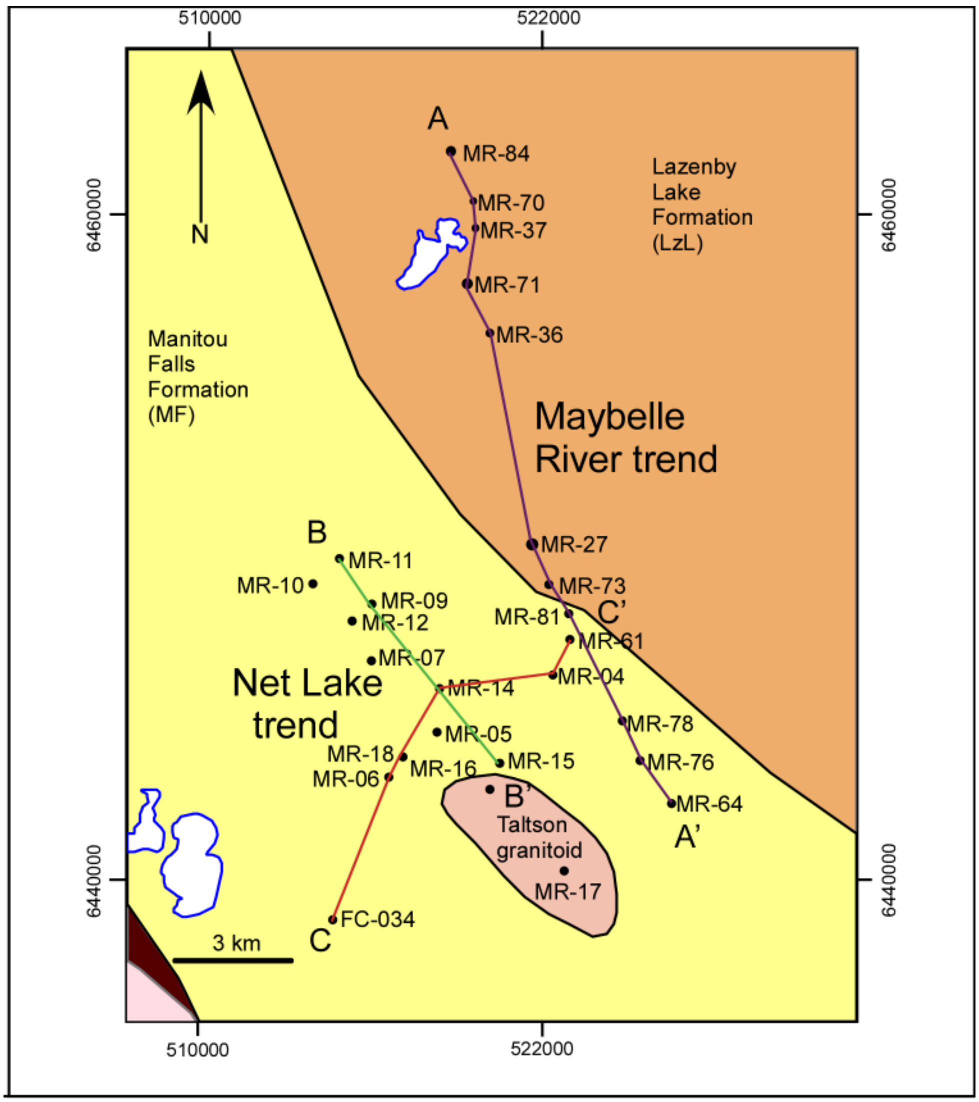
AGS ID	Long1	Lat1	Units present2	Drift thick. (m)	Basement depth	Hole depth	Inclination	Year	Company
FC-034	-110.755	58.085	Dev/MF	36.88	Not present	117.95	-90	1977	Eldorado
MR-04	-110.644	58.150	Dev/MF/FP/Base	40	121.5	248	-60	1986	Uranerz
MR-05	-110.703	58.135	Dev/Base	50	84.6	188	-60	1986	Uranerz
MR-06	-110.726	58.124	Dev/MF/FP/Base	36.7	57.1	191	-60	1986	Uranerz
MR-07	-110.735	58.154	Dev/MF/Base	38	100.4	185	-60	1986	Uranerz
MR-09	-110.735	58.169	Dev/MF/FP/Base	34.7	142.7	172.5	-60	1986	Uranerz
MR-10	-110.765	58.174	Dev/MF/FP/Base	46.7	149.5	194	-60	1986	Uranerz
MR-11	-110.751	58.181	Dev/MF/FP/Base	47.3	164	209	-60	1986	Uranerz
MR-12	-110.745	58.164	Dev/MF/FP/Base	32	115.9	197	-90	1986	Uranerz
MR-14	-110.701	58.146	Dev/MF/FP/Base	62.6	101.75	185	-65	1986	Uranerz
MR-15	-110.671	58.127	Dev/MF/FP/Base	39.7	55.5	192	-60	1986	Uranerz
MR-16	-110.675	58.120	Dev/Base	50	63.4	170	-60	1986	Uranerz
MR-17	-110.639	58.098	Dev/Base	36.5	76.3	186	-60	1986	Uranerz
MR-18	-110.719	58.128	Dev/MF/FP/Base	33.7	78.5	182	-90	1986	Uranerz
MR-27	-110.654	58.185	LzL/MF/FP/Base	34.8	201	278	-60	1987	Uranerz
MR-36	-110.674	58.241	LzL/MF/FP/Base	43	278.2	326	-60	1988	Uranerz
MR-37	-110.682	58.269	LzL/MF/FP/Base	68	308.4	380	-60	1988	Uranerz
MR-61	-110.635	58.159	MF/FP/Base	61.3	182.3	255.8	-60	1989	Uranerz
MR-64	-110.585	58.116	Dev/MF/Base	28	117.8	270.3	-60	1989	Uranerz
MR-70	-110.683	58.276	LzL/MF/FP/Base	64	339.4	417.9	-60	1989	Uranerz
MR-71	-110.687	58.254	LzL/MF/FP/Base	51	275.5	349.6	-60	1989	Uranerz
MR-73	-110.646	58.174	LzL/MF/FP/Base	31	195.3	239	-60	1990	Uranerz
MR-76	-110.600	58.127	Dev/MF/Base	37.5	71.3	137	-60	1990	Uranerz
MR-78	-110.610	58.138	Dev/MF/Base	28.9	59.5	83	-60	1990	Uranerz
MR-81	-110.636	58.166	MF/FP/Base	36.6	173.9	233	-60	1990	Uranerz
MR-84	-110.695	58.289	LzL/MF/FP/Base	39.7	338	389	-90	1990	Uranerz

1 relative to NAD83 datum
2 see Table 2 for explanation of abbreviations

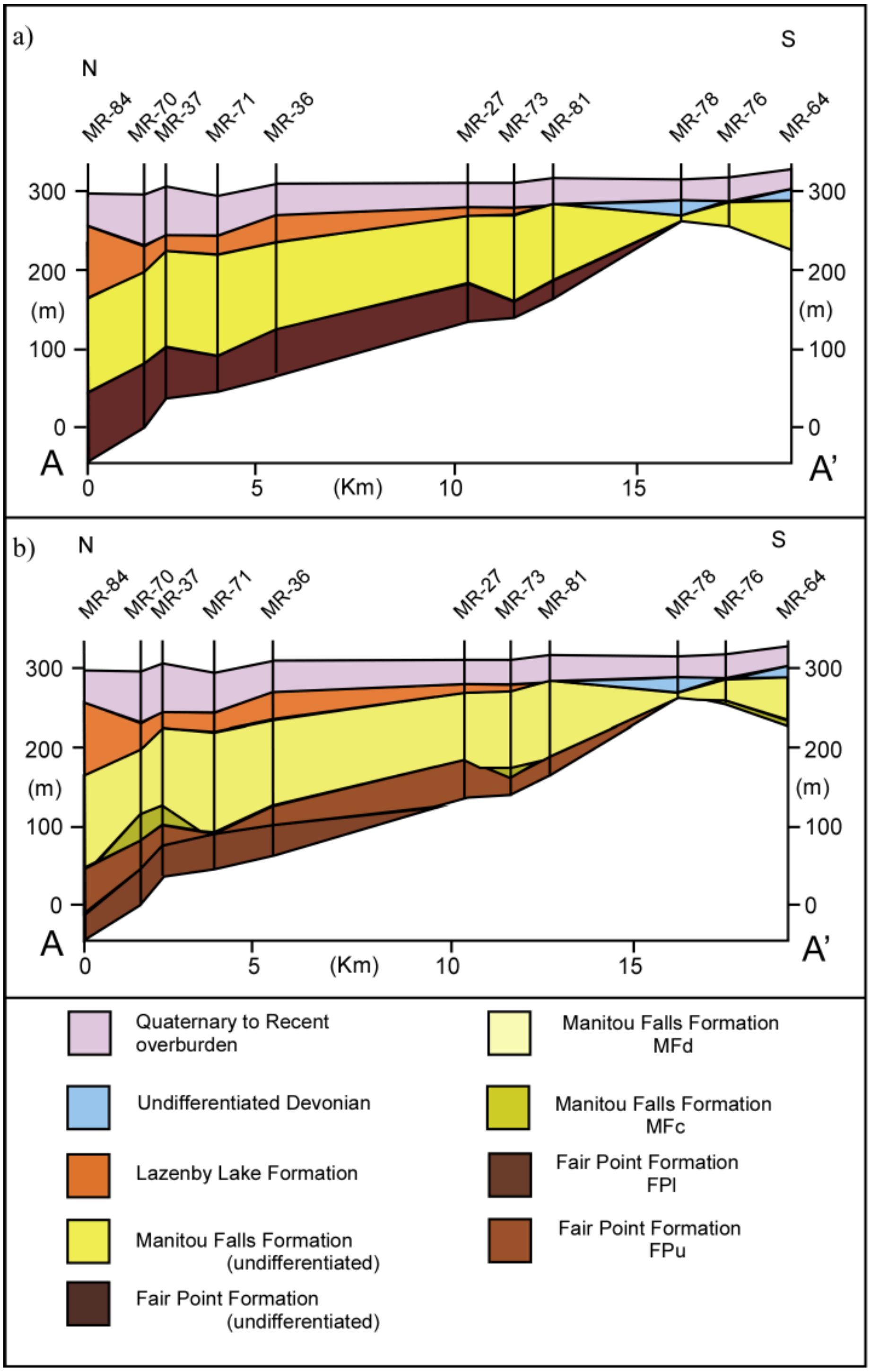
Appendix 2 - Cross-Sections and Thickness Plots

Three cross-sections are included: A-A' runs along the Maybelle River trend, B-B' runs along the Net Lake trend, and C-C' cross-cuts the two trends. All transects are shown on the diagram below.

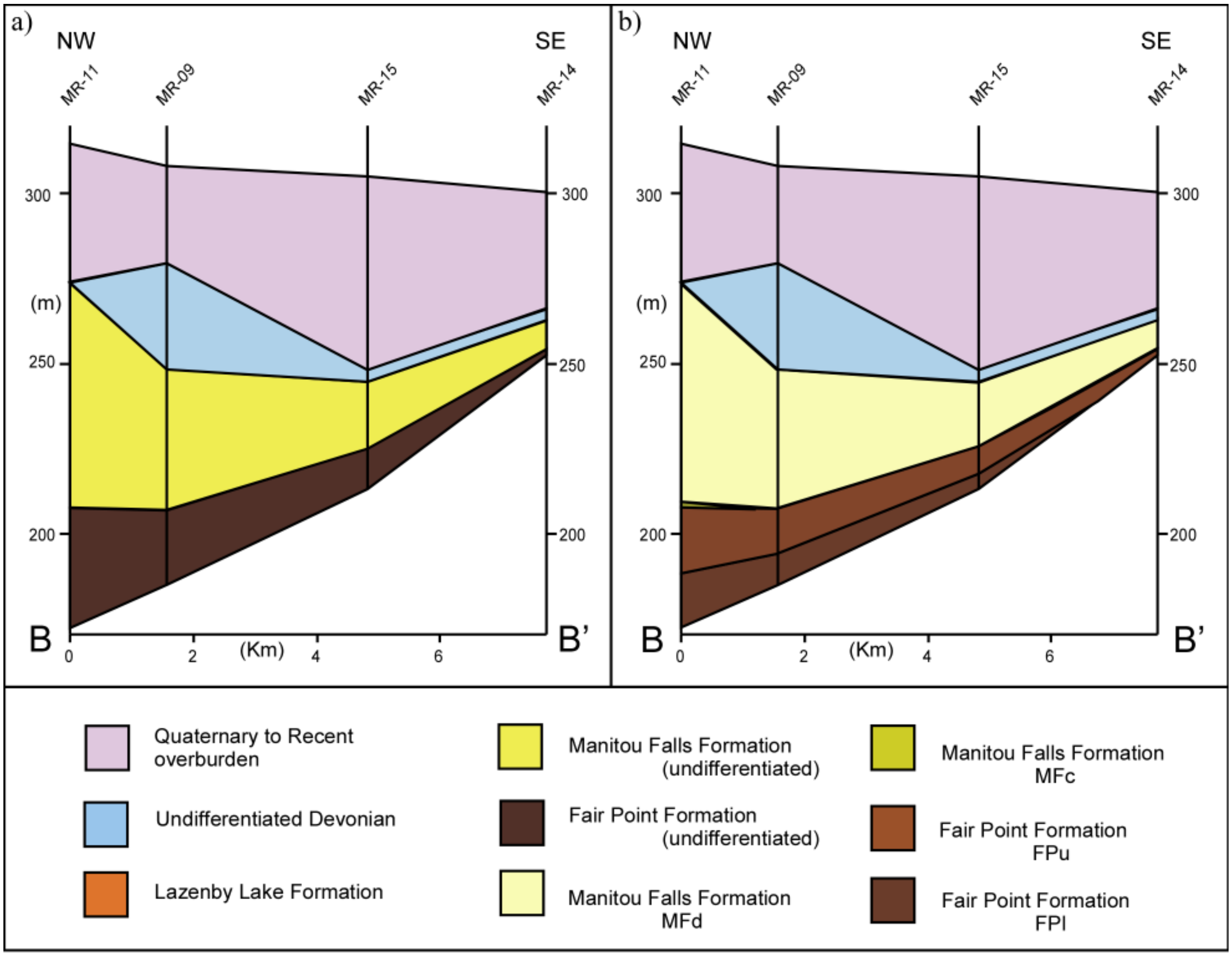
Thickness plots for the Fair Point, Manitou Falls and Lazenby Lake formations, as well as the overlying Devonian outlier, are included.



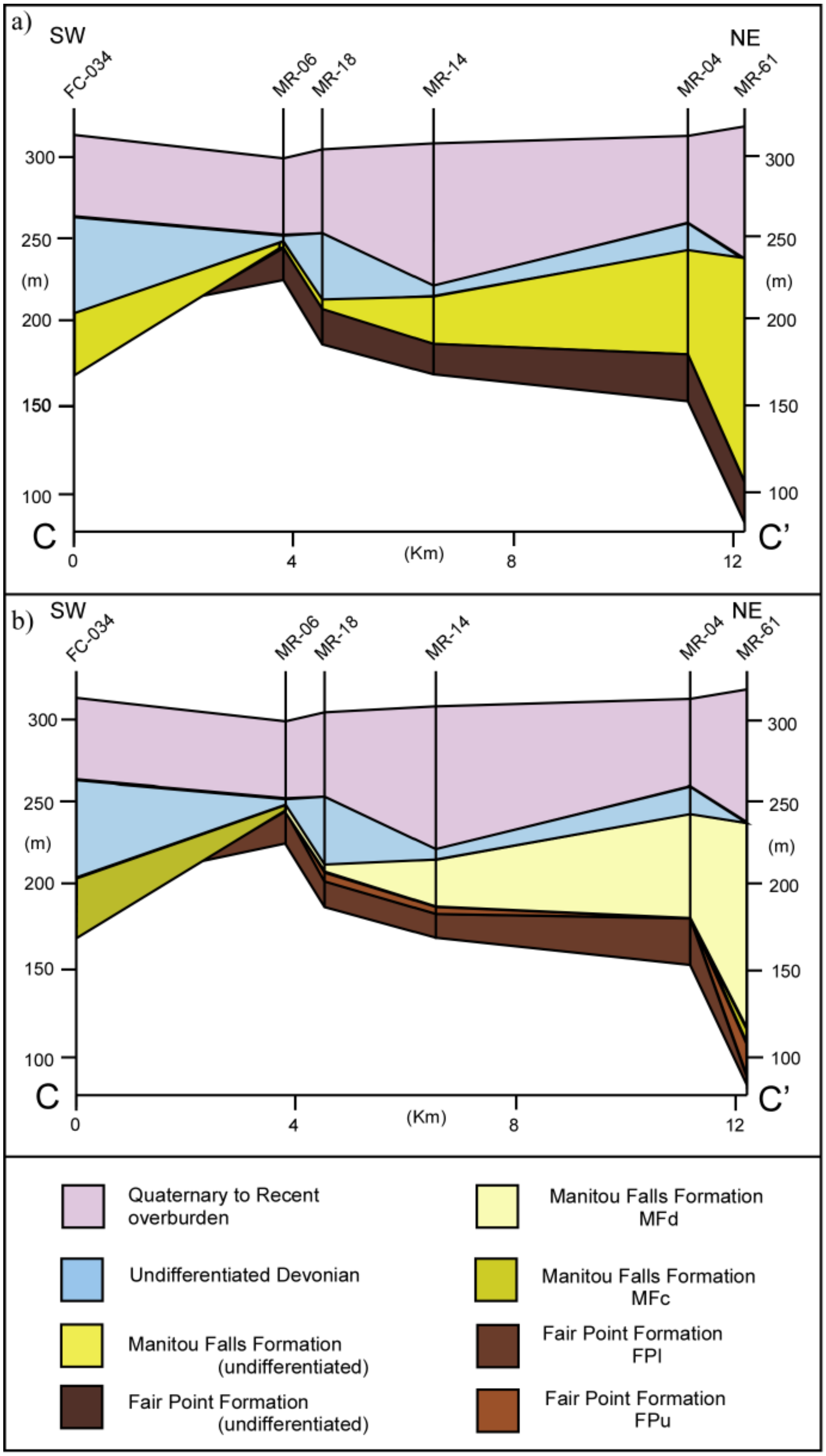
Location of the transects of the study.



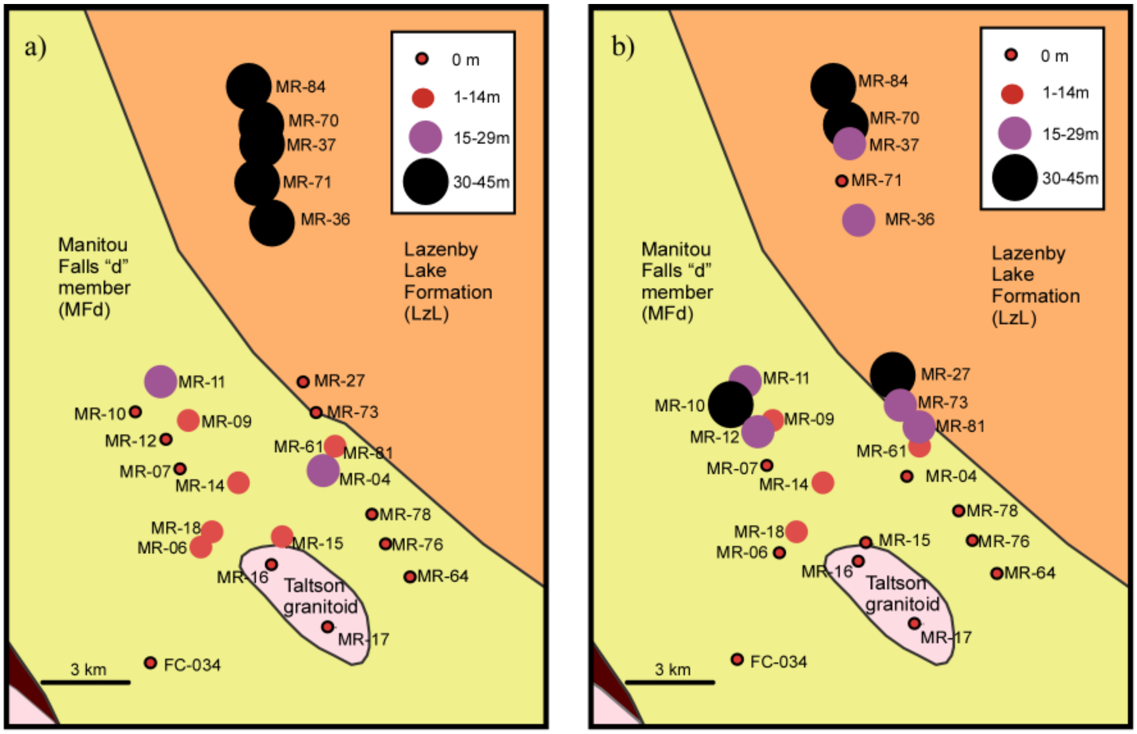
Section A-A' - North-south transect along the Maybelle River trend, with Fair Point and Manitou Falls formations a) undifferentiated, or b) differentiated.



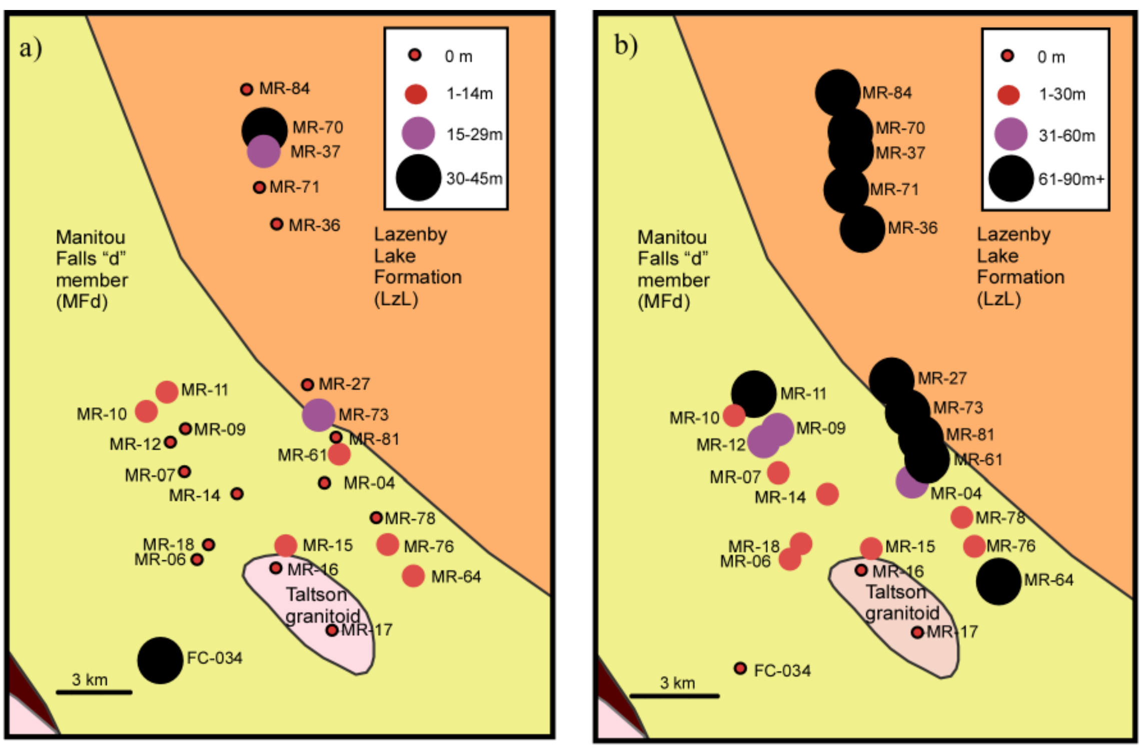
Section B-B' - North-south transect along the Net Lake trend, with Fair Point and Manitou Falls formations a) undifferentiated, or b) differentiated.



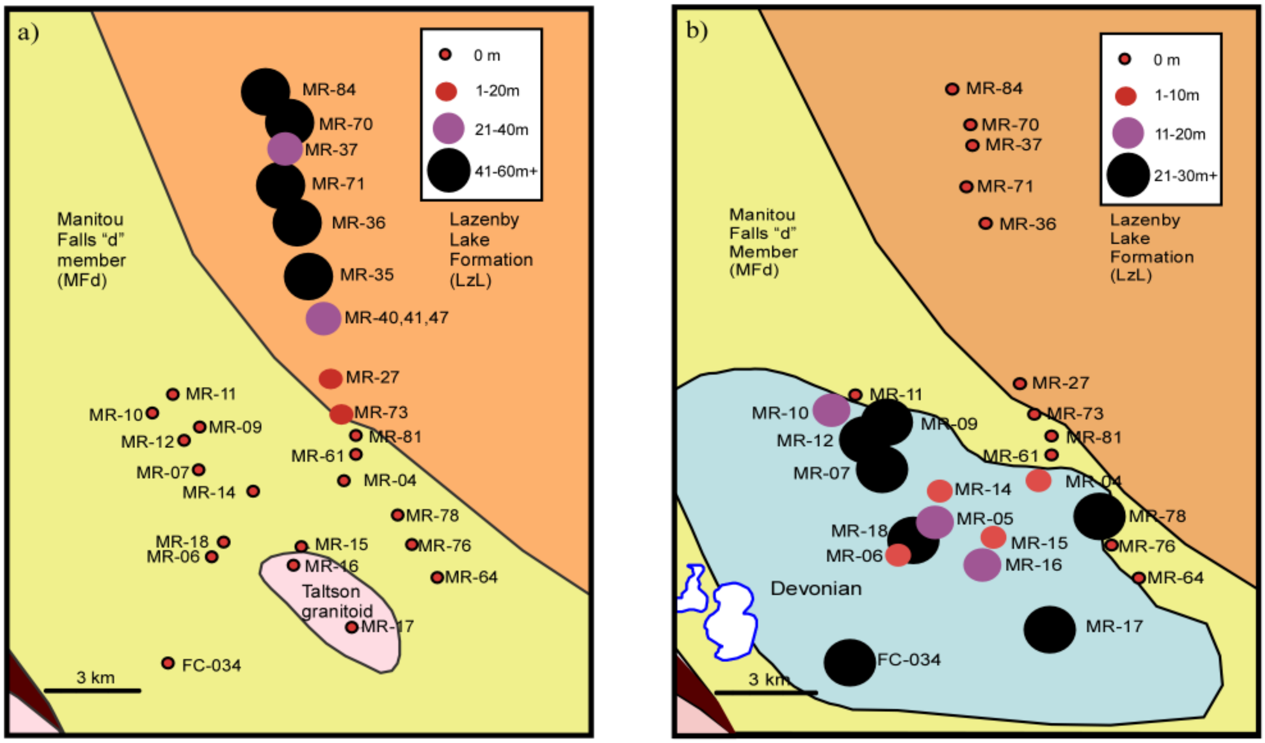
Section C-C' - Southwest-northeast transect cross-cutting the Net Lake and Maybelle River trends, with Fair Point and Manitou Falls formations a) undifferentiated, or b) differentiated.



Fair Point Formation thickness (bubble) plot: a) occurrence and associated thickness of the lower Fair Point Formation (FPl); b) occurrence and associated thickness of the upper Fair Point Formation (FPu). Note that the Fair Point Formation is absent in the southern part of the study area and that FPl is absent in some cores along both trends (e.g., drillholes MR-10 and MR-27).



Manitou Falls Formation thickness (bubble) plot: a) occurrence and associated thickness of the Manitou Falls “c” member. Note that, where occurring, the unit locally reaches an average of 5 m thick but thickens to the north; b) occurrence and associated thickness of the Manitou Falls “d” member. Note that it generally thickens to the north.



Lazenby Lake Formation and Devonian thickness (bubble) plots: a) occurrence and associated thickness of the Lazenby Lake Formation. Note that it general thickens to the north; b) occurrence and associated thickness of the Devonian outlier. Note that the outlier is situated over a basement high (Taltson granitoid).

Appendix 3 - Petrography

Forty thin sections were petrographically examined in order to characterize textural and mineralogical composition of the lower Athabasca Group. Sample set distribution is skewed towards Manitou Falls, with limited samples examined from FPl due to unit coarseness (difficult to cut thin sections). The mineralogy is defined by 400 point counts per sample. Below are the abbreviations for the subsequent terms.

Rounding:
A: angular
sA: subangular
sR: Subrounded
R: rounded
wR: well rounded

Sorting:
pS: poorly sorted
mS: moderately sorted
wS: well sorted

Grain size:
f: fine grained
m: medium grained
m: coarse grained

PSS (Primary Sedimentary Structures)
mass: massive
sR: ripple sand
Pl bedded: planar bedded.

Clays: subdivided into epitaxial (clay produced from the destruction of labile minerals such as feldspars) and matrix (derived from the deposition muds or remobilization of epitaxial clays).

Fair Point Formation						Mineralogy										
Drill Hole Info		**Texture**				**Quartz**		**Feld.**	**Lithics**			**Matrix Clays**				
Hole ID	Depth	Rounding	Sorting	Grain Size (10/50/90)	PSS	%mono+ strained	% poly	%epi-taxial clays	%grani-toid clasts	%mtm clasts	%fg zS	%detri-tal	Texture	%Voids	Unit	Name
MR-06	54.6	sA to sR	pS	m/m/c	mass	53.25	10.25	0.75	0.5	0	0.25	30	micaceous	5.25	FPl	quartz arenite
MR-10	108.7	sA to sR	pS	m/c/c	mass	60.75	11.75	3.25	1.5	1.25	0	17	micaceous	4.25	FPu	quartz arenite
MR-10	116.35	sR to R	mS	f/m/m	mass	76	2.75	0.5	0	0	0.25	11.75	micaceous	8.75	FPu	quartz arenite
MR-14	89.5	R	mS	m/m/c	mass	39.19	14.32	11.35	11.89	0.00	0.54	14.86	micaceous	7.25	FPu	sublitharenite
MR-37	270.4	sA to sR	pS	m/m/c	mass	63.5	13.25	0	1.25	0.5	0	15.5	micaceous	7	FPu	quartz arenite
MR-73	173.3	R	pS	m/c/gr	mass	68	12	0.5	11.75	2.5	0	6	micaceous	9.75	Fpu	sublitharenite
MR-73	187.5	sR to R	pS	m/m/c	mass	43.25	12.75	10.25	2.25	0	2	28.75	micaceous	0.75	FPu	sub-arkose
MR-73	198.6	sR to R	pS	f/m/m	mass	45.75	14.25	14	2	0	1.25	22.25	micaceous	0.25	FPu	sub-arkose
MR-84	296	sR to R	pS	m/m/c	mass	45.75	19	3	3.25	0	1.25	27.75	micaceous	0	FPu	quartz arenite

Manitou Falls Formation						Mineralogy										
Drill Hole Info		Texture				Quartz		Feld.	Lithics			Matrix Clays				
Hole ID	Depth	Rounding	Sorting	Grain Size (10/50/90)	PSS	%mono+ strained	% poly	%epi-taxial clays	%grani-toid clasts	%mtm clasts	%fg zS	%detri-tal	Texture	%Voids	Unit	Name
MR-06	40.8	sR to R	wS	f/m/m	mass	79	3.25	0	0.25	0	0	2	micaceous	15.5	MFd	quartz arenite
MR-07	83.7	R	wS	f/m/m	mass	80.25	0.25	0	0	0	0	0.75	micaceous	18.75	MFd	quartz arenite
MR-07	93.9	R	wS	f/m/m	Sr	79	1.75	0.5	0	0	0	1.75	micaceous	17	MFd	quartz arenite
MR-10	70.6	R	wS	f/m/m	mass	83.25	1	0	0	0	0	1.25	micaceous	14.5	MFd	quartz arenite
MR-10	90.3	R	mS	m/c/c	Sr	76	1	0.25	1.5	0.5	0.25	2.5	micaceous	17.25	MFd	quartz arenite
MR-10	106	R	mS	f/m/m	Sr	84.75	1	0	0	0	0	1.5	micaceous	12.75	MFc	quartz arenite
MR-14	61.15	R	mS	f/m/m-c	Sr	78.5	0	0	0	0	0	18.25	hematite	2.75	MFd	quartz arenite
MR-14	70.8	R	mS	f/m/m-c	Sr	84	2.25	0	0	0	0	1	micaceous	12.75	MFd	quartz arenite
mr-14	80.23	R	vwS	f/m/m	mass	87	0.5	0	0	0	0	2.25	micaceous	10.25	MFd	quartz arenite
MR-15	46.6	sR to R	wS	f/m/m	mass	84.25	1	0	0.25	0	0	1.75	micaceous	12.75	MFd	quartz arenite
MR-37	147.8	sR to R	wS	f/m/m	mass	89.5	2.25	0	0.5	0	0.25	1	micaceous	6.5	MFd	quartz arenite
MR-37	158.87	R to wR	wS	f/m/m	mass	74.25	1.25	0	0	0	0	4	micaceous	20.5	MFd	quartz arenite
MR-37	207.22	R	wS	f/f/m	mass	76	1.75	0	2.5	0	0.25	2.25	micaceous	17.25	MFc	quartz arenite
MR-73	89.6	sR to R	wS	f/m/m	mass	86.75	0.5	0	0.25	0	0	4.5	micaceous	8	MFd	quartz arenite
MR-73	115.3	R	wS	f/m/m	mass	85	1.6	0	0	0	0	10.6	micaceous	4.5	MFd	quartz arenite
MR-73	131.1	R	wS	f/f/m	mass	84.5	0.75	0.25	0	0	0	1	micaceous	13.5	MFd	quartz arenite
MR-76	40.4	R	mS	f/m/m	Sr	79	2.75	0	0	0	0	8	micaceous	10.25	MFd	quartz arenite
MR-76	52.08	sR to R	mS	f/f/m	Sr	79	0.75	0	0	0	0	6.25	micaceous	14	MFd	quartz arenite
MR-76	61	R	wS	f/f/m	mass	73.25	1.25	0	0	0	0	2.5	micaceous	23	MFd	quartz arenite
MR-84	161.5	R	wS	f/f/m	Sr	83.25	1	0	0	0	0.5	8.75	micaceous	6.5	MFd	quartz arenite
MR-84	197	R	wS	f/m/m	Sr	82	1	0	0	0	0	13.8	micaceous	4	MFd	quartz arenite
MR-84	250.6	sR	mS	m/m/c	mass	73.25	3	0.5	0	0	0	11.75	micaceous	11.5	MFd	quartz arenite

Lazenby Lake Formation						Mineralogy											
Drill Hole Info		Texture				Quartz		Feld.	Lithics			Matrix Clays					
Hole ID	Depth	Rounding	Sorting	Grain Size (10/50/90)	PSS	%mono+ strained	% poly	%epi-taxial clays	%grani-toid clasts	%mtm clasts	%fg zS	%detri-tal	Texture	%Voids	Unit	Name
MR-37	75.72	R	wS	f/m/m	mass	88.25	3.5	0	0.5	0	1	2	micaceous	4.75	LzL	quartz arenite
MR-37	86.1	sR to R	wS	f/m/m	mass	77.75	1.5	0.75	0	0	0.25	5	micaceous	13	LzL	quartz arenite
MR-37	89	sR to R	wS	f/f/m	Sr	76.75	0	0	0.5	0	0	4.25	hematite	19	LzL	quartz arenite
MR-73	40.1	R	mS to wS	f/m/m	mass	83.5	2	0	1.25	0	0.75	2	micaceous	10.5	LzL	quartz arenite
MR-73	44.6	sR to R	wS	m/m/c	mass	77.25	3.5	0	0	0	0	15	micaceous	4.25	LzL	quartz arenite
MR-73	47.06	R	mS to wS	f/m/m	mass	80.5	1.75	0	0	0	0.25	13	micaceous	4.5	LzL	quartz arenite
MR-84	40.3	R	wS	f/f/m	mass	79	5.5	0	0.5	0	0	4.5	micaceous	10.5	LzL	quartz arenite
MR-84	61.85	R to wR	mS	f/f/m	pl?	80	0.5	0	0.25	0	0.25	16.5	micaceous	2.5	LzL	quartz arenite
MR-84	83.7	R	mS	f/m/m	mass	85.75	3	0	0	0	0.25	2.25	micaceous	8.75	LzL	quartz arenite
MR-84	111.35	sR to R	wS	f/f/m	mass	85.75	1	0	1.5	0	1.5	3	micaceous	7.25	LzL	quartz arenite

Appendix 4 - Lithostratigraphic Breakdown of the Lower Athabasca Group

Major lithostratigraphic breaks are defined from the following parameters: maximum transported grain size (TGS_MTG); mean grain size; percentage of fines (very fine sandstone and siltstone); percentage of grains over 2mm (TGS_%>2mm); percentage of conglomerate; intraclast aggregate thickness; and matrix clay (MatrixClay). Primary sedimentary structures are outlined. Diamond-drillholes that lack Athabasca Group strata are omitted (e.g., drillholes MR-05, MR-16, MR-17). Non-numerical parameters are defined below.

1. Matrix Clay
Macroscopic interstitial clay was quantifiably estimated.

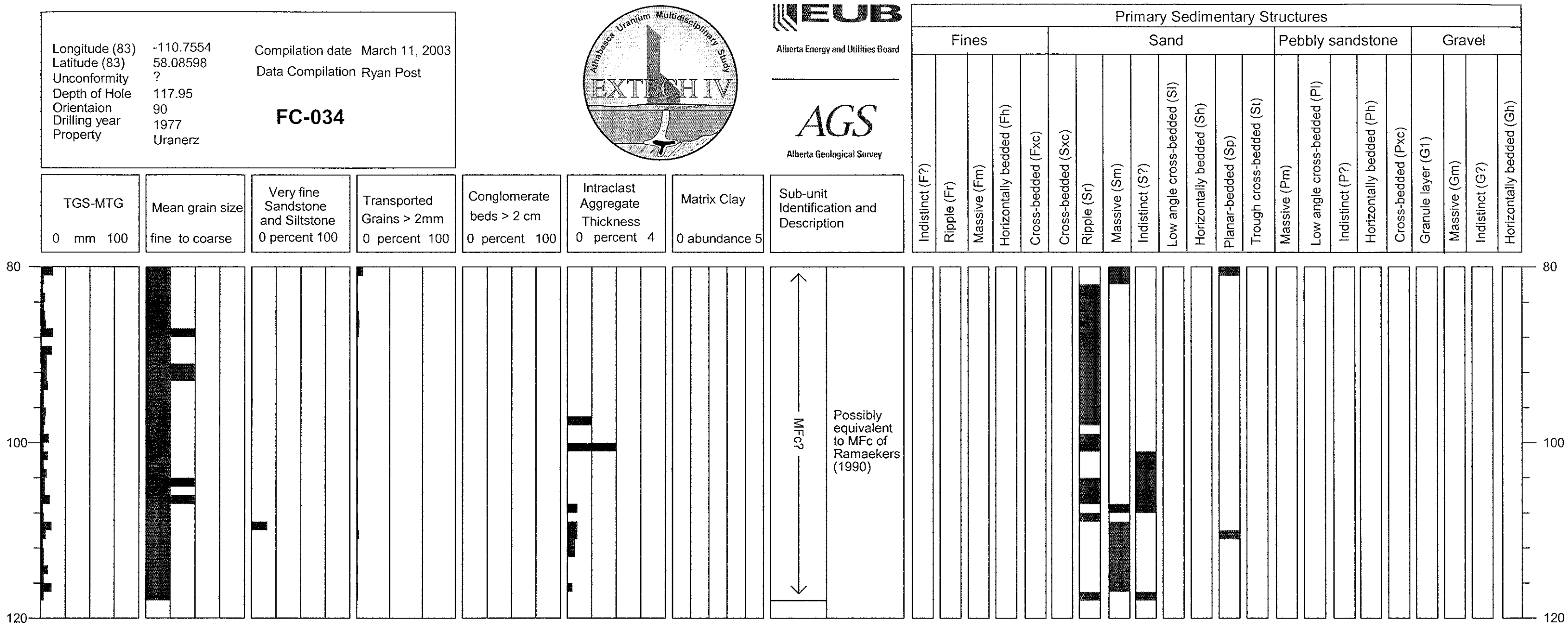
N: none
T: trace evident
Tm: trace to moderate, more sections of interval have trace amounts
Mt: moderate to trace, more sections of interval have moderate amounts
M: minor amounts evident over most of the core
A: abundant as a pore fraction

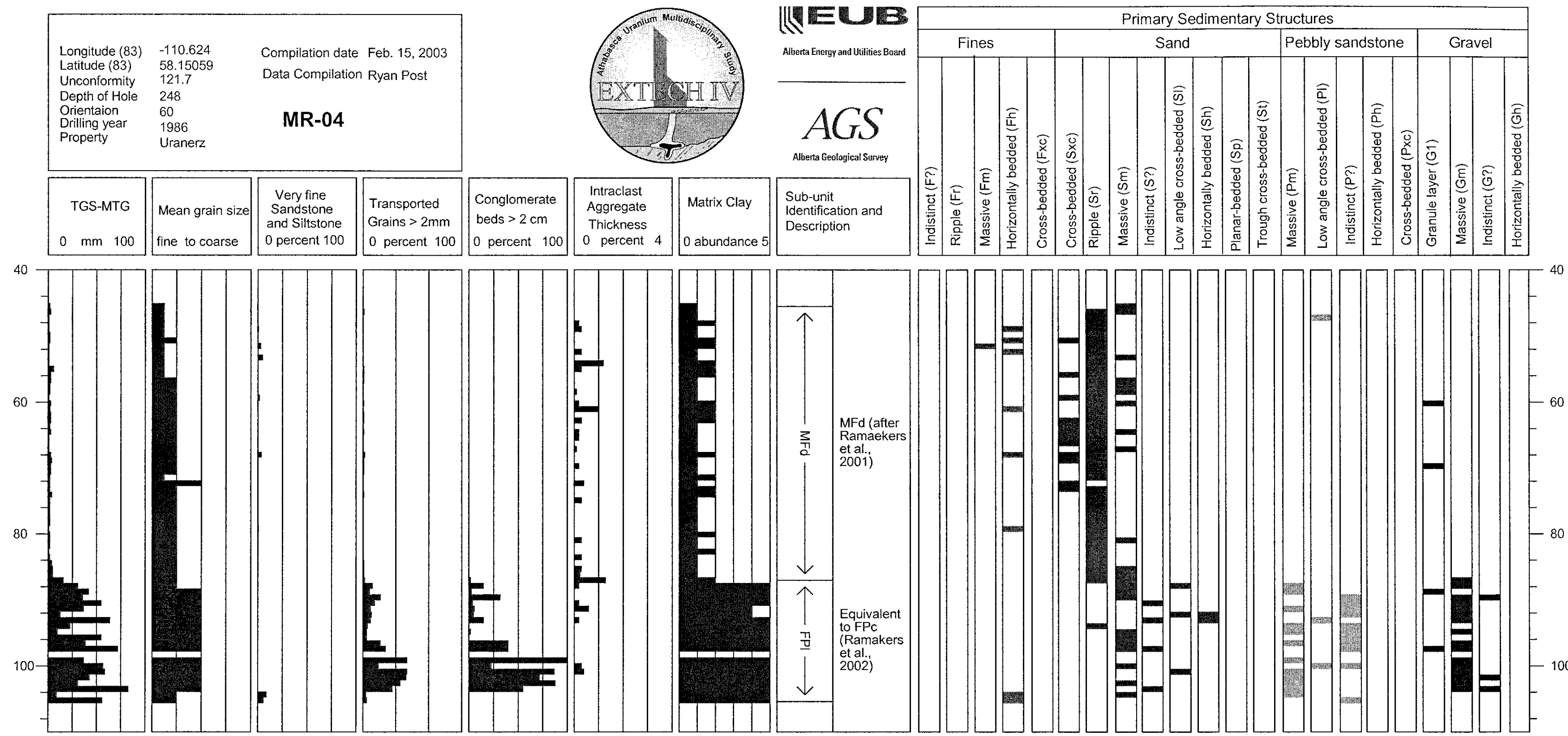
2. Grain size definition

Gravel: over 30% grains greater than 2 mm
Pebbly sandstone: 5-30% grains greater than 2 mm
Sand: fine to very coarse sand, less than 5% grains greater then 2 mm
Fines: very fine sand to mud, less than 5% grains greater then 2 mm

3. Sedimentary structures definition

Massive (M): unit lacks any definable bedding structure
Indistinct (?): indistinct layering within the unit
Ripple (R): ripple crosslaminated, bedsets less than 5cm thick, typically fine to medium grained
Cross-bedded (XC): crossbedded, bed sets greater than 5 cm thick, coarser than fine sand grade
Horizontally bedded (H): horizontal bedded or laminated
Planar cross-bedded (P): planar crossbedded, working criteria: thicker (0.1-2cm) planar crosslamina, often graded
Low angle crossbedded (l): low-angle crossbedding, generally coarse grained; bedding may be crudely to cryptically defined
Trough cross-bedded (t): trough crossbedded
Granule layer (G1): pebble layer one layer thick


Longitude (83) -110.7554
Latitude (83) 58.08598
Unconformity ?
Depth of Hole 117.95
Orientaion 90
Drilling year 1977
Property Uranerz
Compilation date March 11, 2003
Data Compilation Ryan Post
FC-034
TGS-MTG 0 mm 100
Mean grain size fine to coarse
Very fine Sandstone and Siltstone 0 percent 100
Transported Grains > 2mm 0 percent 100
Conglomerate beds > 2 cm 0 percent 100
Intraclast Aggregate Thickness 0 percent 4
Matrix Clay 0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
80
100
120
MFc?
Possibly equivalent to MFc of Ramaekers (1990)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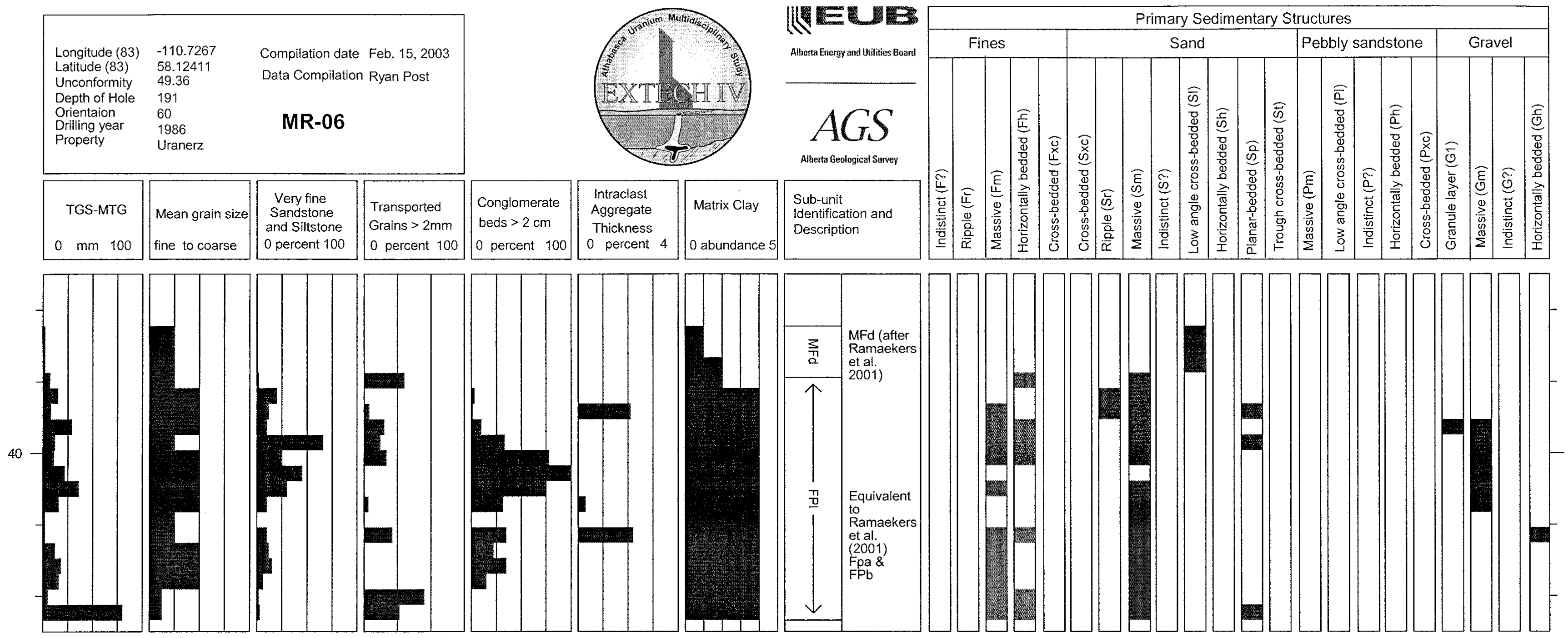
Latitude (83) 58.15059
Unconformity 121.7
Depth of Hole 248
Orientaion 60
Drilling year 1986
Property Uranerz
Compilation date Feb. 15, 2003
Data Compilation Ryan Post
MR-04
EXTECH IV
Athabasca Uranium Multidisciplinary Study
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Sand
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Pebbly sandstone
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Gravel
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
40
60
80
100
MFd
MFd (after Ramaekers et al., 2001)
FPl
Equivalent to FPc (Ramaekers et al., 2002)


Longitude (83) -110.7267
Latitude (83) 58.12411
Unconformity 49.36
Depth of Hole 191
Orientaion 60
Drilling year 1986
Property Uranerz
Compilation date Feb. 15, 2003
Data Compilation Ryan Post
MR-06
EXTECH IV
Athabasca Uranium Multidisciplinary Study
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
MFd
MFd (after Ramaekers et al. 2001)
FPl
Equivalent to Ramaekers et al. (2001) Fpa & FPb
40

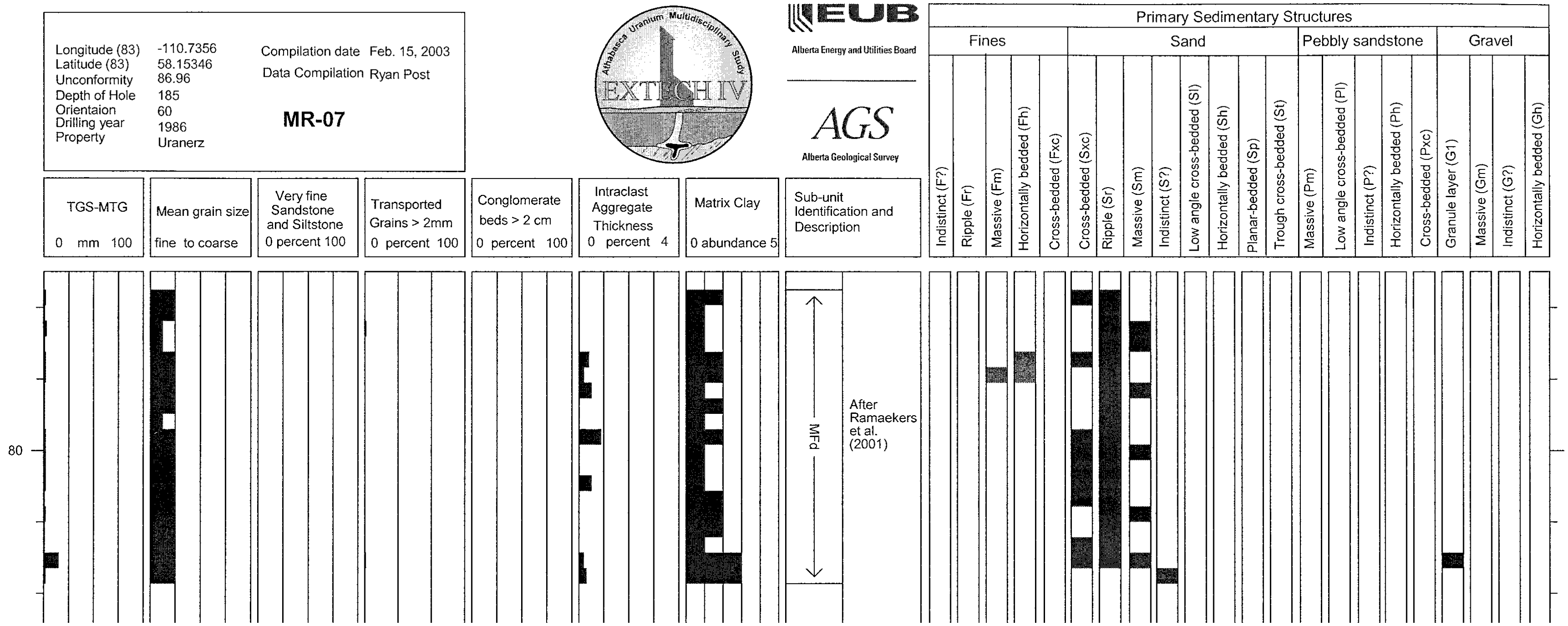
Longitude (83)	-110.7356	Compilation date	Feb. 15, 2003
Latitude (83)	58.15346	Data Compilation	Ryan Post
Unconformity	86.96		
Depth of Hole	185		
Orientaion	60		
Drilling year	1986		
Property	Uranerz		

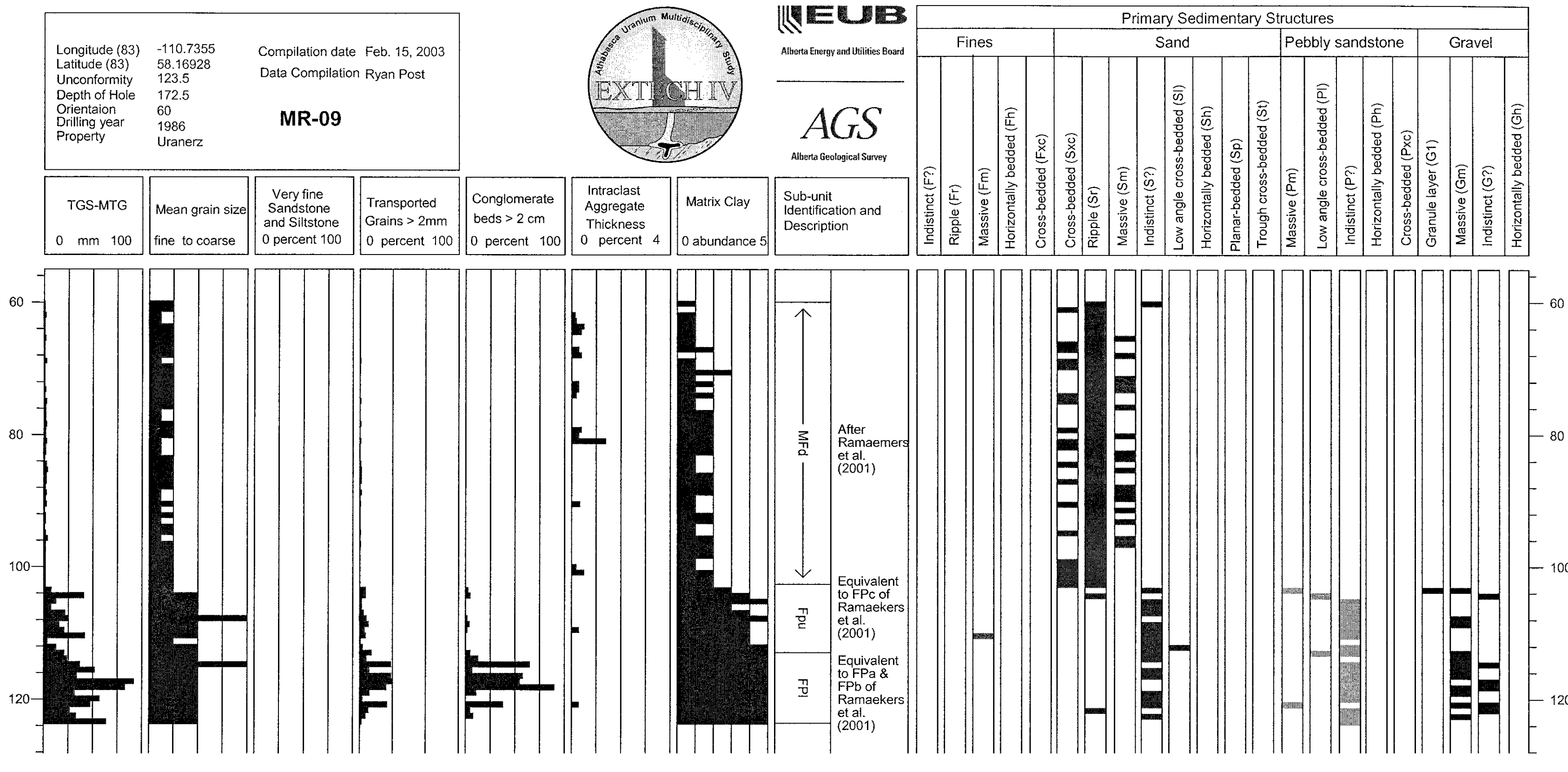
MR-07

Athabasca Uranium Multidisciplinary Study EXTECH IV

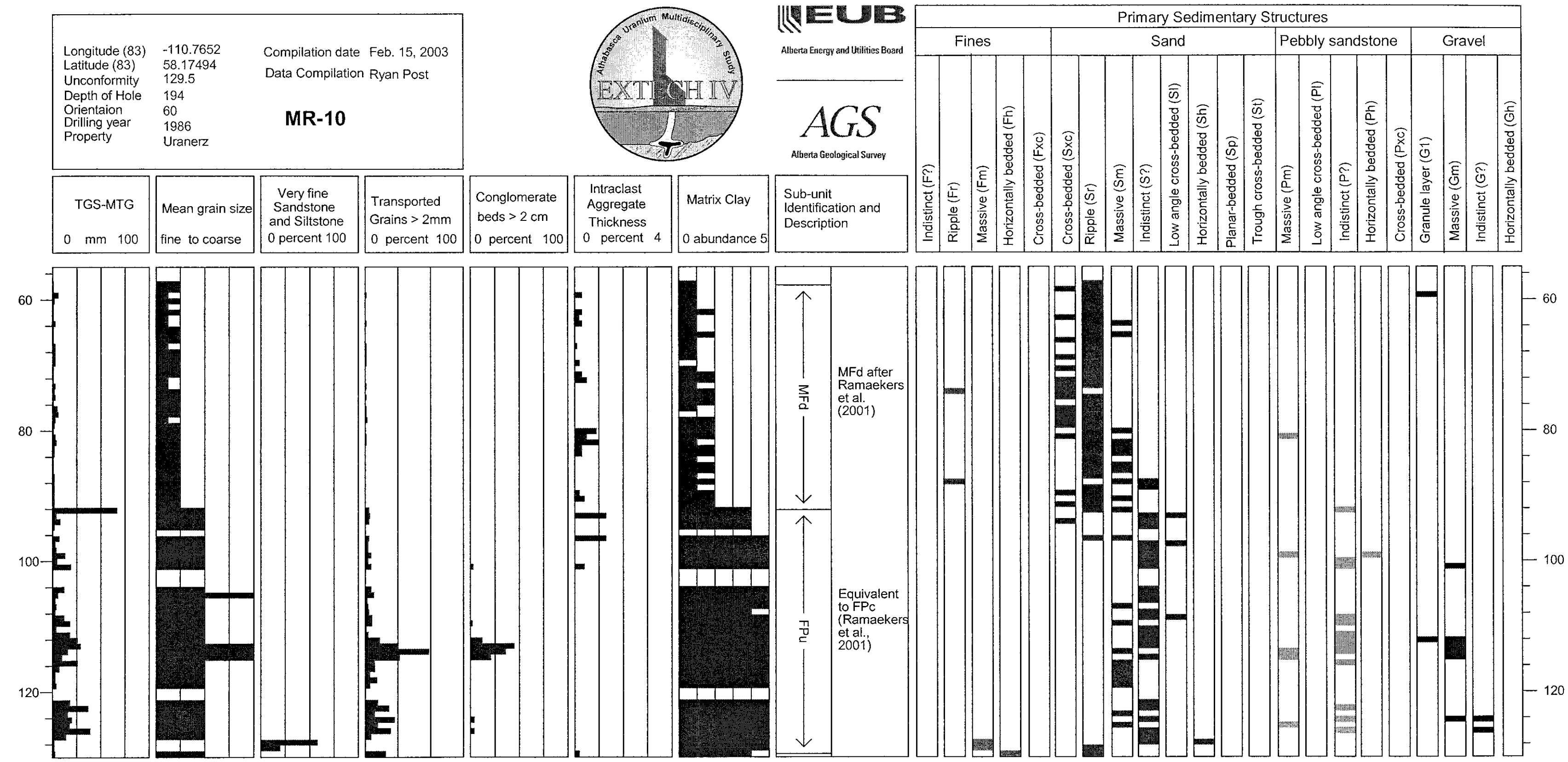
EUB Alberta Energy and Utilities Board

AGS Alberta Geological Survey





Longitude (83) -110.7355
Latitude (83) 58.16928
Unconformity 123.5
Depth of Hole 172.5
Orientaion 60
Drilling year 1986
Property Uranerz
Compilation date Feb. 15, 2003
Data Compilation Ryan Post
MR-09
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
60
80
100
120
MFd
After Ramaemers et al. (2001)
Fpu
Equivalent to FPc of Ramaekers et al. (2001)
FPl
Equivalent to FPa & FPb of Ramaekers et al. (2001)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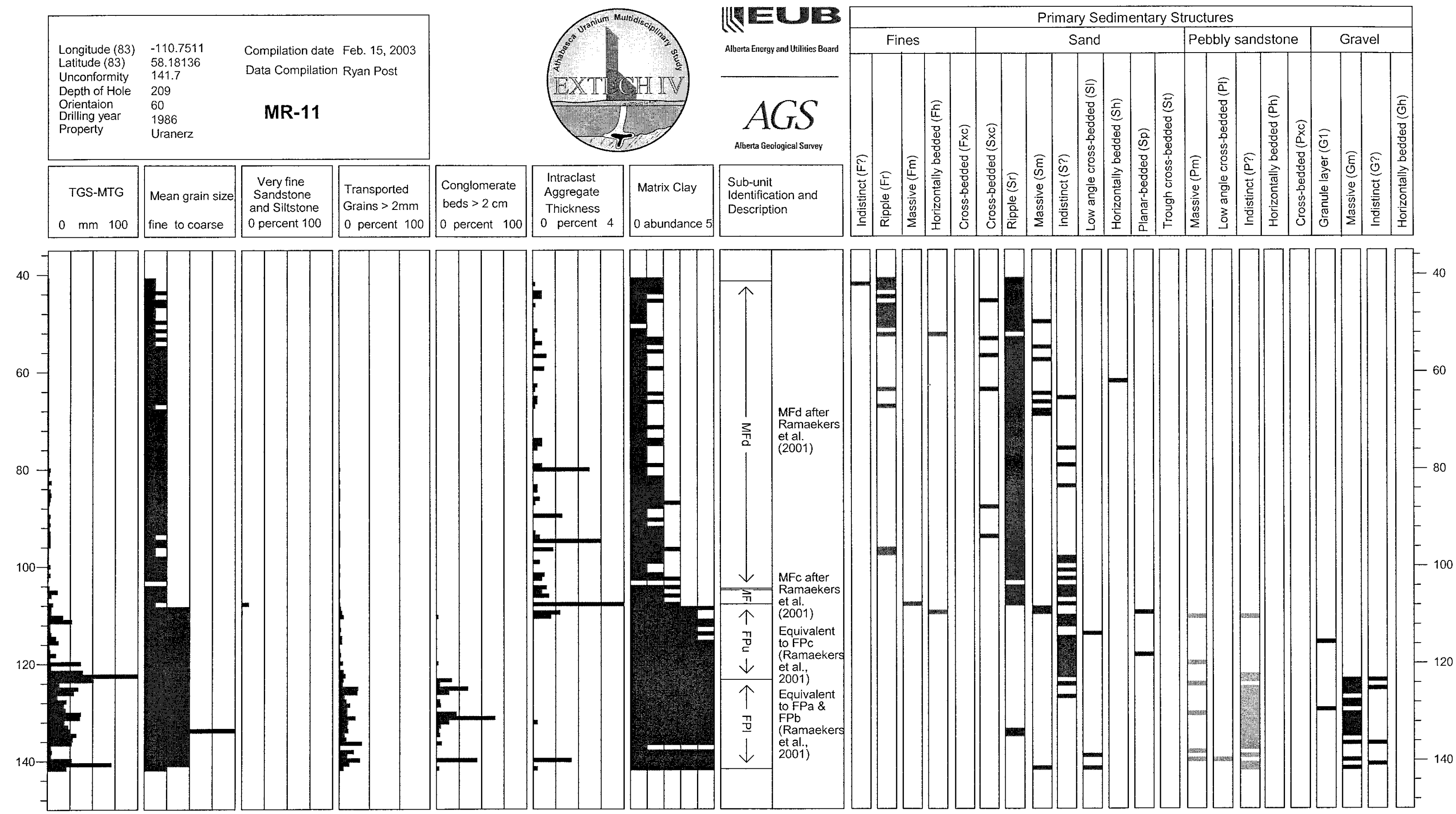
Latitude (83) 58.17494
Unconformity 129.5
Depth of Hole 194
Orientaion 60
Drilling year 1986
Property Uranerz
Compilation date Feb. 15, 2003
Data Compilation Ryan Post
MR-10
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
MFd
MFd after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)
60
80
100
120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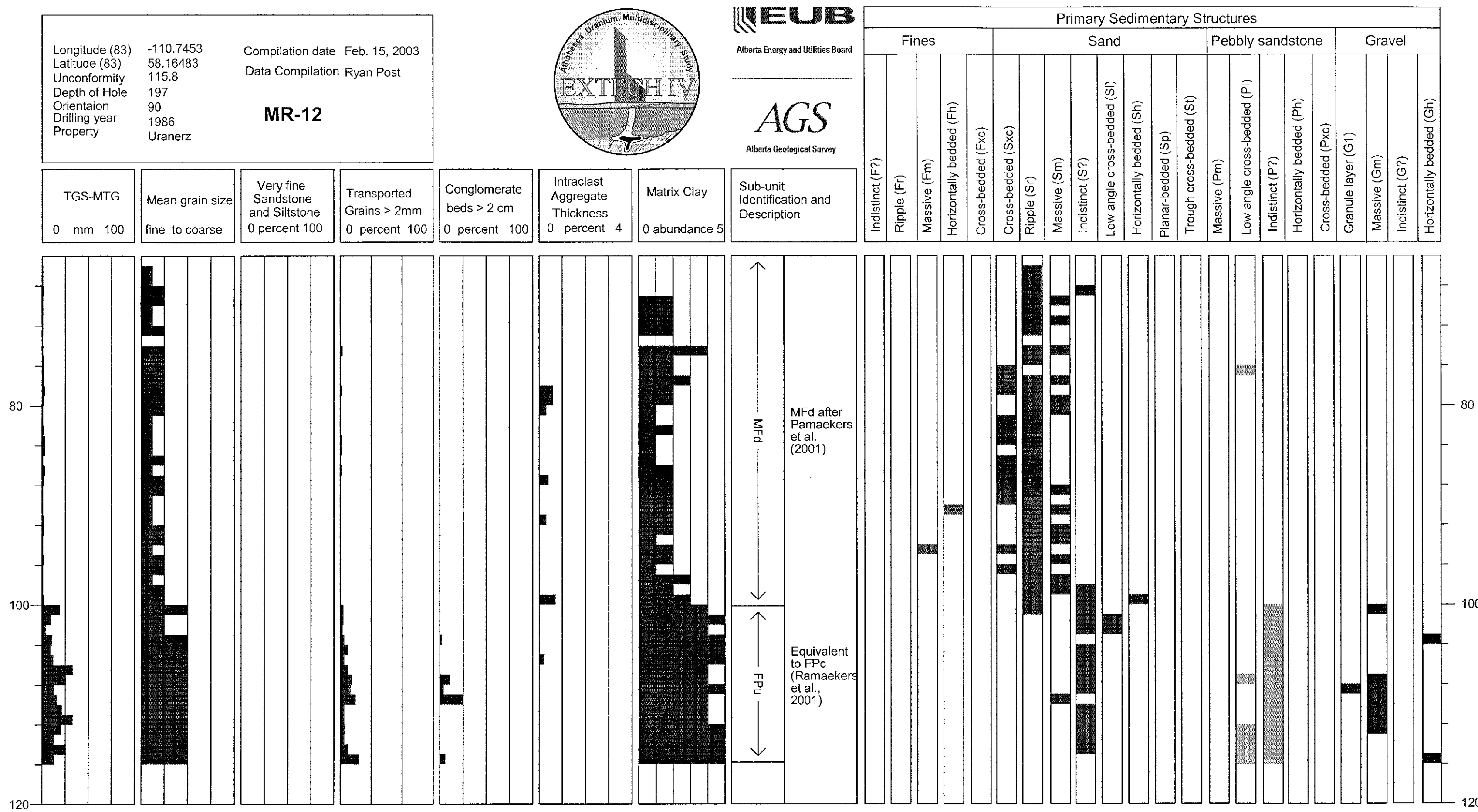
Latitude (83) 58.18136
Unconformity 141.7
Depth of Hole 209
Orientaion 60
Drilling year 1986
Property Uranerz
Compilation date Feb. 15, 2003
Data Compilation Ryan Post
MR-11
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Sand
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Pebbly sandstone
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Gravel
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
40
60
80
100
120
140
MFd
MFd after Ramaekers et al. (2001)
MFc
MFc after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)
FPl
Equivalent to FPa & FPb (Ramaekers et al., 2001)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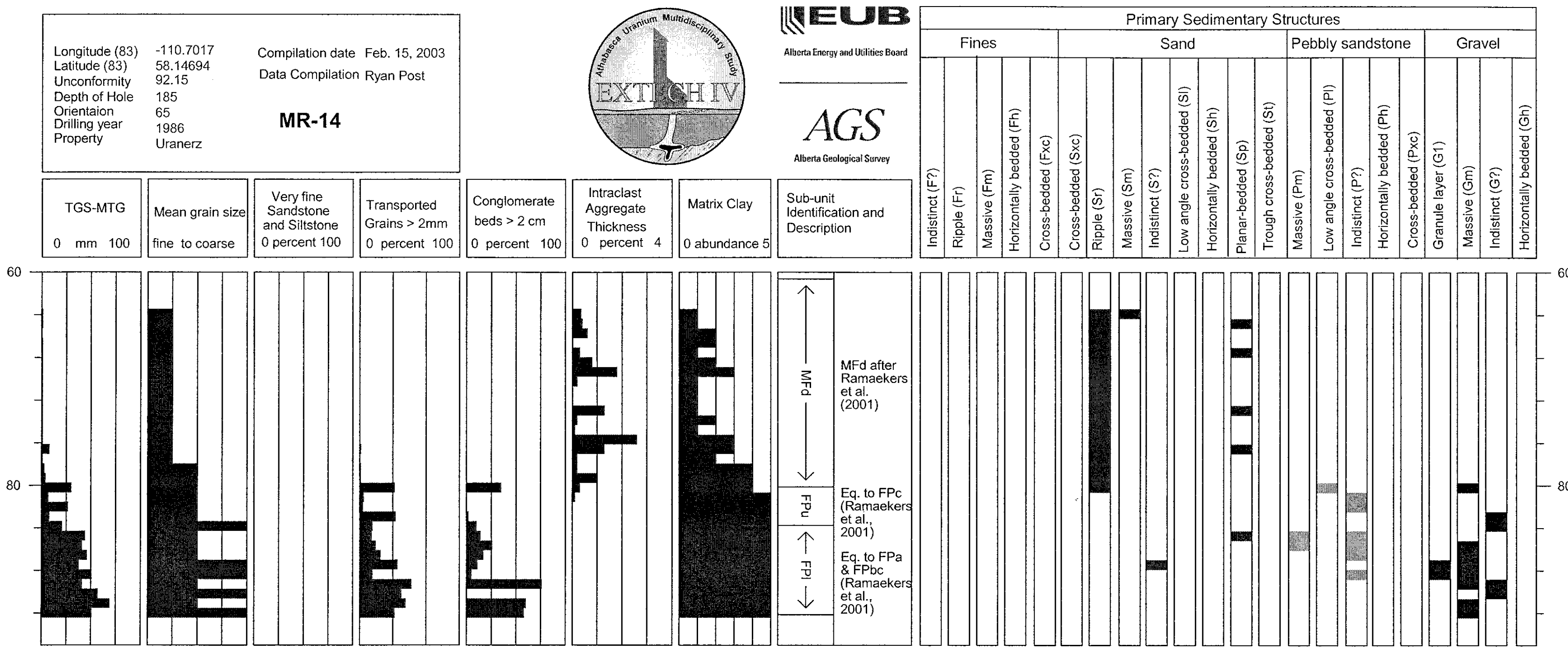
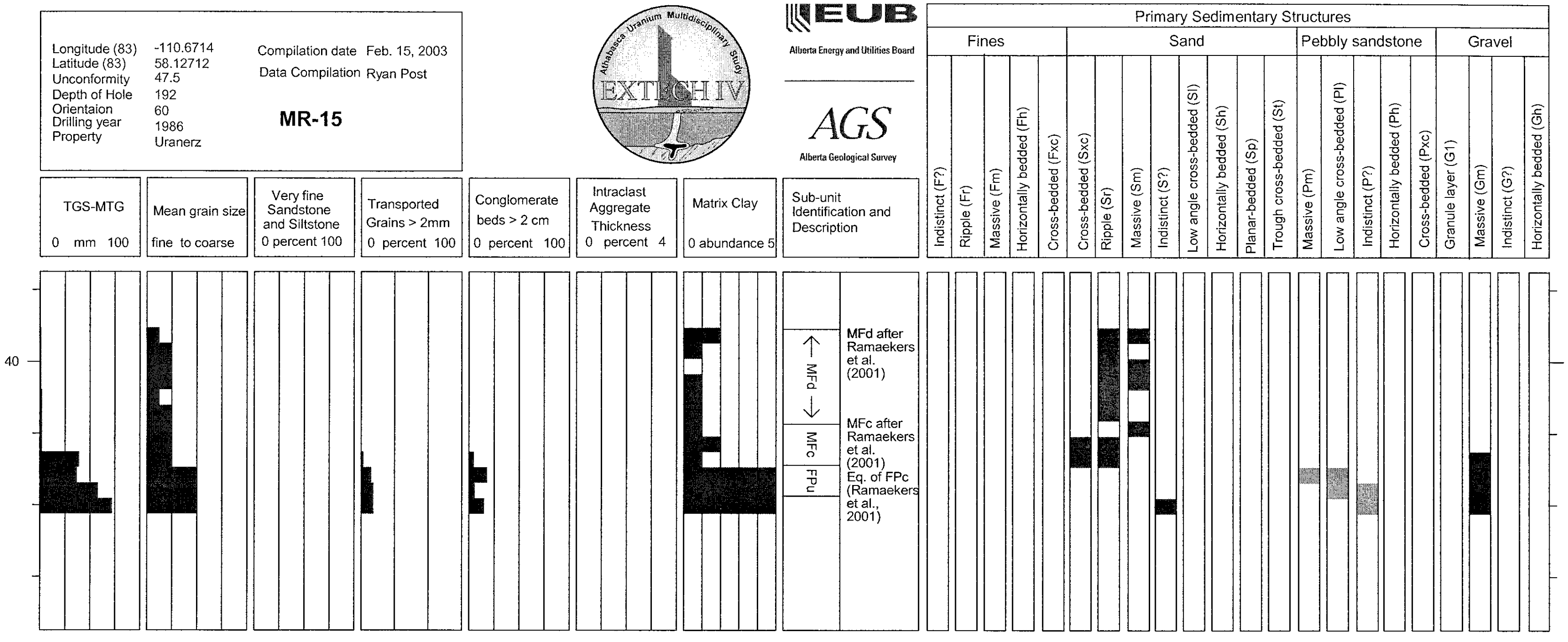
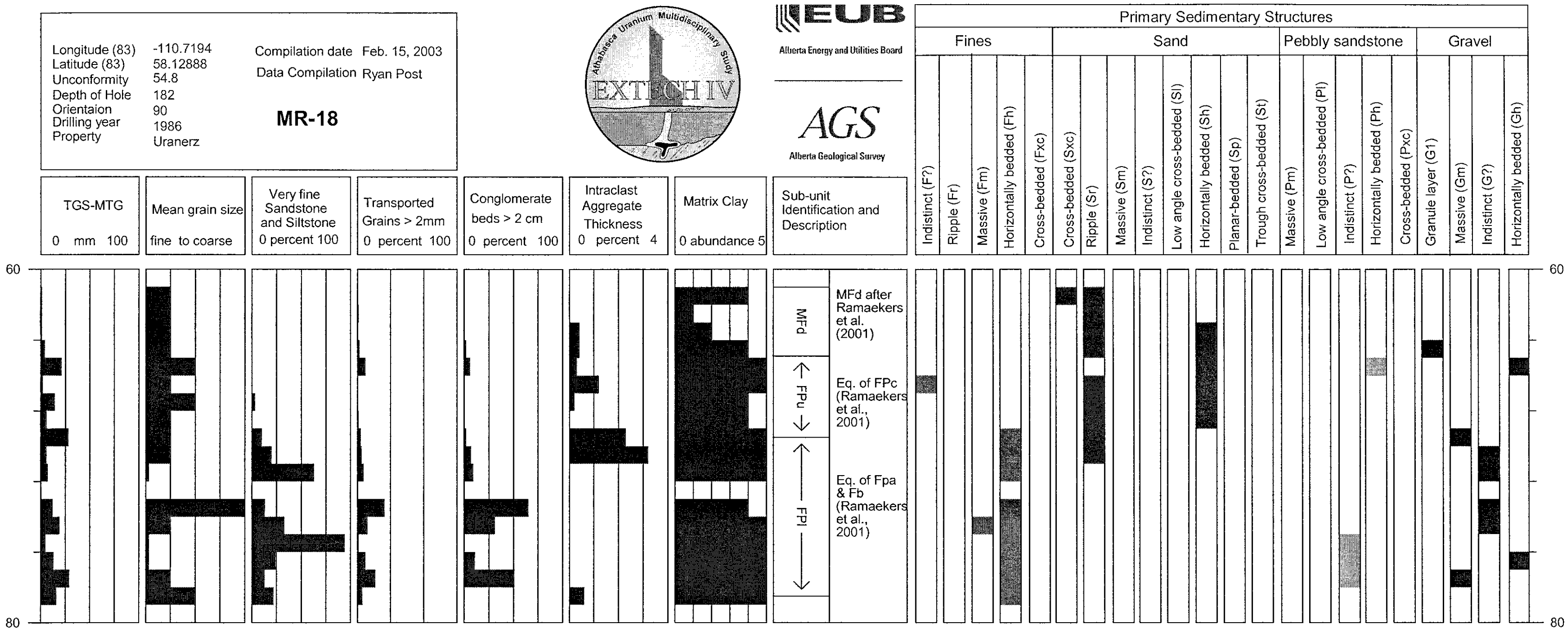
Latitude (83) 58.16483
Unconformity 115.8
Depth of Hole 197
Orientaion 90
Drilling year 1986
Property Uranerz
Compilation date Feb. 15, 2003
Data Compilation Ryan Post
MR-12
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
80
100
120
MFd
MFd after Pamaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)

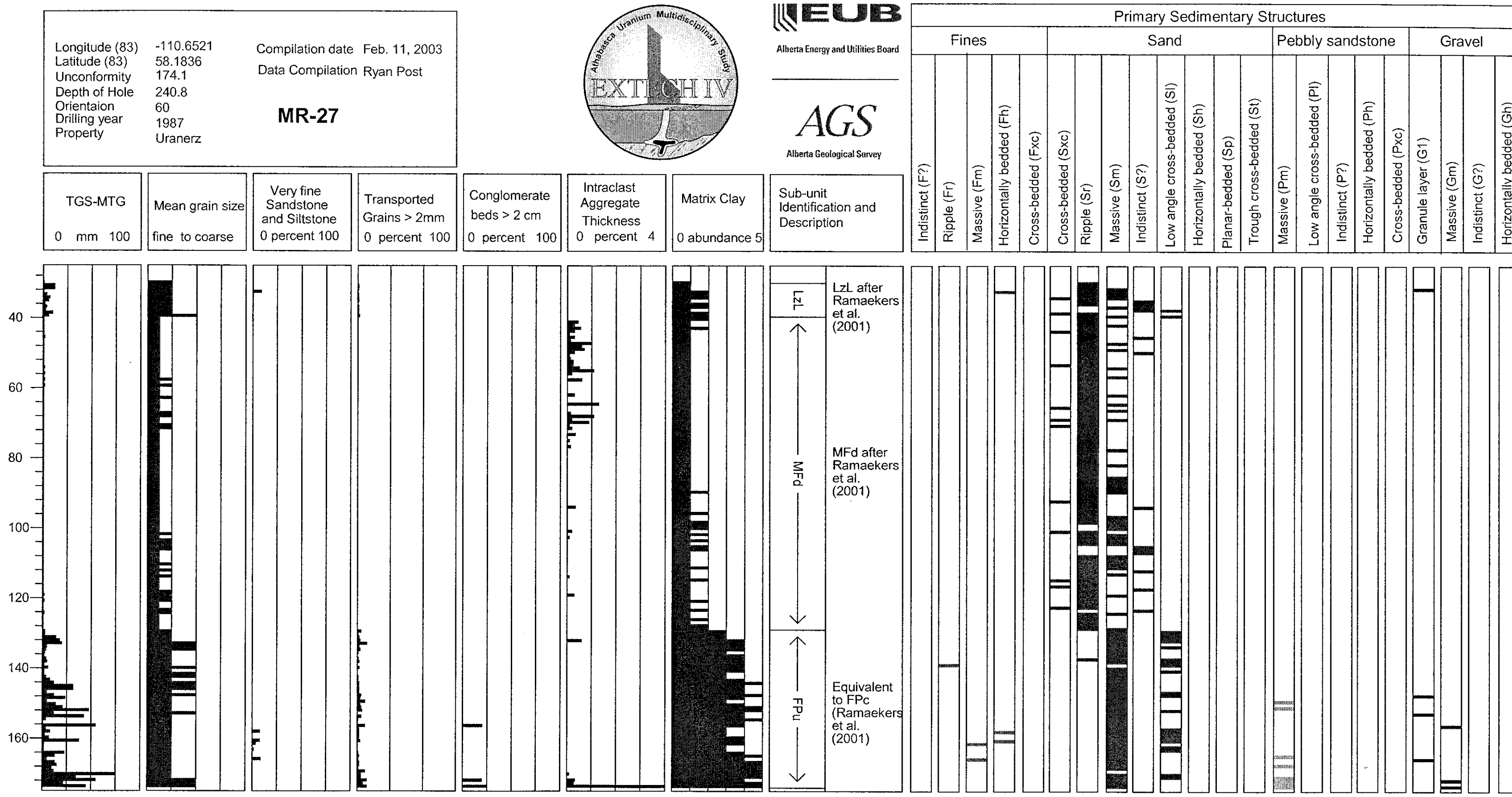

Longitude (83) -110.7017
Latitude (83) 58.14694
Unconformity 92.15
Depth of Hole 185
Orientaion 65
Drilling year 1986
Property Uranerz
Compilation date Feb. 15, 2003
Data Compilation Ryan Post
MR-14
EXTECH IV
Athabasca Uranium Multidisciplinary Study
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
60
80
MFd
MFd after Ramaekers et al. (2001)
FPu
Eq. to FPc (Ramaekers et al., 2001)
FPl
Eq. to FPa & FPbc (Ramaekers et al., 2001)

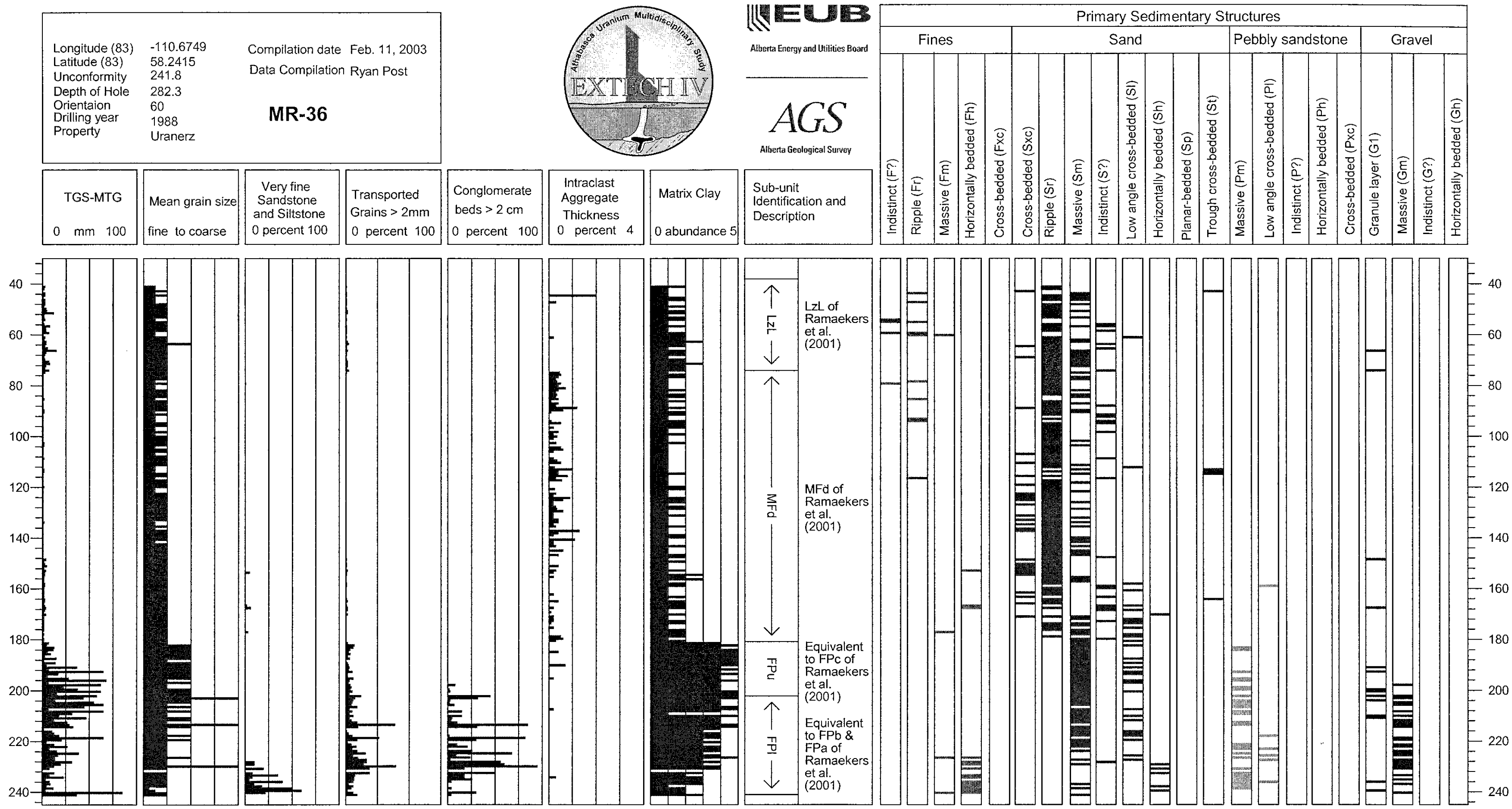
Longitude (83)	-110.6714	Compilation date	Feb. 15, 2003
Latitude (83)	58.12712	Data Compilation	Ryan Post
Unconformity	47.5		
Depth of Hole	192		
Orientaion	60		
Drilling year	1986		
Property	Uranerz		

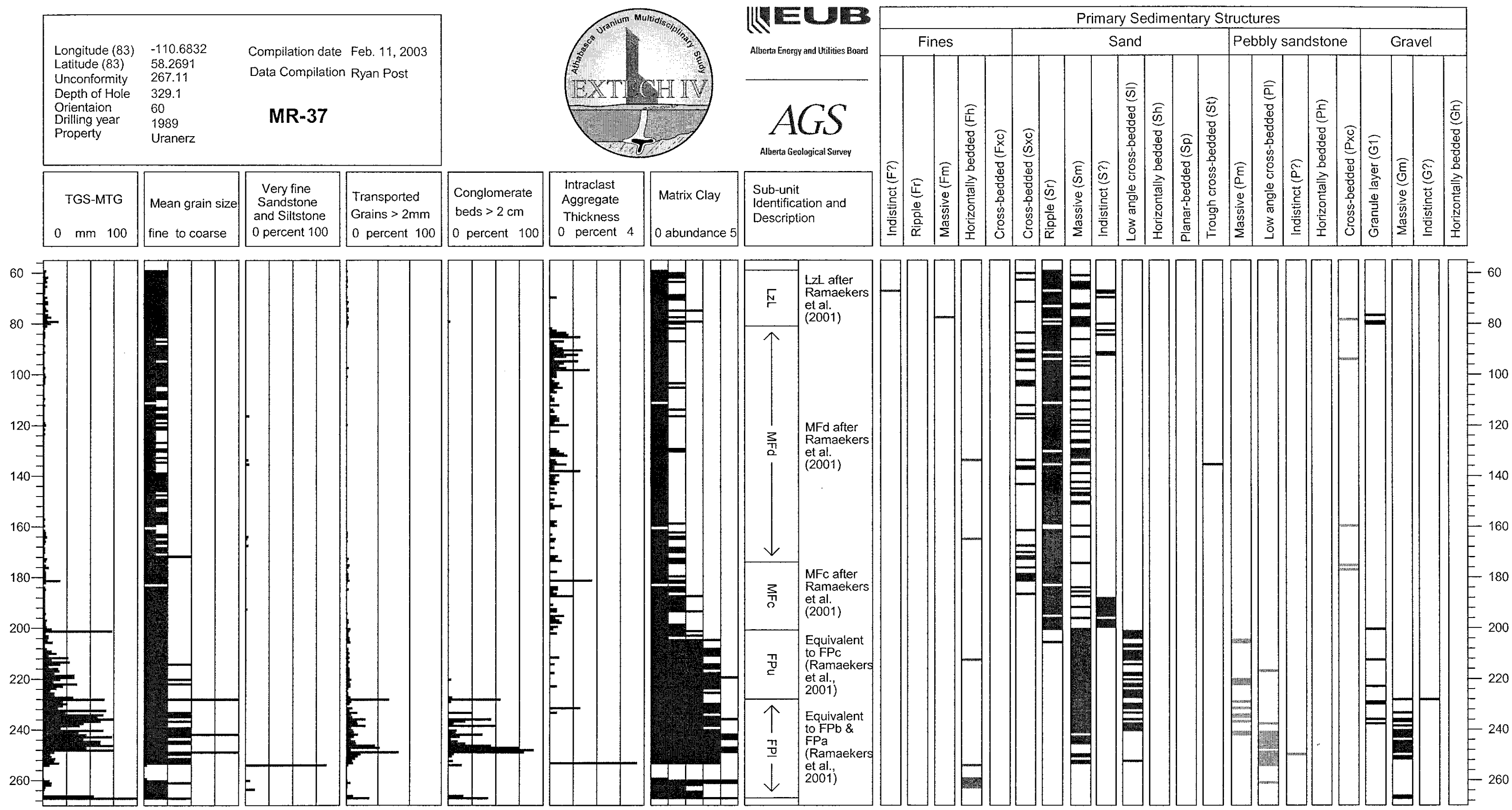
MR-15



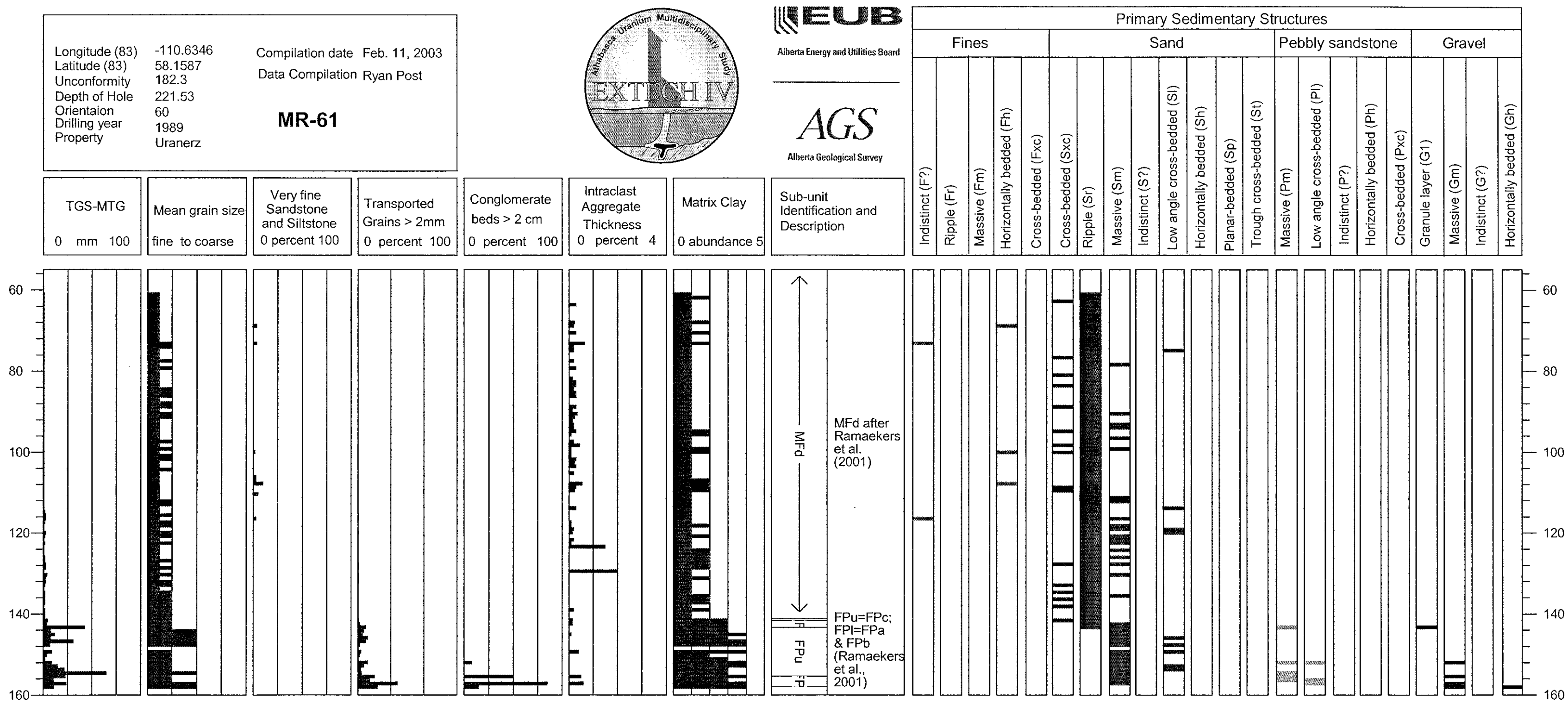

Longitude (83) -110.7194
Latitude (83) 58.12888
Unconformity 54.8
Depth of Hole 182
Orientaion 90
Drilling year 1986
Property Uranerz
Compilation date Feb. 15, 2003
Data Compilation Ryan Post
MR-18
EXTECH IV
Athabasca Uranium Multidisciplinary Study
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
60
80
MFd
MFd after Ramaekers et al. (2001)
FPu
Eq. of FPc (Ramaekers et al., 2001)
FPl
Eq. of Fpa & Fb (Ramaekers et al., 2001)

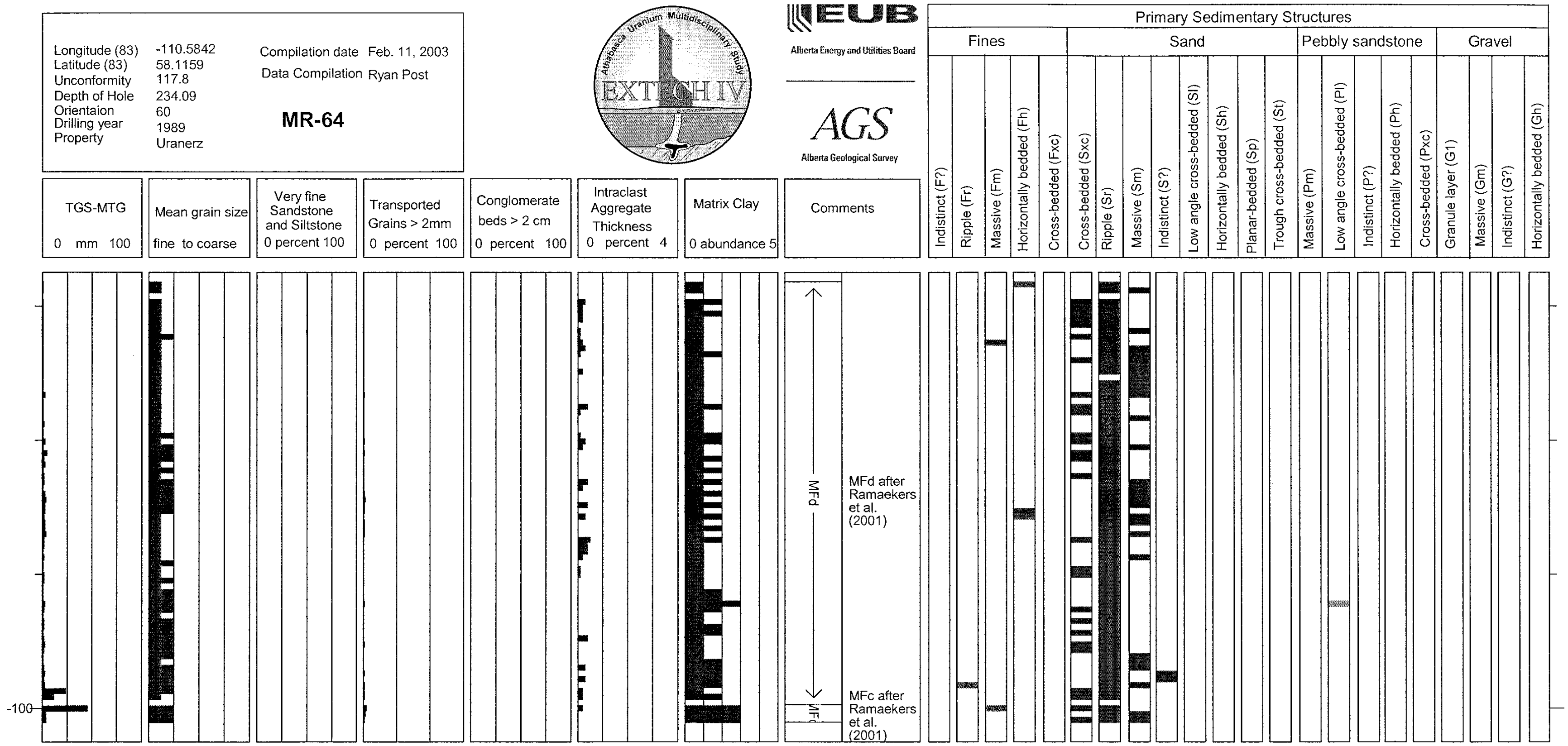

Longitude (83) -110.6521
Latitude (83) 58.1836
Unconformity 174.1
Depth of Hole 240.8
Orientaion 60
Drilling year 1987
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-27
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
40
60
80
100
120
140
160
LzL
LzL after Ramaekers et al. (2001)
MFd
MFd after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al. (2001)

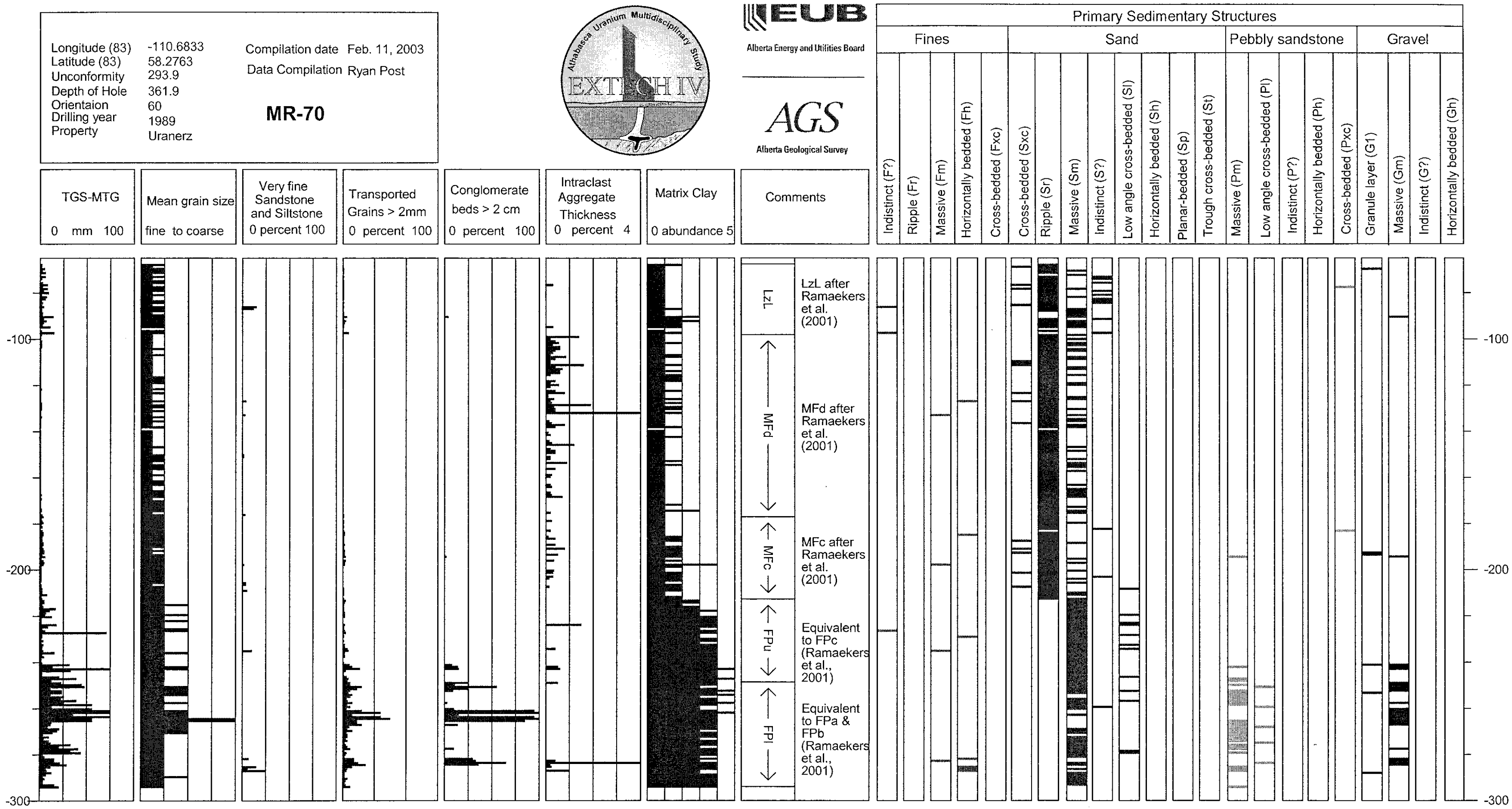

Longitude (83) -110.6749
Latitude (83) 58.2415
Unconformity 241.8
Depth of Hole 282.3
Orientaion 60
Drilling year 1988
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-36
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
LzL
LzL of Ramaekers et al. (2001)
MFd
MFd of Ramaekers et al. (2001)
FPu
Equivalent to FPc of Ramaekers et al. (2001)
FPl
Equivalent to FPb & FPa of Ramaekers et al. (2001)
40
60
80
100
120
140
160
180
200
220
240

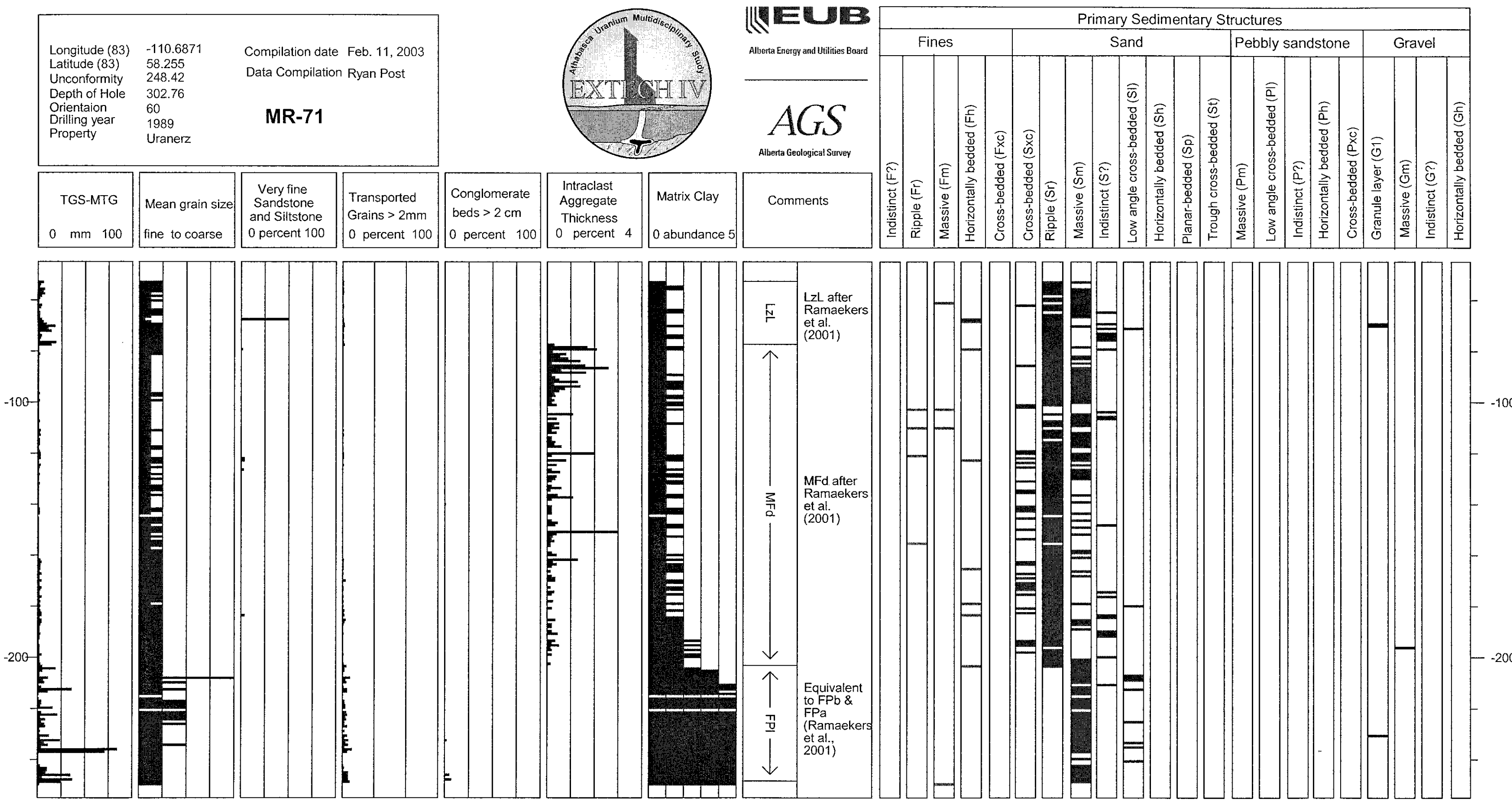


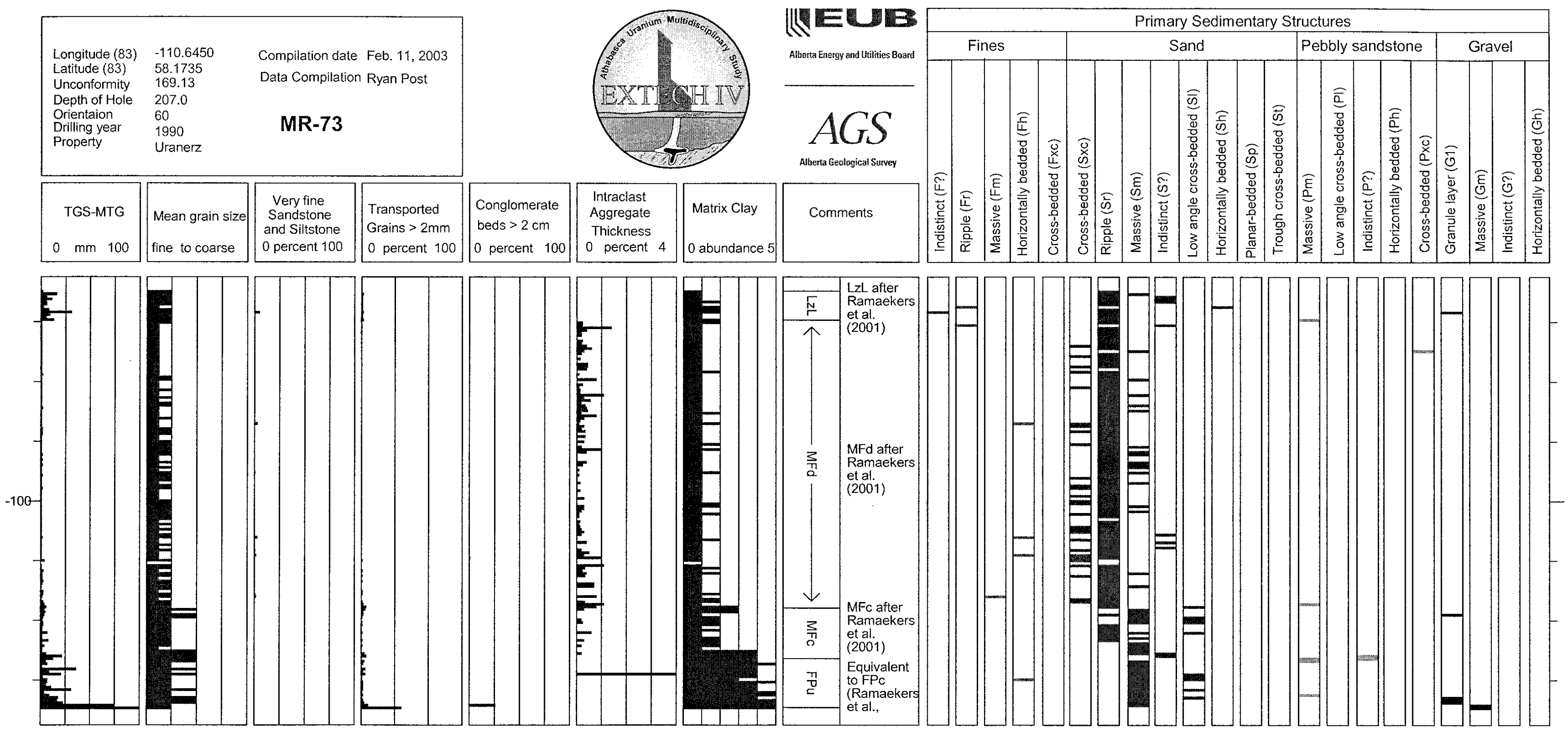
Longitude (83) -110.6832
Latitude (83) 58.2691
Unconformity 267.11
Depth of Hole 329.1
Orientaion 60
Drilling year 1989
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-37
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
LzL
LzL after Ramaekers et al. (2001)
MFd
MFd after Ramaekers et al. (2001)
MFc
MFc after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)
FPl
Equivalent to FPb & FPa (Ramaekers et al., 2001)
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
60
80
100
120
140
160
180
200
220
240
260

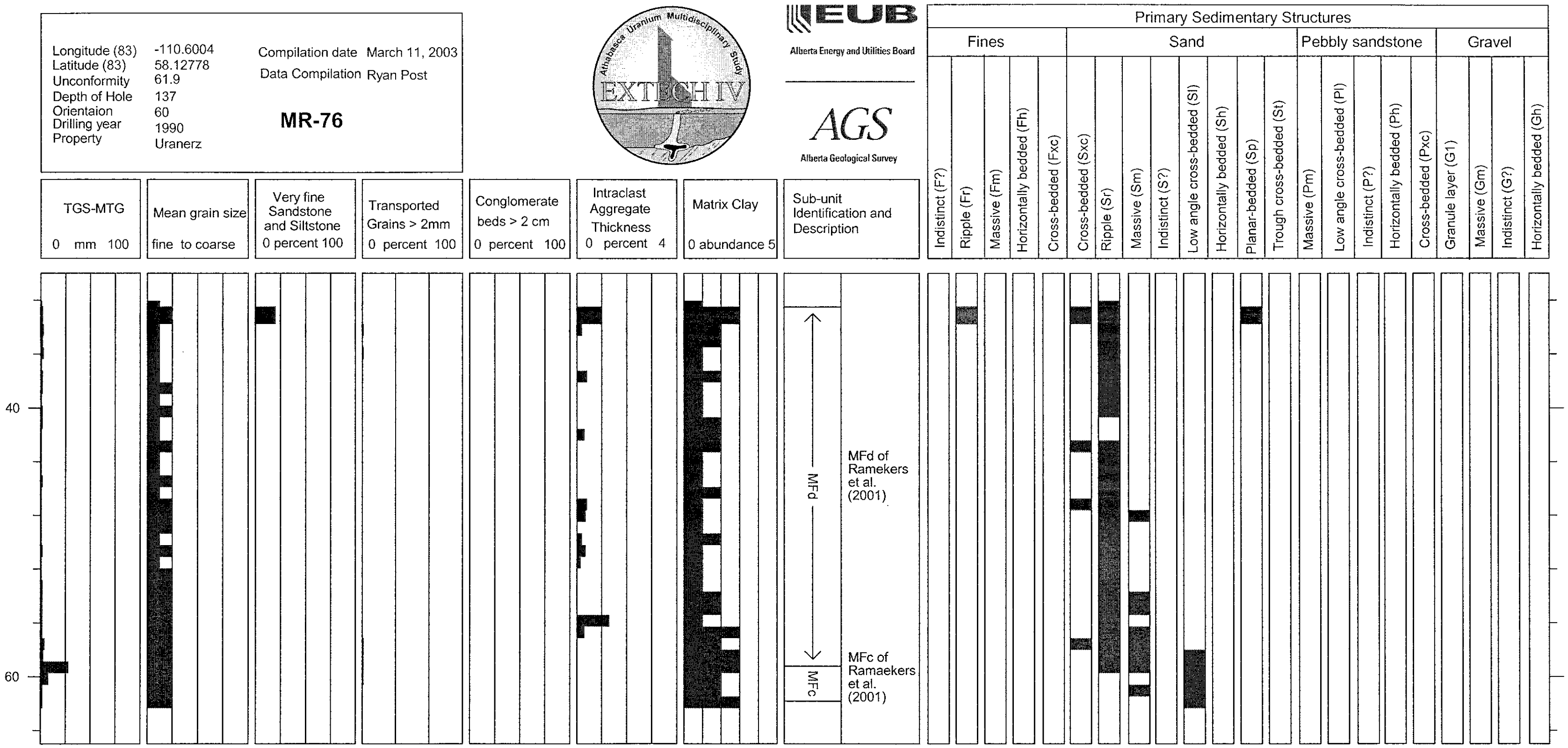

Longitude (83) -110.6346
Latitude (83) 58.1587
Unconformity 182.3
Depth of Hole 221.53
Orientaion 60
Drilling year 1989
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-61
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
MFd
MFd after Ramaekers et al. (2001)
FPu
FPu=FPc; FPl=FPa & FPb (Ramaekers et al., 2001)
60
80
100
120
140
160


Longitude (83) -110.5842
Latitude (83) 58.1159
Unconformity 117.8
Depth of Hole 234.09
Orientaion 60
Drilling year 1989
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-64
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Comments
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
-100
MFd
MFd after Ramaekers et al. (2001)
MFc after Ramaekers et al. (2001)


Longitude (83) -110.6833
Latitude (83) 58.2763
Unconformity 293.9
Depth of Hole 361.9
Orientaion 60
Drilling year 1989
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-70
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Comments
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
LzL
LzL after Ramaekers et al. (2001)
MFd
MFd after Ramaekers et al. (2001)
MFc
MFc after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)
FPl
Equivalent to FPa & FPb (Ramaekers et al., 2001)
-100
-200
-300


Longitude (83) -110.6871
Latitude (83) 58.255
Unconformity 248.42
Depth of Hole 302.76
Orientaion 60
Drilling year 1989
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-71
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Comments
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
-100
-200
LzL
LzL after Ramaekers et al. (2001)
MFd
MFd after Ramaekers et al. (2001)
FPl
Equivalent to FPb & FPa (Ramaekers et al., 2001)
-100
-200


Longitude (83) -110.6450
Latitude (83) 58.1735
Unconformity 169.13
Depth of Hole 207.0
Orientaion 60
Drilling year 1990
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-73
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Comments
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
-100
LzL
MFd
MFc
FPu
LzL after Ramaekers et al. (2001)
MFd after Ramaekers et al. (2001)
MFc after Ramaekers et al. (2001)
Equivalent to FPc (Ramaekers et al.,

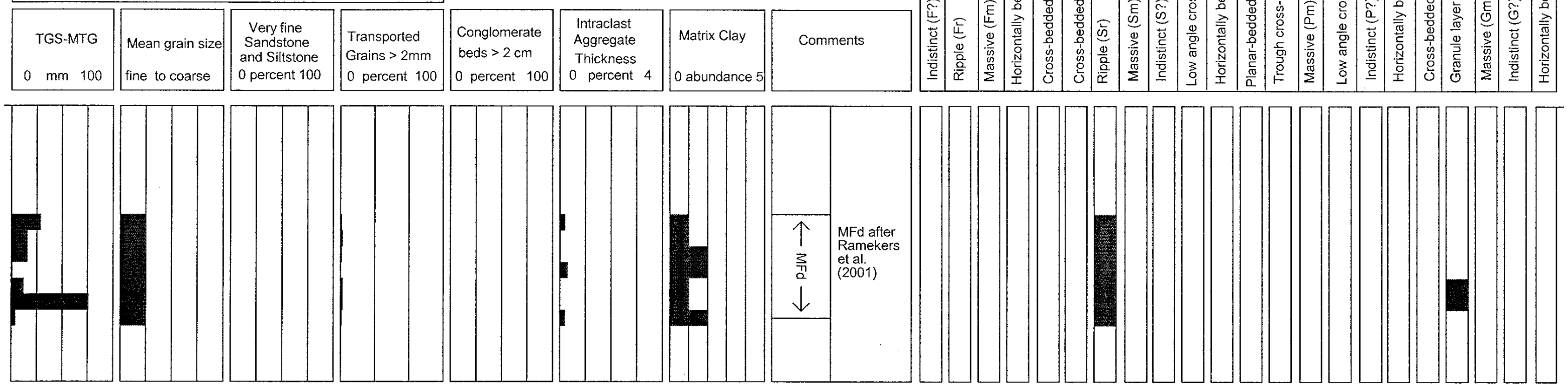

Longitude (83) -110.6004
Latitude (83) 58.12778
Unconformity 61.9
Depth of Hole 137
Orientaion 60
Drilling year 1990
Property Uranerz
Compilation date March 11, 2003
Data Compilation Ryan Post
MR-76
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Sub-unit Identification and Description
MFd
MFd of Ramekers et al. (2001)
MFc
MFc of Ramaekers et al. (2001)
40
60

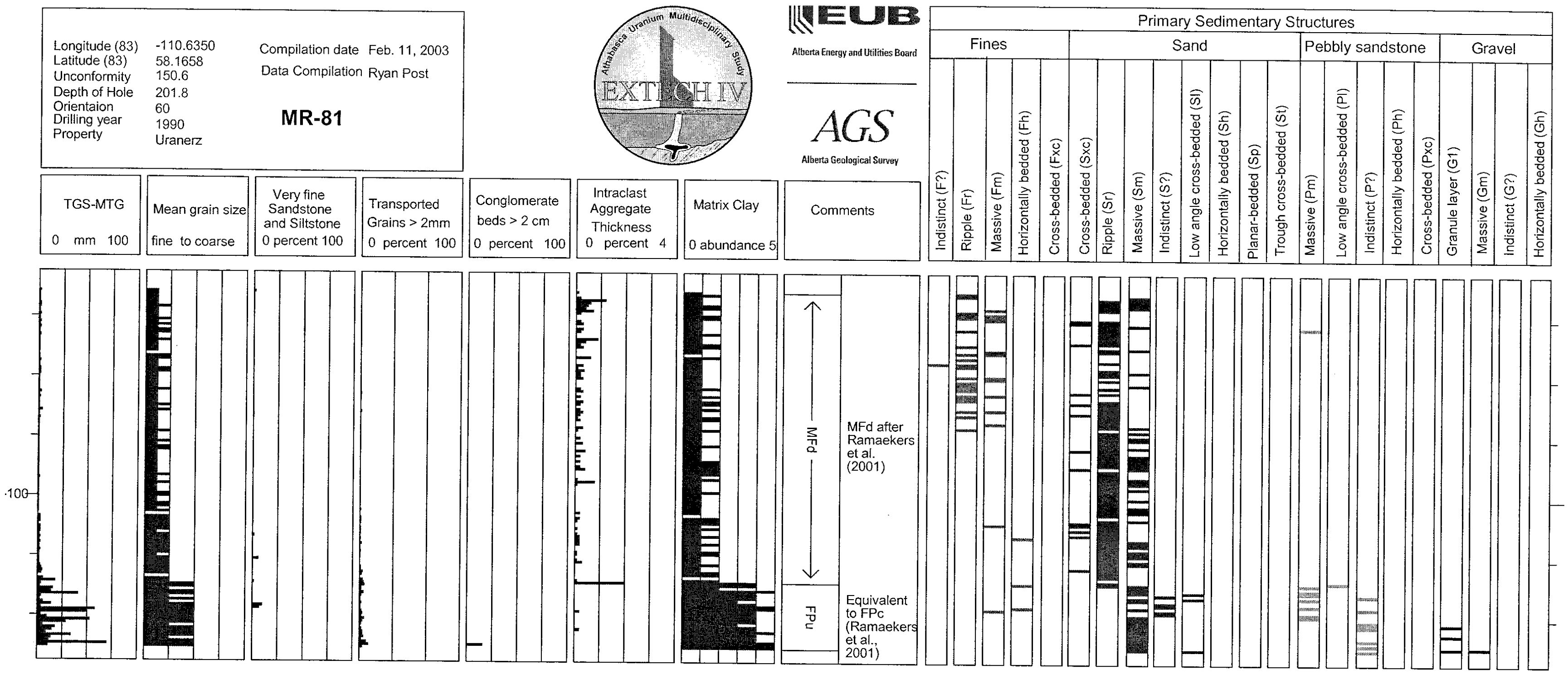
Longitude (83)	-110.6092
Latitude (83)	58.1379
Unconformity	51.45
Depth of Hole	71.9
Orientaion	60
Drilling year	1990
Property	Uranerz

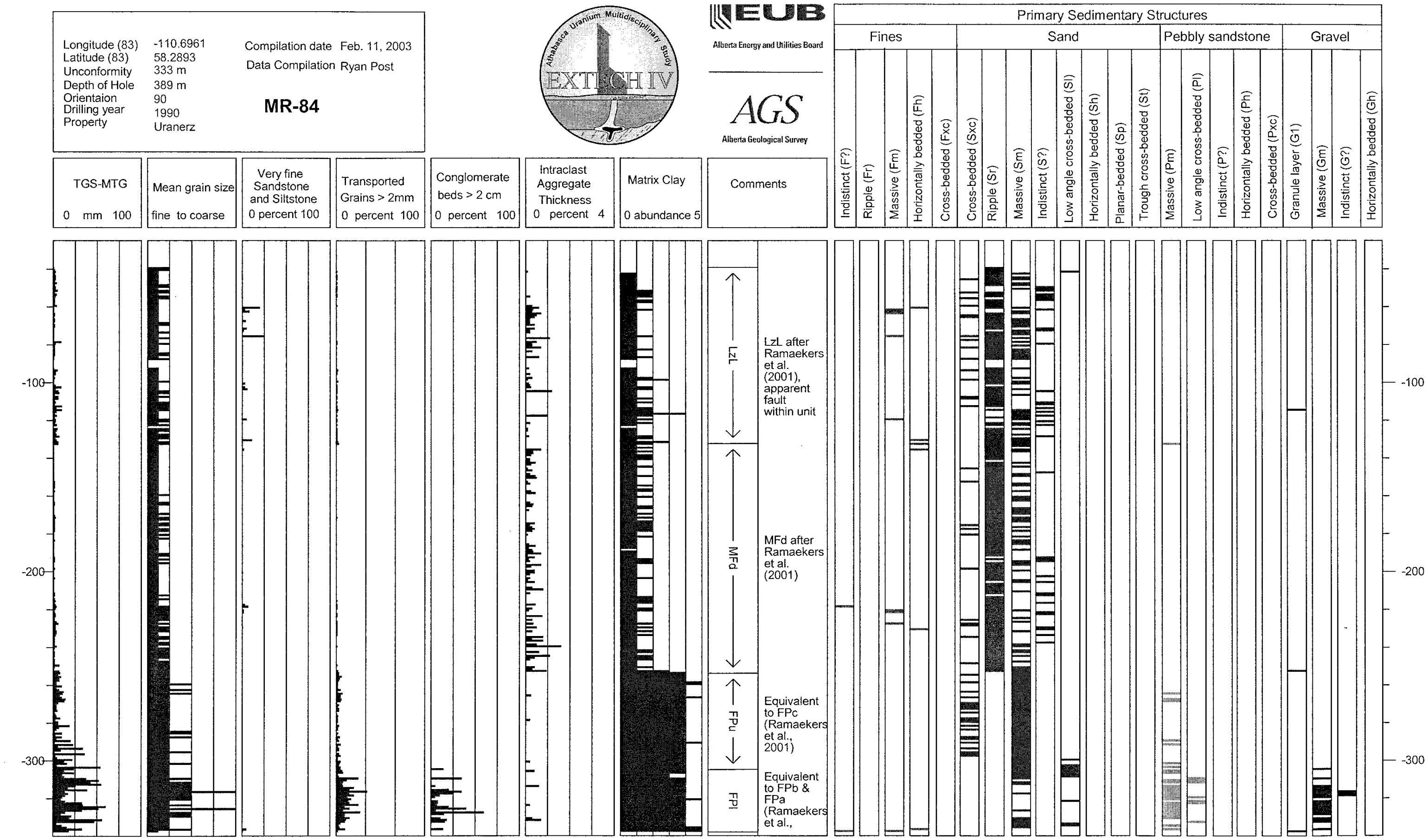
Compilation date Feb. 11, 2003

Data Compilation Ryan Post

MR-78




Longitude (83) -110.6350
Latitude (83) 58.1658
Unconformity 150.6
Depth of Hole 201.8
Orientaion 60
Drilling year 1990
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-81
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Comments
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
-100
MFd
MFd after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)


Longitude (83) -110.6961
Latitude (83) 58.2893
Unconformity 333 m
Depth of Hole 389 m
Orientaion 90
Drilling year 1990
Property Uranerz
Compilation date Feb. 11, 2003
Data Compilation Ryan Post
MR-84
Athabasca Uranium Multidisciplinary Study
EXTECH IV
EUB
Alberta Energy and Utilities Board
AGS
Alberta Geological Survey
TGS-MTG
0 mm 100
Mean grain size
fine to coarse
Very fine Sandstone and Siltstone
0 percent 100
Transported Grains > 2mm
0 percent 100
Conglomerate beds > 2 cm
0 percent 100
Intraclast Aggregate Thickness
0 percent 4
Matrix Clay
0 abundance 5
Comments
Primary Sedimentary Structures
Fines
Sand
Pebbly sandstone
Gravel
Indistinct (F?)
Ripple (Fr)
Massive (Fm)
Horizontally bedded (Fh)
Cross-bedded (Fxc)
Cross-bedded (Sxc)
Ripple (Sr)
Massive (Sm)
Indistinct (S?)
Low angle cross-bedded (Sl)
Horizontally bedded (Sh)
Planar-bedded (Sp)
Trough cross-bedded (St)
Massive (Pm)
Low angle cross-bedded (Pl)
Indistinct (P?)
Horizontally bedded (Ph)
Cross-bedded (Pxc)
Granule layer (G1)
Massive (Gm)
Indistinct (G?)
Horizontally bedded (Gh)
-100
-200
-300
LzL
LzL after Ramaekers et al. (2001), apparent fault within unit
MFd
MFd after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)
FPl
Equivalent to FPb & FPa (Ramaekers et al.,

Appendix 5 - Alteration and Replacement Features, Lower Athabasca Group

Silicification and friability were quantitatively recorded on a metre-by-metre scale. Tectonic structure/ type and replacement type were recorded only where observed. Fracture counts per metre may be overestimated, as some fractures may have been produced during drilling, extraction and boxing of the core. MTG and matrix clay are used to facilitate lithostratigraphic breaks of the unconformity-bounded formations that are defined in Appendix 2. No logs are available for drillholes FC-034, MR-05, MR-16, MR-17. Non-numerical parameters are defined below and are modified from Ramaekers, 2003.

Matrix Clay
n: not visible
t: trace
tm: mostly trace, less moderate
mt: mostly moderate, less trace
m: minor to moderate
a: abundant

Silicification
n: none
w: weak
m: moderate (sparkles)
s: strong, tombstone

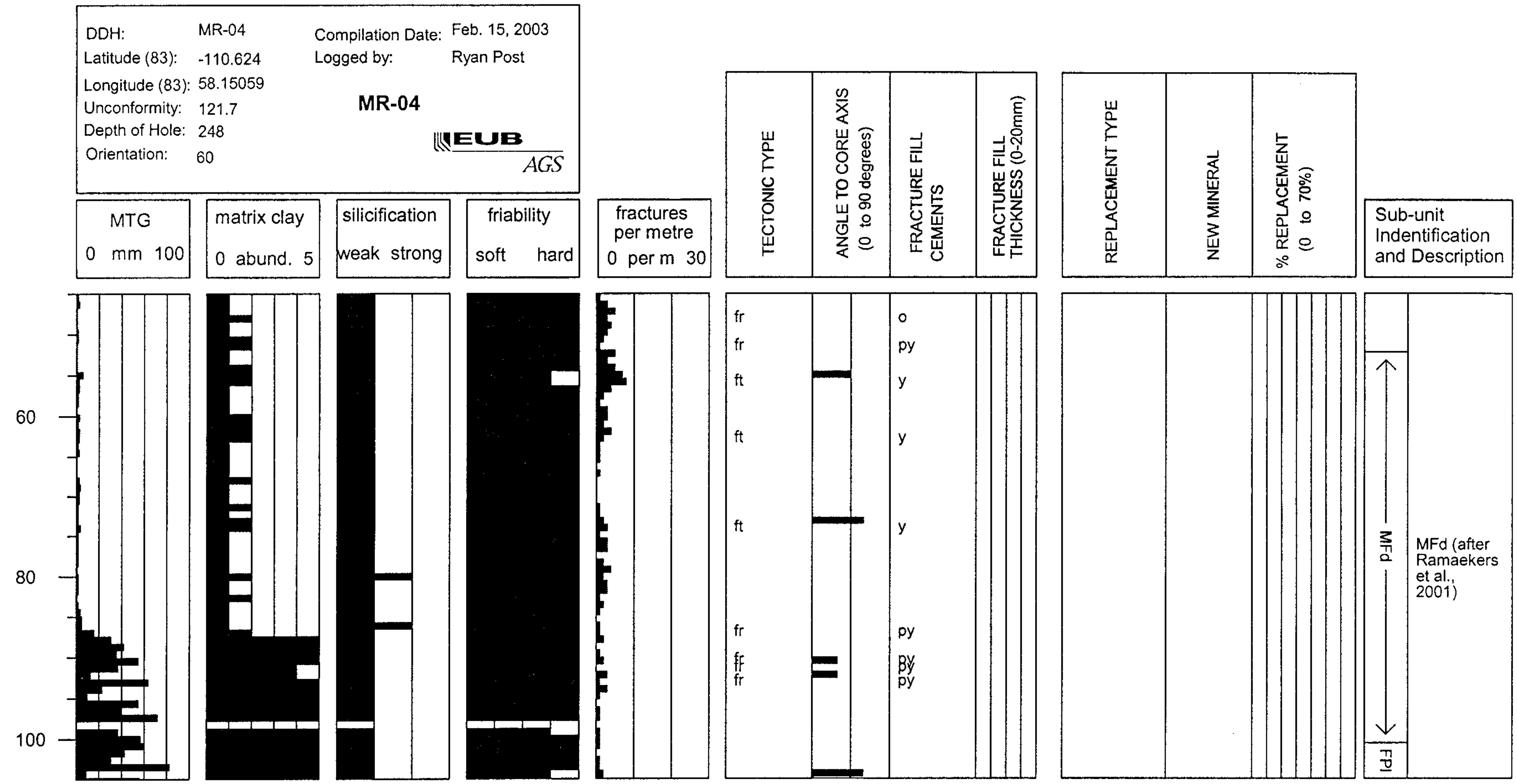
Friability
C: competent, hard to break
e: competent, breaks easily
f: friable; v: very friable; u: unconsolidated
h: hard, mudstone only (fingernail does not scratch)
s: soft, Mudstone only (fingernail gouges)

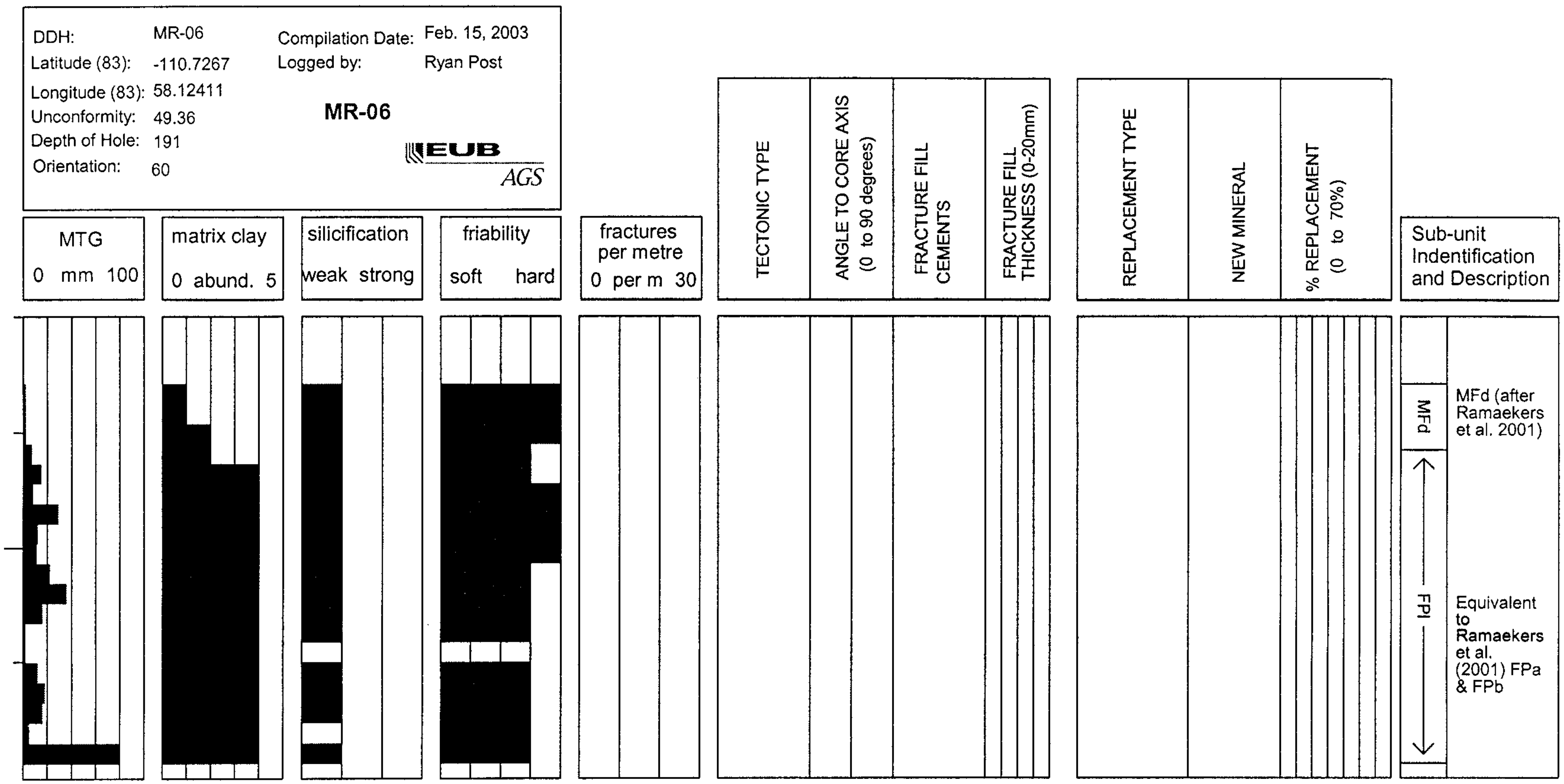
Tectonic Type
ft: fault, unspecified
fd: fault, dip-slip
fs: fault, strike-slip
fr: fracture, no movement
bx: breccia
br: breccia, milled (fault conglomerate)
bc: breccia, crackle
su: sandy gouge, uncemented
sc: sandy gouge, cemented
b: bedding plane
n: not determined

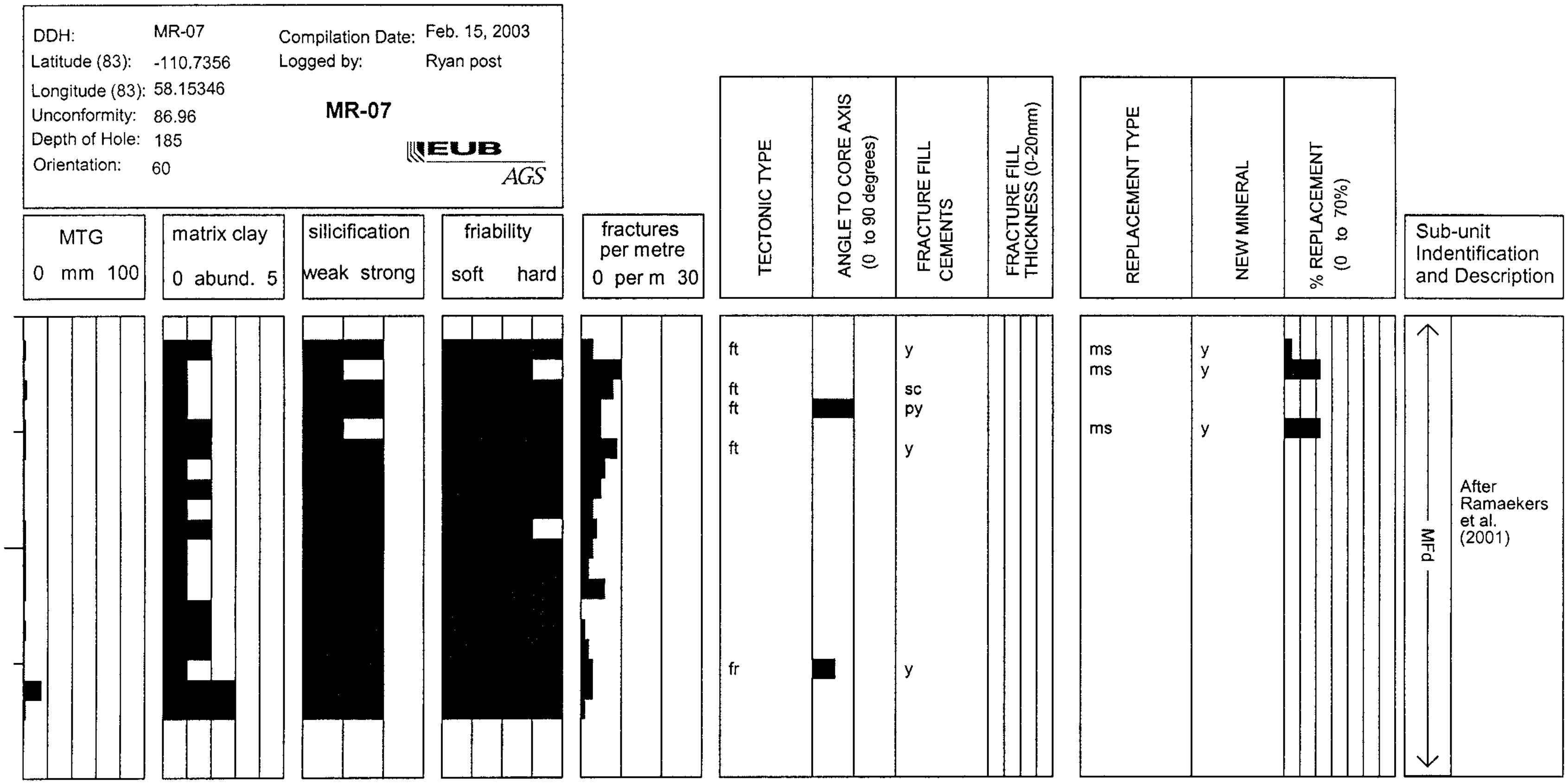
Tectonic Structure Cement/Fill
c: calcite
h: hematite (only if saturated)
py: pyrite
y: clay
g: gouge
sc: gouge, sandy cemented
su: gouge, sandy uncemented
qd: quartz, drusy
qo: quartz, overgrowths
o: other
n: none

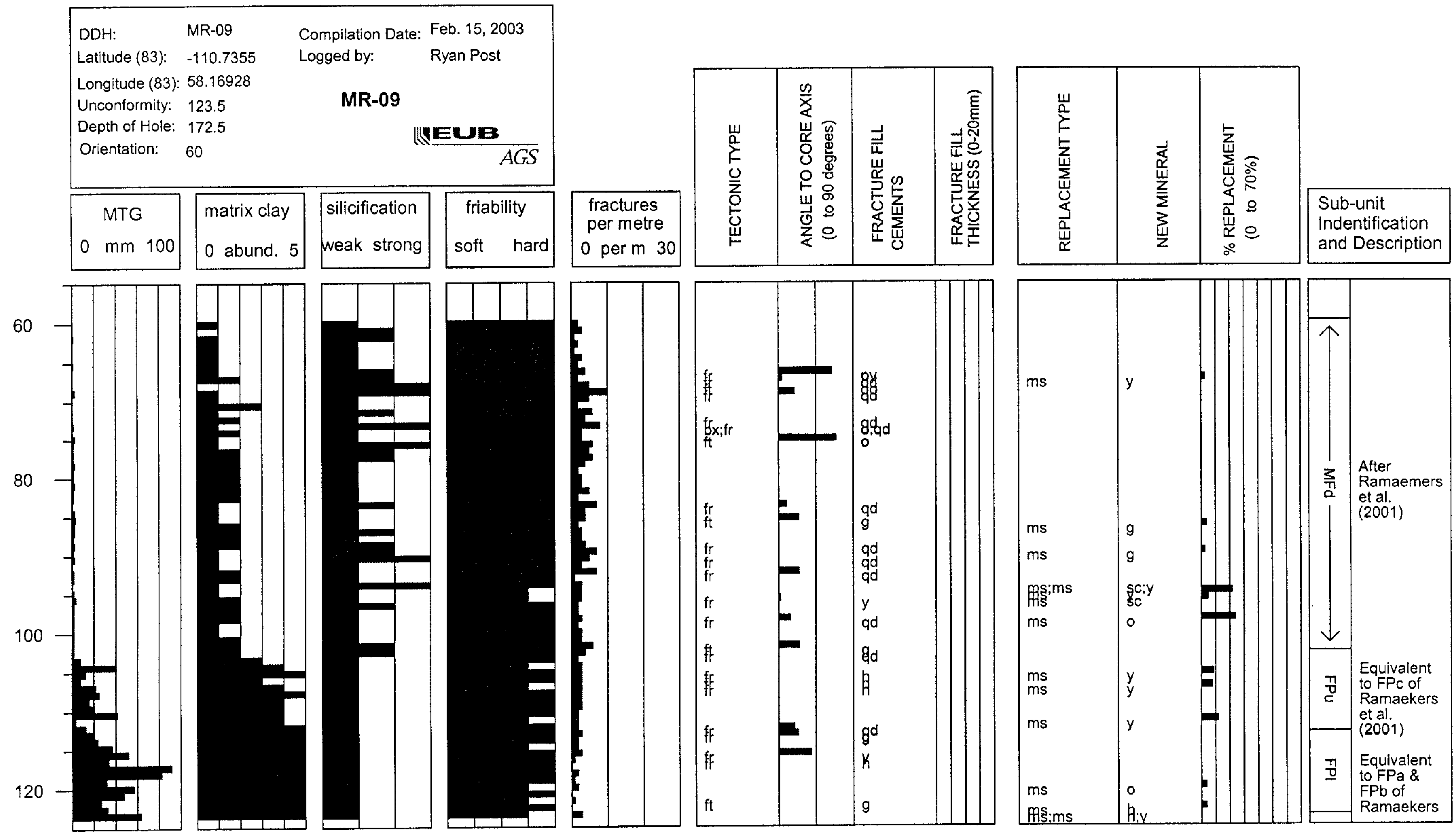
Replacement Type
ms: massive
v: vuggy
pa: patchy
d: disseminated
fi: replace rock within fault zone
fo: replace fault zone and wall rock

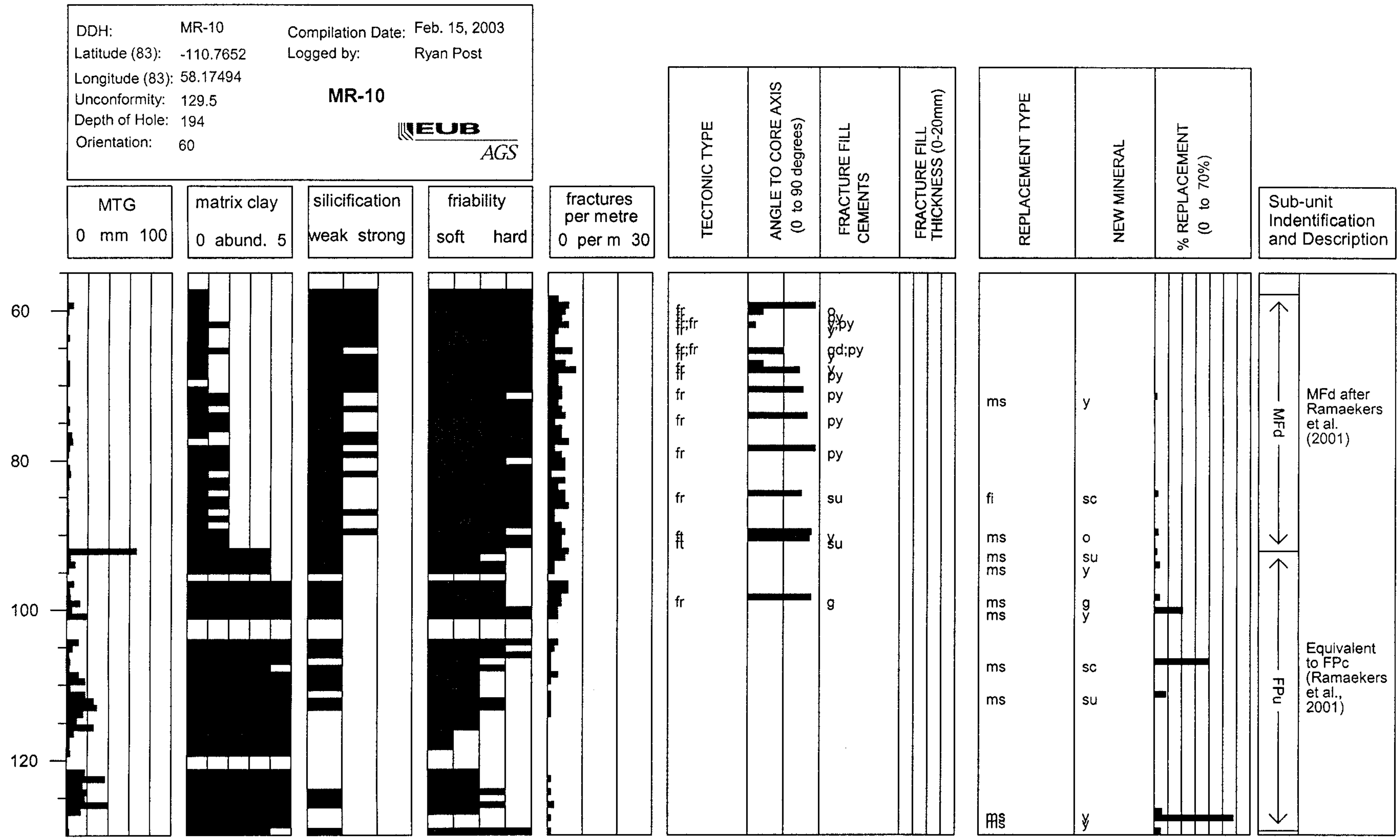
New Mineral
c: calcite
h: hematite (only if saturated)
py: pyrite
y: clay
g: gouge
sc: gouge, sandy cemented
su: gouge, sandy uncemented
qd: quartz, drusy
qo: quartz, overgrowths
o: other
n: none


DDH: MR-04
Compilation Date: Feb. 15, 2003
Latitude (83): -110.624
Logged by: Ryan Post
Longitude (83): 58.15059
Unconformity: 121.7
MR-04
Depth of Hole: 248
Orientation: 60
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
60
80
100
fr
fr
ft
ft
ft
fr
fr
fr
fr
o
py
y
y
y
py
py
py
py
MFd
FPl
MFd (after Ramaekers et al., 2001)


DDH: MR-06
Latitude (83): -110.7267
Longitude (83): 58.12411
Unconformity: 49.36
Depth of Hole: 191
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-06
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
MFd
MFd (after Ramaekers et al. 2001)
FPl
Equivalent to Ramaekers et al. (2001) FPa & FPb


DDH: MR-07
Latitude (83): -110.7356
Longitude (83): 58.15346
Unconformity: 86.96
Depth of Hole: 185
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan post
MR-07
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
ft
ft
ft
ft
fr
y
sc
py
y
y
ms
ms
ms
y
y
y
MFd
After Ramaekers et al. (2001)

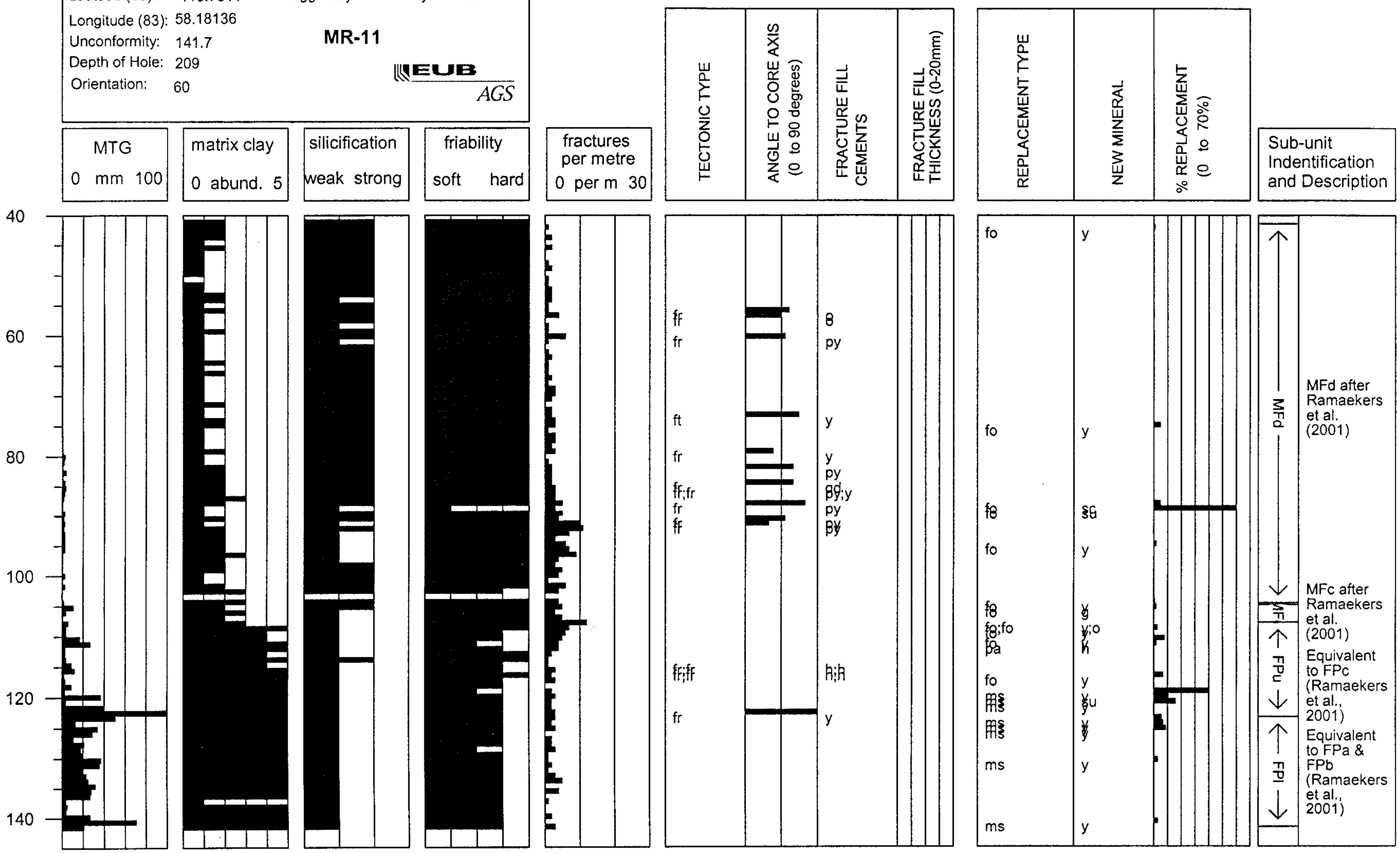

DDH: MR-09
Latitude (83): -110.7355
Longitude (83): 58.16928
Unconformity: 123.5
Depth of Hole: 172.5
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-09
EUB AGS
MTG 0 mm 100
matrix clay 0 abund. 5
silicification weak strong
friability soft hard
fractures per metre 0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
60
80
100
120
MFd
After Ramaemers et al. (2001)
FPu
Equivalent to FPc of Ramaekers et al. (2001)
FPl
Equivalent to FPa & FPb of Ramaekers

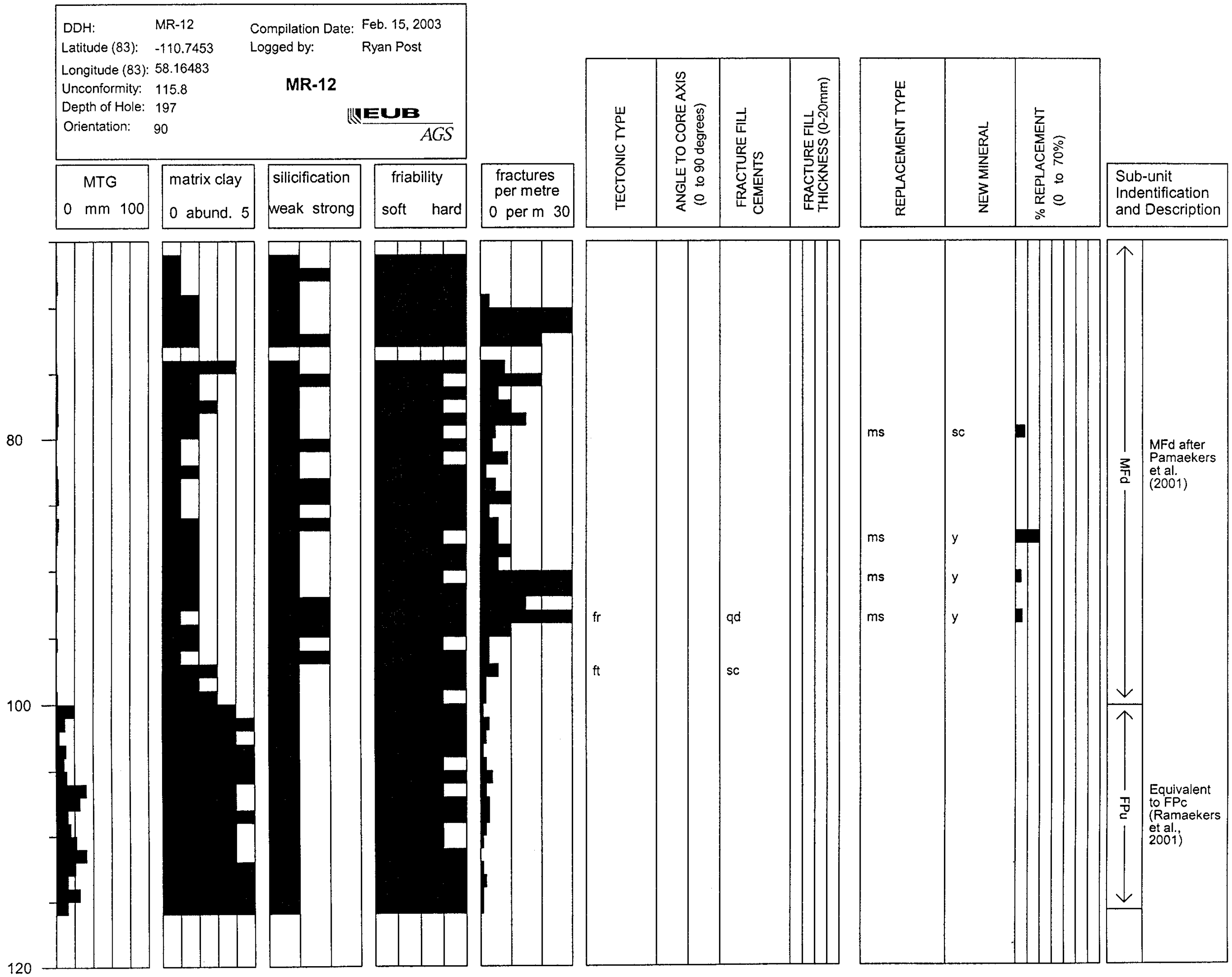


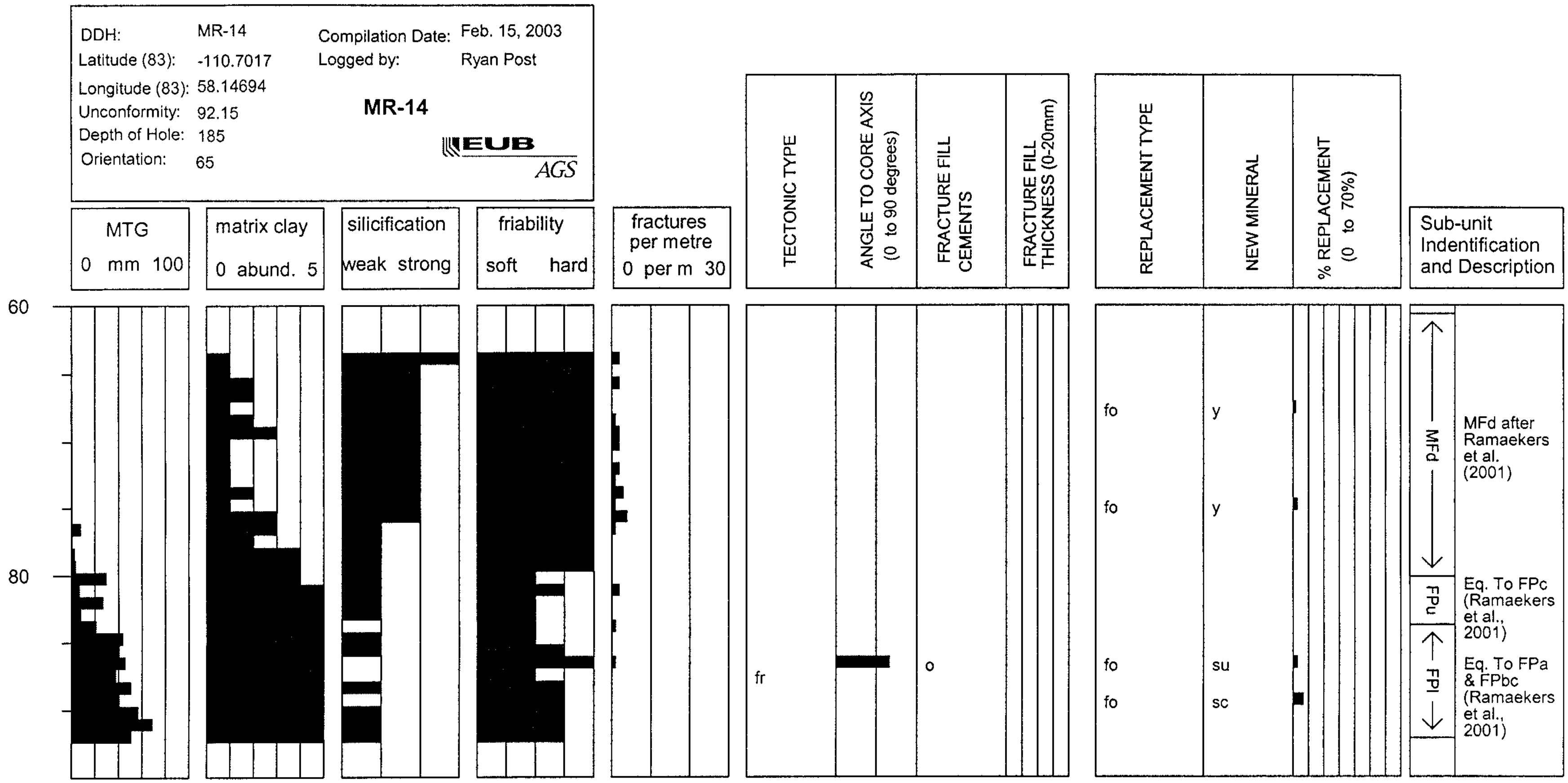
DDH: MR-10
Latitude (83): -110.7652
Longitude (83): 58.17494
Unconformity: 129.5
Depth of Hole: 194
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-10
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
60
80
100
120
MFd
MFd after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)

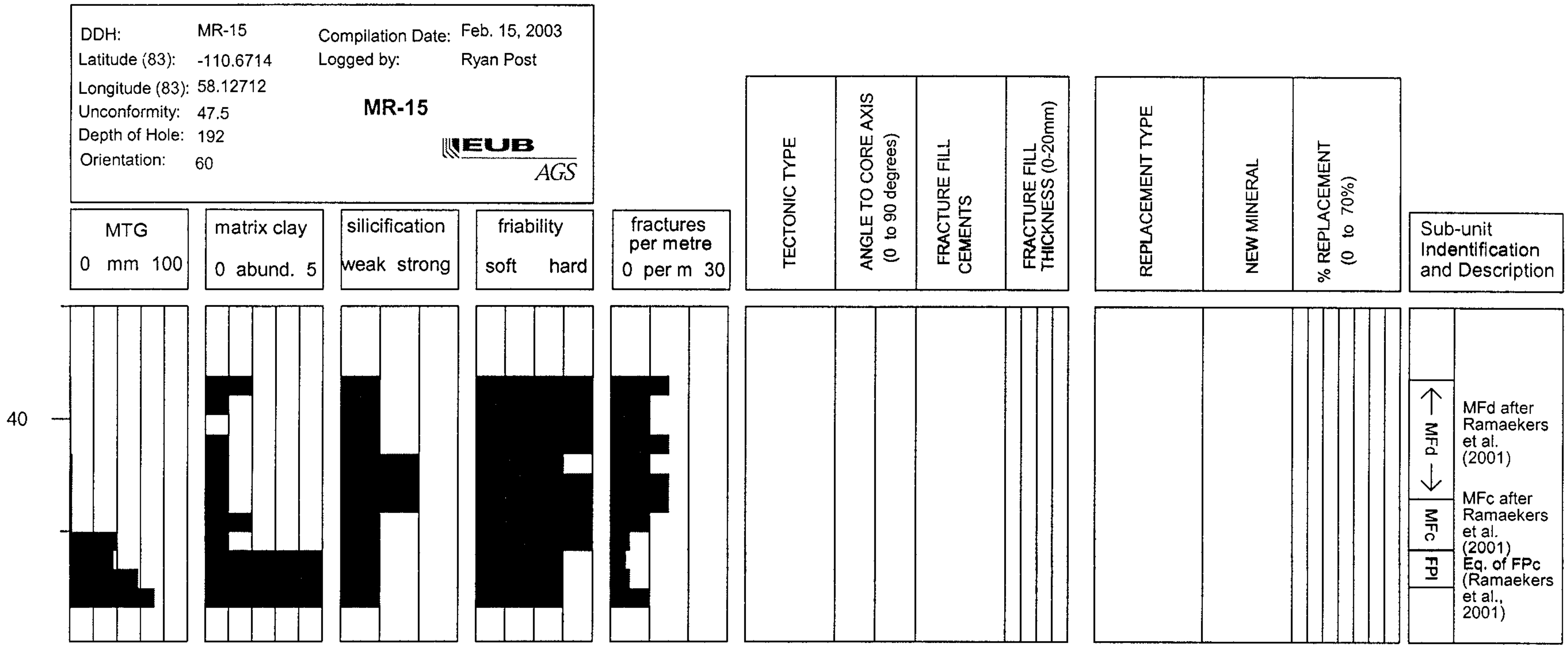
DDH:	MR-11	Compilation Date:	Feb. 15, 2003
Latitude (83):	-110.7511	Logged by:	Ryan Post
Longitude (83):	58.18136		
Unconformity:	141.7		
Depth of Hole:	209		
Orientation:	60		

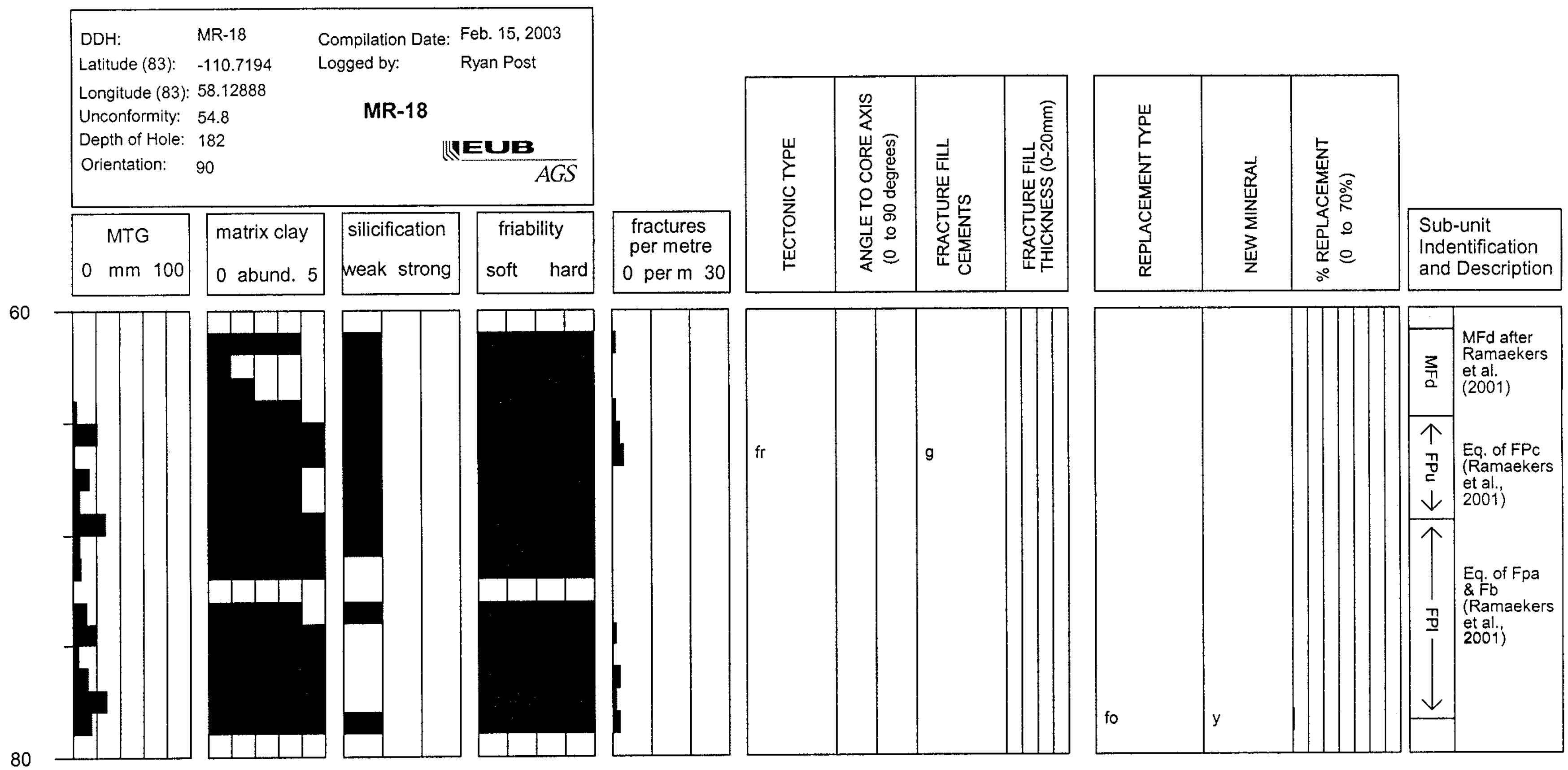
MR-11

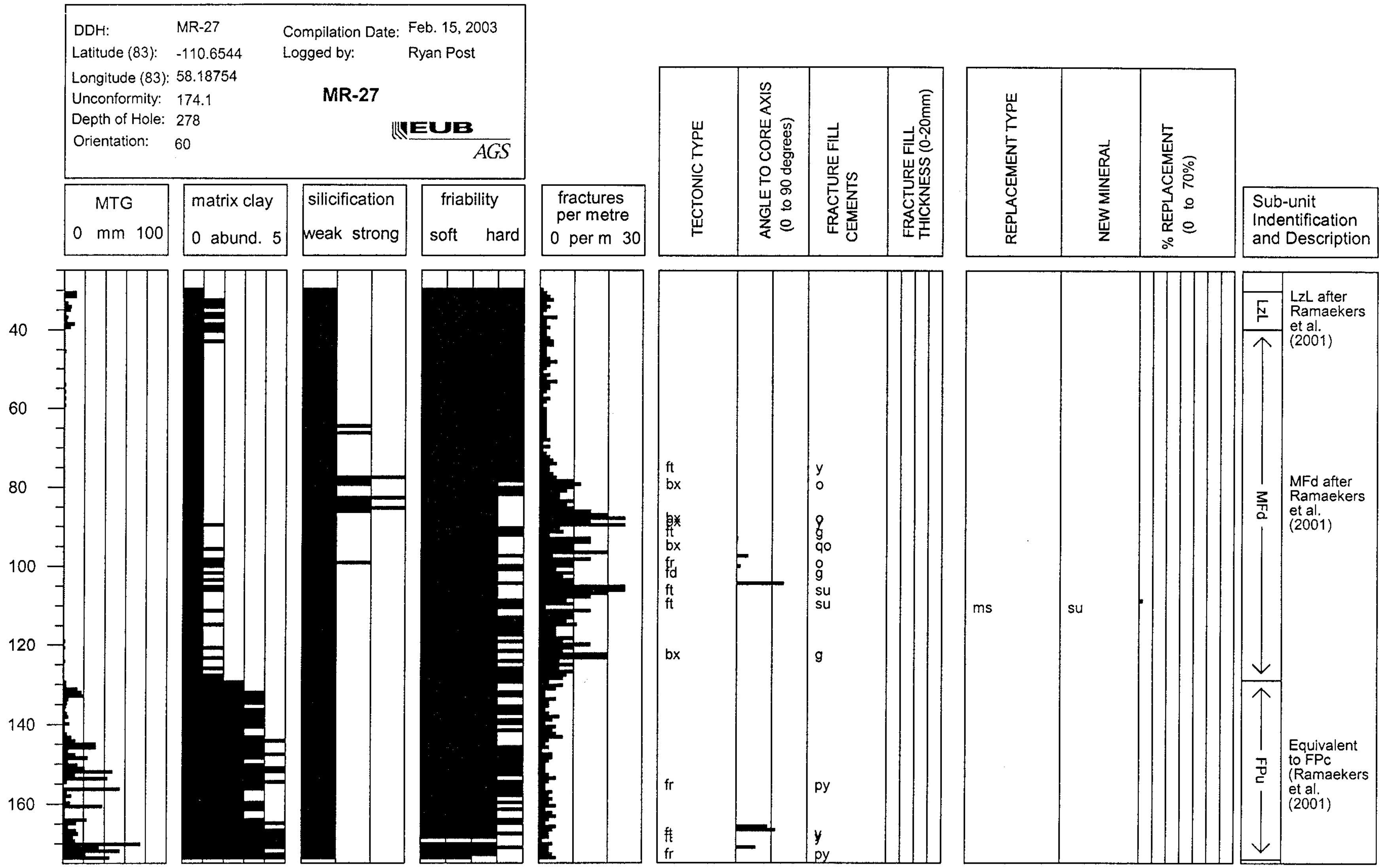


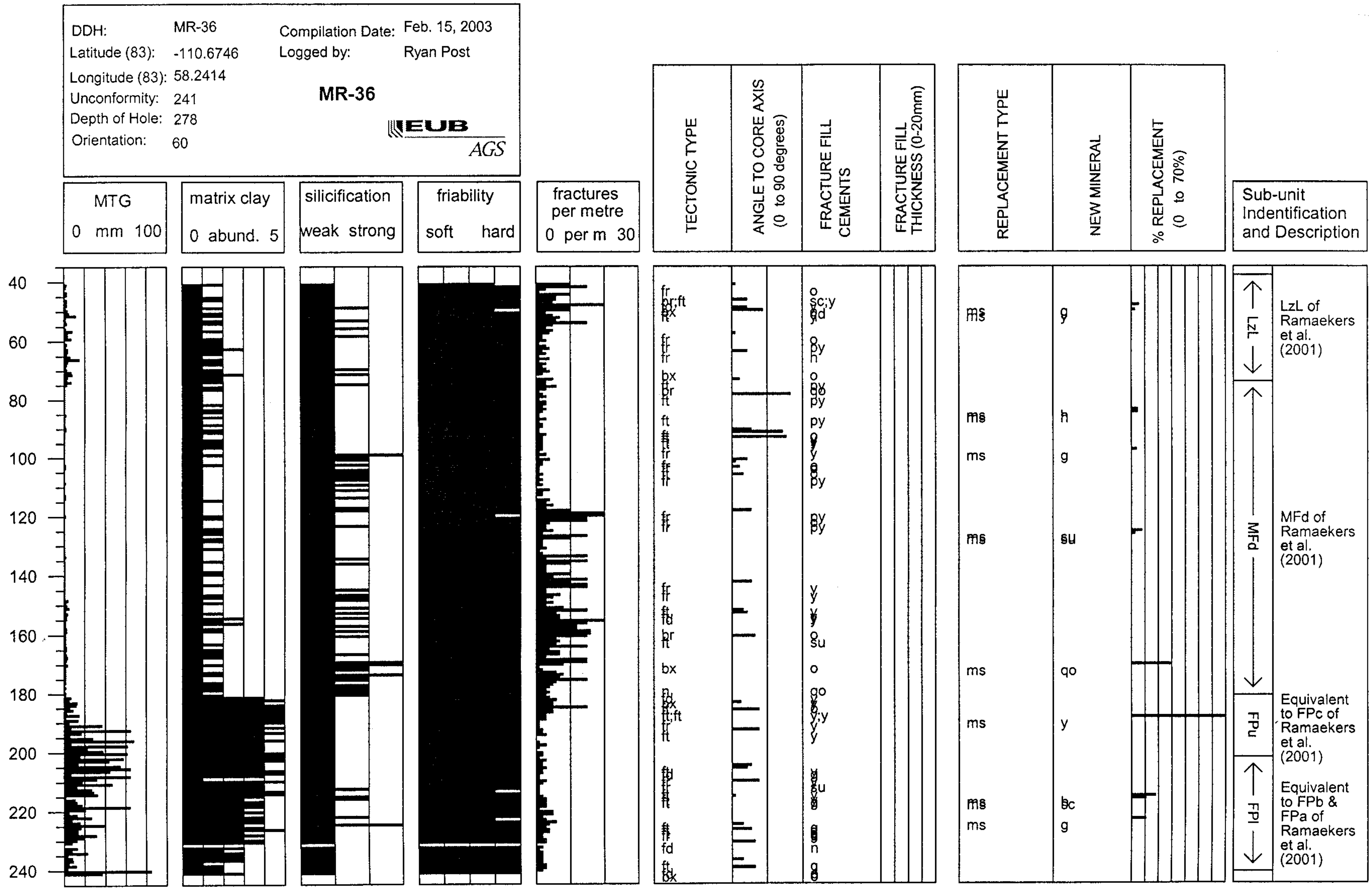

DDH: MR-12
Latitude (83): -110.7453
Longitude (83): 58.16483
Unconformity: 115.8
Depth of Hole: 197
Orientation: 90
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-12
EUB AGS
MTG 0 mm 100
matrix clay 0 abund. 5
silicification weak strong
friability soft hard
fractures per metre 0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
80
100
120
ms
sc
ms
y
ms
y
fr
qd
ms
y
ft
sc
MFd
MFd after Pamaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)

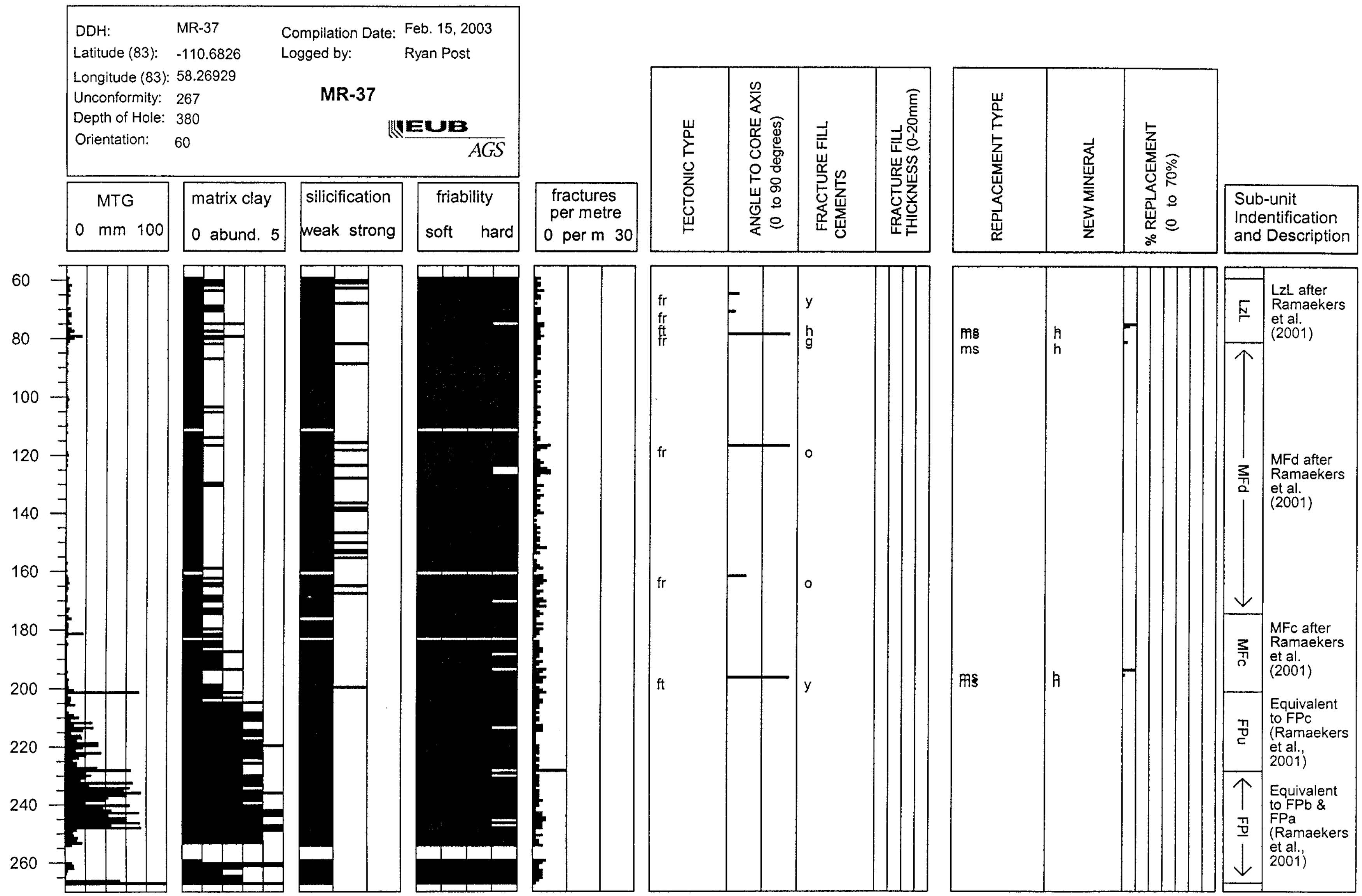

DDH: MR-14
Latitude (83): -110.7017
Longitude (83): 58.14694
Unconformity: 92.15
Depth of Hole: 185
Orientation: 65
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-14
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
60
80
fo
y
fo
y
fr
o
fo
su
fo
sc
MFd
MFd after Ramaekers et al. (2001)
FPu
Eq. To FPc (Ramaekers et al., 2001)
FPl
Eq. To FPa & FPbc (Ramaekers et al., 2001)


DDH: MR-15
Latitude (83): -110.6714
Longitude (83): 58.12712
Unconformity: 47.5
Depth of Hole: 192
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-15
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
40
MFd
MFc
FPl
MFd after Ramaekers et al. (2001)
MFc after Ramaekers et al. (2001)
Eq. of FPc (Ramaekers et al., 2001)

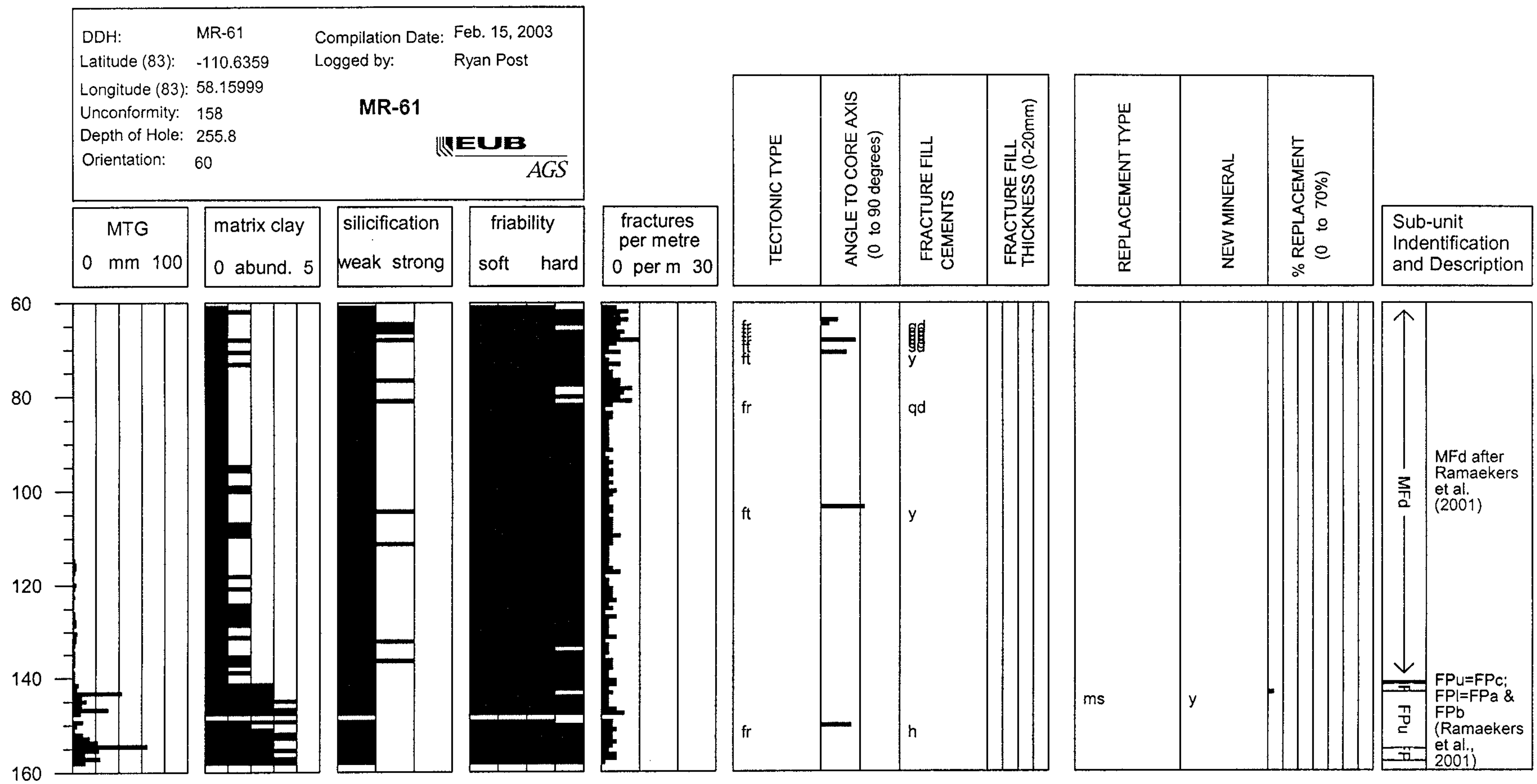

DDH: MR-18
Latitude (83): -110.7194
Longitude (83): 58.12888
Unconformity: 54.8
Depth of Hole: 182
Orientation: 90
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-18
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
60
80
fr
g
fo
y
MFd
MFd after Ramaekers et al. (2001)
FPu
Eq. of FPc (Ramaekers et al., 2001)
FPl
Eq. of Fpa & Fb (Ramaekers et al., 2001)

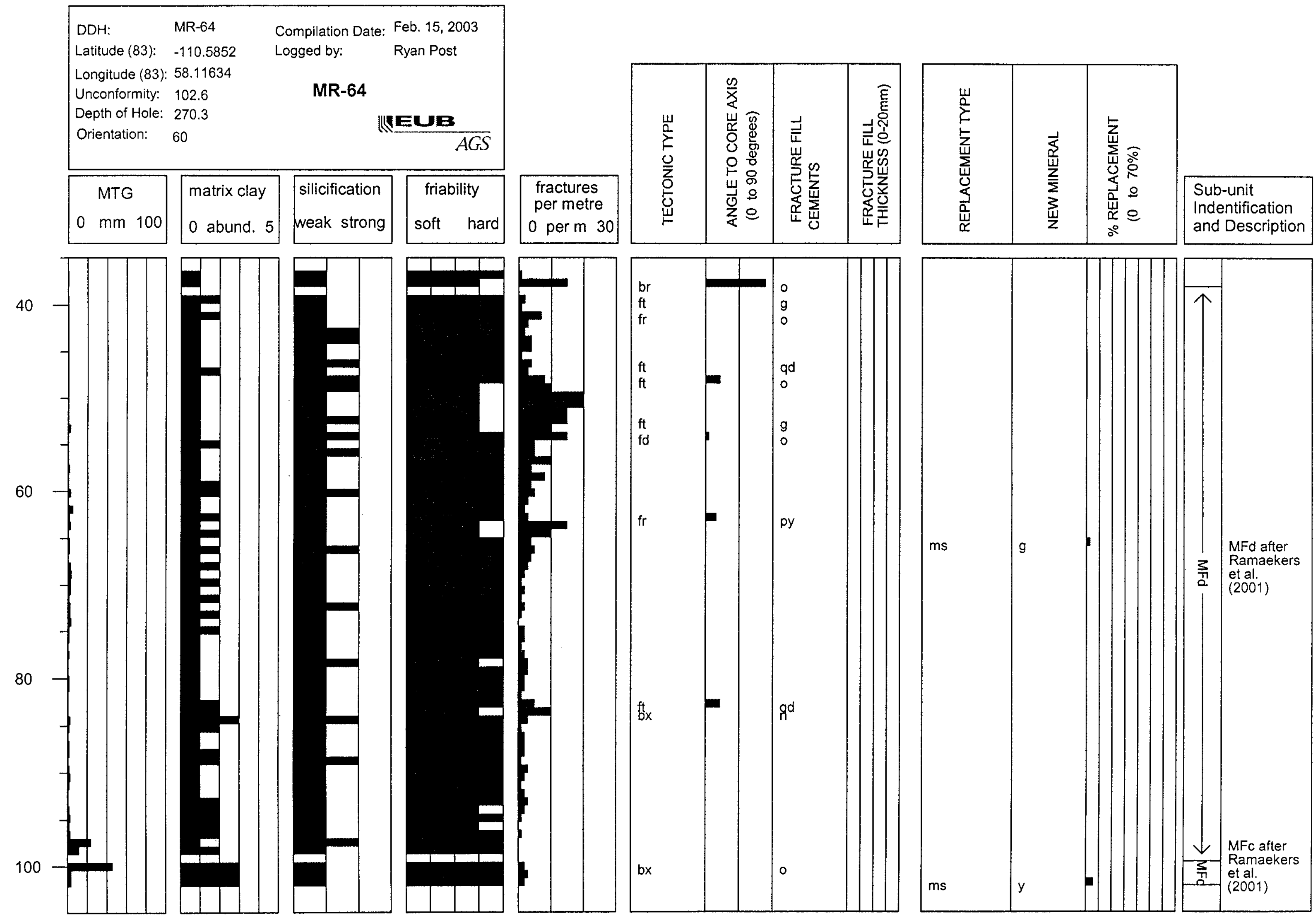

DDH: MR-27
Latitude (83): -110.6544
Longitude (83): 58.18754
Unconformity: 174.1
Depth of Hole: 278
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-27
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
40
60
80
100
120
140
160
ft
bx
bx
ft
bx
fr
fd
ft
ft
bx
fr
ft
fr
y
o
o
g
qo
o
g
su
su
g
py
y
py
ms
su
LzL
MFd
FPu
LzL after Ramaekers et al. (2001)
MFd after Ramaekers et al. (2001)
Equivalent to FPc (Ramaekers et al. (2001)

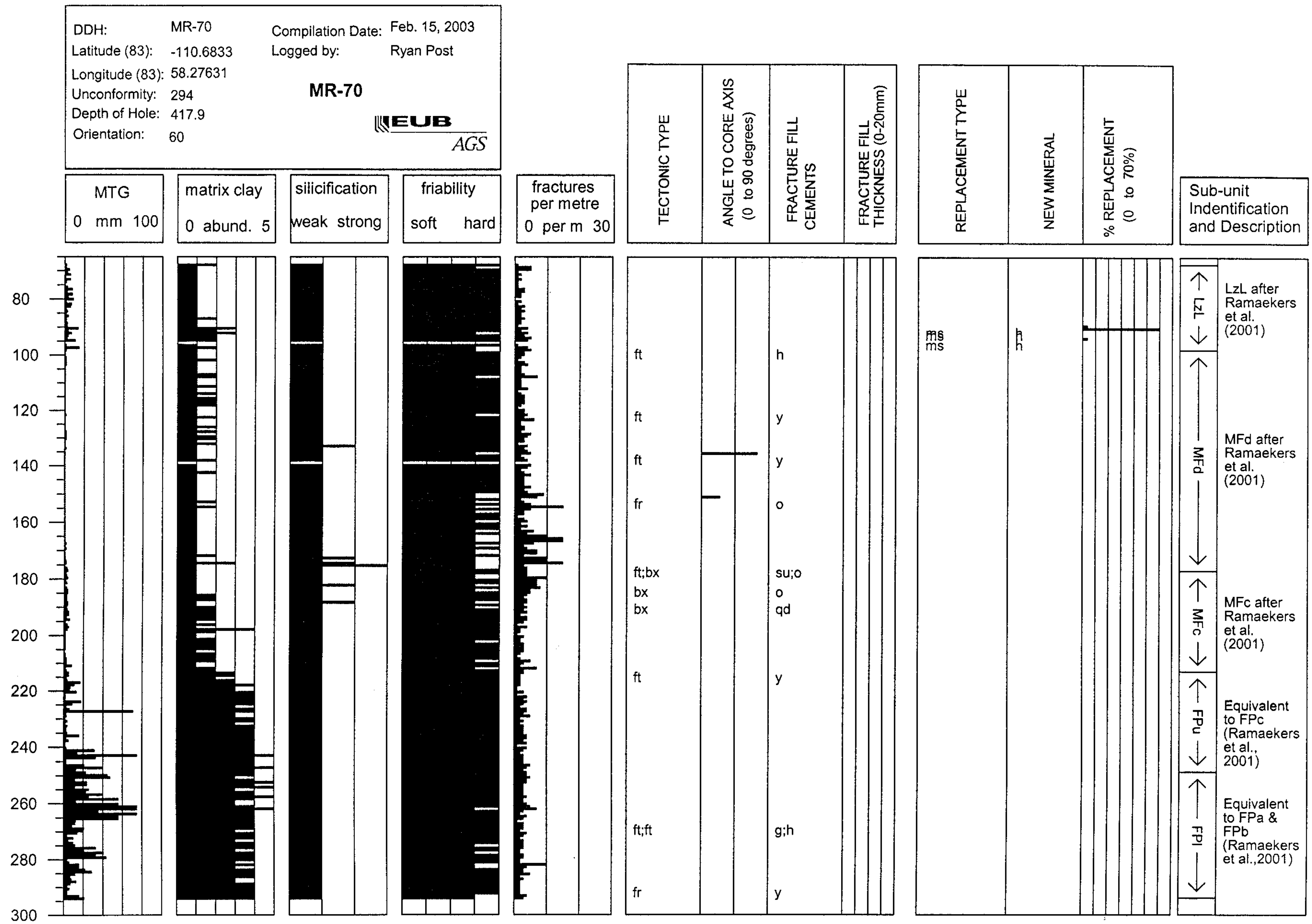

DDH: MR-36
Latitude (83): -110.6746
Longitude (83): 58.2414
Unconformity: 241
Depth of Hole: 278
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-36
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
40
60
80
100
120
140
160
180
200
220
240
LzL
LzL of Ramaekers et al. (2001)
MFd
MFd of Ramaekers et al. (2001)
FPu
Equivalent to FPc of Ramaekers et al. (2001)
FPl
Equivalent to FPb & FPa of Ramaekers et al. (2001)

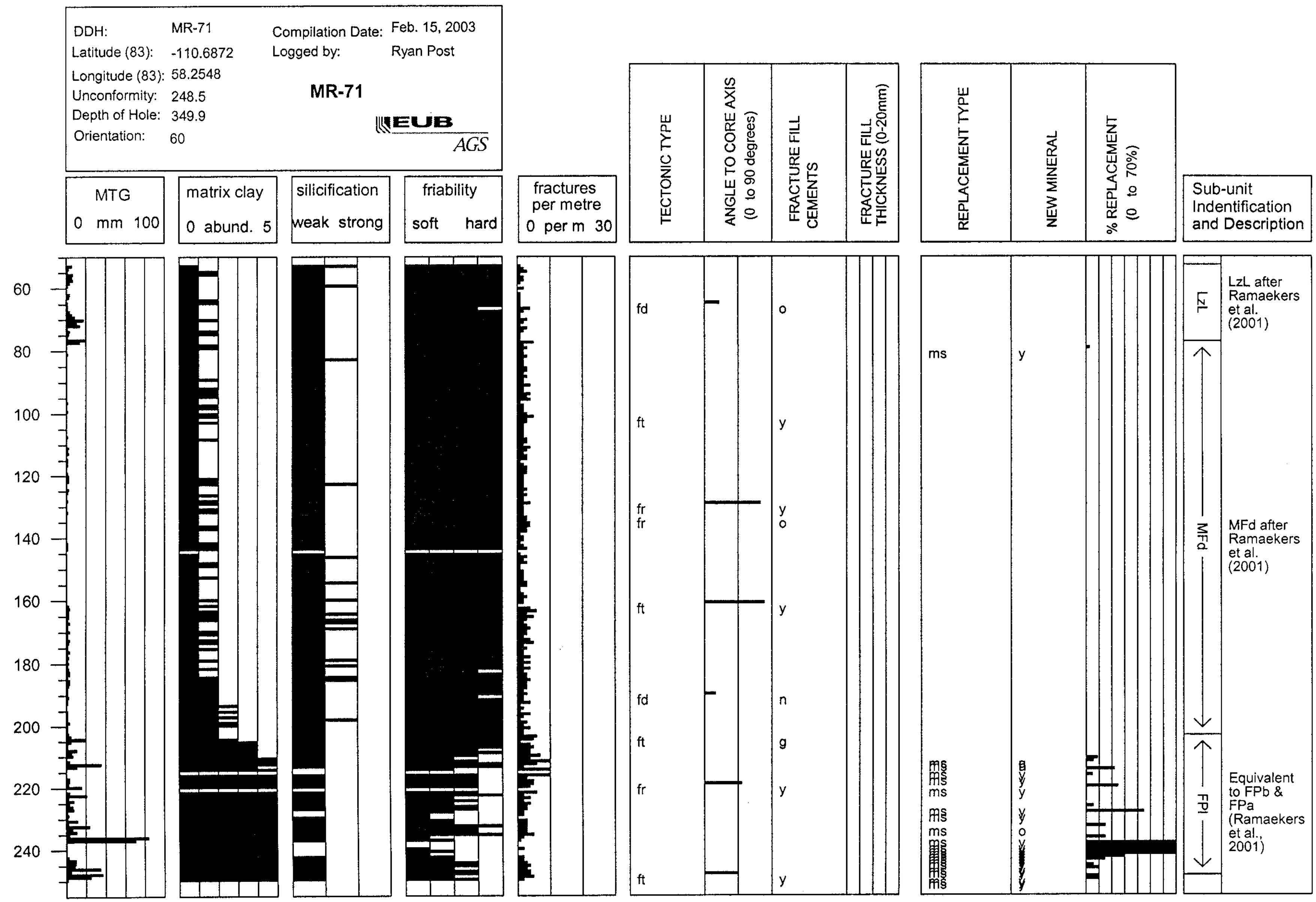


DDH: MR-37
Latitude (83): -110.6826
Longitude (83): 58.26929
Unconformity: 267
Depth of Hole: 380
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-37
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
60
80
100
120
140
160
180
200
220
240
260
fr
fr
ft
fr
fr
fr
ft
y
h
g
o
o
y
ms
ms
ms
h
h
h
LzL
LzL after Ramaekers et al. (2001)
MFd
MFd after Ramaekers et al. (2001)
MFc
MFc after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)
FPl
Equivalent to FPb & FPa (Ramaekers et al., 2001)


DDH: MR-61
Latitude (83): -110.6359
Longitude (83): 58.15999
Unconformity: 158
Depth of Hole: 255.8
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-61
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
60
80
100
120
140
160
fr
ft
fr
ft
fr
qd
y
qd
y
h
ms
y
MFd
MFd after Ramaekers et al. (2001)
FPu
FPu=FPc; FPl=FPa & FPb (Ramaekers et al., 2001)


DDH: MR-64
Latitude (83): -110.5852
Longitude (83): 58.11634
Unconformity: 102.6
Depth of Hole: 270.3
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-64
EUB AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
40
60
80
100
br
ft
fr
ft
ft
ft
fd
fr
ft
bx
bx
o
g
o
qd
o
g
o
py
qd
n
o
ms
ms
g
y
MFd
MFd after Ramaekers et al. (2001)
MFc
MFc after Ramaekers et al. (2001)

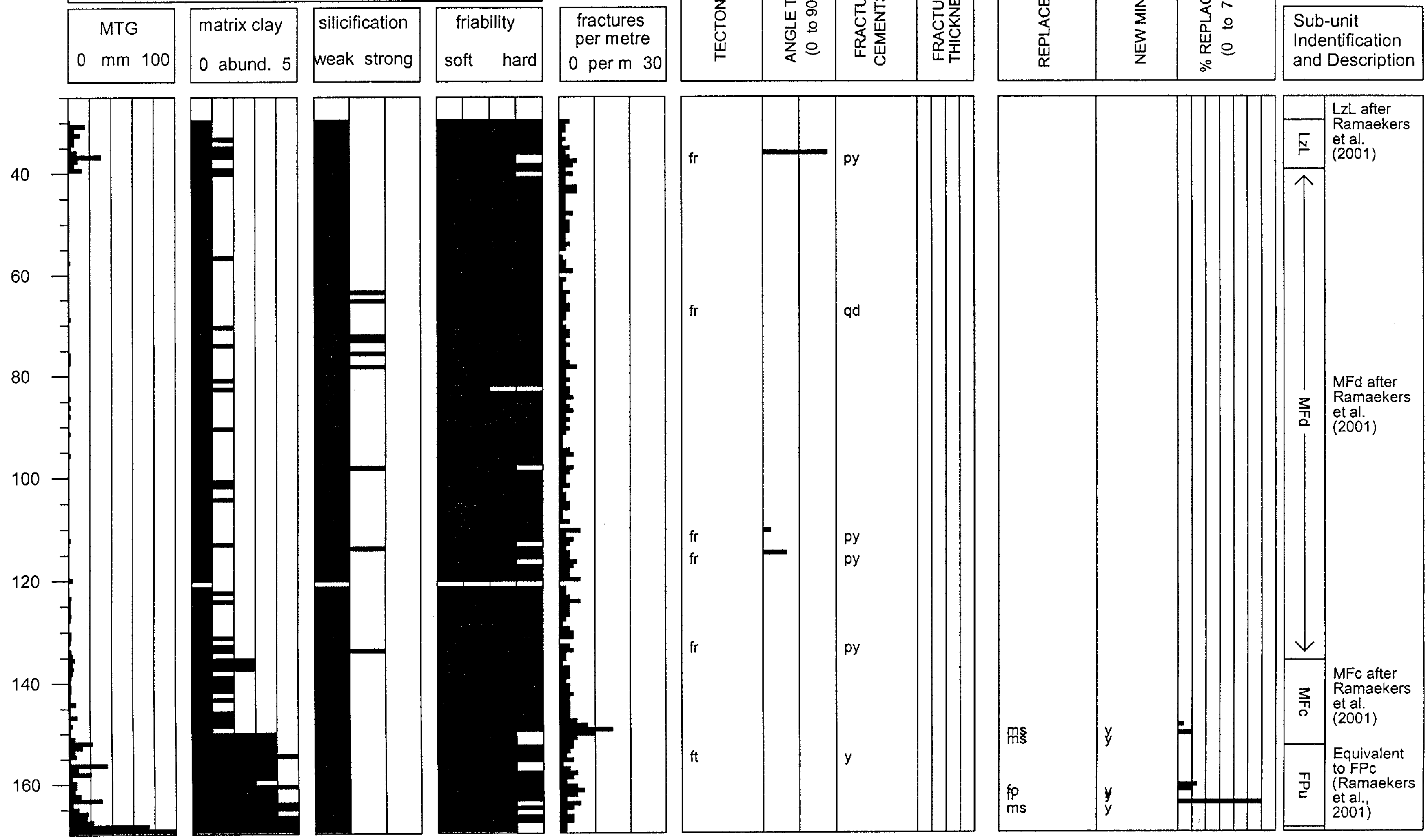

DDH: MR-70
Latitude (83): -110.6833
Longitude (83): 58.27631
Unconformity: 294
Depth of Hole: 417.9
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-70
EUB
AGS
MTG 0 mm 100
matrix clay 0 abund. 5
silicification weak strong
friability soft hard
fractures per metre 0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
80
100
120
140
160
180
200
220
240
260
280
300
ft h
ft y
ft y
fr o
ft;bx su;o
bx o
bx qd
ft y
ft;ft g;h
fr y
ms
ms
h
h
LzL
LzL after Ramaekers et al. (2001)
MFd
MFd after Ramaekers et al. (2001)
MFc
MFc after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)
FPl
Equivalent to FPa & FPb (Ramaekers et al.,2001)

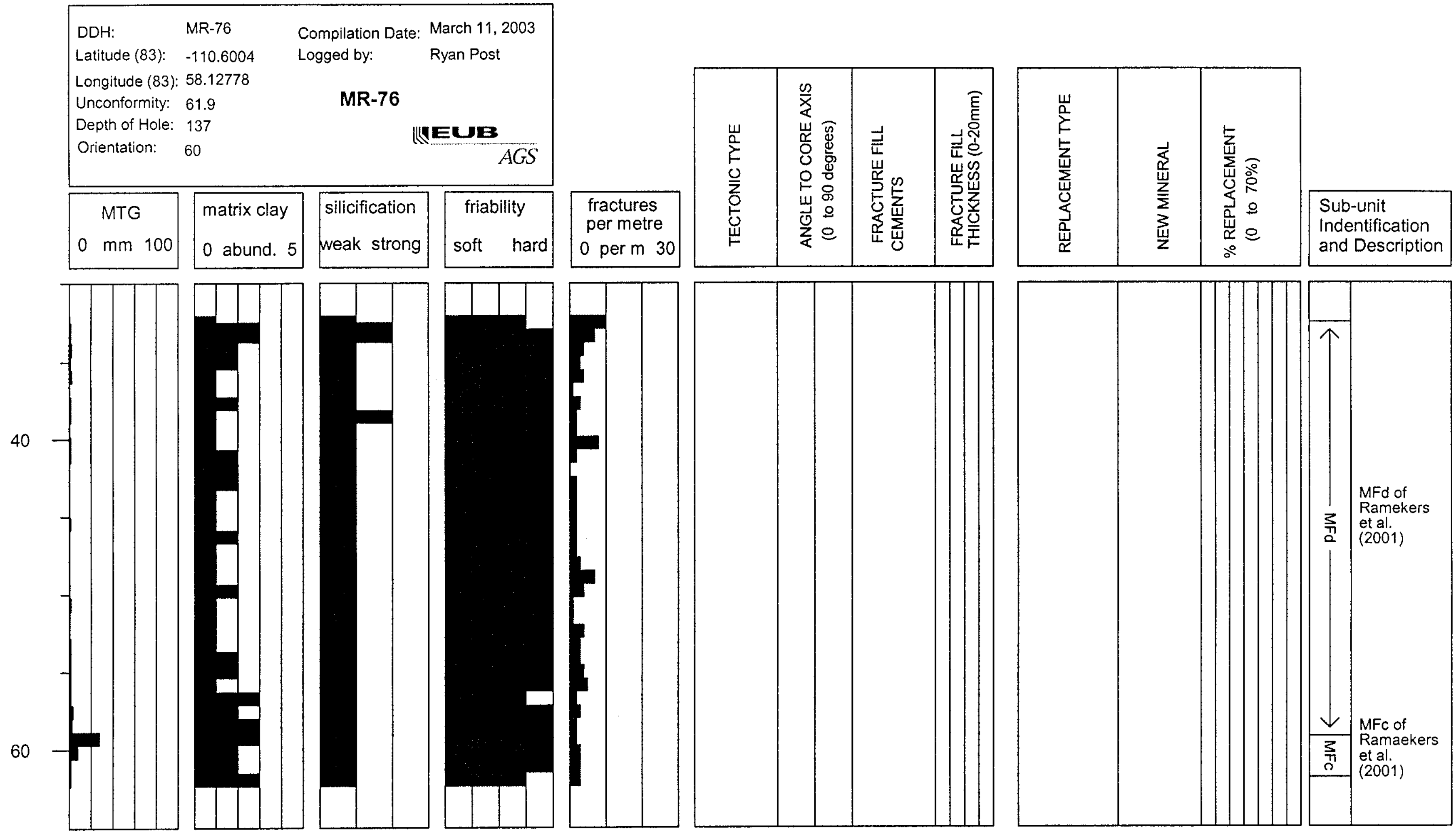

DDH: MR-71
Latitude (83): -110.6872
Longitude (83): 58.2548
Unconformity: 248.5
Depth of Hole: 349.9
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-71
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
60
80
100
120
140
160
180
200
220
240
fd
ft
fr
fr
ft
fd
ft
fr
ft
o
y
y
o
y
n
g
y
y
ms
y
ms
y
o
LzL
MFd
FPl
LzL after Ramaekers et al. (2001)
MFd after Ramaekers et al. (2001)
Equivalent to FPb & FPa (Ramaekers et al., 2001)

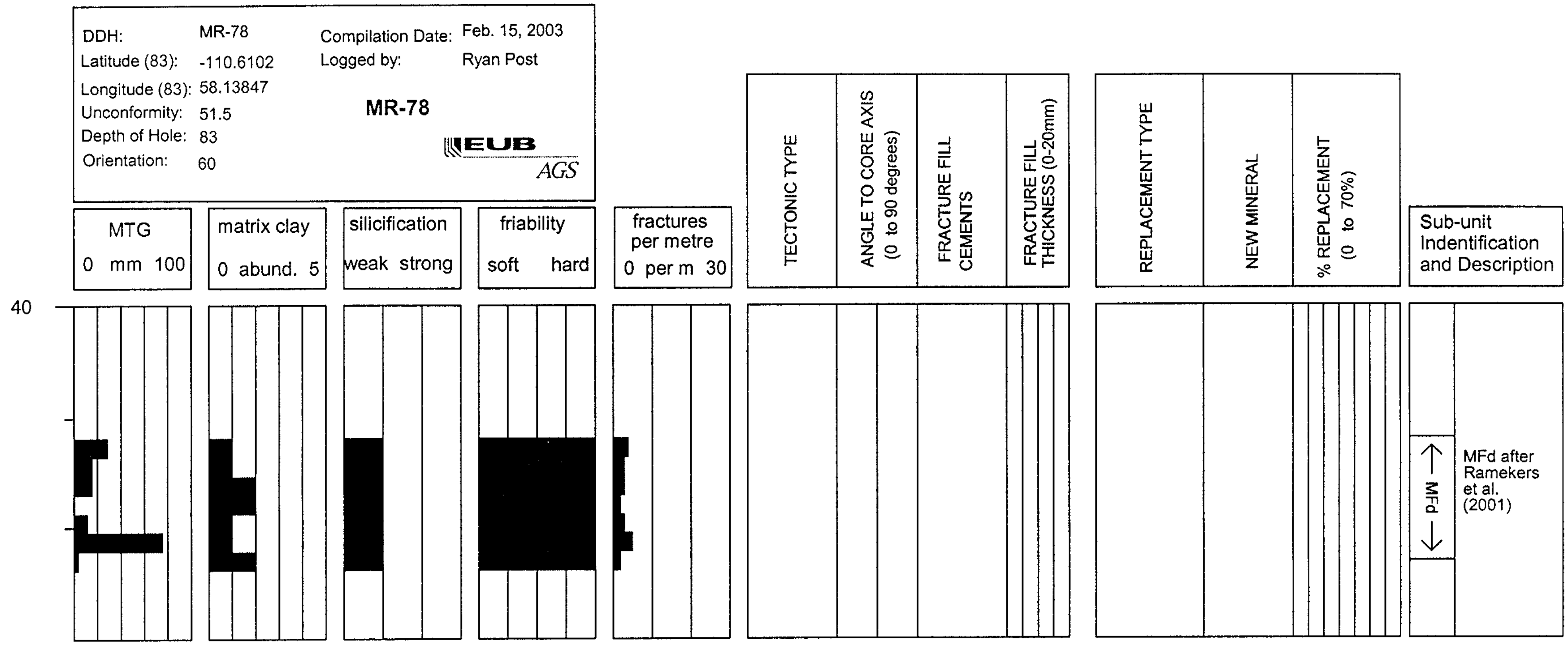
DDH:	MR-73	Compilation Date:	Feb. 15, 2003
Latitude (83):	-110.6467	Logged by:	Ryan Post
Longitude (83):	58.17432		
Unconformity:	169.1		
Depth of Hole:	239		
Orientation:	60		

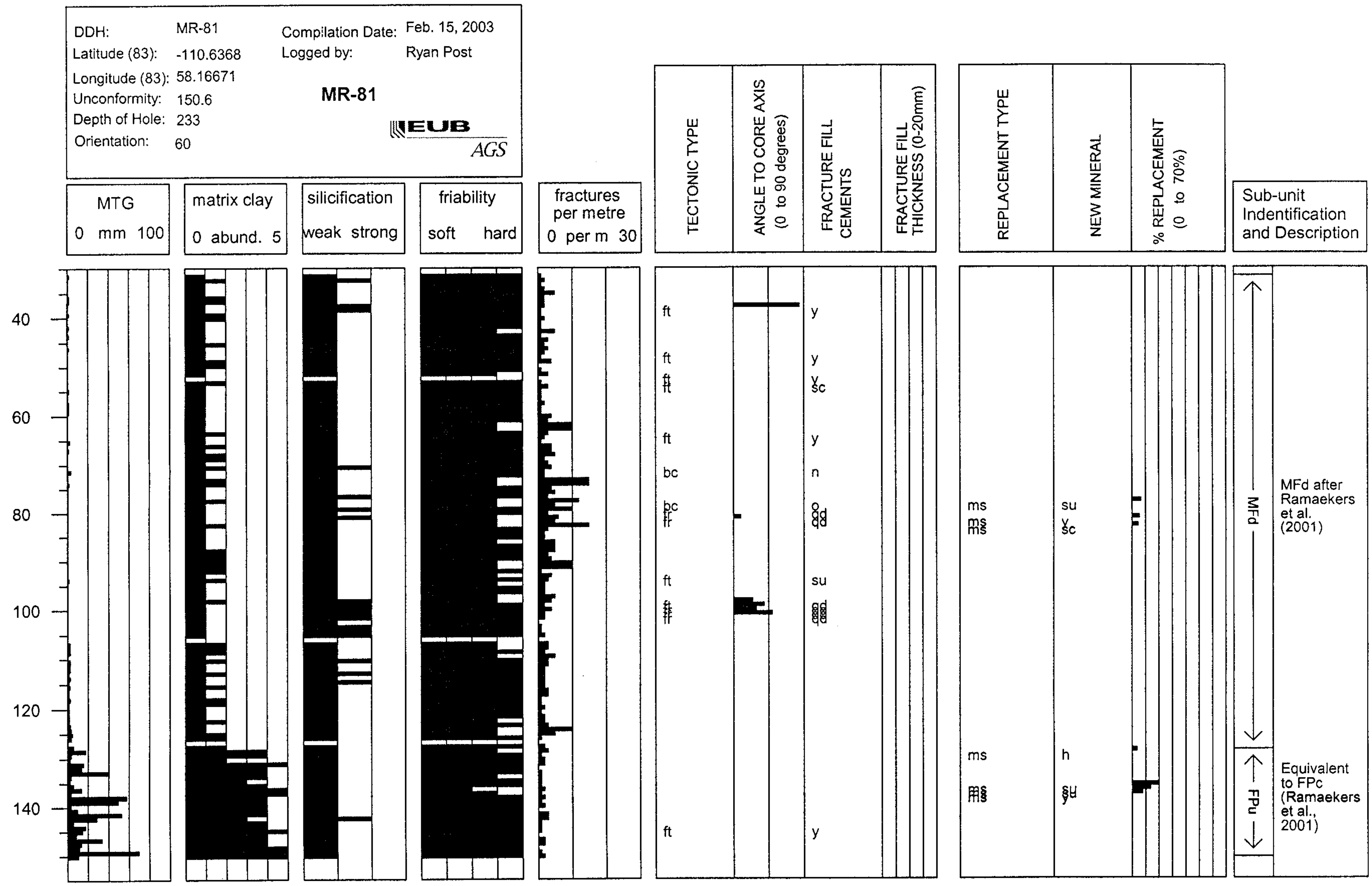
MR-73

EUB AGS




DDH: MR-76
Latitude (83): -110.6004
Longitude (83): 58.12778
Unconformity: 61.9
Depth of Hole: 137
Orientation: 60
Compilation Date: March 11, 2003
Logged by: Ryan Post
MR-76
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
40
60
MFd
MFc
MFd of Ramekers et al. (2001)
MFc of Ramaekers et al. (2001)


DDH: MR-78
Latitude (83): -110.6102
Longitude (83): 58.13847
Unconformity: 51.5
Depth of Hole: 83
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-78
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
40
MFd
MFd after Ramekers et al. (2001)


DDH: MR-81
Latitude (83): -110.6368
Longitude (83): 58.16671
Unconformity: 150.6
Depth of Hole: 233
Orientation: 60
Compilation Date: Feb. 15, 2003
Logged by: Ryan Post
MR-81
EUB
AGS
MTG
0 mm 100
matrix clay
0 abund. 5
silicification
weak strong
friability
soft hard
fractures per metre
0 per m 30
TECTONIC TYPE
ANGLE TO CORE AXIS (0 to 90 degrees)
FRACTURE FILL CEMENTS
FRACTURE FILL THICKNESS (0-20mm)
REPLACEMENT TYPE
NEW MINERAL
% REPLACEMENT (0 to 70%)
Sub-unit Indentification and Description
40
60
80
100
120
140
ft
y
bc
n
su
ms
h
MFd
MFd after Ramaekers et al. (2001)
FPu
Equivalent to FPc (Ramaekers et al., 2001)

DDH:	MR-84	Compilation Date:	Feb. 15, 2003
Latitude (83):	-110.6954	Logged by:	Ryan Post
Longitude (83):	58.28934		
Unconformity:	338		
Depth of Hole:	389		
Orientation:	90		

MR-84

EUB AGS