

# Preliminary Report: Lithostratigraphic Investigations of the Athabasca Basin

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## Abstract

Multi-parameter digital plots of diamond drill holes objectively and effectively delineate the lithostratigraphy of the Athabasca Basin. During 2008, 35 diamond drill holes from several understudied areas in the basin were documented using digital plots. The techniques and logging parameters closely followed those developed by the EXploration science and TECHnology initiative (EXTECH IV) Athabasca Uranium Multidisciplinary Study. Gamma-ray data integrated with the multi-parameter logging method were used in the EXTECH IV research and this study to help define several stratigraphic contacts including the one between the Read Formation and the Bird Member of the Manitou Falls Formation in the east part of the basin. The new quantitative logs also guided repositioning of several unit contacts. In the Dunlop Member of the Manitou Falls Formation (MFd), the intraclast-poor, mudstone-rich informal subunit named MFd-m could not be substantiated in any of the logged diamond drill holes where MFd-m was previously projected; therefore it was removed from the map. The complete lithostratigraphy of the Warnes Member was observed as far east as the eastern shore of Cree Lake and may extend to the Moore Lakes area. In the east-central part of the Athabasca Basin, the mapped unconformity between the Manitou Falls and Lazenby Lake formations has been repositioned ~17 km to the east. This strengthens the regional angular nature of that unconformity, which can now be more confidently interpreted on the southern side of the basin as cutting down through MFd and completely eliminating it about 25 km east of the Cluff Lake road.

**Keywords:** Athabasca Basin, lithostratigraphy, stratigraphy, Manitou Falls Formation, Read Formation, Lazenby Lake Formation, Dunlop Member, Warnes Member, EXTECH IV, sandstone, conglomerate, mudstone, digital logging, core logging, volcanic tuff.

## 1. Introduction

In the second year of the Athabasca Basin stratigraphy project, core logging was undertaken for both regional scale and detailed studies. The focus of the project remained on revising, redefining, and repositioning the lithostratigraphic units of the Athabasca Group, which will be used as the framework for a 3-D model. This study builds on the work completed in 2007 (Bosman and Korness, 2007) and that of the 2000-04 EXTECH IV project. EXTECH IV was a multi-disciplinary collaboration between industry, federal and provincial geological surveys, and universities to better understand targeted aspects of the Athabasca Basin and to develop exploration technology. As part of EXTECH IV, a stratigraphy subproject was designed to refine and develop a better understanding of Athabasca Basin lithostratigraphy, sedimentological processes, sequence stratigraphy, and their relationships to unconformity-associated uranium deposits.

The reader is referred to Bosman and Korness (2007) for details regarding the research methods and changes in the Athabasca Group quantitative lithostratigraphic definitions relative to those set by Ramaekers *et al.* (2007), such as MFd requiring  $\geq 0.6\%$  rather than  $\geq 1\%$  clay intraclasts and MFb requiring  $\geq 1.2\%$  rather than  $\geq 2\%$  conglomerate when logging at 3 m intervals.

Using current 2-D models of the Athabasca Group and new diamond drill hole data, the main goal of this multi-year study is to develop a 3-D model of the Athabasca Basin. A 3-D model will advance our lithostratigraphic knowledge of the Athabasca Basin by: 1) presenting more accurately positioned contacts; 2) improving our understanding of the basin fault systems, when they were active, their timing, location and development; 3) assisting in interpreting basin geometry and evolution; and 4) will be an initial step in analyzing the basin in the 4th dimension. These advancements will improve our understanding of vectors to uranium deposits that are related to reactivated faults.

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During the second year of this study 36 drill logs were generated. Together with those obtained in 2007, these new logs are being used to start filling the data gap in the Cree Lake area (Figure 1). The 2008 drill sites are located along the southern rim of the basin from the Virgin River shear zone (VRSZ) to the Moore Lakes complex with some deeper drill holes on the western and northern sides of Cree Lake (Figure 2). The Rumpel Lake drill hole from the central part of the basin (Figure 1) is stored at the Subsurface Geological Laboratory in Regina and was logged prior to the summer. The 35 drill holes logged during the 2008 summer include: two from the Nuinsco Resources Limited (Nuinsco) Diabase Peninsula property; four from the Titan Uranium Inc. Fleming Project; five from the Virgin River Project of Cameco Corporation (Cameco); three from the CanAlaska Uranium Limited (CanAlaska) Cree East Project; eighteen from the Denison Mines Corporation (Denison) Wheeler River and Moore Lakes projects; and three from the Cree River and Esker Lake projects of AREVA Resources Canada Limited (AREVA) (Figure 2 and Table 2). In addition to these data, CanAlaska and Denison supplied supplementary drill hole data that were obtained using a logging method similar to this project.

Although the parameters and graphic logs are similar in this study to that of EXTECH IV, caution is urged when making direct comparisons between them. Some of the differences in the EXTECH IV papers are due to the non-systematic use of logarithmic scales, the 1 m logging interval, and some variations in the presented parameters. Holes logged in the first year of EXTECH did not include all of the standard parameters collected in subsequent years. Graphical representations of the digital plots also vary in EXTECH IV papers, including the order of the parameters, the colour schemes, and the scales for the various parameters. All drill holes logged during the EXTECH IV study and incorporated in this study are labelled in brackets following the drill hole name [*e.g.*, MC-04 (EXTECH IV)]. In the cross-sections, individual drill hole logs are evenly spaced; however, the approximate intervening distances are labelled between each log.

## 2. Cross Sections

### a) Denison Mines Corp. – Moore Lakes Property

The Moore Lakes Property is located east of the Key Lake haul road and just west of the Moore Lakes complex (ML inset area of Figure 2). Eleven drill holes encompassing the property were logged. Eight of these were used to construct two transects, one oriented northwest and the other northeast (Figure 3). The base of each section is interpreted to be Read Formation, characterized by quartz pebble conglomerate with local red silty mudstone. The conglomerate fines upward from large pebbles and cobbles at the base to small-medium pebbles at the top. A sharp transition to what is interpreted to be MFb-1 is marked by increases in grain size, percentage of conglomerate, and gamma-ray counts, an important parameter in defining the base of MFb-1 (Mwenifumbo and Bernius, 2007). Two lithostratigraphic interpretations for the units above MFb-1 are presented as follows. Ramaekers *et al.* (2007) suggested that MFb-1 was overlain successively by MFb-u, an upward-fining subunit containing fewer conglomerate beds than MFb-u; MFc, containing <0.6% clay intraclasts, and MFd containing  $\geq 0.6\%$  clay intraclasts in drill hole ML-843. MFd may also be present at the top of drill hole ML-540. If this interpretation is correct, either the MFd contact would need to be moved substantially to the east or the Moore Lakes area would be part of a down-thrown block that permitted preservation of a small portion of MFd.

In the alternative lithostratigraphic interpretation, the Warnes Member lithostratigraphy is preserved on the eastern side of the basin. Using this interpretation MFb-1 would be overlain by MFw-lp, a conglomerate-poor equivalent to MFb-1, which would be in turn overlain by MFw-s, which contains <0.6% clay intraclasts. In drill hole ML-843, MFw-s also has an elevated gamma-ray signature that is similar to drill holes in the Cree Lake area (this paper and the 'Diabase Peninsula' section in Bosman and Korness, 2007). Overlying MFw-s, MFw-cr is an intraclast-rich unit, similar to MFd, containing  $\geq 0.6\%$  clay intraclasts. The presence of the Warnes Member on the eastern side of the basin would suggest that the Karras deposystem interfingered with the Ahenakew deposystem much further to the east than previously thought (Ramaekers *et al.*, 2007). With continued logging, the Warnes member stratigraphy, which has been extended to the eastern side of Cree Lake (see the Cree East Project section), is interpreted as contiguous with the stratigraphy in the Moore Lakes area (Figures 1 and 2).

### b) Denison Mines Corp. – Wheeler River Property

The Wheeler River property is located just west of the Key Lake haul road between McArthur River Mine and Key Lake Mine (WR inset area of Figure 2). Seven drill holes were logged along a dominantly south-southeast trend. These holes create a transect that is perpendicular to the north-northeast Wheeler River section in Bosman and Korness (2007). Closely spaced drill holes that traversed the basement quartzite ridge were chosen in an attempt to determine the timing of tectonic activity and deposition of sediments in the Wheeler River area. This work is ongoing and the details will be presented in a future paper.



**Table 1 - Third-order depositional sequences, major unconformities, and lithostratigraphic units of the Athabasca Group (modified after Ramaekers et al., 2007, Table 1).**

	Formation [code]	Member [code]	Informal subunit (designated by dominant lithofacies or position)	
	Overburden [OB]	Includes Quaternary glacial deposits and other unconsolidated sand and gravel		
Sequence 4	Carswell [C]	upper subunit [Cu] (stromatolitic to massive dolostone)		
		lower subunit [Cl] (siliciclastic interbeds, stromatolite, oolite)		
	Douglas [D]	(mudstone, fine to very fine grained quartz arenite)		
		Birkbeck [Ob] (quartz arenite)		
	Otherside [O]	Archibald [Oa] (pebbly quartz arenite, quartz arenite)		
		Marsin [LLm] (upper pebbly quartz arenite)		
Locker Lake [LL]	Brudell [LLb] (conglomeratic quartz arenite)			
	Snare [LLs] (lower pebbly quartz arenite)			
Unconformity				
Sequence 3	Wolverine Point [W]	Claussen [Wc] (clay-rich quartz arenite » mudstone)		
		Brule [Wb]	Wb-sm (quartz arenite > mudstone)	
			Wb-s (nearly all quartz arenite)	
			Wb-m (mudstone > quartz arenite » tuff)	
	Lazenby Lake [LZ]	Dowler [LZd] <sup>1</sup> (quartz arenite, siltstone + mudstone)		
		Larter [LZl] (quartz arenite » siltstone + mudstone)		
		Shiels [LZs] (quartz arenite with pebbly layers)		
Clampitt [LZc] (quartz arenite > siltstone + mudstone)				
		Hodge [LZh] (pebbly quartz arenite + conglomerate)		
Basal unconformity to Mirror Basin				
Sequence 2	Manitou Falls [MF]	Dunlop [MFd] (quartz arenite with $\geq 0.6\%^{3}$ clay intraclasts)	MFd-p (pebbly Dunlop in Moosonees Deposystem)	
		MFd quartz arenite only in most areas		
		Collins [MFC] (quartz arenite)	MFC quartz arenite only in most areas	
		MFC-p (pebbly quartz arenite)		
		Warnes [MFW] <sup>2</sup> (quartz arenite: non-pebbly, pebbly and $\pm$ clay intraclasts)	MFW-up (upper quartz-pebbly quartz arenite)	
			MFW-cr ( $\geq 0.6\%^{3}$ clay-intraclast-rich quartz arenite)	
			MFW-s (quartz arenite)	
				MFW-lp (lower quartz-pebbly quartz arenite)
		Raibl [MFR] <sup>2</sup> (quartz arenite: pebbly and pebbly with $\pm$ clay intraclasts)	MFR-up (upper quartz-pebbly quartz arenite)	
			MFR-cr ( $\geq 0.6\%^{3}$ clay-intraclast-rich quartz arenite)	
	MFR-pcr (quartz-pebbly $\geq 0.6\%^{3}$ clay-intraclast-rich quartz arenite)			
	MFR-s (pebbly quartz arenite, quartz arenite; clay interbeds near base)			
			MFR-lp (lower pebbly quartz arenite); clay interbeds near base	
	Bird [MFB] ( $\geq 1.2\%^{3}$ conglomerate)	MFB-u (upper conglomeratic quartz arenite)		
		MFB-l (lower conglomeratic quartz arenite)		
	Local unconformity separates overlying units from Read and Smart formations			
	Smart [S] (previously MFa)			S-u (upper quartz arenite), informal Shea Creek beds
		S-l (lower quartz arenite)		
		S-mp (local pebbly mudstone)		
Smart appears to be a lateral equivalent of Read				
Read [RD] (previously MFa)			RD-s (low-angle bedded quartz arenite)	
			RD-cg (conglomerate)	
			RD-mp (local pebbly mudstone)	
Reilly [RY]	RYcg (conglomeratic quartz arenite outliers east of Athabasca Basin)			
Basal unconformity to Cree Sub-basin (within Athabasca Basin) and to Reilly Basin (east of Athabasca Basin)				
Sequence 1	Fair Point [FP]	Beartooth [FPb] (pebbly quartz arenite)		
		Lobstick [FPl]	FPl-cs (conglomeratic quartz arenite)	
			FPl-cg (conglomerate)	
			FPl-ps (pebbly quartz arenite)	
	FPl-mp (mudstone, pebbly)			
No formal designation		BL (basal lag, pebbles to boulders)		
Basal Unconformity to Jackfish Basin				
Basement: metamorphosed Archean granitoid gneiss, Paleoproterozoic paragneiss and late intrusions				

**Notes:**

<sup>1</sup> LZd is the distal, finer grained, northeastern equivalent of the four other members (LZh, LZc, LZs, LZl) in the southwestern proximal region.

<sup>2</sup> These tongues of quartz arenite resembling MFC and MFd are distinguished in the Karras and Moosonees deposystems by oblique paleocurrents and separated by an upper pebbly quartz arenite from MFC and MFd of the Ahenakew Deposystem.

<sup>3</sup> These percentages are used to classify data collected at 3 m logging intervals (Bosman and Korness, 2007). For percentages to classify data obtained at 1 m logging intervals refer to Ramaekers *et al.* (2007).

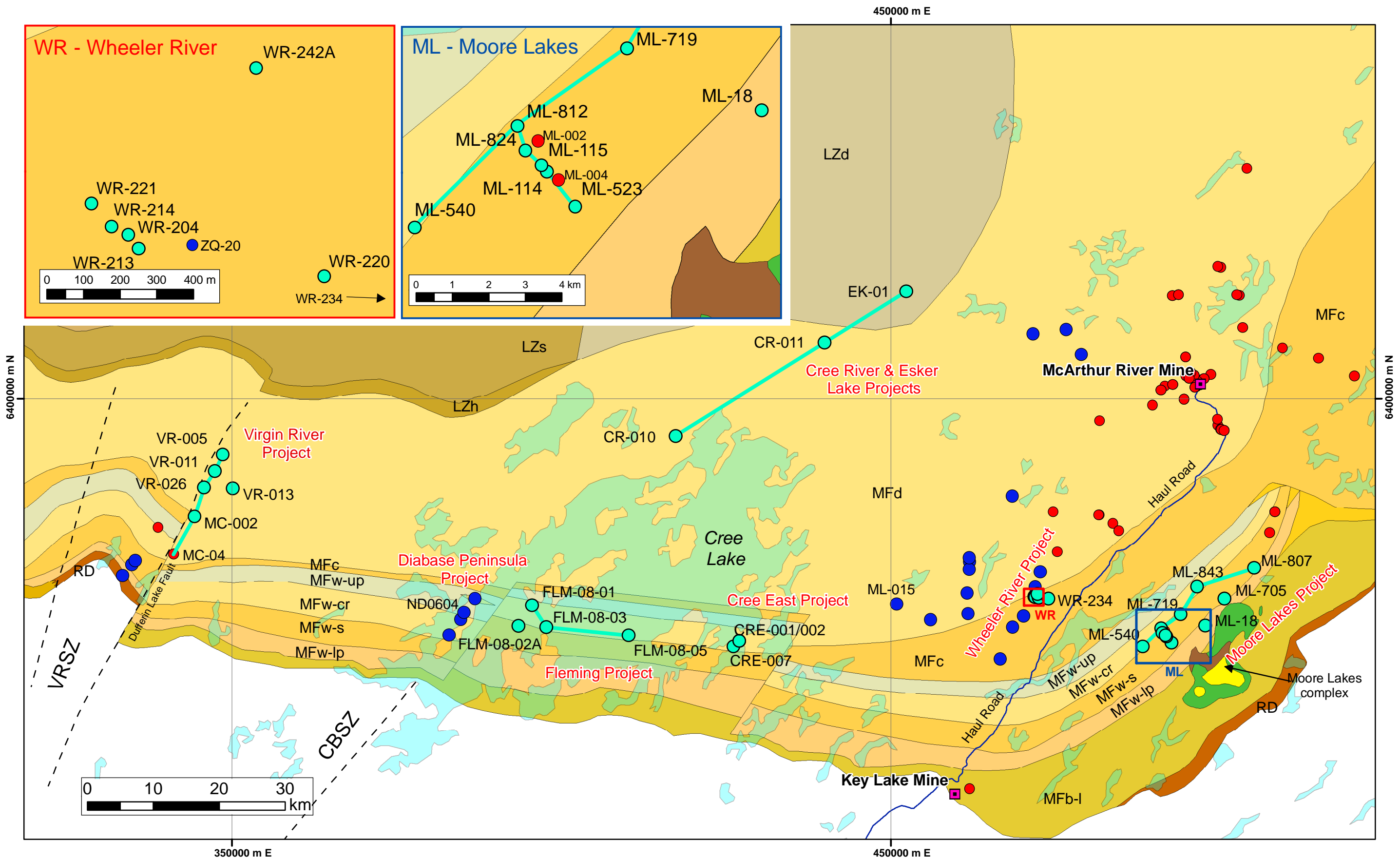


Figure 2 - Enlargement of Figure 1 displaying the location and names of drill holes logged in 2008. Light-blue lines represent the orientation in plan view of the cross sections. Drill holes logged during 2008 are shown as light-blue circles. Dark-blue circles are drill hole locations logged in 2007. The red circles represent the drill holes logged using the multi-parameter digital logging method during the EXTECH IV project. See Table 1 for lithostratigraphic names associated with the map unit codes. VRSZ – Virgin River shear zone; CBSZ – Cable Bay shear zone.

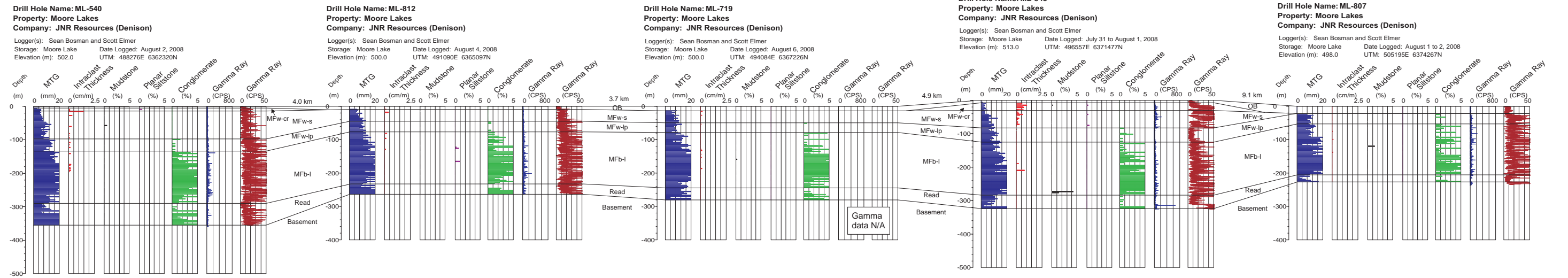
**Table 2 - Metadata for the 35 drill holes logged in 2008. Primary drill log data are available on request from the principal author; sst – sandstone.**

Company	Drill Hole #	Property	Date Finished Drilling	NTS	UTM Coordinates in NAD 83 / Zone 13			Hole Angle (°)	Hole Azimuth (°)	Overburden Depth (m)	U/C Depth (m)	Total Depth (m)	Storage Location
					Easting	Northing	Elevation (m)						
Cameco	VR-026	Virgin River Project	2-Mar-08	74G/12	345765	6386508	540.45	-88	110	7.8	840.7	941	Wide Lake
Uranerz (Cameco)	MC-002	MacFarlane Lake	27-Jul-97	74G/12	344350	6382100	540.00	-90	0	27.4	697.2	774	Wide Lake
Cameco	VR-005	Virgin River Project	24-Mar-08	74G/12	348617	6391500	563.60	-90	0	5.8	906.75	988	Wide Lake
Cameco	VR-011	Virgin River Project	24-Jul-99	74G/12	347415	6388986	564.70	-90	0	6.2	873.3	956	Wide Lake
Cameco	VR-013	Virgin River Project	18-Mar-08	74G/12	350123	6386360	555.00	-90	0	2.6	853.7	945	Wide Lake
AREVA	EK-01	Esler Lake	31-Mar-00	74H/13	452372	6416232	500.00	-90	0	15.75	954.9	1007	Esler Lake
AREVA	CR-010	Cree River	1-Mar-00	74G/09	417348	6394302	505	-90	0	18.4	876.45	950	Esler Lake
AREVA	CR-011	Cree River	16-Mar-00	74G/16	439979	6408473	488.00	-90	0	6.5	948.4	1001	Esler Lake
Titan	FLM-08-01	Fleming	13-Mar-08	74G/07	395543	6388598	496.00	-85	100	42.3	344.75	366.1	Cree Lake – Crystal Lake Lodge
Titan	FLM-08-02A	Fleming	25-Mar-08	74G/07	393475	6365490	495.00	-87	103	58.2	275	340.5	Cree Lake – Crystal Lake Lodge
Titan	FLM-08-03	Fleming	31-Mar-08	74G/07	397709	6365305	492.00	-88	140	39.6	269.02	325.2	Cree Lake – Crystal Lake Lodge
Titan	FLM-08-05	Fleming	6-Apr-08	74G/08	410241	6364016	499.00	-90	0	41.8	271.21	371	Cree Lake – Crystal Lake Lodge
Nuinsco	ND-08-08	Diabase Peninsula	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30.23	512.94	650	Cree Lake – Crystal Lake Lodge
Nuinsco	ND-08-02	Diabase Peninsula	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30.5	410.96	638	Cree Lake – Crystal Lake Lodge
JNR (Denison)	ML-843	Moore Lake	12-Apr-08	74H/06	496557	6371477	513.00	-90	0	5.2	324.8	449	Moore Lake
JNR (Denison)	ML-807	Moore Lake	8-Mar-08	74H/10	505195	6374267	498.00	-90	0	22.8	228	362	Moore Lake
JNR (Denison)	ML-540	Moore Lake	15-Feb-08	74H/06	488276	6362320	502.00	-55	330	4.5	355.95	467	Moore Lake
JNR (Denison)	ML-705	Moore Lake	5-Mar-08	74H/07	500670	6369640	488.00	-70	275	24	212.2	363	Moore Lake
JNR (Denison)	ML-18	Moore Lake	3-Apr-01	74H/06	497773	6365530	488.00	-90	0	30.5	190	275	Moore Lake
JNR (Denison)	ML-812	Moore Lake	7-Apr-08	74H/06	491090	6365097	500.00	-90	0	8.1	264.9	305	Moore Lake
JNR (Denison)	ML-523	Moore Lake	28-Aug-08	74H/06	492670	6362897	510.00	-60	138	9.3	303.5	432.5	Moore Lake
JNR (Denison)	ML-824	Moore Lake	30-Aug-05	74H/06	491308	6364431	503.00	-90	0	6.5	273.7	362	Moore Lake
JNR (Denison)	ML-114	Moore Lake	22-Mar-06	74H/06	491894	6363851	500.00	-90	0	4.6	286.6	330.5	Moore Lake
JNR (Denison)	ML-719	Moore Lake	22-Feb-07	74H/06	494084	6367226	500.00	-90	0	12.6	282.5	335	Moore Lake
JNR (Denison)	ML-115*	Moore Lake	27-Mar-06	74H/06	491748	6364018	500.00	-90	0	6.4	271.1	389	Moore Lake
Denison	WR-214	Wheeler River	13-Jun-06	74H/06	471895	6369912	541.02	-75	320	6.5	314	426.5	KM 52
Denison	WR-221	Wheeler River	22-Jul-06	74H/06	471841	6369976	546.33	-90	0	13.6	lost in sst	265.1	KM 52
Denison	WR-204	Wheeler River	3-Dec-05	74H/06	471941	6369890	539.54	-75	315	6.7	310	430	KM 52
Denison	WR-213	Wheeler River	9-Jun-06	74H/06	471969	6369852	538.00	-75	315	20	161.8	426.3	KM 52
Denison	WR-220	Wheeler River	17-Jul-06	74H/06	472477	6369777	542.00	-70	315	11	299.08	367.6	KM 52
Denison	WR-234	Wheeler River	28-Mar-07	74H/06	473982	6369612	561.28	-70	302	42.7	387.9	491	KM 52
Denison	WR-242A	Wheeler River	11-Oct-07	74H/06	472290	6370346	563.34	-75	315	26.5	332	455	KM 52
CanAlaska	CRE-007	Cree East	12-Apr-08	74G/08	426165	6362350	480.00	-90	150	42.1	275.4	316.1	McIntyre Lake Lodge
CanAlaska	CRE-001	Cree East	1-Mar-08	74G/08	427050	6363190	490.00	-70	150	69.9	lost in sst	158.8	McIntyre Lake Lodge
CanAlaska	CRE-002	Cree East	17-Mar-08	74G/08	427050	6363190	490.00	-75	0	63.3	327.6	441.8	McIntyre Lake Lodge

\* Not shown on Figure 3 cross section.

Southwest

Northeast



Northwest

Southeast

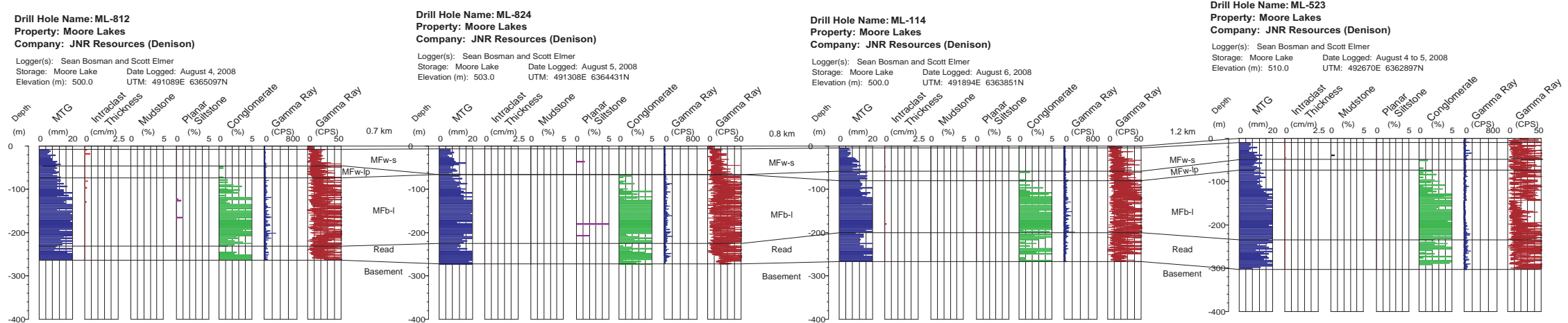


Figure 3 - Two cross sections of the Moore Lakes property intersect orthogonally to form a “T” at ML-812, with individual drill hole locations shown on Figure 2 (see Moore Lakes inset). The eight new quantitative drill logs are integrated with industry gamma-ray logs and are interpreted lithostratigraphically. Rock codes are explained in Table 1. MTG – maximum transported grain size.

### c) CanAlaska Uranium Ltd. – Cree East Property

The Cree East property is located on the eastern side of Cree Lake where three drill holes were logged (Figures 2 and 4). Drill holes CRE-001 and CRE-002 were drilled in the same location because the former was lost in the sandstone. Drill core data from CRE-001 was used to supplement missing data near the top of drill hole CRE-002 for which the upper portion was drilled using a tricone bit with no core recovery. At the base of drill hole CRE-007 is a pebbly unit that includes abundant red clay intraclasts and interbeds of red mudstone with sand-filled desiccation cracks characteristic of Read Formation (Figure 5). At the base of drill hole CRE-001/002, the red mudstones are absent, but the medium to large floating pebbles and a low gamma-ray signature also suggest that this is Read Formation. Overlying the Read Formation is a pebbly sandstone unit with minor thin conglomerate beds. This is interpreted to be MFw-lp, a conglomerate-poor equivalent of MFb. Overlying MFw-lp is a granule to small pebble sandstone interpreted as MFw-s. A medium-grained quartz arenite containing  $\geq 0.6\%$  clay intraclasts above MFw-s in CRE-001/002 and CRE-007 is interpreted to be MFw-cr. MFw-cr is lithologically similar to MFd but, because of its context with nearby holes and the consistency of drill logs along the southern margin, it is interpreted to be MFw-cr. In hole ML-015 from the Moon Lake area (Bosman and Korness, 2007) there is a weak clay intraclast signature in MFb at a depth of  $\sim 420$  m, which may be the northerly extent of the MFw-cr signature. This increase in clay intraclasts does not meet the  $\geq 0.6\%$  clay intraclast definition of MFw-cr and, therefore, cannot be named as such; however, this intraclast signature may indicate the Aheneke/Kerras deposystem boundary is close to drill hole ML-015.

### d) Titan Uranium Ltd. – Fleming Property

The Fleming property is located on the southern part of Cree Lake where three of four logged drill holes form an east-west transect (Figure 2). At the base of the section in all drill holes, an upward-fining pebble-rich conglomerate with a strong gamma-ray signature is typical of MFb-l (Figure 6), so the Read Formation is interpreted to be absent (gamma-ray data for drill hole FLM-08-05 not available). Overlying MFb-l, a pebbly unit contains rare thin conglomerate beds typical of MFw-lp, a subunit of the Warnes Member (Table 1). These beds were interpreted to be part of the Warnes Member based on their similarity to logs from nearby Diabase Peninsula drill holes (Figure 2), which were previously shown to contain MFw-lp (Bosman and Korness, 2007). The granule to small pebble unit overlying MFw-lp in the Fleming section is interpreted to be MFw-s. It also appears to have an elevated gamma-ray signature, again similar to the drill holes in the Diabase Peninsula section. MFw-cr overlies MFw-s in drill holes FLM-08-01, -03, and -05 but was not observed in FLM-08-02a.

### e) Cameco Corp. – Virgin River Property

Five drill holes were logged from the Virgin River property, located just east of the VRSZ on the downthrown side of the Dufferin Lake Fault (Figure 2). Four of the five drill holes were used for a north-northeast cross-section the southern end of which is located approximately 30 km from the southern margin of the Athabasca Basin (Figure 7). Drill hole MC-04 (EXTECH IV) is included so that this section may be correlated with the Sandhill section (Bosman and Korness, 2007). Note that the lithostratigraphic interpretation of the Sandhill section included Read Formation at the base, whereas the additional drill hole and gamma-ray data suggests that Read Formation may not exist in MC-04. In the Virgin River section, MFb-l is interpreted to be the basal unit in drill holes MC-002 and VR-026. Drill hole VR-011 does not contain  $\geq 1.2\%$  conglomerate at its base and is assigned to MFw-lp. In drill hole VR-005, the deepest of the logged drill holes, thin, red mudstone beds and hard, red clay intraclasts at the base is interpreted to be Read Formation (Figure 8). Except for drill hole VR-011, MFw-lp overlies Read Formation or MFb-l in all the drill holes. Overall, MFw-lp thins towards the north. A granule to small pebble unit containing  $< 0.6\%$  clay intraclasts overlies MFw-lp. It is assigned to MFw-s and thickens towards the north. The intraclast-rich unit above MFw-s is interpreted as MFw-cr. Above MFw-cr, a granule to small pebble quartz arenite subunit is assigned to MFw-up. This is followed by sparsely granular quartz arenite with  $< 0.6\%$  clay intraclasts, which is assigned to MFc, and a second quartz arenite containing  $\geq 0.6\%$  intraclasts, which is interpreted to be MFd. The intraclast-poor interval MFd-m, which Ramaekers *et al.* (2007) defined as containing  $< 0.6\%$  clay intraclasts but  $\sim 5$  to 100 % mudstone and siltstone interbeds and being bracketed by lower (MFd-l) and upper (MFd-u) subunits with  $\geq 0.6\%$  intraclasts, is not present in the Virgin River section (the percentages of clay intraclasts in the above definition have been revised to account for a 3 m logging interval).

### f) AREVA Resources Canada Inc. – Cree River and Esker Lake Properties

Three drill holes were logged from the Cree River and Esker Lake properties, which extend northeastward from the northwestern side of Cree Lake (Figure 2). As shown in Figure 9, the stratigraphic thicknesses of individual units in this section are essentially consistent from southwest to northeast. The base of the section is interpreted as Read Formation, which is characterized by quartz pebble conglomerate with sparse red siltstone intraclasts and a gamma-ray response sharply lower than that of the Bird Member of Manitou Falls Formation (MFb). The conglomerate fines upward from medium to large pebbles and cobbles at the base to small to medium pebbles at the top. A sharp transition to what is interpreted to be MFb-l is marked by increases in grain size, percentage of conglomerate, and

**Drill Hole Name: CRE-001 and CRE-002**  
**Property: Cree East**  
**Company: CanAlaska**

Logger(s): Sean Bosman and Scott Elmer  
 Storage: McIntyre Lake Date Logged: August 13, 2008  
 Elevation (m): 490.0 UTM: 427050E 6363190N

**Drill Hole Name: CRE-007**  
**Property: Cree East**  
**Company: CanAlaska**

Logger(s): Sean Bosman and Scott Elmer  
 Storage: McIntyre Lake Date Logged: August 12, 2008  
 Elevation (m): 480.0 UTM: 426165E 6362350N

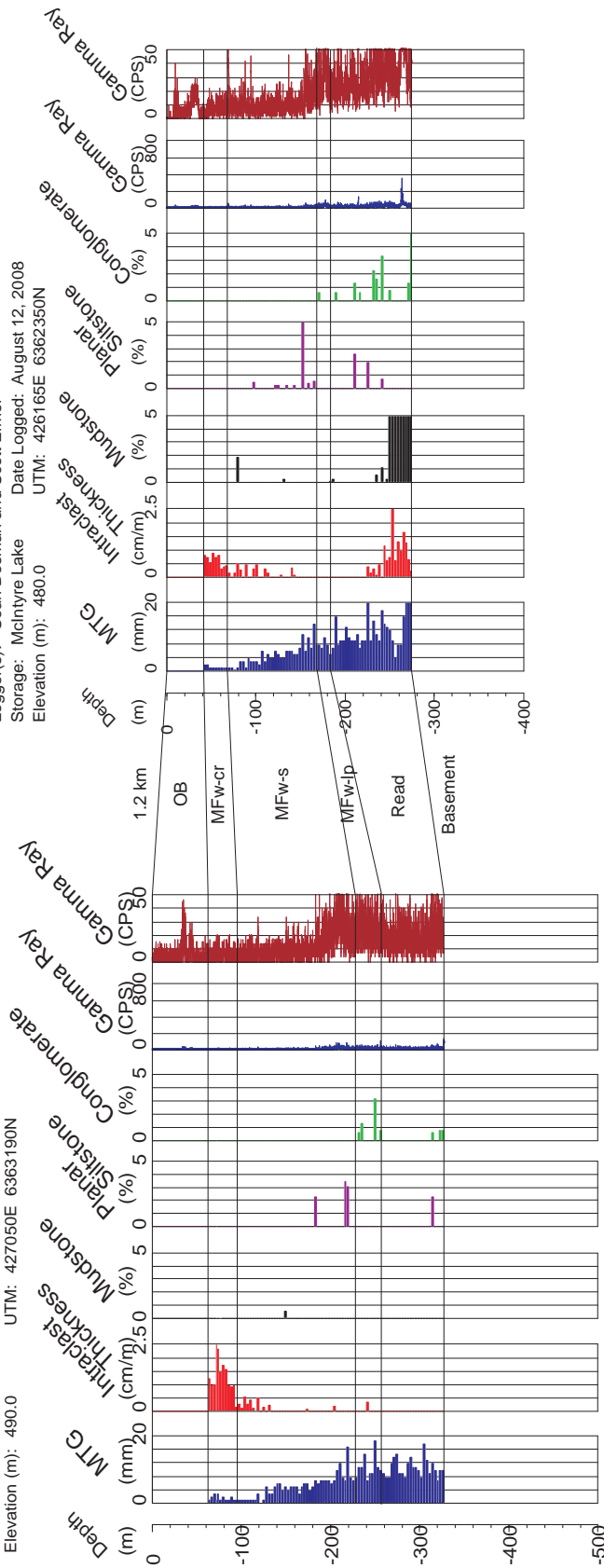


Figure 4 - Cross section from three new quantitative drill logs from the Cree East property and the interpreted lithostratigraphy. Note that drill log CRE-001/002 is a composite section based on data from both drill holes. Rock codes are explained in Table 1. MTG – maximum transported grain size.



**Figure 5 - Large desiccation cracks in red siltstone and mudstone filled with quartz sand at ~255.5 m in drill hole CRE-007.**

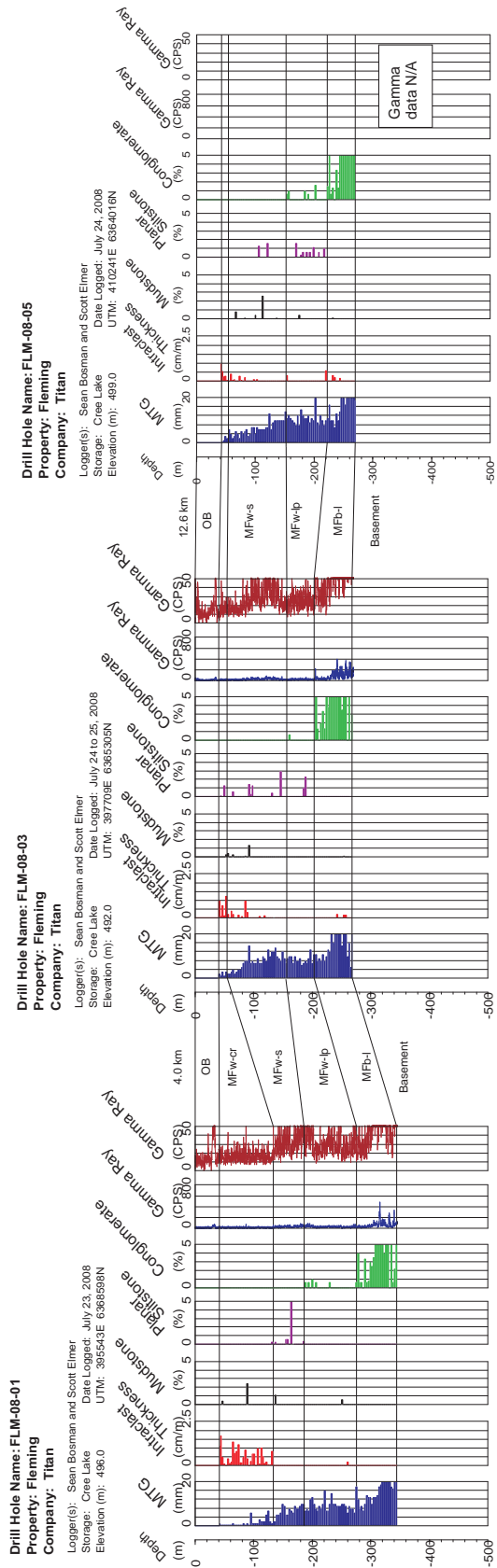
gamma-ray counts. Overlying MFb-1, MFb-u is an upward-fining subunit containing fewer conglomerate beds. It is progressively overlain by MFc and MFd. MFd-m is not present. Near the top of drill hole EK-01, there is an increase in grain size consisting of MTG's <8 mm, a decrease in clay intraclasts, and an increase in mudstones and planar laminated siltstones. These changes are interpreted to represent the reworked Manitou Falls/Lazenby Lake formations unconformity defined by Ramaekers *et al.* (2007). Near the base of the Lazenby Lake Formation are two, 1 cm-thick, polymictic pebble beds separated by 4 cm of sandstone (Figure 10). Just below these pebble beds is a 1.5 m-thick intraformational conglomerate containing centimetre- to decimetre-scale sandstone clasts (Figure 11). These sandstone clasts appear to have the same grain size and colour as MFd. The contact between the intraformational conglomerate and MFd is sharp to transitional.

### 3. Discussion

Modifications to the MFd-m unit include the absence of MFd-m in CanAlaska's West McArthur area, which led to the removal of a large part of MFd-m on the east side of the basin (Bosman and Korness, 2007). Based on the work in this paper, MFd-m has been removed completely. In the Esker Lake, Cree River, and Virgin River drill holes, no unit containing <0.6% intraclasts and ~5 to 100% mudstone and siltstone interbeds over varied intervals was observed (Figures 7 and 9). The amount of intraclasts remains consistently above 0.6% in all of the drill holes within the identified MFd.

Some changes to the mapped lithostratigraphic contacts in Figure 1 of Ramaekers *et al.* (2007) and Figure 23 of Bosman and Korness (2007) are described below with reference to Figures 1 and 2. The explanations show the way in which drill hole intersections are used as proxies for outcrops, thereby providing new constraints on surface map configurations. In all cases, both structural dips of the units intersected by drilling and the surface

**Figure 6 - Cross section from three new quantitative drill logs from the Fleming property and the interpreted lithostratigraphy. Rock codes are explained in Table 1. MTG – maximum transported grain size.**



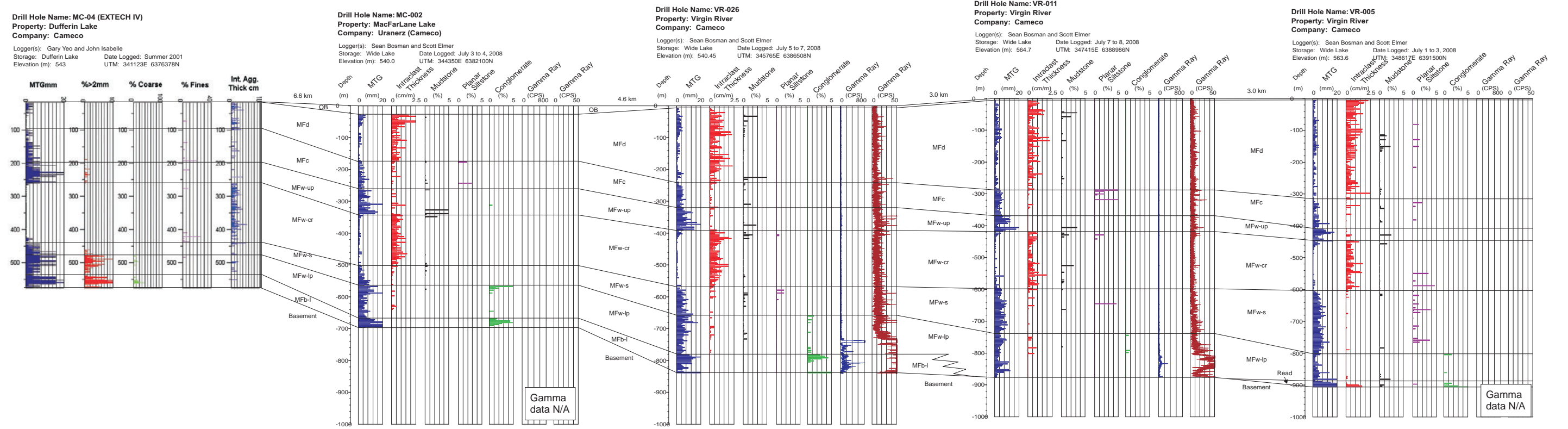
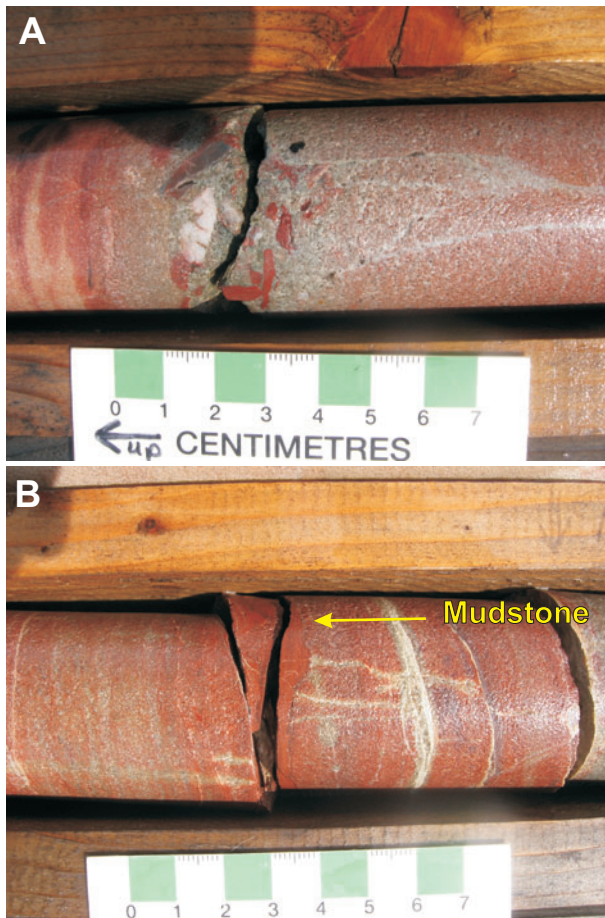


Figure 7 - Cross-section from four new quantitative drill logs from the Virgin River property, MC-04 (EXTECH IV), together with the interpreted lithostratigraphy. Rock codes are explained in Table 1. Red silty mudstone, one of several diagnostic attributes of Read Formation in drill hole VR-005, is shown in Figure 8. MTG – maximum transported grain size.



**Figure 8 - A) Hard red silty mudstone intraclasts and quartzite clasts, and B) thin red mudstone bed in drill hole VR-005 at approximately 900 m are characteristic of Read Formation.**

thicknesses of formations and members, repetition or absence of lithostratigraphic intervals, and variations in sedimentological features may be the result of faulting, a key component of the unconformity-associated uranium deposit model. This project advances lithostratigraphic knowledge by using a set of quantitative parameters to systematically log drill core. Use of these parameters, developed during the EXTECH IV multidisciplinary study, is being continued and refined so that data from the two projects may be combined. Combining gamma-ray logs reinforces the grain size data, provides reassurance in cases of ambiguity, and provides an objective proxy in cases where grain size data are not available. Reasonable confidence may be placed on drill hole data acquired in this fashion because the data are objective, systematic and quantitative. Quantitative results minimize the need for subjectivity, which is particularly important for data obtained from multiple parties. The objectively collected primary grain size data from EXTECH IV (and this study in future) will remain valuable despite considerable reinterpretations as more knowledge is obtained – a transparent and fully traceable process.

Subjective non-systematic rock attributes remain important for lithostratigraphic decisions and to help understand depositional environments and basin development. Lithostratigraphic attributes of this type include the presence of red silty mudstone with desiccation cracks that are unique to the Read Formation, and planar laminated sandstone with sparsely distributed cobbles that are characteristic of the Read and Smart formations. Tuff beds provide unique opportunities to calibrate sequence stratigraphy so that it can be interpreted from the lithostratigraphic framework. Note that the lithostratigraphy is not temporally constrained and in many places transgresses temporal sequence boundaries. Quantitative lithostratigraphic data trends can also be used to interpret sequence boundaries that cross lithostratigraphic boundaries, a subject that has not yet been tackled for the data assembled here.

Logging of drill core in areas with minimal data is important for continuing to build the lithostratigraphic framework of the Athabasca Basin, especially for the development of a 3-D model. As more data are acquired, the lithostratigraphic contacts will continue to be modified. Some of the highlights presented in this study that result

topographic slopes are extremely gentle, such that even the uppermost units cored beneath casing in these drill holes are extrapolated considerable distances laterally from the drill hole collars.

- In the Moore Lakes area, the contacts have been redrafted to include Warnes Member lithostratigraphy. This interpretation is based, in part, on the presence of MFw-cr in two of the drill holes.
- The most significant map boundary change is the unconformity between the Manitou Falls and Lazenby Lake formations in the Cree River and Esker Lake areas. Based on the drill results from AREVA's EK-01 drill hole, the unconformity has been moved approximately 17 km towards the east.
- In the Cree Lake area, drill hole data from several exploration properties were used to extend the Warnes Member to the east. Two faults have been shown on Figure 2 to account for dip-slip and/or possible strike-slip displacements of strata. One fault on the west side of Cree Lake is interpreted as a late reactivation of the Cable Bay shear zone. Displacement is most apparent between the Diabase Peninsula drill holes (dark blue dots along the southwestern side of Cree Lake) and the Fleming drill holes (light blue dots immediately to the east). The uppermost unit cored by drill hole FLM-08-01 is MFw-cr, whereas the stratigraphically overlying MFw-up is the highest unit cored by drill hole ND0604 located further south where, without faulting, the surface stratigraphic units would otherwise be lower.

Understanding the lithostratigraphy of the Athabasca Basin plays an integral role in framing uranium exploration. Changes in the measured and interpreted

**Drill Hole Name: CR-010**  
**Property: Cree River**  
**Company: AREVA**

Logger(s): Sean Bosman and Scott Elmer  
 Storage: Esker Lake Date Logged: July 15 to 17, 2008  
 Elevation (m): 505.0 UTM: 417348E 6394302N

**Drill Hole Name: CR-011**  
**Property: Cree River**  
**Company: AREVA**

Logger(s): Sean Bosman and Scott Elmer  
 Storage: Esker Lake Date Logged: July 17 to 18, 2008  
 Elevation (m): 488.0 UTM: 439979E 6408473N

**Drill Hole Name: EK-01**  
**Property: Esker Lake**  
**Company: AREVA**

Logger(s): Sean Bosman and Scott Elmer  
 Storage: Esker Lake Date Logged: July 13 to 15, 2008  
 Elevation (m): 500.0 UTM: 452372E 6416232N

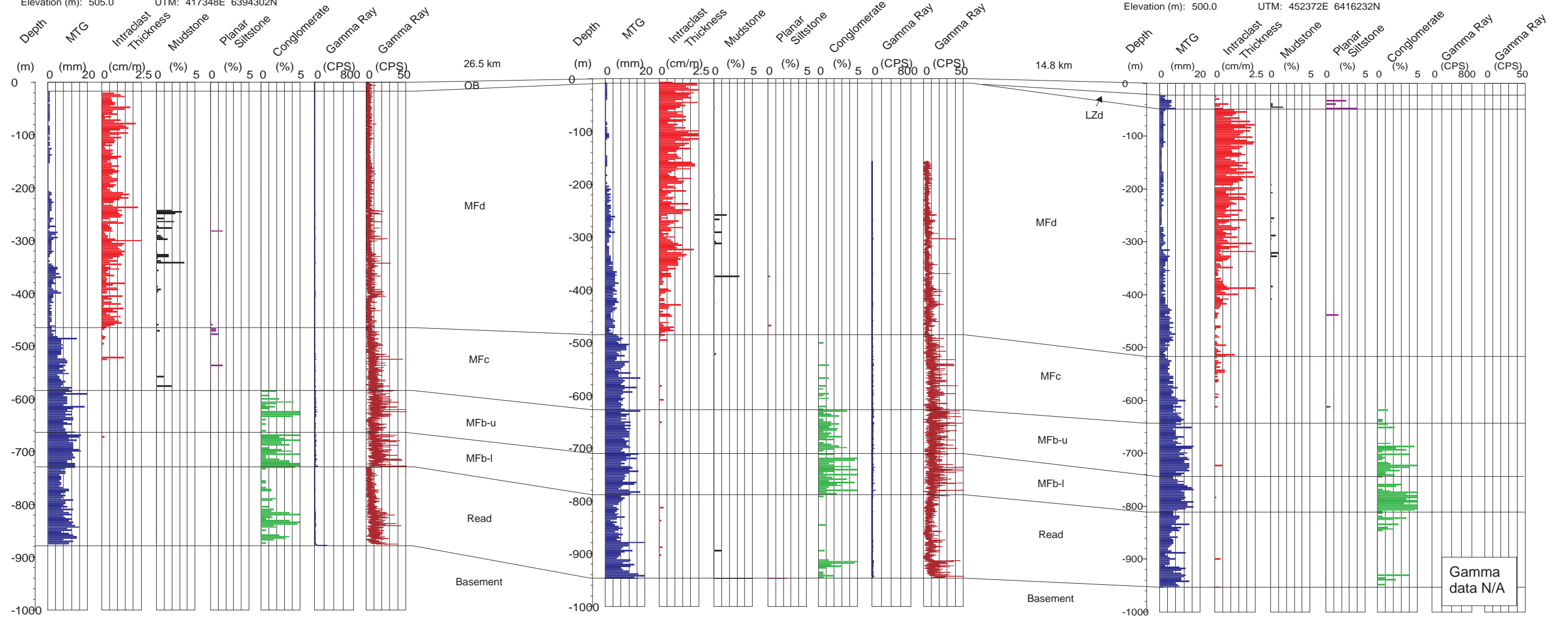


Figure 9 - Cross-section from southwest to northeast based on three quantitative drill logs from the Esker Lake and Cree River properties. The interpreted lithostratigraphic units are symbolized as in Table 1. MTG – maximum transported grain size.



**Figure 10 - One of two polymictic pebble beds near the base of the Lazenby Lake Formation in drill hole EK-01 at ~48.5 m.**



**Figure 11 - A) Slightly rotated sandstone clasts in sandstone matrix interpreted as intraformational conglomerate near the base of the Lazenby Lake Formation. B) Close-up of A, showing near-vertical portion of sandstone matrix separating cobble-sized bedded sandstone clasts with irregular borders. The sand matrix to the cobble conglomerate also contains subrounded pebble-sized sandstone intraclasts. Depths are in metres.**

from lithostratigraphic modifications are also preliminary answers to questions outlined by Ramaekers *et al.* (2007) as follows.

The complete Warnes Member extends from just east of the Cluff Lake road in the west to the eastern side of Cree Lake in the east and is inferred to connect with the Moore Lakes area in the east (Figure 1). The northern extent of the Warnes Member remains to be ascertained. Other results include the elimination of the informal subunit MFd-m.

Gamma-ray data were documented in several areas as additional objective tools to help distinguish the Read Formation from the overlying units of MFb-l and MFw-lp, and to refine the precise contact. Although gamma-ray logs are effective in refining lithostratigraphic contacts, they should be used in tandem with other tools because they do not always correlate with elevated grain size logs as seen in MFw-s. Gamma-ray peaks associated with tuff beds may be useful for lithostratigraphic and sequence correlation. Gamma-ray peaks are also correlated with mudstone beds of the Clampitt Member of Lazenby Lake Formation (LZc) and the Wolverine Point Formation, especially the Brule Member (Wb) (C.W. Jefferson and J. Mwenifumbo, pers. comm., 2008).

With a strong, cross-validated and objective lithostratigraphic framework, additional interpretive and analytical studies can build our knowledge of basin development and mineralization. Gamma-ray anomalies can be more readily explained as either stratigraphic or related to alteration above or beside potential uranium deposits. Sequence stratigraphy and knowledge of potential hydrothermal aquifers and aquitards can be advanced from the preliminary studies of Hiatt and Kyser (2007). Better constraints can be provided for the interpretation of active faulting during and after sedimentation. The stratigraphic framework will be more reliable as a backdrop for 3-D analysis of mineralogical anomalies as evidence for ore-related alteration systems.

#### 4. Acknowledgments

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