Stratigraphy of the Manitou Falls Formation Along the McArthur River High-resolution Seismic Survey B-B', Athabasca Basin, Saskatchewan

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Abstract

During this last season of fieldwork of a M.Sc. project in sedimentology and stratigraphy done at the McArthur River mine site, three boreholes were logged or relogged (i.e., MAC-198, MAC-218 (relogged) and RL-064). Acquisition of new data and testing the actual definition of the different sub-units done on these cores permits the development of an updated stratigraphic cross-section along the high-resolution seismic survey line B-B'. Detailed sedimentology on specific intervals on RL-046 allows the recognition of a sequence boundary (disconformity) between the sub-units MFa4 and MFb1 of the Manitou Falls Formation. Future analysis will permit the development of a systematic description of the different sub-units.

Keywords*: McArthur River, Athabasca Basin, Manitou Falls Formation, stratigraphy, sedimentology, disconformity, seismic survey, uranium, EXTECH IV.*

1. Introduction and Objectives

This study focuses on the regional stratigraphy of the Athabasca Basin along the EXTECH IV north-northwest-trenching high-resolution seismic reflection line B-B' near the McArthur River uranium deposit, Saskatchewan (Hajnal *et al.*, 2001). Core from twenty-one diamond drill holes, located as close as possible to the seismic profile (Figure 1), we used in this investigation.

A primary objective of this study is to develop a systematic methodology for delineation of major stratigraphic units and sub-units within the Manitou Falls Formation of Ramaekers (1990). The sandstone and conglomerate in this formation and paleo-weathered rocks in the underlying Paleoproterozoic Wollaston paragneisses and schists host the largest highest grade uranium deposit in the world at McArthur River. The Cigar Lake, Key Lake, McClean Lake, Rabbit Lake, and Cluff Lake uranium deposits, amongst others, are found in similar settings (Jefferson *et al.*, 2001).

Most of the primary fieldwork was completed during the summer of 2001 and is recorded in earlier papers: 18 holes were logged, detailed paleocurrent directions measured in two holes, and systematic PIMA analysis completed on selected holes (Bernier *et al.*, 2001; Jefferson *et al.*, 2001).

This paper presents new observations on the sedimentology and stratigraphy of the Manitou Falls Formation in the McArthur River area and is a contribution to sub-project 4 of EXTECH IV. Related EXTECH IV stratigraphic-sedimentologic studies include: a basin-wide synthesis (Ramaekers *et al.*, 2001); regional work in the eastern (Yeo *et al.*, 2000; Bernier *et al.*, 2001; Jefferson *et al.*, 2001) and western Athabasca Basin (Yeo *et al.* 2001, 2002; Ramaekers and Jefferson, 2002); and detailed studies at Key Lake (Long *et al.*, 2000; Collier and Yeo, 2001; Long, 2001; Long *et al.*, 2002), McClean Lake (Long *et al.*, 2000; Long, 2001; Long *et al.*, 2002), Shea Creek (Collier *et al.*, 2001), and Maybelle River (Kupsch in Jefferson and Delaney, 2001). Objectives for the 2002 field season were to:

1) clarify the definition of the different sub-units in the Manitou Falls Formation;
2) test for a sequence boundary between units MFa4 and MFb;
3) document the characteristics of sub-unit MFa4 in several boreholes (including some detailed logs);
4) update the stratigraphic cross-section along the McArthur River seismic transect; and

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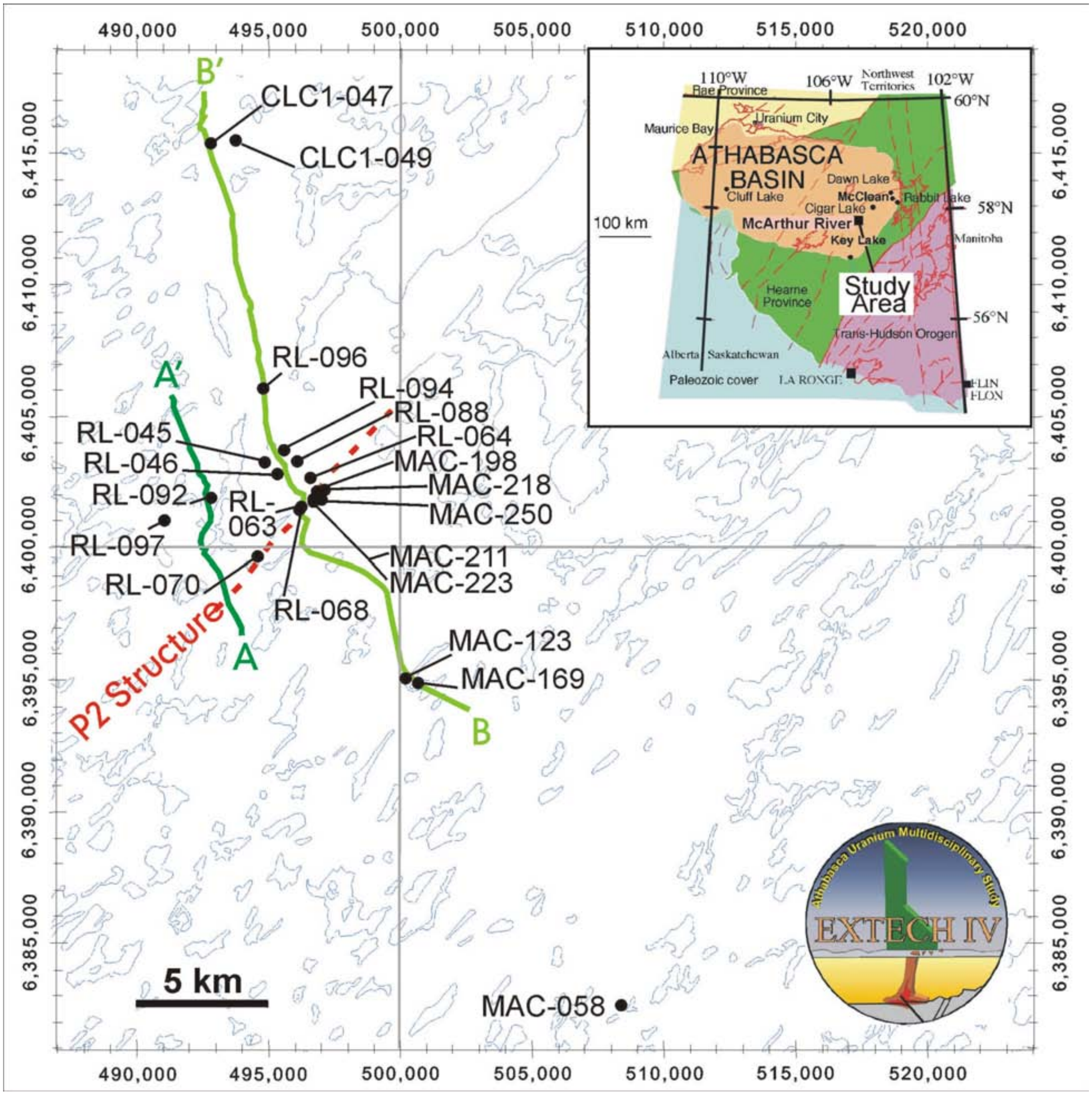

Figure 1 - Map of the McArthur River area showing location of drill cores logged in the present study. Lines A-A' and B-B' are the locations of the regional 2D seismic reflections profiles. Note the location of the P2 structure.

5) systematically analyze samples using PIMA-II and FieldSpec Pro instruments (Percival *et al.*, this volume).

2. Methodology and Preliminary Results

Drill cores were logged at the McArthur River mine site operated by Cameco Corporation using the EXTECH IV logging techniques described in Bernier *et al.* (2001) and Jefferson *et al.* (2001). As only the MFd member is exposed in the immediate area (Ramaekers *et al.*, 2001) nearly all observations are based on drill core, in which a standard set of parameters was measured systematically, on a meter-by-meter basis. This information was collected and entered into a database using hand-held computing devices (Jefferson *et al.*, 2001; Yeo *et al.*, 2001). The data were then transferred to a spreadsheet and used to produce lithologs using LogPlots 2001 (©Rockware) software. For comparative purposes, some equivalent data collected at 1.5 m intervals were obtained from Cameco

Corporation. Detailed sedimentological logging was done using the methodology developed by Long *et al.* (2000) for core at McClean Lake (Long *et al.*, 2002), but was transferred to LogPlots 2001 to allow rapid plotting.

Three boreholes were logged this past summer:

1) MAC-218 (Figure 2); key hole relogged using the EXTECH IV logging technique;
2) MAC-198; a critical hole location only a few tens of meters away from the high-resolution seismic line B-B' (Figure 1); and
3) RL-064; a very interesting hole that transects of clay alteration associated with uranium mineralization.

As outlined in earlier papers, digital plots of drill logs can be used effectively to delimit different sub-units of the Manitou Falls Formation. Figure 2 is a plot of MAC-218. For comparison Figure 3 provides a log based on the five parameters observed when this hole was originally logged in. Figure 4 is a log of RL-046 based on this summer's observations.

Figure 5 represents a detailed digital log of the sedimentology near the contact between MFa4 and MFb1 in RL-046. This log demonstrates the character of the sequence boundary of the interval between MFa4 and MFb1: a marked upward change in facies, from flat-laminated and cross-bedded sandstones to a coarser sandstone and conglomerate with cross-beds (trough?) but lacking flat-laminations (Figure 6). Other differences between MFa and MFb are in the mudstones which typically are red and desiccation cracked, scoured and reworked as intraformational conglomerates in MFa, but grey or green, uncracked, non-scoured and rarely ripped up in MFb.

Sequence boundaries and disconformities are typically difficult to recognize in fluvial strata of the Athabasca Basin due to the general similarly of strata above and below such contacts (MFa and MFb both contain quartz, arenites, quartz pebble conglomerates and mudstones, both have cross-beds, etc.). Documenting such subtle differences and choosing the exact contact is further complicated by the scarcity of continuous exposures of the MF Formation (Ramaekers *et al.*, 2001) and by the apparent gradational nature of the contact over several meters in terms of grain size. RL-046 is the only drill core logged for this study in the McArthur River area where a sharp contact has been observed to be comparable to that documented by Long *et al.* (2000) in the Sue Pit at McClean Lake.

Each sub-unit is a complex aggradational package of fluvial strata, which were deposited by a limited variety of fluvial processes. Some subunits record net fining upward, others a net coarsening upward. Fining-upward packages are interpreted to result from reduction in relief of provenance areas and/or upward reduction in stream power (could be climatic); coarsening upward packages result from the opposite.

A preliminary stratigraphic cross-section along the seismic line was presented by Bernier *et al.* (2001). Since then, further analysis and testing has confirmed the fundamental units recognized in 2001. Using the same UTM coordinates, accuracy of the cross-section has been improved by recalculating the depths of different sub-units based on the inclination of the drill hole and collar elevation with respect to sea level. The colours used in the revised cross-section (Figure 7) are hues of the MF colours proposed by Ramaekers *et al.* (2001) as a "colour code" for the different formations in the Athabasca Basin Characteristics of the different sub-units are summarized in Table 1.

3. Further Research

Systematic description of different sub-units of the Manitou Falls Formation and their associated sedimentary facies is in progress using data collected over the past two field seasons. Descriptive parameters have been supplemented by paleocurrent data and some thing section petrography and point counts. From these, the sedimentary history of the formation will be interpreted.

The stratigraphy will be used to produce a series of stratigraphic cross-sections. The preliminary sequence stratigraphic model will be improved and tested as a contribution to the stratigraphic framework of uranium deposits in the Athabasca Basin.

4. Acknowledgments

I thank Dr. Darrel G.F. Long, Dr. Charles W. Jefferson, and Dr. Paul Ramaekers for introducing me to the thesis area, to techniques for measuring cross-beds in drill core, and for providing continuing discussion and advice during the course of the study. Larry Richardson, Greg Leniuk, Brian McGill, Garth Drever, and Trevor Perkins and many administrative, operational and exploration staff of Cameco Corporation provided generous scientific and logistical support at the McArthur Mine site. Special thanks to Dr. Jeanne Percival, Sean Bosman, Sam Russell, and Maria

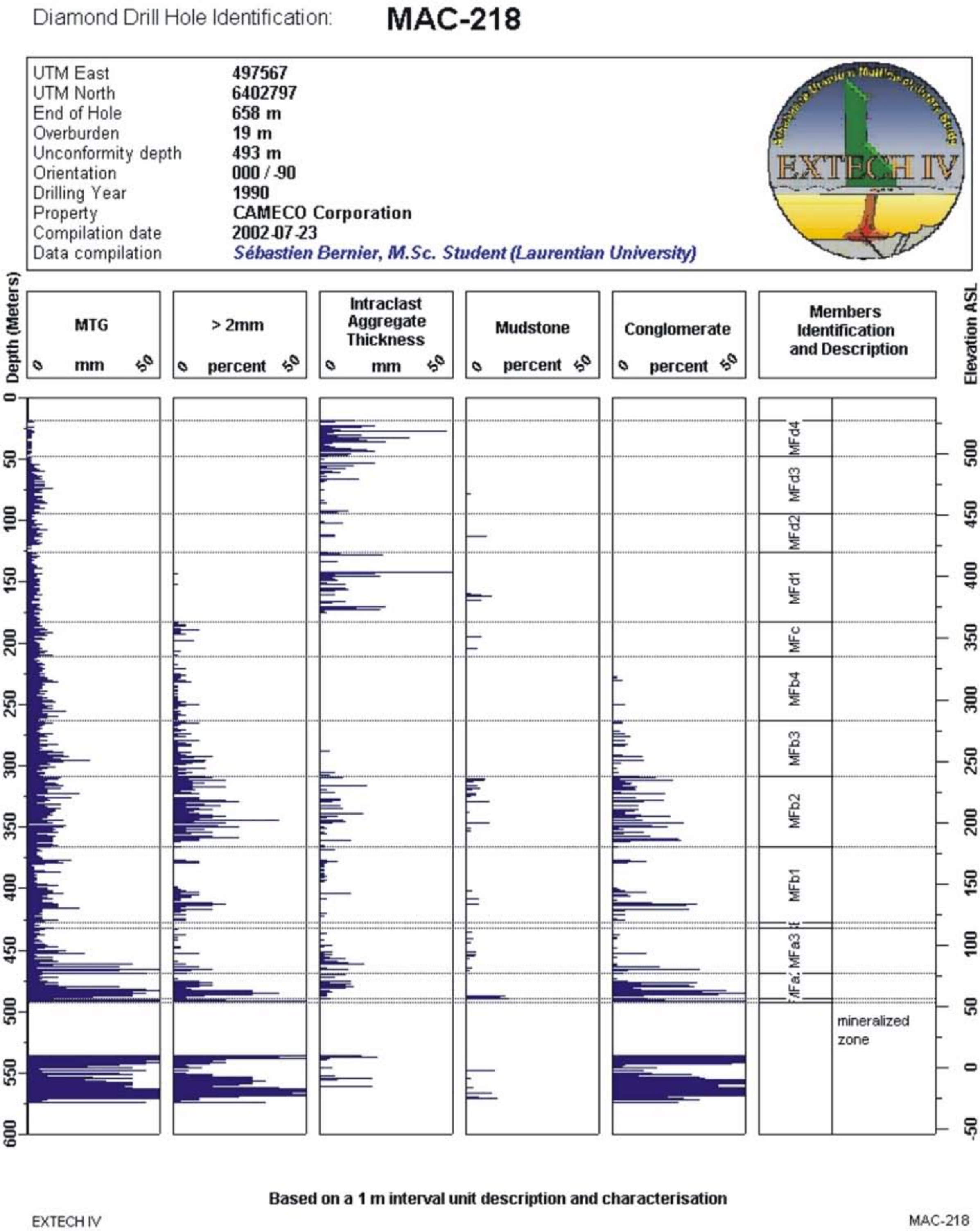

Figure 2 - Digital plot of five parameters measured in drill hole MAC-218 with a preliminary interpretation of the different sub-units.

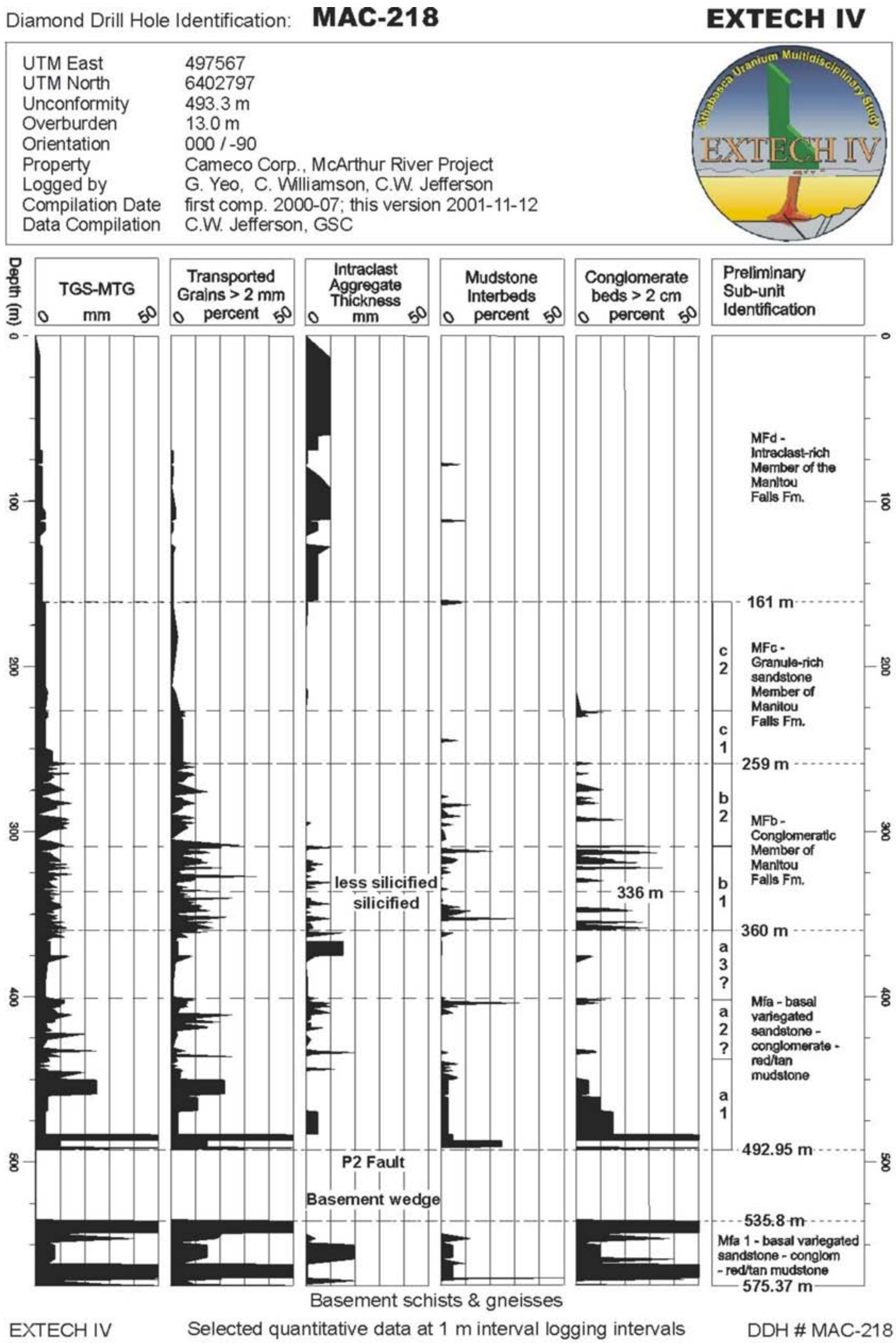

Figure 3 - Digital plot of drill-hole MAC-218, based on a log developed in 2000 during the first year of EXTECH IV. The same five parameters as Figure 2 have been selected: the main differences are the thickness of intervals logged. Note the marked differences in detail, digital presentation, and sub-unit sub-division (graph provided by C.W. Jefferson). In 2000, a number of parameters were collected (e.g., height of sedimentary structure) that were determined to be of little use in defining stratigraphy in the McArthur River area.

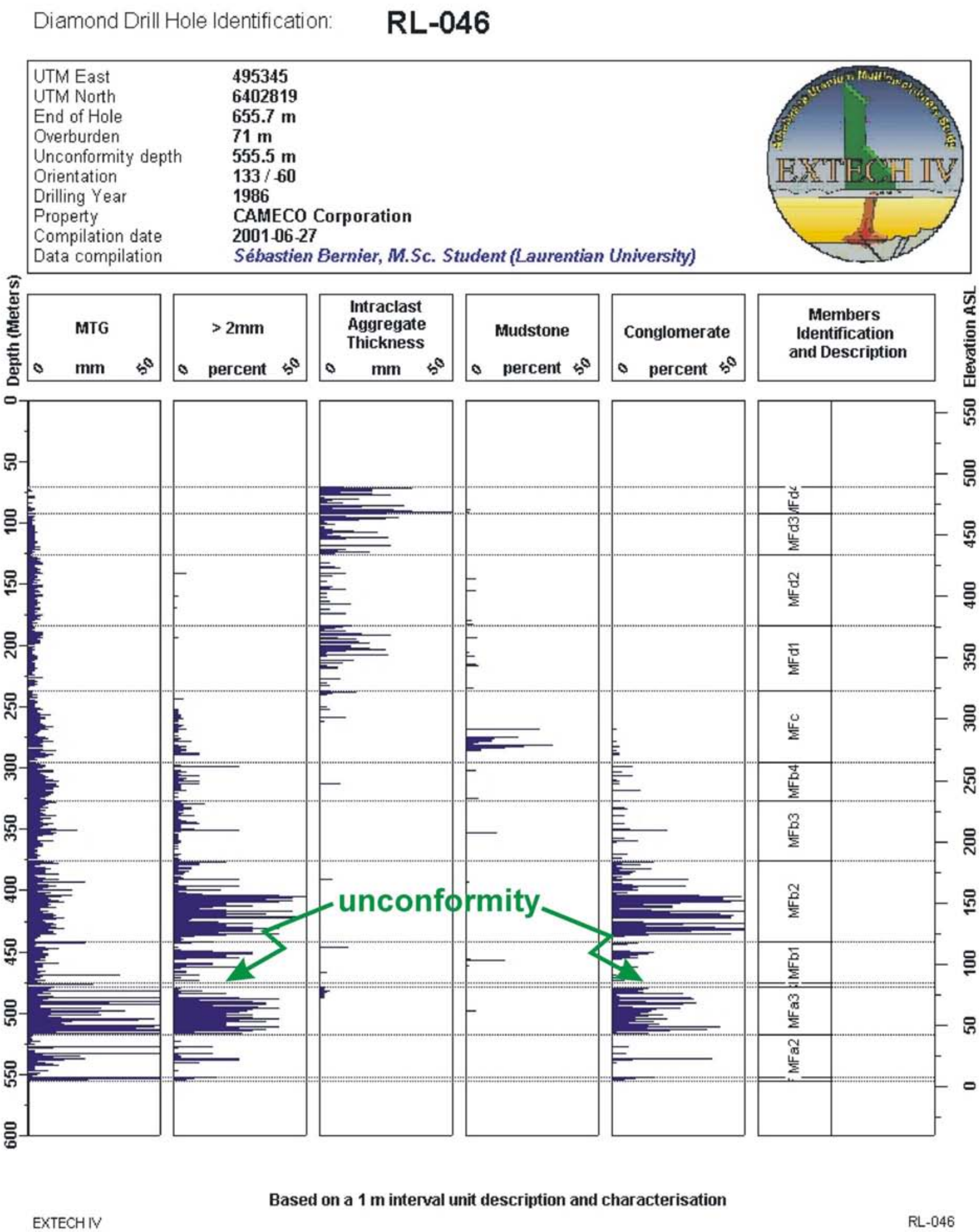

Figure 4 - Digital plot of RL-046 using the meter-by-meter logging technique developed by EXTECH IV.

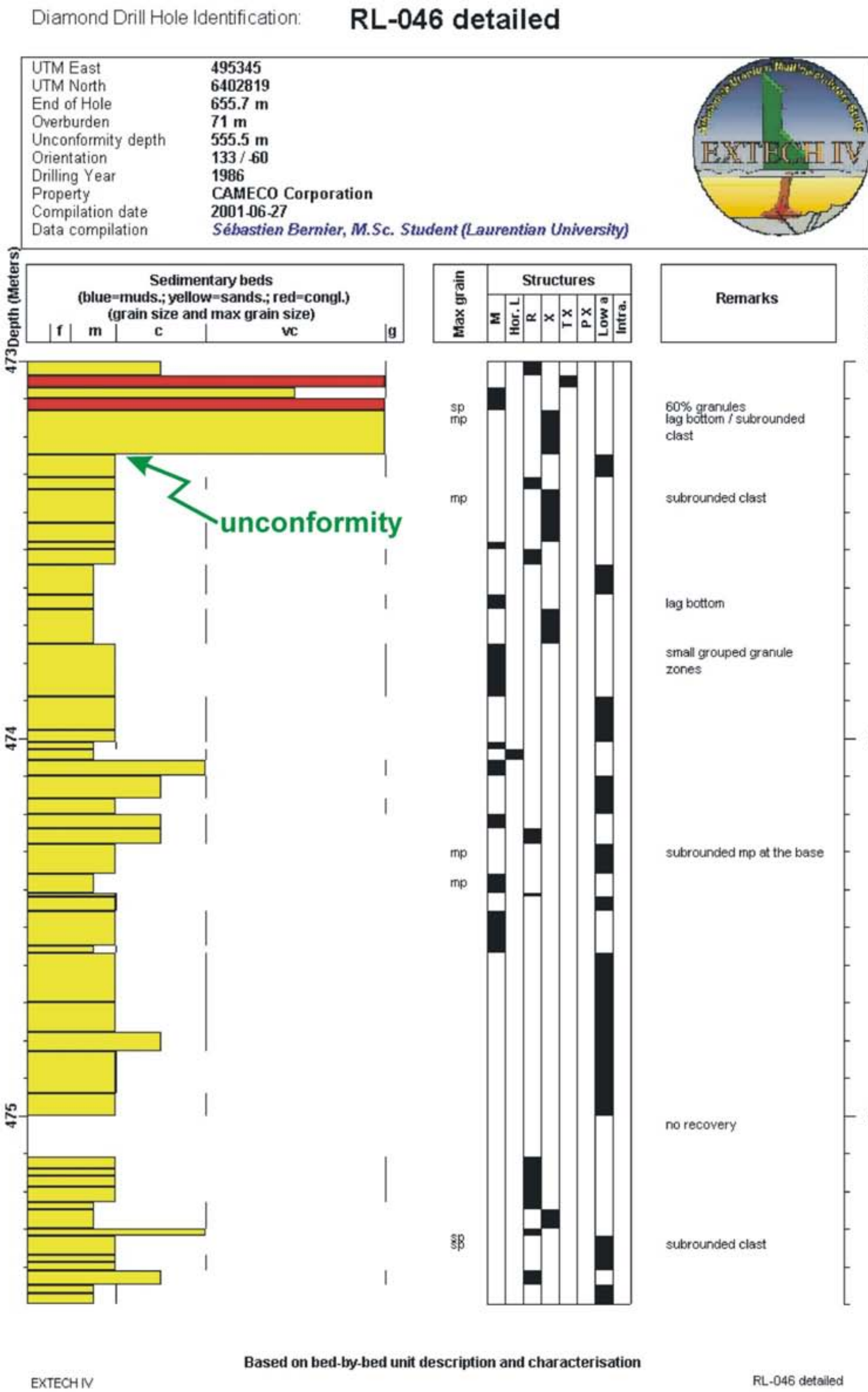

Figure 5 - Detailed sedimentological log based on a bed-by-bed examination of the strata near the proposed discontinuity between MFa4 and MFb1 in RL-046 (location in Figure 4). Note the importance of low-angle cross-beds in distinguishing between MFa4 and MFb1. Sp and mp respectively mean small pebbles and medium pebbles in terms of maximum grain size. Sedimentary structures and sedimentological characteristics recorded include: M (massive beds), Hor. L. (horizontal lamina), R (rippled beds), X (undefined cross-bed), T X (trough cross-beds), P X (trough cross-beds), Low a (low-angle stratification), and Intra (presence of intraclast). The numerical scale used for the grain size will eventually be converted to a non-linear scale.

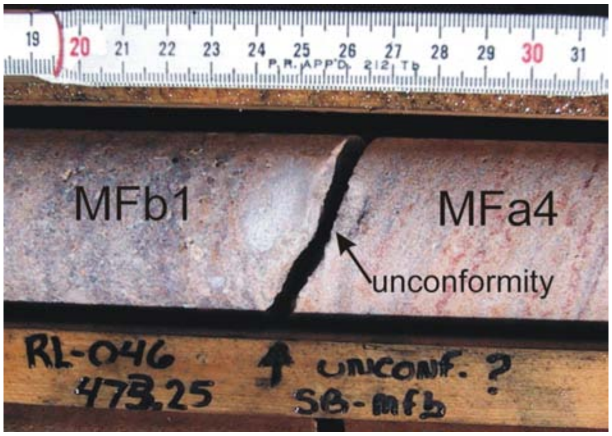

Figure 6 - The interpreted sequence boundary between MFa4 and MFb1 at 473.25 m in RL-046. Grain-size and sedimentary style change abruptly from a low-angle medium- to coarse-grained sandstone (maximum grain size: very coarse sand) in MFa4 to a cross-bedded gravelly sandstone (maximum grain size: medium pebble) in the overlying MFb1. This possible disconformity is very similar in appearance to the disconformity as recognized in drill core and pit walls at the Sue deposit by Long (2000).

Karagiorgakis for help in logging (and lugging) cores, assisting in the field, and fending off bears and wolves.

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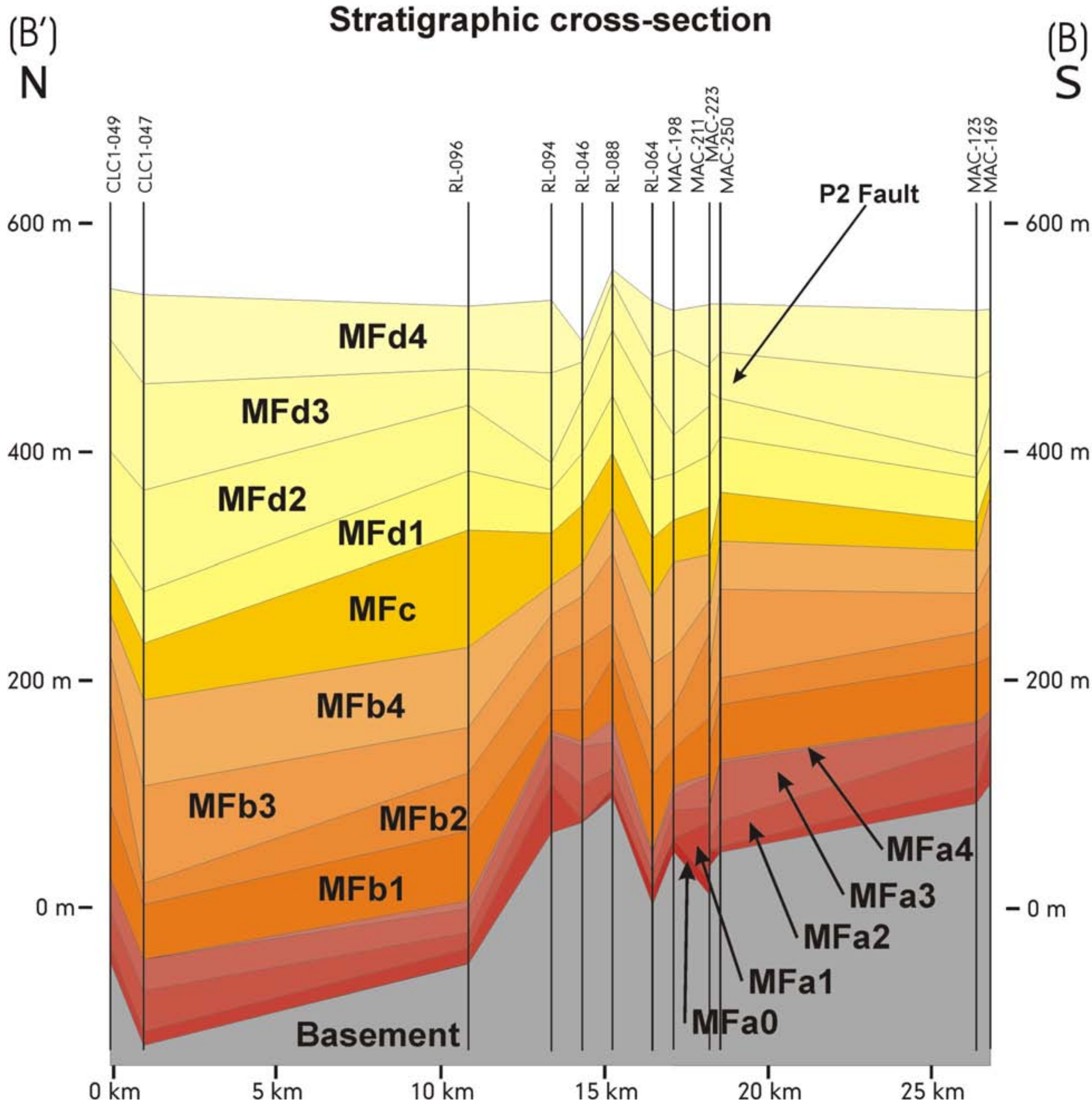

Figure 7 - Stratigraphic cross-section along the seismic survey line B-B' (in Figure 1). Note the apparent displacement of the basal conglomerate (MFa0) across the P2 fault and the continuity of MFa sub-units wrapping over the "paleohigh" in the vicinity of RL-088 without truncation. Datum is modern sea level, vertical exaggeration is x45.

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Table 1 - Summary of sub-units of the Manitou Falls Formation defined in the McArthur River area and described in this subproject.

MF Sub-units	Min. Thick. (m)	Max. Thick. (m)	Aver. Thick. (m)	Dominant Facies Number: Sedimentary Rocks and Grain Size	Minor Facies Number: Sedimentary Rocks and Grain Size	Sequence Type	Typical Section
MFd4	9	80	51	9. Thin pebble layer / medium sandstone /with mudstone intraclasts; 10. Mudstone Intraclast-rich / fine to medium sandstone	7. Medium to coarse sandstone; 11. Claystone / siltstone / mudstone	Fining upward	RL-094 28 to 86 m
MFd3	28	97	48	9. Thin pebble layer / medium sandstone / with mudstone intraclasts; 10. Mudstone Intraclast-rich / fine to medium sandstone	7. Medium to coarse sandstone, 8. Thin pebble layer / medium sandstone; 11. Claystone / siltstone / mudstone	Fining upward	RL-094 86 to 171 m
MFd2	17	89	50	8. Thin pebble layer / medium sandstone; 9. Thin pebble layer / medium sandstone /with mudstone intraclasts	7. Medium to coarse sandstone; 10. Mudstone intraclast-rich / fine to medium sandstone; 11. Claystone / siltstone / mudstone	Fining upward	RL-046 126 to 184 m
MFd1	23	77	45	8. Thin pebble layer / medium sandstone; 9. Thin pebble layer / medium sandstone /with mudstone intraclasts	7. Medium to coarse sandstone; 11. Claystone / siltstone / mudstone	Fining upward	RL-094 193 to 234 m
MFc	19	100	47	7. Medium to coarse sandstone	5. Coarse sandy conglomerate and gravelly sandstone, 8. Thin pebble layer / medium sandstone; 9. Thin pebble layer / medium sandstone /with mudstone intraclasts; 11. Claystone / siltstone / mudstone	Fining upward	RL-096 224 to 326 m
MFb4	25	80	52	5. Coarse sandy conglomerate and gravelly sandstone; 7. Medium to coarse sandstone	4. Coarse conglomerate / pebbly sandstone; 11. Claystone / siltstone / mudstone	Fining upward	RL-096 326 to 396 m
MFb3	26	86	47	5. Coarse sandy conglomerate and gravelly sandstone; 7. Medium to coarse sandstone	4. Coarse conglomerate / pebbly sandstone; 11. Claystone / siltstone / mudstone	Fining upward	RL-096 396 to 437 m
MFb2	20	89	45	4. Coarse conglomerate / pebbly sandstone; 5. Coarse sandy conglomerate and gravelly sandstone; 7. Medium to coarse sandstone	11. Claystone / siltstone / mudstone	Fining upward	MAC-211 291 to 368 m
MFb1	19	67	47	4. Coarse conglomerate / pebbly sandstone; 5. Coarse sandy conglomerate and gravelly sandstone; 7. Medium to coarse sandstone	11. Claystone / siltstone / mudstone	Coarsening upward	RL-097 466 to 506 m
MFa4 (SB)	1	19	4	6. Flat-bedded medium sandstone	7. Medium to coarse sandstone; 11. Claystone / siltstone / mudstone	Uniform	RL-068 459 to 460 m
MFa3	14	52	27	4. Coarse conglomerate / pebbly sandstone; 5. Coarse sandy conglomerate and gravelly sandstone; 7. Medium to coarse sandstone	3. Red-mudstone / sandstone / conglomerate; 6. Flat-bedded medium sandstone; 11. Claystone / siltstone / mudstone	Coarsening upward	RL-097 509 to 548 m
MFa2	6	62	23	4. Coarse conglomerate / pebbly sandstone; 5. Coarse sandy conglomerate and gravelly sandstone; 7. Medium to coarse sandstone	3. Red-mudstone / sandstone / conglomerate; 6. Flat-bedded medium sandstone; 11. Claystone / siltstone / mudstone	Fining upward	CLC1-047 628 to 662 m
MFa1	0	48	14	4. Coarse conglomerate / pebbly sandstone; 5. Coarse sandy conglomerate and gravelly sandstone	3. Red-mudstone / sandstone / conglomerate; 7. Medium to coarse sandstone; 11. Claystone / siltstone / mudstone	Coarsening upward	RL-092 491 to 530 m
MFa0	0	17	5	1. Basal conglomerate	2. Breccia	Abrupt fining upward	MAC-211 508 to 520 m

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