Preliminary Results From a Study of the Geology and Alteration at the Maybelle River Uranium Zone, Athabasca Basin, Alberta, EXTECH IV

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Abstract

A detailed study of 15 drill cores surrounding the uranium zone in the Maybelle River area, in the southwestern part of the Athabasca Basin in Alberta, was undertaken to better define Athabasca Group sedimentology, stratigraphy, and alteration surrounding the deposit. The Athabasca Basin comprises the Fair Point, Manitou Falls, and the base of the Lazenby Lake formations; the basement consists of granitoid gneisses, graphitic mylonites and mylonites. An alteration halo surrounding the uranium zone is similar in characteristic to that associated with deposits in Saskatchewan. Massive clay replacement, quartz dissolution and sandstone collapse, drusy quartz and pyrite lined fractures, chlorite overprinting, and bleaching of core occur in the holes surrounding the uranium zone.

Keywords*: Alberta, alteration, Athabasca Basin, Athabasca Group, basement, Fair Point Formation, Lazenby Lake Formation, Manitou Falls Formation, Maybelle River, Proterozoic, sandstone, uranium.*

1. Introduction

This paper summarizes the preliminary results of work on drill core from the Maybelle River area, Alberta, carried out at the Mineral Core Research Facility (MCRF) in Edmonton in 2002. The Maybelle River area is located approximately 200 km northeast of Fort McMurray, Alberta (Figure 1).

This work forms the basis of an M.Sc. thesis by Barbara G. Kupsch at the University of Alberta, under the supervision of Dr. Octavian Catuneanu (University of Alberta), Dr. Reg A. Olson (Alberta Geological Survey), and Dr. Charlie Jefferson (Geological Survey of Canada). This thesis is part of a larger project entitled EXTECH IV, Athabasca Uranium Multidisciplinary Study, which is an integrated partnership between Cameco Corporation, COGEMA Resources, academia (including the universities of Alberta and Saskatchewan and Laurentian University), the Geological Survey of Canada, Saskatchewan Industry and Resources, and the Alberta Geological Survey (Jefferson and Delaney, 2001).

The goal of this research is to develop a better understanding of Athabasca stratigraphy, sedimentology, and alteration and their roles in the localization of uranium in the Maybelle River area. A major difference between the Maybelle River area and other uranium deposits of the Athabasca Basin is the regional restriction of the Fair Point Formation beneath the Manitou Falls Formation in the western Athabasca Basin (Ramaekers, 1990), and the implications for uranium mineralization in this unique stratigraphic situation. In the central and eastern Athabasca Basin, uranium mineralization is located at or near the unconformity between permeable units of the basal Manitou Falls Formation of the Athabasca Group and the underlying Paleoproterozoic basement gneisses and schists. In addition to proximity to the sub-Athabasca unconformity, other controls include basement fault and fracture-zones, and proximity to graphitic pelitic gneiss that flank structurally competent Archean granitoid domes (Quirt, 1989). In contrast, in Alberta at the Maybelle River area, a high-grade uraniferous zone (e.g., intersected in diamond drill hole MR-39 which averages 5 m at 21% U_3O_8, see Orr ,1989) was intersected at the base of the Fair Point Formation near the unconformity with underlying metamorphosed basement sedimentary and igneous rocks.

The Fair Point Formation is a westward-thickening clastic wedge of clay-rich, poorly sorted pebbly sandstone between the Manitou Falls Formation and basement (Ramaekers, 1990). The Maybelle River study area is on the southern fringe of the Fair Point Formation and is associated with a north-trending re-entrant defined to the west on an isopach map; this parallels the Maybelle River trend (Ramaekers, 2002). The basal unit in the Athabasca Basin south of the Maybelle River study area is the Manitou Falls Formation.

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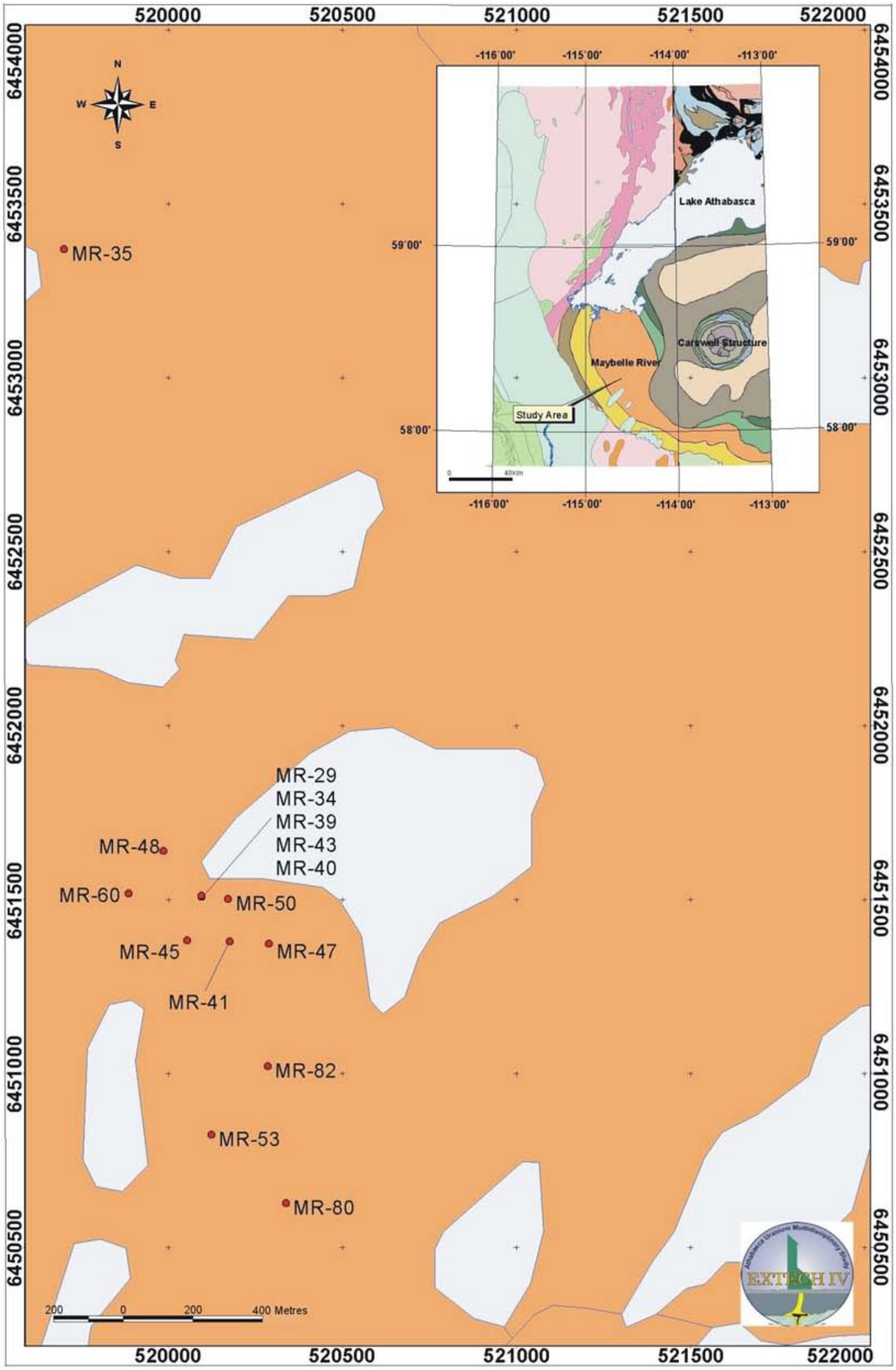

Figure 1 - Map of the Maybelle River area showing the location of drill holes logged as part of this study. Light areas are lakes, darker areas are Lazenby Lake Formation, inset is after Ramaekers** et al. **(2001).

2. Methodology

The focus of this study was to log in detail core from 15 holes and study selected aspects of the Athabasca Group and underlying basement at and near the Maybelle River uraniferous zone (Figure 1). Drill holes were chosen with tight spacing nearest to and including ddh MR-39, with the other 14 holes radiating outward up to 2 km. These holes were chosen to get better coverage around the deposit in order to map the extent of the alteration halo and the stratigraphy characterized by the Athabasca Group. The Athabasca Group sediments were logged on a metre-by-metre scale on a Palm PDA. In total, 37 parameters were captured, which included the Jefferson *et al*. (2001) parameters, plus several additional parameters which are listed in Table 1. The additional parameters such as "Tectonic Structures" and "Replacement" were added to capture detailed structure and alteration features.

This paper presents preliminary results for a representative drill hole using selected parameters: maximum transported grain size (MTG), percent of grains greater than 2 mm (%>2mm), percent sum of cross-section thickness of all intraclasts measured individually (% intraclasts), percent of mud size particles (%M), percent of silt and very fine grained size particles (%F), and percent conglomerate beds greater than 2 cm thick (%C) (Figure 2). These parameters were chosen to be consistent with the stratigraphic work being done in the rest of the Athabasca Basin (e.g., Bernier *et al*., 2001; Collier *et al*., 2001; Jefferson *et al*., 2001; Yeo *et al*., 2001).

Basement units are logged into a preliminary database designed at the Alberta Geological Survey (AGS). Parameters captured are listed in Table 2. Basement was logged to characterize units associated with the deposit, the extent of alteration in the basement, and to document structures that may have controlled the deposition of uranium.

Table 1 - Additional parameters used for digital logging of Athabasca Group drill core on the Alberta side of the western Athabasca Basin (after Jefferson* et al.*, 2001).

Parameter	Variables (as recorded)
Drill Hole	AGS ID (e.g. MR-35)
AM_Colour	Accessory Mineral Colour= Bk (Black), Bn (Brown), BR (Black-Red), Gn (Green), Gy (Grey), R (Red, bright), M (Maroon, brick), Y (Yellow), etc., n (n/a)
AM_Distribution	L (in laminae and X-laminae), D (disseminated), n (n/a)
SSS_2ndStructures	Secondary Sedimentary Structures = b (ball and pillow), c (convolute bedding), d (clastic dykes), f (flame structure), l (load casts), m (sandfilled mudcracks), o (overturned / oversteepened Xlam), pc (pedogenic carbonates), pi (pedogenic pisolites), ps (pedogenic silica), r (scour), sy (syneresis cracks), sl (slump, sedimentary fault), s2 (o'steep multiple beds), u (understeep)
Hydroc_Type	Hydrocarbon Type = p (pyrobitumen), t (tar), h (heavy oil), l (light oil), o (odour), n (n/a)
Hydroc_Distribution	b (buttons, f (along fractures), il (intergranular, saturated), n (n/a)
Hydroc_Saturation	Number (%)
TectonicStructureType	bc (crackle breccia), br (fault conglomerate), bx (breccia), fd (dip-slip fault), fr (fracture, no movement), fs (strike-slip fault), ft (fault, unspecified), su (uncemented sandy gouge), sc (cemented sandy gouge), n (n/a)
TectonicStructure_Angle to core axis	Number
TectonicStructure_Fracture Fill Cemement	a (apatite), c (calcite), d (dolomite), s (siderite), h (hematite), l (limonite), m (marcasite), py (pyrite), pi (pitchblende), td (dravite), ts (schorl), y (clay), g (gouge), sc (gouge, sandy cemented), su (gouge, sandy uncemented), qc (chalcedony), qd (quartz, drusy), qo (quartz overgrowths), o (other), f (feldspar, overgrowths), n (none)
TectonicStructure_Fracture Fill Thickness	Number
Replacement_Type	b (botryoidal), ps (pseudomorphing or pseudomorphous), ms (massive), mn (manto, stratabound), v (vuggy), pa (patchy), d (disseminated), l (linings of voids), fi (replace rock within fault zone), fo (replace fault zone and wall rock)
Replacement_New Mineral	a (apatite), c (calcite), d (dolomite), s (siderite), h (hematite), l (limonite), m (marcasite), py (pyrite), pi (pitchblende), td (dravite), ts (schorl), y (clay), g (gouge), sc (gouge, sandy cemented), su (gouge, sandy uncemented), qc (chalcedony), qd (quartz, drusy), qo (quartz overgrowths), o (other), f (feldspar, overgrowths), n (none)
Replacement_%	Number (%)
Remarks	Alphanumeric

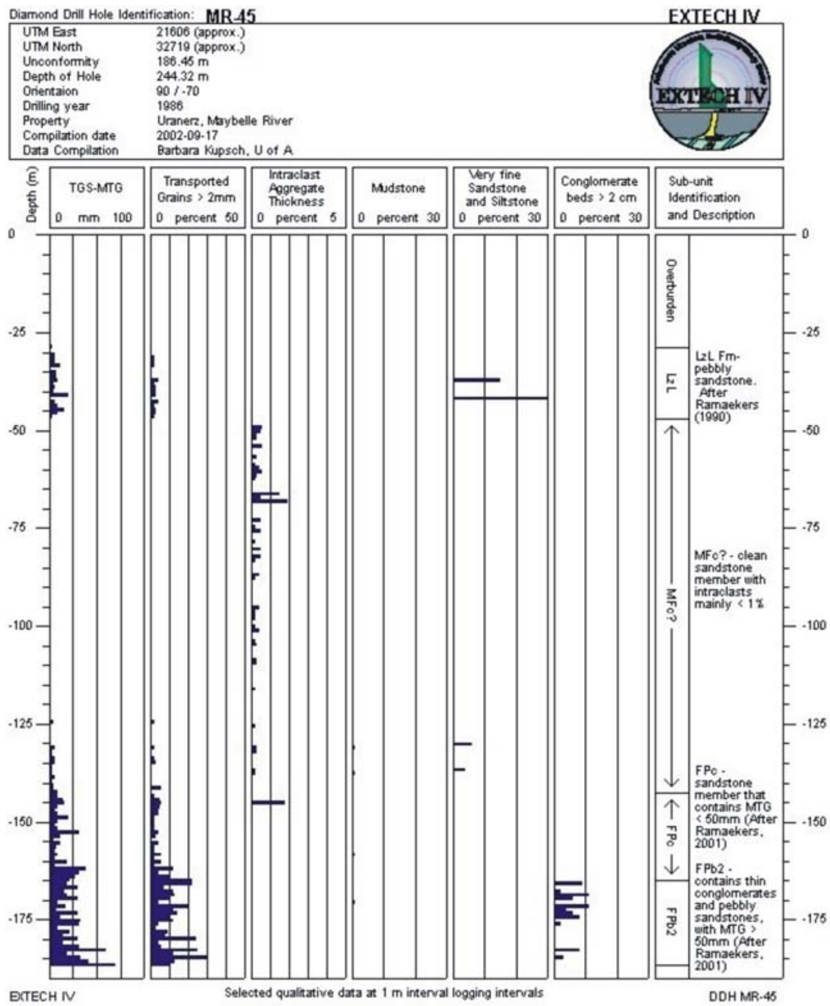

Figure 2 - Plot of MR-45 from the Maybelle River area illustrating six parameters and the stratigraphic subdivisions distinguished. Plot from Rockware's LOG PLOT 2001 software. Location is shown on Figure 1.

3. Geology

a) Basement

The north-western part of the basin in Alberta is underlain by rocks of the Rae Structural Province (Hoffman, 1988). Basement rocks underlying the Athabasca Basin are comprised of an alteration zone that overlies, in places, fresh basement. The altered basement sits below the unconformity and typically comprises a bleached, red and green zone. The thickness and extent of each of these three types of alteration zones are variable in the Maybelle River study area. A bleached zone occurs in and around the mineralized hole, but is not seen further away. Directly below the bleached zone, or in some holes, directly underlying the unconformity, is the red zone where hematite and clay predominate (Ramaekers, 1990). This zone, when present, ranges from 2 to 30 m in thickness. Below this is the green zone, ranging from 1 to 8 m where present, where chlorite and illite predominate (Ramaekers, 1990).

Basement rocks underlying the basin in Alberta consist of four types of granitoids and two mylonitic rock types, as described and interpreted by Wilson (1986). At Maybelle River, basement rocks are mainly granitoid gneiss, mylonite, and graphitic mylonite. Many of the basement rocks along the Maybelle River trend, contain mylonite; eight drill cores (specifically MR-29, -40, -41, -47, -50, -53, -80, and -82) along the east side of the trend, intercepted graphitic mylonite. This graphitic unit is most likely the cause of the EM conductor that occurs along this trend on company maps (Orr, 1989). The mylonites indicate a major structural zone of high strain and shear along this trend. As well, there is probably one or more brittle faults.

b) Athabasca Group

Three formations of the William River Sub-group of the Athabasca Group underlie the Maybelle River area: the Fair Point, Manitou Falls, and the Lazenby Lake formations.

Fair Point Formation

The Fair Point Formation has been subdivided into four subunits (Table 3) by Ramaekers *et al*. (2001), of which only two are recognized in the Maybelle River area. The Fair Point Formation ranges in thickness from 30 to 50 m in the study area and thickens to the west.

Table 2 - Parameters used for digital logging of basement drill core below the western Athabasca Basin, Alberta (established by the Alberta Geological Survey).

Parameter	Variables (as recorded)
Depth From	Number (m)
Depth To	Number (m)
Rock Type	Amphibolite, biotite amphibolite, garnet amphibolite, diorite, granodiorite, gabbro, gneiss, plagioclase gneiss, K-feldspar gneiss, micaschist, graphite schist, granitoid, monzonite, syenite, pegmatite, migmatite, mylonite, quartzite, breccia, metapelites
Regolith	Bleached zone, red zone, red-green zone, green zone, altered zone (not catagorized into bleach, red, green zone)
Colour	Black, Green, Black-Red, Blue, Blue-Grey, Brown, Cream, Dark Green, Gold, Grey, Lead, Light Brown, Light Green, Orange, Pink, Purple, Red, Rusty, White, Yellow, Yellow-Grey
Grain Size	Very fine (<1 mm), fine (1-3 mm), medium (3-10 mm), coarse (>10 mm)
Metamorphic Facies	Plutonic, volcanic, greenschist, amphibolite, granulite, retrogressed, mylonitic, metasedimentary
Primary Mineral	Quartz, feldspar, ?feldspar, k-feldspar, plagioclase, mafics, ?mafics, biotite, muscovite, hornblende, olivine, pyroxene, garnet, almandine garnet, chlorite, andalusite, cordierite, epidote, kyanite, serpentine, sillimanite, staurolite
Modal %	Number = percent of the mineral in the rock for the interval
Texture	Massive, nonfoliated, slightly foliated, foliated, banded, relic sedimentary bedding, brecciated
Alteration-Intensity	Very weak (0-2% modal), weak (2-10% modal), moderate (10-25% modal), strong (25-50% modal), very strong (50-75% modal), intense (75-100% modal)
Alteration-Type	Disseminated, foliation concentrated, on fracture, patchy, pervasive, pseudomorphic, specks, stringers, vein
Alteration-Colour	Black, Green, Black-Red, Blue, Blue-Grey, Brown, Cream, Dark Green, Gold, Grey, Lead, Light Brown, Light Green, Orange, Pink, Purple, Red, Rusty, White, Yellow, Yellow-Grey
Alteration-Mineral	Calcite, carbonate, chlorite, clay minerals, epidote, graphite, hematite, limonite, opaque minerals, pyrite, quartz, sericite, sulphides
Vein-Colour	Black, Green, Black-Red, Blue, Blue-Grey, Brown, Cream, Dark Green, Gold, Grey, Lead, Light Brown, Light Green, Orange, Pink, Purple, Red, Rusty, White, Yellow, Yellow-Grey
Vein-Mineral	Calcite, carbonate, chlorite, clay minerals, epidote, graphite, hematite, limonite, opaque minerals, pyrite, quartz, sericite, sulphides
Planar Structure-Structure Name	Cleavage, inferred bedding, joints, fault, fold axis, foliation
Planar Angle-Angle to Core Axis	Number (degrees) = 0 to 90
Linear Structure-Structure Name	Fold axis, intersection lineation, slicken lines, stretching lineation
Linear Structure-Angle to Core Axis	Number (degrees) = 0 to 90
Nature of Lower Contact	Transitional, sharp
Comments	Alphanumeric

Table 3 - Stratigraphic summary of the Fair Point Formation (after Ramaekers et al., 2001).

Formation	Member	Lithology
Fair Point	FPc	Pebbly sandstone, sandstone; MTG <50 mm; horizontal and low-angle cross-bedding common
	FPb2	Pebbly sandstone, sandstone, thin conglomerates; MTG >50 mm; horizontal and low-angle cross-bedding common
	FPb1	Conglomerate and sandstone; horizontal and low-angle cross-bedding common
	FPa	Conglomerate, pebbly sandstone, sandstone, siltstone; horizontal and low-angle cross-bedding common

Fair Point b2 Sub-member

The Fair Point b2 Sub-member (FPb2), the lowest unit of the Athabasca Group at Maybelle River, consists of coarse-grained sandstones with disseminated pebbles, interbedded pebbly sandstones, thin conglomerate beds, and local siltstone beds and/or clay intraclasts. FPb2 is poorly sorted and has abundant interstitial clay. Fining-upward trends characterize some sandstone intervals; some contain pebbly sandstones. The sandstones appear massive in most sections, with minor horizontal laminae and low-angle cross-beds. The conglomerates also appear massive and are matrix supported. The MTG of pebbles locally exceeds 50 mm. The pebbles are subangular to subrounded and are dominantly quartz with minor rock fragments and platy limonitic gneiss pebbles interpreted to be reworked regolith (Ramaekers *et al*., 2001). The upper boundary between the FPb2 Sub-member and the FPc Member is gradational and marked by the loss of conglomerate beds and pebbles over 50 mm in diameter (Figure 2).

Fair Point c Member

The Fair Point c member (FPc) is a coarse-grained sandstone with minor interbedded pebbly sandstones and disseminated pebbles, and generally is thinner than the underlying FPb2. Siltstone beds and clay intraclasts are minor components. It is moderately to poorly sorted and has abundant interstitial clay. Fining upward units from very coarse to medium grained sandstones are common. The sandstones appear massive in most sections. Some horizontal and low-angle cross-beds are found. The MTG of pebbles is less than 50 mm. This unit has a low percentage of coarse material compared to the underlying FPb2. The contact between the FPc member and the overlying Manitou Falls Formation is regionally unconformable, and easily recognized in core as a sharp break between underlying poorly sorted, massive appearing, coarse-grained sandstone with abundant interstitial clay and overlying well sorted, coarse- to fine-grained sandstone with well defined bedding and trace amounts of interstitial clay. On plots of the drill logs, however, the start of Manitou Falls Formation is placed where the MTG is greater than granule size and intraclasts begin to appear consistently (Figure 2).

Manitou Falls Formation

Only one member of the Manitou Falls Formation, which probably corresponds to MFc (Ramaekers *et al.*, 2001), is recognized.

Manitou Falls c? Member

The Manitou Falls MFc? member has an average thickness of 95 m at the Maybelle River, thickening slightly to the north. It is a moderately sorted, fine- to medium-grained sandstone, containing common but <1% clay intraclasts as well as minor mudstone and siltstone interbeds. The basal few metres of this unit is coarse-grained sandstone with disseminated granules and small pebbles. This fines up into a fine- to medium-grained sandstone with a MTG of 1 mm for most of the member. It is dominated by ripple cross-bedding with minor massive bedding and some low-angle cross-beds at the base. Intraclasts increase toward the top of the unit, but are still less than 1%. The upper boundary with the Lazenby Lake Formation, which is sharply gradational and interpreted to be conformable, is defined at the loss of intraclasts and the gain of pebbles (Figure 2).

The Manitou Falls strata at Maybelle River are provisionally assigned to member MFc based strictly on the similarity of lithologic characteristics with those for MFc as described by Ramaekers (1990). Correlation is unclear with Manitou Falls sections on the western side of the basin in Saskatchewan. It loosely corresponds with the Manitou Falls c Member at Shea Creek, but does not contain the G1 layers or thin conglomerate beds described by Collier *et al*. (2001). The characteristics correspond closer to Manitou Falls d Member in the Shea Creek area but do not contain more than 1% intraclasts (Collier *et al*., 2001). Further study of this unit and comparison by sequence analysis with the rest of the western side of the basin is needed to determine if or how this corresponds to one or more of the members in Saskatchewan.

Lazenby Lake Formation

The basal part of the Lazenby Lake Formation (LzL) is the youngest part of the Athabasca Group that is preserved in the Maybelle River study area. It is overlain unconformably by Quaternary deposits. An average thickness of 20 m is preserved in the immediate Maybelle River area; it thickens to the north but, until recently, was not recognized in Alberta (Ramaekers *et al*., 2001). The Lazenby Lake Formation is a fine- to medium-grained sandstone with disseminated pebbles and pebbly sandstone beds at the base. The unit fines upward from a coarse- to a fine-grained sandstone. Mudstones and clay intraclasts are rare. The LzL is dominated by ripple cross-bedding with minor massive bedding. Overturned bedding is common. Pebble beds one layer thick (G1 layers) or thin conglomerates are sparse above the lower contact. The pebbles are rounded and quartz dominated. The amount and size of the pebbles increases toward the base of the unit. The MTG is commonly over 2 mm and can attain 30 mm toward the base.

This feature along with the percentages of clasts greater than 2 mm makes it clearly recognizable on statistical plots of drill logs (Figure 2). G1 layers are common but not always at the base of LzL. Therefore, this author suggests that the first pebble be the marker for the LzL/MF contact. This is easily recognized on logs (Figure 2).

4. Alteration

Another component of this drill-core study is to define and map the alteration zone surrounding the Maybelle River uranium mineralization. Host rock alteration that typically surrounds uranium deposits in the Athabasca Basin is characterized by the conversion of framework and matrix grains to clay minerals, intensive quartz dissolution, locally associated collapse of the overlying sandstone (e.g., Cigar Lake) and residual enrichment of clay, a shell of secondary hematite, oxidation/reduction features, extensive bleaching, formation of euhedral quartz veins, tourmaline, chlorite±siderite alteration, destruction of graphite, and formation of solid hydrocarbons (Quirt, 1997; Ruzicka, 1997). Some alteration haloes are plume shaped and locally extend several hundreds of metres above the unconformity, but are smaller, funnel-shaped and converging downwards onto the fault zone below the unconformity (Ruzicka, 1997).

Preliminary observations from core within the Maybelle River study area revealed alteration features that are similar to those associated with uranium deposits in the eastern Athabasca Basin. For example, clay alteration has completely replaced the sandstone for up to 2 m adjacent to mineralization in sections in the FP; some clay alteration is also in the lower MF. As well, clay replacement and infilling along fractures and faults occurs in the FP and MF. Highly fractured areas occur in the MF due to quartz dissolution. Drusy quartz veins are mainly up-section in the MF, above the fractured zones. Pyrite is common in fractures in MF and LzL. Bleaching of the core increases closer to the high-grade uranium intersection (MR-39). Chlorite overprinting seems constrained to the FP. Major chlorite overprints upper basement rocks. A bleached zone in the basement overprints the top of the red zone as seen in cores close to MR-39. In summary, all of the above features increase in intensity closer to uraniferous hole MR-39.

5. Future Analysis and Conclusions

Work during the first year of this M.Sc. project has helped define four units within the lower Athabasca Group that were deposited in the Maybelle River area. These are: Fair Point b2 Sub-member, Fair Point c Member, Manitou Falls c? Member, and the Lazenby Lake Formation. The thickness of these formations is relatively uniform. Alteration features associated with the uranium zone increase in intensity closer to the currently known, best mineralized hole MR-39. These features, along with similar alteration patterns, association with graphite, and evidence of a major fault zone, suggest a strong similarity between uranium mineralization in the Maybelle River area and that in the Saskatchewan part of the basin.

Further work is planned to better define and classify formations comprising the Athabasca Group in the Maybelle River study area and to better document alteration mineralogy and zoning. Cross-sections of the drill log data collected using Palm PDA will be plotted to show variations between drill holes and correlations throughout the study area. Detailed facies logging and petrography are underway, to help define the depositional environment of each formation. Paleocurrent measurements will be collected to determine fluvial directions and source areas. This work will be complemented by a more regional stratigraphy–alteration study being done in the Maybelle River area by the Alberta Geological Survey (R. Post, pers. comm., 2002). The Maybelle River studies will be correlated with comparative studies currently being done (Collier and Yeo, pers. comm., 2002) in the western part of the Athabasca Basin in Saskatchewan, and more regionally in both Alberta and Saskatchewan by Ramaekers (pers. comm., 2002). Thus, it is anticipated this complementary and correlative work will assist in better defining the Manitou Falls Formation in the Maybelle River study area. Samples for geochemistry have been collected from five drill holes within the Maybelle River uraniferous trend. These are currently being processed. These five holes make a cross-section across the altered zone. These data will help define the characteristics and the extent of the alteration halo associated with the uranium. PIMA data, which were collected for eight drill holes, must be analyzed, to help define the types and areal extent of clay alteration associated with the Maybelle River uraniferous zone.

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