Petrographic Characteristics of the Athabasca Group Sandstones from the Rumpel Lake Drill Core, Athabasca Basin, Northern Saskatchewan

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Abstract

Petrographic analysis of the Athabasca Group sandstones using the Rumpel Lake drill core has been undertaken in an attempt to construct a diagenetic sequence through the stratigraphy and understand the fluid chemistry during diagenesis. This report presents preliminary petrographic observations of the five formations that are present in the Rumpel Lake drill core (in ascending order: Read, Manitou Falls, Lazenby Lake, Wolverine Point, and Locker Lake). Point-counting data show that the Athabasca Group sandstones range from quartz arenite to quartz wacke. Six different cements have been documented: syntaxial quartz overgrowths, kaolinite, illite, hematite, chert, and dolomite. Kaolinite, illite, and hematite are also present as recrystallization and/or replacement phases. Petrographic observations and point-counting data suggest that diagenesis is complex and may contain several repeating dissolution/precipitation events.

Keywords: *Athabasca Basin, Athabasca Group, sandstones, petrography, point counting, diagenesis.*

1. Introduction

In 2010, a project was undertaken to examine the Athabasca Group sandstones geochemically and petrographically utilizing the Rumpel Lake drill core. The main objectives of this project are to: 1) constrain the geothermal gradient at a high resolution using fluid inclusion microthermometry and illite geothermometry, 2) document the changes in salinity with depth using fluid inclusion microthermometry, and 3) petrographically document the changes in sandstone composition and establish a diagenetic sequence for the formations present in the Rumpel Lake drill core. The reader is referred to Scott *et al*. (2011) for details about the initial findings of fluid inclusion microthermometry and petrographic characterization. Microthermometric studies were continued from 2011 on fluid inclusions located in the syntaxial quartz overgrowths on quartz grains and are still ongoing. This year, microscopic examination of the samples was continued, and point counting was completed on all collected sandstone samples. This report presents preliminary petrographic observations and mineralogical trends of the five formations within the Rumpel Lake drill core.

2. Geological Setting

The Athabasca Basin contains late Paleoproterozoic to Mesoproterozoic sedimentary rocks of the Athabasca Group, which unconformably overlie Archean to Paleoproterozoic metamorphic rocks (Ramaekers *et al.*, 2007). The Athabasca Group is divided into the following formations, in ascending stratigraphic order: Fair Point, Reilly, Read, Smart (lateral equivalents), Manitou Falls, Lazenby Lake, Wolverine Point, Locker Lake, Otherside, Douglas, and Carswell (*ibid.*). The Rumpel Lake drill core, a stratigraphic drill hole drilled by Gulf Minerals at Rumpel Lake (Figure 1), contains five of these formations (in ascending order: the Read, Manitou Falls, Lazenby Lake, Wolverine Point, and Locker Lake formations). These five formations are further subdivided into 10 members: Manitou Falls–Dunlop, Collins, Warnes, Bird, and Raibl members; Lazenby Lake–Dowler member; Wolverine Point–Claussen and Brule members; and Locker Lake–Brudell and Snare members (Ramaekers *et al*., 2007).

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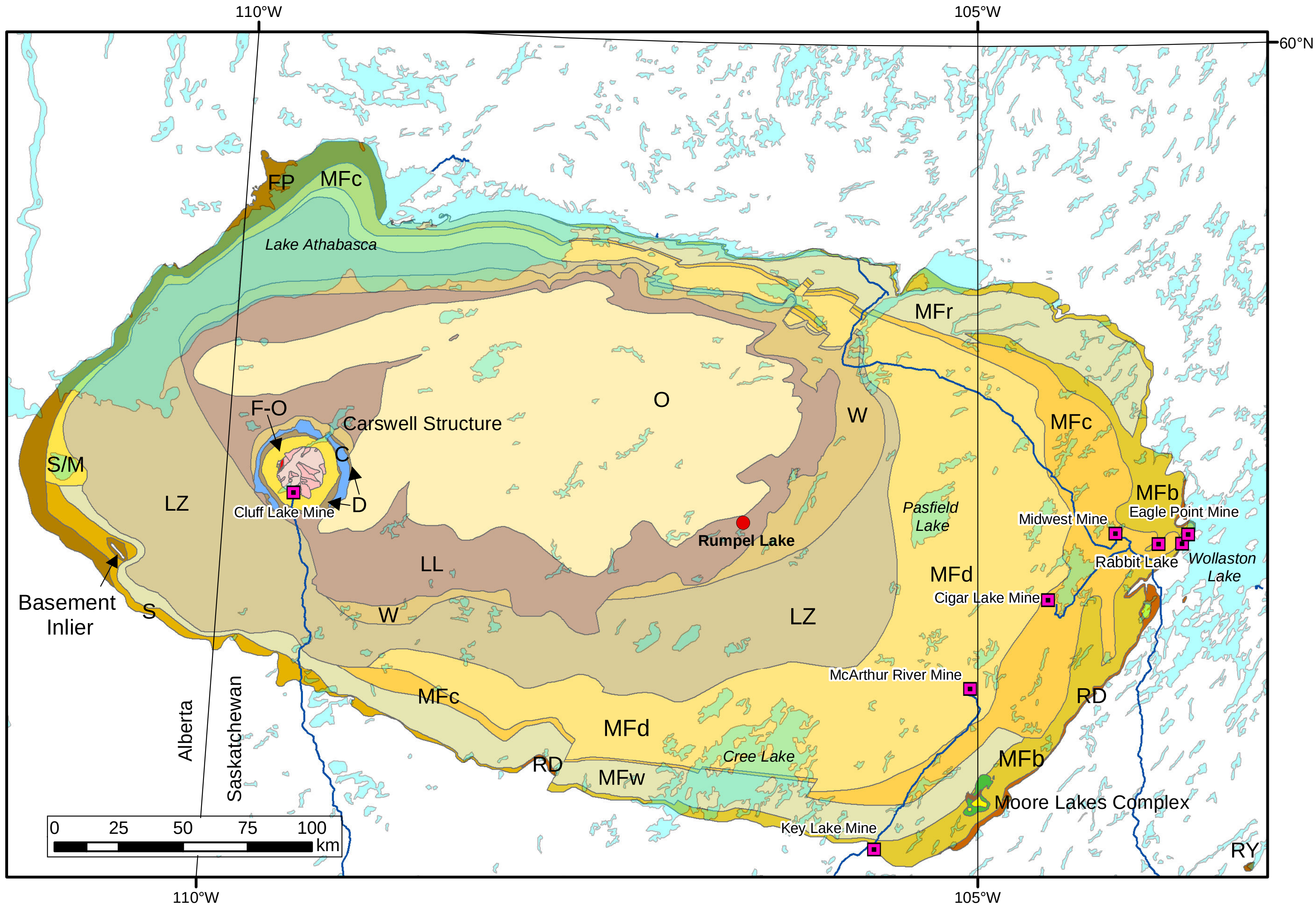


Figure 1 – Location of the Rumpel Lake drill hole (red dot), Athabasca Basin. Athabasca Basin formations are: FP = Fair Point, RY = Reilly (outlier – southeast of basin), S = Smart, RD = Read, MF = Manitou Falls (members: b = Bird, r = Raibl, w = Warnes, c = Collins, and d = Dunlop), LZ = Lazenby Lake, W = Wolverine Point, LL = Locker Lake, O = Otherside, D = Douglas, C = Carswell, S/M = undifferentiated Smart/Manitou Falls formations, F-O = undivided Fair Point to Otherside formations in the Carswell Structure. Pink units within the Carswell structure are basement rocks. Red squares represent major uranium deposits. Dark blue lines represent roads.

3. Petrographic Features and Point-counting Data

An Olympus BX51 transmitted/reflected light petrographic microscope was used to identify all mineral phases present. Each sample was point counted using a standard of 250 counts, except for samples of mudstones due to their fine-grained clast size. Samples were stained using the method first described by Gabriel and Cox (1929), which utilizes sodium hexanitritocobaltate (III) to stain potassium feldspar, and amaranth to stain plagioclase feldspar. Only half of the thin section was stained for each sample. Dolomite cement was identified using the Dickson staining method for carbonate minerals (Dickson, 1965). Rock names (*i.e.*, quartz arenite) are based on the quartz-feldspar-lithic (QFL) naming scheme (Williams *et al*., 1982). The timing and textural relationship of matrix (*i.e.*, material that is less than 30 µm in size) is not well-defined in the Athabasca Group sandstones. For example, matrix commonly in-fills secondary pore spaces resulting from quartz dissolution (both grain and overgrowth), which contradicts the genetic implications that matrix is depositional material. Therefore, this material has been given the term fine-grained interstitial material (FGIM) in the following descriptions, unless a definite origin (matrix, cement or replacement) has been determined. Primary and secondary porosity was determined based on textural relationships observed during point counting. Where an identified pore space showed no evidence of dissolution on the grain boundaries, it was classified as primary porosity. Where the pore space between clasts showed evidence of dissolution on the quartz grain boundaries, the center of the pore was classified as primary porosity and the outer edges of the pore space was classified as secondary porosity. Any other phases that were dissolved (*i.e.*, cement, FGIM) and not consequently in-filled were classified as secondary porosity.

a) Locker Lake Formation

A representative photo of sandstone from the Locker Lake Formation is shown in Figure 2A. A total of six sandstone samples were collected from the Locker Lake Formation. Sandstones of this formation range from quartz arenite to quartz wacke, with FGIM percentages ranging from 2 to 20.4%. Quartz (0.4 to 4.4%), kaolinite (0.4 to 2.4%), illite (0 to 2.8%), and hematite (0 to 3.2%) form cements in this formation. Primary porosity ranges from 0 to 2%, and secondary porosity ranges from 0 to 7.2%. Kaolinite and illite are also present as recrystallization/ replacement products. No feldspars were located via staining.

b) Wolverine Point Formation

A representative photo of sandstones from the Wolverine Point Formation is shown in Figure 2B. A total of 16 sandstone samples were collected from the Wolverine Point Formation. Sandstones of this formation range from quartz arenite to quartz wacke, with FGIM percentages ranging from 4.8 to 20.8%. Quartz (0 to 26.8%), kaolinite (0 to 2.2%), illite (0 to 2.8%), hematite (0 to 4%), and chert (<1%) form cements in this formation. Primary porosity ranges from 0 to 2%, and secondary porosity ranges from 0 to 16%. Kaolinite, illite, and hematite are also present as recrystallization/replacement products. No feldspars were located via staining.

c) Lazenby Lake Formation

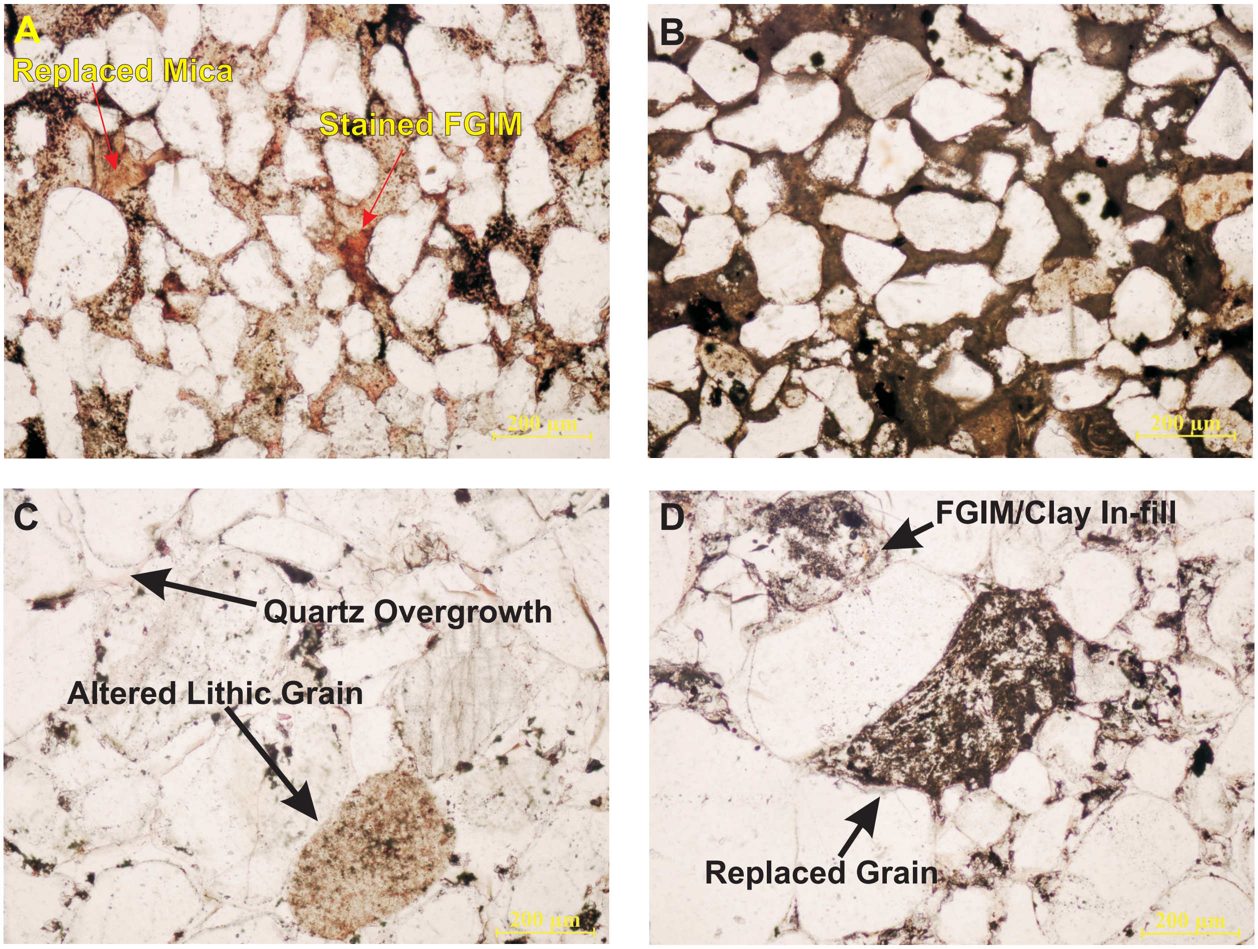
A representative photo of sandstones from the Lazenby Lake formation is shown in Figure 2C. A total of nine sandstone samples were collected from the Lazenby Lake Formation. Sandstones of this formation range from quartz arenite to quartz wacke, with FGIM percentages ranging from 3.2 to 42.6%. Quartz (0 to 20.8%), kaolinite (0 to 3.6%), illite (0 to 1.6%), and hematite (0 to 0.4%) form cements in this formation. Primary porosity ranges from 0 to 0.4%, and secondary porosity ranges from 0 to 6.4%. Kaolinite, illite, and hematite (minor) are also present as recrystallization/replacement products. No feldspars were located via staining.

d) Manitou Falls Formation

A representative photo of sandstones from the Manitou Falls formation is shown in Figure 2D. A total of 57 sandstone samples were collected from the Manitou Falls Formation. Sandstones of this formation range from quartz arenite to quartz wacke, with FGIM percentages ranging from 1.2 to 21.2%. Quartz (0 to 15.2%), kaolinite (0 to 6.4%), illite (0 to 3.6%), hematite (0 to 4.8%), and dolomite (<1%) form cements in this formation. Primary porosity ranges from 0 to 1.2%, and secondary porosity ranges from 0 to 6.8%. Kaolinite, illite, and hematite are also present as recrystallization/replacement products. No feldspars were located via staining.

e) Read Formation

A representative photo of sandstones from the Read formation is shown in Figure 2E. A total of 13 sandstone samples were collected from the Read Formation. Sandstones of this formation range from quartz arenite to quartz wacke, with FGIM percentages ranging from 0.4 to 16.4%. Quartz (0 to 7.2%), kaolinite (0 to 7.6%), illite (0 to 0.8%), and hematite (0 to 2.8%) form cements in this formation. Primary porosity ranges from 0 to 0.8%, and secondary porosity ranges from 0 to 8.8%. Kaolinite, illite, and hematite (minor) are also present as recrystallization/replacement products. No feldspars were located via staining.



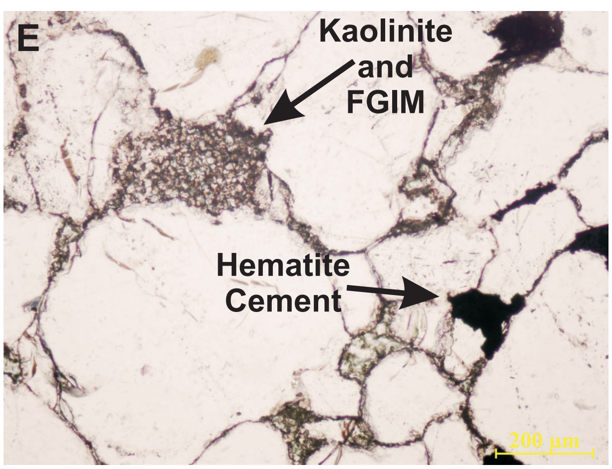


Figure 2 – A) Sandstone from the Locker Lake Formation containing large amounts of fine-grained interstitial material (FGIM) with hematite cement interstitially between clasts, a replaced mica grain (by illite and minor kaolinite), and FGIM that was stained pink during the staining test indicating that calcium is present in the FGIM; plane polarized light (PPL). B) Sandstone from the Wolverine Point Formation containing large amounts of interstitial dark FGIM between the clasts; PPL. C) Sandstone from the Lazenby Lake Formation containing minor amounts of FGIM, an altered lithic grain and large quartz overgrowths; PPL. D) Sandstone from the Manitou Falls Formation containing small amounts of FGIM; quartz overgrowths have been variably dissolved in this sample with the secondary porosity being in-filled by fine-grained clays and FGIM; grain replacement by FGIM is also present in this photo; PPL. E) Sandstone from the Read Formation containing formless hematite cement and a secondary pore space being in-filled by FGIM and crystalline kaolinite/dickite; PPL.

The Athabasca Group sandstones have undergone a series of diagenetic events which include compaction, dissolution, cementation, and replacement. The degree of compaction generally increases with depth – with grain relationships ranging from long contact to concavo-convex contact (Figures 3A and 3B). FGIM, quartz cement, and quartz grains are commonly dissolved throughout the drill core, creating secondary porosity (Figures 3C and 3D). Quartz cement (syntaxial overgrowths) is the most common type of cement and is the earliest stage of cementation (Figure 4A). Primary and secondary porosity is variably cemented, either exclusively with kaolinite, illite or hematite, or with mixtures of kaolinite, illite, and hematite (Figure 4B). Dolomite and chert cements are quite rare throughout the entire core (Figures 4C and 4D), as is partial and total grain replacement by various minerals (*i.e.*, kaolinite, illite, and hematite; Figures 4E and 4F).

Correlation diagrams for depth versus porosity and depth versus quartz cement have been constructed to constrain any relationships they may have with depth (Figures 5 and 6). Primary porosity is very minor throughout the core (generally 0%), with maximum primary porosity values reaching 2% in the Lazenby Lake and Wolverine Point formations (Figure 5A). Secondary porosity is more abundant than primary porosity throughout the entire core, with maximum secondary porosity values reaching 16% (Figure 5B). Quartz cement is widely variable throughout the top three formations of the core (between 0% and 26.8%). After the Lazenby Lake–Manitou Falls Formation contact, the amount of quartz cement steadily declines towards zero (Figure 6).

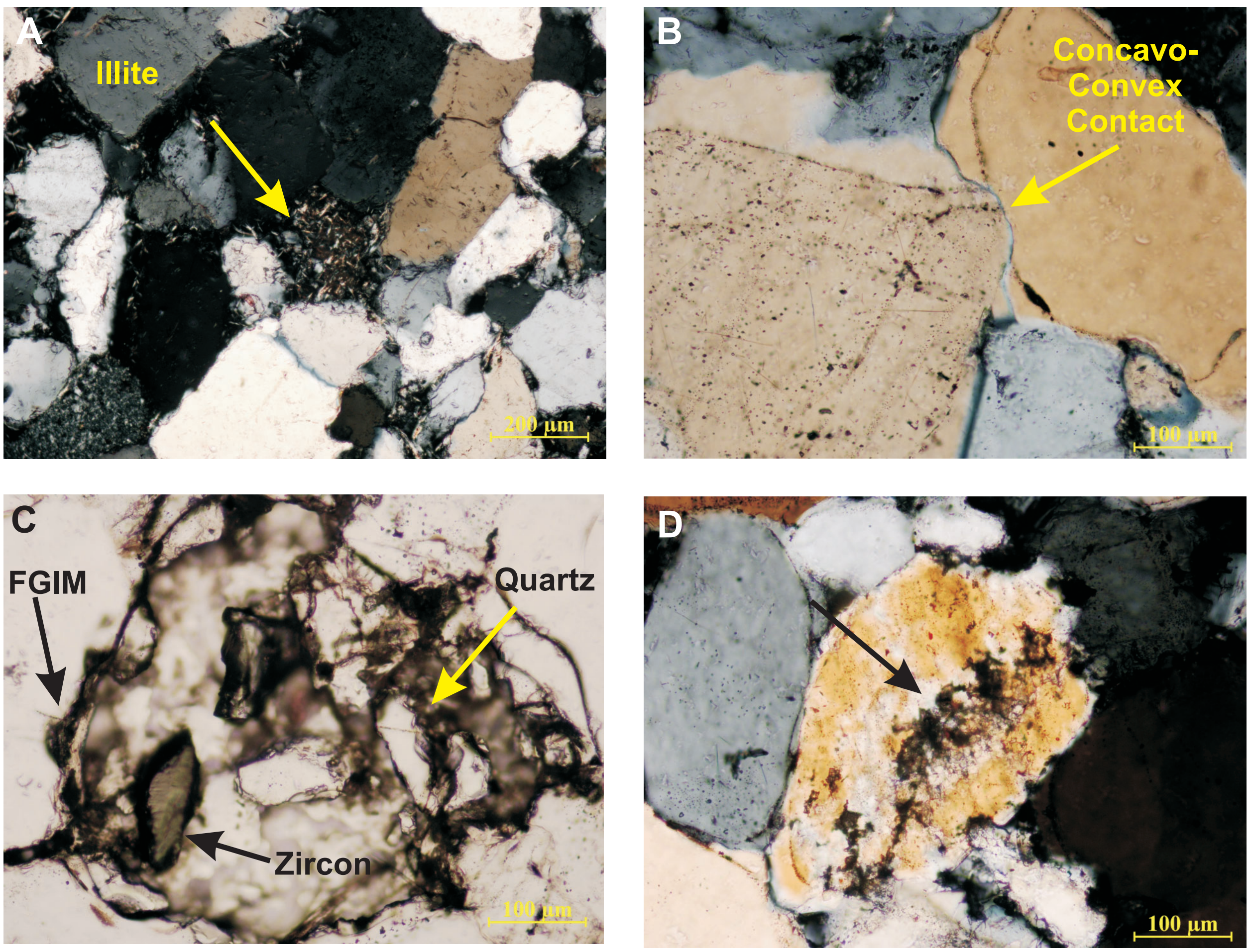


***Figure 3** – A) Long grain contacts present between quartz grains. Illite is shown cementing a secondary pore space; cross polarized light (XPL). B) Concavo-convex contact between quartz clasts; XPL. C) Secondary pore space that was previously filled with fine-grained interstitial material (FGIM), zircons (still present), and quartz; plane polarized light. D) Partially dissolved quartz grain and quartz overgrowth that has been filled with FGIM (shown by the arrow); XPL.*

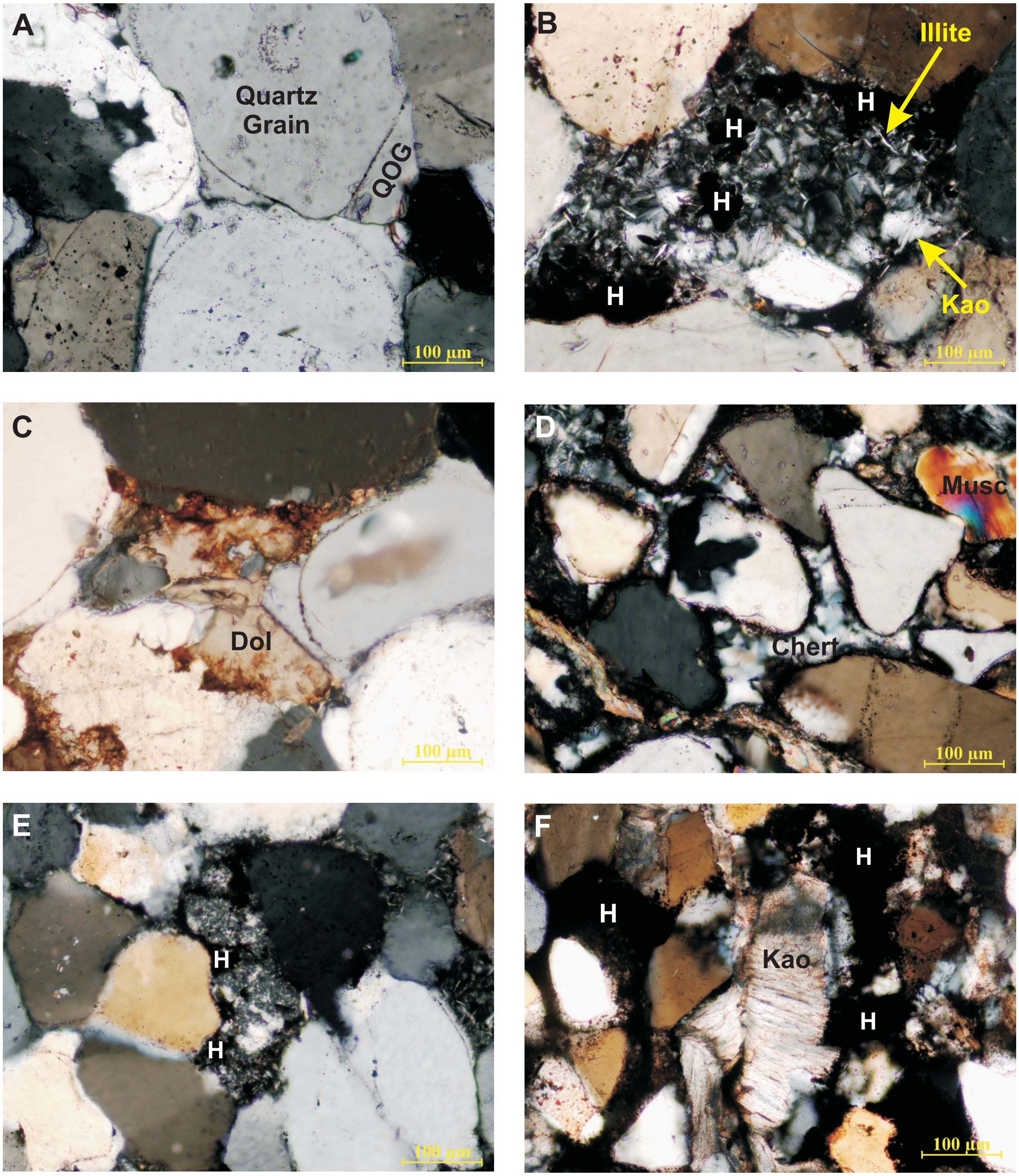


Figure 4 – A) Undisturbed syntaxial quartz cement on quartz grains; cross polarized light (XPL); QOG = quartz overgrowth. B) Kaolinite (Kao), illite, and hematite (H) cements all intergrown inside a secondary pore space; XPL. C) Dolomite (Dol) cement inside a secondary pore space showing no colouration after staining; XPL. D) Chert cement occurring between quartz grains with a non-cemented muscovite (Musc) clast; XPL. E) Grain replacement by a mixture of illite (bright thin needles) and hematite (H); XPL. F) Grain replacement by coarse-grained kaolinite (Kao) with hematite (H) cement in between quartz clasts; XPL.

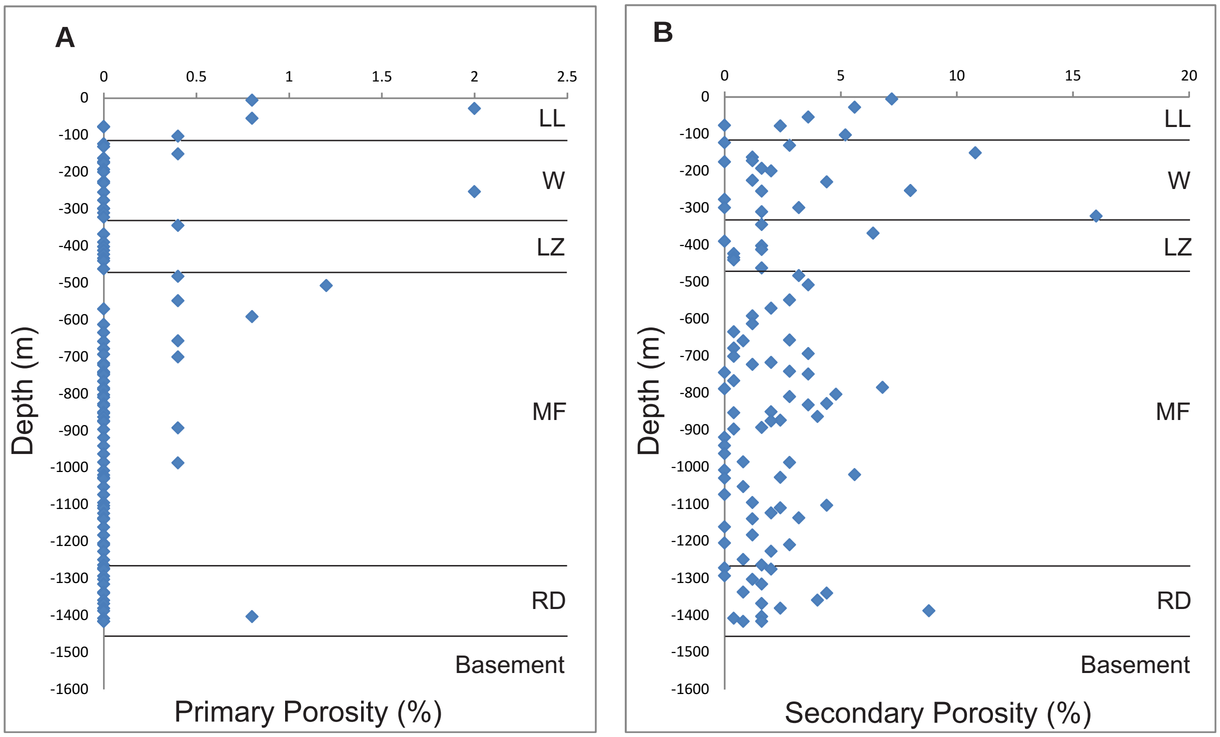


Figure 5 – A) Correlation diagram between depth (m) and primary porosity (%) with the formation boundaries drawn on for reference. B) Correlation diagram between depth (m) and secondary porosity (%) with the formation boundaries drawn on for reference. Formation codes: RD = Read, MF = Manitou Falls, LZ = Lazenby Lake, W = Wolverine Point, and LL = Locker Lake.

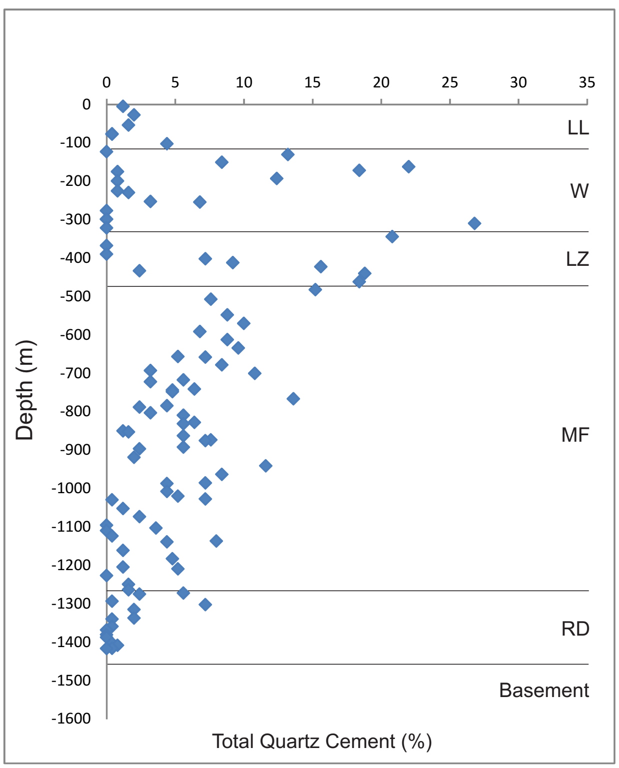


Figure 6 – Correlation diagram between depth (m) and total quartz cement (%) with the formation boundaries drawn on for reference. Formation codes: RD = Read, MF = Manitou Falls, LZ = Lazenby Lake, W = Wolverine Point, and LL = Locker Lake.

4. Discussion and Conclusions

Porosity and cementation correlation diagrams were created to aid in deciphering the diagenetic history of the Athabasca Group sandstones. Porosity values are variable within a stratigraphic formation, although this phenomenon has been previously described by Thomas and Wood (2007) who found porosity ranges from 0% to approximately 14% in the Manitou Falls Formation and 0% to approximately 10% in the Read formation, which may indicate that post-cementation dissolution is the main control on porosity within the sandstones. The decrease in quartz cement with depth may indicate that significant compaction has occurred in the Manitou Falls and Read formations. Furthermore, the quartz cementation trend may indicate that the unconformable surface between the Lazenby Lake Formation and Manitou Falls Formation represents a major erosional unconformity, which has been previously suggested by Lenard (Sask. Ministry of the Economy Assessment File 74J07-SE-0002). Further petrographic analysis of all samples collected and detailed comparisons of diagenetic mineral assemblages and textures need to be completed to test this hypothesis, which will greatly enhance our knowledge of the depositional and diagenetic history of the Athabasca Basin.

5. Acknowledgements

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