

Hydrothermal Alteration in Hydro-fractured Athabasca Sandstone: Distal Expression of Uranium Mineralization?

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Summary

The Athabasca Group in northern Saskatchewan and Alberta consists of a 100,000 km², 1400 m+ thick, Proterozoic sedimentary basin comprised of four sequences of fluvial conglomeratic sandstone deposited between 1760 and 1500 Ma (Ramaekers *et al.*, 2007). In 2000-2004 the basin was the focus of a multi-disciplinary, multi-agency study (EXTECH IV) to improve the framework geology and exploration technologies for unconformity-associated uranium deposits (Jefferson and Delaney, 2007). Following this, the Saskatchewan Ministry of Energy and Resources initiated a program to revise, redefine and reposition the lithostratigraphic units of the Athabasca Group. During field activities in 2007, an unusual bed was observed in drill core near the top of the Manitou Falls Formation of the Athabasca Group. The layer was so unusual that it was first thought to represent a new tuffaceous layer in the Manitou Falls Formation. A layer such as this would be an excellent stratigraphic marker, possibly suitable for dating. However, detailed examination points to another origin for this enigmatic layer, a hydrothermally-altered hydraulic breccia.

Introduction

As part of the Saskatchewan Ministry of Energy and Resources Athabasca Basin Stratigraphy Project to build a 3-D basin model, detailed core logging at various prospects took place between 2007 and 2009 (*cf.* Bosman *et al.*, 2008). During field work in 2007, an unusual clay-rich bed was observed in drill core from Cameco's Moon Lake property (Fig. 1A and B). This 6-cm grey, friable, thinly-laminated bed is in strong contrast to the overlying and underlying fine-grained competent sandstone of the Manitou Falls D (Dunlop: MFd) Formation. The Dunlop Formation in the Athabasca Group is an intraclast-rich and conglomerate-poor unit. Typically, it contains well-rounded, medium- to fine-grained quartzarenite with about 1-3% dickite matrix and clay intraclasts dominated by dickite (Ramaekers *et al.*, 2007). It is commonly interbedded with mudstones. Fine-grained sandstone above and below this friable bed appear to be concordant and the matrix contains mixed kaolin-group minerals (sub-equal mixture of kaolinite and dickite) based on infrared spectroscopy.

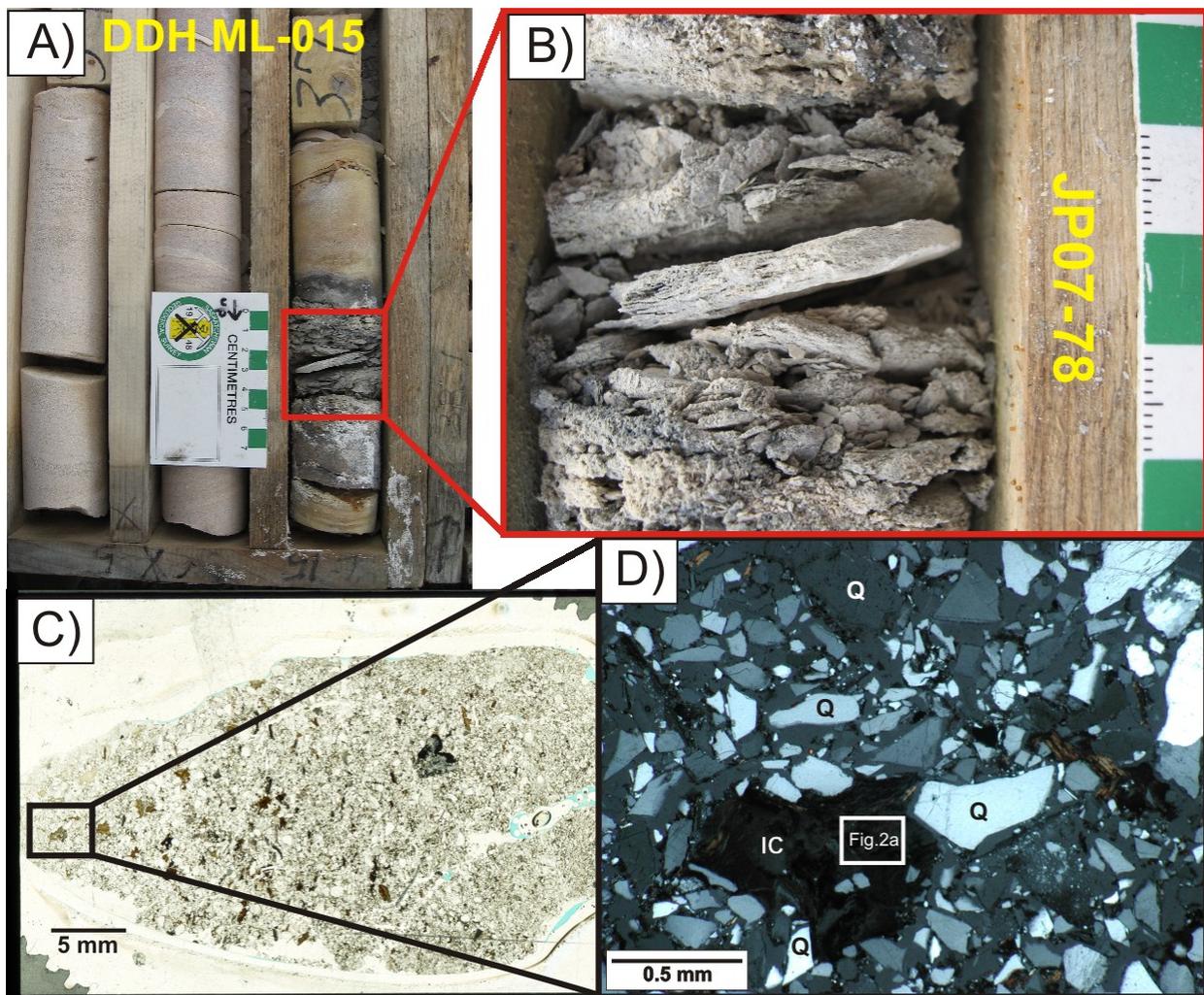


Figure 1. A) Sample JP07-78 taken from ML-015 drill core, at 36.8 m. B) Detail showing the friable, thinly laminated, grey clay-rich layer. C) Microphotograph of a polished thin section of the enigmatic layer. D) Photomicrograph of boxed area in 2(C), illustrating the angular quartz grains (Q) and deformed intraclast (IC). Image taken under crossed nicols.

Results

Petrographic analyses of the clay-rich layer showed poorly sorted, angular quartz grains (Fig 1C and D), chert, deformed intraclasts (Fig. 1D and 2A), altered mica (muscovite and biotite) (Fig. 2B) and zircon fragments. Scanning electron microscopy and electron probe microanalyses revealed traces of amphibole (hastingsite), K-feldspar (orthoclase), tourmaline, anatase, magnetite, aluminophosphate (APS) minerals (Fig. 2B) and arsenopyrite. The amphibole and K-feldspar occur as inclusions in quartz grains. The deformed intraclasts contain silt- to clay-size angular quartz grains and illite (Fig. 2A). The APS and anatase (Fig. 2C) minerals appear to be hydrothermal in origin based on their textural (< 2 μm euhedral grains) and mineral associations. Note the blocky plates of kaolin/dickite relative to the hairy illite forming in the pores and the corroded quartz grain boundary with minerals oriented perpendicular to the boundary. Alteration of kaolin/dickite to illite appears to occur *in situ* (Fig. 2D); the core of this cluster (slightly darker grey) grades into illite at both ends. Finally, this bed is also marked by a strong gamma-ray signature, probably related to thorium-bearing APS minerals.

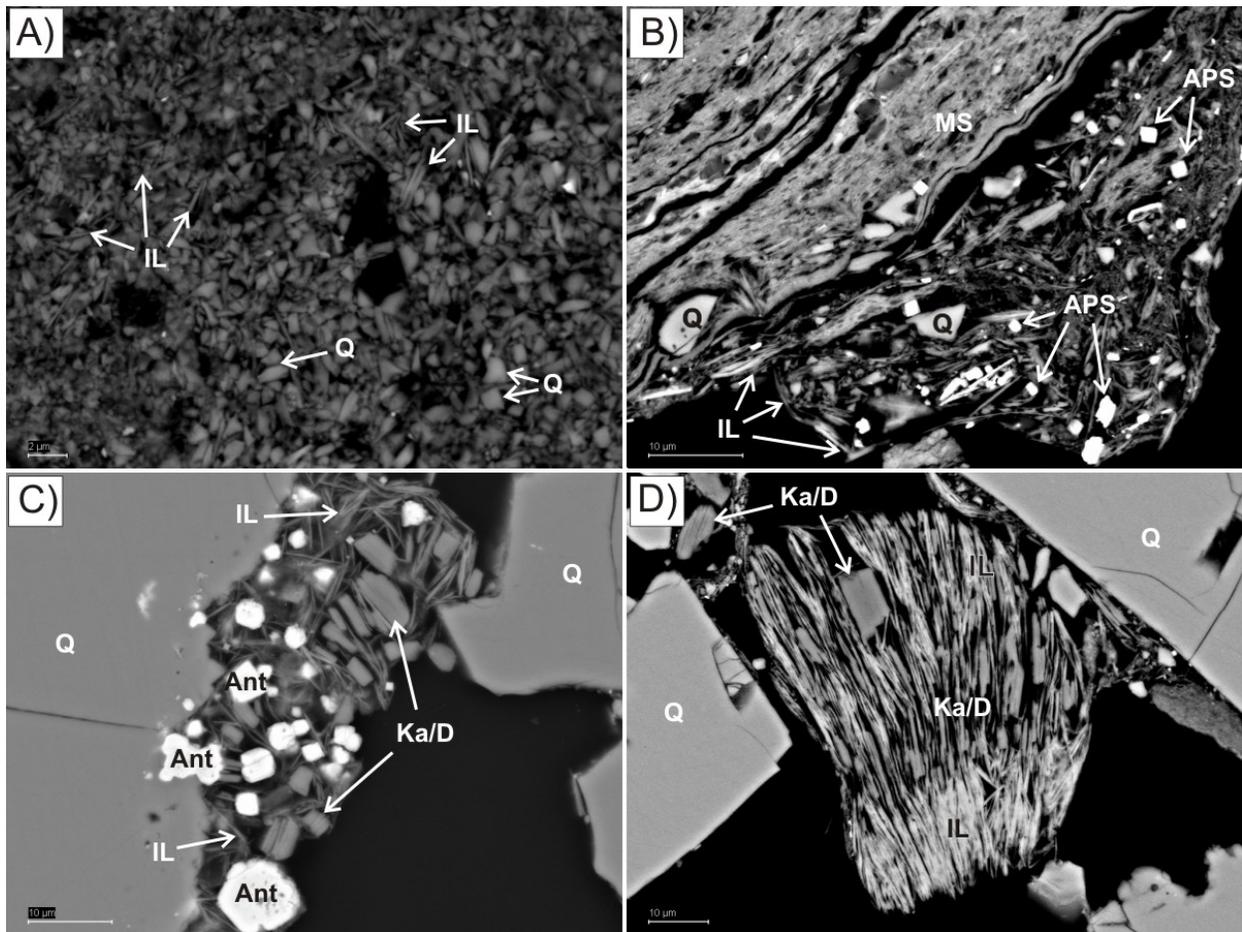


Figure 2. Backscatter electron images of: A) intracrystalline view of angular quartz with randomly oriented illite (IL). B) Altered muscovite (MS) adjacent to pore-filling cluster of randomly-oriented minerals (Q, APS, IL). C) Matrix kaolinite/dickite (Ka/D) with hydrothermal(?) anatase (Ant) aligned along corroded quartz grain boundary. D) *In situ* alteration of kaolinite matrix to illite.

Conclusions

Can this bed represent hydrothermal alteration following or during an episode of brecciation (tectonic or hydraulic)? This is suggested by the high angularity of the quartz grains, the illite alteration, the gradational contact above and below the breccia into laminated sandstone, and the silicification. The illitization and silicification shows that the post-fracturing alteration is similar to what is seen in the ascending columns of hydrothermal systems above mineralized zones. The location of the occurrence suggests that it represents part of the horizontal, bedding plane parallel path of a hydrothermal system whose ascending and descending columns are hosted by vertical fault and fracture zones. The location of the sample site not very far below the overlying impermeable Wolverine Point Formation mudstones suggests that the area was subject to fluid flow forced from vertical ascent along a fault system into a bedding-parallel path below the mudstones. Much of the divergent lateral flow of the hydrothermal system is taken up by fluid movement along stylolites. Some of the younger generation of stylolites show bleaching and illitic alteration suggesting they are part of the same hydrothermal system as the ascending columns over the mineralized zones and the hydraulically fractured material shown here. This represents an understudied component of hydrothermal systems that emplaced the

uranium ores. A thorough understanding of these entire systems may reveal a vector for uranium mineralization.

Acknowledgements

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References

- Bosman, S.A., Elmer, S. and Jefferson, C.W., 2008, Preliminary report: lithostratigraphic investigations of the Athabasca Basin: *In* Summary of Investigations 2008, v. 2, Saskatchewan Geological Survey, Saskatchewan Ministry of Energy and Resources, Miscellaneous Report 2008-4.2, CD-ROM, Paper A-1, 15 p.
- Jefferson, C.W. and Delaney, G. (eds.), 2007, EXTECH IV: Geology and Uranium EXploration TECHnology of the Proterozoic Athabasca Basin, Saskatchewan and Alberta, edited by C.W. Jefferson and G. Delaney, Geological Survey of Canada Bulletin 588 (also Saskatchewan Geological Society Special Publication 18; Geological Association of Canada, Mineral Deposits Division, Special Publication 4), 644 p.
- Jefferson, C.W., Thomas, D., Quirt, D., Mwenifumbo, C.J. and Brisbin, 2007, Empirical models for Canadian unconformity-associated deposits: *In* Proceedings of Exploration 07: Fifth Decennial International Conference on Mineral Exploration, edited by B. Milkereit, p. 741-769.
- Ramaekers, P., Jefferson, C.W., Yeo, G.M., Collier, B., Long, D.G.F., Drever, G., McHardy, S., Jiricka, D., Cutts, C., Wheatley, K., Catuneanu, O., Bernier, S., Kupsch, B. and Post, R.T. 2007, Revised geological map and stratigraphy of the Athabasca Group, Saskatchewan and Alberta. *In* EXTECH IV: Geology and Uranium EXploration TECHnology of the Proterozoic Athabasca Basin, Saskatchewan and Alberta, edited by C.W. Jefferson and G. Delaney, Geological Survey of Canada Bulletin 588, p. 155-191 (also Saskatchewan Geological Society Special Publication 18; Geological Association of Canada, Mineral Deposits Division, Special Publication 4).