Characterization of Mineralization and Deposit Style of the Mountain Lake Uranium Deposit, Hornby Bay Basin, Nunavut

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Summary

The Mountain Lake uranium deposit is situated within the Proterozoic Hornby Bay Basin, in the Bear Structural Province of the Canadian Shield. It is located in quartz arenites of the LeRoux Formation, near its upper boundary with interbedded carbonaceous shale and fine-grained sandstone of the Fort Confidence Formation. Downward-moving methane gas, originating in overpressured Fort Confidence Formation shales, is proposed as the primary reducing agent for the precipitation of the uraniferous ore minerals uraninite/pitchblende. Heat and pressure associated with the 1270 Ma Mackenzie igneous event is proposed as the cause of rapid, significant burial, which moved the carbonaceous shales into the gas window.

Introduction

The Mountain Lake uranium deposit lies within the Paleo-Mesoproterozoic Hornby Bay Basin, which shares many characteristics with other uraniferous sedimentary basins in Canada, including age, sequence stratigraphy, sedimentology, basin fill, and relationship with underlying basement rocks. However, the Mountain Lake deposit differs from those of other basins such as the Thelon and Athabasca because it is hosted within the sedimentary column, not at it's basal unconformity. The sandstones of the upper LeRoux Formation host the deposit, near, but not at, the upper contact with the carbonaceous mudstone-rich Fort Confidence Formation.

The purpose of this study was to further characterize the nature of the deposit through the examination of ore mineralogy and to define a sequence of events leading to the formation of the deposit.

Geologic Setting

The Hornby Bay basin is a part of the Coppermine Homocline, which is a succession of sedimentary and subordinate volcanic rocks that overlie the ca 1.84-1.92 Ga Wopmay Orogen along the exposed northwestern margin of Laurentia. The basin contains significant northwest- and northeast-trending faults, which were formed during the collisional phase of the Wopmay Orogen. Many of these faults were later re-activated during Hornby Bay Basin deposition.

Mapping by Baragar and Donaldson (1973) established a stratigraphic framework for the Hornby Bay Basin including the siliciclastic-dominated Hornby Bay Group (>1000 m) and carbonate-dominated Dismal Lakes Group (>1500 m), which are overlain by a thick (~3 km) succession of continental basalt flows and subordinate fluvial sandstones of the Coppermine River Group.

Maclean and Cook (2004) identified four subsequences: A1, consisting of the Big Bear and Fault River formations; A2, consisting of the Lady Nye, East River, and Kaertok formations; A3, consisting of the LeRoux Formation and Dismal Lakes Group and; A4, consisting of the

Coppermine River Group. Recent revisions to the stratigraphy place the boundary between A2 and A3 at the base of the LeRoux Formation, rather than the top (see Hahn et al; this volume).

Geology of Deposit

The Mountain Lake uranium deposit is hosted in quartz arenites and conglomerates of the LeRoux Formation. In the region of the basin in which the Mountain Lake deposit resides, field relationships show that strata of the Hornby Bay Group were uplifted, tilted, and partially eroded prior to deposition of the Dismal Lakes Group. This provided an opportunity for unconformable deposition of the Lady Nye Formation (A2) onto granitic basement rocks in the region of the Mountain Lake deposit. The deposit is bounded by nearly vertical faults which were active during deformation and early deposition of the LeRoux Formation.

Petrology

The host rock is a silicified fine-grained quartz arenite to framework-supported monomict quartz arenite conglomerate with a quartz arenite matrix. Quartz overgrowths are present around all detrital grains, identifiable through hematite dust rims and fluid inclusions. Bright green and yellow uranium oxides are evident in hand samples and through reflected light microscopy. Barite veins and crystals associated with pyrite and covellite were observed rarely. In thin section, ore minerals were observed within and cutting across quartz overgrowths. Pyrite, sulpharsenides, and Cu-sulphides were identified using SEM.

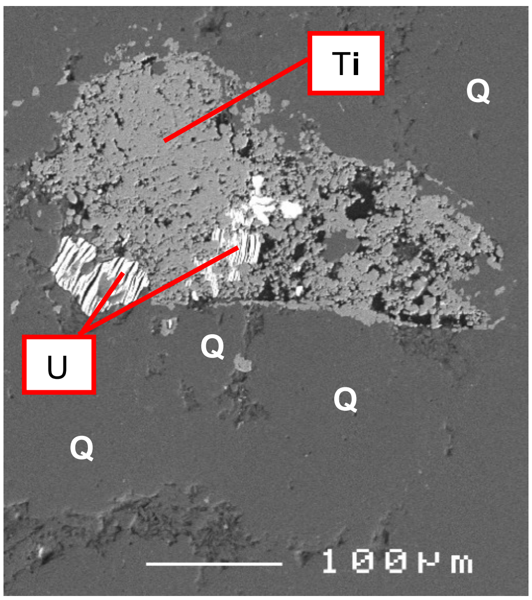


Figure 1: Backscatter image showing uraninite (U) and titanite (Ti) mineralization in interstitial pore space between quartz crystals (Q)1.

Two categories of uranium minerals were identified through SEM, 1) uranium containing low phosphorous and calcium, and 2) uranium containing high phosphorous and low calcium. Titanium oxide is present intergrown with high phosphorous uranium Figure 1). Low phosphorous uranium was observed partially replacing detrital apatite.

Two phases of uranium were identified utilizing electron microprobe techniques. Uraninite (UO_2) was identified as a reduced phase, and autunite ($Ca(UO_2)_2(PO_4)_2{\bullet}10\text{-}12H_2O$) was identified as an oxidized phase.

Sequence of Alteration

Two separate alteration stages are evident. The first stage is a silicification event during which syntaxial quartz overgrowths where precipitated around detrital grains. It is unclear whether this event was due to diagenesis, hydrothermal alteration, or a combination of both. Intergrown sulphides within the quartz overgrowths indicate that sulphides and quartz precipitated together.

The second stage of alteration was controlled by circulating hydrothermal fluids, which precipitated sulphides, sulpharsenides, and autunite. These are observed as intergrown euhedral to anhedral crystals, or as replacements of earlier phases.

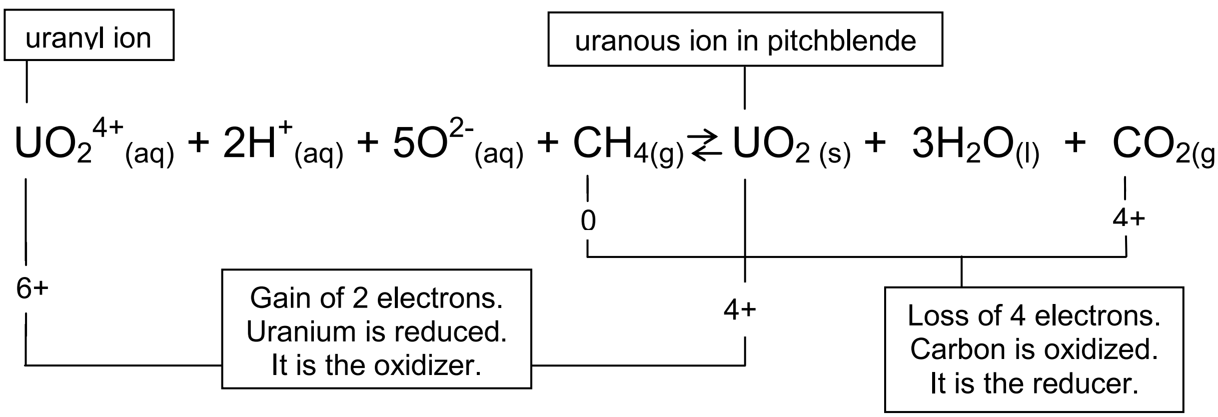
Deposit Genesis

The age of mineralization is not well constrained. Miller (1981) originally proposed an age of ca. 1050 Ma. New research indicates that it may in fact be older, based on an age of 1284±11 Ma from xenotime and apatite cement, interpreted to have precipitated at roughly the same time as the uranium (Davis et al., 2008). The date is significant because it is within error of the

Mackenzie igneous event, 1270 Ma, which deposited extensive flood basalts on top of the Hornby Bay Basin sediments.

Increased pressure and temperature associated with burial, as well as the heat from the magmatism, has a two-fold importance in the proposed model for mineralization. The first is the liberation of fluids from pore spaces, which dissolved uranium in solution in its oxidized state. The second is the production of methane gas from cracking of organic carbon, common in shales of the Fort Confidence Formation.

To precipitate uranite/pitchblende (UO_2), there must be a reducing agent to transform the uranium in solution from its oxidized state (uranyl, U^{6+}) to it's reduced state (uranous, U^{4+}) which can be incorporated into the ore mineral uraninite/pitchblende. This transformation requires the presence of a reducing agent, proposed to be carbon, as found in methane (CH_4).



Since uranium mineralization in the Mountain Lake deposit occurs in the sandstones of the LeRoux Formation, which do not contain significant organic carbon, the methane must have migrated into the underlying sandstones from the overlying Fort Confidence carbonaceous shales.

Assuming that the uranium mineralization was coeval with the Mackenzie igneous event, then methane was likely produced through burial of the Fort Confidence shales during eruption and deposition of the Coppermine lavas. Rapid deposition of the basalts resulted in significant increases in pressure and temperature within the Fort Confidence formation shales, moving them into the gas window. Methane was produced, and the shales became overpressured due to the increase in volume within the formation. Some methane is likely to have escaped upward into the overlying dolostones, and eventually to the atmosphere through faults and fractures. However, much of the methane would have moved downward, due to overpressuring, into the uppermost LeRoux Formation sandstones, which were relatively permeable. This downward-moving reducing front resulted in the precipitation of the uraninite and pitchblende that comprise the Mountain Lake uranium deposit (See Figure 3).

Conclusions

1. The Mountain Lake Deposit is composed of at least two uranium mineral phases, uraninite and autunite. Uraninite may be further split into two populations, 1) uranium containing low phosphorous and calcium, and 2) uranium containing high phosphorous and low calcium.
2. The first alteration event produced syntaxial quartz overgrowths, cementing the deposits, while the second event caused precipitation of alteration minerals and uranium phases.
3. Precipitation of the main ore mineral, uraninite, was facilitated by a downward-moving reducing front of methane, produced by the overlying overpressured Fort Confidence Formation carbonaceous shales.
4. The deposit is classified as a tabular, sandstone-hosted deposit.

5. The age of phosphatic cements that are associated with the uranium minerals is within error of the the Mackenzie Igneous event. Heat and pressure produced by the deposition of thick extrusive volcanics provided an environment for the production of hydrocarbons (e.g. methane) that acted as a reducing agent for precipitation of the ore minerals in the deposit.

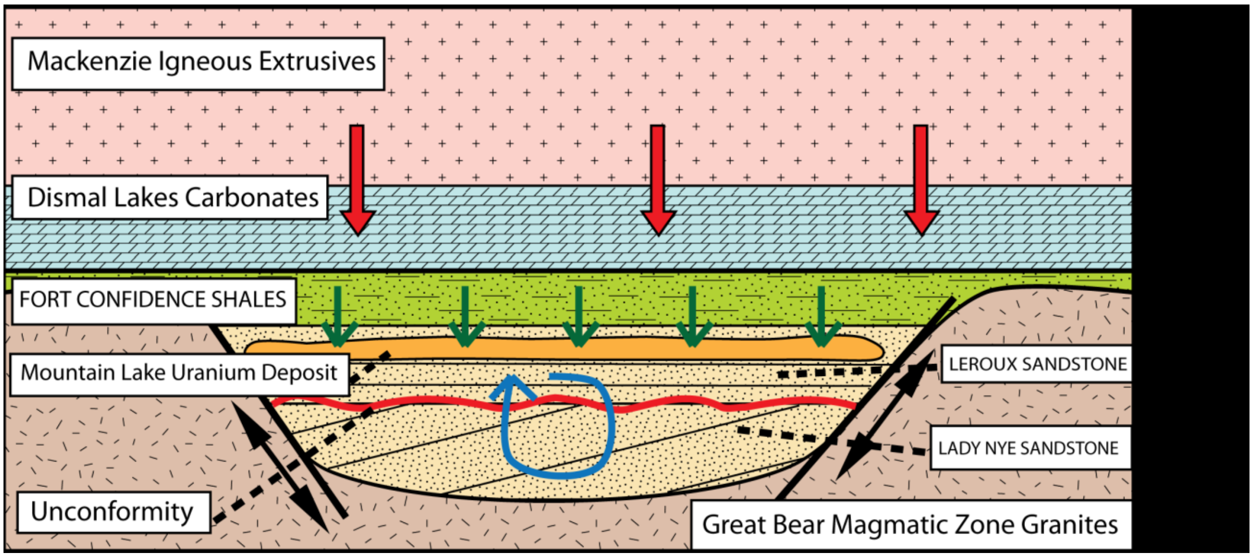


Figure 3: Proposed model for precipitation of uranium ore minerals of the Mountain Lake deposit. Red arrows indicate pressure and temperature due to the deposition of the Mackenzie Igneous Event extrusive volcanics, which moved the Fort Confidence Formation shales into the gas window. The green arrows indicate downward movement of methane from the source shales into the upper LeRoux Formation sandstones. The orange shaded area indicates the area in which uranium mineralization occurred, which corresponds to the depth of intrusion of methane gas.

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