

Petrological and Geochemical Investigation into the Michelin Uranium Deposit, Central Mineral Belt, Labrador

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The Michelin uranium deposit of Labrador's Central Mineral Belt (LCMB) has a measured and indicated resource of 67,126,000 lbs. and an inferred resource of 36,089,000 lbs. for an approximate total of 103,000,000 lbs. of U_3O_8 making it one of Canada's largest untapped uranium resources. Located approximately 140 km north of Happy Valley – Goose Bay and 40 km southwest of Postville, the deposit was originally discovered in 1968 as part of ground follow-up work by BRINEX on an airborne radiometric anomaly detected the year before. The deposit was explored and partially developed by BRINEX through the 1960's and 70's until 1981 when the project was halted due to the collapse of the uranium market. With the climb in the price of uranium over the last several years, the deposit is being evaluated and tested by Aurora Energy Resources for possible production.

Despite the extensive research and development carried out on the deposit over the past five decades, there are still many unanswered geological questions concerning the deposit that are of great importance to optimizing mineral development, and further exploration on both the deposit itself and similar regions of the uranium-rich LCMB. The mineralization at Michelin most likely represents the result of broad uranium stripping from the Aillik Group felsic volcanics, but this connection has yet to be definitely proven and the reasons for uranium concentration at specific sites such as Michelin remain unknown. Other aspects that are of particular importance include definition of the geological setting, the style and extent of alteration, and the timing of deformation and mineralization.

This study is an attempt to document the basic geological context of the mineralization and focuses on four main aspects; host rock lithology, alteration, mineralization and timing. Approximately 300 homogeneous core samples were collected from ten diamond drill holes that constitute a three-dimensional cross section through the main ore body. Samples are from the entire deposit including all rock types in the hanging wall, footwall, and ore zone (both uranium-mineralized and unmineralized).

The Michelin Deposit is hosted in a variety of Aillik Group felsic volcanic rocks; a rhyolite from Michelin Ridge, approximately 2 km north of the Michelin deposit, has been U-Pb zircon dated at 1856 Ma (Scharer *et al.*, 1988). These rocks were affected by the Makkovikian Orogeny ca. 1810 to 1790 Ma and have been metamorphosed to upper greenschist facies (Wilton, 1996). The deposit is dominated by two main rock types, a finely porphyritic rhyolite and a coarsely porphyritic rhyolite, along with several minor lithologies. The generally massive, finely porphyritic

rhyolite comprises most of the hanging wall and footwall along with some of the ore zone. It is characterized by approximately 5% albite and potassium feldspar phenocrysts (3-5 mm in diameter), and 2-3% quartz phenocrysts (1-3 mm across) set in a feldspar and quartz-rich matrix. The matrix contains 5 to 15% mafic minerals which are mostly biotite with minor chlorite, amphibole and magnetite. The unit is well foliated as defined by elongated, recrystallized quartz phenocrysts. The mafic phases can locally constitute small, 1-5 cm thick, dykelets.

Geochemically the unit contains ~70-75% SiO₂, 12.5% Al₂O₃, 3.5% FeO, 0.3% MgO, 1.2% CaO, 5% K₂O, 4% Na₂O, 0.36% TiO₂, 0.045% MnO and 0.07% P₂O₅, with < 10 ppm U.

The coarsely porphyritic rhyolite occurs as small, 2-15 m thick, units within the hanging wall and footwall and is the dominant rock type in the ore zone. This rhyolite subtype appears to represent synvolcanic concordant units which have sharp to locally gradational contacts with other lithological units. The coarsely porphyritic rhyolite is very similar to the finely porphyritic unit with a feldspar and quartz-rich groundmass that contains 5-15% biotite along with minor chlorite, amphibole and magnetite. It is characterized by 5-15% potassium feldspar, with minor albite, phenocrysts (~1.0 cm across), and 1-3% quartz phenocrysts (1-2 mm in diameter). The unit is well foliated as defined by the mafic mineral phases and elongated, recrystallized quartz phenocrysts. It is geochemically similar to the finely porphyritic unit with ~70-75% SiO₂, 12.5% Al₂O₃, 3% FeO, 0.3% MgO, 1.1% CaO, 5.5% K₂O, 3.5% Na₂O, 0.3% TiO₂, 0.035% MnO and 0.06% P₂O₅, < 10 ppm U, and slight REE enrichments.

Other rock units associated with the Michelin deposit include: 1) a granitoid intrusion in the hanging wall to the south of the deposit which classifies as granite to granodiorite and is moderately foliated towards the contacts, 2) a non-porphyritic rhyolite unit in the hanging wall to the west of the deposit which appears to be a phenocryst-poor equivalent of the finely porphyritic unit except that it has higher silica contents and visible flow banding textures, and 3) a mafic-rich, 2-3 m thick, coarsely porphyritic rhyolite unit, located in the hanging wall approximately 50 m above the ore zone which is well foliated and contains a much higher percentage (25-40%) of mafic minerals.

There are also several phases of mafic dikes through the deposit, including: 1) pre-kinematic amphibolite schist which is well foliated and concordant to host rock fabric, but with erratic distribution throughout the deposit, 2) syn-kinematic gabbroic dikes that are weakly foliated (foliation strongest at dyke contacts) and are for the most part concordant, and 3) two separate phases of post-kinematic dikes; a) a strongly magnetic gabbro dike, and b) a diabase dike, both dike types are discordant and occur predominantly in the hanging wall.

The ore zone constitutes an almost stratigraphic unit with a strike length of ~1,200 m, depth of ~1,000 m and a thickness of ~10-80 m. It consists of multiple, thin intervals of both coarsely and finely porphyritic rhyolite, intruded by both pre and syn-kinematic mafic dikes. These units are very similar to their hanging wall counterparts except for a greater percentage of mafic minerals, up to 20%, and a quartz-poor nature, in particular quartz phenocrysts are absent.

Geochemically the ore zone units contain 16% Al₂O₃, 4.5% FeO, 0.7% MgO, 2% CaO, 0.1% K₂O, 9.5% Na₂O, 0.5% TiO₂, 0.075% MnO and 0.1% P₂O₅, with ~62-68% SiO₂; the concentrations of the other elements appear elevated due to the large loss of silica.

That the mineralized rocks at the Michelin deposit have undergone a very extensive and intense hydrothermal alteration is evident in the drill core where sodic alteration envelopes the deposit and hematite alteration is readily visible in the mineralized ore zone. Detailed geochemical and SEM analysis, however, indicate that alteration associated with the mineralization is actually much more extensive and occurred in two separate styles. The first style is a widespread sodic metasomatism which also occurs sporadically throughout the regional extent of the Aillik Group. At the Michelin deposit this alteration is well developed through the hanging wall, locally beginning up to 100 m above the ore zone; the thicker the ore zone, the more intense and thicker the sodic alteration. The metasomatism becomes more intense towards the ore zone and tends to quickly drop off in the footwall. The alteration involves a complete replacement of potassium feldspar by albite. Initially the matrix is replaced along with the rims of larger orthoclase phenocrysts, as the alteration intensifies, entire phenocrysts are pseudomorphed by albite. In the ore zone, potassium is almost non-existent and the only feldspar is albite. In drill core, the unaltered volcanics are smooth to the touch and have a pinkish grey color, once the sodic replacement is encountered, the core gradually becomes friable, whiter and more granular in nature. The second style of alteration is localized to the mineralized zone and appears to be directly related to uranium mineralization, the stronger the mineralization, the more intense the alteration. The most obvious expression is the hematite alteration of the rocks in the ore zone; color goes from a slight pink to a deep red, depending on the strength of the alteration. The alteration is first visible in the hanging wall above the ore zone as small, 2-10 cm thick, concordant bands that are weakly uranium mineralized. The number and size of these bands intensify in the more mineralized areas of the ore zone. The alteration apparently results from the oxidation of magnetite grains, a common mineral phase in the felsic volcanic rocks. Magnetic-susceptibility readings are lower throughout the ore zone, but geochemical data indicate that iron concentrations are almost the same in the ore zone as in the hanging wall rocks. The geochemical data also indicate an almost 10% decrease in SiO_2 values in the mineralized rocks induced by the removal of quartz in the groundmass and phenocrysts. This quartz destruction created vugs and cavities in the ore zone which were subsequently filled by a number of different minerals including the uranium-bearing phases. Due to the large loss of silica, mass loss gain calculations had to be performed to accurately gauge alteration trends. The calculations show that there is a strong mass gain in Zr, minor gains in Y, V and the LREE, and mass loss in Rb and Ba.

Economically exploitable mineralization at the Michelin deposit is entirely uraniferous, and although there are significant increases in V, Y and Zr contents above background, they nowhere high enough to be considered economically viable. The most important and abundant uranium-bearing mineral phase is uraninite (UO_2) which also has a range of different elements substituting into the crystal lattice, including Pb, Si, Ca, Zr and Ti. The uraninite grains always contain at least one of these elements and locally up to three or four others. Minor uranium-bearing phases present include brannerite ($(\text{U,Ca,Ce})(\text{Ti,Fe})_2\text{O}_6$) and uranophane ($\text{Ca}(\text{UO}_2)_2\text{SiO}_7 \cdot 6\text{H}_2\text{O}$). The uranium grains are minute (10-40 microns in diameter) grains that are generally anhedral in shape and which seem to grow in clusters of multiple grains. Uraninite grains, for the most part, are associated with at least one alteration mineral phase and predominantly are associated with three or four. These phases include: 1) sodic-rich pyroxenes and amphiboles which formed due to the intense sodic metasomatism, 2) secondary zircons, 3) magnetite and hematite grains, the actual crystallization of uraninite appears to have been

triggered by the oxidation of magnetite, 4) calcite, which may represent a late stage, minor calcic alteration, and 5) titanite along with minor ilmenite, allanite, andradite and monazite all of which seem to have been formed as a result of alteration.

SEM analysis of mineralized thin sections indicates that mineralization occurs in three distinct locations in the host rocks. The most common area is in small clusters, with associated alteration grains, located in the small vugs and cavities created from quartz phenocrysts destruction. Uraninite grains are also sparsely disseminated throughout the albitic groundmass wherein quartz was dissolved, one common location is on the boundaries of large albite phenocrysts. The final location is along small fractures and cracks in the albite phenocrysts where uranophane is developed and which is thought to represent later stages of weathering.

In summary, the Michelin deposit has undergone an intense widespread sodic metasomatism and a more localized alteration directly related to the mineralization. Uranium minerals are associated with a number of other mineral assemblages related to the alteration and were deposited in the space left behind by the dissolution of quartz in the ore zone.

References

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