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Information from this publication may be used if credit is given. It is recommended that reference to an abstract in this volume be made in the following form:


Cover:

Upper left: Dr. Colin Card entering data from core of the Patterson Lake alkaline igneous complex at Purepoint Uranium Group’s Hook Lake project core cache near Patterson Lake. Photo by Sean Bosman.

Bottom right: Junior geological assistant Renee Larsen taking a spectrometer reading on an outcrop near Steephill Lake in the northern Glennie Domain. The instrument measures gamma ray radiation, which allows for the in situ estimation of potassium, uranium and thorium in the rock. Geologists use this data to aid with rock identification. Photo by Samantha Van De Kerckhove.

Centre photos, from bottom left to upper right:
Carbonatite in drill core from the Patterson Lake alkaline igneous complex, Patterson Lake area, drilled at Denison Mines Corp.’s Hook-Carter project northeast of Patterson Lake, southern Athabasca Basin. The photo shows a carbonatite dykelet intruding sheared country rock. Alkaline igneous complexes—and carbonatites in particular—are associated with rare-earth element and rare-element mineralization. Current theory is that the Patterson Lake alkaline igneous complex was emplaced via deep-seated structures rooted in the region of the Fond du Lac gravity low, which is the geophysical expression of a zone of crustal extension that was active between 1.85 and 1.80 Ga. (See abstract on page 36 of this volume.) Photo by Colin Card.

Crescentic and lunate gouges indicate ice-flow direction on an outcrop in the southern Reindeer Lake area of north-central Saskatchewan. The southern Reindeer Lake area is prospective for gold and base metals, and small-scale ice-flow indicators such as those shown here are used to reconstruct the relative ice-flow history of an area, to aid explorationists in planning more effective drift prospecting projects. (See abstract on page 38 of this volume.) Photo by Michelle Hanson.

Sheared metatexitic pelite with attenuated leucosome, from an outcrop in the Robertson Lake area of north-central Saskatchewan, near the boundary between the Wapassini and Kyaska lithotectonic thrust sheets. (See abstract on page 25 of this volume.) Photo by Samantha Van De Kerckhove.

Anastomosing network of cataclastic deformation bands in Read Formation sandstone from drillhole HL-063 (UTM 476317E, 6379667N, Zone 13N) from the Hughes Lake project (81.967% owned by Cameco Corporation, and 18.033% owned by Orano Canada Inc. (previously AREVA Resources Canada)), in the southern Athabasca Basin. Deformation bands are strain localization features that develop in porous sedimentary rocks soon after deposition. Current studies are investigating the role deformation bands may have played in creating fluid pathways related to uranium deposits throughout the Athabasca Basin. (See abstract on page 13 of this volume.) Photo by Gary Delaney.

This volume may be downloaded at:

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Technical Session 1: Uranium – Global Distribution, Ore Systems and Exploration
The Saskatchewan Geological Survey at 70+
Gary Delaney and the Staff of Saskatchewan Geological Survey

Abstract

Geological studies in Saskatchewan date back to the early 1800s when members of the first Franklin Expedition traversed the Saskatchewan and Churchill River systems, noting lignite deposits in young surface rocks. The Geological Survey of Canada (GSC) undertook the first formal evaluation of the province’s mineral potential, conducting traverses through the region during the late 1800s, identifying copper mineralization in the Amisk Lake area and on the north shore of Lac La Ronge.

After the federal government transferred responsibility for mineral resources to the province in 1930, the Department of Natural Resources (DNR) was established, with initial geological expertise provided by the University of Saskatchewan. The Mineral Resources Branch was created in 1947 from the Mines Division of the DNR, and a Prospector’s School was created in La Ronge to encourage exploration in the province.

The Saskatchewan Geological Survey (SGS) was formally established in 1948, with a mandate to map areas of mineralization in northern Saskatchewan, and carry out geological surveys in areas of potential for oil and gas and other economic mineral resources in southern Saskatchewan. An initial focus of the SGS was mapping economically prospective areas of the exposed Canadian Shield, and compiling mineral occurrences and exploration data from assessment work reports. In the 1950s and early 1960s the Petroleum Geology Branch of the SGS was expanded, to deal with an influx of petroleum-related information from industry. In 1958 the Subsurface Geological Laboratory in Regina was opened, offering a repository for drill core and samples from the petroleum industry for examination and research. This was the first such facility in Canada. By 1960, the SGS had eight field parties mapping, while the Industrial Minerals Branch undertook research on a variety of mineral resources (bentonite, pumicite, sodium sulfate, silica sand, uranium and germanium in lignite, marl, kaolin and potash) in the southern part of the province. The Precambrian Geological Laboratory, a repository for mineralized Precambrian core, subsequently opened in La Ronge in 1965.

An influx of federal funds in the mid-1970s enabled the SGS to map more ground at better resolution, and to develop an Economic Geology division. The federal cost-sharing programs ended in the 1980s, but the resultant expanded geological framework for the province paved the way for increased exploration activity for decades to come.

The SGS, now a branch of the Ministry of Energy and Resources, has changed considerably over the past few decades. Hip chains and Mylar overlays have given way to in-field data collection tablets and GIS-based technologies, enabling geologists to interpret their observations in real time, in the context of multi-layered data sets such as geochemical, geophysical and radiometric data.

The SGS also continues to improve the way geoscience data is delivered to the public, through the digitization of historical mineral assessment data, and via the development of the Saskatchewan Mining and Petroleum GeoAtlas, an award-winning online data dissemination portal. Looking to the future, the SGS is positioning itself to maximize the data it collects by moving into new frontiers such as big data and artificial intelligence.

Collaborations with universities and the GSC are still going strong and, more recently, partnerships with the geological surveys of South Australia, China and India have enabled personnel exchanges, sharing of expertise and best practices, and helped to develop capacity in a number of areas including field mapping, ore deposit studies and 3D modelling.

The SGS also plays an important role in developing Saskatchewan’s future geoscientists. Each year up to 20 summer students are hired from the geology departments of Saskatchewan universities. Some of these students have been supported to undertake undergraduate and graduate theses, and some have gone on to join the SGS.

Staff of the SGS are proud to have provided the geoscience foundation for Saskatchewan to become a top global mining and petroleum jurisdiction, and look forward to playing a key role in helping the province realize the full potential of its natural resource sector for the next 70 years and beyond.
Towards a Framework for Understanding Global Uranium Mineralisation with Collaborative IAEA and Member State Initiatives

Martin Fairclough 1, William Slimmon 2 and Oleksandra Valter 1

Abstract

The International Atomic Energy Agency (IAEA), under the impetus of Atoms For Peace And Development, partners with international experts and organisations to provide support to its Member States in all areas of the Uranium Production Cycle. In order to enable Member States to maximise opportunities for their security of uranium supply, the IAEA has recently released a number of data-driven outputs to provide support for governments and explorers in their programs for developing uranium production. In particular, IAEA has worked with experts from the Saskatchewan Geological Survey and the Geological Survey of South Australia to enhance its global uranium deposit (UDEPO) database in order to publish the World Distribution of Uranium Deposits 1:35 000 000 scale map, both in hardcopy and as an enhanced functionality Adobe PDF digital file. The map illustrates 2831 uranium deposits subdivided into the IAEA Uranium Deposit Classification of 15 major types and 49 subtypes. This output is supported by a detailed document related to the revised deposit classification, as well as a complementary document providing insights into the statistical distribution of the supporting data. Moreover, a further release focussed specifically on the important class of deposits where uranium is present as a co- or by-product in polymetallic deposits. The application of this framework of uranium data is illustrated for soon-to-be-released publication of modelling of potential future uranium resources. To complete the necessary data inputs for a robust analysis of uranium deposits of the future (i.e., “where”, “how much” and “how many”) future releases are concerned with the global distribution and characterisation of uranium provinces.

1 International Atomic Energy Agency (IAEA), Vienna International Centre, PO Box 100, 1400 Vienna, Austria
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Application of a Minerals System Approach to the Athabasca Basin

Ken Witherly 1, Francis Moul 2 and Victoria Tschirhart 3

Abstract

The concept of a mineral systems approach emerged in the mid-1990s when Australian researchers (Wyborn et al., 1994) recognized that methodologies applied to petroleum deposits could also be applied to mineral deposits. While the concepts are deemed innovative, there have been challenges as to what to measure and how best to build a framework of mineral systems. Geological concepts are still evolving (McCuaig and Hronsky, 2014; McCuaig, 2018). In the meantime, the role of geophysics is being expanded to examine data sets that can be assessed in the framework for possible evidence of mineral systems (Witherly, 2014; Dentith, 2018).

The Athabasca Basin in northern Saskatchewan hosts a number of large, high-grade uranium deposits. While a number of the deposits, particularly those in the east, have been studied in some detail, the exploration focus has been on the unconformity interface separating Athabasca Group sedimentary rocks from older crystalline basement. As such, this interface is the source of most of the geological information available for analysis. In the parlance of mineral systems, this provides only targeting-scale understanding and carries little information about the overall mineral system. Currently, the best source of such information is the geophysical data that covers the basin and surrounding regions; however, by and large this data has not been processed or interpreted with the concept of investigating the possible evidence of a mineral system being present in the basin.

This study will examine what existing data sets could be used for such a purpose and what additional data sets could be useful based on programs elsewhere. A key element of a mineral systems assessment will be defining what are proxies in the geophysical space that can be related to geological character—only with this approach can a true mineral systems approach be successful.


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2 Condor North Consulting ULC., 1112-1030 West Georgia Street, Vancouver, BC V6E 2Y3
3 Geological Survey of Canada, 601 Booth Street, Ottawa, ON K1A 0E8
Sedimentary Rocks of the Athabasca Supergroup, Elk Point Group, Mannville Group and Younger Diamictite in the Patterson Lake Region (NTS 74F), Northwest Saskatchewan

Sean A. Bosman 1

Abstract

Sedimentary rocks in the Patterson Lake region include the Paleo- to Mesoproterozoic Athabasca Supergroup, Devonian Elk Point Group, Cretaceous Mannville Group and a younger diamictite. Systematic multiparameter and descriptive logging of uranium exploration drillcore and petroleum drillcore and drill cuttings have facilitated production of an updated geological map of these cover rocks, near the southwest margin of the Cree Basin (Athabasca Basin) and northeast edge of the Western Canada Sedimentary Basin (in Saskatchewan).

Surface map boundaries of the groups and formations of the Athabasca Supergroup remain largely unchanged; however, the downhole resolution of these stratigraphic units is greatly improved due to the higher density of logged drillcore. For example, this logging has highlighted that, in some areas, the Manitou Falls Group, Bird Formation sits directly on crystalline basement. Downhole paleocurrent data from the Lazenby Lake and Manitou Falls groups suggests that the Kerras (northwest-trending paleocurrents), Ahenakew (west-trending paleocurrents) and Bourassa (north-trending paleocurrents) fluvial deposystems are all present in the Patterson Lake region. Several drillcore preserve evidence of local sheet flow and debris flow deposits in the Manitou Falls Group, Bird Formation, suggesting syn-sedimentary faulting at the time of deposition. Deformation bands are created through strain in porous and granular sedimentary rocks and because the total number of these strain indicators in each formation of the Manitou Falls Group is not uniform, it suggests that porosity varied during deposition or was modified during post-depositional diagenetic effects. Additional strain can cause faulting; and when focused at the contact between the Athabasca Supergroup and the rocks of crystalline basement it can be difficult to differentiate a fault contact from an unconformity. High angle contact, slickenlines and other structural features suggest a fault contact and may be accompanied by significant missing stratigraphy, which is important information for geological models.

Map extents of the Phanerozoic rocks in the area have been modified significantly. Devonian rocks have a fairly limited spatial extent but are more common than previously documented, generally shown as northeast-trending polygons, likely preserved due to structural/depositional lows. Cretaceous rocks are spatially much more limited than previously mapped, likely due to misinterpretation of the diamictite as being Cretaceous. The Cretaceous polygons are significantly larger than the Devonian polygons and generally underlie the Cree Lake moraine. The diamictite is very widespread and, in part, can be interpreted using topography. Study of drillcore containing Phanerozoic rocks also provided evidence of a saprolite developed on the crystalline basement. This saprolite contains coalified root traces, implying exposure and deep chemical weathering of the crystalline basement during the Phanerozoic Eon. Updated map boundaries of the Phanerozoic rocks may facilitate geotechnical and geophysical studies by industry stakeholders as they work towards development and additional exploration of the resources in the Patterson Lake region.

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Integrated Geochronological, Geophysical and Isotopic Investigation into the Patterson Lake Corridor of the Southwestern Athabasca Basin, Canada

Eric Potter 1, Victoria Tschirhart 1, Jeremy Powell 1, Colin Card 2, Dinu Pana 3, Brian McEwan 4, Raymond Ashley 5, Cameron MacKay 6 and Kenneth Wheatley 7

Abstract

Discovery of the Triple R and Arrow deposits plus several occurrences in the Patterson Lake Corridor (PLC), outside and along the southwestern margin of the Athabasca Basin, has opened up a new uranium district in the basin. The known mineralized zones extend from the unconformity to several hundred metres into the basement, which is composed of metamorphosed and altered mafic to ultramafic intrusions and orthogneisses of the Taltson Domain. Although hosted in reactivated fault structures, the atypical basement geology challenges the traditional unconformity-related deposit model. To address this, the Geological Survey of Canada's (GSC) Targeted Geoscience Initiative (TGI) uranium fluid pathways collaborative government-industry-academia research program is examining the role of long-lived reactivation of crustal-scale shear zones in driving fluid flow to sites of uranium mineralization. The research is integrating geophysical, geochronological, geochemical, and structural studies to both constrain the multi-phase deformational and alteration histories of the PLC basin, and quantify the expressions of fertile alteration along the reactivated fluid pathways that span the southwestern Athabasca Basin.

Recently acquired magnetotelluric (MT) and airborne gravity datasets are improving the knowledge base of shallow- to mid-crustal structures. The MT survey crosscuts the central axis of the PLC and extends over 100 km. The 2 km line-spaced airborne gravity survey extends across the broader region, covering ~15,000 km². Through inversion of geophysical datasets, these surveys will serve to image the geometry of major buried structures within and adjacent to the PLC and shed light into the regional framework hosting the uranium deposits.

To understand the long-term reuse of these high-strain corridors, structural data, micaeous and clay-rich samples were collected for geo-thermochronology, isotope and fluid inclusion studies. Presently, in situ and step heating 40Ar/39Ar analyses of muscovite are being conducted at the GSC noble gas laboratory to constrain the age of ductile structures, regional quartz flooding events, and subsequent brittle recrystallization. Samples from clay halos proximal to mineralized horizons are being dated via the K-Ar method to determine the timing of hydrothermal alteration related to uranium mineralization. Additionally, the Fe, Mg, S and B isotopic signatures of clay-rich alteration are being investigated to examine fluid-rock interactions along the fault/fluid conduit. These small variations may provide a means of identifying fertile fault corridors and vectoring to ore within established districts. Although still in data collection stages, the integrated and multidisciplinary nature of TGI research aims to provide valuable information for informing future exploration efforts and understanding the broader lithostructural setting of the region.

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6 Purepoint Uranium Group Inc., 111 - 2 Avenue S, Unit 530, Saskatoon, SK S7K 1K6
7 Forum Energy Metals Corp., 800 West Pender Street, Suite 615, Vancouver, BC V6C 2V6
NexGen Energy’s Arrow Deposit, Southwestern Athabasca Basin, Saskatchewan: Ideal Geological Characteristics Leading to Progressive Project Development

Troy Boisjoli

Abstract

Situated in northern Saskatchewan and straddling the southwestern margin of the Athabasca Basin, NexGen Energy Ltd.’s wholly owned Rook I property includes the entirely basement-hosted Arrow uranium deposit. Ideal geological characteristics along the Patterson Lake Corridor (PLC), especially in the vicinity of Arrow, and aggressive drilling since the discovery of Arrow in February of 2014 have resulted in an Indicated Mineral Resource estimate of 179.5 Mlbs U₃O₈ contained within 1.18 Mt grading 6.88% U₃O₈, and an Inferred Mineral Resource estimate of 122.1 Mlbs U₃O₈ contained within 4.25 Mt grading 1.30% U₃O₈.

The Arrow deposit consists of multiple high-grade veins within five zones, know as the A1 through A5 Shears. These zones are associated with graphitic shear zones that have undergone brittle re-activation within intensely silicified basement rocks. The overall orientation of the stacked shear system hosting the deposit has been identified as being sub-vertical, with mineralization being intersected as shallow as 110 m, and the deepest intersection at 980 m. There is also an identified elevation control, with mineralization plunging to the southwest and northeast. The current mineral resource indicates the deposit has dimensions of 895 m (strike) by 300 m (width) by 870 m (vertical). The deposit remains largely open at depth, and new parallel mineralized shears (A0 and Z1) were discovered to the northwest of the current footprint during the winter of 2018.

The alteration halo proximal to the mineralization comprises dravitic-chloritic-illitic-sericitic clays; however, the extent of this alteration is limited, and intensely silicified basement rocks separate the mineralized zones. In addition to the competent basement rocks providing favourable conditions to localize mineralizing fluids, they also provided exceptional geotechnical characteristics for mine design. A metallurgical study investigated the use of the Paste-Backfill method for use in underground stope stability; the results showed this method met or exceeded all benchmarks set forth in the Pre-Economic Assessment (PEA) mine designs. Additionally, the results from the study show Arrow to be characterized as mono-metallic, with uranium recovery of 97.6% at anticipated mill grades. Geotechnical and hydrogeological studies also described the crystalline basement host rock as an ideal setting for conventional long-hole stope mining method, substantially de-risking the deposit.
Application of High Resolution 2D Marine Seismic Technique for Geological and Geotechnical Objectives at Patterson Lake South Triple R Uranium Deposit

Sorin Dobrovicescu 1, Ross McElroy 2 and Ray Ashley 2

Abstract

Patterson Lake South is located in Canada’s Athabasca Basin, home to the world’s richest uranium mines. The project is host to the Triple R deposit - the most significant high-grade, near-surface project in the region. For the pre-feasibility study stage of the proposed open pit and dyke a better understanding of the sediments above the basement was needed. A 2D marine seismic survey was acquired in 2016 to help on geological and geotechnical aspects of the project.

The geophysical challenge was to adapt a marine type survey to a lake’s constraints. Also the shallow depth of the objective was a limitation. A 2D marine seismic survey grid was designed with lines 50 m apart. A streamer was also designed with 24 single receivers 2 m apart. Distance between shots used was 1 m. The source used was a bubble gun able to send a 20-600 Hz signal with the central frequency at 350 Hz.

The data acquired is of outstanding quality and resolution – both vertically and horizontally. The interpretation of the data created a very detailed model of the sediments above the basement and provided answers to several geotechnical issues, and also identified areas where additional drill-hole data was needed.

The presentation will detail every step of the survey from design to interpretation and also will show examples on how the seismic data was used for geological and geotechnical purposes.
The H/V Passive Seismic Method for Mapping Glacial Overburden Thickness

Clint Keller 1

Abstract

The horizontal-to-vertical (H/V) passive seismic method has been in use for over twenty years; however, the main focus has been on geotechnical investigations, building site characterization, and earthquake hazard analysis. The method is based on the hypothesis that ground consisting of a rigid substratum (i.e., bedrock) overlain by a soft soil layer (in our case glacial overburden) has a sufficient acoustic impedance contrast to be measured by passive seismic recording. Based on this model, natural microtremors (usually considered as seismic noise in typical active seismic surveys) are measured to characterize the overburden and bedrock layers.

Passive seismic data was collected in the eastern Athabasca Basin, northern Saskatchewan, in an attempt to map the overburden thickness over an area known for significant variability in the depth to bedrock. Since thickening of the overburden can pose logistical difficulties, increase costs, and elevate risk when attempting to diamond drill, highlighting problematic areas to avoid prior to drilling is advantageous. Mapping the overburden thickness is also useful in constraining other geophysical datasets, particularly when modelling gravity data.

In the appropriate geological conditions, the passive seismic method was found to be effective in mapping overburden thicknesses greater than 100 metres. When compared with drilling data, the error in the estimation of the overburden thickness was generally less than 15%. The method is inexpensive to deploy, requires minimal field training for field acquisition, and involves little post-processing. The majority of the data collected was high quality, however surficial areas with very dry, unconsolidated sands appeared to generate the weakest responses, likely due to poor coupling between the instrument and the ground.

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Evidence for Uraniferous Brines Within the Athabasca Basin and Significance for Uranium Exploration

Guoxiang Chi 1, Haixia Chu 2, Eric Potter 3, Simon Jackson 3 and Duane Petts 3

Abstract

It is generally agreed that the ore-forming fluids for the unconformity-related uranium deposits of the Athabasca Basin were brines derived from the basin. However, it remains controversial whether uranium was extracted from the basin sediments or basement rocks. The argument for a basin source of uranium is based mainly on the oxidized nature of the sedimentary rocks, which would have been favourable for uranium dissolution and transport. The argument for a basement source for uranium, on the other hand, is built on the observation that uranium concentrations are generally higher in the basement rocks than in the currently preserved sedimentary rocks (mainly sandstones) in the basin. Many of the fluid inclusions from the uranium deposits also contain Ca-dominated brines, which could not be derived from the basin because the sandstones contain low concentrations of Ca. Deciphering this uranium provenance problem is important for uranium exploration.

Microthermometric and LA-ICP-MS analyses were conducted on fluid inclusions in quartz overgrowths from sandstones of the Athabasca Basin. The samples were collected from various stratigraphic intervals (Read, Manitou Falls, Lazenby Lake and Wolverine Point formations) from four drill cores (DV10-001, BL-08-01, WC-79-1, and Rumpel Lake) that are distal to uranium deposits. The results indicate that Ca-rich and uraniferous (up to ~27 ppm U) brines were widely developed within the basin, regardless of the stratigraphic level and location in the basin. The uranium concentrations are two orders of magnitude higher than most geological fluids, and overlap with those found within uranium deposits (Richard et al., 2016). Mass balance calculations suggest that Ca-rich brines could have developed within the basin if the initial sediments in the basin contained small amounts (~3%) of Ca-rich minerals such as plagioclase. The observed uranium concentrations could have been achieved if the initial sediments contained the same level of uranium as the average basement rocks (3.7 ppm U). Textural studies indicate that when such uraniferous brines were developed, the basin sediments were not significantly compacted, which is consistent with a recent proposal that the unconformity-related uranium deposits in the Athabasca Basin were formed at shallow (~3 km or less) depths (Chi et al., 2018). Thus, our results suggest that large amounts of uranium were extracted from basin sediments by basin brines, which may have been the dominant source of uranium for the unconformity-related uranium mineralization.

This finding has important implications for uranium exploration in the Athabasca Basin. If uranium for mineralization was mainly derived from the basement, the exploration strategy would be to identify basement blocks fertile for uranium sourcing. Conversely, if the uraniferous fluids were widely developed within the basin, as suggested in this study, then the exploration strategy should focus on identifying favourable pathways (structures) that can channel the uraniferous fluids to favourable reducing environments near the unconformity and in the basement. Furthermore, the results of this study suggest that even though the majority of uranium deposits that have been discovered so far are mainly distributed in the eastern part of the Athabasca Basin, there is a great potential to find more uranium deposits in the western part of the basin, in addition to the recent major discoveries in the Patterson Lake corridor.


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Saskatchewan Geological Survey 10 Open House 2018, Abstract Volume
Technical Session 2: Structural Geology and Ore Deposits
Structural Summary of the Cigar Lake Unconformity-type Uranium Deposit, Athabasca Basin, Saskatchewan

Shawn Harvey 1

Abstract

The Cigar Lake deposit is a world-class unconformity-type uranium deposit with a protracted history of faulting and fault reactivation contributing to deposit formation and subsequent modification. Primary mineralization is situated at or above, but in close proximity to, the unconformity between Paleoproterozoic Wollaston Group metasedimentary rock and Paleoproterozoic to Mesoproterozoic Athabasca Group conglomerate and sandstone at a depth between 410 and 450 m.

In the Wollaston Group basement rock, evidence of early ductile deformation is provided by a well-developed schistosity and local development of foliation-parallel protomylonites that are concentrated in cordierite- and graphite-bearing psammopelitic to pelitic schist. Within this overall higher-strain zone there is a 10-40 m semi-brittle fault zone along the current axis of the deposit. This zone consists of a series of semi-brittle faults that are typically less than 0.5 m wide but can locally exceed 3 m. These graphite-enriched faults are variably defined, with an outer damage zone crackle breccia giving way to an inner core zone mosaic to chaotic breccia with contorted foliation within a graphite-rich matrix. Reactivation of basement structures is commonly characterized by narrow (<20 cm) graphite- and pyrite-rich gouge and cataclasite. These textures commonly overprint and locally cross-cut older breccia fabrics. The semi-brittle faults and reactivation structures acted as effective fluid pathways.

The deposit is positioned atop a 10-15 m linear east-trending basement high with a width of 80-110 m. Potential unconformity offset is interpreted along east-trending basement faults situated along the southern and northern edges, with offsets of less than 2 m. Minor mineralization associated with these fault offsets occurs locally.

In the overlying Athabasca Group there are a series of steeply-dipping brittle faults. The faults are dominantly east-west striking and dip to both the south and the north. These faults are open fracture zones characterized by crackle to lesser mosaic breccia, cataclasite and gouge with common silica dissolution. Along some of the steeply-dipping faults, ‘perched’ mineralization up to 320 m above the primary unconformity mineralization has been observed and is indicative of the long-lived nature of faulting and fluid flow. Proximal to the primary unconformity mineralization the fault structures exhibit textures compatible with hydrothermal breccia with common silica dissolution. Locally, the hydrothermal breccia is characterized by ball zone breccia composed of rounded sandstone fragments wrapped in clay, and locally uranium-clay, matrix.

Overall, the deformation history at Cigar Lake initiated with Trans-Hudsonian foliation development and local ductile shearing. Semi-brittle faulting within the high-strain zones was accompanied by graphite enrichment and permeability enhancement. Following exhumation of the basement rocks and development of the Athabasca Basin, the area was subjected to extensional faulting and common silica dissolution that is well-defined in the lower Athabasca Group. Within the basement, this faulting resulted in reactivation along the pre-existing weaker graphitic discontinuities. It is at the interface between the reactivated semi-brittle fault zone and the overlying sandstone hydraulic breccia dissolution zone that development of unconformity-type mineralization occurred.

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Structural Evolution of Deformation Bands in the Athabasca Basin

Drew C. Lubiniecki 1, Rosalind C. King 1, Simon P. Holford 2, Mark A. Bunch 2, Dave Thomas 3 and Gary Delaney 4

Abstract

The post-sandstone structural history of the late Paleoproterozoic Athabasca Basin is surprisingly poorly constrained, considering the unequivocal spatial relationship of high angle reverse, oblique transpressional and transcurrent faults with high-grade unconformity-related uranium mineralisation in the basin. Deformation bands within the basal Athabasca Group, notably the Manitou Falls Formation sandstone, are recognized around faults associated with many of the uranium deposits. Fault-induced deformation of porous granular sedimentary rocks (>10% porosity by volume) is accommodated in discrete zones of localised strain, commonly known as deformation bands. These structures form as a result of compaction, due to sediment loading or high stress, and are extremely sensitive to discrete changes in the local stress regime. Deformation bands are currently used as an exploration criteria for identifying areas of post-depositional sandstone faults, and therefore prospective areas of mineralisation. In that deformation bands are sensitive indicators of stress regimes, this study is investigating their use to better understand the role of far-field palaeostresses on the structural evolution of the Athabasca Basin. For the first time, we present a regional model of Athabasca Basin palaeostress, and make the critical observation that the majority of the deformation bands highlighted in this study have formed prior to uranium mineralization.

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The Structural and Lithological Evolution of the Patterson Lake Corridor, Southwestern Athabasca Basin, Saskatchewan

Dillon Johnstone 1, Kathryn Bethune 1 and Victoria Tschirhart 2

Abstract

The Patterson Lake corridor (PLc) is located along the southwest margin of the Athabasca Basin and is host to recently discovered unconformity-related uranium deposits (e.g., Triple R, Arrow) and prospects (e.g., Spitfire, Harpoon, etc.). It extends for more than 50 km along a northeast trend and is situated in highly-deformed Paleoproterozoic basement rocks of the southern Rae Province, which are proximal to, and underlie the Athabasca Basin. The metatectonic history of the region surrounding the PLc is remarkably complex, marked by at least four major ductile deformation phases and granulite facies metamorphism. Previous deposit-scale studies (i.e., Arrow and Spitfire) have indicated the importance of structural and lithological controls in concentrating the uranium system. However, as a whole, the PLc’s structural framework, tectonic evolution, and setting within the larger context of the Rae Province, remains poorly understood. Therefore, as part of Natural Resources Canada’s (NRCan) collaborative Targeted Geoscience Initiative 5 (TGI 5), this study aims to fully determine the PLc’s structural-tectonic evolution and related controls on uranium mineralization by investigating the structural and lithological characteristics of the rocks hosting these promising new deposits.

Drill-core investigations verified that highly altered granite, granodiorite, ultra-mafic and subordinate alkali intrusive basement rocks define a subvertical northeast-trending heterogenous high-strain zone cut by a complex network of anastomosing semi-ductile shears and brittle faults. Initial studies indicate that the PLc’s structural architecture is primarily the result of type-2 fold interference, whereby early north-trending isoclinal recumbent folds (F1) were refolded by upright northeast-trending tight to isoclinal folds (F2) creating ‘boomerang’ patterns. This is supported by ubiquitous composite S1/S2 gneissosity, vertical ductile stretching lineations, reverse-sense kinematic indicators (e.g., c-f fabric, rotated porphyroclasts, etc.), variable northeast- to northwest-trending fold axes, and curvilinear multi-scale magnetic edges (‘worms’) derived from airborne magnetic data. Further vertical attenuation and weak overprinting occurred as the result of upright northeast-trending folds (F3). This event is characterized by spaced and crenulation cleavage (S3), as well as kink folds. It is interpreted that right-lateral semi-ductile shears that form conductors and host uranium mineralization throughout the PLc developed within the southeast limb of an east-northeast trending regional-scale buckle fold (F4). This mega-structure is co-linear to F3, and thus, may represent a continuum of the earlier event. The early ductile and brittle-ductile structures are cross-cut by at least two discrete brittle fault sets that are expressed at a range of scales from microscopic to macroscopic. The earliest is a set of northeast-trending transtensional shears and associated north-trending normal faults which are most likely coeval with the development of the Athabasca Basin. A northwest- and north-trending conjugate fault set postdates the development of the Athabasca Basin, and is thought to be responsible for ubiquitous centimetre-scale subhorizontal reverse faults and the oblique reverse dextral reactivation of brittle-ductile shears. In addition, the cross-cutting faults most likely provided pathways for uranium-bearing fluids to move through and penetrate along the reactivated brittle-ductile structural grain.
Implicit Model Creation for the Application of Geophysical Inversion and Forward Modelling: Drill Target Generation for Undercover Ore Deposits

Daniel Gerger 1, Gabriel Courrioux 2, Charles Gumiaux 3, Dwayne Kinar 1, Grant Harrison 1 and Patrick Ledru 1

Abstract

Exploration for undiscovered uranium deposits across the Wollaston-Mudjatik Transition zone of the Athabasca Basin, Saskatchewan, Canada is complicated by a thick sandstone and overburden cover, masking the geophysical response of the basement-sandstone unconformity surface that provides a favourable pathway and trap for mineralizing fluids. Alteration envelopes associated with uranium deposition can be used as important vectors in the exploration for these buried ‘blind-target’ deposits as they can significantly alter the physical properties, notably density and resistivity, of the surrounding host rock and resultantly the geophysical response. Innovative and adaptable operational workflows can be developed to better target low density anomalies associated with alteration haloes at or near the unconformity interface through the reconciliation of observational and interpretive data by utilizing geological constraints within a 3D model for geophysical forward and inversion modelling.

The aim of this project is to focus on the spatial distribution of density across the Getty Russell project, operated by Orano Canada Inc. along the Wollaston-Mudjatik Transition zone north and along the geological trend of the historical Key Lake mine-site, and to reconcile this distribution determined from available field data with the observed gravimetric response. This is accomplished through the application of forward and inversion modelling on a 3D block model of the project (9000 x 9000 x 1600 m) within 3D Geomodeller software using a Heli-Falcon Airborne Gravity Gradiometer survey flown in 2016 as a constraint via the observed gravimetric response. Field observations in the form of logged lithology and structure, physical property measurements, and oriented data taken from drill-hole intersections contribute to the creation of a reasonable 3D geological model that acts as the main constraint for inversion. Results from the inversion suggestive of areas of interest must be reconciled with known metallogenic guides for uranium mineralization, principally graphitic horizons, as they intersect the unconformity surface in association with re-activated fault networks.

The Getty Russell project area focuses primarily on 'ingress-style' mineralization and therefore the coherent mapping and creation of a 3D alteration envelope encompassing all known basement alteration zones is paramount. A 3D block model has been created through implicit modelling from sparse drill-hole data to aid in three-dimensional visualization, forward and inversion processing, and target optimization. When combined with an 'expert-driven' approach to data analysis regarding known and favourable factors within the geological context of the project area, identification of zones of physical property variation unaccounted for in the geological model can be used to vector towards zones of interest for improved drill targeting for deeply buried ore deposits.

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The EADDF Initiative – A Plea in Favour of a Rational Way to Submit Assessment Data

Charles Beaudry 1

Abstract

A study by Richard Schodde, recently commissioned by PDAC, highlights that despite a doubling in exploration expenditures, the rate of economic discoveries has remained relatively unchanged over the last two decades. The conclusion is that exploration performance is gradually deteriorating. PDAC advocates for measures that can improve exploration discovery rates, and to address this the Geoscience Committee strives to develop initiatives that improve the type, quantity and quality of public geoscience information available to mineral explorers. The Exploration Assessment Digital Data Formats (EADDF) initiative was developed to address this issue. PDAC assembled a working group which, after nearly three years of work, produced a comprehensive format for submission of assessment data that is simple and does not require specialized proprietary software, but can be produced with Microsoft Excel or an open-source equivalent. The format is based primarily on the Australian model, which has been in use for nearly 20 years.

When adopted across all provincial and territorial jurisdictions in Canada, the format will provide data that is consistent in form and easy to import and integrate into geoscientific compilations, even across provincial boundaries. Currently, the EADDF standard is being implemented in a number of jurisdictions across Canada, and efforts continue to encourage jurisdictions to adopt such a standard. However, PDAC wants to highlight the fact that the format is fully operational, can be implemented “as is” and nothing prevents companies and explorers from submitting their own exploration assessment data in the formats proposed in the EADDF version 1.0.

PDAC sees the EADDF initiative as a critical, forward-looking strategy that will lead to higher quality exploration data and improved discovery rates in the future. The proposed talk will present a summary of the rationale behind the process, how the format was developed, and show examples of data for constructed templates that accommodate most data types produced by mineral exploration programs.

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Structural-Tectonic Evolution of the Santoy Shear Zone, a Splay of the Tabbernor Fault Zone: Late-Orogenic Gold, Controlled by a Major Crustal Zone

Kathryn Bethune 1, Chase Wood 2 and Devon Steubing 3

Abstract

The Santoy shear zone in northeast Glennie Domain is host to several economic gold deposits, including the Santoy Zone 7, Zone 8 and Gap (Zone 9) deposits. Structural analysis combined with U-Pb dating provide valuable constraints on the timing and mechanisms of shear zone development. Titanite and zircon in the calc-silicate assemblage developed along and marginal to shear zone-hosted quartz veins have been dated at ca. 1755 Ma, indicating that mineralization took place at a relatively late stage in the tectonic evolution, likely during early ductile deformation along the Tabbernor fault zone, immediately to the east. It is proposed that the Santoy shear zone initiated as a splay of the Tabbernor fault during the late stages of D3 folding, as strain localized along the highly transposed western limb of the Carruthers Lake synform. Strain was partitioned into weaker mafic volcanic rocks in contact with more competent granitoid units. During D3 the earlier S2 foliation, along with subparallel and discordant quartz veins, were folded about open to close moderately N-plunging F3 folds. These folds become progressively tighter toward a 'central auriferous zone', in which highly sheared and altered steeply ENE-dipping mafic volcanic rocks, along with subparallel transposed tonalitic sheets/dykes, were invaded by an anastomosing network of classic fault-fill veins. Deformation occurred by a combination of pure and simple shear, with dextral-reverse displacement and tectonic transport along the N-plunging lineation. Calc-silicate layers/lenses show well-developed boudinage structures. High fluid pressures, coupled with mechanical anisotropies of the tonalite dykes/sheets, are inferred to have played a role in cyclic failure and vein emplacement. The ore bodies were strongly influenced by the D3 strain regime with ore shoots elongated along L3. An upper limit to mineralization is provided by the ca. 1736 Ma age derived from a crosscutting but weakly folded non-mineralized pegmatite emplaced at the end of D3. Later development of discrete foliation-parallel ductile-brittle faults, with evidence of two slip lineations and minor sulphide remobilization, indicate more than one displacement episode related to sequential reactivations of the Tabbernor fault. All rocks were then cut by a younger set of E-W-trending brittle faults, recording more significant displacements, as rocks were further cooled and uplifted to higher crustal levels. From a regional perspective, this study has demonstrated that D3 was much longer lived than previously thought, with a revised estimated extent from ca.1770 Ma, based on regional metamorphic ages, to the ca. 1736 Ma age of the pegmatite. This reinforces results of a previous thermochronological study indicating a substantial difference in cooling/exhumation histories across the Tabbernor fault, with the west side showing a prolonged uplift history relative to rapidly exhumed, higher grade rocks on the eastern side. In conclusion, the Santoy gold deposits have all the hallmarks of mesothermal, orogenic-style gold deposits. The associated distinctive calc-silicate alteration implies somewhat deeper mineralization depths than is typical of such deposits but also attests to the depth extent of the system. The Tabbernor fault thus represents a deep-seated, crustal-scale fault whose future gold prospectivity should not be overlooked.

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Exploration Update on the Olson Gold Project

Paul C. Stewart ¹

Abstract

The Olson Project is located south of Brownell Lake, and 100 km east of La Ronge in northern Saskatchewan. Reconnaissance geological mapping was completed in the area in 1913 by McInnes and in 1926 by DeLury. Exploration southwest of Brownell Lake in the Alsmith Lake area was first undertaken by the Knox Saskatchewan Syndicate, Selco Exploration Company and Hudson Bay Exploration and development from 1957-1974. Prospecting, trenching, magnetics, EM surveying and diamond drilling in the area discovered gold and minor copper mineralization. In the 1980s and mid 1990s E.F. Partridge, Carina Mineral Resources, and Waddy Lake Resources completed basal till sampling, prospecting, trenching, channel sampling, diamond drilling, EM and magnetic surveying southeast of Brownell Lake and east of Olson Lake discovering additional zones of gold mineralization. In the 2000s historical gold showings in the area were followed up by a numbered Saskatchewan company and Galaxy Graphite. Follow up work included prospecting, VLF-EM, magnetic and IP-resistivity surveying, prospecting and diamond drilling.

The 9628 hectare Olson Project is located within the Glennie Domain and is host to the Brownell Lake Greenstone Belt (BLGB). Within the Olson Property the BLGB consists of the Brownell Lake Group and the Wapawekka Lake Formation. The Brownell Lake Group consists of mafic to intermediate metavolcanic rocks with lesser schist and granitoid intrusive. The Wapawekka Lake Formation consists of metasandstone with plagioclase porphyry sills, with minor intermediate metavolcanics. The Brownell Lake Pluton is one of several large intrusive bodies within the Olson Property; intrusions range from diorite to granodiorite. Along the southern edge of the property is the east-trending Hartley Shear Zone.

There are twenty known gold bearing mineral occurrences within the Olson Project, with two distinct styles of mineralization recognized to date. The majority of the showings are hosted in arsenopyrite-mineralized shear zones and quartz veins. Highlight historical assays include 7.5 m of 2.07 g/t Au including 0.65 m at 13.0 g/t Au in metavolcanics at the Olson Lake Showing (from drillholes) and 18.3 m at 1.11 g/t Au at the sheared contact between metapelite and metavolcanics at the Emco Showing (from drillholes). Intrusion related stockwork veining host to sulfide mineralization is present at Ackbar Lake (7.4 g/t Au (grab sample)), and the Kalix Showing (4.0 g/t Au over 8.0 m (channel sample)).

Over the past year Eagle Plains Resources has completed a compilation of all historical work on the Olson Project. During June 2018 historical showings were prospected while soil sampling was completed in areas with poor sample coverage. Highlight grab samples include 16.9 and 45.1 g/t Au from arsenopyrite-mineralized quartz veining at the Point Showing, and 8.2, 10, and 13.0 g/t Au from arsenopyrite-mineralized shear zone at the Juba showing. Soil sampling defined two anomalous trends (>80 ppb Au) at the Jena-Juba and Point-Ackbar Lake Showings including six samples that assayed >1000 ppb Au. Follow up prospecting in these areas in early September discovered numerous arsenopyrite-mineralized quartz veins and shear zones. Assay results of the follow up work are still pending.
SSR Mining Inc.’s Update of Exploration Activities in the Pine Lake Greenstone Belt, SK

Anders Carlson 1, Paul Kremer 1 and Lee Hess 1

Abstract
Aggressive exploration at the wholly owned Seabee Gold Operation and Fisher Gold option property will continue in 2019 as SSR Mining affirm their commitment to making new gold discoveries in Saskatchewan. Surface drilling and field programs in 2018 have helped to delineate new target areas across a 56,000+ hectare swath over the Pine Lake greenstone belt, which has produced approximately 1.5 million oz. of gold since production began in 1991. On the optioned Fisher Property, the exploration program has been facilitated by exceptional outcrop exposure across large areas caused by forest fires in 2017. Geological mapping and prospecting in these areas in 2018 has led to the discovery of several vein systems in a variety of geological and structural environments. The new field data, when combined with the recent exploration and resource conversion successes at the Santoy Mine Complex through surface and underground drilling programs, continue to highlight the belt's growing exploration potential at both near-mine and regional scales.

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Technical Session 3: Emerging and Established Base Metal Camps
Saskatchewan Exploration and Development Highlights 2018

Gary Delaney \(^1\) and staff of the Saskatchewan Geological Survey

Abstract

Over the past year Saskatchewan maintained its role as a global leader in potash and uranium production as the world's largest potash producing jurisdiction, and second largest producer of primary uranium. The province set a record for volumes of potash produced and sold in 2017, and a number of other commodities, including gold, coal, base metals, sodium sulfate, salt and clays, were also mined. A wide diversity of geologic settings and mineral deposits, combined with a stable policy and regulatory environment, continue to attract attention from local juniors to international major mining companies as the province solidifies its reputation as a destination to do business.

Saskatchewan's value of mineral sales in 2017, mostly from potash and uranium, was approximately $6.7 billion (B) up slightly from last year's $6.4 B but still down from $8.2 B in 2015 and $7.3 B in 2014. The decrease can be primarily attributed to lower realized sales prices for potash and uranium.

In its annual survey of mining companies active in the province, the Ministry of Energy and Resources' Saskatchewan Geological Survey (SGS) determined that an estimated $193.5 million (M) was planned to be spent on mineral exploration in 2018, an increase over the $170 M spent in 2017 and on par with the $199 M in 2016. Most of the 2018 expenditures were planned for uranium and potash projects, but the survey results also reflect a renewed interest in diamonds, base and precious metals, as well as rare earth elements and specialty metals.

In a separate Canada-wide survey, Natural Resources Canada (NRCan) found that national expenditures for mineral exploration plus deposit appraisals was approximately $2.00 B in 2017, down significantly from the $4.23 B spent in 2011. NRCan estimated that Saskatchewan's portion of these expenditures will constitute approximately 7.4% in 2018, down from 9% in 2017 and 14% in 2016. The province's decreasing percentage of national expenditures is primarily a reflection of rising base and precious metal commodity prices, for which exploration is more robust in other jurisdictions. Despite the current lower prices for its principal commodities, Saskatchewan continues to be recognized as one of the most favourable jurisdictions in the world for investment in the mining sector. This was reflected in the 2017 Survey of Mining Companies by the Fraser Institute, in which, out of 91 jurisdictions, Saskatchewan ranked first in Canada and second in the world in its Investment Attractiveness Index. The index rates jurisdictions based on a combination of their geologic attractiveness and their Policy Perception Index, a composite measure of the effects of government policy on attitudes toward exploration investment.

In a similar vote of confidence, The Mining Journal recently released its second annual World Risk Report for security of investments in resource capital. The survey compared 91 jurisdictions around the world and ranked Saskatchewan third globally in its Investment Risk Index. The index reflects hard risk factors such as mining codes, taxes and regulations, infrastructure and energy security, along with public perception factors such as ease of doing business, political transparency and social stability.

At the end of October 2018 active mineral dispositions in Saskatchewan totaled 5.61 M hectares (ha), down slightly from the 5.74 M ha held at the same time one year ago. Total active potash dispositions fell to 95 dispositions totaling 2.44 M ha, down from 110 dispositions totaling ~2.89 M ha one year ago. In total, nearly 8.2 M ha of land is currently held in Saskatchewan under the mineral, potash, coal, quarry, and alkali disposition regulations.

In 2018, the Mineral Development Strategy, announced in the Speech from the Throne 2017, was implemented to support diversification of Saskatchewan's mineral sector by encouraging exploration for precious metals, base metals and diamonds. To date, three initiatives have been introduced as part of the Strategy: 1) the acquisition of new airborne magnetic and electromagnetic geophysical data, acquired in partnership with the Geological Survey of Canada in the Creighton/Flin Flon area; 2) focused geoscience studies, conducted by the SGS in areas in and around the new geophysical surveys and, 3) a 'Targeted Mineral Exploration Incentive' (TMEI: http://www.saskatchewan.ca/mineral-exploration-incentive), to support drilling in a defined area of high potential for base metals, precious metals and diamonds. The TMEI offers successful applicants a 25% rebate on eligible drilling costs to a maximum of $50,000 per year, on a prorated basis.

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Nickel and Cobalt in the Athabasca Basin: Dufferin Lake and Cree Lake Areas

Charles Normand 1, Robert Mohrbutter 2 and Matt Hughes 3

Abstract

To contribute to the understanding of nickel-cobalt mineralization in the Athabasca Basin, examples of nickel-arsenic–rich mineralization were examined in drillcore from Dufferin and Cree lakes. The mineralization in both areas is poor in uranium. It is comparatively arsenic-poor in hydrothermally altered diabase at Cree Lake, and very rich in nickel (±cobalt) and arsenic at the unconformity between Athabasca Supergroup siliciclastics and basement rocks in the Dufferin Lake area.

Significant nickel-cobalt mineralization (>1%) was intersected in three drillholes spaced 200 m apart on the Dufferin Lake fault system (zone of reactivation of the Virgin River shear zone). The best mineralized interval occurs in drillhole SW-060 (65° plunge at collar) where weighted average U, Ni, Co and Zn concentrations of 0.14%, 20.94%, 0.44% and 0.13%, respectively, were calculated over 7.9 m. Ni/Co ratios are elevated, varying between 4 to 259. The maximum value for As/Ni+Co (partial digestion) is 1.4, suggesting the presence of niccolite and/or rammelsbergite. In drillhole SW-060, the nickel-cobalt mineralization is hosted in sandstone, which contains >0.1% Co+Ni over a vertically calculated thickness of 37.4 m above the unconformity with the basement metapelite, including a basement wedge located 0.8 m above the unconformity. Brecciated massive mineralization occurs 11 m above the unconformity and is underlain by a powdery zone of green-oxidized mineralization. Mineralization in the basement wedge consists of semi-massive nickel arsenide rosettes set in a dark matrix. Examination of mineralized core revealed that nickel arsenide mineralization developed after regional black hematite cementation/replacement of sandstone and bleaching, and was overprinted by a complex succession of brittle faulting (including brecciation), desilicification/silicification, clay alteration (including teal-coloured tourmaline) and veining (specularite, carbonate, quartz) events.

Hydrothermally altered diabase in the Cree Lake area between Diabase Peninsula and Lazy Edward Bay provides examples of arsenic-poor, nickel-cobalt mineralization. Northwest-trending diabase dykes (>20 m thick, >10 km strike length) of the ~1.27 Ga Cree Lake dyke swarm cut Manitou Falls Formation siliciclastic rocks in the area. Nickel-cobalt mineralization is generally concentrated near the clay-altered and deformed margins of the dykes as very fine-grained metallic minerals disseminated in a chloritized matrix and in thin quartz veins. Inspection of drillcore geochemical analyses from 30 drillholes that cut diabase revealed that Co+Ni assay values >0.1% are present in only 4 of the holes (e.g., up to 0.23% Co, 0.48% Ni and 0.16% Zn in drillhole ND1203). Mineralization is arsenic-poor and shows As/Ni+Co ratios (partial digestion; average ratio of ~0.04) similar to the average in unmineralized diabase. These values suggest that nickel and cobalt are hosted in one or more arsenic-bearing sulfide mineral(s). Ni/Co ratios in mineralized portions (average ratio of ~2.66) are similar to those in unmineralized, least-altered diabase (average ratio of ~3.00). Mineralization may have formed by local redistribution of metals during hydrothermal alteration without fractionation of nickel and cobalt. Although no evidence for the addition from an external source for nickel or cobalt was identified, this possibility cannot yet be ruled out.

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The West Bear Cobalt-Nickel Deposit – First Steps into Developing the Athabasca Basin into a World-Class Cobalt District?

Roger LeMaitre 1

Abstract

Discovered in 2002, tentatively probed in 2004 and 2005, and the target of a focused exploration campaign by UEX in the winter of 2018, the West Bear Cobalt-Nickel Deposit represents a new exploitable exploration commodity target in what is undoubtedly the world’s premiere uranium exploration and mining district, the Athabasca Basin.

UEX completed a $1.6 million – 41 hole drilling campaign in the winter of 2018 that defined the West Bear Cobalt-Nickel Deposit between vertical depths of 15-85 m and over a minimum strike length of 200 m. The 2018 program was highlighted by several world-class cobalt intersections including 4.90% Co and 2.08% Ni over 8 m, 3.78% Co and 1.47% Ni over 3.0 m, and 2.00% Co and 1.26% Ni over 10.5 m. July’s maiden interim resource estimated that the deposit contains 3.07 M lbs Co and 1.78 M lbs Ni at an average grade of 0.50% Co and 0.29% Ni. High-grade cobalt-nickel mineralization remains open for expansion in all directions.

The association of significant cobalt and nickel concentrations within many unconformity uranium deposits in the Athabasca Basin is well-known and was established decades ago. Uranium explorationists have used anomalous cobalt and nickel concentrations in the unconformity environment as proximal pathfinder elements to vector towards uranium mineralization.

The West Bear Cobalt-Nickel Deposit is unusual in the fact that world-class high-grade cobalt concentrations occur in the same metallogenic and structural system as the West Bear Uranium Deposit. However, the cobalt and nickel mineralization is physically separated from the nearby uranium deposit, does not itself contain uranium, and the body of mineralization can likely be extracted independently from the nearby uranium deposit.

Cobalt-nickel mineralization occurs east of the West Bear Uranium Deposit primarily hosted in the very strongly graphitic basement rocks of the West Bear Graphitic Unit that has been subjected to post-Athabasca brittle fault deformation. Often primary and secondary features of the host lithology and structure have been obliterated by intense hydrothermal clay alteration. This geological environment is the same as that in which many basement-hosted unconformity-related uranium deposits have been discovered. At West Bear, the uranium and cobalt-nickel deposits are hosted in different locations within the same continuous hydrothermal clay alteration and brittle structural system.

Cobalt-nickel mineralization consists of skutterudite (CoAs2-3) and nickel-skutterudite (NiAs2-3) in solid solution with minor to trace amounts of cobaltite (CoAsS). Dominant gangue minerals are clay, quartz and graphite. Reflectance spectrometry from 24% of the holes in the cobalt-nickel deposit and QUEMSCAN analysis indicate that the dominate clay species are illite and chlorite. This is in sharp contrast at the uranium deposit only 200 m along strike to the west where the clays are dominantly kaolinite and dravite. The nature and detailed geographical information regarding this transition of dominant clay species within the same hydrothermal body is currently unknown and will be investigated in the coming year.

In addition to developing West Bear, UEX is committed to finding more of these cobalt deposits that undoubtedly exist in the Basin that may be mineable exclusively by a cobalt-only economic rationale.

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Summary of Bedrock Geology Investigation on Areas Surrounding Robertson Lake and Palmer Lake, Glennie Domain, Reindeer Zone

Samantha R. Van De Kerckhove 1, Shelby R. Brandt 2, Ralf O. Maxeiner 1 and Svieda M. Ma 1

Abstract

Bedrock mapping was completed in the area surrounding Robertson and Palmer lakes in north-central Saskatchewan in the summer of 2018 at scale of 1:20 000. This work is the western extension of adjacent mapping in 2017, centred on Wapassini and Glennie lakes. The area around Robertson Lake is dominated by sedimentary rocks, and is part of the Kyaska lithotectonic sheet. The Palmer Lake area is underlain by abundant intermediate plutonic rocks and minor mafic volcanic and associated gabbroic rocks, and is part of the Wapassini lithotectonic sheet. Syntectonic, anatectic, quartzofeldspathic intrusive rocks generated during the regional D2 event, and syn- to post-tectonic medium-grained to pegmatitic granite were emplaced across the entire area.

The main regional foliation trends east-northeast and represents a composite S1/S2 fabric resulting from isoclinal F2 folding of the original S1 fabric. Map-scale F3 folds are open to close, upright, and northwest trending, whereas F4 folds are open to close, typically coaxial to F2 folds, and east-northeast trending. East of Robertson Lake, a basin structure, defined by mafic volcanic rocks and gabbroic rocks, has resulted from F3 - F4 fold interference. A number of high-strain zones were mapped this summer, including a discontinuous zone that marks the boundary between the Kyaska and Wapassini lithotectonic sheets; a large corridor of consistently high-strained rocks surrounding Nugent Lake termed the Nugent Lake high-strain corridor; and the Boyce Lake high-strain zone, which is a mylonite zone that delineates the boundary between the Wapassini and Cartier lithotectonic sheets. Rocks in the mapped area have been metamorphosed under upper amphibolite–facies conditions.

The mapped area is centred 30 km west of the Seabee gold operation and 35 km north of the Pitching Lake copper deposit. Based on regional geological considerations and anomalously high gold and copper assays from samples collected in 2017, it is believed that the area has some potential to host orogenic gold and volcanogenic massive sulfide deposits.

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Geology, Geophysics and Geochemistry of the Janice Lake Copper Project

Ken Wheatley ¹ and Rick Mazur ¹

Abstract

The Janice Lake area is located approximately 200 km north of La Ronge and 50 km southeast of Key Lake, immediately west of the Needle Falls Shear Zone. Copper mineralization was discovered in the area in 1953 by Simon Eninew and has been investigated on and off throughout the decades by various explorers. Forum acquired the claims from Transition Metals in the spring of 2018 and completed a small drill program in August/September.

The project is underlain by metamorphosed rocks of the basal Wollaston Group; the Rafuse and Janice Lake formations that are interpreted to have formed from a series of arkosic sediments, fanglomerates/conglomerates, and psammopelitic locally grading to pelitic sediments. The rocks currently have variable dips but generally strike to the northeast. These have been later cut by granitic dykes that appear to have a more north-south orientation.

Copper in the form of chalcocite (Cu$_2$S) appears to be hosted mainly in the mafic-rich meta-pelitic layers, but can also be found in more arkosic materials. Native copper is also present and can be found with the chalcocite, but is noted mainly on the upper and lower borders of the chalcocite zone, and is interpreted by the authors to be deposited by a later mineralization event, or at the end of the chalcocite deposition once the sulphur in the system was used up. To date, the mineralization is consistently within 200 m of surface in drill holes, and is present in over 20 outcrop occurrences on the property over a distance of 8 km. Malachite, azurite and various forms of copper oxides are present at surface in outcrop and boulders, and along fractures in drill core.

Higher grades of copper (>4%), especially in the chalcocite zones, show elevated Ag with local grades of up to 45 g/tonne. Zinc is also locally present and has returned up to 1% over 5.5 metres.

It was noted by Noranda that copper mineralization occurred along the outer margin of magnetite-bearing metamorphosed redbeds. Due to the magnetic nature of these metasediments, an airborne magnetic survey effectively mapped out the distribution of this unit and therefore could be used to identify areas of potential mineralization. Magnetic susceptibility readings were taken on some of the historic drill holes, and at 1 metre increments along the current drill core; the readings do appear to drop off below the mineralized zone.

Phelps Dodge performed 2D inversion depth modelling on previous IP data and completed several fill-in lines to complete the survey. Mineralization appears to be associated with chargeability highs, with or without resistivity lows, but more work needs to be done with this survey to confirm these results. It currently appears to be an excellent tool for targeting the mineralization.

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Brabant-McKenzie Deposit – An Update of 2018 Exploration

Kent Pearson¹ and Finley Bakker²

Abstract

The Brabant-McKenzie project, which hosts the Brabant-McKenzie deposit is located approximately 175 km northeast of La Ronge, Saskatchewan, approximately one kilometre off of provincial Highway 102. The deposit was discovered in 1956 as a surface showing. Periodic work over the period 1957 to 2012 has included prospecting, geological mapping, trenching, sampling, airborne and ground geophysics and 146 diamond drill holes for over 33,000 metres on the deposit and regional targets. The deposit is classified as a metamorphosed volcanic-hosted massive sulphide (VMS) deposit and shares many textural and metamorphic characteristics with other massive sulphide deposits, such as those of the Manitouwadge camp in Ontario and of the Sherridon area in Manitoba. It is hosted in a series of gneisses and amphibolitic units all of which are variously intruded by pegmatic dykes. Regional metamorphic grades range from upper amphibolite to lower granulite facies.

Variable amounts of pyrrhotite, sphalerite, pyrite, chalcopyrite and galena occur as tabular to lensoid bodies of disseminated to massive sulphide, sulphide-rich breccias, concordant to discordant veins and veinlets. Two main mineralized zones are defined as the Upper Mineralized Zone (UMZ) and Lower Mineralized Zone (LMZ), which strike northeast, dipping on average 51 degrees west-northwest. The geological model tentatively correlates the continuity of the UMZ mineralization over a strike length of 1100 metres and from the surface down dip for approximately 1000 metres. The UMZ has an average thickness over 5.15 metres with an approximate maximum true thickness of 23 metres. The LMZ is located on average 25-30 metres below the UMZ. The continuity of mineralization occurs over a strike length of about 800 metres and from the surface down dip for approximately 800 metres. The average thickness of the LMZ is approximately 5.85 metres and has an approximate maximum true thickness of 24 metres. Historically, the deposit’s textures within the sulphide-rich breccias suggested that it had been injected but is more likely, remobilized.

Since 2017, Murchison Minerals Ltd. (Murchison) has focused its exploration programs on the Brabant-McKenzie project, including geophysics, extensive drilling, regional prospecting, mapping and sampling. Beginning in 2017, the company has conducted two drilling campaigns of approximately 14,000 metres and was focused on expanding the extents of the deposit and increasing the total resource tonnage. Murchison announced an updated 2018 resource estimate, which outlined 2.1 million tonnes grading 7.08% zinc, 0.69% copper, 0.40% lead and 39.6 g/t silver or 9.98% zinc equivalent in the indicated category. An additional 7.6 million tonnes grading 4.46% zinc, 0.57% copper, 0.19% lead and 18.4 g/t silver or 6.30% zinc equivalent is defined in the inferred category. The resource estimate is based on a zinc equivalent cutoff grade of 3.5% and includes the addition of 19 new diamond drill holes totaling 9004 metres from the January to March 2018 drill program. The resource estimate also included a comprehensive re-interpretation of the geology, using current and historical drilling data and reports.

Regionally, the Brabant-McKenzie project hosts a number of known mineralized showings and airborne geophysical targets over approximately 18 km strike of prospective VMS geology. Currently, the company has defined six priority targets, of which three are drill ready. These include Anomaly D, TOM2, T2T and Priority 3 geophysical targets and Main Lake and McIvor Channel mineralized showings. Murchison’s future exploration programs will focus on efforts to continue to add resource tonnage and define the extents of the deposit. The company also plans to proceed with a metallurgical study on the deposit. Regionally, the exploration program will also continue to drill test Anomaly D as well as initiate a drill program to test TOM2 and T2T. Programs designed to further define Main Lake and Priority 3 as additional drill targets are currently underway.

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Project SPHALERITE: Sub-Phanerozoic Core Logging and Enhanced Geoscience Research Initiative

Ralf Maxeiner 1, Omid Mahmoodi 1 and Ryan Morelli 1

Abstract

New airborne electromagnetic, magnetic and gravity gradient survey data were acquired in three areas west-southwest of Flin Flon, Manitoba, in 2018 as part of a federal–provincial initiative to support exploration for base and precious metals in the region. Electromagnetic and associated magnetic surveys were funded as part of the Saskatchewan Mineral Development Strategy, aimed at diversifying and supporting the province’s mineral industry. Gravity gradient and associated magnetic surveys in the same areas were funded by Natural Resources Canada as part of its Targeted Geoscience Initiative. These surveys form the basis of a new multiyear, multidisciplinary project that aims to expand ore space to depth and is, in this test case, targeting the sub-Phanerozoic basement of the western Flin Flon Domain. The Sub-Phanerozoic core Logging and Enhanced geoscience Research Initiative (project SPHALERITE), was launched in the spring of 2018, and focused on one of the three geophysical survey areas—the Bigstone Lake subproject.

The Bigstone Lake area is approximately 400 km² and is centred on Limestone Lake, roughly 85 km west of the Saskatchewan–Manitoba border and just east of Deschambault Lake. In the first year of the project, geoscience work focused on four key tasks: 1) modifications to Saskatchewan’s diamond-drill hole database, 2) re-logging and compilation of available drillcore data (focusing primarily on core from the Bigstone Lake subproject area), 3) collection of samples for geochemical and isotopic characterization of volcanic rocks and sedimentary assemblages, and 4) a preliminary geological interpretation of the Bigstone Lake area.

Approximately 350 diamond-drill holes were completed in the Limestone Lake area between 1965 and 2015, of which about 120 were focused on the Bigstone deposit (Zn, Cu), the remainder being more regional in nature. Core from a total of 18 drillholes was re-logged: seven of these holes had targeted the deposit, the remaining 11 holes were more regional in nature. The majority of the rock types intersected in the drillholes are felsic to mafic volcanics, but sedimentary and exhalative rocks are also present. Plutonic and subvolcanic rocks are less abundant in the drillcore studied, despite the fact they underlie a large part of the subproject area. The volcanic rocks have locally been affected by alteration processes, and mineralization is locally present.

The association of syngenetic copper stockwork mineralization and zinc-rich massive sulfide lenses, as well as closely associated iron formation, are good evidence that the Bigstone deposit originated as a volcanogenic massive sulfide deposit, as suggested by previous workers. Preliminary observations and previous work suggest the presence of two variably zinc-rich exhalative horizons, flanking a central copper-rich stockwork zone, which can be interpreted in different ways, depending on stratigraphic facing directions. Unfortunately, no unambiguous indications of stratigraphic facing directions were detected in any of the diamond-drill holes. Emplacement of post-mineralization feldspar porphyry dykes and later fault-induced fluid migration have caused remobilization of some of the sulfides.

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New Airborne Geophysical Surveys in the Creighton–Flin Flon Area

Omid Mahmoodi 1, Ralf O. Maxeiner 1, Ryan Morelli 1 and Olivier Boulanger 2

Abstract

The Saskatchewan Geological Survey initiated a multiyear geoscience project in the Creighton–Flin Flon area, near the Saskatchewan–Manitoba border, as part of the Saskatchewan Mineral Development Strategy, a program which is aimed at diversifying the province’s mineral industry. This project was launched in collaboration with the Geological Survey of Canada and Manitoba Geological Survey in the spring of 2018 and is focused on understanding the economic potential of the sub-Phanerozoic basement rocks in the western Flin Flon Domain. New airborne geophysical surveys were completed for three areas between Deschambault, Amisk and Tobin lakes. The surveys were designed to help understand the basement geology, in particular, the distribution of volcanic sequences that might host volcanogenic massive sulfide (VMS) deposits and the expressions of ore-forming systems to depth, as well as to provide guidance for exploration. The locations of the airborne surveys were selected to cover areas lacking geophysical data or to provide higher quality data for areas previously covered by historical surveys. In this first year of the project, three surveys were conducted using CGG’s (Compagnie Générale de Géophysique) HeliTEM EM/magnetic system, and two surveys were conducted using CGG’s Falcon gravity gradiometer system. Each survey used a line spacing of 200 m with 1200 m tie-lines. In order to provide value-added products to the new surveys, physical rock properties, including specific gravity, magnetic susceptibility and conductivity, were measured during the summer of 2018 on core samples from drillholes collared in the survey areas. In total, core from 18 boreholes was examined and more than 3000 measurements were collected, to better understand the link between geological and geophysical features in the area. Conductivity measurements clearly defined sulfide mineralization zones in drillcore. Specific gravity and magnetic susceptibility measurements could not only indicate the mineralized zones, but could also differentiate between some lithological units, based on their physical characteristics.

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The Sub-Phanerozoic Basement Geology of the Flin Flon Domain: Perspectives from Manitoba

Kyle Reid

Abstract

Nearly 25 years ago, the NATMAP Shield Margin Project completed the first geological compilation of the Flin Flon Domain where it dips shallowly beneath Phanerozoic cover to the south. However, significant knowledge gaps still exist in Manitoba and Saskatchewan. In response to the knowledge gaps in Manitoba, the Manitoba Geological Survey has been compiling geophysical and geological drillhole data to create new 1:50 000 scale sub-Phanerozoic geological maps. To this point, the eastern portion of the Flin Flon Domain has been the focus, but future efforts will encompass the National Geoscience Committee’s cross-boundary gravity gradiometer survey. This area represents the starting point for collaborative (i.e., company, provincial and federal) integration of large amounts of data and the development of a larger 3D geological model of the region.

Presented in this talk is a summary of the work completed, underway and poised to start by the Manitoba Geological Survey in the Flin Flon Domain, including re-examining historical drillcore, handling and filtering of historical drill log data, geochemical data collection and interpretation, and aeromagnetic interpretation.
Developing Canada's Next Base Metal Mining District: McIlvenna Bay Feasibility Study Underway

Roger March 1

Abstract

Foran Mining Corporation is focused on exploration and development of Zn-Cu-Au-Ag volcanogenic massive sulphide (VMS) deposits in the Hanson Lake District of east-central Saskatchewan. The Hanson Lake District is comprised of two Paleoproterozoic supracrustal assemblages at the underexplored western limit of the Flin Flon-Glennie Complex within the Reindeer Zone of the Trans-Hudson Orogen. The Flin Flon-Glennie Complex is one of the most significant mining districts in the world, with ~170 million tonnes of production from 29 past and present producing VMS deposits. Foran's McIlvenna Bay deposit is one of the largest undeveloped base metal deposits in Canada and could be the centre of gravity for district scale mining in the Hanson Lake District, with the potential for additional mill feed coming from satellite deposits. The region has excellent infrastructure including highways and secondary roads, existing hydroelectric power and nearby metal processing facilities, railhead and skilled labour in Flin Flon.

The McIlvenna Bay deposit is host to a mineral resource of 13.9 million tonnes indicated and 11.3 million tonnes inferred. A 2014 preliminary economic assessment was based on a 5,000 tpd underground mining operation at McIlvenna Bay, which estimated pre-production capital costs of $249 M with sustaining capital of $150 M over a 14-year mine life, deriving an estimated pre-tax NPV of $382 M, an IRR of 22% with a 4-year payback period. This operation would be highly-leveraged to metal prices.

In December, 2017 Foran signed an agreement with Glencore Canada Corporation, whereby Glencore would provide professional and technical services, assistance, guidance, and advice in connection with the objective of completing a Feasibility Study on Foran’s McIlvenna Bay Project. In exchange for the above, Glencore received the exclusive right to purchase or toll process all of the concentrates and/or other mineral products produced at prevailing market rates. In January 2018, Foran launched a large infill and expansion diamond drill program at the deposit to support the study, consisting of over 25,000 metres of drilling in 65 drill holes, designed to convert as much of the resource as possible into minable reserves, collect samples for metallurgical studies, and provide additional detailed geotechnical data to assist in mine planning. The program also included hydrogeological studies to better quantify groundwater flow regimes in the area, and additional environmental baseline work to prepare the project for permitting and mine development.

Feasibility studies will investigate several potential development scenarios. Work is underway on both a revised resource/reserve estimate for the deposit, incorporating the results of the 2018 drill program, and advanced metallurgical studies which will feed into the feasibility study, which is targeting the 4th quarter of 2019 for completion.

The McIlvenna Bay deposit is classified as a Felsic-Siliciclastic VMS deposit within the rocks of the Hanson Lake Assemblage and Foran’s Bigstone deposit, situated 25 km to the west, is a high-grade Cu-rich VMS within the rocks of the Northern Lights Assemblage. Numerous exploration targets exist in the Hanson Lake District within the prospective stratigraphic packages that host McIlvenna Bay and Bigstone. The exploration potential for the discovery of additional high-grade zinc and/or copper VMS deposits in the Hanson Lake District is high and Foran will continue its focus on additional discoveries in 2019.

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Technical Session 4: Emerging Projects and Advances in Exploration
Results from the Brine Sampling Project: Investigating the Lithium Potential of Brines in Saskatchewan

Gavin K.S. Jensen ¹

Abstract

Deep formation brines are a source of a variety of industrial minerals in other basins around the globe, including compounds of bromine, iodine, lithium, magnesium, and potassium. Typically, only major ions analyses are completed, and these trace elements are not included in routine oil and gas analysis. The recent surge in lithium carbonate demand has resulted in the need for other sources of lithium to be investigated; one such source could be formation waters.

In 2011, the Saskatchewan Geological Survey initiated a formation fluids sampling project that targeted currently producing oil and gas wells penetrating Paleozoic strata in Saskatchewan. The objective of this study is to investigate the abundance, and stratigraphic distribution, of naturally occurring minerals in the formational brines in the province of Saskatchewan. The geochemical analyses from these samples are the first to populate a public “exploratory” database of trace element compositions of sub-surface brines in the province of Saskatchewan.

The application of halogen systematics can be applied to these newly collected samples which could elucidate the history of brine migration. These results may be able to provide a better understanding of the fluid migration in the basin and the potential for future hydrocarbon and mineral discoveries. Preliminary results indicate that some samples derive their salinity from evaporitic concentration, while other samples derive their salinity from halite dissolution.

Another factor that was investigated was the possibility of varying brine composition through time. Wells that displayed high concentrations of lithium were resampled five years apart to determine if the brine composition had varied.

These initial results could foster another industry in the province of Saskatchewan and lead to a better understanding of fluid migration in the Williston Basin.

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Digital Petrography – Application of Automated Mineralogy to Revolutionize and Revitalize Petrology

Lucy Hunt ¹ and Steven Creighton ¹

Abstract

Optical mineralogy has been the only method for detailed observations in petrology from its inception in the 1820s until the invention of the electron microprobe in the 1950s. Until now there has not been an efficient method available to combine quantitative mineral abundances and mineral chemical compositions with the qualitative and intuitive textural interpretations of a skilled petrographer. Digital petrographic analysis by QEMSCAN is a major technological leap forward that is revolutionizing petrology.

QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy) analysis was developed to provide essential mineralogical and textural information for extractive metallurgy. The technology combines back-scattered electron images and semi-quantitative point chemical analyses to generate mineralogical data maps. QEMSCAN analysis, applied to petrographic thin sections, rock cores or fragments, generates a pseudocolour map of the entire thin section, or a representative section of a core or fragment, comprising millions of individual analyses.

One of the advantages of digital petrography is the ability to identify mineral subtypes rather than broad groups. For example, it is possible to determine and map the abundance of different types of chlorite (chamosite, sudoite and clinochlore). Additionally, it becomes possible to identify minerals with atypical compositions (e.g., fayalitic olivine or spessartine-rich garnets). Combining the textural and mineralogical data reveals a greater depth of the history of a sample; elucidating prograde and retrograde metamorphic changes or multiple fluid-related alteration events.

Digital petrography provides the best method for analysing very fine-grained or heavily altered, effectively opaque, rocks. The spatial resolution of QEMSCAN is the activation volume of the mineral being analysed, typically 1-3 μm, finer than the resolving power of most petrographic microscopes, and certainly too fine for accurate mineral identification and point counting. For siltstones and mudstones with digital petrography, parameters such as modal mineral abundance, grain size, and microstructural features (e.g., porosity, fractures and vein characterisation) are all collected and imaged, most of which would be too small to be determined by traditional petrography. Highly altered and opaque samples, such as are common in uranium deposits, are virtually impenetrable by optical microscopy, but digital petrography, being based on chemical composition, is not limited to only investigating transparent minerals.

Digital petrography can be performed on any flat polished surface, whether this is a traditional thin section, a thick section, a cut piece of rock or a core, with features down to 2 microns being identified and characterised. The qualitative chemistry allows for different mineral species to be identified, and the quantitative chemical composition measured by electron microprobe can augment the qualitative mineralogy to further enhance one’s understanding of the sample. Digital petrography by QEMSCAN is a major advancement in petrology, comparable to the invention of optical petrography.
The Patterson Lake Alkaline Igneous Complex: Evidence for Deep-Seated Structural Control in the Patterson Lake Corridor, and Implications for Mineral Exploration

Colin D. Card

Abstract

A suite of alkaline igneous rocks and associated alteration facies is named the Patterson Lake alkaline igneous complex. The alkaline rocks are nested in wide zones of metasomatic rock, likely fenites, that are typically burnt orange or green in colour. Amphibole-bearing syenites are among the oldest of the alkaline intrusive rocks. Several xenolith-rich clinopyroxene syenite dykes are also nested in the fenitized zones. White to light green clinopyroxenite dykes are associated with the fenites locally. Xenolith-rich, calcite carbonatite dykes are the youngest constituents of the Patterson Lake alkaline igneous complex and are associated with a second phase of light green metasomatic rock.

Alkaline igneous complexes, and carbonatites in particular, are associated with rare-earth element and rare-element mineralization. The Patterson Lake alkaline igneous complex is spatially associated with the Fond du Lac gravity low anomaly. The anomaly is underlain in part by ca. 1843 Ma granites of the Clearwater Domain and granites of similar age, e.g., ca. 1810 Ma, north of the Athabasca Basin. A swarm of ca. 1825 Ma lamprophyre dykes north of Lake Athabasca falls within the known age range of the granites, as do the ca. 1818 Ma Uranium City alkaline mafic dykes and the comagmatic alkaline mafic volcanic rocks of the Martin Group. The working model is that the Patterson Lake alkaline igneous complex was emplaced via deep-seated structures rooted in the region of the Fond du Lac gravity low, which is the geophysical expression of a zone of extension that was active between 1.85 and 1.80 Ga.
The Geological Evolution of High-Grade Rare Earth Element Mineralization on the Alces Lake Property, Northern Saskatchewan

James Sykes 1 Irvine R. Annesley 2 and Krisztina Pandur 3

Abstract

The Alces Lake property, northern Saskatchewan, is an emerging world-class high-grade rare earth element ("REE") deposit endowed with critical REEs required for the permanent magnet industry. Surface channel samples and diamond drill hole results have identified total rare earth oxide ("TREO") concentrations exceeding 20 wt% TREO in multiple zones at or near surface, including maximum concentrations of 53 wt% TREO.

Over the course of June to September, 2018, Appia Energy Corp. completed a field program exploring for rare earth elements, which consisted of i) overburden stripping that delineated 7 REE zones at surface (Bell, Charles, Dante, Dylan, Ivan, Wilson and Wilson South-Central), ii) the collection of 844 systematic channel samples taken from all 7 exposed zones, iii) the collection of 6 heavy mineral black beach sand samples exploring for sediment-hosted monazite and REEs at surface, and iv) completion of the first-ever diamond drill program on the Alces Lake property; 15 diamond drill holes into 3 zones (Charles, Ivan and Wilson).

The REEs are completely hosted within monazite; a REE-rich phosphate with proven and successful economic extractability for over 50 years. Monazite, a red mineral, is coarse-grained, on average spanning 0.5 to 3.0 mm across the widest axis.

Monazite tends to form as isolated grains, banded, or as clustered masses exceeding 85% monazite at the Ivan and Dylan zones, for example. Previous studies of Alces Lake monazite have suggested a crystallization date of 1927.1 +/- 1.2 Ma, which puts it at the last quarter of the Taltson-Thelon Orogeny. Petrographic studies have shown monazite crystals to be euhedral to rounded, suggesting undisturbed crystalline growth for the former and a physically active lifestyle for the latter.

The world-class REE mineralization is hosted within a polyphase anatexite containing massive braided biotite schist and quartzofeldspathic pegmatite augen. Monazite appears to be equally distributed within schist and pegmatite. This mineralized anatexite system has been observed to clearly cross-cut previously solidified gneissic material, suggesting late orogenic development.

The entire geological suite at Alces Lake is part of a regional synformal anticline, with the eastern limb of the anticline hosting the REE zones. Outcrop-scale folds have been shown to influence the deposition of monazite (Charles and Ivan), but not in all cases (Wilson and Dylan). Late brittle re-activated structures in the area cross-cut regional fabric and offset monazite deposition, supporting a late relative timeframe for the formation of the polyphase anatexite.

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Drift Prospecting Around Southern Reindeer Lake

Michelle Hanson

Abstract

The southern Reindeer Lake area is prospective for gold, base metals and diamonds, consequently, a surficial geology program, including sediment sampling, was undertaken in 2017 and 2018. Southern Reindeer Lake is proximal to areas that have produced gold and base metals, and to recently discovered diamond-bearing kimberlites in areas of the exposed Sask craton. In the study area, La Ronge Domain rocks host historic gold occurrences containing up to 0.6 oz/ton gold (20.6 g/tonne; Saskatchewan Mineral Deposit Index (SMDI) files 0501 and 0513) and volcanic-associated massive sulfides containing up to 95,000 ppm Cu (9.5%; SMDI 1786) and up to 4.4% Zn (SMDI 4810). Hitherto, no public kimberlite indicator mineral (KIM) data was available for the study area; however, the Sask craton potentially extends into the study area at depth.

This surficial geology project is designed to assist with the assessment of the mineral potential of the area by conducting a regional-scale till sampling program and a reconnaissance-scale KIM and gold grain sampling program, as well as an interpretation of the local and regional glacial history. Two-hundred and thirty-four till samples were collected and fine-fraction (<0.063 mm) geochemical analysis of these samples is ongoing. Results will establish regional background till geochemistry data, as well as potentially identify prospective areas and suitable sampling media for further geochemical exploration. Thirty-eight bulk samples were collected from eskers and adjacent glaciofluvial sediments for KIM analysis and gold grain recovery. Preliminary results indicate the presence of sand-sized gold grains in some of these samples.

The glacial geology of the southern Reindeer Lake area is complex. There were at least five ice-flow phases, one of them potentially from a previous glaciation, that could have affected glacial dispersal. The area has an abundance of ideal glacial sediments and landforms for drift prospecting, including widespread till coverage, and regularly spaced glaciofluvial corridors, which are the primary target for reconnaissance-scale KIM sampling. The former, however, has been consistently modified by glaciofluvial and glaciolacustrine processes. Glaciofluvial corridors cross the area every ~10–15 km and a significant portion of the area was inundated by a proglacial lake. There is evidence suggesting a re-advance of the ice sheet into the area after inundation by the lake, which complicates identification of suitable sampling material.
Petrology, Chemistry, and Geochronology of the Pikoo Kimberlites, Saskatchewan

Denelle Smyth ¹, D. Graham Pearson ¹, C. Sarkar ¹, Larry Heaman ¹ and B. Kupsch ²

Abstract

The Pikoo kimberlite field, located in east-central Saskatchewan, is set in the Precambrian Shield of the Trans-Hudson Orogen and underlain by the Sask craton. The first Pikoo kimberlites were discovered by North Arrow Minerals in 2013 and, until now, no in-depth study on the petrology and chemistry of the Pikoo kimberlites has been published. Ten discreet kimberlite occurrences have been identified, five of which have proven to be diamondiferous. Sampling thus far indicates the best diamond grades are from the PK150 body, with less favourable microdiamond results reported from the PK346 kimberlite (http://www.northarrowminerals.com/projects/pikoo/). These two occurrences of different diamond potential were examined in detail using thin sections for petrographic analysis and an electron probe microanalyzer (EPMA) to characterize mineral chemistry. A small subset of samples from the PK151, PK312, and PK314 kimberlites, of which the latter two are diamondiferous, were also examined for comparison.

Many traditional approaches to characterizing a new kimberlite discovery are not applicable to the available samples from the Pikoo bodies due to the pervasive and intense degree of alteration that has impacted the rocks. Almost no fresh olivine remains and even relatively robust phases such ilmenite, perovskite, and spinel group minerals (including chromite) can exhibit significant alteration or replacement. Despite these difficulties, PK346 and PK150 have proved to be petrographically distinct in terms of mineralogy and alteration style and display some key differences in mineral chemistry. Ilmenite grains from both PK346 and PK150 plot in the kimberlite field defined by Wyatt et al. (2004) and have complete overlap. In contrast, groundmass phlogopite analyses from PK150 plot along the kimberlite trend while PK346 groundmass phlogopite occurs as poikilitic plates and exhibits Al-depletion, following the lamproite/orangeite trends defined by Mitchell (1995). Phlogopite from PK151 has compositions similar to PK150, while grains from PK312 and PK314 have intermediate compositions.

Preliminary U-Pb results for perovskite measured via LA-ICP-MS indicate that the Pikoo kimberlites have a lower intercept age of 415 Ma, which is significantly older than the nearby Cretaceous Fort à la Corne Kimberlite Field (~106 to ~95 Ma; Heaman et al., 2004) but similar to several kimberlites identified from the Slave craton (Orion 435.4 ± 2.8, DryBones Bay 441.4 ± 0.8, Cross 450.4 ± 2.2, Ursa 463 ± 16.0; Heaman et al., 2003). These newly-reported ages for the Pikoo kimberlites open up the possibility of more widespread diamond-bearing kimberlite activity across North America in circa Siluro-Ordovician times.


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Renewed Evaluation of the Star-Orion South Diamond Project

George Read

Abstract

Star Diamond Corporation (formerly Shore Gold Inc.) has conducted extensive evaluation on the Star and Orion South kimberlites using core drilling, large diameter drilling (LDD) and underground bulk sampling. These exploration methods provided information on kimberlite size and internal structure, diamond grade estimation and diamond price estimation, respectively, which in turn have been used to estimate the Indicated and Inferred mineral resources available within these kimberlites. The most recent mineral resource estimate was published in December 2015. In early 2018 a Preliminary Economic Assessment (PEA) was published based on the 2015 mineral resource estimate. The results of the PEA estimate that some 66 million carats of diamonds can be recovered over a 34 year life of mine (LOM), resulting in a post-tax and royalty NPV of $2.0 billion and an IRR of 19%. The pre-production capital cost is estimated at $1.41 billion with a total capital cost of $1.87 billion (including direct, indirect costs and contingency) over the LOM, and an initial capital cost payback period of 3.4 years.

In mid-2017 Star Diamond Corporation executed an option to joint venture agreement with Rio Tinto Exploration Canada (RTEC) and simultaneously agreed to convert Newmont's 31% Project interest to an equity interest in Star Diamond Corporation. Consequently, Star Diamond Corporation holds 100% interest in the mineral dispositions over the Fort à la Corne field. Rio Tinto refers to the Project as Project FalCon. RTEC commenced their field work in 2017 with the drilling of 10 pilot holes at their proposed bulk sample sites, in close proximity to the Star underground development and LDD holes. For these pilot holes, sonic cores were collected in the overburden and diamond drill core was collected from the kimberlite. During 2018 RTEC specified and ordered a Bauer CSM Rig for grouting and stabilization of the top 20 metres of unconsolidated overburden, a Bauer Trench Cutter Sampling Rig and a Bauer desanding and sample bagging plant. In addition these kimberlite samples will be processed in an on-site, state-of-the-art bulk sampling plant ordered from Consulmet. It is RTEC’s intention to drill the first Trench Cutter hole before the end of 2018. The Trench Cutter Sampling Rig excavates a 3.2 by 1.5 metre hole to a maximum depth of 250 metres below surface. Every 10 metres of advance is estimated to yield some 100 tonnes of kimberlite from which diamonds greater than 1.0 millimetres will be recovered using the bulk sample plant. It is RTEC’s intention to drill ten bulk sample holes on the Star Kimberlite and 20 holes on the Orion South Kimberlite.
Technical Posters
The Northern Manitoba Mining Academy: Providing Resource-related Training and Support for Research
Paul Alexandre ¹

Extension-driven 1850-1550 Ma Sedimentation, Magmatism, Fluid Alteration and Mineralization in the Rae Province
Ken Ashton ² and Colin Card ²

Improved Mineral Exploration, Processing, and Production Using Synchrotron Spectroscopy: Examples from Canadian Orogenic Gold Deposits
Neil Banerjee ³ and Lisa Van Loon ⁴

Structural Analysis of the Robertson and Palmer Lakes Area, Glennie Domain, Reindeer Zone, Saskatchewan, Canada
Shelby Brandt ⁵, Samantha Van De Kerckhove ² and Kathryn Bethune ⁵

Examination of White Micas at the Arrow Uranium Deposit, Saskatchewan: Preliminary Observations
Sean Cross ⁶, Sean Hillacre ⁶,⁷, Kevin Ansdell ⁶ and Brian McEwan ⁷

Geothermal Potential in Saskatchewan – Application and Feasibility
Janis Dale ⁵, Brian Brunskill ⁸ and Laurence Vigrass ⁵

University of Saskatchewan, Department of Geological Sciences Poster
Department of Geological Sciences, University of Saskatchewan: Research and Services ⁶

University of Regina, Department of Geology Poster
Department of Geology, University of Regina ⁵

The Role of Extended Basement Faults in Localization of Unconformity-related Uranium Deposits in the Athabasca Basin
Khalifa Eldursi ⁵, Guoxiang Chi ⁵, Kathryn M. Bethune ⁵, Zenghua Li ⁵, Patrick Ledru ⁹ and David Quirt ⁹

Mapping the World Distribution of Uranium Deposits (2nd edition); International Atomic Energy Agency
M. Fairclough ¹⁰, J. Irvine ¹¹, L. Katona ¹¹ and W. Slimmon ²

Research on Pores in Coal and Flow Simulation by X-ray Computed Tomography Technology
Huihuang Fang ⁶, Samuel L. Butler ⁶ and Shuxun Sang ¹²

Modelling Methane Dynamics in Fluid Fine Tailings in an Oil Sands End Pit Lake
Daniel Francis ⁶, Qinyang Liu ⁶, Sean K. Carey ¹³, S. Lee Barbour ⁶ and Matthew B.J. Lindsay ⁶

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⁹ Orano Canada Ltd.
¹⁰ International Atomic Energy Agency
¹¹ Geological Survey of South Australia
¹² China University of Mining and Technology
¹³ McMaster University
Preliminary Ice-flow History, Southern Reindeer Lake
Michelle Hanson

Development of a Plate Margin Database with Applications to Greenfields Mineral Exploration
Peter Hone and Bruce Eglington

Mineralogy and Geochemistry of the Kipalu Iron Formation, Belcher Islands, Nunavut
Simranjit Kharal and Camille A. Partin

Nature and Role of Deformation Bands in Post-Athabasca Faulting and Genesis of Unconformity-related Uranium Deposits; Case Study of the C1 Fault Zone and Related Structures in the Eastern Athabasca Basin, Northern Saskatchewan
Arin Kitchen, Kathryn Bethune, Gary Delaney and Erik Miller

In-mine Time-domain Electromagnetics Inversion and Forward Modelling Using COMSOL Multiphysics
Todd LeBlanc and Samuel Butler

Numerical Modelling of 1D & 2D Earth Magnetotellurics and the Effect of Power Line Noise on the Magnetotellurics Signal
Ang Li and Samuel L. Butler

Controls of Basement Lithologies on Strain Localization and Their Implications for the Formation of Unconformity-related Uranium Deposits in the Athabasca Basin
Zenghua Li, Guoxiang Chi, Kathryn M. Bethune, Khalifa Eldursi, David Quirt and Patrick Ledru

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Structural Comparison of Deformation Bands and Underlying Basement Units along the C1 Fault Trend, Athabasca Basin
Erik Miller, Arin Kitchen and Kathryn Bethune

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5 University of Regina
6 University of Saskatchewan
9 Orano Canada Ltd.
14 Geological Survey of Canada
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4 LISA CAN Analytical Solutions Inc. 
5 University of Regina 
6 University of Saskatchewan 
15 SSR Mining Inc.
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New U-Pb SHRIMP Result for an Intermediate Volcanic Rock, 
Western Glennie Domain, Reindeer Zone

Ralf O. Maxeiner ¹ and Nicole M. Rayner ²

Abstract

A new U-Pb SHRIMP zircon result has been obtained for an intermediate volcanic tuff breccia from the western Glennie Domain of the Trans-Hudson Orogen. The sampled rock is part of a volcanic succession west of the northern end of Lac La Ronge that represents an extension of a volcanic succession in the Sulphide Lake area to the northeast. The rock was chosen for geochronological analysis in order to test if this succession is part of one of the older (i.e., circa 1890 to 1860 Ma) volcanic assemblages previously recognized in the Reindeer Zone, or if it is part of a younger suite of circa 1848 to 1837 Ma supracrustal rocks identified along strike to the northeast and throughout much of the Reindeer Zone (i.e., Mullock Lake assemblage, McLennan Group).

The tuff breccia sampled is part of a sequence of felsic to mafic volcanic and volcaniclastic rocks, and crosscutting dykes. The breccia is interpreted to stratigraphically overlie a sequence of partly pillowed mafic volcanic flows that are ascribed to the >1864 Ma Freestone Lake assemblage.

The weighted mean ⁰⁷⁰⁷Pb/²⁰⁶Pb age of 12 analyses with low Th concentrations is 1792 ±26 Ma, which is interpreted to represent a metamorphic overprint. A single analysis of a zircon grain with more prismatic morphology yielded an older ⁰⁷⁰⁷Pb/²⁰⁶Pb age of 1877 ±20 Ma and may represent the primary crystallization age of the zircon.

Broadly speaking, the 1877 Ma single zircon age for the sampled rock is similar to that hosting volcanogenic massive sulfide (VMS) deposits in the Hanson Lake area at the western extent of the Flin Flon Domain a few hundred kilometres to the southeast (e.g., McIlvenna Bay and Bigstone deposits), although volcanic rocks hosting the deposits there are more dacitic to rhyolitic in composition. Closer to the sampled outcrop, the Elizabeth Lake deposit, 10 km to the northwest, and the Pitching Lake deposits, 70 km to the east of the sample location, are small VMS deposits that are hosted by mafic to intermediate volcanic rocks.
Geochronological Results from the Southern Athabasca Basin Region, Saskatchewan

Colin D. Card 1, Nicole Rayner 2, Graham Pearson 3, Yan Luo 3 and Rob Creaser 3

Abstract

Age determinations were obtained for three samples in the southern Athabasca region using U-Pb dating techniques. Two samples from the southwest Rae Province were dated using zircon and the SHRIMP method. The first, a diorite collected from drillcore from the basement to the southwest Athabasca Basin returned a crystallization age of 2655 ±27 Ma, with a metamorphic overprint at 1927 ±9 Ma. A Sm-Nd isotopic analysis for the sample returned a $T_{DM}$ of 3.05 Ga, with an $\epsilon_{Nd}$ of -0.6 calculated at the age of emplacement. The diorite’s age, Sm-Nd isotopic character and composition are similar to rocks in the Dodge Domain north of the Athabasca Basin.

A sample of monzogranite from the Taltson Domain south of the Athabasca Basin returned a crystallization age of 2121 ±15 Ma, with a metamorphic overprint at 1924 ±7 Ma. The sample has a $T_{DM}$ of 2.75 Ga, with an $\epsilon_{Nd}$ of -3.8 at the time of the monzogranite’s emplacement. The monzogranite was likely generated due to crustal melting associated with emplacement of the Proterozoic massif-type Clearwater anorthosite complex, which has returned a similar U-Pb zircon age.

The third sample, from the southern Hearne Province, was dated in situ using the LA-ICP-MS technique on the mineral rutile. The sample, collected from drillcore in the basement to the southeast Athabasca Basin, is predominantly constituted of hydrothermal quartz. The rutile, which is genetically related to the host hydrothermal quartz, returned an age of 1640 ±29 Ma. This age is similar to the age of tuffaceous clasts in the Wolverine Point Group of the Athabasca Supergroup. The age demonstrates that hydrothermal activity accompanied a ca. 1.64 Ga volcanic event in the Athabasca region.
Ice-flow Indicator Mapping and Preliminary Ice-flow History, 
Southern Reindeer Lake (NTS 64D/10 and /11, 
with Parts of 64D/06 and /09)

Michelle A. Hanson ¹

Abstract

Ice-flow indicator mapping was undertaken in the southern part of Reindeer Lake during the 2017 and 2018 field seasons. Southern Reindeer Lake is prospective for gold and base metals, thus a thorough understanding of ice-flow patterns and relative history is fundamental to future drift prospecting projects. Hitherto, there was a conspicuous absence of recorded ice-flow indicators in the study area. Previous data extracted from regional geological maps comprised only two crag-and-tail and eleven striation measurements, showing a preference of flow toward the south-southwest.

Nearly 1400 new measurements were made at 247 sites and at least five ice-flow phases are noted in the southern Reindeer Lake area. Larger, polished crystals in dioritic rocks and quartz veins appear to be the best surfaces on which to find micro-scale ice-flow indicators. The dominant ice-flow direction in the area, represented by the most measurements, the largest areal spread of measurements, and the most diverse indicators, is to the south-southwest. This ice flow likely represents a Late Wisconsinan, post-Last Glacial Maximum flow. Deposition of much of the sediment in the area likely results from this flow, making this direction significant for future drift prospecting projects.

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A New U-Pb Age for the Hudson Granites and Lamprophyre Dykes in the Southern Rae Province of Saskatchewan

Ken Ashton ¹, Colin Card ¹ and Nicole Rayner ²

Abstract
Crosscutting relationships amongst felsite and lamprophyre dyke sets in the south-central Beaverlodge Domain of the southern Rae Province imply that the two sets are broadly coeval. A new U-Pb SHRIMP age of 1825 ±10 Ma for one of the felsite dykes, together with lithological and geochemical similarities, suggest that the felsites are part of the Hudson granite suite, and that the spatial association of felsite and lamprophyre dykes in the Beaverlodge Domain represents an extension of the igneous association between Hudson granites and lamprophyre-minette magmatism in the central Rae and adjacent Hearne cratons. The lamprophyres and granitic rocks similar to the felsite dykes are also spatially associated with the Martin Group continental redbeds, which were being deposited at 1820 Ma. This is considered analogous to the spatial association of Hudson granites and lamprophyre-minette magmatism with the Baker Lake Group of the Dubawnt Supergroup in the Northwest Territories and Nunavut. The localities of the felsite and lamprophyre dykes in the south-central Beaverlodge Domain, and the Hudson granite, lamprophyre dykes, and Baker Lake Group in the central Rae and adjacent Hearne cratons, lie along a continuous, low-gravity corridor (Fond du Lac gravity low) that may be partly related to an abundance of these late granites and associated fluids. The inferred conduit to the mantle could be important for the transfer of economic mineral concentrations to the shallow crust. The Martin Group and minor spatially associated quartz porphyries and granite pegmatites lie along a separate but parallel, less-intense gravity low in the hanging wall of the Black Bay fault, which may have provided a linked conduit for igneous products generated in the Fond du Lac gravity low.

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Notes