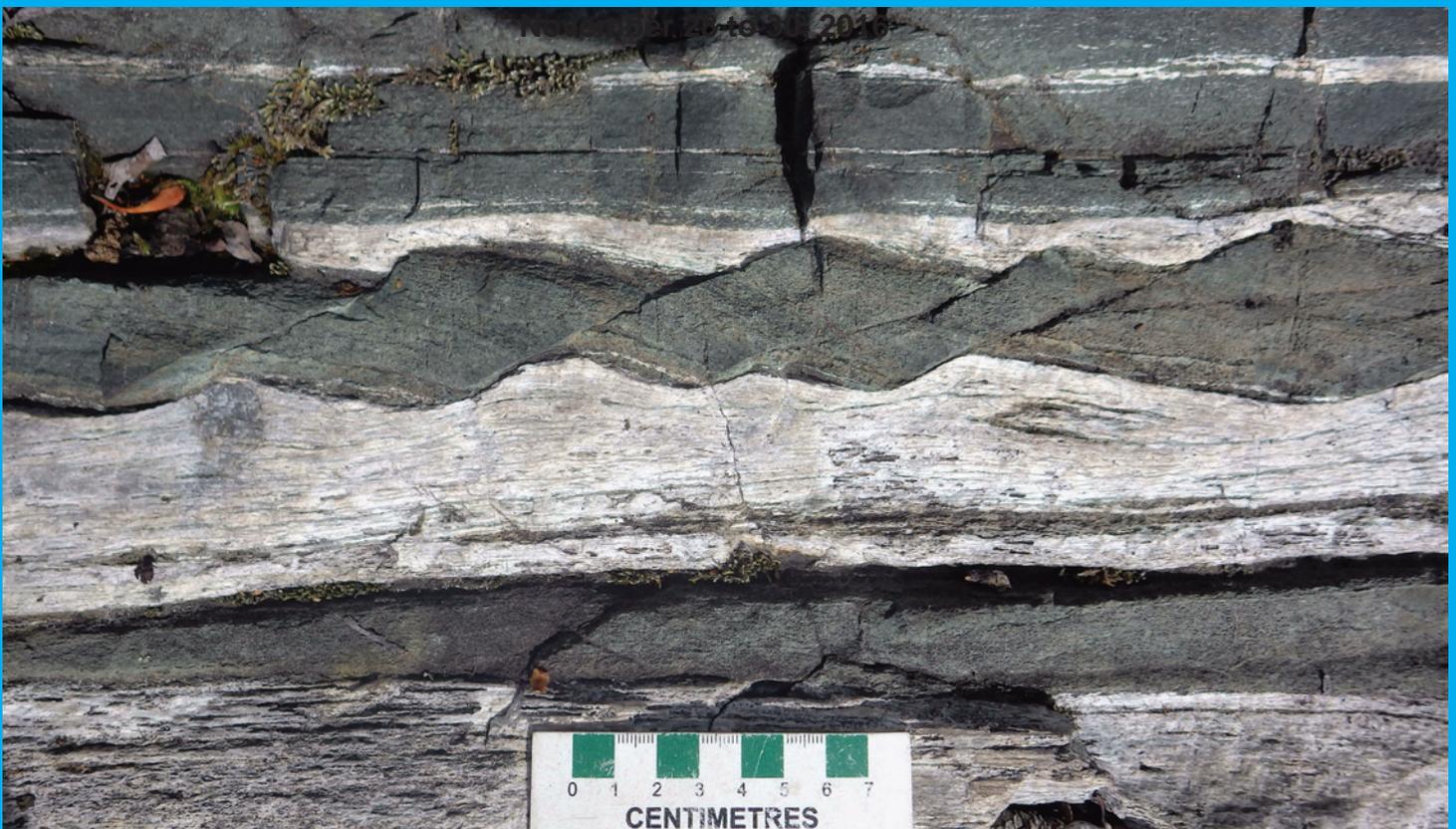


Open House 2016
November 28 to 30, 2016
Abstract Volume

Saskatchewan
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Cover:

Part of the Snowbird Tectonic Zone, the Tantato Domain in north-central Saskatchewan retains evidence of a lengthy history of deformation, spanning the Archean to the Proterozoic Eons. Bedrock within this domain preserves pervasive dextral and sinistral mylonitic fabrics developed during the Archean Eon, and more confined mylonite zones produced during deformation that extended into the Proterozoic Eon.

The four-centimetre-wide layer of mafic rock within leucotonalite mylonite visible in the centre of the photo on the cover (photo courtesy of Anastasia Comtois-Poissant) is an excellent example of an indicator of the sinistral sense of shear that accompanied Proterozoic ductile deformation along the four- to six-kilometre-wide, 1.90 to 1.87 Ga Cora Lake shear zone in the southern part of the Tantato Domain. Segments of the shearband-boudinaged layer of mafic rock—developed between north-northeast-striking, synthetic sinistral shear bands oriented at a 35° angle to the foliation in the confining envelope of thicker, foliation-parallel (N245/62°) mafic layers—show an asymmetric clockwise rotation of 15°. Domino-style boudinage that produced foliation drag and counterclockwise asymmetric rotation of mafic layers between east-southeast-striking antithetic dextral shears was also observed at this location. Within the Cora Lake shear zone, gold mineralization locally accompanied quartz veining that developed along much narrower (~100 m), southwest-striking sinistral shear zones during uplift of the Tantato lozenge through the transition between ductile and brittle rheologic styles of deformation.

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* Indicates a paper found in the *Summary of Investigations 2016, Volume 2*. These papers are found at: <http://www.publications.gov.sk.ca/deplist.cfm?d=310&c=4774> under 'Summary of Investigations'.

Technical Session 1: Uranium Geoscience and Exploration

The Spatial Distribution of Identified and Speculative Global Uranium Resources

Martin Fairclough ¹, Bill Slimmon ², Mark Mihalasky ³, Francine Mihalasky ⁴, Laszlo Katona ⁵,
Malcolm Aranha ¹ and Jonathon Irvine ⁵

Abstract

The International Atomic Energy Agency (IAEA) provides a number of avenues to better understand current and future uranium supply and demand relationships for the use of "Atoms For Peace And Development" on behalf of its Member States. These include Uranium – Resources, Production and Demand (the "Red Book") and the World Distribution of Uranium Deposits (UDEPO) database. The former reports Member States' viewpoints on Identified (IR), Unconventional, and Undiscovered/Speculative (SR) resources, and is on the order of a total of 21 Mt U of approximately 7 Mt each in recent times. However, historically much of IR has not been extracted, due to various technical, social, economic or political reasons, while production of unconventional resources has additional technical and economic restrictions. Moreover, reported figures for SR are ad hoc and poorly documented, cannot be relied upon for production projections, as well as potentially being several decades away from being extracted. Therefore, the actual amount of uranium available to satisfy demand is significantly lower than could be optimistically estimated.

IAEA partners with experts from Member States to provide solutions to such supply issues, and in particular, in delineating the spatial distribution of uranium mineralisation to provide a framework for future deposit discovery. Previous maps of global uranium deposits are several decades old (1995), and recent expansion of the UDEPO database has provided the opportunity to show the distribution of IR in a far superior manner with a greater number of deposits and wider range of sizes, accompanied by a new deposit classification scheme and additional supporting information not previously available. Improved and expanded information for grades and tonnages is allowing statistical generation of quantitative assessments accompanied by uranium province and permissive tract delineation. While not uncommon for other commodities, few public quantitative assessments have previously been carried out for uranium on the province scale, even fewer at a national scale (such as the NURE in United States), and none at the global scale. One notable and semi-quantitative attempt is the International Uranium Resource Evaluation Project (IAEA-OECD, 1978-1984), which concluded that there was 6.6-14.8 Mt U of speculative resources, as well as an additional 3.3-7.3 Mt U in less well documented areas of the former Soviet Union and China. While these figures are not statistically based or repeatable, being based solely upon expert opinion, they are the only available figures for the moment.

The forthcoming World Distribution of Uranium Deposits map and the updated and expanded UDEPO, as well as a number of Technical Documents related to uranium provinces, spatial and quantitative modelling techniques, and case studies, will provide far more robust insights into current and future uranium supply and the nature of actual and potential uranium resource distribution.

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Ore-System Controls and Implications for the Unconformity-Related Uranium Model: The View from the Western Athabasca Basin

Colin Card ¹

Abstract

Framework geological investigations of drillcore from several uranium exploration projects in Saskatchewan's western Athabasca Basin region were undertaken in order to better characterize the geological controls on uranium ore systems in crystalline rocks of the Rae Province, which lie below the Athabasca Supergroup. Two major basement rock types were identified in the region. The first comprises orthogneisses derived from quartz monzodioritic or quartz dioritic protoliths, with the original composition of the original plutonic rocks difficult to discern due to later alteration. The second is a suite of mafic to ultramafic plutons that intruded the orthogneisses. Variable composition (gabbro to clinopyroxenite) and grain size (fine and coarse grained) suggest that the mafic to ultramafic suite was originally a layered intrusive complex.

The rock units have been observed in drillcores derived from drilling that targeted fault zones with long fluid-flow histories. As a result, metasomatic mineral assemblages that predate uranium mineralization are common. Albitization is suspected to be amongst the oldest metasomatic events and is developed in the orthogneisses. In the mafic to ultramafic suite, an early assemblage of chlorite and white mica prevails. These events preceded at least two pervasive silicification events. In the mafic to ultramafic suite these events led to disaggregation and further sericitization of the rocks. At least two later phases of vein quartz crosscut the silicified mafic to ultramafic rocks. Pervasive silicification converted the orthogneisses into 'pseudopelites'. Pseudopelites contain a mineral assemblage similar to those in high-grade metapelites, which includes plagioclase, quartz, biotite, garnet and sillimanite. However, in pseudopelites no two minerals in the assemblage were stable at the same time. Biotite is the oldest mineral and was consumed first by plagioclase and then by quartz, which consumed both minerals. Protracted silicification led to the destruction of biotite and plagioclase with both minerals replaced by sillimanite. Both sillimanite and biotite were also replaced by garnet. As silicification proceeded, garnet was eventually replaced by quartz. Therefore, crosscutting relationships suggest that this mineral assemblage was generated by metasomatic processes rather than the original composition of the altered rocks.

Hydrothermal graphite and Fe-sulphides postdate the pervasive silicification. The minerals were emplaced in brittle-ductile structural zones that developed along competency contrasts between hard (e.g., silicified) and soft (e.g., chloritized or sericitized) rocks. In quartz-rich rocks, graphite and Fe-sulphide are hosted by anastomosing fracture networks, whereas the softer rocks were replaced. Uraniferous fluids later used the same fault systems and the resultant mineralization overprinted the graphite and Fe-sulphide-bearing structures.

The metasomatic mineral assemblages documented in crystalline rocks in the fault zones of the western Athabasca region are very similar to those of the eastern Athabasca Basin, regardless of original rock protolith. Therefore it is reasonable to assume that similar pre-ore geological processes were active in deep-seated structures across the Athabasca region.

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Arrow: The Basin's Largest Undeveloped Deposit

Garrett Ainsworth ¹

Abstract

The Arrow Deposit is a basement-hosted uranium discovery made by NexGen Energy Ltd. in February 2014 at its Rook I property in the southwest Athabasca Basin, northern Saskatchewan. On March 3, 2016 NexGen announced the results of its maiden independent Mineral Resource estimate for the Arrow Deposit. Based on holes drilled and assayed to the end of October 2015 (AR-14-01 to AR-15-62), the estimate is an Inferred Mineral Resource of 201.9 M lbs of U₃O₈ contained in 3.48 M tonnes of mineralization grading 2.63% U₃O₈.

The Arrow Deposit mineralization is associated with numerous sub-vertical graphitic shears across a strike length of 645 m, width of 235 m, and vertical extent of 920 m. Drilling from early-January to mid-November 2016 has greatly expanded mineralization to a strike length of 895 m, and a width of 300 m, which remains open in all directions. Highlights from 2016 drilling include discoveries of significant high grade mineralization within the A1 and A5 shears, and the zone 180 m southwest of the Arrow Deposit.

The Patterson corridor has uranium mineralization confirmed by drilling along an approximate 14 km strike length, of which 9 km of that strike length is covered by NexGen's Rook I property. In May 2016, Geotech flew a ZTEM survey along the Patterson corridor, which has revealed one of the most valuable geophysical datasets in the southwest Athabasca.

Regional exploration 4.7 km along trend and northeast of the Arrow Deposit has yielded another discovery, known as the Harpoon zone. This high grade discovery was unlocked with drill hole HP-16-08, which intersected 17.0 m of continuous mineralization (220.0 to 237.0 m) including 4.5 m of off-scale radioactivity (>10,000 to >61,000 cps) with dense accumulations of massive to semi-massive pitchblende.

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Advances in Radon Detection: The Evolution of RadonEx Survey Techniques

Linden Charlton¹, Josh Charlton¹ and Joshua Owen¹

Abstract

The electret ionization chamber (EIC) radon measurement technology employed by RadonEx has its conceptual roots in the early days of uranium exploration and its proof of concept in the exacting environmental and industrial/residential markets. RadonEx has succeeded in adapting this unique time-integrated technology back to its roots in uranium exploration. Since our inception in 2006 RadonEx has tested and modified the EIC technology to cover a wide range of geological and physiographic conditions. RadonEx surveys have contributed to several uranium discoveries over the past 10 years. This presentation chronicles the EIC technology and the types of surveys that we specialize in. It touches on radon flux, radon in water measurement, and the many variables that enter into interpreting radon results in field conditions.

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Unraveling and Growing the High Grade Gryphon Uranium Deposit, Wheeler River Project, Athabasca Basin, Canada

Chad Sorba ¹, Clark Gamelin ¹, Yongxing Liu ¹, Lawson Forand ¹ and Dale Verran ^{1,2}

Abstract

The high grade, basement hosted Gryphon Uranium Deposit is located on the Wheeler River Project in the southeastern portion of the Athabasca Basin between the McArthur River uranium mine and the Key Lake mill complex. The deposit was discovered in early 2014 and was estimated to contain inferred resources of 43.0 million pounds U₃O₈ (above a cut-off grade of 0.2% U₃O₈) based on 834,000 tonnes of mineralization at an average grade of 2.3% U₃O₈ in the maiden NI 43-101 mineral resource estimate completed in late 2015. The Wheeler River Project is a joint venture between Denison Mines (60%), Cameco (30%) and JCU (10%).

The Gryphon deposit occurs within metamorphosed pelitic basement rocks of the Wollaston Supergroup, Hearn Province, below the unconformity with the overlying, relatively undeformed Athabasca Group sandstones. In the vicinity of the deposit the basement stratigraphy dips moderately to the southeast and a marked change in the regional basement stratigraphic strike, from northeast to north-northeast, is observed. The deposit plunges to the northeast along a fault zone (the G-Fault) which occurs along a rheological boundary between hangingwall graphite-rich pelitic gneisses and a more competent pegmatite-dominated footwall. The deposit comprises a series of stacked, parallel lenses (A, B and C Series) conformable to the stratigraphy and dominant S₁ foliation and is intimately associated with brittle fault strands and graphite-rich pelitic gneisses. The plunge of the deposit is controlled by structural dilation as a result of reverse-sinistral faulting over shallower S₁ foliation dips. Higher grades and thicknesses correspond with larger fault displacements. Mineralization within the lenses is dominated by massive, semi-massive or fracture-hosted uraninite associated with an alteration assemblage comprising hematite, dravite, tourmaline, illite, chlorite and kaolinite. Secondary uranium minerals, including uranophane and carnotite, and associated sulphides are trace in quantity. A prominent conformable 'quartzite' occurs along the G-Fault and is interpreted to represent a zone of pre- or syn-mineralization silicification. A distinctive geochemical and clay-rich alteration halo is evident surrounding mineralization, occurring preferentially in basement pelitic gneisses, and extending upward into the basal portion of the Athabasca sandstone along the mineralized fault structures. Elevated values of uranium, molybdenum, lithium, selenium, yttrium, radiogenic lead and bismuth define a geochemical halo with boron occurring most distal from mineralization. Progressive alteration of cordierite porphyroblasts within pelitic gneisses serve as a vector grading towards mineralization while dravite, paragonite, clay-sericite and quartz-silicification dominate proximal to mineralization.

Further exploration drilling in the vicinity of the Gryphon deposit during 2016 has discovered additional mineralized lenses (D Series) occurring in the pegmatite-dominated footwall. These lenses are generally conformable to the stratigraphy and are intimately associated with subordinate graphite-rich pelitic gneisses and a newly identified Basal Fault comprising numerous brittle fault strands. Pre- or syn-mineralization cross faulting, which is difficult to detect due to drill hole orientations, is being recognized to play an important role in the distribution and grade of mineralization. To date, two significant cross faults have been identified supported by structural measurements and modelling of geochemical and spectral clay data.

Exploration success in recent years is a result of continued evaluation of model concepts and further recognition of the important geologic indicators. The results to date demonstrate that Gryphon is part of a large and robust mineralizing system with the potential to host additional zones of basement hosted uranium.

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² The abstract was reviewed by Dale Verran, MSc, Pr.Sci.Nat., Denison's Vice President, Exploration, who is a Qualified Person in accordance with the requirements of NI 43-101. For further related technical information and technical documents and reports please see Denison's profile on SEDAR (www.sedar.com).

Lithostratigraphic and Structural Controls of Uranium Mineralization in the Kiggavik East, Centre and Main Zone Deposits, Thelon Basin: A Potential Analogue for the Athabasca Basin

Dillon Johnstone ¹, Kathryn Bethune ¹, Dave Quirt ² and Antonio Benedicto ²

The Kiggavik uranium (U) deposits are located in the central part of the Rae subprovince, approximately 80 km west of Baker Lake, Nunavut, and are primarily owned and operated by AREVA Resources Canada Inc. Like uranium deposits present in northern Saskatchewan's Athabasca basin, the Kiggavik deposits are considered to be unconformity-related uranium deposits, by which younger siliciclastic sediments of the Thelon basin overlay highly deformed U mineralization hosting Paleoproterozoic and Archean basement rocks along an angular unconformity. The tectonic history of these basement rocks is remarkably protracted and complex, extending from the Archean (2.8 Ga) to the Mesoproterozoic (1.5 Ga). This complexity has led to uncertainty regarding the affiliation of rock units and the controls on U mineralization at Kiggavik. The aim of this study is to better determine the lithostratigraphic and overall structural relationships of rocks hosting the Kiggavik East, Main, and Centre Zone deposits, thereby providing an analogue for U mineralization in the Athabasca basin where similar controls may be present.

In 2015, detailed drill-core investigation and mapping around the Kiggavik East, Main, and Centre Zone deposits reaffirmed the presence of <2.7 Ga metasedimentary rocks of the Archean Woodburn Lake group (WLg), ~2.6 Ga metavolcanic rocks of the Snow Island Suite (SIS), and quartzite belonging to the early Paleoproterozoic Ketyet River group (KRg). Further, field observations, geochemical analysis, and petrographic investigations during this study revealed that an unusual unit of metavolcaniclastic rocks, inferred to be of epiclastic origin and part of the SIS suite, is more extensive than previously thought. This unit occupies intervals up to 100 m thick and appears to be a major host of U mineralization.

Drill-core investigation in the Kiggavik East area also verified that the KRg quartzite, and other rock types, define a homoclinal sequence of alternating gently north-northwest-dipping units. Assuming that regional age/stratigraphic relationships are correct, there are numerous down-hole younging direction reversals, suggesting that these repetitions are tectonic. A tectonic origin is also supported by the ubiquitous strong transposition of primary bedding and highly-strained contacts parallel to foliation, as well as the presence of east-northeast-trending mesoscopic-scale isoclinal recumbent folds. The current geometry of these units is therefore attributed to regional-scale early ductile D₁ or D₂ structures with nappe style isoclinal or sheath folding along a décollement, with possible local over-thrusting of the basement WLg. The degree of control of the U mineralization by older ductile structures versus younger brittle structures remains unclear. For example, mineralization is localized in part along early ductile contacts, especially in the epiclastic unit where it is next to the quartzite. However, mineralization also bears a close spatial relationship to larger regional-scale brittle structures that developed in a Riedel shearing system in response to the main Thelon Fault. D-shear and P-shear structures appear to have primary controls on U mineralization at the Main and Centre Zone deposits.

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Unresolved Issues in the Beaverlodge Uranium District

Ken Ashton ¹, Guoxiang Chi ², Rong Liang ³ and Jacklynn Kennicott ⁴

Abstract

The Beaverlodge uranium district comprises variably mylonitized Archean to Paleoproterozoic granitoid and supracrustal rocks that last underwent amphibolite facies metamorphism and ductile deformation at 1.90 Ga. Following exhumation, the Rae craton was subjected to ca. 1.84 Ga accretionary tectonic activity to the west and to multiple 1.83-1.80 Ga tectonothermal events during the Trans-Hudson orogeny. The resulting distal tectonic effects included widespread faulting in the Beaverlodge district, leading to deposition of the Martin Group redbeds, and coeval crustal extension, which led to the emplacement of alkaline mafic volcanic rocks and dykes, and lamprophyres. Uranium mineralization developed in breccia zones along basement faults and disseminated nearby, and as veins cutting both the basement and Martin Group. The increased rock permeability along these deformation zones facilitated fluid flow, resulting in fluid alteration (e.g., hematitization, albitization) and uranium mineralization. However, several aspects of the mineralizing process remain unresolved (e.g., timing relative to Martin Group deposition and albitization, sources of fluids and uranium, ore precipitation mechanisms).

Uranium was neither gained nor lost during replacement albitization, and the pitchblende within deposits hosted by albitites is generally restricted to crosscutting fractures and veins; however, many granite-hosted pitchblende occurrences within fracture zones also contain albitite, and many mineralized quartz and carbonate veins are rimmed by albite.

Geologists have long debated the role of the Martin Group based on its spatial association with many deposits. Although the Martin Group is mineralized, the biggest deposits are located in the basement, and many of those are associated with a series of faults that appear truncated by the Martin basin. This, together with a distinction between 'breccia ore', which dominates within the basement-hosted fault zones, and 'vein ore', which occurs as monomineralic and pitchblende-bearing quartz and/or carbonate veins in both the basement and Martin Group, may indicate multiple mineralizing events.

Fluid temperatures calculated from chlorite geothermometry (300-330°C) suggest a deep magmatic-metamorphic source for the main breccia-type mineralizing event, whereas lower temperatures (100-250°C) and fluid pressures derived from fluid inclusion work on veins infer a shallow source (i.e. the Martin sedimentary basin). However, the stable isotopic compositions of mineralized veins are consistent with derivation from the mixing of two fluids derived independently from the basement and Martin Group.

The non-continuous nature and apparent low permeability of the Martin Group make it an unlikely source of uranium relative to the extensively mylonitized, dominantly granitic rocks in the basement. It is unclear whether the metals that characterize the complex deposits (e.g., Ni, Co) are also locally derived or emplaced from depth.

There are probably multiple triggers for pitchblende precipitation, including the reduction of uranium (U+6) by ferrous iron in chloritic fault zones. In vein-type ores, precipitation may result from the mixing between an oxidizing, U-bearing fluid and a reductant-bearing fluid, coupled with a decrease in fluid pressure caused by fracturing.

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Effective Utilization of the Seismic Reflection Technique, in the Athabasca Basin, with Moderate Cost

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Through the support of several industrial and institutional partners, the Seismic Laboratory of The University of Saskatchewan has now participated in a number of active seismic reflection experiments, both on the west and east sides of the Athabasca Basin. Results of the investigations at Shea Creek, McArthur River, and Keefe Lake illustrate that the seismic investigations can provide an effective and highly relevant structural image of the subsurface, with resolution which no other geophysical technique can match. Correlation of similar seismic signatures, on several distant but inter-related seismic sections, allowed spatial extension of promising exploration target zones previously unrecognized. Within the 3D seismic volume comparable reflectivity patterns defined the complex areal distribution of mineralization related fault system. Beyond these novel contributions, extended analysis of seismic signal attributes (amplitude, frequency), optical televiewer [OTV], and full-wave [FWS] data offer detailed lithological characterization, including alteration zones, clay content, as well as porosity and fracture density information. All these structural and geologically relevant anomalies are primary indicators of mineralization. Contrary to all these novel advantages, the seismic method is still not a standard component of the Athabasca Basin exploration process, mainly because of its negative attribute of "it is very expensive". Comparing the costs of all geophysical techniques to the cost of a single logged drill-hole illustrates that the results of a properly designed seismic data acquisition program not only leads to more effective planning of a drilling program, but also would lead to a much quicker recognition of the major mineralized zone(s), by reducing the number of required exploratory boreholes. And, as a consequence would translate into a significant reduction of the total exploration expenditure. Unquestionably, the drilling of boreholes provides the most explicit reliable information to a certain depth, but only within a very small area. Directly connecting the borehole information to seismic results extends the reliability regionally, thus facilitating a reduction in the number of boreholes drilled and hence increasing the efficiency of the exploration programs.

Selected Bibliography

Fritz, F.P. (2000): The economics of geophysical application; in Ellis, R.B., Irvine, R. and Fritz, F. (eds.), *Practical Geophysics III for the Exploration Geologist*, Northwest Mining Association, *Practical Geophysics Short Course 1998, Selected Papers*.

Hajnal, Z., Takacs, E., Pandit, B. and Annesley, I.R. (2015): Uranium mineralization indicators from seismic and well log data in the Shea Creek area at the southern margin of the Carswell impact structure, Athabasca Basin, Canada; *Geophysical Prospecting*, doi: 10.1111/1365-2478.12274., p.1-24.

Takacs, E., Hajnal, Z., Pandit, B. and Annesley, I.R. (2015): Mapping of alteration zones with seismic-amplitude data and well logs in the hard-rock environment of the Keefe Lake area, Athabasca Basin Canada; *The Leading Edge*, <http://dx.doi.org/10.1190/tle34050530.1>, p.530-538.

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Basement Hosted Mineralization at the Christie Lake Project

C. Trevor Perkins ¹ and Nancy Normore ¹

Abstract

Christie Lake is a uranium project located just 9 km northeast and along strike of Cameco's McArthur River mine, the world's largest uranium mine. The P2 fault which hosts all of the mineralization at McArthur extends onto the Christie Lake Project and we believe is the same fault that is hosting the known mineralization at Christie Lake. The project is currently owned by JCU (Canada) Exploration Company Ltd. (90%) and UEX Corporation (10%). In early 2016, JCU and UEX entered into an option agreement by which UEX can earn up to 70% ownership. UEX is the project operator.

PNC Exploration Canada Co. Ltd. originally started (the project) between 1985 and 1990 and actively explored the property until 1997. Exploration resulted in the discovery of two adjacent mineralized zones, the Paul Bay and Ken Pen deposits, with non NI 43-101 compliant geological resources totaling 20.87 million lbs. U₃O₈ with an average grade of 3.22% U₃O₈. These two deposits sit at the southwest end of a 1.5 km long mineralized conductive trend defined by ground electromagnetic surveys. Additional conductors on the property remain sparsely tested or completely untested with diamond drilling.

The Christie Lake Project lies within the western part of the Wollaston Domain that is part of the Cree Lake Mobile Zone of the Trans-Hudson Orogen. Depth to the unconformity between the Archaean granite or Aphebian metasedimentary assemblage and the overlying Helikian Athabasca Group sandstone and conglomerate ranges from about 405 to 485 m. Sandstone outcrop exposure is very poor due to glacial overburden cover of up to 90 m. Sandstone above the unconformity is structurally disrupted, clay (kaolinite-illite-sudoite) enriched and locally anomalous in uranium. The unconformity, however, is not disrupted.

The Wollaston Group was deformed and metamorphosed during the Hudsonian Orogeny. Within the project area, major faults trending northerly, northeasterly, easterly and southeasterly have been inferred from the regional magnetic data. Evidence of multiple folding and faulting has also been encountered by drilling in the western part of the property. The northwest trending Mackenzie diabase dikes have not been encountered by drilling. Basement metamorphic rocks have been subdivided into two units, an "Upper Unit" and a "Lower Unit". The Upper Unit consists mostly of metasediments and the Lower Unit mainly of psammites and quartzo-feldspathic gneisses. The Upper Unit includes a graphitic unit near its base. The clay assemblage in the basement is dominated by kaolinite-illite-sudoite ± clinocllore.

Uranium mineralization is basement-hosted, fracture-controlled to disseminated, and monomineralic. Mineralization is closely related to the graphitic unit that is often brecciated. Lead, nickel, cobalt, vanadium, molybdenum, boron and gold are anomalous within the mineralized areas. Quartzite and quartz-rich lithologies are generally below, or sometimes inter-fingered with the graphitic package. These units provide the competency contrast along which faulting and mineralization is concentrated.

UEX is applying modern-day uranium exploration thinking to expand the two known deposits down-dip below the unconformity and continue exploration along the 1.5 km mineralized trend, which extends to the northeast. Growing resources at Christie Lake will add to UEX's substantial Athabasca Basin-hosted uranium resource inventory, underpinned by our existing quality uranium deposits hosted at our Hidden Bay and Shea Creek projects.

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**Technical Session 2: Geology and Mineral Deposits
of the Reindeer Zone**

Insight into the Crustal Structure and Mineral Potential of the Western Reindeer Zone, Eastern Brabant Lake–Western Wapiskau River Area

Ryan M. Morelli ¹, Zhang Yinghui ² and Jaida L. Lamming ³

Abstract

Bedrock mapping was undertaken at 1:20 000 scale in the eastern Brabant Lake–western Wapiskau River area in 2016 to better define the geological history and mineral potential of the west-central Reindeer Zone. Two distinct lithostructural sequences are exposed in this area, each likely corresponding to major, previously designated thrust sheets that are integral to the crustal structure of the western Reindeer Zone. The eastern sequence, part of the Wappasini sheet, is underlain by an igneous-dominated assemblage comprising mafic to intermediate volcanic sequences, some with minor felsic components, that are cut by an array of intrusive rocks. The latter include fine- to coarse-grained mafic and intermediate constituents, some of which are probably contemporaneous with the volcanic rocks, though are dominated by widespread medium-grained granodiorite and tonalite plutons. The western sequence, defining the Kyaska sheet, consists of a sedimentary-dominated assemblage of migmatitic psammopelite and pelite, with thin vestiges of calcic sedimentary interlayers associated with minor dioritic constituents. A domal feature exposed within the sedimentary rocks on easternmost Brabant Lake exposes medium-grained felsic to intermediate plutonic rocks, collectively designated as the Eastern Brabant Plutonic Complex (EBPC). Thin, semicontinuous layers of mafic to intermediate volcanic rocks are spatially associated with these plutonic rocks and exhibit both tectonic and intrusive contacts with them. Mylonite zones, some with brittle overprints, are observed at contacts between the sedimentary rocks of the Kyaska sheet and plutonic rocks of the EBPC, as well as in the northeast part of the map area along the Wapiskau River. Though not exposed, the boundary between the sedimentary-dominated western sequence (Kyaska) and the igneous-dominated eastern sequence (Wappasini) is defined by a marked topographic low that is interpreted to represent a tectonized zone. Rocks in the map area have been affected by at least two early isoclinal folding events (D_1 , D_2), a widespread set of later (D_3) upright, north-trending, tight to close folds that control the gross structural distribution of lithological units, and later (D_4) open, upright, east-southeast-trending folds. The rocks have been metamorphosed under a minimum of upper amphibolite facies conditions, with widespread evidence of metamorphic-derived partial melting. Collectively, the lithological and structural characteristics of the rocks fit well within the existing thrust sheet model and indicate that the EBPC is a structural inlier of Wappasini sheet rocks mantled by sedimentary rocks of the Kyaska sheet. Furthermore, widespread mylonites exposed in the northeast along the Wapiskau River might represent basal portions of the Wappasini sheet, and rocks of a structurally underlying (Cartier?) thrust sheet might be exposed in the vicinity. The main economic potential for rocks of the area is for volcanogenic massive sulphide–related copper and zinc, as indicated by the presence of minor sulphidic zones and possible syngenetic alteration associated with some of the volcanic rocks.

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Structural-Stratigraphic Transitions and their Implications for Base Metal Mineralization in the Brabant Lake Area of the Reindeer Zone

Kent Pearson ¹ and Graham Gill ¹

Abstract

The Brabant-McKenzie deposit (the "Brabant-McKenzie" or "Deposit") is located approximately 175 km northeast of La Ronge, Saskatchewan just off of Highway 102. Murchison Minerals Ltd. ("Murchison") acquired Brabant-McKenzie through a 2014 merger of Flemish Gold Corp. and Manicouagan Minerals Inc.

The Deposit is classified as a metamorphic volcanic massive sulphide and has often been compared to the Geco deposit of Manitouwadge, Ontario. It is hosted in a series of gneisses and amphibolitic units, all of which are variously intruded by pegmatitic dykes. Regional metamorphic grades range from upper amphibolite to lower granulite facies.

Disseminated to massive mineralization is dominated by pyrrhotite, pyrite, chalcopyrite and sphalerite plus or minus galena. Two main mineralized zones have been defined as the Upper Mineralized Zone and Lower Mineralized Zone with modeled stringer zones(?) defined as Hangingwall and Footwall zones.

Mineralization is defined over a distance of approximately 1 km and down dip over 500 metres. Murchison believes, based on geological and geophysical data, that structurally, the two mineralized zones represent the limbs of an isoclinal fold which strikes northeast, dips on average 50 degrees west-northwest and exhibits a plunge approximately to the north. While both mineralized zones average true widths of approximately 5 m in thickness, the deposit exhibits boudinaging (both along strike and down plunge) and consequently thicknesses can range from 2 m to up to 13 m.

The Brabant-McKenzie deposit was discovered in 1956 as a surface showing. Periodic work on the Deposit over the period 1957 to 2015 has included geological mapping, sampling, airborne and ground geophysics and over 31,000 m of drilling. A 2008 NI 43-101 resource statement outlines 1.5 million tonnes grading 9.2% zinc, 0.8% copper, 33 g/t silver in the indicated category and an additional 3.0 million tonnes grading 5.6% zinc, 0.6% copper and 14 g/t silver in the inferred category.

Regionally, the Brabant-McKenzie property hosts a number of known mineralized showings and airborne geophysics targets over approximately 16 km of strike.

In 2015, Murchison geological consultants undertook a compilation of the Deposit's historical data and produced its own geological interpretation. Using this interpretation, a number of exploration targets were defined and used to design programs, which will test the tonnage increase potential on the Deposit.

Murchison's recent fieldwork includes a December, 2015 ground geophysics program designed to test a regional airborne conductor south along strike of the Deposit and as infill coverage of the Deposit. In October, 2016 Murchison began a regional follow up program on known showings and geophysics conductors. The company also began work on a planned downhole geophysics program, which will test down dip and strike potential on the Deposit. Results will be used in the design of an anticipated early 2017 drill program.

¹ Murchison Minerals Ltd.

Evaluating Development Scenarios for Base Metal Production in the Hanson Lake VMS District, Eastern Saskatchewan

Roger March ^{1,2}, Dave Fleming ² and Patrick Soars ²

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 MT 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 would be the centre of gravity for district scale mining in the Hanson Lake District with potential for additional mill feed 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 PEA was based on a 5,000 tpd underground mining operation at McIlvenna Bay with both ramp and shaft access drawing ore from five mineralized zones, including a copper stockwork zone underlying massive sulphide, with the construction of an onsite concentrator and tailings facility. Under this scenario pre-production capital costs were estimated at \$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.

Given today's low metal price environment, Foran is assessing alternate development scenarios for McIlvenna Bay with lower capital requirements and simplified mining scenarios designed to reduce operating costs. The objective is to position the company for the next cycle of increased metal prices, one that may see zinc prices increase relative to copper. One line of investigation has been to evaluate the potential economic impact of toll milling in nearby Flin Flon on a scaled down operation with ramp-only access, which would reduce development costs, negate the need for a tailings facility and reduce power requirements. A second round of metallurgy is underway to investigate the impact on recoveries of blending massive sulphide with copper stockwork, which could support the bulk mining of multiple zones together. Another opportunity may lie in the engineering of an operation directed towards massive sulphide only. The partitioning of zinc and copper into thicker parts of the McIlvenna Bay deposit and the large size of the overall mineral resource provides flexibility to focus mining on more valuable portions of the deposit.

The McIlvenna Bay deposit is classified as a Felsic-Siliciclastic VMS deposit with demonstrated Zn-rich characteristics. Foran's Bigstone deposit, situated 25 km to the west within the Northern Lights Assemblage, is a smaller tonnage, high grade Cu-rich VMS with a dominant intermediate-mafic component to the stratigraphy. The exploration potential for the discovery of additional high grade zinc and/or copper VMS deposits in the Hanson Lake District is high.

¹ Foran's Qualified Person, as defined in NI 43-101, with respect to technical information contained in this abstract.

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La Ronge 'Horseshoe': Project Update and Summary of Recent Field Investigations at Bartlett, Sulphide and Nemeiben Lakes

Ralf O. Maxeiner¹, Nicole M. Rayner² and Robert A. Creaser³

Abstract

This talk will summarize the main geological building blocks of the La Ronge 'Horseshoe' project, a bedrock mapping initiative aimed at revising the geological framework of an approximately 4000 km² area between the Churchill River and Lac La Ronge. Geologically, the project area is located in the southwestern Reindeer Zone and includes components of the Glennie, Kisseynew, La Ronge, and Rottenstone domains. The project commenced in 2010 and was aimed at studying the domainal relationships and collisional history in one of the most enigmatic parts of the Reindeer Zone for the purpose of better understanding the geological history and assessing its mineral potential. In addition to the many 1:20 000 scale bedrock maps thus far completed on the 'Horseshoe' project, there was also considerable emphasis on supporting analytical work. Important new datasets containing U-Pb geochronological, Sm-Nd isotopic and geochemical results have allowed advancement of our understanding of the evolution of the Reindeer Zone and the Trans-Hudson orogen in general.

Identification of isotopically evolved, highly strained crust, juxtaposed against the western extent of rocks belonging to the Flin Flon – Glennie complex may suggest the presence of a previously unrecognized paleosuture. Recognition of an isotopically variable suite of 1.848-1.837 Ga arc plutonic rocks with local Neoproterozoic inheritance could be interpreted as the root of a forearc, emplaced along the western edge (present day) of the Flin Flon – Glennie complex. Reinterpretation of the circa 1.85-1.84 Ga McLennan Group as a component of an expanded forearc assemblage (Mullock Lake assemblage), as opposed to a molasse, may be significant in the context of paleotectonic reconstructions. All of these features are important in focusing future exploration for volcanogenic massive sulphide deposits, mafic intrusion hosted Cu-Ni-(PGE) deposits, porphyry copper-gold deposits and orogenic gold deposits.

In 2016, several new areas were investigated in order to facilitate the production of a 1:50 000 scale bedrock compilation map; two areas were investigated in detail. At Bartlett Lake, upper amphibolite facies volcanic rocks of the La Ronge domain and psammitic-psammopelitic rocks of the Crew Lake assemblage are intruded by gabbroic rocks of the Bassett Lake intrusion and younger quartz dioritic and tonalitic plutons. The Sulphide Lake area is dominated by supracrustal rocks that have been metamorphosed at upper greenschist to lower amphibolite facies conditions. An older heterogeneous succession of wacke, argillite and predominantly intermediate to lesser felsic volcanoclastic rocks is interpreted to be unconformably overlain by the Mullock Lake assemblage, consisting of volcanogenic polymictic conglomerate, felsic volcanoclastic rocks and flows. Younger gabbroic rocks and feldspar porphyry sheets, intrusive into the supracrustal rocks, are more prevalent than previously documented. A mylonitic event has been correlated with D₂ deformation; quartz veins are parallel to the S₂ foliation. D₂ mylonitic fabrics are deformed by prominent metre to outcrop-scale Z-folds, which are related to a regional F₃ folding event. Gold occurrences at Sulphide Lake are epigenetic in origin.

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The Chico Project – Exploring for Gold along the Tabbernor Fault

Jarrod Brown ¹

Abstract

The Chico Au project is located 40 km south-southeast of the Seabee Gold mine within granitic gneiss and dioritic-gabbroic units of the Glennie Domain. The property is transected by the north-south trending Tabbernor Lake fault system – a major crustal-scale shear within the Trans Hudson Orogen, that has been traced over 1500 km from the Wollaston Lake area of northern Saskatchewan to within 100 km of the Black Hills in South Dakota.

A number of significant gold occurrences are located within 10 km of the trace of the Tabbernor fault. Probable splays of the Tabbernor Lake fault system in the Laonil Lake region contain shear hosted quartz-tourmaline-pyrite-pyrrhotite-gold mineralized veins which typify ore-hosting structures at the Seabee mine. The 1+ million ounce producing mine-complex has set the bar for the region with 2014-2015 head grades in excess of 8 g/t Au.

The gabbro-granitoid hosted Seabee and mafic volcanic hosted Santoy mines exemplify splay-related gold deposits that are off-axis to the Tabbernor fault by several kilometres. Other similar off-axis gold occurrences to the south include the gabbro hosted DD-showing at Eisler Lake, granite and mafic volcanic hosted showings in the Georges Lake area, and gabbro and mafic volcanic hosted mineralization at the Footprint and WEK occurrences along the sub-parallel Uskik Lake fault.

A number of near-axis (<2 km from the fault axis) gold occurrences are also known. From north to south, they include the mafic volcanic hosted Tabbernor(Wilbert) showing, the newly discovered volcanic hosted Fisher showing at Kettle Falls, the gabbro-diorite hosted Chico zone at Manawan Lake, and several showings in the Prongua–Lariviere Lake area with both mafic volcanic and granodiorite hosts.

Notably, gold mineralization in the study area is found in a multitude of host rock types. Features that are in common with them all include 1) mineralization in 2nd and 3rd order shear systems within 10 km of a major crustal-scale fault (i.e., Tabbernor); 2) mineralization concentrated near (but not necessarily at) major lithological boundaries; and 3) vein occurrences typically associated with sub-parallel granitoid dyke systems.

Gold mineralization at the Chico property occurs along contacts between diorite and granitic gneiss within a northeast trending, 20 to 150 m wide ductile and brittle shear zone that hosts sheeted and ribbon quartz veins containing minor pyrite, pyrrhotite and chalcopyrite. Historical trenching and drilling (1988-1993) defined a mineralized strike length of over 1400 m. Results from chip sampling by Corona include 14.3 g/t Au over 1 m. Follow-up diamond drilling by Cameco returned five significant intercepts from a single hole ranging from 3.7 g/t over 1.5 m, to 36.0 g/t over 0.3 m. Despite the significant surface discoveries of gold along three structural trends, mineralization remains remarkably untested at depth and along strike extensions. Eagle Plains Resources Ltd. obtained the property by staking in 2015 and completed a \$100,000 program of prospecting, geological mapping, soil geochemistry and channel sampling in the summer of 2016. Based on the encouraging results, a 2000 m drill program has been permitted for 2017.

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New Ownership at Seabee – Silver Standard Pursues Exploration Growth through Drilling and Acquisition

Anders Carlson ¹ and Carl Edmonds ²

Abstract

After 25 years of continuous mining, the Seabee gold operation has new ownership. On May 31st, Silver Standard Resources completed the acquisition of Claude Resources Inc. in a US\$329.4 million transaction. Silver Standard's investment represents a belief not only in Seabee's ore-bodies but also in the prospectivity of the district. The new management group has since made a commitment to bolster exploration efforts at Seabee and elsewhere in the belt. On October 6th, Silver Standard announced an option agreement to explore the Fisher gold project, which lies directly south of the Santoy mine complex. The four-year option period will allow Silver Standard to apply the exploration principles that it has gained at Seabee to a much larger area within the Pine Lake greenstone belt.

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**Technical Session 3: Exploration Overviews and
Tantato Domain Geoscience**

Saskatchewan's Mineral Sector Going into 2017: Status and Outlook

Gary Delaney ¹ and the Saskatchewan Geological Survey Staff

Abstract

In 2015 Saskatchewan was the world's largest potash producer, and the second largest producer of primary uranium. There was also production of coal, gold, base metals, sodium and potassium sulphate, silica sand and clay products. In 2015, the value of mineral sales, mostly from potash and uranium, was approximately \$8.2 billion (B), up from \$7.3 B in 2014 and \$7.1 B in 2013.

Saskatchewan's potash miners produced 18.2 million (M) tonnes KCl in 2015 with sales valued at about \$6.1 B. For 2016, as of the end of September, volumes of potash sold were similar to 2015, and although the sale price has decreased, it appears to have stabilized recently. For the remainder of the year, and into 2017, potash demand is forecast to be strong. A significant development, announced in late August 2016, was the proposed merger of Potash Corp and Agrium Inc. On the development front, in the summer of 2016, K+S Potash Canada GP started the commissioning of its Legacy potash solution mine. A number of other potash projects, ranging from early exploration to advanced development, continued to make progress over the past year.

Saskatchewan produced 34.6 M pounds (lb) of triuranium octoxide (U₃O₈) in 2015, accounting for about 22% of global primary uranium production. Value of sales was \$1.8 B. Production for 2016, which will come largely from the McArthur River/Key Lake and Cigar Lake/McClean Lake operations, is forecasted to be 35 M lb U₃O₈. The value of uranium sales is forecasted to be flat due to surplus supply in the market from both primary and secondary sources.

Claude Resources Inc.'s Seabee operation, Saskatchewan's sole gold producer, achieved a record production of 75,748 ounces (oz) of gold (Au) in 2015. In the first three quarters of 2016, the operation, which was taken over by Silver Standard Resources Inc., produced 58,338 oz Au. Production guidance for the year is 65,000 to 72,000 oz Au.

In 2016 it is estimated that over \$226 M will be spent on mineral exploration which is similar to the previous three years when exploration expenditures averaged about \$221 M. An estimate by Natural Resources Canada indicates that Saskatchewan will account for 16.4% of Canadian exploration expenditures in 2016, up from 15.1% in 2015. This puts Saskatchewan on track to rank second nationally for exploration spending, after Ontario. The bulk of the spending is anticipated to be for uranium and potash, although there is also renewed interest in diamond exploration. Uranium exploration spending is forecasted to remain robust in 2016, with projected expenditures of about \$133 M, mainly on projects in the Key Lake to McArthur River corridor in the east part of the Athabasca Basin region, and near Patterson Lake in and adjacent to the southwest part of the basin.

There is active diamond exploration in three areas in Saskatchewan. In the Fort à la Corne forest, in central Saskatchewan, Shore Gold Inc. continued to advance the FALC-JV Star-Orion South diamond project. About 100 km west of Flin Flon, at the Pikoo project, operator North Arrow Minerals Inc. has identified ten discrete kimberlite occurrences, five of which have been tested and proven to be diamondiferous. In 2016 in the northwest part of the Athabasca Basin, a junior exploration company, CanAlaska Uranium (CanAlaska), used data from a high resolution government aeromagnetic survey to identify a large number of potential kimberlite targets. As an outcome, DeBeers Canada is investing the first \$1 M of a potential \$20 M staged option-participation deal on CanAlaska's property. Many other companies have been attracted to the area and as of October 20, 2016, a total of 586,453 hectares (ha) was under disposition.

As of October, 31, 2016, active mineral dispositions, issued pursuant to The Mineral Tenure Registry Regulations, totaled about 8.04 M ha. In addition, there were 117 active potash dispositions, issued pursuant to The Subsurface Mineral Tenure Regulations, comprising permits and leases, totaling about 2.90 M ha.

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Signs of Life? The State of Exploration in Canada

Robert Schafer ¹

Abstract

This presentation will provide a national perspective on the state of mineral exploration in Canada, situated within a global context. Key topics will include the state of exploration finance globally, and within Canada; the state of exploration expenditures within Canada as compared to key competitors, and the factors affecting how competitive Canadian jurisdictions are at attracting investment. It will conclude with an overview of the specific actions PDAC is taking nationally to help support a competitive and responsible exploration industry to access the land and capital needed to discover and develop deposits of the minerals and metals that make modern life possible.

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Northern Saskatchewan Soils Database and Other Highlights of the Boreal Watershed Initiative

Pritam Jain ¹ and Lynn Kelley ¹

Abstract

The Boreal Watershed Initiative is a recently-completed multidisciplinary five year project carried out by the Saskatchewan Ministry of Environment. The project was designed to provide baseline information on environmental indicators and inform environmental decision-making in the province's north. One of the project components was a regional-scale soil survey incorporating some 236 locations north of approximately 54°. Data from the survey has been compiled in an ArcGIS geospatial database, which may be of interest to the geological community as a planning or orientation resource for geochemical exploration.

The primary purpose of the soil survey was to assess the vulnerability of the landscape to acidic precipitation. Previous work on the geochemistry of headwater lakes in the region had indicated low acid-neutralizing capacity (ANC) in some northern Saskatchewan lakes, particularly those located within the Athabasca Basin. The low ANC is a reflection of low base-cation weathering rates in the drainage basins of the headwater lakes. The soil survey enabled an assessment of the potential interaction between precipitation, runoff and the landscape. Results of the survey are intended to inform and support future environmental monitoring, impact assessment, land reclamation, land use planning, and regulatory decision-making.

The ArcGIS geospatial database entitled Soils of the Boreal and Taiga EcoRegions of Saskatchewan, will be demonstrated. The database will be appended to the Boreal Watershed Initiative final report. The database contains positional information for each location sampled, and soil description and characteristics, soil horizon thicknesses, as well as photographs of the excavated soil profile and surrounding terrain. Laboratory results for cation exchange capacity, nutrients, major elements, and metals are also documented in the database.

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Ice Streams in Saskatchewan: Implications for Drift Prospecting in Areas of Fast Ice Flow

Michelle A. Hanson ¹

Abstract

An ice stream is an area within an ice sheet that flows much faster (up to 300 metres per year) than the surrounding ice. Ice streams are large (>20 km wide, >150 km long) and commonly produce streamlined landforms, e.g., drumlins and megafaultings. The streamlined landforms display notably convergent flow patterns at the ice stream onset and divergent flow patterns toward the terminus. Ice streams also have sharply delineated margins marked by abrupt changes in landform pattern and/or lateral shear moraines. Ice streams can be found in topographic lows and are commonly found overlying areas of deformable sediment, such as till, which is conducive to fast flow. Similarly, ice streams are more commonly found overlying sedimentary bedrock than harder crystalline bedrock because of the potential for increased glacial erosion and thus greater till cover over the former. Lastly, ice streams can form a distinct style of dispersal train.

Paleo-ice streams were prominent features of the Laurentide Ice Sheet during the Late Wisconsinan and recent work has shown that they played a significant role in the last deglaciation of Saskatchewan. Several paleo-ice streams have been documented across southern Saskatchewan and along the southeastern margin of the Athabasca Basin (e.g., Ross et al., 2009), but only preliminary work has been done to document paleo-ice streaming in other areas of the province, for example, over the Athabasca Basin (e.g., Campbell et al., 2007; Ross et al., 2009).

Drift prospecting—the tracing of lithological and geochemical mineralization in glacial sediment back to its bedrock source—can be used to trace, for example, uranium, kimberlite indicator minerals, gold, and base metals. In Saskatchewan, drift prospecting has resulted in the discovery of some significant deposits, for example, uranium in the Athabasca Basin and kimberlites around Deschambault Lake. Fundamental to the success of a drift prospecting project is a detailed understanding of the glacial geology of the area. Fast ice flow results in a large sediment flux and longer sediment transport distances compared to regular ice flow, both of which have serious implications for drift prospecting.

This presentation will address what an ice stream is; how to identify a paleo-ice stream; where paleo-ice streams have been documented and proposed in Saskatchewan; and the significance of paleo-ice streams for drift prospecting programs.

References

- Campbell, J.E., Klassen, R.A. and Shives, R.B.K. (2007): Integrated field investigations of airborne radiometric data and drift composition, Nuclear Energy Agency-International Atomic Energy Athabasca test area, Saskatchewan; in Jefferson, C.W. and Delaney, G. (eds.), EXTECH IV: Geology and Uranium EXploration TECHnology of the Proterozoic Athabasca Basin, Saskatchewan and Alberta, Geological Survey of Canada Bulletin 588, p.533-554.*
- Margold, M., Stokes, C.R., Clark, C.D. and Kleman, J. (2015): Ice streams in the Laurentide Ice Sheet: a new mapping inventory; Journal of Maps, v.11, p.380-395.*
- Ross, M., Campbell, J.E., Parent, M. and Adams, R.S. (2009): Palaeo-ice streams and the subglacial landscape mosaic of the North America mid-continental prairies; Boreas, v.38, p.421-439.*

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Tectonic Significance of the Nolan-Zemlak Domain Boundary, Tazin Lake Area, NW Saskatchewan: Investigating the Possibility of an Arrowsmith-Age Suture Zone in the WSW Rae

Kathryn Bethune ¹, Michael Cloutier ¹, Jordan Deane ¹ and Ken Ashton ²

Abstract

The Thelon orogen was once ascribed to collision of the Slave craton and/or Buffalo Head terranes with Rae. Evidence is mounting, however, for a distinctly older orogenic belt inboard of the Thelon tectonic zone, the 2.5-2.3 Ga Arrowsmith orogen. The western Rae may therefore have a longer-lived accretionary history than originally surmised with internal, older suture zones obscured by younger tectonic events. One such candidate is the Nolan-Zemlak domain boundary of northwestern Saskatchewan. Preliminary results of field investigation and laboratory study of rocks across this boundary, aimed at more fully evaluating its nature and testing the suture hypothesis are reported herein. Fieldwork this past summer has confirmed the previously established lithostructural framework. The most internal parts of the Nolan domain, inboard of the north shore of Tazin Lake, comprise essentially undeformed biotite ± hornblende-bearing granite to granodiorite, locally containing enclaves of more mafic composition (diorite, quartz diorite), and have yielded ~2.6 Ga crystallization ages. Porphyritic varieties are common and typified by 3-5 cm K-feldspar megacrysts in a medium- to coarse-grained matrix. Over 7-8 km, these rocks show a progressive southward increase in strain, becoming mylonitic in character along the south shore of Tazin Lake, where protomylonitic granite of inferred ~2.6 Ga age is in contact with a distinctive unit of younger (~2.5 Ga) highly magnetic cream-grey-weathering hornblende ± biotite granodiorite of the Zemlak domain. The strain gradient is accompanied by the appearance of abundant lit-par-lit leucosome of a distinctive pink leucogranite of suspected ~1.9 Ga age, which also locally forms map-scale bodies. Mylonitization is most intense within a 3-5 km corridor straddling the Nolan granite-Zemlak granodiorite contact, which is also the locus of a body of ultramafic and associated gabbroic-dioritic rocks. Broadly, this structural corridor comprises several anastomosing east-northeast-trending mylonite zones bounding lensoid panels of less deformed (protomylonitic) granitoid rocks. The foliation dips moderately to steeply either north-northwest or east-southeast and stretching lineations plunge shallowly (5 to 30°) to the south-southwest and east-northeast. Rare kinematic indicators indicate left-lateral displacement. Some mylonite zones are paralleled by significant east-northeast-trending topographic lineaments; toward these breaks, the ductile foliation is overprinted by low-grade mylonite, strongly chloritized foliated cataclasite and more irregular zones of cataclasis/brecciation. Such ductile-brittle faults may represent a continuum (ductile to brittle) in fault zone evolution but kinematic indicators of opposed sense (right lateral) support the inference of a separate, reactivation phase. This system includes the Tazin Lake fault, that was likely active during and following Martin Group deposition at 1.82 Ga. Younger, discrete brittle faults and fracture-joint sets pervade the region, with dominant west-northwest and north-south trends. The Nolan-Zemlak domain boundary zone therefore clearly records a complex tectonic history and the nature of activity at Arrowsmith time remains largely unknown. Geochemistry and coupled LA-ICP-MS split stream U-Pb and Hf isotopic analysis will be undertaken to better evaluate crystallization and metamorphic ages in archival and newly collected samples, and to constrain igneous petrogenesis. Structural-microstructural analysis, coupled with *in situ* dating, will be undertaken to better constrain the related deformational history.

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Au-PGE-U and REE-Th-U Mineralization in Altered Tantato Domain Basement Gneiss, Stony Rapids Area, Saskatchewan

Charles Normand ¹

Abstract

Bedrock geological examination of Tantato Domain granulite facies metamorphic rocks that crop out along the south shore of the Fond du Lac River two kilometres west of Stony Rapids was undertaken to characterize known Au-PGE-U and REE-Th-U mineralization in the area. The high-grade metamorphic rocks are exposed in a series of low-lying outcrops that have been affected by regolith alteration below the unconformity with unmetamorphosed Athabasca Group siliciclastic sedimentary rocks.

Au-PGE-U and REE-Th-U mineralization occur in close spatial association with the paleoregolith. The Au-PGE-U mineralization is part of a more extensive, narrow belt of similar Au-PGE-U-mineralized occurrences in basement rocks along the northern edge of the Athabasca Basin between the Black Bay fault and the Cora Lake shear zone. One occurrence of Au-PGE-U mineralization was visited in 2016 and is hosted by an altered, bleached and oxidized zone developed in mafic granulite. Contact relationships between the mineralized basement rocks and paleoregolith or Athabasca Group sediments were not observed. Similar alteration zones in the larger Athabasca Basin region have been assigned a hydrothermal origin postdating deposition of Athabasca Group siliciclastic rocks. The presence of a pre-existing thick overlying accumulation of non redox- and non pH-buffering sandstone on top of the basement, now apparently eroded at all reported occurrences, is believed to have been a requirement for the formation of Au-PGE-U mineralization.

The REE-Th-U mineralization occurs in paleoregolith, a few tens of metres north of the overburden-covered unconformity between basement and the Manitou Falls Formation. It represents the only known occurrence of this style of mineralization in the province. The mineralization consists of a small, gently dipping, quartz- and monazite-rich layer of an as yet undetermined nature in the paleoweathered basement. The paleoregolith exhibits a diagenetic foliation cut by numerous generations of fractures that extend into unaltered basement rocks. Alteration haloes observed in garnetiferous diatexite at the margins of some of these fractures near paleoregolith show an increase in eTh concentrations of up to 8.5 times that in the host rock, suggesting mobility of thorium during circulation of hydrothermal fluids of probable basinal origin. Calculated eU/eTh ratios of monazite mineralization and Th-rich alteration haloes associated with fractures are similar, suggesting a genetic link between the two.

Widely differing types of alteration and radiometric eU and eTh signatures between Au-PGE-U and REE-Th-U mineralization suggests that the two types of mineralization are unrelated.

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Brittle Deformation and Associated Hydrothermal Alteration and Mineralisation in the Southern Tantato Domain, Saskatchewan

W. Thomas Ogilvie ¹, Bruno Lafrance ¹ and Charles Normand ²

Abstract

The Archean rocks of the Tantato Domain, north of the Athabasca basin, are overprinted by brittle faults, fractures, and veins associated with multiple generations of brittle structures, hosting sub-economic occurrences of uranium and gold. Previous research efforts have focused on the structural controls of known gold occurrences in the domain; however, the relative timing and effects of multiple, successive brittle deformation events on uranium mineralisation has not been studied. Furthermore, the nature of the mineralising fluids of both uranium and gold has received little attention. Although the Tantato Domain itself is generally considered un-economic in both gold and uranium, the rocks of the Tantato Domain continue under and become basement to the Athabasca Basin. Thus, the analysis of the 3D architecture and slip kinematic history of faults in the southern Tantato Domain, and the correlation of those faults to upper-crustal deformation features observed within the Athabasca Basin, can provide insight into the kinematic history of sub-Athabasca Basin faults, which control the emplacement of the Athabasca uranium deposits.

Four major brittle deformation events affected the southern Tantato Domain. The first deformation event, D₁, is a brittle-ductile event characterized by quartz + tourmaline + sulfide ± gold veins with high-temperature alteration halos of biotite in mafic granulite or chlorite + epidote in metanorite. These veins occur in conjugate hybrid shear fractures with average orientations of 315° and 355° and sub-vertical dips, suggesting northwest-southeast bulk shortening. The second, purely brittle deformation event, D₂, is characterized by fractures and faults with average orientations of 330° and 090°, steep dips, and sub-horizontal slickenlines, suggesting west-northwest–east-southeast bulk shortening. The third deformation event, D₃, forms brittle faults and fracture sets with average orientations of 300° and 060°, moderate to steep dips, and sub-horizontal slickenlines, suggesting east-west bulk shortening. Veins along these faults and fractures contain hematite + chlorite + carbonate, have strong hematite alteration halos, and are the only structures found to be hosting uranium mineralisation in the southern part of the domain. The final deformation event, D₄, marked a return to D₁ bulk shortening directions, and produced brittle structures overprinting D₁ brittle-ductile structures. D₄ structures strike 355° and 315° with sub-vertical dips and they host carbonate veins with strong hematite alteration halos. Mapping in the Athabasca Basin revealed the presence of a single generation of cataclastic deformation bands with an average orientation of 300°. These structures are thin, discontinuous, and they exhibit normal movement with a minor strike-slip component. Since they are similar in orientation to D₃ structures, those structures associated with late hematite alteration and uranium mineralization in the Tantato Domain, they are interpreted as coeval structures within the Athabasca Basin.

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New Regional Geology and Mineral Occurrences of the South Rae in Northwest Territories from GEM2: Implications for Continuation of the Boomerang, Black Bay and Axis-Thye Lake Trends

Sally Pehrsson ¹, Edith Martel ², John Percival ¹, Janet Campbell ¹, Martin McCurdy ¹, Daniele Regis ¹, Pedro Acosta-Gongora ¹, Eric Theissen ³, Dylan Jamieson ⁴, Gabriel Lauzon ⁵, Benjamin Neil ³, Bernadette Knox ², Dan Gibson ³ and Shoufa Lin ⁴

Abstract

The South Rae domain in Northwest Territories (NWT), last mapped in 1955 at reconnaissance scale, has been the focus of a new 3-year joint GSC-GNWT GEM 2 project to upgrade understanding of its crustal and surficial geological history.

Mapping in 2012, 2015 and 2016 of parts of NTS 75A, B, 75 F, G has defined six new distinct domains, each with a unique magmatic and tectonometamorphic record and herein described from southeast to northwest. The Firedrake domain comprises Neoproterozoic felsic-intermediate orthogneiss, mafic-ultramafic rocks and paragneiss, all injected by late migmatitic granitoids and recording 1.894 Ga 8-11 kbar granulite conditions with subsequent decompression and partial exhumation by 1.84-1.80 Ga. McCann domain consists of Neoproterozoic metagranitoids, diatexite and paragneiss intruded by 2.2-2.08 Ga gabbro-norites. It records medium-pressure, high-temperature 2.45-2.3 Ga Arrowsmith orogenesis and minimum 8 kbar 1.88 Ga metamorphism. The Penylan domain predominantly comprises a 2.03-2.05 Ga clinopyroxene-garnet-plagioclase-absent gabbroic anorthosite-gabbro complex metamorphosed at 1.9-1.85 Ga. The magnetically low Howard Lake domain is underlain by andalusite wacke, schist and calc-silicate and felsic-mafic plutonic rocks that extend over 100 km to the northeast where they host the Boomerang Lake U prospect. Lynx Lake domain comprises Archean granitoids with remnants of a previously unmapped low- to moderate-grade greenstone belt. Porter domain includes metagranodiorite with gabbroic enclaves and broad zones of brittle-ductile greenschist-grade deformation and chlorite-hematite-epidote alteration.

Domain boundaries are characterized by ductile high strain and appear to be the locus of multiple movements. The presence of quartzite and metaschist (possible Paleoproterozoic Hill Island Lake group) and small belts of unmetamorphosed <1.9 Ga Nonacho group sediments west of the Howard Lake fault highlight that it is the western boundary of a large regional high pressure uplift extending from Lake Athabasca to Baffin Island and bounded on the east by the Snowbird Tectonic zone. Black Bay fault (BBf) and Wholdaia Lake shear zone (WLSz) accommodated late uplift of the Firedrake domain and are associated with 1.9-1.83 Ga syenitic magmatism.

Surficial investigations have outlined a complex glacial history in this region. Information was gathered on the sediment types and distribution and landforms as well as the pattern and history of both ice flow and ice margin retreat. New till and indicator mineral analyses, along with ice flow history, provide a regional-scale framework for provenance and dispersal studies, and mineral exploration, highlighting that an older southerly flow appears to be a main transport direction. Short-lived ice marginal lakes or an extensive glacial lake resulted in significant reworking of till and glaciofluvial sediments.

We present new lake sediment analyses and mineral occurrences for map sheets 75K and parts of 75B. Numerous anomalies are noted down-ice and along the BBf, consistent with Hoidas-style REE-U-Au mineralization and a large polymetallic anomaly at Scott Lake occurs at the southern terminus of the WLSz. The largest Re anomaly found in Canada occurs north of Snowdrift River.

The implication of the geometry and history of the deep crustal terrane for Athabasca Basin formation, U and Au deposits and kimberlite localization will be discussed.

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Technical Session 4: Potash, Diamonds and More

Helium in Southwestern Saskatchewan: Accumulation and Geological Setting

Melinda Yurkowski ¹

Abstract

Saskatchewan is experiencing renewed interest in potential helium production in the southwest due to increasing commodity prices. Helium was reported in gas analyses from wells in southwestern Saskatchewan as early as the 1950s, with anomalous values of helium up to 2%. Helium was produced in the early 1970s from four Swift Current area wells and two wells recently began producing in southwest Saskatchewan.

With the mounting interest in helium, the Saskatchewan Geological Survey initiated a program to better understand the generation, accumulation and geological setting of helium resources in the province. This included an exhaustive examination of gas analyses in Ministry of the Economy well files from southwestern Saskatchewan, which identified anomalous helium concentrations in stratigraphic intervals, particularly the lower Paleozoic but ranging from the Cambrian to the Cretaceous within the study area.

Understanding the source, migration and trapping of the helium is critical in understanding where the economic accumulations occur. Although the physical processes required to trap economic amounts of helium (source, migration, carrier beds and trap with seal) are similar to hydrocarbon natural gas traps, helium differs from hydrocarbon gases in two significant ways: it has a non-organic source, and it occurs as a very small molecule – roughly half the size of a methane molecule. It therefore requires a more robust seal for its reservoir than hydrocarbons. The two likely models for the development of helium plays in southwest Saskatchewan are:

- 1) generation of helium by radioactive decay of uranium and thorium in Precambrian granitic basement rocks; migration along fracture / fault systems developed throughout the Phanerozoic by the numerous tectonic elements in this part of the province (e.g., the Great Falls Tectonic Zone); and pooling/entrapment in sediments draping structural highs with effective seals such as silicified siltstone; and*
- 2) generation of helium by radioactive decay of uranium and thorium naturally occurring in the shales of the lower Paleozoic rocks (primarily Deadwood Formation shales), with migration into stagnant pore water, partitioning of the helium from the water into gas, and pooling/entrapment as noted above.*

Based on current understanding, the most viable exploration models seem to be closed structures created by Cambrian to Cretaceous sediments draped over Precambrian monadnocks.

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Innovating Potash Coring in the Prairie Evaporite Formation, Saskatchewan

Megan Frederick ¹

Abstract

A new development in potash coring has been a joint venture of innovation between K+S Potash Canada and the coring contractor, Baker Hughes. The retrieval of potash core in Saskatchewan has historically been done either by conventional or wireline methods. Both methods are a simple core barrel and auxiliary equipment ranging no more than eighteen (18) metres of length. Coring operations typically take multiple trips which increases the chance of stuck tools, core loss, and increased rig cost. Over the years, coring has decreased due to the time and cost of core retrieval.

The focus from K+S Potash Canada was to decrease rig time and costs while being able to continuously core an eighty (80) metre or more length of four (4) inch potash core in the Prairie Evaporite Formation without compromising the integrity of the core. The Geology Department and Drilling Department at K+S Potash Canada has worked closely with Baker Hughes to incorporate oilfield technology of continuous coring to successfully retrieve not only the four Prairie Evaporite Members, but also the Second Red Beds and a bit of the Dawson Bay Formation. K+S Potash Canada and Baker Hughes have successfully cored several wells continuously over eighty (80) metres in length without core loss.

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Metal Contents of the Cretaceous Oil Shales of the Pasquia Hills, Saskatchewan

Murray C. Rogers ¹

Abstract

The results of a multi-element geochemical study are reported from the selective sampling of drillcore from five holes that examined the Cretaceous oil shale section on the northwest flank of the Pasquia Hills in east-central Saskatchewan.

Black shales, particularly organic-rich shales, commonly have anomalous and in some cases potentially economic metal contents. Upper Cretaceous oil shales of the Niobrara (First White Speckled Shale) and Favel (Second White Specks) formations occur at shallow depth, in subcrop and as local outcrop in the Pasquia Hills and extend in subcrop at depth through central Saskatchewan. Although the oil shales in the Pasquia Hills have been extensively drill tested since the 1960s for their kerogen (oil) potential, there is no public record that they have been examined in any detail for their metal contents.

The core from several recent drillholes from this region is stored at the Subsurface Geological Laboratory of the Ministry of the Economy in Regina. Five of these holes from a 2012 program on the northwest flank of the Pasquia Hills were selected for sampling. The oil shale sections in these holes average about 30 m in thickness. Four representative one-metre chip samples of the core were taken from each hole approximately equidistant through each core section. The samples were then sent for multi-element analyses by Inductively Coupled Plasma–Optical Emission Spectroscopy (ICP-OES) and Fire Assay (Au, Pt, Pd) – ICP-OES packages.

The United States Geological Survey (USGS) standard for metalliferous black shales was used as a basis to interpret the results. The gold values with one exception are highly anomalous with 19 of the 20 samples exceeding the USGS standard of 5.6 ppb, with an arithmetic mean (average) value for all 20 samples of 45 ppb (8X) and a high value of 129 ppb (23X). Based on the limited number of drillholes and samples, the mean gold values for the holes display a general westward increase with the highest mean value of 103 ppb Au in the most western hole. A low-temperature hydrothermal source to the west is inferred for the anomalous gold. The Tabbemor Fault Zone, a major, north-trending, crustal structure, has been interpreted to project near or through this area and could have played a role as a fluid conduit. Other metalliferous elements include Ag, Zn, Se, P₂O₅, Sr, and V. Based on the level of values and the consistent distribution of these metals both within the individual holes and between the holes, their source has been attributed to absorption of metals by organic matter from seawater and further concentration in minerals during diagenesis in the reduced, anoxic sediments.

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Cyclic Igneous, Sedimentary and Uranium Ore-Forming Events in Laurentia's Core: Evidence of the Breakup of Nuna (and Other Supercontinents?) in the Athabasca Basin

Colin Card ¹, Sean Bosman ¹, Robert A. Creaser ², Graham Pearson ², Yan Lou ² and Anthony Reid ³

Abstract

There is a general notion that ca. 1.75-1.50 Ga sedimentary rocks were deposited into the intracratonic Athabasca Basin. In reality, the basin contains the remnants of several sedimentary basins each with unique depositional axes and depocentres, the most extensive being the Cree Basin. The bulk of the preserved lithostratigraphic units are of the Manitou Falls (MF) Group, the basal part of Cree Basin. The Cree Basin is capped by rocks of the Lazenby Lake (LZ) and Wolverine Point (WP) groups. Although the former contains the typical quartz arenitic strata, the WP Group contains relatively abundant mudstone beds, indicating a change in depositional conditions. Furthermore, the basal WP Group contains clasts of ash-fall tuff, which have yielded a ca. 1.64 Ga depositional age. Chemostratigraphy for the Cree Basin section indicates a geochemical boundary at the top of the MF Group, with strata of the LZ and WP groups containing comparatively elevated concentrations of a number of elements, including the rare earths. There is a corresponding change in the composition of clay minerals across the same boundary. Sm-Nd isotopic results also highlight this boundary with epsilon Nd values (calculated at 1.65 Ga) averaging -6.5 in the MF Group compared with an average of 0.2 in the LZ and WP groups. One explanation for the observed boundary is the emergence of juvenile rocks in the Cree Basin's source region. A single detrital zircon analysis for the WP Group, with youngest detrital zircons between 1.68 and 1.65 Ga, supports this hypothesis because that range is absent in the MF Group. A possible mechanism for the change in source area is the initiation of a nearby large igneous province (LIP), which would provide a source for the WP tuff. Rutile dating in basement to the Athabasca strata has identified a ca. 1.64 Ga silicification event that supports the notion of a local heat source driving fluids from the basement into the overlying sedimentary rocks. We propose a potential LIP in the Athabasca Basin's source area between ca. 1.68-1.64 Ga. This proposed event is likely the first of many <1.7 Ga LIP events in the region. To that end, compilation of the ages from primary uraninite grains establishes a correlation between the age of ore-forming fluid events in the Athabasca Basin, and well-known ages of LIPs and time-equivalent sedimentary basins that developed during the breakup of the supercontinent Nuna.

The Athabasca Basin was conducive to other major igneous events. The Athabasca Supergroup is crosscut by mafic intrusions of at least three ages: ca. 1.27, 1.17 and 1.11 Ga. Given the cyclic nature of igneous activity in the region, it is unsurprising that the western Athabasca Basin is being actively explored for diamonds. Kimberlite, which carries the diamondiferous rock, is commonly associated with other alkaline igneous rocks. Consistent with that potential association, the Patterson Lake uranium exploration corridor, in the western Athabasca Basin, is host to Saskatchewan's only identified carbonatite. The undeformed calcite carbonatite dyke (age unknown) demonstrates the deep-seated nature of the region's fault zones.

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The Search for Kimberlites: Airborne Magnetic Data Processing in the Northwest Athabasca Basin

Omid Mahmoodi ¹

Abstract

Magnetic susceptibility data have been widely used as a standard geophysical method for diamond exploration due to previous success in differentiating the magnetic signatures of the kimberlitic host rocks and surrounding country rocks. Regional airborne magnetic data with 400 m line spacing collected from the northwest Athabasca Basin were processed to find magnetic signatures reflecting potential kimberlite occurrences. If not eroded, kimberlites form circular or elliptical anomalies in closed clusters. High-pass filters and analytic signal were applied to the data to enhance the boundaries and centres of magnetic anomalies. Resultant grids were used to manually locate anomalies. Magnetic anomalies occurring in clusters and spatially associated with dykes and structural discontinuities were proposed as potential targets. A matched-filter, grid-based approach was also used to identify roughly circular anomalies based on their correlation with an anomaly generated by a vertical magnetic cylinder located at a 30 m depth. Although some of the targets detected by this method had already been manually selected, more anomalies potentially associated with intrusions were added. The located 3D Euler deconvolution was also implemented, to estimate depth to the magnetic source for selected anomalies. The product was a map indicating the locations and estimated depth of selected anomalies, which could be of interest for further exploration in the area.

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Pikoo Diamond Project – 2016 Exploration Update

Ken Armstrong ¹ and Barbara Kupsch ¹

Abstract

The Pikoo Diamond Project is located in the northern Sask Craton, approximately 140 kilometres east of La Ronge and 10 kilometres from the community of Deschambault Lake. Iterative till sampling programs, geophysics and drilling led to the 2013 discovery of the first kimberlites in this area. Continued exploration through follow-up till sampling programs, ground geophysical surveys and exploration drilling in 2014 and 2015 led to several more kimberlite discoveries. As of November 2016, following another ground geophysical and drilling program, nine to possibly eleven discrete kimberlite occurrences have been discovered within the property. Kimberlite PK346, discovered in 2016 just 25 m north of the PK314 kimberlite is interpreted as a near vertical NE trending body with a true width of approximately 16 m and contains microdiamonds bringing the total of diamondiferous kimberlites on the property to five. The 2016 drilling also helped delineate the other four diamondiferous kimberlites (PK150, PK311, PK312 and PK314) as well as provide more samples for microdiamond analysis and mantle chemistry. The kimberlites discovered in the North Pikoo area (including PK346) are located directly up ice from unsourced, high interest, high chrome garnets found in till samples. The mineralogy and abundances of kimberlite indicator minerals within these kimberlites suggest there may still be an undiscovered bedrock source for these high interest garnets. PK150 remains the most significant discovery to date and microdiamond data suggest a relatively coarse diamond distribution, however the body is not big enough to warrant further stand-alone investigation. Follow-up, tighter spaced till sampling was conducted in the summer of 2016 at the head of the main indicator trains to guide target selection for a 2017 winter drill campaign. The exploration history of the project will be reviewed, including a description of the kimberlite occurrences and lessons learned that may guide future discovery.

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Technical Posters

The Beaverlodge Uranium District: 2016 Update

Ken Ashton ¹, Guoxiang Chi ², Rong Liang ² and Jacklynn Kennicott ²

Multimedia Surficial Survey of the McArthur River U Deposit Footprint

S.R. Beyer ³, T. Kotzer ⁴, K. Kyser ³, K. Ansdell ⁵ and K. Wasyluk ⁵

Garner River Gold Exploration Project: From Idea to Reality

Megan Binner ⁵, Corrie Davidson ⁵, Matthew Nadeau ⁵, Hoang Anh Tu Nguyen ⁵, Jordan Gashyna ⁵ and Chi Pu ⁵

Heavy Mineral Compositions from a Glacial Till in Saskatchewan: Classifications and Constraints on Source, with a Focus on Garnets

Katelynn Brown ⁵ and Kevin Ansdell ⁵

Petrogenesis of Granitoid Rocks Across the Nolan-Zemlak Boundary

Michael Cloutier ², Kathryn Bethune ² and Ken Ashton ¹

Structural-Kinematic Relations Across the Nolan-Zemlak Domain Boundary

Jordan Deane ² and Kathryn Bethune ²

Department of Geological Sciences Poster

University of Saskatchewan, Research and Studies

Department of Geology Poster

University of Regina

Modelling Geological Factors Affecting Fluid Flow and Heat Transfer Related to U Mineralization in the Eastern Athabasca Basin

K. Eldursi ², Z. Li ², Guoxiang Chi ², Kathryn Bethune ², D. Quirt ⁶ and P. Ledru ⁶

Multivariate Analysis of Kimberlite Indicator Mineral Trends Across Canada

Brett Ferguson ⁵ and Bruce Eglington ⁵

Sedimentology and Stratigraphy of the Dinosaur Park Formation (Campanian) in Southwestern Saskatchewan, Canada

Meagan Gilbert ⁵

South Tantalus Quaternary Project: Overview

Michelle A. Hanson ¹

Structural Analysis and Preliminary Alteration-Mineral Paragenesis of the Arrow Uranium Deposit, Athabasca Basin, Saskatchewan: Implications for Controls on Mineralization

Sean Hillacre ⁵, Kevin Ansdell ⁵, Galen McNamara ⁷ and Brian McEwan ⁷

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Deformation History of the Black Bay Fault and Associated Mineralization: Examples from Saskatchewan and Southern Northwest Territories

Dylan Jamison⁸, Pedro Acosta Gongora⁹ and Shoufa Lin⁸

Textural Relationships of the Ubiquitous Blue Quartz within Rocks Hosting the Arrow Zone, Athabasca Basin, Saskatchewan: Can Primary and Secondary Quartz Be Identified?

Jill Johnson⁵, Kevin Ansdell⁵, Sean Hillacre⁵, Galen McNamara⁷ and Brian McEwan⁷

Lithostratigraphic and Structural Controls of Uranium Mineralization in the Kiggavik East Zone, Central Zone, and Main Zone Deposits and Their Potential Extensions to the Northeast

Dillon Johnstone², Kathryn Bethune², Antonio Benedicto Esteban⁶, Dave Quirt⁶ and John Robbins⁶

Till Composition and Glacial Dispersal Patterns in South Rae Craton, Northwest Territories

Gabriel Lauzon¹⁰, Janet Campbell⁹ and Sally Pehrsson⁹

Modeling Time-domain Electromagnetics in a Mine Environment

Todd LeBlanc⁵ and Sam Butler⁵

Airborne Magnetic Data Processing, Northwest Athabasca Basin in Search for Kimberlite Occurrences

Omid Mahmoodi¹

Using Hyperspectral Data to Characterize Alteration Minerals in Drill Core from the Cigar Lake U Deposit

Magali Mathieu⁶, Régis Roy⁶, Patrick Launeau⁶, Michel Cathelineau⁶ and David Quirt⁶

La Ronge Horseshoe: Project Update and Summary of Recent Field Investigations at Bartlett, Sulphide and Nemeiben Lakes

Ralf O. Maxeiner¹, Nicole M. Rayner⁹ and Robert A. Creaser¹¹

Evaluating Mineral Potential in the Rae Domain of Northern Saskatchewan and Southeastern Northwest Territories with New Lake Sediment Geochemical Data

Martin McCurdy⁹, Sally Pehrsson⁹, Hendrik Falck¹², Steve Day⁹ and Janet Campbell⁹

Time and Space Variations of the Geological Map of the Arctic Region

Dean Meek⁵, Bruce Eglinton⁵ and Luis Buatois⁵

Geological Character of the Lavender Lake-Wapiskau River Area, Northern Glennie Domain, and Implications for Mineral Potential

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Trace Element Attenuation in Canadian Urban Streams: Investigation of Controlling Factors

*Aidan C. Mowat*⁵, *Bruce M. Eglinton*⁵, *Matthew B.J. Lindsay*⁵, *James W. Roy*¹³ and *Greg Bickerton*¹³

Response of the Cr Isotope Proxy to Environmental Changes 444 Million Years Ago: Ocean Oxygenation Recorded in Carbonates

*Matthew Nadeau*⁵ and *Chris Holmden*⁵

Au-PGE-U and REE-Th-U Mineralization in Altered Tantalum Domain Basement Gneiss, Stony Rapids Area, Saskatchewan

*Charles Normand*¹

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Preliminary Petrographic and Geochemical Analysis of Host Rock Lithologies at the Arrow Uranium Deposit, Athabasca Basin, Saskatchewan: Primary Mineralogy and Interpretation of Protolith

*Courtney Onstad*⁵, *Kevin Ansdell*⁵, *Sean Hillacre*⁵, *Galen McNamara*⁷ and *Brian McEwan*⁷

A New, Safe, Rapid Digestion Method for Uranium Exploration Using ColdBlock™ Digestion Technology

*Kirill Pereverzev*¹⁴ and *Matthew Leybourne*¹⁵

Targeted Geoscience Initiative (TGI) Uranium Ore Systems Project

*Eric Potter*⁹, *Victoria Tschirhart*⁹, *Dawn Kellet*⁹, *Bill Davis*⁹ and *Louise Corriveau*⁹

An Overview of the Recovery Program for Woodland Caribou in Northern Saskatchewan

*Murray C. Rogers*¹

A Lithochemical Study of the Metal Contents of the Cretaceous Oil Shales in East-Central Saskatchewan

*Murray C. Rogers*¹

Geological Atlas of Saskatchewan

*Bill Slimmon*¹

C29/30 Kimberlite, Candle Lake, Saskatchewan: Background, and Representative Samples from Drillhole CL-06-09

*Robert Suffern*⁵, *Kevin Ansdell*⁵ and *Perry Ksniuk*¹⁶

Mineralogy and Geochemistry of Fracture Coatings in Athabasca Group Sandstone as Records of Primary and Secondary Elemental Dispersion

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Ion Exchange Reactions in a Constructed Watershed for Oil Sands Mine Closure

Colton Vessey⁵ and Matthew Lindsay⁵

An Investigation into the Primary Mechanisms Changing the Distribution of Porosity in a Medium Subjected to Shear

Zoë Vestrum⁵ and Samuel Butler⁵

Fluid Inclusion Study of Halite and Sylvite from the Middle Devonian Prairie Evaporite, Saskatchewan

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Notes