# Regional Setting and General Characteristics of the Centennial Unconformity-related Uranium Deposit, Athabasca Basin, Saskatchewan

Kyle Reid* and Kevin Ansdell
Department of Geological Sciences,114 Science Place, University of Saskatchewan, Saskatoon, Saskatchewan, S7N 5E2 kdr197@mail.usask.ca

Dan Jiricka and Gary Witt
Cameco Corporation, Exploration Division, 2121-11th St., Saskatoon, Saskatchewan, S7M 1J3

And

Colin Card
Saskatchewan Ministry of Energy and Resources, Northern Geological Survey, 200-2101 Scarth St., Regina, Saskatchewan, S4P 2H9

## Summary
The Centennial deposit represents the first discovery of high-grade unconformity-related uranium mineralization in the south-central portion of the Athabasca Basin. The deposit shares similarities to those in the eastern end of the basin, but also contains notable variations. Similarities include association with metasedimentary basement units, clay alteration enveloping the mineralization and a brittle deformation zone extending from the basement into the sandstone. Insignificant amounts of graphite in basement rocks that underlie mineralization as well as the lack of significant post-Athabasca structural displacement are considered unique features of the deposit. Electromagnetic conductor modeling, as well as comparison of lithology and structure at the deposit to outcrop at the southern edge of the Athabasca Basin suggests that mineralization is associated with an extension of the Virgin River Shear Zone along the contact between Virgin Schist Group and Lloyd Domain rocks.

## Introduction
The Athabasca Basin contains the world's richest uranium deposits and provides approximately 20% of the current global uranium supply, exclusively from unconformity-related uranium deposits. The majority of exploration and development has been largely restricted to the eastern end of the basin, but uranium mineralization has been discovered in the western portion of the basin (e.g. Cluff Lake, Maybelle River Zone, Shea Creek, and Maurice Bay deposit). In 2004, Cameco Corporation discovered significant uranium mineralization approximately 120 km WNW of Key Lake in the vicinity of Wide Lake, Saskatchewan (Fig. 1). Prior to this time, no significant uranium mineralization had been found in this portion of the Athabasca Basin, an area underlain by the continental scale shear zone known as the Snowbird Tectonic Zone. This new zone of mineralization, known as the Centennial deposit, has both similarities and differences from some of the world class deposits located in the eastern portion of the Athabasca Basin. This project is designed to characterize the geological setting, mineralogy and geochemistry of both alteration and mineralization, and to compare the deposit to other deposits in the basin. This report will provide information on the regional and local geological setting of the deposit, based on outcrop mapping in the Westgate Lake area along the south-central margin of the Athabasca Basin and examination of drill core at the deposit itself (approximately 30 km apart), providing the background for later reports on the detailed petrological and geochemical characteristics of the mineralization and alteration.

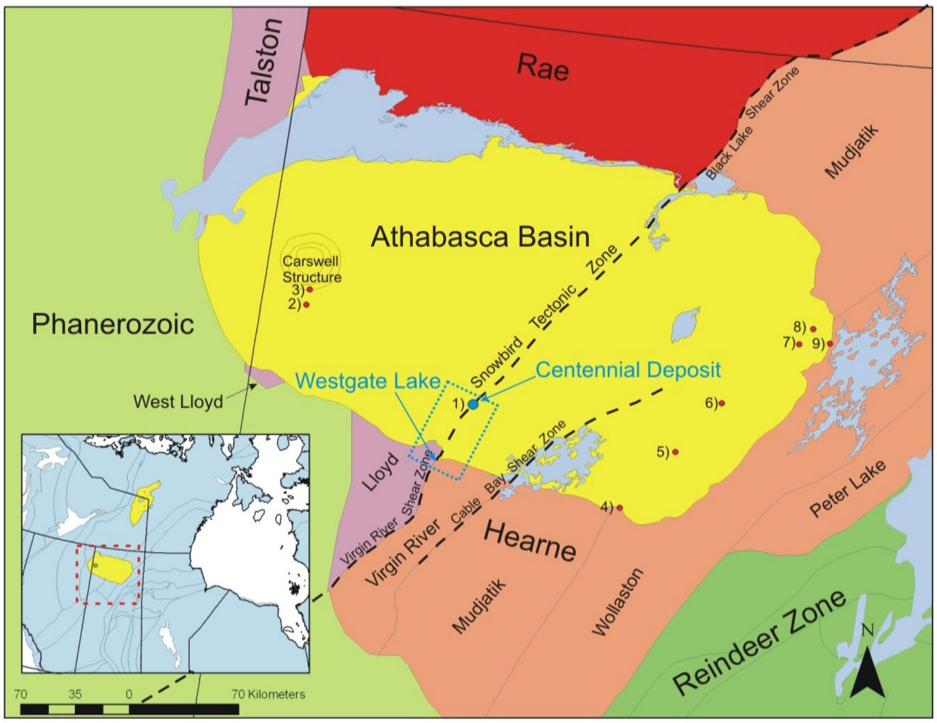


Figure 1: Location of the Centennial deposit and Westgate Lake area. 1) Centennial, 2) Shea Creek, 3) Cluff Lake, 4) Key Lake, 5) McArthur River, 6) Cigar Lake, 7) Midwest, 8) Dawn Lake, and 9) Rabbit Lake. Modified after Card et al. (2008)

## Regional Setting

The Centennial deposit is associated with the major continental scale shear zone known as the Snowbird Tectonic Zone (Hoffman, 1988), which separates the Lloyd Domain from the Virgin River and Mudjatik Domains to the east. Where this feature is exposed at the southern edge of the Athabasca basin it is present as a 5-7 km wide zone of highly strained and mylonitized rocks that are referred as the Virgin River Shear Zone (VRSZ: e.g. Lewry and Sibbald 1980, Card et al., 2008). Card et al. (2008) interpreted the VRSZ to represent a suture between the Virgin River Domain and Lloyd Domain, which entrained a narrow package of lower metamorphic grade (lower to middle amphibolite) pelite and psammopelitic schists termed the Virgin Schist Group (VSG: e.g. Johnson, 1968). The Virgin River Domain has contains upper amphibolite facies assemblages, whereas the Lloyd Domain has been subject to granulite facies conditions. The two domains interpreted to have had separate tectonometamorphic histories prior to being sutured (Card and Bosman, 2007 and Card et al., 2008). The high metamorphic grade rocks are overprinted by amphibolite facies metamorphism along the VRSZ.

## Observations and Interpretations

Comparison of outcrop from Westgate Lake to drill core of basement rock beneath the Centennial deposit indicates that there are lithological similarities between the two locations. The deposit is spatially associated with a combination of variably mylonitic feldspar porphyroclastic granitoid and lower metamorphic grade metasedimentary rocks. Metasedimentary rocks vary from muscovite and graphite bearing pelitic schists to quartzite, with pelitic schists interpreted to be analogous to the Virgin Schist Group observed at Westgate Lake. Modeling of electromagnetic conductors shows a series of semi-continuous conductors that extend from near Westgate Lake to the vicinity of the Centennial deposit. These likely represent conductive lithologies such as graphitic and sulphidic horizons within the Virgin Schist

Group and suggest it extends as a discrete package of rocks to the Centennial deposit. However, in the immediate basement to the mineralization only weakly graphitic lithologies are observed suggesting there is no spatial relationship between mineralization and the identified EM conductor. Felsic to intermediate feldspar porphyroclastic gneisses are similar to feldspar porphyroclastic rocks observed in the Lloyd Domain at Westgate Lake.

The Lloyd Domain, Virgin Schist Group, and Virgin River Domain are all interpreted to have separate early structural histories ($S_1$) that are affected by a common northeast-trending $D_3$ event that is most prominently observed in the VRSZ (Card et al., 2008). From a regional perspective $D_2$ is only observed in the Virgin River and Mudjatik Domain (Card and Bosman, 2007). A steeply west-dipping foliation/cleavage observed in schistose metasedimentary rocks associated with the deposit is interpreted to be analogous to the steeply WNW dipping regional $S_3$ foliation/cleavage observed at Westgate Lake. At both the deposit and Westgate Lake, VSG rocks show west-over-east displacements suggesting that to some degree early ductile processes were similar.

The deposit forms a NNE-SSW trend over a length of at least 650 m and is found at a depth of approximately 800 m close to the unconformable contact between basement rocks and the overlying Athabasca Group (Jiricka and Witt, 2008). Mineralization is located approximately 300 m east of the interpreted location of the post-Athabasca Dufferin Lake fault. There, it straddles an unconformity high formed at the contact between highly strained weakly mylonitic metasedimentary and granitoid rocks of the basement. At this contact is a steeply west-dipping zone of brittle deformation which represents the reactivation of earlier ductile structures of the Snowbird Tectonic Zone/VRSZ under brittle conditions. Brittle faulting is best developed in the quartzite located in the hanging wall of the fault zone. Granitoid and metasedimentary rocks form the footwall and hanging wall to the fault zone, respectively. This brittle deformation extends into the Athabasca Group as desilicified and clay-indurated breccias which sometimes contain minor perched uranium mineralization. A notable difference with other deposits is that the brittle structure with which mineralization is associated, does not appear to have substantial post-Athabasca displacement (Jiricka and Witt, 2008). In contrast, the adjacent Dufferin Lake fault has post-Athabasca displacement which is more similar in magnitude to the P2 Fault at McArthur River, and the Collins Bay fault at the Collins Bay zones.

The Athabasca Group column above the deposit is variably silicified, desilificied, hematized, clay-indurated and commonly has a sooty grey appearance. Basement rocks have been locally affected by a pervasive dark green chloritization. In locations distal to mineralization, paleoweathering is observed affecting granitoid rocks as pitting and dissolution of feldspar up to 100 m below the unconformity. Within 30 m of the west-dipping brittle fault zone associated with mineralization is a zone of pale green alteration that can be observed overprinting the dark green chloritization. The pale green alteration is subsequently overprinted by a creamy yellow alteration and fracture-controlled hematite closer to the mineralization (0-15 m). Pale grey clay is observed filling fractures that cross-cut earlier alteration, and which are in turn cross-cut by dark green hairline fractures. Weakly graphitic metasedimentary lithologies of the hanging wall appear to extend into areas of uranium mineralization, but graphite has not been observed within the strongly clay altered zone that surrounds the mineralization.

Uranium mineralization at the Centennial deposit most commonly extends continuously from a few metres into the Athabasca Group and up to 30 m into basement, though locally it is perched up to 50 m above the unconformity. In the basement, mineralization is generally associated with intensely clay altered and faulted pelite and quartzite, locally it is found adjacent to strongly chloritised granitoid. Earthy to sub-metallic black blebs of uraninite intimately associated with brick red hematite are believed to represent primary mineralization. Uranium secondary minerals are ubiquitous and are commonly observed as white and yellow fractures and haloes around black uraninite blebs. The abundance and variety of uranium secondary minerals suggests multiple fluid events have affected the primary mineralization.

A post-mineralization diabase, potentially related to the MacKenzie dike swarm, intrudes as an irregular feature along the west-dipping brittle fault zone with local sill-like protuberances. Relatively fresh diabase is seen intruding uranium mineralization in certain locations, although it does not appear to have assimilated the mineralization. Closer to the unconformity and in the Athabasca Group the diabase is generally intensely clay altered and is in some cases mineralized (up to 6500 cps, SPP2). This would suggest that a post-intrusion fluid has remobilized and precipitated uranium in or at the contact of the diabase due to its reduced character.

## Conclusions

Based on lithological and structural similarities between outcrop at Westgate Lake and basement rocks at the deposit, the Centennial deposit is considered to be associated with an extension of the VRSZ along or near the contact between the Lloyd Domain and VSG rocks. Brittle deformation associated with mineralization is likely the result of reactivation of earlier ductile structures along this contact. The deposit has a complex paragenetic history with crosscutting alteration events in the basement and the Athabasca Group, and primary uranium mineralization has been overprinted by secondary minerals, including those that post-date the intrusion of the diabase.

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