MINING INNOVATIONS AT McARTHUR RIVER OPERATION

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ABSTRACT

McArthur River Operation is the world's largest high grade uranium deposit and is located in Northern Saskatchewan. McArthur River came into production in December 1999 with a number of innovative technologies to allow for mining of a high grade uranium deposit in challenging geotechnical and hydrological conditions. The raisebore mining method has been supplemented by the continued development of a boxhole mining technique to allow for mining of mineralization that cannot be accessed with a drill chamber from above. An innovative freeze wall re-design – a cathedral freeze wall, was implemented in 2009 to allow for top access of a new orebody in the unconformity area of the Athabasca Sandstone. This paper highlights some of the ongoing improvements to the mining method and the innovative risk mitigation applied to manage the extraction of this challenging orebody.

INTRODUCTION

The Province of Saskatchewan is home to some of the world's largest present and past producers of uranium concentrate, U_3O_8. The uranium deposits in the Athabasca Basin are of hydrothermal origin located along ancient faults at the unconformity between the Archean basement and the overlying sandstones of Proterozoic Age (Fig. 1). Often near the uranium deposits, the hydrothermal alteration has created weak rock mass conditions at depth, combined with abundant ground water at hydrostatic pressures in the Athabasca sandstone. Most of the underground uranium mines have experienced significant unplanned inflows into their operations and have required mining innovations to mitigate these risks during development and ore production. Similar experiences have occurred during the process of shaft sinking. This paper highlights some of the ongoing improvements to the mining method and the innovative risk mitigation applied to manage the extraction of this challenging orebody. Interested readers can obtain detailed explanations from the referenced papers.

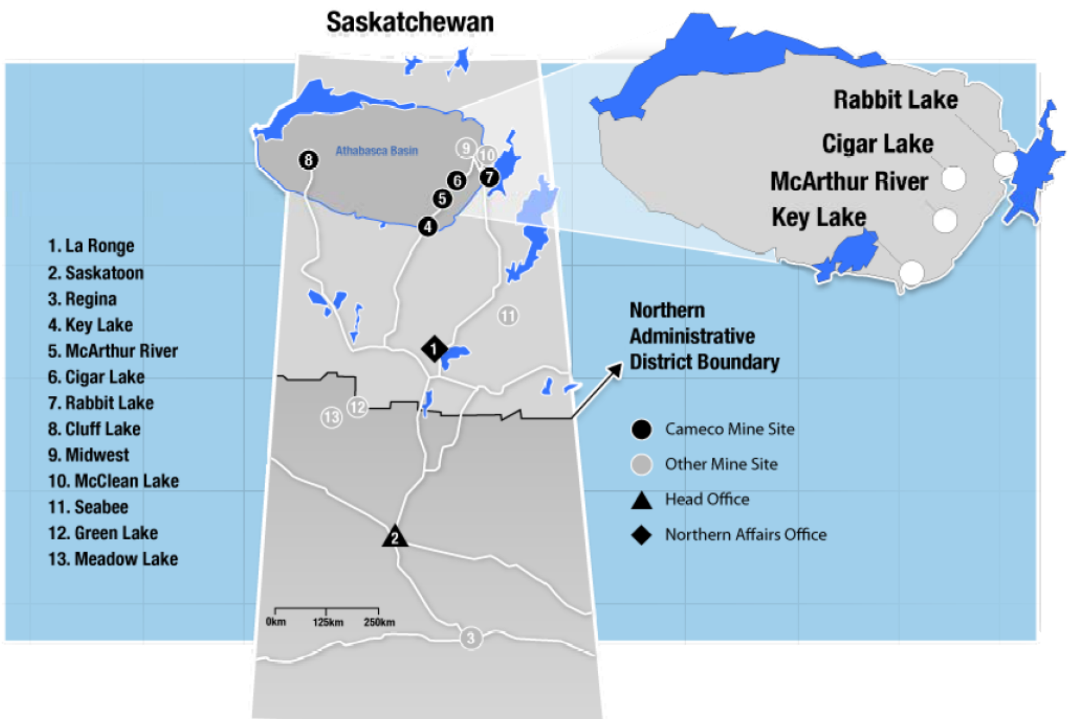

Figure 1 – Mine sites of the Athabasca Basin, and other mine sites in northern Saskatchewan, Canada (McArthur River Operation 2010)

INNOVATION WITH RAISEBORE MINING and ARTIFICAL GROUND FREEZING

The mining at McArthur River operation involves a number of challenges including control of groundwater, weak rock mass conditions, and radiation protection from high grade uranium ore. Based on these challenges, it was identified during initial mining studies that non-entry mining methods would be required to mine the deposit. The raisebore mining method was selected as an innovative approach to meet these challenges and was adapted to meet the McArthur River conditions since production started in 1999 (Jamieson, 1997).

As part of the initial mining of the Zone 2 orebody, the raiseboring mining method was coupled with artificial ground freezing to provide a stable three-sided wall around mineralization. For the first 10 years of mining the Zone 2, the orebody could be accessed above and below in the relatively dry and stable basement rock (Ref Figure 2). The factors that drove the artificial ground freezing decision were the need to (1) stabilize the altered ground around the perimeter of the mineralization, and (2) hydraulically isolate the ore from the high pressure water. The hydrostatic pressure ranges around the ore range from 4 to 5 MPa dependent on depth. A significant collapse or fall of ground in the dry basement rock that is near the unconformity contact can greatly increase the local hydraulic conductivity by the propagation of fractures into the water bearing sandstone and trigger a mine inflow (Bashir, 2010).

The raiseboring mining method, as a non-entry mining method, was chosen to reduce the potential for (1) radiation exposure with the mineralization in the form gamma, radon progeny, or long-lived radioactive dust, and to (2) control the size of and rate of the ore extraction, thereby increasing the stability of the ore blocks in variable ground conditions. The raisebore mining method, drill chamber, and extraction chamber set-up allowed for (3) single pass ventilation through the extraction chambers or a push-pull system to be located in the drill chamber. The raiseboring mining method also allowed for (4) selective mining where vertical raises could be overlapped to ensure that no ‘skins’ of highly valuable ore would be left behind or lost due to instability (Ref Figure 3). A paper from Jamieson and Frost (1997) further discusses raisebore mining, controls in place around raisebores to reduce radiation exposure, and other mining methods that have been proposed but not used to date.

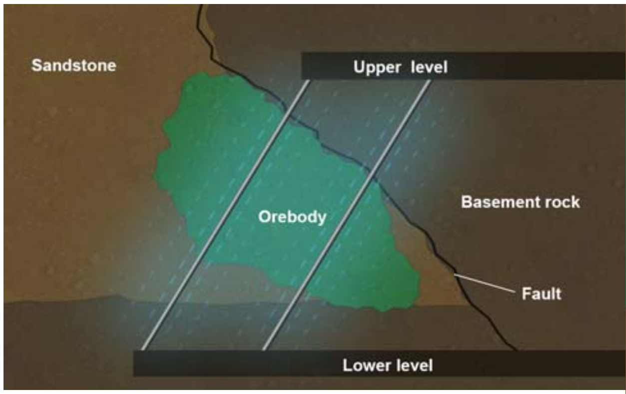

Figure 2 Vertical section view through orebody showing two inclined ground freezing pipes (McArthur River Operation, 2010)

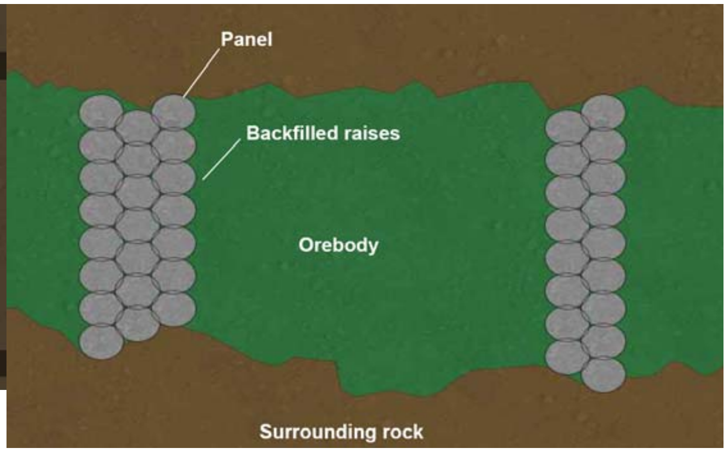

Figure 3 Plan view through orebody showing overlapping vertical raises (McArthur River Operation, 2010)

INNOVATION USING BOXHOLEBORING

The boxhole mining method is proposed for future areas of the mine where hydrogeological conditions render it impractical for access development above the ore. Boxhole boring has been used safely to develop orepasses and ventilation raises at mines in South Africa and South America; however it has not been used as a mining method for uranium ore extraction. As with the previous successful development of the raisebore mining method, Cameco intends to take existing methods and equipment from boxhole boring and modify them to create a mining method that is safe and economic for extracting high-grade uranium ore. To develop this new mining method, McArthur River has embarked on a test mining program that will run from 2009 to 2012 prior to the full-scale implementation of the boxhole mining method for commercial ore production. The test program is being conducted using a 53RH-EX boxhole drill supplied by Atlas Copco. (Goetz, 2010)

The envisioned boxhole mining system will employ two separate mining levels, which are both located below the orebody in competent basement rock (Ref Figure 4). The boxhole drill and auxiliary equipment are set-up in the lower level, drill chamber (Ref Figure 5). A 15m waste rock pillar separates the drill chamber from the extraction chamber above. The extraction chamber contains a muck chute which is sealed to the back of the chamber and used to deflect drill cuttings from the raise (Ref Figure 6). A steel head cover is used on top of the muck chute to provide overhead protection when operators are working under an open raise. A seal box is used on the floor of the extraction chamber to minimize the amount of mineralized muck that could reach the drill chamber. The drilling process consists of piloting a hole from the drill chamber through the 15m pillar between chambers, recollaring and piloting to the top of the ore body. (Goetz, 2010)

After completion of the pilot hole, the reamer is attached to the drill string within the extraction chamber and the raise is reamed along the pre-drilled pilot hole to the top of the ore body. Stabilizers are added to the drill string at fixed intervals to minimize oscillation and bending stresses on the drill string during reaming. Cuttings fall by gravity into the muck chute, which deflects them to the side of the chamber. Muck removal is expected to follow similar practices currently in use for raisebore mining, but engineering studies will be carried out in the future to optimize this task. (Goetz, 2010)

Upon completion of reaming, the drill string is tripped out and the reamer removed. The raise is then backfilled with concrete using a new innovative technique that employs a backfill plug form attached to the boxhole drill string to support an initial concrete plug. The plug form, which has a rubber seal around it, is pushed into the bottom of the raise to create a good seal with the walls of the raise. A portable concrete pump is then used to pump concrete via a Sclair pipe to form an initial plug. Once the plug has reached a UCS of 10MPA, the second and final pours are then done via backfill holes drilled from nearby excavations to the top of the raise. (Goetz, 2010)

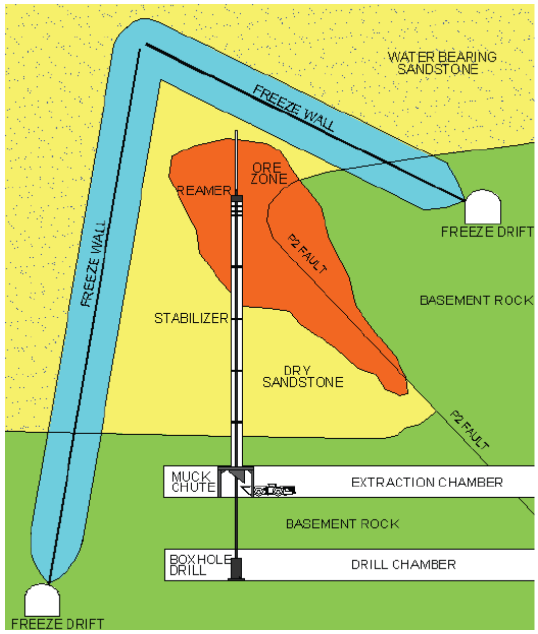

Figure 4 Vertical section view showing boxhole extraction and drill chambers (Goetz, 2010)

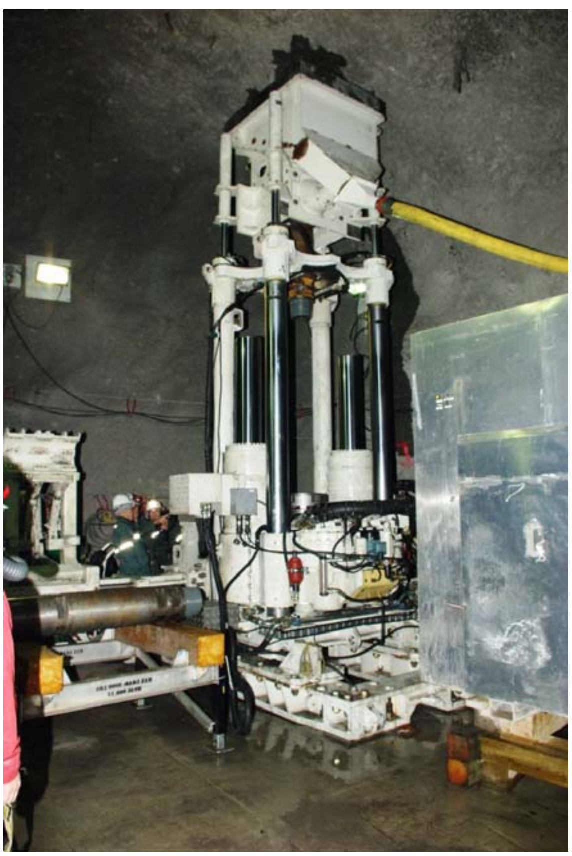

Figure 5 Boxhole drill, and drill chamber set up (McArthur River Operation, 2010)

Figure 6 Muck chute, and extraction chamber set up (McArthur River Operation, 2010)

INNOVATION IN OVERCORING FREEZEPIPES

During the initial preproduction development at the start of operations, a series of freeze pipes were drilled through the Zone 2 orebody to divide the Zone 2 orebody into two sections, this allowed for the completion of the freeze wall in time for planned production in 1999. However the internal freeze wall and the steel pipe remained as a future challenge to be removed by the next generation of miners. The internal freeze wall and steel had temporarily sterilized approximately 11 million pounds of U_3O_8.

Many years prior to 2008, conceptual work had started on how to remove these steel pipes, which consisted of three or more nested freeze pipes that have been grouted in place with cement. Specialized overcoring tools were developed by mine geology staff and the drilling contractor (Boart-Longyear) to drill around the outer most freeze pipe, cut the blind end of the freeze pipe (down hole), retrieve metal cuttings, and the pull the cut pipes up and through the collar (Ref Figure 7). It took approximately two years of continuous work for the group to develop the technique. In the end, the previously inaccessible uranium was freed-up and has since been mined. The mine geology department and drilling contractor were recognized amongst other Cameco innovation projects in 2009 for a company wide innovation award (Cameco Clarifier, 2009).

Figure 7 Overcoring bit and set up for freeze hole removal (Cameco Clarifier, 2009)

INNOVATION IN BLASTING FREEZEPIPES

Although the overcoring of freeze pipes continues today, overcoring was found not to work in all circumstances. Challenges to overcoring occurred where there was shifting of ground due to freezing and heaving. Where the outer steel casings were broken and offset, the overcoring bit could not be properly lined up causing the overcore bit to cut through rather than around the freeze pipe, leaving pipe behind; in these circumstances a new freezepipe removal technique was required. Perforation of the casing was investigated; however the multiple layers of steel and cement made this common oil industry technique of hydrofracturing ineffective. Reaming though the freeze pipes with modified reamers was also field trialed with no success. A new method to either cut or destroy the freeze pipes was required; a method was devised to lower explosives down the centre freeze pipe. The explosives had to be capable to shatter all the surrounding pipes and overcome the burden that comprised the last few metres of the end of the freeze pipe and the surrounding rock to the free face created by the raisebore.

Eight Pentolite boosters were strung together by two lines of detonating cord and a carry-strap. In order to provide weight to lower the charge through the inner freeze pipe, a steel ball wrapped in tape was attached to the string to act as weight (Ref Fig 8). Each metre of charge destroyed approximately two metres of freeze pipe, and shattered approximately half a metre up the hole where the burden of rock was too great to be overcome (Ref Fig 9).

Before field trials were conducted, extensive numerical modelling of the detonation of the charges, damage to freeze pipes, and the damage zone were completed through Global Technology Development, Orica. A Job-Hazard-Analysis was completed with the blasting crews, due to the uniqueness of the work at hand.

Figure 8 Eight Pentolite boosters (Preece, 2011)

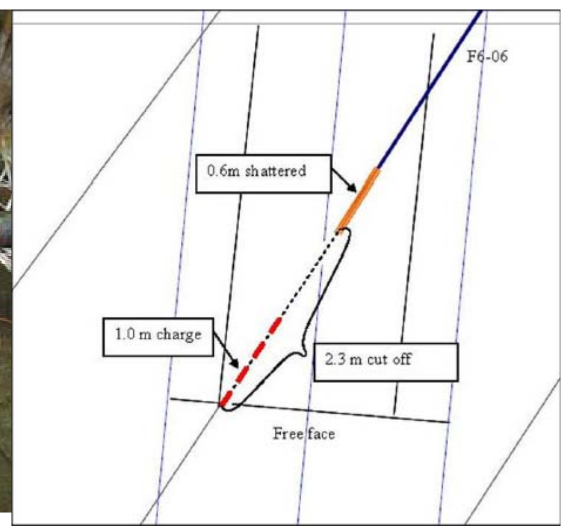

Figure 9 One metre charge at bottom of freeze hole, with raisebore free face (Preece, 2011)

INNOVATION IN MINE DEVELOPMENT THROUGH THE UNCONFORMITY

During the first ten years of mining at McArthur River Operation, it was not possible to complete preproduction development above the orebody. However a significant investment in freeze pipe drilling, the use of mechanical cutting, NATM ground support techniques, attention to radiation protection, and inflow preparedness were combined to successfully complete the first drift through the unconformity, and into the formerly water bearing sandstone.

Artificial ground freezing was used to create a cathedral or tent above the future overcut drift, labeled 'Panel 5 Freeze Wall' (Ref Fig 10). The toes of the freeze holes were approximately 3 metres apart with the end of the freeze holes interlacing and overlapping by a few metres. The cathedral was created from two freeze pipe fans, one collared on the 530mL from the north of the future development and another fan collared on the 530mL from the south of the future development. Both fans were drilled up to intersect the 500mL elevation, which would be meet approximately 7 to 10 metres above the future development, shown as '510-8225 R/B Chamber to Develop' (Ref Fig 10). There were over 150 freeze holes drilled, with an average length of 100 metres each. Holes were drilled above the orebody, and then into the page down the footwall side of the ore. The drilling process took approximately two years to complete with six months of freezing required to meet a minimum thickness of 3 metres of frozen ground.

Radiation protection of the workers was critical to the design of the 510-8225N Chamber; additional care was taken because it was known there was potential for ore stringers to be intersected during development. Specific instructions for developing the chamber required the use of an enclosed cab for the mechanical cutting, a dust sampling program, a dust suppression system, a push-pull negative ventilation system, a designated mineralized remuck, and a contingency plan to deal with a potential mine inflow. (Yameogo, 2010)

A series of geomechanical analyses was performed to check and cross-check the design for the raisebore chamber. The following analyses were conducted for the Zone 2 Panel 5 area: hazard identification, kinematic stability, numerical simulation, analytical method, and empirical design calculations. (Yameogo, 2010)

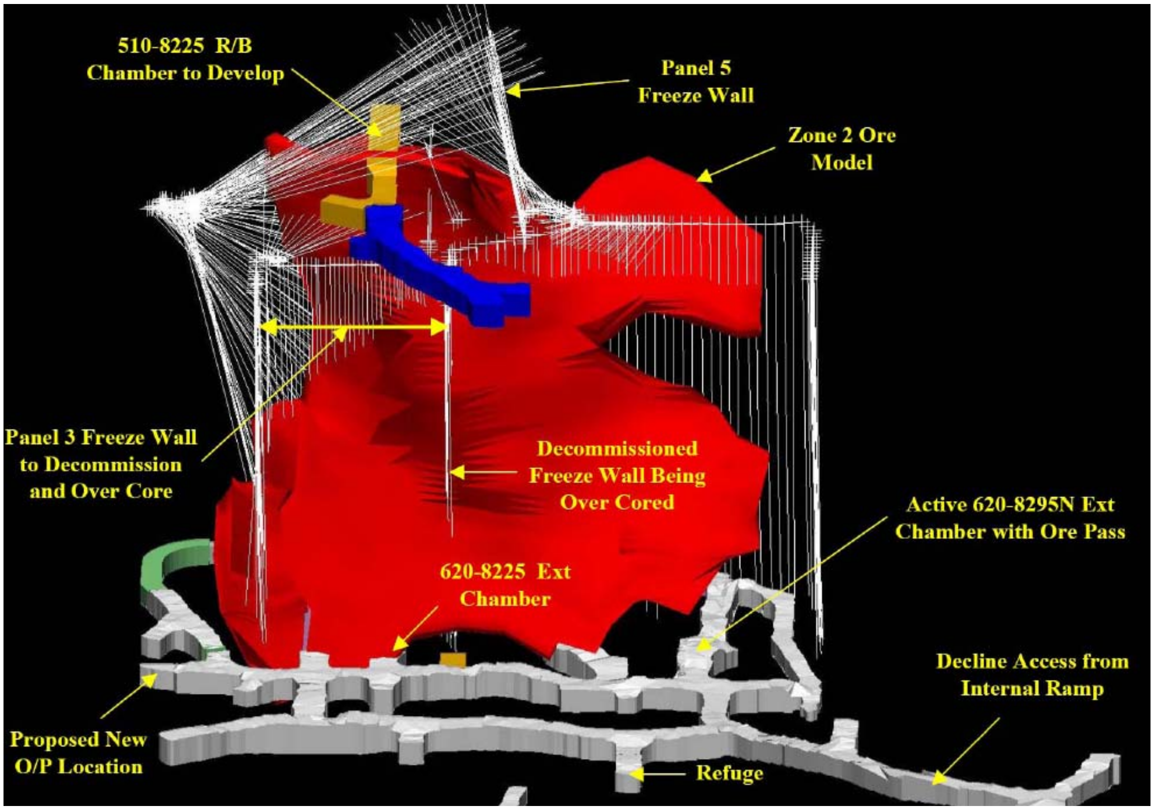

Figure 10 Crosscut raisbore drift located above the ore, under a freezewall, and through unconformity (McArthur River Operation, 2010)

CONCLUSION AND DISCUSSION

The McArthur River Operation will continue to benefit from mining innovations, many of which will be developed in-house by operators, contractors, and staff at the mine site. These innovations and techniques allow for new mining opportunities in the Athabasca Basin, near the unconformity and above the ore to maximize extraction. Current projects not discussed include high-pressure waterjet cutting of the freeze pipes, a specialized freeze hole drilling rig for vertical (up) holes, and a composite hydrostatic lining to keep future shafts in the Athabasca Basin dry.

ACKNOWLEDGEMENTS

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