GLOBAL URANIUM CONFERENCE 2022

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Abstract Book

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South Australia’s Radiation Protection and Control Act 2021

Daniel Bellifemine, Manager – Mining and Radiation, Environment Protection Authority

Radiation provides significant benefits to Australians, through its use in medicine, mining, science and industry. The EPA (Environment Protection Authority), as the States independent radiation safety regulator, seeks to facilitate the benefits of safe and justified uses of radiation, with social and intergenerational equity, while controlling radiation sources to prevent harm to people or the environment.

A new Radiation Protection and Control Act 2021 will come into operation by 11 February 2023.

This presentation will provide an overview of the features of this Act, including how it operates in the Uranium mining sector.

Uranium and Energy – What is the Risk?

Douglas Boreham
Professor and Division Head of Medical Sciences at the Northern Ontario School of Medicine

Uranium is currently the only affordable energy source to power and protect the environment from climate change. The province of Ontario in Canada has a population of 15 million people and has a nuclear fleet of 18 CANDU nuclear reactors providing 60-65% of the province's clean electricity.

Canada and Australia have abundant supplies of Uranium but nuclear energy in Australia and elsewhere is challenged because of the fear of low dose ionizing radiation exposure.

There is a world class underground life sciences laboratory called SNOLAB in which we can study the biological effects of low dose ionizing radiation. SNOLAB was originally constructed for Astro-particle physics research (Nobel Prize in Physics 2015).

In SNOLAB our research program is called: Researching the Effects of the Presence and Absence of Ionizing Radiation (REPAIR project).

The aim of this presentation will be to show that low dose ionizing radiation exposure is not harmful and that uranium and nuclear energy are safe.

Can the uranium sector cope with a major extended boom

John Borshoff

There is little doubt more uranium will need to be discovered and over the next 20 years to support the newly invigorated and growing nuclear sector. This phenomenon is occurring because of some remarkable circumstances and is what the sector has been hoping for. But with this are challenges to be overcome to be able deliver what we preach.

Since Fukushima in 2011 our industry has for 10 years been in a dying, sedentary mode, holding on grimly to survive, In order to keep businesses afloat, many have had to shed staff and keep expenditure to the bare minimum in what could be likened to hibernation to ride out an extended winter.

When uranium prices reach the incentive levels needed to encourage new mine development (and exploration) a pandoras box could open. A huge, new responsibility is emerging for the junior companies especially those with production aspirations.

Imagine that 6 to 10 ISR operations might be needed to produce 3 to 5Mlb coming from 3 to 4 Corporates. Imagine the 4 to 5 new conventional uranium operations on top of this that will need to come online to produce 15 to 25Mlb and the 60 or so existing uranium companies growing to more than 200, all over the next 10 years, and the enormous effort that will be required for all this to occur.

This address will attempt to identify these challenges that will need to be overcome to re-establish and to better ensure we will be able to deliver our part into the vital nuclear industry.

Kayelekera - Challenges of Developing a Mine in an Emerging Mining Jurisdiction

Keith Bowes, Managing Director, Lotus Resources

The Kayelekera Uranium Mine is located in the Karonga region of northern Malawi.

The mine is a past producer having operated for 5 years between 2009 and 2014 during which time it produced ~11MLbs U_3O_8 equivalent.

Lotus Resources acquired the asset in March 2020 and since then has focused on maintaining the asset in a good standing while undertaking various studies to develop a restart strategy that will ensure an economic operation and also to overcome some of the issues experienced by the previous operators.

The key challenges facing the Company for the restart of the mine that will be discussed include:

- Government expectations and equitable distribution of revenues
- Community buy-in for a restart
- Overcoming historical operating issues
- Financing options versus off-take options
- Availability of labour and skillsets
- Managing supply chain and costs

Uranium Supply: Is History Repeating Itself?

Mark Chalmers, Energy Fuels

Uranium markets and prices have followed clear patterns during the more than 70-year history of modern production. Today, tighter supplies, increasing demand and geopolitical tensions are changing the landscape rapidly. As a result, uranium prices are the highest they've been in many years. However, to the careful observer, this should not have come as a surprise.

How quickly can the industry respond? What can past historical trends, going back to the 1950's, show us today? What is the role of long-term contracts? Most uranium supply companies tend to promise the world but are unable to deliver on these promises.

From the producer's perspective, the future is clear. As the aforementioned factors take hold, and as the price of uranium goes up, how will things unfold? Several projects will undoubtedly be announced, but few will actually contribute to the global supply coffers. Some utilities will bet on the "wrong horses" and end-up short.

History repeats, and there are lessons learned from the past that can definitely be applied to the future.

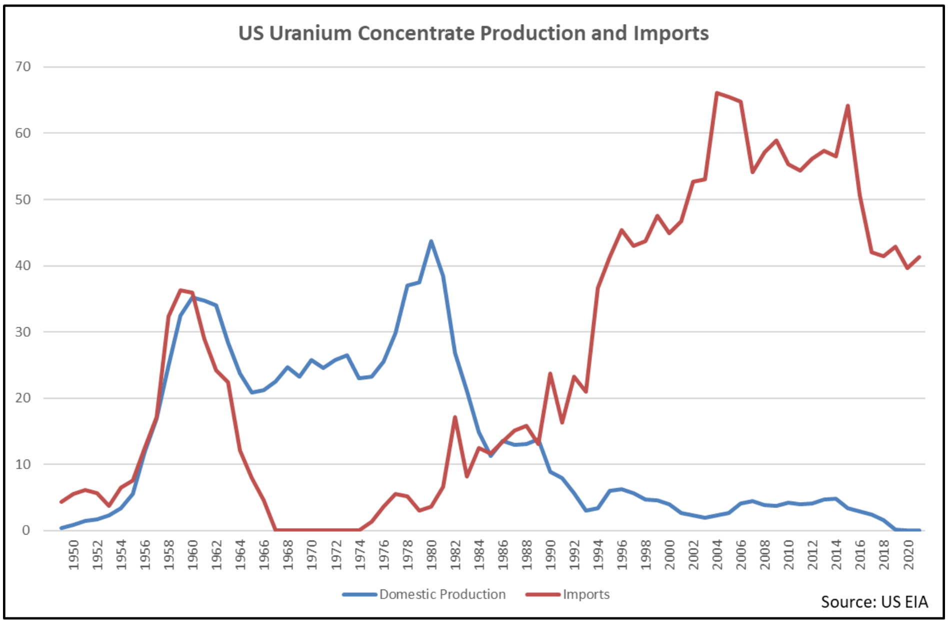
There is plenty of uranium in the World – the question is which companies will actually produce, how much and at what price?

Nuclear Wasteland? Never again.

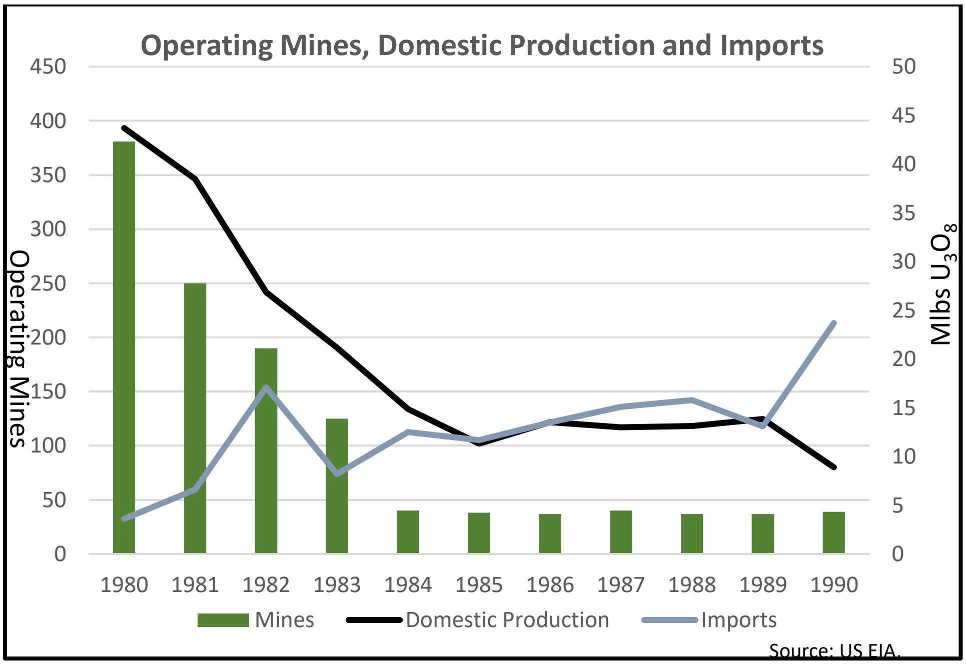
Greg Cochran, Aurora Energy Metals Ltd

Historical US Uranium Production

Just after World War 2, the US Atomic Energy Commission (AEC) began to incentivise domestic uranium production, with the government paying significant discovery bonuses and offering ten-year price guarantees. Uranium was also imported into the US up to the end of 1966, before an eight-year prohibition was imposed. US uranium production peaked in 1980 at 43.7 Mlbs U_3O_8 and by the end of 1981, cumulative local production and imports added together exceeded a billion pounds. That was also the first year the total US inventory was published, and it stood at 159.2 Mlbs!



Initially, the uranium produced was for weapons production until the first nuclear power reactors were commissioned in the early 1950's, after which demand then gradually shifted away from weapons towards the peaceful use of the atom. By the mid 1970's nuclear capacity stood at 41,000 Mwe and an additional 97,400 MWe were being built. Throughout the 1970's US uranium production surged, initially as a result of the ban on imports but then also spurred on by nuclear energy's gathering momentum and the rapidly increasing price of uranium. The oil crisis of 1973 also had a significant impact. Between 1966 and 1980 US uranium production doubled, but that came at great environmental cost as 381 uranium mines were operating in 1980, implying an average annual production rate of only 115,000 lbs. per mine.



Health and Environmental Legacies

The government incentives that induced the boom in uranium production also incentivised the worst behaviours, with almost all US uranium mining companies ignoring the most basic safety, health and environmental standards. Indigenous miners were the most at risk; for example it was estimated that Navajos made up at least a quarter, and possibly as much as 41% of the 12,000 miners working in the industry in the 1970's. In fact, whilst uranium mining risks were well understood almost from the beginning, information was consciously withheld by the AEC that controlled the industry and the nuclear weapons program.

The AEC also regulated workers' exposure to radiation, but only outside of the mines and even ignored and actively suppressed information about the dangers. The following quote, from a document written in the 1940's but only made public by the DOE in 1994, shows the extent of the deception: "knowledge of the results of this study might increase the number of claims of occupational injury due to radiation".

Interestingly, the Bureau of Mines did not inspect uranium mines because it lacked the authority to do so until the Metallic and Non-metallic Mine (MNM) Act of 1966 was passed (but even then it took until the following year before the Bureau actually got to visit a uranium mine).

Returning to the plight of the Navajo miners, a report published in 2000 concluded that between 1969 and 1993, their risk of contracting lung cancer was nearly 30 times higher than for non-miners. This gave rise to a unique and sad fact that amongst the Navajo, exposure in a single occupation accounted for the majority of lung cancers in the entire population.

However, it was not just the health of uranium mine workers that suffered during this period. Well over 200 million tonnes of uranium mill tailings had been accumulated up to 1980, when regulations were at last introduced for the remediation of uranium mill tailings.

Uranium mill tailings at the former Atlas Mining site, Moab, Utah
Source: Joanne Ciccarello | Christian Science Monitor | Getty Images

Critical Mass and Sustainability

It was no coincidence that the number of mines plummeted throughout the 1980's. Clearly, the unusually small mine-model, with operations usually supplying ore to centralised processing plants based on a hub and spoke strategy, was not sustainable. Due to their lack of scale, those operations could not carry the overheads required to implement proper safety and health programs or rehabilitate the mines once exhausted.

Some might argue it was the decline in price that prompted the closure of the mines and whilst that is undeniably true, price doesn't explain the industry's inaction on health, safety and environmental matters during the 1970's when prices were are all time highs.

Aurora's Mine of the Future

The Aurora Energy Metals Project, which includes a large, well-defined uranium deposit (69.3 Mt @ 248 ppm eU_3O_8 for 37.9 Mlb eU_3O_8), has the scale to not only avoid the industry's historical catastrophes, but also to be a standout example of a "Uranium Mine of the Future" that can meet the USA's desire for longer-term sources of sustainably and responsibly mined domestic uranium.

To achieve this the Company is already investigating a net zero vision for the development of its uranium-lithium project by taking advantage of a nearby supply of reliable, low-cost, hydro-generated electricity. This clean power advantage alone already puts it well down the path to net zero but allied with in-pit crushing technology and world leading conveying solutions, progress towards that goal will be accelerated and is likely to position the project favourably.

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Keywords: Historical US Uranium Production, Environmental Legacies, Critical Mass and Sustainability, Aurora's Mine of the Future

Australian Uranium and the Honeymoon Mine Re-Start

Duncan Craib, CEO, Boss Energy

This presentation will highlight Australian Uranium operations and production, in particular the re-start of the Honeymoon Mine in South Australia.

Boss Energy are entering into an exciting new phase of development, with the Enhanced Feasibility Study completed in 2021, and the project on track for production of 2.45Mlb of U_3O_8.

Boss Energy's Honeymoon project is supported by highly skilled hydrogeologists, geologists, and management with proven operational experience. To further enhance their position, Boss Energy has identified an innovative approach to determine the economic recovery of In-situ Recovery (ISR) deposits.

Boss Energy and WGA have been granted an Accelerated Discovery Initiative (ADI) grant by the South Australian Government, to deliver this 'proof of concept' geophysical data processing tool for sedimentary uranium deposit evaluation for ISR during Greenfields exploration. If successful, this tool has the potential to be rolled out to other operations.

Nuclear medicine: an update on a uranium dependent industry

Geoff Currie

The Australian nuclear sector is complex, but this presentation provides clear and detailed mapping of the sector including emerging applications.

The presentation explores the medical applications in the nuclear sector more deeply.

Specific insights are provided with respect to recent challenges to the nuclear medicine sector, opportunities, and new approaches in this uranium dependent industry.

Permitting and the Rook I Project

Leigh Curyer, NexGen Energy

Rook I is a proposed uranium mine and mill development located in Saskatchewan's southwestern Athabasca Basin.

It will be a significant supplier of uranium to meet growing global demand for a zero emissions clean energy source.

This presentation will highlight the permitting processes that NexGen Energy followed for the project.

Uranium Mineralogy – Challenging but Imagine if…

Kathy Ehrig1,2, Edeltraud Macmillan1, Nigel J Cook2, Cristiana Ciobanu2

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Naturally occurring uranium minerals are noteworthy, typically for the relative ease at which they are remobilized in mineral deposits post initial formation/precipitation. Uranium minerals can occur as sub-micron to several mm diameter individual particles, clusters of particles, or in veins which vary in size from sub-mm to metres in width.

The chemical composition of any individual uranium mineral particle, regardless of size, can also vary significantly. The processing routes (both plant configuration and operating conditions) used to extract uranium from uranium bearing ores are fundamentally dependent on the specific uranium minerals present, the presence of other elements in the uranium minerals, the uranium mineral particle size and the types of gangue minerals which are associated with the uranium minerals. This is further complicated by the fact that uranium may also occur at <1% to ppm concentrations in non-U-bearing minerals such as hematite. High precision and spatial resolution analytical instrumentation is required to characterize how uranium occurs in ore and gangue minerals within any specific uranium deposit.

The breccia hosted iron oxide Olympic Dam Cu-U-Au-Ag deposit is, without doubt, the world’s largest uranium deposit. Uranium is recovered onsite at Olympic Dam via open tank sulfuric acid leaching of flotation tailings generated from a copper sulfide flotation circuit. Uraninite, coffinite, brannerite and hematite are the predominant U-bearing minerals. The average uranium mineral particle size is ~20 microns, yet a significant amount of uranium occurs in hematite at the sub-micron scale. Each of the uranium minerals contain different concentrations of uranium, all of which is not recoverable under current plant operating conditions. The uranium minerals are variably distributed across the entire deposit.

This presentation will describe BHP Olympic Dam’s ongoing journey to optimize uranium recovery, and hence minimize uranium losses, via the continual use of macro to nano-scale mineralogical measurement methods to characterize the ore and waste in advance of mining and processing.

Keywords: mineralogy, Olympic Dam, uraninite, coffinite, brannerite

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Uranium Production Uplift at BHP Olympic Dam

Georgina Furniss1, Rahul Ram2, Kym Dudley3

The BHP Olympic Dam operation utilises Tails leach (TL), Counter-current decantation (CCD), Uranium Solvent extraction (USX), and Precipitation/Calcination to produce Uranium oxide concentrate (UOC).

Following a period of instability, a continuous improvement program was initiated to uplift UOC production. This program focused on specific operational, metallurgical, and reliability issues across the aforementioned processes to improve the stability of the circuit, reduce key driver variability, and resolve long-term issues. This presentation will provide details on various improvements and their subsequent contribution to the UOC production uplift.

The development of a silica management program mitigated adverse impact of colloidal silica on the USX circuit. This included tracking additional metrics of mineralogical changes to TL feed; modification of procedures for better free acid compliance and control in TL; refurbishment of the clarifier; improvements to flocculation and coagulant addition and control in the CCD circuit; and the development of an in-field test in the CCD circuit to identify colloidal silica with associated rapid response triggers.

A solvent management program was employed in the USX circuit to improve overall USX extraction and throughput. This included the development of an in-house method to measure extractant strength; review of procedures and development of online calculators for managing solvent inventory; optimisation of the regeneration and stripping circuit to improve solvent health; and development of new procedures to manage Tricanter operation to minimise the adverse impacts of CRUD.

The deployment of a USX maintenance program has improved the reliability and availability of equipment. This work encompassed a major maintenance campaign to clean lines, units, and equipment within the USX circuit. Additionally, a new maintenance strategy was developed for the regular maintenance of Pulse columns (PC), and a greater focus was placed on incorporating thermography and maintenance schedules to align with shutdown clean works to improve the integrity and reliability of process flow paths during operation.

This work was supported by standardisation of procedures and routine tasks across production with an enhanced focus on training, operation discipline, regular in-field checks, and a pro-active approach to troubleshooting instability in the plant. Together, this comprehensive program has led to significant improvements in the current operation of the TL-CCD-USX-Precipitation/Calcination circuit at Olympic Dam, providing an overall uranium recovery and stability improvement, an increase in UOC production, and a significant reduction in the total number of silica-related impacts.

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Keywords: Uranium leaching, uranium solvent extraction, colloidal silica, clarification, counter-current decantation, operational strategy, operational discipline.

Georgina Furniss[1], Rahul Ram[2], Kym Dudley[3]

Australian Exploration in the Uravan Mineral Belt USA

Nicole Galloway Warland, Mark McGeough, Thor Mining

The US Uranium-Vanadium Project comprising the Vanadium King, Radium Mountain, and Wedding Bells group of claims, lies within the 110km long Uravan mineral belt extending across Colorado and Utah. The Uravan mineral belt and adjacent uranium-vanadium mining districts of the Colorado Plateau are reported to have produced, over the past 100 years, in excess of 85 million lbs of U_3O_8 and over 660 million lbs of V_2O_5 from the Salt Wash Sandstone member of the Jurassic, Morrison Formation. The average production grades from the Uravan mineral belt from the 1940's to 1979 are reported to be 0.25% U_3O_8 and 1.29% V_2O_5 (Thamm. et al., 1981[b]).

The uranium-vanadium deposits are hosted mainly in the Salt Wash member of the Morrison Formation, classified by the International Atomic Energy Agency (IAEA) as "Salt Wash type" sandstone hosted uranium deposits. They are considered unique amongst the sandstone-hosted type of deposits in that they are predominantly vanadium (V_2O_5) with accessory uranium (U_3O_8). They occur as tabular bodies in reduced sequences of highly oxidised, feldspar-rich sandstones that have substantial fossilised plant material. High grade uranium and vanadium occur together, although vanadium has a much larger halo. Based on production figures vanadium exceeds uranium in ratios ranging from 3:1 to 10:1 with the ratio increasing the further south you travel.

Larger deposits are found in paleochannels (braided streams in the Jurassic period) where accumulations of plant material led to more reduced conditions being retained over time. The Salt Wash member consists of interbedded fluvial sandstone and floodplain-type mudstone.

Uranium occurs primarily as uraninite and coffinite while vanadium is mostly found in the mineral montroseite and vanadium rich alumino-silicates. At surface, the yellow uranium-vanadate carnotite is easily spotted.

Thor Mining Plc is completing a drilling program aimed at targeting the Salt Wash member at shallow depth in areas where no previous exploration has occurred.

Samphire Uranium Project, South Australia – Early Development stage ISR

Greg Hall, Alligator Energy

Alligator Energy is advancing the Samphire Uranium project 20kms south of Whyalla in South Australia. The In-situ Recovery (ISR) amenable project lies in shallow (<90m) sand beds with extensive historical drilling information available.

Alligator has undertaken an additional 50-hole core and rotary mud drilling program, providing new and accurate assay, Prompt Fission Neutron (PFN) and gamma derived grade data, to support the historical data. On this basis an updated Samphire mineral resource estimate has been published comprising indicated and inferred resources at an increased ISR amenable cut-off grade. New leach and recovery test work through ANSTO is underway, and a Scoping Study model and framework has been established to evaluate these results. A further 100-hole drilling program will be commencing in October to enhance and expand the existing resource, and approval documents are being prepared to support an in-situ recovery trial on site next year.

Technologies in Advanced Nuclear Power Reactors

Dr John Harries, Australian Nuclear Association

Over 70% of the current fleet of nuclear power reactors and 80% of the nuclear power reactors under construction are Pressurised Water Reactors (PWRs). Several hundred more PWRs are used for naval propulsion.

In addition, there are 14% Boiling Water Reactor (BWRs) and 11% Pressurised Heavy Water Reactors (PHWRs).

Notwithstanding the proven success of technologies in the current fleet of nuclear power plants, there is considerable international effort to improve existing designs and develop new technologies for advanced nuclear power plants.

Numerous Small Modular Reactor (SMR) designs have gained funding for engineering design, and some are already being assessed by nuclear regulators.

Considerations on Selection of Alkaline and Low-pH ISR Chemistries

Wayne W. Heili, Peninsula Energy

Peninsula Energy developed the Lance Uranium ISR project in 2015 as an Alkaline In-Situ Recovery facility. Subsequently, the Company recognized the potential for enhancing the process performance through the application of Low-pH ISR chemistry.

A systematic approach has been taken to evaluate the technical and economic potential for transitioning Lance from Alkaline to Low-pH ISR.

The presentation will review the key considerations on selection of the ISR process chemistry along with the physical and operational changes that are required to transition from one chemistry to another.

Nuclear Medicine: Cancer Therapeutics from Radium in Process Streams

Dr Julian F. Kelly, Chief Technology Officer "entX"

Rapid progress is being achieved in the field of radio-immunotherapies for treating different types of cancer.

It is now possible to selectively target cancer cells with exquisite precision using tailored peptide molecules. Attaching a short-range radioactive emitter (releasing α or β particles) to such molecules provides a means for killing cancer cells without causing significant harm to surrounding healthy tissue.

A number of such 'radioligand' (RLT) cancer drugs have been recently approved and numerous others are in clinical trials/ trial planning. The market potential for these therapeutic agents is strong given their clinical effectiveness (see Figure). Corporate evidence includes the acquisition by Novartis of "*Lutathera*" for $US3.9 billion and "*Endocyte*" for $US2.1 billion (both in 2018). Both these drugs use β-emitting lutetium-177 (^{177}Lu) isotope as a cytotoxic payload.

This positive clinical and market scene for RLT drugs is marred by supply chain constraints for their vital radioisotope component.

The most efficacious radioisotopes for widespread RLT deployment are the α-particle emitters: lead-212 (**^{212}Pb**) and actinium-225 (**^{225}Ac**). Producing these in a clinical setting requires that these short-lived radioisotopes are generated from a longer-lived parent isotope.

- The optimal parent isotope for ^{212}Pb is thorium-228 (^{228}Th), from which it can be 'milked' directly. ^{228}Th occurs naturally in small amounts in the thorium decay chain yet can be concentrated effectively by capturing its own parent, radium-228 (**^{228}Ra**), from thorium-rich mineral sources.
- The main parent isotope for ^{225}Ac is radium-226 (**^{226}Ra**) which is irradiated by energetic protons in a suitable medical cyclotron. ^{226}Ra occurs naturally in the main uranium decay chain and is often concentrated in mineral process streams where this element occurs.

In both cases there are difficulties in reliably sourcing useful amounts of a parent radium isotope. Thus, mineral players who produce NORM can potentially help alleviate supply chain constraints for emerging cancer (radio)pharmaceuticals. Of the two main naturally occurring radium isotopes, it is ^{228}Ra that is the most sought after, given the more favourable attributes of ^{212}Pb as a cytotoxic agent in a medical setting.

Growth projections for the usage of ^{212}Pb in 2030 indicate that ~150000 doses could be required as a pipeline of radio-immunotherapeutics reach the market. This rapidly increasing demand for ^{212}Pb will create a substantial and consistent demand for its ^{228}Th parent isotope – upwards of 3 GBq per year.

The presentation will elaborate on the opportunity for uranium/thorium producers to supply radium into the nuclear medicine sector, in particular, to meet demand for radioisotopes for emerging cancer treatments.

Uranium Market Update 2022: Policies and Prices

Treva Klingbiel, TradeTech

Climate change initiatives have brought nuclear fuel requirements above pre-Fukushima levels, and the market finds itself in a structural supply deficit just as concerns over energy security have emerged as a primary policy concern.

Today, while undersupplied, the uranium market is poised for substantial growth on the demand side, which is supported by encouraging policy news in Europe, Asia, and the USA that signals stronger demand for uranium in the long term.

Globally, the commitment to securing energy independence, and the prospect that nuclear power will be an integral part of electricity generation in the future, comes at a time when utilities continue to grapple with uncertainty surrounding the imposition of additional sanctions and other logistical difficulties that could disrupt the delivery of Russian enriched uranium product (EUP) to the USA and Europe due to the ongoing war in Ukraine; constraints on deliveries of Russian nuclear fuel into the Western market, whether by law or by choice, only deepens the supply deficit in the Western market.

Inflation and mining cost creep remain at center stage in (re)evaluating mining costs among both established and emerging producers. The timely development of new uranium mines is therefore associated with each respective project's incentivized price to production. In a high inflationary environment, however, developers and producers may struggle to contain costs, which means prices to incentivize new production may also change. Accordingly, the front end of the nuclear fuel cycle has shifted from a market characterized by comparatively low uranium, conversion, and enrichment prices to one of higher prices and increased volatility.

A shortfall in available material should accelerate the drawdown of excess mobile inventories, thereby realigning the supply and demand balance. In turn, new emerging projects, in addition to those under care and maintenance, will be needed to offset an increasingly restricted uranium supply base in the near term, and a diminishing supply base over the longer term.

Small Modular Reactors – The Landscape for Advanced Nuclear

Lenka Kollar, Co-founder, Helixos

Advanced nuclear power reactor companies are now actively competing for contracts in countries all over the world. Companies like NuScale Power, TerraPower, GE Hitachi Nuclear Energy, X-Energy and Rolls Royce are currently pitching for tenders in the US, Canada, and Europe.

As environmental pledges are made by governments to decarbonize, more focus is being put on secondary energy needs such as process heat for industry, desalination of water, and clean hydrogen production.

Additionally, advanced nuclear designs such as small modular reactors (SMRs) are an ideal option to repurpose aging coal plants. Many coal plant jobs are directly, or indirectly through training, transferrable to an SMR plant, and the transition would revitalize historic energy communities in addition to the cost savings of connecting to the existing grid and transmission, compared to alternatives.

This presentation will cover new technologies, such as advanced and small modular reactors, along with the necessary infrastructure issues for successful deployment. That includes the business model, finance, regulatory, and stakeholder factors needed to rapidly expand advanced nuclear energy to the levels forecast. Comprehensive social design will be important in gaining the trust of communities and successfully deploying more SMR power plants. Coal communities especially have an opportunity to transition their plants and jobs to producing clean energy.

The International Energy Agency (IEA) has published a roadmap towards net zero by 2050 which calls for huge scale-ups of wind and solar this decade, with hydro and nuclear energy providing a foundation for the transition to low-carbon electricity.

The IEA forecasts that new nuclear capacity addition will reach 30 gigawatts per year in the early 2030s and that the amount of energy supplied by nuclear power will increase by 40% by 2030 and double by 2050. The goals set by the World Nuclear Association (WNA) are even more aggressive. The WNA Harmony Programme calls for tripling nuclear generation by 2050 to provide 25% of global electricity in order to meet the growing demand for sustainable energy.

Development of the Tiris Uranium Flowsheet

Mark Maley, Senior Hydrometallurgist, ANSTO, James Quinn, Senior Hydrometallurgist, ANSTO
Bob Ring, Principal Consultant, ANSTO, Will Goodall, Acting CEO, Aura Energy

Aura Energy is currently developing the Tiris Uranium Project in Mauritania, with a current JORC resource of 56 Mlb U_3O_8 at 100ppm cut-off grade. Mineralisation at Tiris is flat-lying, at surface and to a depth of up to 7 m. The ore is free-digging and readily upgradeable, with favourable leaching characteristics in a conventional heated alkaline leaching circuit. As Tiris is a carnotite deposit, it also contains a significant amount of vanadium (18.2 Mlb V_2O_5).

ANSTO has been working with Aura on the development of the flowsheet for recovery of ~800,000 lb U_3O_8 pa, and potentially vanadium pentoxide, from the ore.

The flowsheet involves upgrading of the ore by scrubbing and screening, with pilot testing demonstrating a 550% increase in the uranium grade to 1,572 ppm U_3O_8, recovering 90% of the uranium whilst rejecting 80% of the mass. The process also results in extensive rejection of gypsum, reducing overall reagent consumption in the carbonate leaching process.

The rejection of chloride and sulfate, present in both the groundwater and the ore, is critical to successful operation of alkaline leaching flowsheets. High concentrations of these species in the pregnant leach solution (PLS) can decrease loading of uranium in the ion exchange circuit.

Strategies for the management of these anions, using both membranes and manipulation of the processing circuits, will be discussed.

Bulk leaching of upgraded ore, followed by conventional uranium ion exchange and precipitation, has also been completed. This work resulted in the generation of a UO_4 product meeting the ASTM standard for limit without penalty for all elements, demonstrating that a saleable uranium product can be readily generated.

Aura is also investigating options for the recovery of vanadium as a by-product. Whilst the vanadium is readily coextracted with the uranium in leaching, in conventional carnotite processing the ion exchange step is operated to reject vanadium to the barrens. The economic recovery and subsequent separation of vanadium pentoxide has not been demonstrated at commercial scale, although various circuits have been proposed.

Potential flowsheets integrating both uranium and vanadium recovery will be explored and discussed along with test work results.

Defying Economies of Scale in Bulk Tonnage Mining

Brandon Munro, Bannerman Energy

Bannerman Energy's Etango Uranium Project in Namibia is a bulk tonnage development that, whilst low-grade, benefits from a large and homogenous ore body with favourable minerology, low stripping ratio, excellent recoveries via sulphuric acid heap leaching and ready access to infrastructure. Bannerman's 2015 Definitive Feasibility Study (DFS) proposed a large-scale development scenario based on a 20Mtpa plant throughput for the 270Mlbs Etango deposit.

Bannerman is now completing a DFS on a much smaller, 8Mtpa development approach named Etango-8. In addition to reducing development complexity associated with the scale and capital requirements of the original Etango development, it has been noted that Etango-8 has superior economics to Etango-20, defying the common assumption that bigger is always better in bulk tonnage mining.

This presentation will describe the process undertaken in the 2019 scaling study that arrived at Etango-8 and describes the characteristics of the Etango orebody that enabled the Etango-8 development pathway.

The hydrothermal nature of alaskite-hosted uranium mineralisation at the Omahola Project, Namibia

Dr Alex Otto, Deep Yellow Ltd.

The Omahola Project is located to the south of the world-class alaskite-hosted uranium deposits Rössing and Husab. Geologically the area is situated in the southern Central Zone of the ~540-500 Ma Damara orogen. The stratigraphy is dominated by metamorphosed Neoproterozoic sediments, including clastics, calc-silicates, gneisses, and marbles. The metamorphic grade reached the lower granulite facies with temperatures of ~800 C under low pressure of 4 – 5 kbar (Goscombe et al.,2017). The stratigraphy has been intensively deformed resulting in a dome and basin map pattern due to multiple folding events. The orogen is characterised by intensive intrusive magmatism starting ~570 Ma with tholeiitic to calc-alkaline intrusive and evolving to S-type leucogranites peaking at 510 Ma.

Uranium mineralisation is associated with sheeted leucogranite intrusions, locally termed alaskite. The nature of uranium mineralisation has been attributed to partial melting of the metasedimentary country rocks (Nex et al., 2001; Cuney and Kyser, 2008; Gray et al., 2021). Nex et al. (2001) has classified leucogranite sheets into 6 types (A-F) based on field relationships with types D and E being the most uraniferous type. Most subsequent workers in the area have adapted this classification with Gray et al (2021) the most recent work.

This presentation represents a new interpretation of existing work and new data based on a mineral system approach. The overall clastic nature of the Damara sediments represents evolved crustal material that provides a uranium enriched source region. Coincidentally, the high content of radionuclides (U, Th, K) in these sediments may account of the heat necessary to reach granulite facies conditions and incipient melting of the sedimentary pile during the orogeny. Field evidence show that the leucogranite melts preferentially intrude the core of domes (i.e., Ida Dome) and minor anticlinal structures as evident at the Ongolo and MS7 deposits. The majority of leucogranite intrusions are similar in textural style and composition albeit show significant differences in relative ages across the Omahola area.

The observed cross cutting nature between different sets of leucogranites and their relationship to its deformed host rocks is an expected feature in a highly ductile and inhomogeneous host rock that exhibits high competency contrast. Thus, the classification into different types of leucogranites is thought to be irrelevant for the study area. It is notable that uranium content in the leucogranites increases towards the Khan – Roessing Formation contact, which has been observed across the region (i.e., Rössing, Husab, Garnet Valley).

The significance of the Rössing formation lies in its competence difference between its marble units and the adjacent pyroxene bearing Khan gneisses. While the marble would take up a large amount of strain in form of ductile deformation, the more competent gneisses will react brittle and thus provide the pathways for the melts to intrude. The second significant observation is the spatially extensive occurrence (1-10km's) of skarns within the Rössing marbles. These skarn assemblages are temporal and spatially distinct. The more distal and earlier assemblage is dominated by wollastonite, scapolite and clinopyroxene. Texturally the wollastonite forms veins and stockworks within scapolite-pyroxene calc-silicates. The proximal garnet rich skarn is hosted in gneisses and are spatially associated with uranium mineralisation (i.e., MS7, Ongolo, Inca, Garnet Valley). These observations indicate the significant role hydrothermal fluids had during uranium mineralisation. The hydrothermal activity is also evident of key textural and compositional characteristics within the leucogranite sheets. Typical for the magmatic-hydrothermal transition that can be observed in the Omahola area are pegmatite pods within a more fine-grained granite, as well as quartz veins and pods. The chemical composition of the mineralised leucogranites shift towards very high silica content (85% -95% SiO_2) indicating the influence of hydrothermal alteration within the leucogranites. The reaction of carbonates to the various skarn minerals produces porosity within the Rössing formation and thus creating an outlet that focusses the regional fluid flow. It is likely that the magmatic fluids within the leucogranite reacted to the pressure differential by percolating throughout the melt and thus concentrating uranium towards the Rössing-Khan boundary. The increased fluid flow at the fold hinges is expressed as garnet skarns in the surrounding host rocks and as uranium mineralisation within the leucogranites.

Previously a key argument against a significant hydrothermal component is the lack of uranium within the host rocks of the leucogranites. The clearly hydrothermal nature of the Inca deposit and uranium mineralisation at Ongolo South contradicts this argument. At Inca, uranium mineralisation is part of an evolving hydrothermal system that is associated with the water rich late stage of skarnification. At an even larger scale, the outer most expression is the enrichment of iron at the Shiyela magnetite/hematite deposit ca. 25 km south of the alaskite hosted Ongolo deposit.

In summary, uranium gets enriched by a two-stage process that involved (1) the melting of mostly clastic sediments followed (2) by a hydrothermal enrichment at the magmatic-hydrothermal transition.

The key structural setting is at anticlinal fold hinges as exemplified at the uranium deposits of the Omahola area (i.e., Ongolo, MS7, Inca), which show a change from S- to L-tectonics.

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Predicting Uranium ISR using Machine Learning Applications

Jess Page, Manager Data Analytics, Wallbridge Gilbert Aztec

Boss Energy are entering into an exciting new phase of development, with the Enhanced Feasibility Study completed in 2021, and the project on track for production of 2.45Mlb of U_3O_8.

Boss Energy's Honeymoon project is supported by highly skilled hydrogeologists, geologists, and management with proven operational experience. To further enhance their position, Boss Energy, in collaboration with WGA, have identified an innovative approach to determine economic recovery of In-situ (Leach) Recovery (ISR) deposits.

Boss Energy and WGA have been granted an Accelerated Discovery Initiative (ADI) grant by the South Australian Government, to deliver this 'proof of concept' geophysical data processing tool for sedimentary uranium deposit evaluation for ISR during Greenfields exploration. If successful, this tool has the potential to be rolled out to other operations.

The proposed tool will take information available at the exploration stage of the project and predict ISR decline curve and uranium extraction. The tool has the potential to assist operations in wellfield planning and be integrated with process plant models for economic optimisation of uranium production. This paper and presentation will provide an interim update on the development to date.

WGA have recommended a machine learning approach to the 'proof of concept' tool, based on review of literature, Honeymoon operational datasets, and current modelling methodology.

Key findings are:

- Application of our machine learning approach to predicting decline curve is novel. Although machine learning is used in adjacent applications, such as prediction of mineralisation, iron deposits, stratigraphy, and lithology within the vicinity of the uranium body, it has not been used to predict decline curves in uranium ISR.
- Faster and more simple algorithms than current modelling techniques to predict uranium recovery. Current practices in the industry require a detailed profile of the deposit and require significant computing power: Most of the models use Reactive Transport Modelling (RTM), which couples' numerical models of the metallurgical and hydrodynamic processes occurring underground. These sophisticated models can produce and track production curves to a high level of integrity. The disadvantage is that these models use significant computing power to produce results, and since they require a detailed understanding of the spatial distribution of both physical and chemical properties within the deposit, they can be very sensitive to this data.

The suitability of several machine learning models was assessed with two recommended for proof of concept models:

- Hybrid metallurgical, hydrodynamic and machine learning model, to leverage both known relationships, and the potential increase in accuracy provided by machine learning algorithms
- Systems, also known as compartment, model, which is a mathematical approach to describing material transmission across a system. Compartment modelling was selected because it is well suited to small datasets, and the historical available data, consisting of 48 production curves, would be considered a small dataset for machine learning applications. Systems modelling, commonly used in pharmaceutical kinetic modelling, is a similar shape to an ISR decline curve.

The following opportunities have also been identified which have the potential to improve production planning and well field development tooling:

- The dataset generated by Boss Infill drilling during feasibility evaluation of the deposit contains extensive information (Borehole magnetic resonance tool, and density and neutron logs). While this data is not available for historic drillholes, and hence able to be used as in input to model historic PLS curves, it will be very useful at later stages of the development to link to future production data.
- Once the simplified models are developed, there is potential for adaptive approaches such as Kalman filters to feedback measurements to forward predict production curves.
- Application of machine learning to lithology interpretation, to accelerate and improve accuracy of the geologist's inputs into the wellfield prediction tool.

Model development will be progressed during the next phase leading up to the delivery of the final report in February 2023. WGA will progress model training and scoring and selection of a 'go forward' model for delivery in a test interface to interact with the model.

McArthur River Mine and Key Lake Mill: Pathway to Production

Brian Reilly, Cameco

The McArthur River Mine and Key Lake Miill, located in northern Saskatchewan, Canada, are the world's largest high-grade uranium mine and mill.

In service since 1999 and 1983 respectively, Cameco operates the ISO 14001 certified locations, which have collectively produced 535 million lbs using a variety of mining methods.

After being held in safe care and maintenance since 2018, on February 9, 2022 Cameco announced plans for the operation’s gradual return to production.

This presentation will explore the progress on the pathway to returning to production.

Overseeing the restoration of the Ranger uranium mine

Keith Tayler

The Supervising Scientist was established in 1978 to ensure the protection of people and the environment from the effects of uranium mining in the Alligator Rivers Region.

Uranium mining in the Alligator Rivers Region ended with the cessation of uranium processing at Ranger on the 8th of January 2021 however the Supervising Scientist continues to oversee rehabilitation activities at Ranger, and other former mining sites in the region.

Ranger must be restored to a standard which would allow it to be incorporated into the dual World Heritage listed Kakadu National Park and the uranium tailings isolated in the mined-out pits for 10,000 years. The extremely high standard of rehabilitation required at Ranger, combined with the outstanding cultural and environmental values of the surrounding region, are generating international interest. The rehabilitation of Ranger has the potential to reset the international benchmark in mining restoration.

This presentation will cover an overview of the rehabilitation verification program and some examples of how the office is applying leading-edge technology - particularly the use of drones, DNA analysis and artificial intelligence - to revolutionise the way environmental monitoring is undertaken. These tools make the work safer and more efficient whilst also dramatically increasing the amount of data that can be captured and processed.

Is there a future without nuclear power?

John Vagenas, Managing Director, Metallurgical Systems

Since the Industrial Revolution, our society has become hopelessly dependent upon energy to function and maintain our quality of life. As the world's population and economy continue to expand, our energy needs are increasing too.

The way we currently produce energy needs to change:

- 80% of our energy comes from fossil fuels, the production of which accounts for 75% of global greenhouse gas emissions – resulting in a 6% increase in 2021 to 36.3 billion tonnes, their highest-ever level.
- Burning fossil fuels comes at a large cost to human health, with at least five million deaths attributed to air pollution each year.
- Fossil fuels are a finite resource that at current usage levels will be depleted within 50 years.

Following COP26 and as of September 2022, around 140 countries have now announced, or are considering, net zero targets to be achieved by 2050.
However, in the global race to net zero, most countries' efforts are exclusively focused on expanding wind and solar generation and pumped hydro projects. Energy storage capacity is largely overlooked, or not considered seasonally, and nuclear technology is consistently given very little focus.

In 2021, while the world invested US$755 billion in the deployment of low-carbon energy technologies – of which 50% was in renewables generation technologies – just 4% was invested in nuclear technology.

Why is this the case? And why is investing in nuclear technology so imperative?

This presentation, (referring to a recent study by Associate Professor Simon Michaux, Sustainable Minerals Institute at the University of Queensland), will:

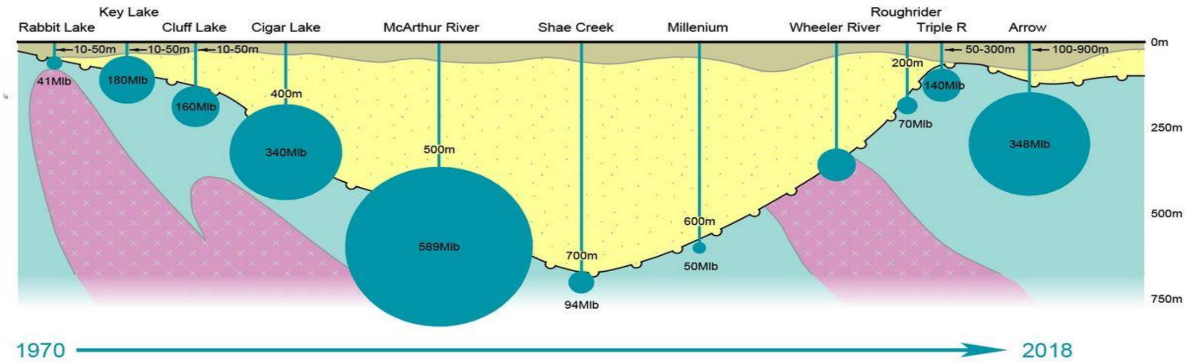
- Examine the energy and minerals requirements for the world to achieve its transition to net zero.
- Explain the role nuclear energy must fulfil for society to continue to thrive.
- Examine the energy mix and some of the key barriers to proposed energy storage systems.
- Discuss some of the challenges associated with rapidly scaling up nuclear-generated energy, and how we can best position the nuclear industry to be ready when the time comes.

Uranium Exploration Under Deep Cover

Andrew J. Vigar, Executive Chairman, Terra Uranium,
Mike McClelland, President Canada, Terra Uranium

The Athabasca Basin in Saskatchewan, Canada, is a world-class district with some of the largest, highest-grade uranium deposits in the world.

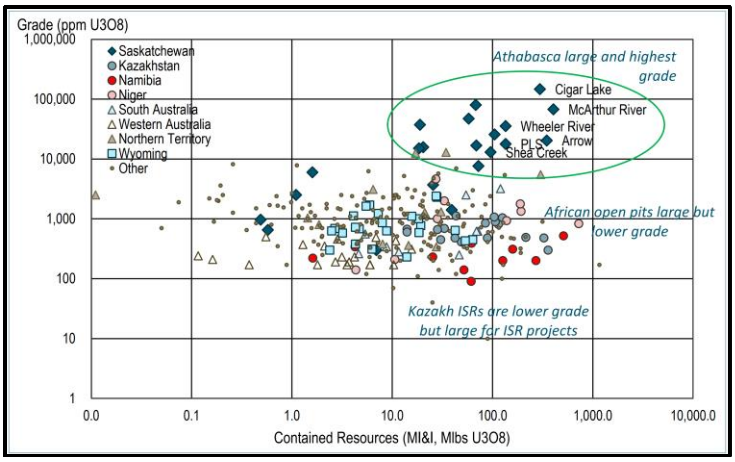
However, over the last 40 years, over $2B has been spent in exploration with 50,000 drill holes and only two high-grade unconformity-associated uranium deposits worthy of Tier One recognition (> 2% and >200M lb contained U_3O_8) have been declared. The McArthur River and Cigar Lake deposits are both hosted at the unconformity and immediately overlying sandstones under deep cover and were both discovered more than 30 years ago.



Athabasca Basin Deposits with time and depth

Source – Alligator Energy

Recent advances in exploration geophysics and geochemistry, along with the application of Insitu Recovery via solution mining, again makes the targeting of these Giant deposits under Deep Cover a viable proposition.

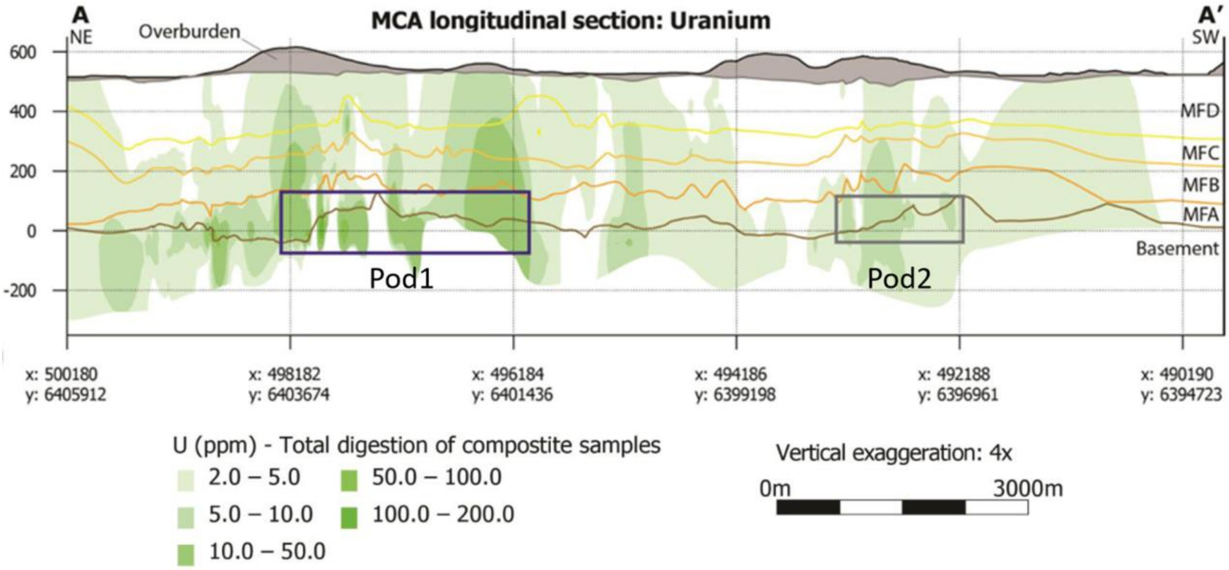


Deposits ranked by grade and contained Uranium

Source – Sprott Uranium Trust 2021

Saskatchewan's undiscovered uranium giant deposit's will be hidden under deep sandstone cover. Historical exploration activities have focused on the Mudjatik and Wollaston / Mudjatik Transitional Zone geological domains where the depth to unconformity ranges up to 1,000m below surface, but the majority of past activity does not go beyond 650m, as this was considered the practical depth limit for mining. The entire Athabasca Basin has a 2.52% success rate for drill holes encountering mineralization, 2.98% in the Eastern Athabasca, 2.64% in the Wollaston / Mudjatik Transitional Zone, and 4.5% for the Mudjatik. The Mudjatik is underexplored with less than 2,000 drill holes due to unconformity depths up to 1,000m or more, and the lack of exploration techniques in the past suitable for exploring, targeting, and even drilling to these depths. This area is where the new discoveries will be made.

The larger the deposit, the larger the geochemical halo and geophysical signature. This is well represented by the McArthur River Deposit, which has values in excess of 5ppm uranium in altered sandstones at surface, 500m above the deposit.



McArthur River Long Section (Uranium in Sandstone)

Showing presence of Uranium geochemical halo developed at surface 500 m above the deposit

Source: CIMIC 185 Ansdell 2018 Society of Economic Geology U Overview Uranium Presentation

When exploring at these depths the technical framework must be modern and tactical with successive and strategic results driven to ensure the highest probability of encountering uranium. Confident valuable resources are being expended on programs that advance targeting toward defining diamond drill core drilling.

Terra Uranium has targeted a section of the Cable Bay Shear Zone where depth to the Mudjatik basement is up to 1,000m. Terra Uranium's geoscience toolbox is modern, using technologies that correlate and enrich data resolution of the subsurface. Structural analysis, gravity and magnetics help to define the basin architecture and target domains. Surface geochemistry identifies alteration halos in the overlying sandstone.

Geotech's ZTEM airborne geophysical system can define 8 to10m-wide conductive corridors with the potential to host uranium bearing structures at depths more than 1km. Geotech's complimentary VTEM can map resistivity variations in shallower sandstone alteration halos to depths up to 500m that may coincide with greater depth ZTEM signatures.

Ambient Noise Tomography (ANT) is a third modern geophysical tool but uses passive seismic where surface sensors which measure ambient noise from within the Earth, requiring no costly and environmentally challenging active noise generation, such as vibrating machines or explosives. ANT is a proven exploration tool for surveying to depths of 1,300 meters for visualizing structure, basement and mineralization and fault driven mineralization, estimating the size and orientation of deposits, identification of depth to basement without drilling, and specific targeting of resources to optimize drill programs. Combining these systems in 3D using modern quantitative geophysical inversion modelling technology creates high resolution Earth Models that can be geologically analyzed and validated.

Keywords: Uranium, Athabasca Basin, Exploration, Deep Cover, Geoscience