



# Trekkopje Definitive Feasibility Study

Trekkopje is the site of a green fields project, consisting of a very large, low-grade, shallow uranium resource hosted in calcium carbonate cemented (calcrete) conglomerates.

The project rests in the arid desert region of western Namibia, in southwestern Africa, situated in gently sloping terrain.

Trekkopje will be an open pit operation, primarily using large hydraulic excavators loading haul trucks. With a planned production rate of 100,000t/d of crushed ore and an average stripping ratio of 0.23:1 (waste to ore), the mine life is expected to last approximately 13 years, based on the current resources. The crushing plant will be designed to crush ore at a rate of 7,000t/h to a product size of 100% passing 38mm. It will consist of two Primary Crushers and two Secondary Crushers running parallel, each with a throughput of 3,500t/h. The ore will then be agglomerated and conveyed to an on-off heap leach pad, sized to contain 300 days of ore. Uranium will be recovered from the heap leach pad using a carbonate/bicarbonate solution and ion-exchange. Based on the current mine plan, the

majority of the spent ore and waste will be placed back into the shallow open pits, allowing for an overall reduced mining footprint and concurrent reclamation.

The site facilities at Trekkopje will include a solution-process uranium recovery plant, offices, mobile mining fleet service facilities, mobile ore crushers and conveyor systems, upgraded access roads, a temporary construction man camp, power-line infrastructure, an on-site water desalination plant, and a seawater desalination plant, located at the coast near Swakopmund with a pipeline water delivery system.

Beginning in mid-2006, UraMin Inc. (the owner at the time), commissioned SRK to coordinate and lead a multidisciplinary team of global consultants over a 20-month period to develop the Definitive Feasibility Study (DFS) that was issued in 2008. While South African consultants worked on the process, infrastructure,

environmental and permitting aspects of the project, SRK worked closely with the client team to review the exploration program to ensure that all work was 43-101 compliant. SRK developed Resource and Reserve statements and mine plans; provided metallurgical, site geochemistry and hydrogeology assessments; performed site geotechnical evaluation and engineering design, including pit slope and heap leach pad design; and performed economic modelling. The study was compiled into an overall DFS document, which was then used to support the mine permit application and the decision to advance the project to construction.

Late in the DFS program, UraMin was acquired by the world energy expert AREVA, as part of their global uranium supply strategy.

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## Final Design of the Trekkopje Heap Leach Pad

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**SRK** was retained by UraMin Inc. (now AREVA Resources Southern Africa) for the final design of the heap leach pad at the Trekkopje Mine in Namibia. The goal was to perform a geotechnical site investigation and complete the engineering design for a new 30 million-tonne, on-off, uranium heap leach pad and associated process solution ponds. SRK designed the 2.5Mm<sup>2</sup> pad to optimize the grading requirements, designed the containment and solution collection system, performed stability analysis and water balance, and designed the solution conveyance and solution pond system.

SRK provided a detailed schedule of quantities, drawings and specifications to support AREVA with the construction bidding process.

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## Trekkopje Client Focus

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**U**raMin was established in February 2005, with the goal of developing global uranium properties. At the time UraMin's projects included numerous exploration licenses in Chad, Mozambique, and Canada, as well as advanced exploration projects in four African countries, including Bakouma in the Central African Republic, and Rystkuil in South Africa, with Trekkopje in Namibia being the company's largest project.

In June 2006, UraMin contracted SRK Consulting, Inc. to advance the project through a scoping study and ultimately undertake a Bankable Feasibility Study (BFS) for the Trekkopje Project, including several NI 43-101 Compliant Mineral Resource statements.

In June 2007, AREVA offered UraMin more than US \$2.5 billion in cash for 100% of UraMin's share capital in a friendly takeover bid. The transaction was successfully completed in August 2007, with ownership transferred to AREVA; the company was renamed AREVA Resources Southern Africa.

Iain Macpherson, the former UraMin MD said that:

*SRK were carefully selected for the task with a view to providing a broad range of inputs to support the development of the business from a very early stage and*

*remained an integral part of the process through to the eventual sale to AREVA. They provided a strong client focus from the outset and were able to complement the UraMin team seamlessly, right from the early scoping stage through to the production of the feasibility study.*

*SRK are of course renowned for their considerable technical and project management expertise and experience and UraMin consciously ensured that SRK worked as an integral part of the project team. This was essential in the early days and proved to provide considerable value add as the projects developed.*

*One of SRK's key strengths turned out to be the ability to tailor their service to the evolving imperatives of the business. They were particularly valuable in the insight that they provided on both technical and business strategic issues as the projects advanced through the studies at the same time as UraMin itself evolved throughout the process.*

*I have no doubt that SRK contributed considerably to the success of UraMin and that they provided substantial value add to the business not only in the traditional technical areas, but also in the development of the business itself.*



# The Napperby Project in Australia

The Napperby Uranium Project is located 175km northwest of Alice Springs in the Northern Territory of Australia. The mineralization occurs within a 20km paleochannel, trending approximately east-northeast. Carnotite mineralization resides mostly in sands and sandy clays as finely disseminated particles and blobs up to 5cm long; it can also be found in overlying calcrete as joint coatings.

This relatively low grade deposit was discovered and explored by CRA Exploration and Uranerz in the late 1970s. Toro Energy Limited has an option agreement with Deep Yellow Limited to acquire 100% of the project at a capped price per lb of contained resource.

Toro Energy commissioned SRK to estimate the resources of the deposit. Current drilling is a mixture of Deep Yellow and Toro Energy auger holes and Toro Energy sonic holes. The drill-hole spacing is mostly 100m x 100m with a central zone drilled at 50m x 50m and, very locally, some infilling at 25m x 25m. (See Figure)

The sonic holes proved quite successful in this mostly unconsolidated material, allowing excellent core recoveries. All samples were assayed for uranium and other chemical elements. Radiometric measurements down-hole were used to study the disequilibrium and establish the relationship between chemical grades and gamma-derived uranium grades (eU).

Because of the relatively large drill-hole spacing, it was difficult to establish a proper geological model; SRK used the Leapfrog™ software to create a mineralization envelope at a 50ppm threshold constraining the estimation.

Within this envelope, 1m composites were created, and analysed geostatistically. As expected, the variograms show poor continuity with ranges up to 110m, and high short-distance variability.

From a resource estimation viewpoint, the current drill spacing is large when compared to potential Selective Mining Unit (SMU) size.

Since direct estimation of the SMUs may lead to unacceptable biases and over-smoothing, it is preferable to use local recoverable estimation methods. These methods aim at estimating the proportion of ore within larger panels, the size of which is linked to the current data spacing. They account for the **support effect** (We are interested in SMU, not composite, grades) and can also handle the **information effect** (The final selection at mining stage will be based on grade control data, which implies some residual uncertainty in assessing the SMU grades).

Various methods exist for estimating local recoverable resources. The two most common are Multiple Indicator Kriging (MIK) and Uniform Conditioning (UC). In this case, SRK has selected the Uniform Conditioning method as giving a reasonable estimate of the local recoverable resources as an Inferred resource compliant under the JORC Code.

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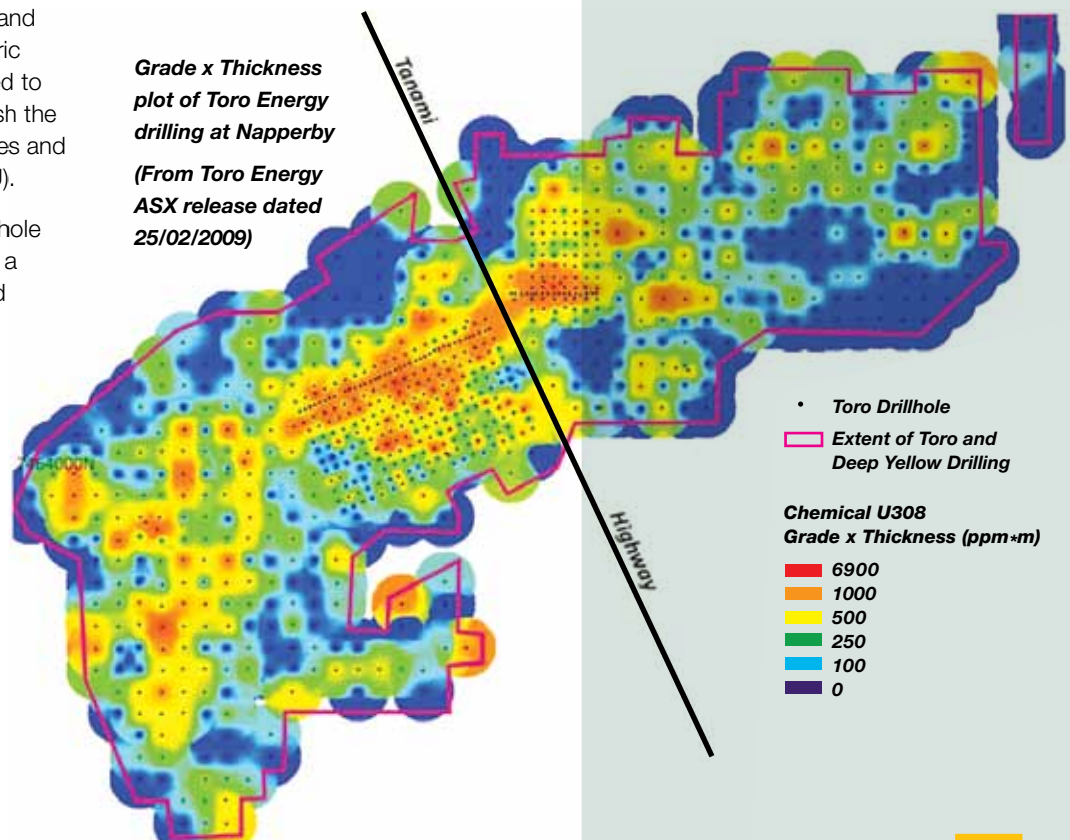
# Daniel Guibal

Daniel Guibal, Min. Eng M.Sc., is a Corporate Consultant in Geostatistics and Resources with SRK Consulting (Australasia), based in the Perth Office. With over 35 years' experience in resources,



Daniel's particular fields of expertise include resource estimation, resource classification (JORC), recoverable resource evaluation (non-linear geostatistics) conditional simulation of orebodies, application of conditional simulation to grade control and risk analysis, sampling theory, design, implementation and audit of grade control and resource estimation systems, mining simulation, open pit optimization and training of professionals in statistics, geostatistics, sampling and grade control. He has worked on many uranium deposits of various types for major and junior mining companies. He is a Fellow of the AusIMM and a Chartered Professional (Mining).

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# Gamma Probe eU% Data QA/QC Procedures



*Gamma logging truck, Namibia*

The most common method used to determine in-situ uranium grades from drillholes is down-hole gamma logging, and the conversion of probe-measured counts-per-second (CPS) to “equivalent” in-situ uranium grades (eU% or eU<sub>3</sub>O<sub>8</sub>%). Although it is an indirect measurement of uranium grade that requires diligent attention to calibration and correction factors, the eU-determined grade is essentially equivalent to any other analytical method, and should have quality assurance and quality control (QA/QC) protocols in place to guarantee the accuracy and precision of results. Understanding gamma-log QA/QC procedures and providing recommendations for implementation

provides SRK’s clients with better quality information for their uranium database.

**Standards:** Where the analytical process for chemicals would incorporate standard reference materials (SRMs), the gamma probe’s equivalent would be the probe calibration report from a known drillhole in a specially-constructed test pit. These calibration holes are typically located at government-run nuclear testing facilities. The U.S. Department of Energy maintains a calibration facility for radiologic instruments in the western U.S. at Grand Junction, Colorado. A calibration report from the facility will provide the K-factor (conversion factor) for determining eU% grade, and other correction factors for the specific

gamma probe in use. Primary calibration should be done on a regular basis; yearly as a minimum. Secondary forms of calibration can be carried out in the field at the project site, and should be a regular part of the gamma-logging process. Portable calibration sleeves containing a low-level radioactive source, such as thorium, can and should be used before logging each drillhole. In addition, where possible, a control hole with mineralization should be designated for each project as a hole to remain open for re-logging at the beginning of each day the probe is in operation. These secondary forms of calibration allow the detection of instrument error or instrument drift, and provide verification of depth readings.

**Blanks:** A drillhole in known barren rocks can provide a measure of background radiation and a check of the gamma probe instrumentation. A control hole with mineralization can often act as a hole that measures background radiation as well.

**Duplicates:** Duplicate assay equivalents are essential, and should include:

- Re-logging a percentage of drillholes with the same gamma-probe (duplicates), and
- Re-logging a percentage of drillholes with a different gamma-probe, by the same contract logging company (replicates).

**Outside** (secondary lab) **checks** include:

- Re-logging a percentage of drillholes with a third-party gamma-probe, using a different contract logging company (outside check on duplicates), and
- Re-logging a percentage of drillholes with a spectral probe (K, U, Th), providing verification of grade from uranium.

**Other checks** include:

- Prompt fission neutron (PFN) logging a percentage of drillholes for a) verification of uranium grades, and b) state of equilibrium in comparison with gamma logs, and
- Globally comparing eU data distribution from gamma logging with the global chemical assay-data distribution of drillhole samples. Both sets of

measurement represent the deposit, but by using different sampling methods and different sample volumes, it is possible to achieve a comparative check on methodologies and an indication of equilibrium.

**Equilibrium:** A state of equilibrium, or the ratio of chemical U to radiometric U (U/eU) for the same sample volume, is best done on core or reverse circulation (RC) samples. A common method is called “closed can” radiometric analysis, where a sample is allowed to equilibrate in a canister for approximately 3 to 4 times the half-life of radon gas, and the radiometric eU is, therefore, back-calculated and compared to an ICP or XRF analysis for the sample.

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**Carnotite coating  
pebble from calcrete-  
hosted uranium  
deposit, Namibia**

## Allan Moran

**A**llan V. Moran, BSc. Geological Engineering (1970), is a Principal Geologist with SRK's Tucson, Arizona office. He is an Oregon-registered geologist, and a Certified Professional Geologist through



AIPG. Allan has 38 years of diversified experience in mineral exploration, exploration management, mine geology, and geologic/economic evaluations for major and junior mining companies. He spent 6 years conducting exploration for uranium in varied geological environments in North America in the 1970s, and in the past 3 years with SRK, he has worked on uranium deposits worldwide, from exploration concepts through resource definition to feasibility study.

Allan's duties have included a broad spectrum of functions in exploration geology, geochemistry and geophysics, drilling supervision, mine-scale geology, deposit geologic modeling, geologic database construction, maintenance, and verification; and collaboration with resource modelers in deposit block modeling and resource/reserve estimation. He has managed the technical and fiscal aspects of these functions, and, as a Qualified Person, he has authored technical reports to comply with Canadian National Instrument form 43-101, compiled feasibility reports on developing deposits, and contributed to due diligence evaluations of acquisition and merger opportunities.

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## Rob Bowell

**R**ob Bowell, Ph.D. C.Chem. C.Geol, is a Principal Geochemist in our Cardiff office. He has 20 years of experience and background in mineral exploration in tropical and deeply weathered terrains. His mining consulting work



covers the fields of due diligence, financial and technical audits, process chemistry, uranium extraction, environmental geochemistry, environmental engineering and mineralogy, with extensive experience in gold, copper and uranium mining in North America, Brazil, Chile, Southern, East and West Africa and Eastern Europe.

Rob has worked on numerous uranium projects, including process chemistry studies for granite-hosted uranium (Namibia), carbonitite deposits (Brazil), vein deposits (Czech Republic, Slovakia and Democratic Republic of the Congo); sedimentary-related deposits, including roll front (in Wyoming, Texas, Kazakhstan, Russia, Niger, Tanzania, Botswana, Ukraine and South Africa) palaeo-conglomerate deposits (in Canada and South Africa), phosphorites deposits (in Central African Republic) and calcrete deposits (Botswana, Mali, Namibia and Ukraine). Investigating these deposits included assessing different process routes, such as Autoclave, In-Situ Leach, Agitated and Ambient Tank and Heap Leach operations, using acid and alkaline reagents involving SX and IX recovery, as well as precipitation methods.

Some of his more recent uranium projects have included; Rössing, Valencia and Trekkopje in Namibia; Sondema in Niger; Ryst Kuil in South Africa; Letlhakane in Botswana; Bakouma in CAR; Musonoi in DRC; Poco de Caldas in Brazil; Příbram, and the Stratz mine in the Czech Republic; Kuriskova in Slovakia; and several projects for ARMZ in Kazakhstan and Russia.

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## Mineralogy Matters



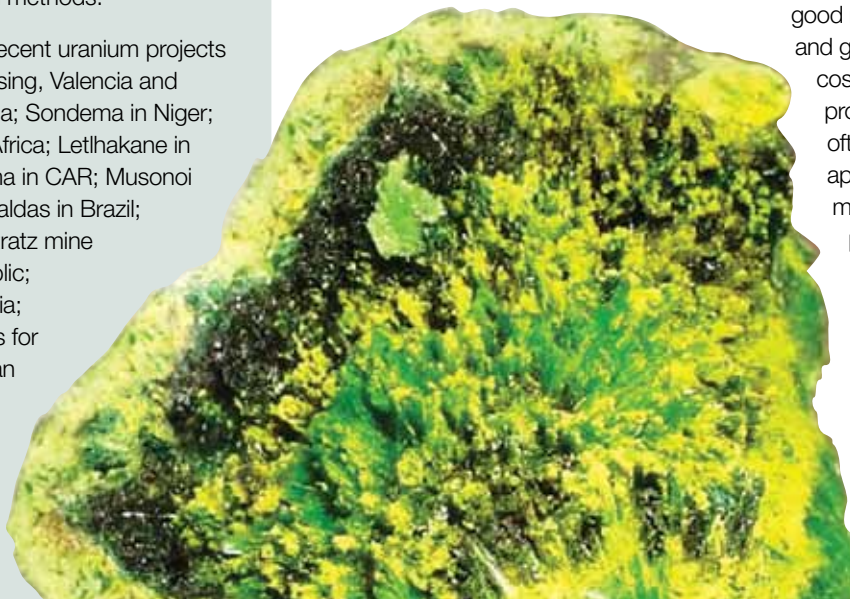
*U(VI) minerals and pyrite oxidation products in Karoo shale hosted uranium ore, Botswana*

**U**ranium is unique amongst metallic elements. Its chemistry is such that it can form both a cation and oxyanion in natural waters (ions that are positively- and acutely-negatively charged) and can combine with different chemical groups to be soluble under both acid and alkaline conditions -- such versatility can be extremely useful to exploit in mineral processing. The mineralogy of uranium is no less complex, and the element can form oxides, silicates, hydroxides, vanadates, arsenates, phosphates, sulfates, carbonates, molybdates and even uranates. Uranium is a major component

of 347 known natural minerals, not dissimilar to copper, but whereas only 25 or so copper minerals are important economically, almost a third of all uranium minerals can occur in economic quantities. As the susceptibility of these minerals to acid or alkaline solutions, temperature, biological matter and oxidants varies widely, it is essential to characterize the mineralogy of the ore in order to select the most efficient method of processing.

Such studies are carried out routinely by SRK Consulting in collaboration with research laboratories and metallurgical facilities throughout the world to provide clients with comprehensive high quality analysis and good mineralogical understanding of uranium and gangue mineralogy to ensure the most cost-effective and efficient method of processing is applied. Such studies are often termed Geometallurgy, which is the application of material, geological and mineralogical characteristics to mineral processing in order to determine the metallurgical properties of those materials. It incorporates the principles of process mineralogy and material characterization as a tool for predictive metallurgy.

*Secondary copper uranium minerals Musonoi, DRC*





Geometallurgy can be applied to any uranium deposit and is a cost-effective technique in characterizing a commodity in defining process options, and providing an early warning assessment of potential metallurgical issues.

Highly-variable or strongly-zoned uranium deposits benefit from the evaluation, since sample heterogeneity from the deposit will be high, and it is likely that the ore will show strong variation in metallurgical performance.

Where multiple deposits will be processed at a central facility, Geometallurgical studies can provide a useful insight into assessing any potential problems or uranium loss without expensive and lengthy metallurgical tests.

Legacy issues present a common problem with uranium deposits, where archived core

for a reactivated site is limited and sufficient material is not available for large-scale testing. Geometallurgy can be applied to determine the representative nature of the material, as well as identify process issues early in the project evaluation.

Completing a Geometallurgical study on uranium orebodies can greatly reduce risk through:

- Comprehensive characterization of geological and mineralogical features and assessment of the implications of these on metallurgical performance, gangue reagent consumption, grindability and encapsulation issues;
- Construction of 3D models of geometallurgical characteristics, to define their spatial distribution and for use in resource estimation and block modelling;

- Incorporating deposit variability into the plant design;
- Predicting time-related metallurgical issues by inputting geometallurgy data into mine planning so that plant throughput, uranium production, and operating costs can be predicted based on the concentrate grade, mineralogy, p80 requirement, recovery issues and ore hardness. This can be completed on quarterly, annual or life-of-mine time scales depending on depth of knowledge;
- Optimizing plant design to account for ore heterogeneity;
- Effective material handling and blending over the life of mine; and
- Optimizing mineral resource exploitation and uranium production

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#### ***Carnotite on calcrete, Namibia***





## George Even

George Even is a Principal Geologist and Partner in the SRK Chile office. His 37 years of experience range from work on grassroots exploration programs to open-pit stability design. After spending 10 years in exploration and mining in North America, he has spent the last 27 years based in Santiago. His project experience includes the design and implementation of exploration programs and the development of structural and geotechnical models. He has conducted numerous technical and due diligence reviews throughout South and Central America.



George Even

SRK's Santiago geologists are able to carry out exploration programs and mine-based resource-reserve estimations, as well as integrate their services with the mining department.

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**Salta Study Sectors using the Digital Terrain Mapper and Hyperspectral Survey**

## Grass Roots Uranium Exploration in Argentina

In 2007 the CEO of UrAmerica Ltd, a private, UK-based exploration company, contracted SRK (Chile) to conduct a technical review, make recommendations, and field check their uranium exploration efforts in the Chubut and Salta Provinces in Argentina. SRK made numerous visits to these areas and issued a series of reports as the exploration phases progressed.

Uranium exploration work has been carried out sporadically within the San Jorge Basin, in the central part of the Chubut Province, since the 1960s, mainly by the Comisión Nacional de Energía Atómica (CNEA), of the Argentine government. The same government agency carried out explorations in the Tonco-Amblayo Basin in the Salta Province beginning in 1959.

During the 2007 Phase I exploration, UrAmerica S.A., based in Buenos Aires, used various criteria designed by their Chief Geologist to select target areas for taking exploration concessions and for initial target prioritization. These consisted of identifying known radiometric areas and the positions of associated paleo-depositional courses, acquiring

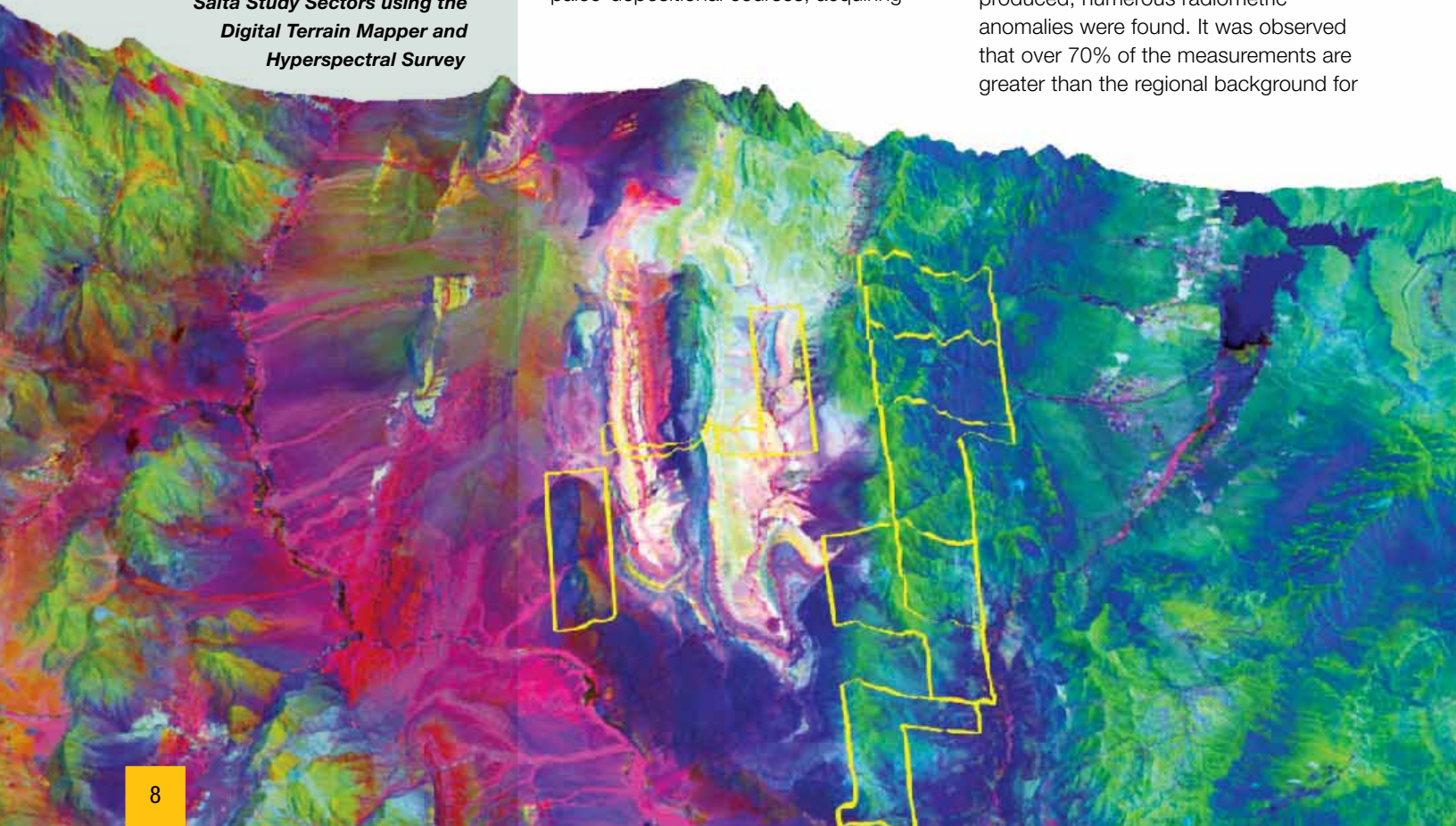
exploration claims, and collecting ASTER and Hyperspectral data and data processing.

UrAmerica then evaluated the following datasets during Phase I for both the San Jorge and the Tonco-Amblayo Basins exploration areas: Uranium-potential target digital map, geological digital map, structural digital map, mineral abundance digital maps, field rock spectral library and a shadowed-coloured relief image.

In 2008, the Exploration Phase IIA focused on ground radiometric surveys, as well as geochemical rock, stream sediment, and soil sampling in the Chubut and Salta project areas.

The ground gamma radiometry/spectrometry survey was performed with a RS-230 BGO Super-SPEC hand-held radiation detector manufactured by Radiation Solutions, Inc. Two different kinds of measurements were taken: in-vehicle and over-ground readings. In total, 12,817 gamma readings were taken over 4,200 linear kilometres, as well as 415 in-situ measurements.

From the analysis of the gamma images produced, numerous radiometric anomalies were found. It was observed that over 70% of the measurements are greater than the regional background for







**Chubut area: compiling in situ spectral database**

uranium equivalent, while about 1% have values ten or more times higher.

Along with the ground gamma survey, 377 rock and soil samples were collected in the field from 67 locations in and around the project zones, representing a variety of lithological units. A 42-element ICP analysis was performed on each sample, including testing for potassium, uranium and thorium.

The 2008 exploration stage produced significant geochemical results with medium-to-high values in rocks and sediments compared with the regional background. These anomalous zones also correspond to the radiometric anomalies.

All of the rocks that exhibited visible features of interest, as well as gamma responses and geochemical anomalies,

belong to outcrops from geologic units that are known to be associated with uranium deposits of economic relevance in the two basins.

Based on the encouraging results of the Phase I and Phase IIA exploration, a Phase IIB exploration program has been planned, consisting of systematic geochemical sampling in each of the zones that will quadruple the previous sampling. Additionally, a grid has been developed for a continuous gamma radiometric survey over rock, sediments and in trenches, focusing on those areas previously corroborated by both gamma and geochemical corresponding anomalies. These explorations are aimed toward obtaining drill targets during 2009.

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## SRK Saskatoon

While SRK Vancouver successfully provided services to the uranium mining industry in Canada for many years, in 2006, to enhance its range of professional services to Canada's major producers, SRK opened an office in Saskatoon, home to both Cameco Corporation and AREVA Resources. Mark Liskowich, who came with over 15 years of environmental protection, stakeholder consultations and regulatory experience with Saskatchewan's uranium industry, opened the office.

The staffing complement increased to three with the addition of Dino Pilotto, a mine engineer specializing in open pit mining methods and Don Hovdebo, a well-established, independent consultant for Saskatchewan's uranium producers, with a focus on environmental protection and assessment, permitting and licensing, mine closure and policy development for both industry and government.

In 2008 Cliff Revering, a geological engineer and Qualified Person, who specializes in geological modeling and resource estimation, joined the office, as did Jamie Taylor, a civil engineer in training, and Melisa Pitz, with a master's degree in soluble geochemistry and contaminant movement in groundwater.

Along with SRK specialists throughout North America, the Saskatoon team provides expert advice and professional services at all stages of a project life. These services range from securing regulatory approvals for exploration, through public and government consultations, geological modeling and resource estimations, scoping, prefeasibility and feasibility studies, tailings options studies and environmental assessment, to life cycle cost evaluations, due diligence, and closure planning and implementation.

In addition to continuing its involvement in Canada, the Saskatoon team plans to apply its knowledge and experience in uranium mining around the world.



## Matthew Dey

**M**atthew Dey, PhD, CEng, is a Senior Chemical Engineer based in Cardiff. He has over 15 years of experience in the geo-environmental field. He specializes in evaluating and applying geochemistry and process engineering to a wide range of mining and engineering problems. His main fields of expertise lie in the chemical treatment of mine wastes and waters, including waste cyanide solutions, acid rock drainage and saline water. His Ph.D. thesis on The Origins and Control of Acid Mine Drainage provides background for his academic research in process engineering and chemistry, environmental geochemistry and environmental engineering.



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**SRK is assisting BHPBilliton with the geochemical characterisation of the tailings for the proposed expansion of the Olympic Dam mine**

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## Developing Uranium Processing Expertise

**W**orking with academia often gives SRK the chance to investigate alternative solutions or develop new ideas that can aid in the understanding and resolution of clients problems, e.g. SRK has strong links with Cardiff University. Currently, Professor Keith Williams, assisted by Dr. Devin Sapsford, is developing a laboratory facility specifically for uranium processing assessment and development within the Characterisation Laboratories for Environmental Engineering Research (CLEER), as part of the School of Engineering.

The links with the university date back to the time when Cardiff University had a strong mining research and teaching department. Currently, Dr. Rob Bowell and Dr. Matthew Dey of the SRK office in Cardiff are visiting senior research fellows in the School of Engineering.

SRK (UK) regularly uses the current laboratory facilities to undertake metallurgical and environmental testing. With the recent demand for uranium, the need for reliable laboratory facilities to undertake process development and assessment work has increased.

Currently, the CLEER laboratory facilities can only take lower level materials from uranium projects, up to a maximum of 1000 ppm uranium and the quantity of material they can hold is limited. However, they are currently in the process of applying for a licence

from the UK Environment Agency to accept materials up to 5% uranium and significantly increase the volume of material for testing. This operational licence is expected to be granted by summer 2009.

The laboratory facilities had a recent £2.5 million refit and have full analytical capabilities, from XRF and XRD, to solution analysis by ICP and IC; in addition, there is access to electron microscope equipment. This has often proved valuable for investigations into what is happening at a particle level when results are not as expected. The facilities also incorporate full preparation facilities and a bottle-roll testing service but with the granting of the licence, they are developing a larger scale capability for solution extraction. This will include heap leach and ISL evaluation services, both from solution extraction to recovery and formation of yellow cake.

Similar collaborative projects are also being sought at the various Research institutes within Russia, which will include full autoclave evaluation and assessment of in-situ methods of uranium extraction.

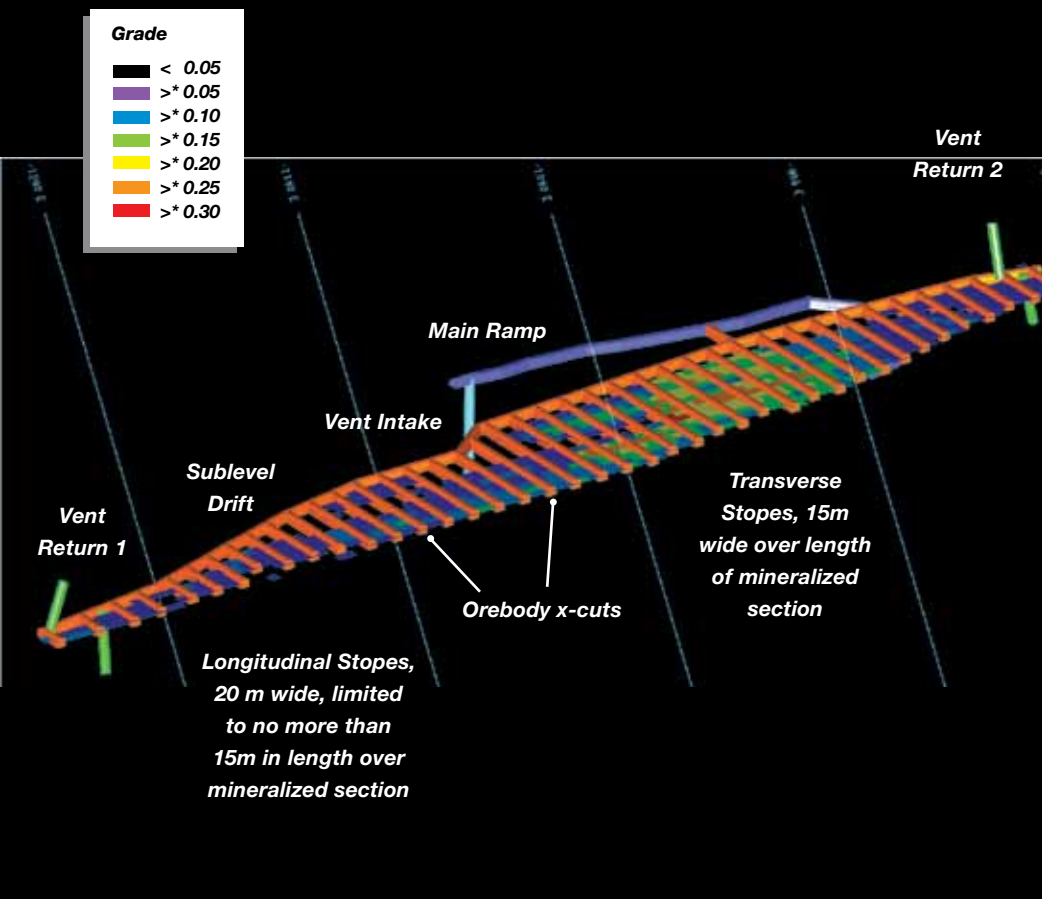
With access to these facilities, SRK will be able to assess processes independently, as well as assist with the development of processes and investigating materials that are problematic for conventional processing operations.

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# Underground Uranium Scoping Study



Conceptual sublevel layout for transverse and longitudinal LH stoping

**SRK** conducted a scoping study of the underground components of two uranium deposits in Labrador, Canada. The study took on preliminary geotechnical investigations to define the underground context, followed with an analysis of the most appropriate mining methods. The geotechnical study took all of the available information from core logs and core photos to assess the deposit rock quality and to estimate the underground span capabilities, preferred stoping sequence, and potential ground control methodologies, according to defined geotechnical domains.

The deposit was conducive to mining by the long-hole method, using a primary and secondary stoping sequence with tailings backfill to maximize extraction and reduce surface storage. A trade-off study was conducted to consider shaft

vs. ramp access. The preferred method was estimated to be ramp access and haulage, and the study included a preliminary mine design based on that criteria.

Development and stoping schedules were developed in sequence to provide the required feed to the processing plant so that deliveries would fit with the open-pit mine schedule. Based on the mine design and schedule, the study scoped the mine infrastructure, including ventilation and de-watering unit operations.

SRK delivered preliminary cost estimates for the underground mine, identified risks and opportunities, and made recommendations to advance the project to the next level.

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## Gordon Doerksen

**G**ordon Doerksen, P.Eng., PE, is a Principal Consultant - Mining based in SRK's Vancouver office. Gordon has over 20 years of operations, engineering and management experience on mines in Canada, the United States, South America and Africa. His diverse mining operations background includes working in a variety of mines, both underground and open pit, extracting a wide range of commodities. His technical strengths lie in mine design, scheduling, equipment selection, costing, project management and practical solutions to operational problems.



Gordon Doerksen

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## Larry Cope

**L**arry Cope, a senior hydrogeologist holds a Master of Science degree with 25 years' experience consulting to the mining industry. He specializes in mine water management, hydrogeologic characterization and environmental data management. For the uranium mining industry, Larry has collaborated with clients on baseline investigations, the design of groundwater monitoring programs, and statistical evaluation of radionuclide data for numerous uranium sites to meet regulatory reporting and internal client performance evaluations.



Larry Cope

He is currently supporting in-situ recovery (ISR) well-field designs for projects in Russia and Kazakhstan for Atomredmetzoloto (ARMZ) and an Alternate Concentration Limits (ACL) application for the Rio Grande Resources Panna Maria site, which has involved a close working relationship with the Department of Energy and state regulators.

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## Nick O'Reilly

Nick O'Reilly is a Senior Exploration Geologist in SRK Exploration Services, based in the United Kingdom. He has over 10 years' experience in exploration program design, due diligence and project management, ranging from grassroots stage through to near-term production.



Nick O'Reilly

Nick's current areas of expertise lie with uranium and gold, in Africa, Asia, South America and Australasia, for a variety of junior market listed (AIM, TSX, ASX), private, and financial sector clients. He has designed, set-up and run a number of successful exploration projects in extreme climates and remote locations.

He holds a Master's degree in mineral project appraisal from the prestigious Royal School of Mines and a B.Sc. honours degree in Applied Geology from the University of Leicester. Nick previously worked in the City of London and for Rio Tinto. He is a current member of the Association of Mining Analysts and of the Institute of Materials, Minerals and Mining.

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## Uranium Exploration: the SRK Exploration

Since 2005 SRK Exploration Services (SRKES) has been a global player in project origination, appraisal and management for uranium exploration. The team has worked on 10 of the 12 major deposit classes and was one of the pioneers at resurrecting interest in the exploration of Saharan Africa. Back in 2005, in a bid to re-evaluate prospects in the context of modern methods and a burgeoning new market, the team visited the Ministries of Mines in Niger and in Mali, and dusted off historic reports detailing the work that had been done in the 1970s by the Japanese and French. SRKES ran a number of reconnaissance missions and identified a small surface resource in northern Mali on behalf of a client.

Northeast Mali represents a near mirror image of the geological situation of the famous Arlit uranium deposits of northern

Niger. The French company, AREVA, is actively mining through its interests in the Arlit open pit and Akouta underground mine. In 2007, production in Niger had a total output of 3,720 tonnes or 8.2 million pounds of  $U_3O_8$ . Here, the sandstone-hosted uranium resources are all contained in the sediments of the Tim Mersoï basin, which lies on the western flank of the igneous complex constituting the Air Massif. In Mali, the intrusive and volcanic centre is that of the Adrar des Iforas, and the potential host rocks are the sandstones, conglomerates and phosphate deposits of the Tilemsi Basin.

Elsewhere in Africa, SRKES implemented and managed two successful uranium drilling projects in Cameroon and Madagascar. While one project has been sold to a major, the other is ongoing and continues to provide exciting results. In South America, SRKES set up

*Spectrometer measuring very high natural radiation from a Uranium rich skarn in southern Africa*







*Harsh environment for sandstone hosted roll front deposits in northern Niger*

and managed a large ground survey exploration program in Colombia, a project which also caught the eye of a uranium major.

In Central Asia, the company has been active in the due diligence of 8 concessions in the CIS, including sites adjacent to the historic Marly Su mines of Kyrgyzstan (where the British allegedly mined uranium in the 1940s), and in evaluating the potential of the former underground mines of northern Kazakhstan.

More recently, SRKES has been involved in evaluating the exploration and mining sector on behalf of financial institutions and fund managers interested in taking advantage of the potential undervaluation of many players, which has resulted from the current economic slowdown and uncertainty.

One such study, a comparable transaction analysis of uranium properties, looked at some 140 transactions that occurred over the period 2007-08 when projects changed hands for sums up to half a billion dollars. This flurry of activity was

spurred on by the uranium pricing peak of July 2007, when  $U_3O_8$  spot prices hit US\$136/lb. This level was, in fact, the highest the yellow commodity has achieved, the last great spike in pricing occurred at the end of the 1970s when prices reached US\$43/lb. Adjusting for inflation, this was equivalent to almost US\$115/lb in terms of 2007 dollars.

Whilst much of the speculative action and 're-flogging of dead horses' that occurred during the price build-up and over the price spike have died away, there is still a strong core of investors following the commodity. The current, relatively-low spot price has little bearing on miners or near-term producers, who will have secure future sales and price contracts with their electricity-generating customers. The longer-term exploration outlook is good, with a projected shortfall in production versus demand, against a backdrop of 44 nuclear power stations currently under construction and over 370 planned or proposed globally.

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## SRK Exploration Services

**SRK** Exploration Services (SRKES) provides services to companies undertaking exploration activities around the world. As part of the SRK Group, our dedicated exploration team has the added advantage of drawing upon the expertise of the SRK Global Group as needed.

SRKES has developed a series of exploration service packages available for any project, any time, in any environment. For clients, this adds up to prompt and cost-effective exploration expenditure. Since 2003, SRKES can claim to be a truly global partner in the SRK Group, fulfilling commissions for contracts in over 40 countries, on 4 continents, over the past 6 years.

SRKES builds skilled and experienced teams, which can work effectively in any given environment, react to on-site changes, and report quickly and informatively on current and future progress. We employ a standardized approach to field sampling methods, recording field data, and using exploration techniques that meet industry standards. At the same time, we recognize the need to be innovative and fully informed about advances in geological theory and exploration practices.

Our prime objective is to provide quality exploration data to construct robust 3D geological models for resource calculation that adds value to a project.

SRKES has a solid core of exploration managers and geologists experienced in exploration and development, who can plan and manage projects across various commodities, geological environments and geographic regions, worldwide. SRKES' field teams are supported by specialist consultants in associated fields, such as structural geology, geochemistry, and geophysical interpretation, who provide technical input and interpretation at all stages of a project.

## Dmitry Yermakov

**D**mitry Yermakov, Senior Engineer (Processing) with SRK in Moscow, has 15 years of professional experience. He has completed a number of processing training courses, including practical advanced training at Australian operations. During his professional career, Dmitry has worked as a chief metallurgist/ chief technologist, chief engineer, deputy director of the gold recovery plant, manager of a fire assay laboratory, head of a tailings facilities and a foreman of the process shift. Dmitry has experience in operating modern equipment from various Russian and western manufacturers.

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## Vladimir Ugorets

**V**ladimir Ugorets, a Principal Hydrogeologist, joined SRK Denver in July 2007. From 1995 to 2007, he worked for Hydrologic Consultants Inc. of Colorado (HCI) as Senior Hydrogeologist, and prior to that, he was a lead Hydrogeologist at HYDEC, in Moscow, Russia. He has 17 years of hydrogeological experience in Russia.

Vladimir's areas of expertise include mining hydrogeology, water supply, numerical modeling of groundwater flow and solute-transport, optimization of dewatering systems, design of extraction/injection wellfields, remediation of ground-water contamination, and ground-water management.

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## In-Situ Recovery

**W**here a uranium orebody exists in a saturated sandstone aquifer, boreholes can be drilled into it and the surrounding water treated with chemicals. This treatment enables the uranium to be dissolved and leached from the orebody, as the chemical solution circulates through it. The solution is then pumped back to the surface through different boreholes and the uranium is recovered. This process is known as solution mining. The aquifer is treated with either an acid or alkali, depending on the geological characteristics of the orebody.

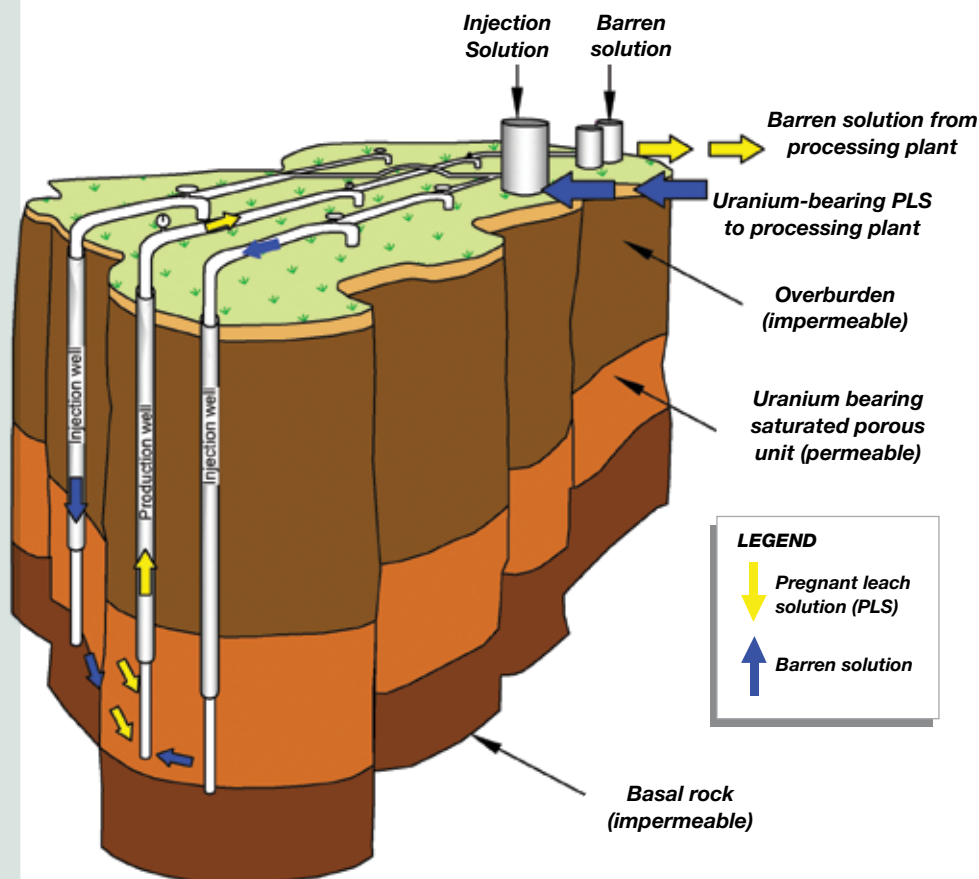
In-Situ Recovery (ISR) is the preferred method for developing small uranium deposits contained in underground water systems (aquifers). This method is preferred because the deposit can be developed without destroying the aquifer, at a lower cost and with much less visual impact. The solution is brought to the surface processing plant, where it is treated with chemicals that cause the uranium to precipitate from the solution. The remaining solution is returned underground to its original source.

SRK has been involved in the evaluation, monitoring, design and development of several ISR projects located in the Czech Republic, Kazakhstan, Russia and the

USA. Such projects require specialists in geological resource determination, geochemistry, process engineering and hydrogeology to collaborate in designing a wellfield to extract uranium, and then develop an appropriate recovery process plant to separate uranium from the leaching solutions. Such projects are attractive because they minimize surface disturbance and require considerably less capital investment than more conventional mining operations.

Currently, a team of consultants managed by Mr Jeff Volk, principal geologist in SRK Denver, from SRK offices in Cardiff, Denver and Moscow are collaborating on the evaluation and design of ISR projects at Khiagda in Russia and Zarechnoye in Kazakhstan. Members include SRK principal geochemist Dr Rob Bowell, senior geochemist Mr Kent Petersen, principal hydrogeologists Dr Vladimir Ugorets and Mr Larry Cope, and SRK senior process engineers Dr Matt Dey and Mr Dmitry Yermakov. These projects each aim to produce close to 1000 tonnes of uranium a year using ISR methods.

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# Institutional Controls on Radioactive Mine Wastes

During the last decade, most jurisdictions around the world implemented legislative requirements for mining and milling operations to prepare closure plans for decommissioning and reclamation, and to post a bond or other financial instrument of sufficient value to cover the cost of the closure. A decade or more later, those same jurisdictions now face the question of how and under what circumstances they are willing to accept the return of such properties, once the operator has fulfilled their closure obligations, demonstrated compliance and now requests release from further financial bonding. This situation is further complicated when the site involves former uranium mill and tailings operations, where international conventions and national nuclear regulatory frameworks play an overriding and often defining role.

In 2005, the Government of Saskatchewan was faced with the challenge of developing an institutional control framework to manage such properties – more than 30% of the world's uranium (and highest grade uranium) is being mined and milled there. As a result, the institutional control framework needed to meet international, national and provincial obligations, while ensuring that future generations would not be burdened with having to shoulder that responsibility.

When approached by the Saskatchewan government to assist, Don Hovdebo of SRK's Saskatoon office took on the challenge and led a team of 5 different provincial government departments over 6 months to develop an effective institutional control

(IC) and management framework. The management framework applies to mineral properties, including nuclear sites that have been successfully decommissioned and reached a closed-site status.

The final IC framework addresses all applicable articles of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management that is administered by the International Atomic Energy Agency (IAEA), the requirements of the federal Nuclear Safety and Control Act, the expectations of the Canadian Nuclear Safety Commission, and provincial Acts and regulations that apply. As well, the framework gained the support and inclusion of traditional users and other stakeholders in the area of the sites and the support of the mining industry, without placing an unnecessary burden on them. The project provided draft legislation and regulations, which were promulgated by the Provincial Legislature in March of 2007.

Currently, one former gold mine and mill site and five former uranium mine sites are in the final stages of being registered in the Saskatchewan IC management framework. This makes Saskatchewan one of the few jurisdictions in the world to have a formal, revenue-neutral mechanism for the permanent, long-term monitoring and maintenance of former uranium mine sites, decommissioned radioactive tailings facilities, as well as a wide variety of the more conventional decommissioned and reclaimed mines and other industrial sites.

Don Hovdebo: dhovdebo@srk.com

## Don Hovdebo

As a Principal Consultant in SRK's Saskatoon office, Don Hovdebo has successfully concluded an extensive list of projects with a particular focus on the uranium and gold mining industry in western and northern Canada.



Don Hovdebo

The projects range from collecting required baseline environmental and socio-economic data, preparing permit applications, environmental protection plans, environmental management systems, and environmental impact assessments to conducting audits and preparing annual compliance reports. Don served as an advisor to a federal/provincial public review panel on environmental assessment that was appointed to review the development of 9 uranium deposits in northern Saskatchewan. In addition, he led a team of 5 government departments in developing a policy and management framework for the institutional control of mineral properties, including nuclear sites, that have been successfully decommissioned and reached a closed site status.

Don Hovdebo: dhovdebo@srk.com



Closed Uranium Adit Near Uranium City Saskatchewan

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## Dave Luppnow

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**D**avid Luppnow, Principal Consultant (Geotechnics) with SRK in Perth, has over 18 years of experience in site investigations, site selection, design, construction, reclamation and project management of engineered structures for mine waste disposal, including tailings dams, heap leach pads and mine waste dumps. He has managed multi-disciplinary studies for a broad range of tailings projects, such as raised tailings facilities located upstream, centerline and downstream. He has specific tailings project experience covering varied climatic conditions, mineral types and continental areas across Africa, North and South America, Asia, India and Europe. He has specific leach pad experience in Indonesia, Mongolia, West Africa, USA and Chile for copper, gold and most recently, uranium. David's experience also extends to dump leaches and dedicated and re-usable pads.



His recent uranium experience focused on the feasibility design for a new tailings operation in Niger, and the feasibility, detail design and construction management of a new leach pad there. David also led a scoping study for a new uranium operation in Botswana, including the design portion of the leach pad.

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## SOMAIR Uranium Mine Heap Leach Pad

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**A**REVA NC (AREVA) retained SRK Consulting between 2005 and 2007 to undertake the feasibility and detail design of a dedicated heap leach pad and associated ponds for lower-grade uranium ore at their SOMAIR operation in Niger. The heap leach design work undertaken by SRK included determining the pad capacity and footprint area, designing the environmental containment and lining system, stability analyses, surface hydrology and pad water balance, pond sizing and the leach pad drainage system.

AREVA and its subsidiary, SOMAIR, have a long history of leach pad operation; the current leach pad is constructed over preexisting leach pads from the late 1970s and early 1980s. SRK optimized the design to limit the cut-and-fill earthworks, while still providing pad-drainage slopes for gravity drainage through a solution channel to the ponds.

As designed, the leach pad has a capacity of 17 million tonnes of uranium ore, based on an annual production of 1.4 million tonnes. The final pad was designed with a height of 30m, comprising five-6m lifts. The leach pad and pond has a composite lining

system consisting of a 300mm-thick, low-permeability clay layer overlain by a 2mm-high density polyethylene (HDPE) liner.

The drainage system is made up of perforated pipes placed in a herring bone pattern within individual cells, and connected to collection pipes that drain to the process ponds. This piping was then covered with overliner material, consisting of selected and screened ore material.

In 2008, SRK assisted AREVA with quality assurance and quality control (QA/QC) for the project by providing an engineer. The SRK engineer oversaw and coordinated the construction QA/QC on site during critical earthwork stages of pad and process pond construction. SRK also provided engineering and design support to the project during construction.

At the completion of the earthworks construction phase, SRK produced an as-built report and drawings, detailing the construction process and any changes to the design that occurred during the earthworks construction phase.

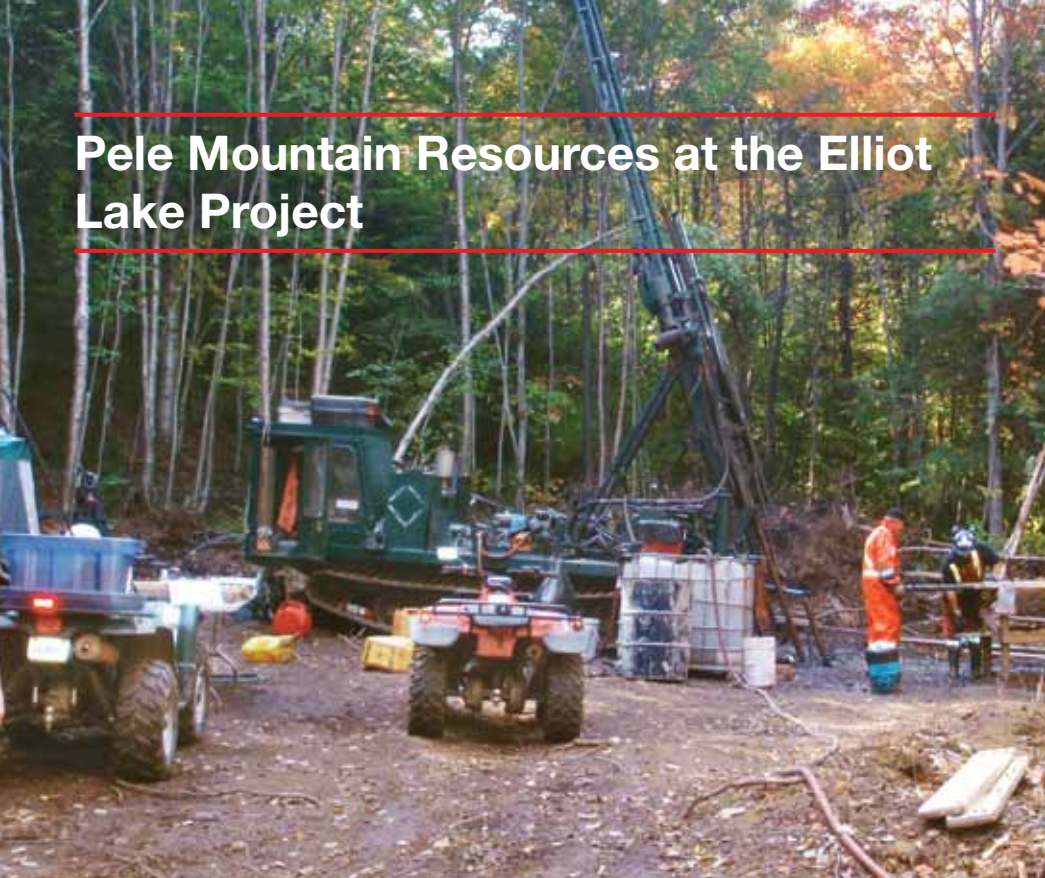
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### *Leach pad construction - Placement of the clay liner*





# Pele Mountain Resources at the Elliot Lake Project



*The drill site and the geotechnical logging and handling by the drillers*

**P**roduction of uranium in the Elliot Lake Camp began in 1955. An estimated 135,000 tons of uranium metal was produced from 12 mines by the end of 1989, at an average grade of approximately 0.09%  $U_3O_8$ . All of the mining took place underground and the primary mining method used was mechanized room and pillar.

The ore was hoisted and transported to a central mill for crushing and grinding, and was leached using sulphuric acid to dissolve the uranium. The uranium was then extracted from the solution using solvent extraction or ion exchange processes.

In addition to the primary production, small amounts of uranium were extracted from the mine water being pumped to the surface beginning in 1960. Denison Mines Corporation had maintained a limited underground bacterial leaching program since the mid-1960s and in 1980, initiated a research program to expand production from bacterial leaching. The underground leaching was carried out on lower grade ore blasted from the roof into the empty stopes, after the primary ore extraction was completed. The stopes were sealed with bulkheads and then flooded for leaching. Air was introduced into the stope to accelerate the leaching. Spray leaching

was also tested to extract the uranium from a portion of the broken ore.

Pele Mountain Resources (PMR) began staking claims in the area in 2005, and in February 2008, commissioned SRK to prepare a preliminary mine layout that utilized the in-stope leaching method. SRK prepared 3D layouts for main ramps, sublevel access, mining panels and ventilation infrastructure. Drilling and blasting in the panels were designed to minimize the amount of reef material extracted and trucked to the surface, while maximizing the amount of uranium that could be recovered using the underground bacterial in-stope leaching program. The recovery of uranium in the production schedule was based on a time-recovery curve representing the leaching process.

SRK assisted PMR with the field exploration, reviewing the field data and drilling program, and developed a hydrogeologic and geotechnical program to collect data for future technical studies. SRK also assisted PMR with the submission of the Project Description to the regulatory authority.

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Ken Reipas: kreipas@srk.com

## Ken Reipas

**K**en Reipas is a Principal Mining Engineer in SRK's Toronto office and has 28 years of experience in mine operations, mine engineering and consulting. Prior to joining SRK, Ken worked at several open pit and underground mining operations in Canada, involved in the bulk mining of iron, coal, gold and base metals. He specializes in underground projects and has undertaken work related to technical studies, due diligence reviews, operational assistance, mine reopening and care and maintenance.



**Ken Reipas**

Ken Reipas: kreipas@srk.com

## Terry Mandziak

**M**r. Terry Mandziak has more than 16 years of diversified professional geotechnical engineering experience for mining projects in North America, South America, Turkey, China and Africa.



**Terry Mandziak**

His responsibilities include the design of tailings and heap leach projects, including developing specifications, construction drawings, bid documents and construction programs. Most recently, Terry was responsible for managing a multidisciplinary team of consultants for the Trekkopje Uranium Project, in which SRK (Denver) was commissioned with preparing a Feasibility Study, and designing the heap leach pad.

Prior to joining SRK, Terry spent five years managing heap leach pad construction projects at Barrick's Veladero project in Argentina and Anglogold's Cripple Creek & Victor Gold Mine in Colorado, in addition to seven years designing tailings and heap leach pad projects with other consulting firms.

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## Tracey Laight

**T**racey Laight, MSc, CGeol, is a Senior Resource Geologist based in SRK's Cardiff office since 2003. With over 9 years of experience, Tracey has worked on projects involving precious metals, base metals and uranium deposits.



Tracey Laight

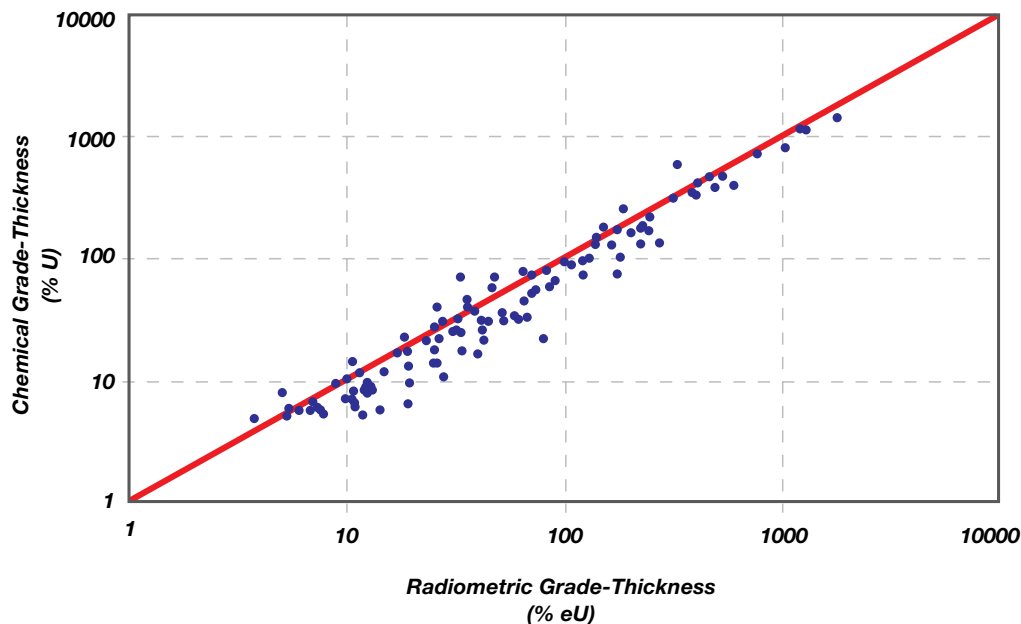
Tracey has a key role in developing SRK UK's Uranium Group and spearheading the development of the specialisation in Uranium Resource Geology.

As a Resource Geologist, she is largely involved with using specialist software to aid 2D and 3D geological modelling, geostatistical and statistical analysis, and resource block modelling. Tracey has worked globally on projects involving a variety of commodities for feasibility studies, due diligence and technical reports and audits, as well as Competent Person's Reports as part of Stock Exchange Listings. Prior to joining SRK, Tracey worked in the mining and aggregates industry, gaining practical experience in exploration, resources, mine geology, hydrogeology, and drilling and sampling.

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## Using JORC and CIM Guidelines for Uranium

Radiometric - Grade Correlation



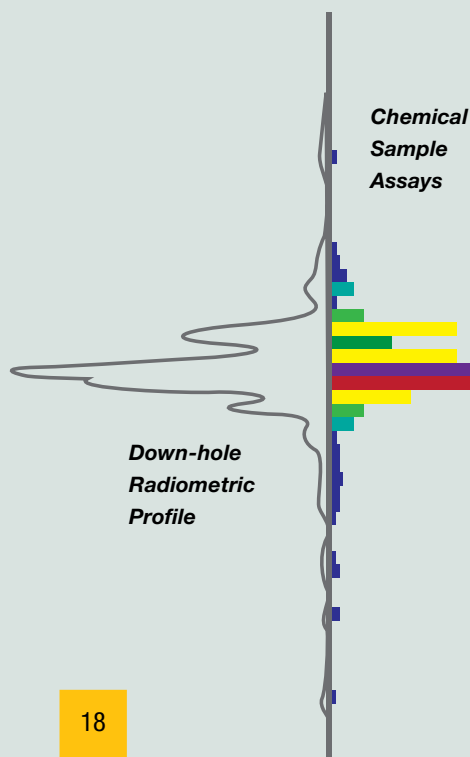
**SRK** has considerable experience in classifying resource and reserve estimations in accordance with internationally recognized reporting codes, such as JORC, CIM and SAMREC. Transparency, materiality and competence direct the operation and application of these codes. Whilst the committees involved with these codes decided that a separate code for uranium was not needed, additions and amendments to update uranium exploration for reporting have been made to the JORC and CIM codes. The changes are primarily related to the occurrence of uranium in some deposits, where and how the uranium data is sourced, and how it is extracted.

Undertaking a resource estimation on a uranium deposit is no different from any other estimate in terms of the methodology used, however one aspect unique to uranium deposits is the ability to use equivalent grade data obtained through down hole radiometric probing of drill holes to supplement chemical assay databases (equivalent grades are denoted by prefix "e"). Often, radiometric data provides the majority of the data in the database, with chemical assay only performed on a small percentage. The radioactive decay of uranium into various uranium isotopes and associated daughter products produces radioactivity that can

be measured with an assortment of down hole logging equipment and probes. Down hole logging, such as Prompt Fission Neutron (PFN) and gamma techniques, play a vital role in terms of fast, low-cost drilling methods.

The radiometric data can be converted into equivalent grade data by determining an appropriate conversion factor, referred to as the "K factor", for the type of logging equipment used and the characteristics of the borehole (i.e. open hole vs. cased hole, diameter of borehole, fluid filled vs. air filled borehole, etc.) in which the probing was conducted. The reliability of equivalent grade data must be demonstrated through rigorous protocols that address: continuous calibration of equipment, equipment testing prior to each use, and direct validation of radiometric data against chemical assay data. Contamination of the borehole can occur by the smearing of mineralized material along the borehole wall or drill rods through which the probing takes place, or by the diffusion of radon within the borehole. Twinning of drill holes should be undertaken where possible and chemical sampling should be carried out to confirm the radiometric logs. When the precision of the equivalent assay has been demonstrated, it may be merged with chemical assay data for the purpose of estimating the mineral resources.

Borehole Trace





## Resource Estimation

Where radiometric logging has been used, the presence of uranium-bearing minerals should be established and relationships with uranium mineralogy identified along with associated gangue mineralogy from drill hole samples. Where equivalent grade data comprises the majority of the grade information for a deposit, it is essential to have good spatial distribution of chemical assay data across the deposit for validation purposes. By comparing the radiometric data with the chemical data, over the full grade spectrum, small-scale variability's and overall sampling error can be determined. Validation of radiometric data against chemical assays is essential to ensure that contamination of the borehole was not introduced during the drilling process, and to determine the degree of disequilibrium that may exist within a deposit. Disequilibrium occurs between uranium and its daughter isotopes when there is an imbalance between the uranium content and the radioactivity emitted by a mineralized rock. A common cause of this phenomenon is the removal of more soluble uranium from a deposit through groundwater interaction, resulting in an overestimation of the uranium content based on the radiometric data.

Quality Assurance and Control (QA/QC) procedures applied to other commodities should be applied to uranium deposits. Quality control of radiometric data can only be achieved through a rigorous program of calibrating individual assaying and logging tools. Representative holes must be cored, radiometrically logged for calibration purposes, and rock samples collected to provide information on density. Bulk densities are important and have high significance in logging correction factors between the test models and the natural rock environments; however, it can be quite difficult to determine and the results may be quite variable in soft sediments.

If it has been determined that the uranium deposit should be mined using in-situ recovery (ISR) techniques, it is important to note that the reporting codes, such as JORC and CIM, have amended their reporting guidelines to take this method of extraction into consideration. Minimum mining width, cut off bulk density and dilution are less applicable to ISR; however, the weight of the assay is critical. Recovery

is of particular importance in these environments, and factors which may affect this include permeability, porosity, hydrologic confinement, amenability of minerals to dissolution, and the ability to return groundwater to its original baseline quality. Metallurgical, stratigraphical, petrophysical, hydrological and geochemical studies are important, if not critical. For ISR operations the quantity, quality and recovery should be reported based on facts from field tests and trials. These factors play a large part in determining the classification using the JORC and CIM codes.

As with all other deposits, the spacing of holes for ISR deposits is determined by the formation, structure and continuity of the deposit; however, the porosity and permeability will also influence spacing, while ground water level, quality and transmissivity are critical to ISR projects.

With uranium once again becoming a favoured commodity, many countries continue to change their opinions and develop legislation concerning the mining of uranium. Renewed interest in uranium has grown with the drive towards sustainable energy and initiatives towards reducing emissions linked to climatic change. A gap in uranium exploration experienced during the 1980s and 1990s has led to many historical uranium discoveries being revisited. A great deal of historical data exists for many of these discoveries, all of which must be understood and tested before it can be accepted and used as the basis of an up-to-date resource estimation.

Having experience working with differing types of uranium hosts, SRK understands how these factors can affect a project and take them into account when classifying resource estimations using JORC and CIM guidelines.

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## Cliff Reverting

**C**liff Reverting is a Geological Engineer and Senior Consultant with SRK in Saskatoon. He has 14 years of experience related to mineral exploration, mine production and project evaluation. His uranium experience includes grassroots and advanced exploration project planning and management, geological modeling and mineral resource estimation, on numerous projects located in Northern Saskatchewan and Nunavut.



Cliff Reverting

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Checking the grades



## Vic Hills

Vic Hills is an Associate Principal Consultant to SRK. He has over 30 years of experience in the precious metals industry, specializing in the mineral processing aspects of technical studies, due diligence, project commissioning and construction management.



In his pre-consulting roles, Vic developed from metallurgical superintendent to consulting metallurgist for a precious metals mining company. His operational experience included the management of gold, uranium and sulphuric acid plants employing a variety of technologies. Subsequently, he had technical responsibility for the concentrator and smelter of an operating platinum mine, as well as an associated base and precious metals refinery.

Since joining SRK as an Associate in 1997, he has been directly involved in numerous technical reviews, feasibility studies and due diligence exercises for project finance and equity transactions. He has also taken on a monitoring role as an independent engineer and is a signatory of numerous Competent Persons' Reports.

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## Mineral Processing Overview

### Introduction

Historically, the most commonly encountered flowchart for uranium processing consisted of conventional comminution followed by atmospheric leaching, solid/liquid separation, solvent extraction purification and finally ammonium diuranate (ADU) or yellow cake precipitation.

Today a number of alternative technologies are considered. The choice of technology is often driven by the uranium mineralogy and the lithology and nature of the host rock, subject of course to the normal financial, technical and marketing criteria imposed on projects.

### Impact of Mineralogy and Lithology

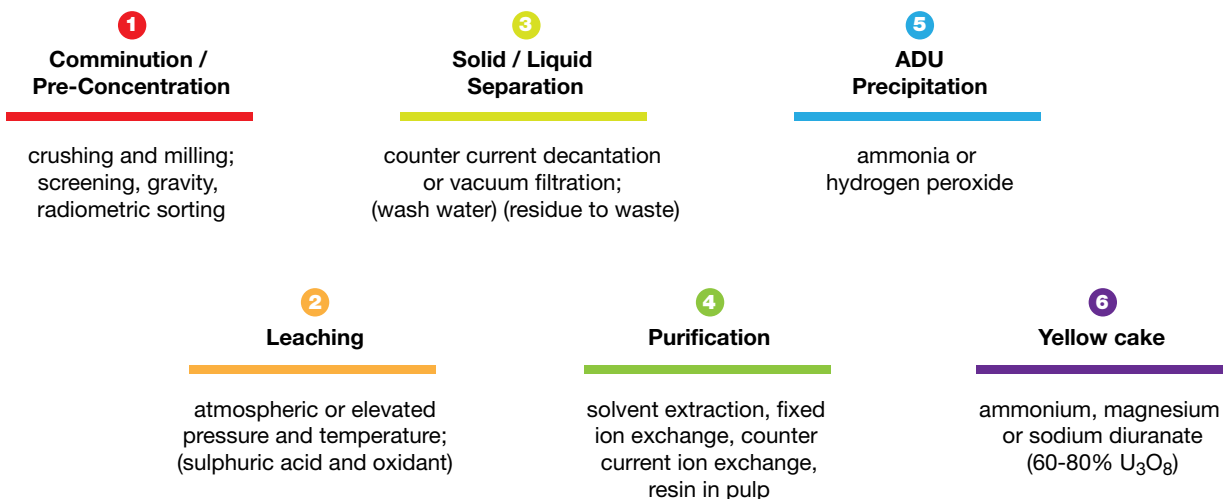
Tetravalent uranium has low solubility in both dilute acid and carbonate solutions and oxidation to the hexavalent state is necessary to achieve economic recovery. Tetravalent minerals include uraninite, uranothorite and coffinite (as found at Dominion Reefs in South Africa), whilst carnotite (as present

at Langer Heinrich in Namibia) is an example of a hexavalent uranium mineral. Typical oxidants include pyrolusite, sodium chlorate, hydrogen peroxide, SO<sub>2</sub>/air and ferric ion.

Multiple oxide minerals, such as brannerite, are more complex and refractory and may require fine grinding, prolonged leaching in hot acid, or leaching at elevated pressure and temperature in autoclaves. Such minerals are the focus of recent exploration in Zambia. Euxenite is another example of a refractory rare earth oxide and one that was present in the Dominion Reefs feed material that was subjected to pressure leaching. Uranium can also be associated with elements, such as carbon and phosphorous, that in turn affect process selection.

The nature of the host rocks plays a major part in process route selection. The presence of carbonate minerals at levels that result in uneconomically-high acid consumption, for example, would likely favor the selection of alkali leaching.

Figure 1.1: Typical Acid Leach Flowsheet



## Potential to Pre-Concentrate

Screening can be an effective means of pre-concentration where uranium minerals preferentially report to certain size fractions of run-of-mine or primary crushed material.

Radiometric sorting is applicable to certain deposits particularly where the radioactive mineralized ore is sufficiently liberated from low-grade material and gangue. During the 1980s, radiometric sorting was incorporated into a number of plants and more recently Rossing Uranium (Namibia) has installed a demonstration plant.

## Leaching

The numerous leaching options that present themselves include heap leaching, in-situ leaching, resin in pulp leaching/adsorption and leaching in agitated vessels or autoclaves under acid or alkali conditions.

Heap leaching was successfully employed on a number of earlier projects. It would still be applicable

on low-grade ores where capital and operating costs need to be minimized. Traditionally, acid heap leaching was practised but consideration can also be given to alkaline heap leaching, as presently being implemented at Trekkopje (Namibia).

In-situ leaching (ISL) finds application where the ore and host rock structure as well as the surrounding aquifers permit its use. Current examples where ISL is employed or being considered include Uranium One's Akdala mine plus their South Inkai and Kharasan projects in Kazakhstan and their Honeymoon project in Australia.

Resin in pulp (RIP) was used extensively in the USA and Russia in the past for uranium extraction. A number of suppliers are developing new and improved resins and RIP is likely to be a contender in future projects.

Sulphuric acid leaching is probably the most widely applied technology. See Figure 1.1 for a typical acid leaching flowchart.

Alkali leaching is the second major leach option considered. A typical alkali leaching flowsheet is shown in Figure 1.2.

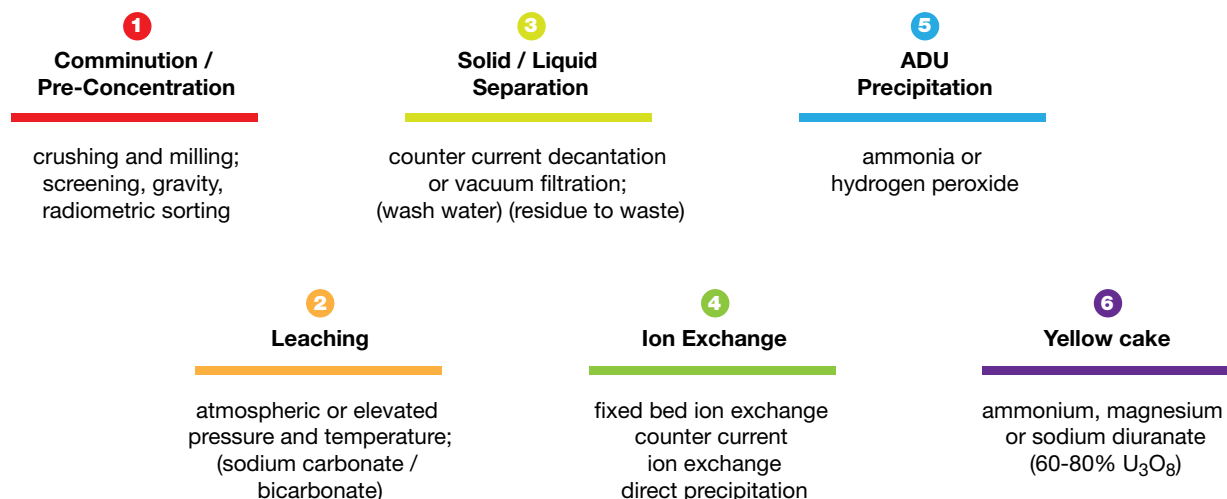
Purification steps ahead of ADU precipitation might include solvent extraction, ion exchange or direct precipitation. In the case of both acid and alkali leaching, the purification steps need to be customized according to the levels of other contaminants, such as vanadium, molybdenum, arsenic and silica that need to be removed ahead of ADU precipitation.

## Conclusion

In order to identify the optimum uranium extraction flowchart, it is clearly necessary to have a good understanding of the ore mineralogy and host rock lithology, supported by a well-designed metallurgical test program. Engineering trade-off studies can assist in selecting the optimum process route.

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Figure 1.2: Typical Alkali Leach Flowsheet





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## David Pearce

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**D**avid is a mining engineer based in SRK's Moscow office. He has 20 years of experience, including six years at Rossing Uranium. With SRK he has led several large multi-disciplinary audits for financing and stock exchange listings including the listing of ENRC (2007) and Vedanta (2003) on the London Stock Exchange.



David Pearce

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## SRK Russia

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**SRK** Russia employs some 34 people principally in its Moscow office. SRK Russia's team consists of resource geologists, mining engineers, a processing engineer, environmental scientists, financial analysts and technical translators. Established in August 2006 it has rapidly grown through its ability to provide an effective interface between Russian clients and information and international experience and project evaluation methods. It is led by David Pearce, an experienced mining engineer and project manager with some 20 years experience, and Andrey Melnikov, a financial analyst with some 8 years experience in the minerals consulting industry and five years in the banking industry.

Combined with the leadership shown at the Minex Forum, Russia's principal mining conference, and participation in the GKZ-CRIRSCO joint committee to explore standardising the links between the Russian and international resource-reserve reporting codes, SRK has established itself as the leading international mining consultancy in Russia and the CIS.

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## Re-engineering the Elkon Deposit

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**E**lkon in South Yakutia, East Russia, is the world's largest known, undeveloped uranium deposit. It occurs as a series of narrow sub-parallel, steeply-dipping veins located within the Yuzhnaya fault zone, covering a strike length of some 20km and extending from about 100m to 1600m below surface. On average, the veins are 2 to 3m thick but vary between 12m to <1m in thickness. Along the strike, the veins pinch and swell significantly over short distances.

The deposit was identified in the 1960, and explored extensively in the 1960s and '70s, with more than 2300 boreholes drilled and 52km of underground exploration workings completed.

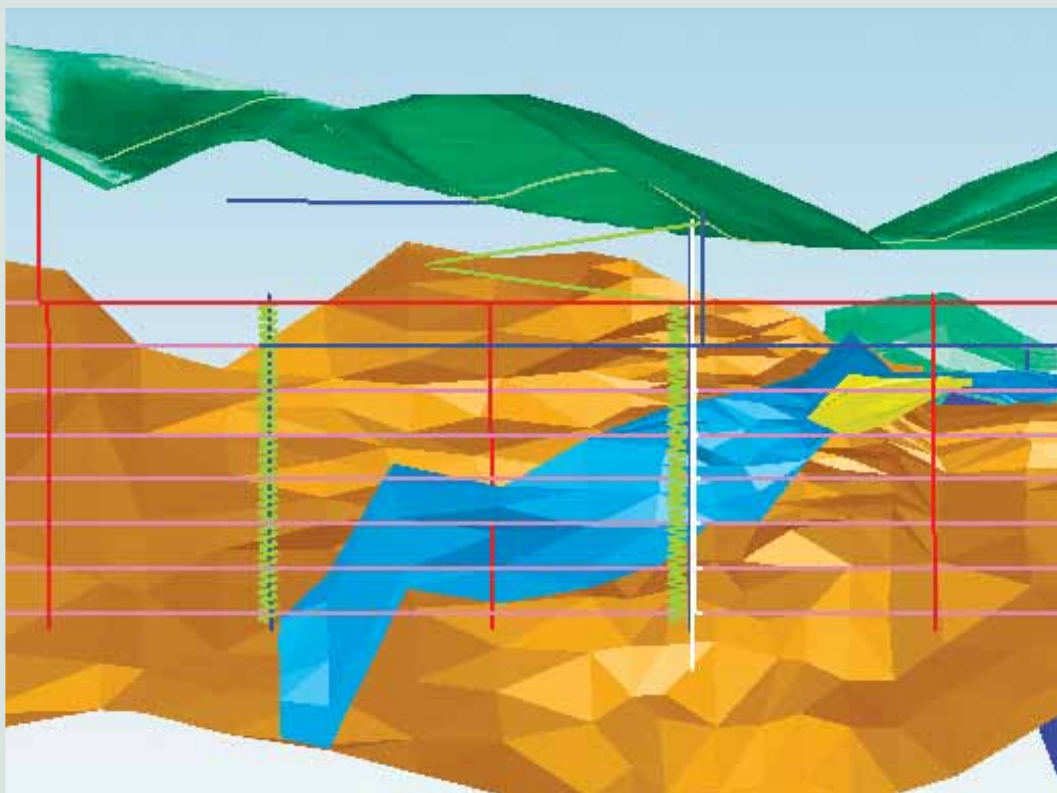
The entire Yuzhnaya mineralized zone is located within an old Precambrian fault zone, though the rocks inside the zone were altered and deformed during several progressive tectonic events, which resulted in structural reactivation. Gold-uranium and molybdenum-uranium mineralization is associated with alkaline dikes displaying hydrothermal-metasomatic alteration. The principal uranium mineral is brannerite,  $(U^{4+}, Ca)(Ti, Fe^{3+})_2O_6$ , which requires more aggressive leaching than most uranium minerals, so, with the development of

the Priagunsky deposit, Elkon was not developed.

Atomredmetzoloto (ARMZ), the Russian state uranium mining company, engaged SRK to re-evaluate the deposit and to develop a plan that would meet the requirements of international funding and investment. Knowing that the need for narrow-vein underground mining methods and expensive processing methods would challenge the project economics, SRK aimed to develop a plan that could bring to bear the potential economies of scale and the fact that ore-sorting had been demonstrated to be effective.

SRK created a computerized geological model using the Soviet geological interpretations and borehole data. The model was used to determine the natural rate for different mining options and to identify the impact of different cut-off grades on resources. Taking into account the morphology of the deposit defined by the underground workings and the rock strength data, SRK concluded that a long-hole, open-stoping mining variant, combined with unconsolidated back-filling with development waste, is likely to be the most appropriate solution.

*Cross-section and block model of the Yuzhnaya deposit, Elkon, Russia*



## Nikolai Yenshin

Nikolai is a Senior Mining Engineer in the SRK Russia office. He has over 10 years' experience working on projects mainly in Russia, Kazakhstan and Mongolia.

He specializes in strategic planning and the evaluation of mines, mine performance improvement management, and underground mine design, as well as the implementation of new technology. He is currently overall Project Manager for studies of uranium assets at different levels for the Atomredmetzoloto (ARMZ) projects in Russia.



Nikolai Yenshin

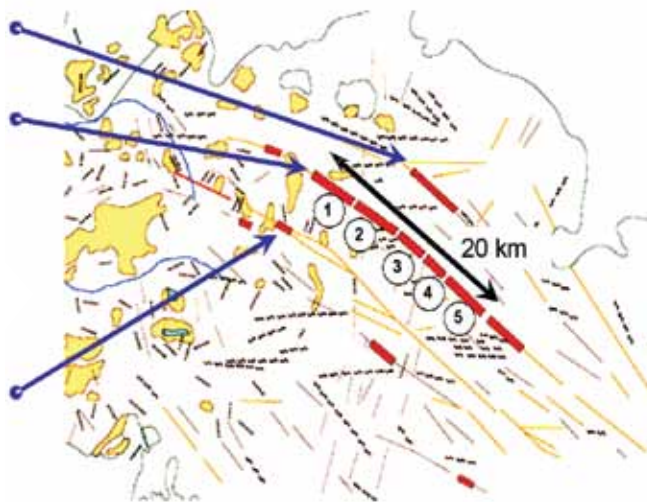
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**Severnoye zone**  
(exploration target)

**Yuzhnaya zone**

- 1 Elkon
- 2 Elkon plateau
- 3 Kurung
- 4 Neprokhodimoye
- 5 Druzhnoye

**Interesnaya zone**  
(exploration target)



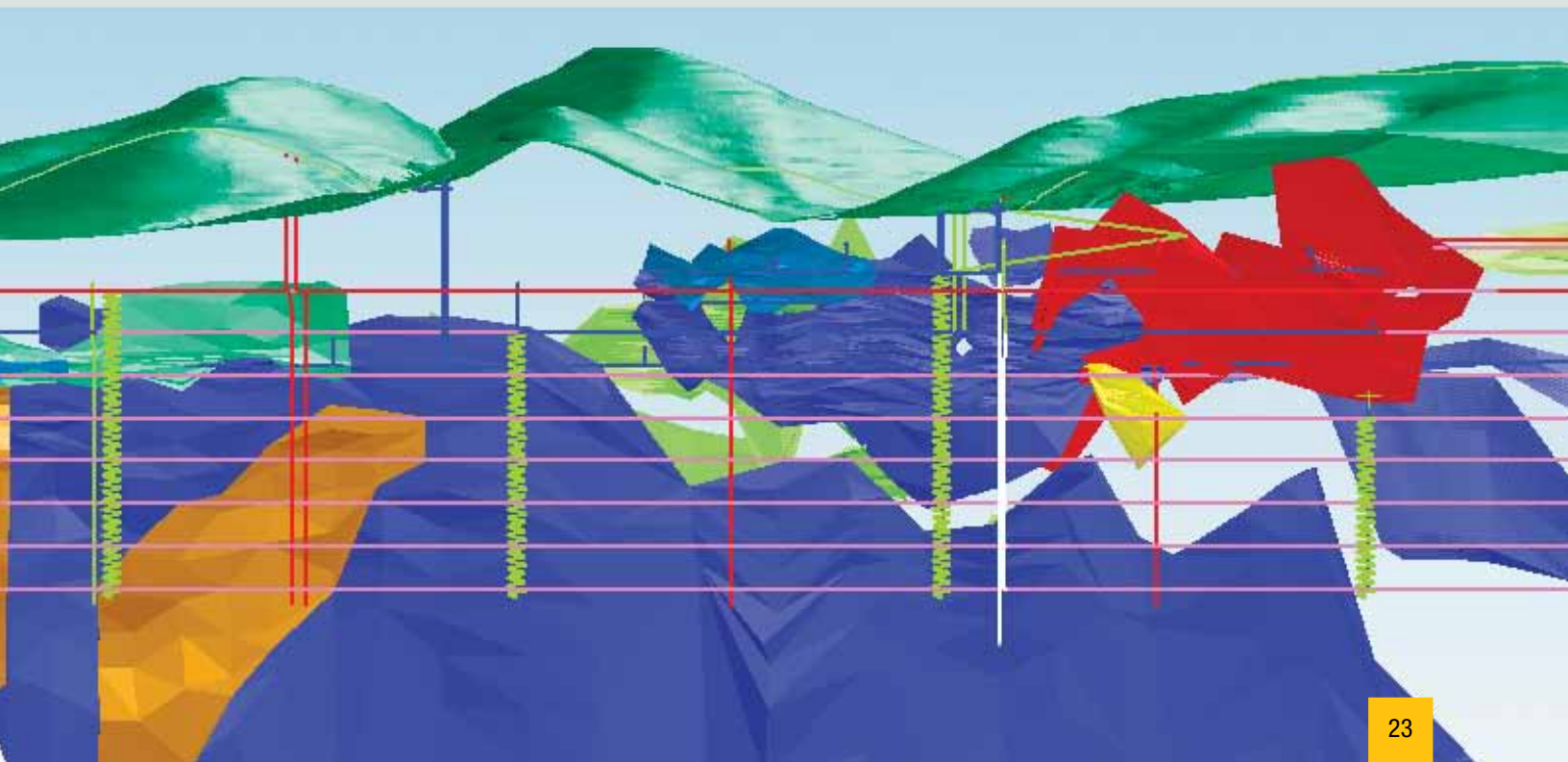
Occurrence of  
Elkon deposits

SRK drew heavily on the existing test-work to recommend a base case of pressurised acid leaching for the initial project feasibility analysis and identified a number of additional tests, which will be completed during the summer of 2009, to assess whether the flow sheet can be optimized.

With all of the data in Russian and often available only as hard copies, SRK created a team of Russian and UK employees and associates and worked closely with

the client's own specialists and Russian design institutes to update the options and to re-engineer the operation to significantly reduce the overall costs-per-pound of  $U_3O_8$  from previous studies. The studies are ongoing with further data collection and test-work scheduled for 2009 and a Feasibility Study to begin in September.

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## Kelly Sexsmith

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**K**elly is a principal geochemist in our Vancouver office with over 16 years experience. She holds a B.Sc. in geological sciences from the University of British Columbia and a M.Sc. from the Colorado School of



Mines. Kelly specialises in the geochemical characterisation of mine wastes. Her experience includes design and supervision of geochemical test programs, geochemical modelling, development of conceptual waste management plans, and prediction and monitoring of water quality from tailings, waste rock and pit walls.

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## Characterizing the Long-term Stability and

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*Key Lake Deilmann In-Pit Tailings Management Facility*

**SRK** has been providing consulting services to Cameco Corporation for over 15 years. During this time, our geochemists have characterized and monitored geochemistry and water quality issues associated with all types of uranium mine tailings stored in the Above-Ground Tailings Management Facility at Key Lake Mine, the Deilmann In-Pit Tailings Management Facility at Key Lake, and the Rabbit Lake In-Pit Tailings Management Facility at Rabbit Lake Mine. Our work has supported regulatory approvals and licencing conditions at these facilities, addressing the requirements and standards of both the Provincial and Federal regulatory agencies, including the federal Canadian Nuclear Safety Commission (CNSC).

At both sites, sulphuric acid is used to extract the uranium from the ore. After recovery, the acidic solutions are neutralized with lime. Sulphate, arsenic, iron, uranium and other metals in the

acidic solutions are removed during the neutralization process forming secondary mineral precipitates. These are combined with residues from the leaching process and then discharged to the tailings management facilities. The chemical stability of the secondary minerals is critical to the long-term geochemical performance of the facility, ensuring that these elements are not released back into the tailings porewater.

SRK's predictions of long-term geochemical performance at these facilities rely on a combination of laboratory testing, equilibrium modeling, and site-specific monitoring data from earlier phases of tailings deposition. The laboratory tests typically include solids characterization to establish the elemental composition of the tailings, aging tests to assess the short-term solubility of the tailings, and mineralogical characterization to support the modeling assumptions.

# Porewater Quality of Uranium Mine Tailings



*(Photo courtesy of Cameco Corporation)*

Major improvements in mineralogical techniques have occurred in recent years, and, thanks to university research funded by Cameco Corporation and other mining companies operating in the region, many of the previously unknown phases controlling metal solubility have now been identified. Cameco completes drilling investigations at each of their tailings facilities every few years to monitor and assess the geochemical performance of the different types of tailings, and to confirm the results of the predictions. Typically, SRK is involved in the data review so that the predictions of long-term geochemical performance can be updated. Currently, Cameco is funding an Engineered Tailings Research Program at the University of Saskatchewan to better understand how the tailings characteristics can be improved to reduce concentrations in the porewater to even lower levels. Quarterly workshops are held to ensure

that the results of these studies are reported back to the site operators, consultants and management in a timely fashion.

The design of the tailings facilities is also critical to the long-term geochemical performance. The Deilmann and Rabbit Lake facilities represent the third generation of tailings management in the area, and are situated in mined-out open pits. They benefit from the naturally low permeability of the surrounding rock, constructed features that allow improved tailings consolidation and groundwater bypass, and deposition methods that minimize the potential for oxidation. SRK's work over the last fifteen years has helped Cameco Corporation understand the effect of these factors in minimizing long-term contaminant releases.

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## Ken Black

**K**en Black, P. Eng. in mine engineering, joined SRK in the Tucson office in 2006 as a Principal Consultant. Previously, he was employed by Rio Algom at the corporate level, providing governance on expansion and closure and in Elliot Lake for more than 12 years during the expansion and closure of Elliot Lake properties.



**Ken Black**

Ken specializes in environmental assessment, waste management, occupational health and safety, mine permitting, public consultation, risk-based facility closure planning at the BHP Billiton's closed mines in Canada. He participated in feasibility studies for the rehabilitation and expansion of low grade deposits. Ken provided corporate governance on health, safety and environmental radiological protection. He collaborated with labour unions, government and industry in developing the uranium mining regulations for the Canadian Nuclear Safety Commission. He is currently involved in the environmental and radiological review of the Atomredmetzoloto (ARMZ) project in Russia.

Ken has been involved in life-cycle activities (i.e. exploration, permitting, operation and closure) for the mining industry in North and South America. His engineering, environmental, safety and risk assessment work has included the closure of the San Manuel mine, processing, smelter and tailings facilities in Arizona. Recently, he completed an approved closure plan for a ferro-manganese smelter in Tennessee.

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## Peter Gleeson

Peter Gleeson joined SRK's Perth office as Principal Consultant (Geology) at the end of November 2006. He graduated from Leicester University in England with a B.Sc. (Hons) degree in mining geology, and later obtained an M.Sc. in geostatistics from Queensland University in Australia. Peter has over 25 years of experience in consulting and production roles, including 10 years as an open-pit and underground mine geologist, nine years as an exploration geologist, and over six years as a consultant. He has worked on resource estimation projects, project evaluations and 3D modelling studies in different geological environments, with commodities, ranging from precious and base metals to iron ore. In the past four years Peter specialized in uranium, working on resource estimation, evaluation and exploration projects in Niger, Southern Africa and Australia.

He has performed mine feasibility, mine planning and expansion studies, as well as audits, in Australia, Southern Africa, West Africa, North America, South America, Europe and Indonesia, and he has had extensive exposure to diverse world-class ore deposits and mineral systems.

Peter has used several innovative geological modelling and resource estimation technologies that improve companies ability to produce 3D geological models and interpretations in exploring and valuating mineral deposits. He is an expert user of such modelling software packages as Vulcan, GOCAD, Geomodeller, FracSIS, Leapfrog and Datamine.

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Peter Gleeson

## Lethakane Uranium Project, Botswana

In 2008, A-Cap Resources Ltd appointed SRK to undertake a scoping study of their Lethakane Uranium Project located in east-central Botswana. The site is approximately 80km south of Francistown near the town of Serule, and is adjacent to the main highway and railway, linking Gaborone and Francistown. The extent of the work for the scoping study included undertaking the mining optimization, evaluating the mineralogy and metallurgy, a review of the geology, exploration program and resource definition, an evaluation of the water supply potential, the project environmental requirement, and then selecting a process option. SRK developed capital and operating cost estimates for four scenarios to within a scoping-level of accuracy, which is generally considered to be +/-35%.

The ore body consist of three ore types, namely: calcrete, secondary mineralized and primary mineralized material. The scoping study only considered the calcrete and secondary ore, as additional testwork for the primary material is ongoing.

Two process options were considered: a heap leach pad and tank leaching with an

associated tailings facility for the Whittle optimization runs. The optimization runs were also undertaken at two uranium prices of USD55/lb and USD80/lb  $U_3O_8$ , reflecting a lower and upper bound price range. SRK also considered two production rates, namely: 20,000 and 40,000 tonnes per day.

Following the optimization step, the tank leach option was not taken forward to develop a cost estimate. The scoping study proposes conventional open pit mining using excavators and trucks. The calcrete ore at Mokobaesi was assumed to be free-dig, while the secondary ore in the mudstones will require drill and blasting.

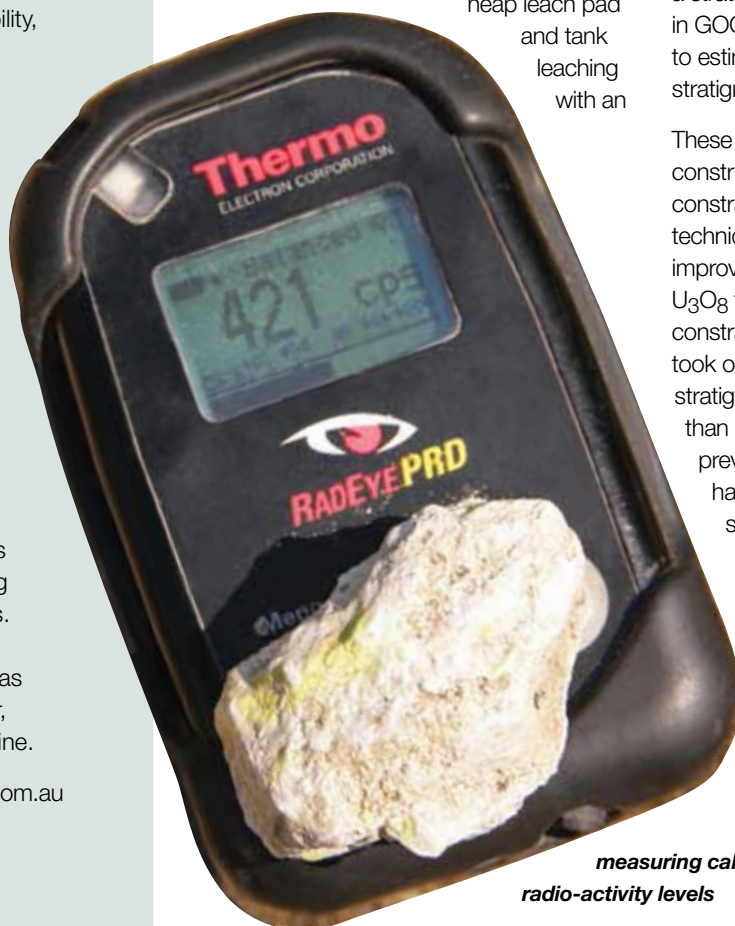
SRK provided A-Cap with ongoing advice with regard to metallurgical testwork that was, and is still, being undertaken.

Separate from the scoping study work, SRK undertook the resources estimation for the project. In preparing the new resource estimate, SRK used a more geologically-appropriate modelling technique to better constrain the estimate. Using a combination of Leapfrog and GOCAD software SRK built a stratigraphic S-Grid model of the resource in GOCAD and used Ordinary Kriging to estimate the grade within appropriate stratigraphic horizons.

These techniques resulted in a more rapid construction of the geological model constraints and mineralization shells. The techniques employed also produced an improved head grade of some 30% higher  $U_3O_8$  than previous poorly (geological) constrained estimates. The technique took only those samples in a specific stratigraphic horizon into account, rather than averaging across horizons as had previously been the case. SRK now has the capability of modelling thin stratabound mineralisation horizons relatively accurately and effectively, across large distances in three dimensions.

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measuring calcrete  
radio-activity levels

## Kuriskova Uranium Project, Slovakia

The Kuriskova Uranium Project is an advanced-stage uranium exploration property, with established uranium resources, located in Eastern Slovakia and controlled by Tournigan Energy Ltd (Tournigan). The Kuriskova uranium deposit is best described as an epigenetic vein-type uranium deposit, although it may have had precursor supergene and/or hypogene origins.

Potentially, the Project is an underground-mineable deposit that consists of a tabular Main Zone uranium deposit that is vein-like in shape, and an adjacent stockwork zone of mineralization. The Main Zone has moderate-to-steep dips, at an average thickness of 2 to 8 meters, strike and dip extents of several hundred meters, and average grades ranging from 0.1%  $U_3O_8$  to over 0.5%  $U_3O_8$ . The Main Zone accounts for 68% of the total pounds of uranium contained

in the deposit. All mineralized zones, combined, represent an Inferred resource of 3.78 million tonnes at a grade of 0.215%  $U_3O_8$  (17.9 million pounds of  $U_3O_8$ ), and an indicated resource of 1.19 million tonnes at a grade of 0.558%  $U_3O_8$  (14.6 million pounds of  $U_3O_8$ ); with an Inferred 3.2 million pounds Mo as a potential by-product.

SRK provided an initial resource estimate based on historical drilling and Tournigan's drilling of Kuriskova in 2006 and 2007; and prepared a NI 43-101 Technical Report for the client. SRK estimated the resource in close association with Tournigan's technical staff based in Slovakia and Tournigan's database and resource manager. SRK followed-up with a review and audit of Tournigan's update of its in-house resource model based on 2008 drilling.

*...continued on page 28*

## Terry Braun

Terry Braun is based in SRK's Denver office and has more than 20 years of professional experience in mining and environmental projects. His practice incorporates various elements of environmental compliance activities with engineered solutions for potential environmental liabilities at mining and other industrial operations. He develops and often implements projects that require negotiations with regulatory agencies and other stakeholders to achieve client objectives.



**Terry Braun**

Terry leads multi-disciplinary project teams to address the unique technical issues associated with mining operations. His experience in the uranium industry includes environmental reviews of in-situ uranium recovery projects, scoping studies for proposed uranium mill tailing facilities and closure planning/implementation under the U.S. Uranium Mill Tailings Remedial Action program.

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**Core drilling high-grade Sandstone-hosted uranium deposit, Utah, USA**





## Neal Rigby

Dr. Neal Rigby, Group Chairman in the SRK Denver office, is a Principal Mining Engineer with 35 years experience in the international mining industry.

For the past twenty years, Neal has focused his activities as a senior participant in numerous major reports, supporting the rationalization, merger, disposal and acquisition activities of international mining companies and mining finance institutions. This includes presentations to shareholders, stock exchanges and financial institutions regarding the "bankability" i.e. fundamental value and risks and opportunities, of mining projects. Most recently his consulting work has been directed at the restructuring and sale of mining assets and the scoping and implementation of business improvement strategies. Neal has undertaken conceptual through feasibility studies in over 50 countries worldwide, for a wide range of metalliferous, coal, diamonds and industrial mineral projects.



## Kuriskova Uranium Project (continued)

During this process SRK provided Tournigan with uranium geology and resource modeling expertise that added value to the understanding of the deposit. As with many historical uranium projects, the database, by necessity, is a mix of both gamma eU% and assay U% data. A comparative analysis of gamma-only grades with XRF-determined grades was necessary to validate the use of historical data. SRK examined the relationship of gamma to assay data before including the eU% data in the resource estimation. This cannot be done on a hole-to-hole basis, as there are no true twin holes. An interval-to-interval comparison of U% and eU% is only available for recent drillholes with both analyses, and even this comparison is problematic because the from-to intervals are often different but, more importantly, the geometric (volume) support of the samples differ considerably.

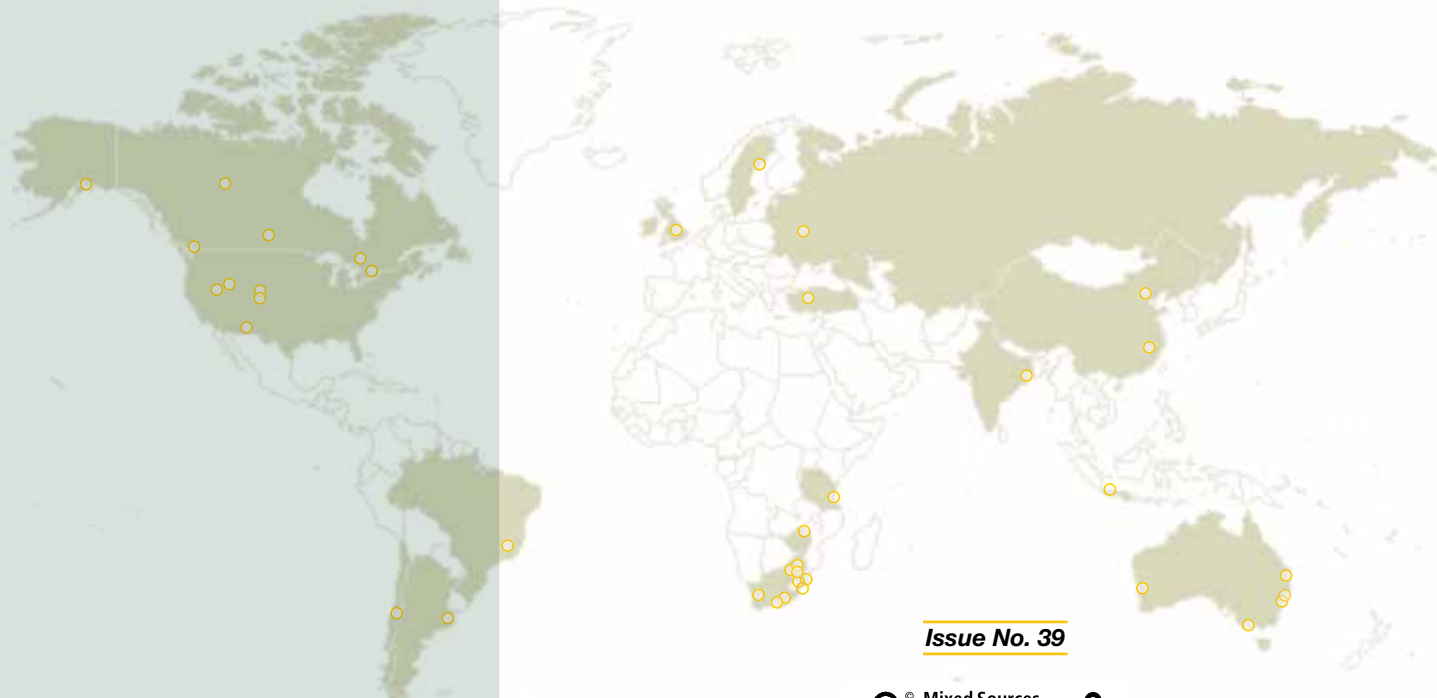
For Kuriskova, the best method of comparison was to examine the grade

distributions of each data set within the Main Zone wireframes, where the bulk of the total resource is located. The gamma data at 0.5m composites, from within the gamma wireframe for the Main Zone, were compared in a cumulative frequency plot with the assay data as 0.5m composites, from within the assay wireframe for the Main Zone. The grade distribution plots are nearly identical, providing confidence that the historical gamma-only data accurately represents the deposit grades. This type of analysis is just one of many concerns in dealing with uranium resource estimation with historical project databases.

By providing uranium expertise, SRK has helped Tournigan better understand the Kuriskova deposit, and added value in the process.

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