

## Exploration for mineral deposits – global trends

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Standing on an undeveloped iron ore deposit, Pilbara, WA, with the Brockman Formation forming the Hamersley Ranges in the background

**M**easuring the effectiveness of geological exploration and looking for trends that will lead to improved exploration success are key drivers for continued investment in the exploration industry.

Expenditure on exploration in Australia, for example, reached a peak in 2008, which reflects a massive increase in exploration for iron ore resources and, to a lesser extent, coal resources. The correction after the global financial crisis in late 2008 resulted in a significant drop in 2009 – up to 42% globally, most of which was recovered in non-ferrous mineral exploration expenditures in 2010.

The Australian Bureau of Statistics report on current trends shows continuing strength, but the return on expenditure on new deposits has been disappointing. Geoscience Australia identifies only one gold discovery, three base metal discoveries and one molybdenum discovery from 2008-2010.

This decreasing discovery rate is reflected in Australia strongly focused on brownfields drilling, with 63% of expenditure on those targets. While the latest trends show a slight increase in greenfields exploration, the overall trend shows a continuing focus on areas with a higher probability of success.

With respect to greenfield exploration, the industry is moving from a phase of discovery of near-surface deposits to generating methods for discovery of deposits at depth, either below an unconformity or within a basement terrane, but with no exposure at surface.

*...continued*

# Exploration for mineral deposits *(continued)*

Both areas present significant exploration challenges if the cost of discovery is to remain within economic bounds.

## PETER WILLIAMS

Peter has over 40 years experience in the minerals industry, including 18 years as a consultant on a range of projects from project reviews and audits and public reporting, to structural studies on both a regional and orebody scale. He has conducted major interpretation projects from aeromagnetic data for exploration targeting, and has worked in a range of geological terranes in Australia, West Africa, East Africa, Zimbabwe, Zambia, Democratic Republic of Congo, Indonesia, Papua New Guinea, Vanuatu, Solomon Islands and Europe.



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SRK remains at the forefront of providing high-quality support to exploration companies active in both brownfields and greenfields exploration. Search for deep or buried deposits relies on exploration targeting from geophysical datasets or specialised geochemical datasets by applying quality structural geology to geological interpretation of them. Geological analysis remains a key component of greenfields exploration support, and detailed mapping and advanced visualisation of structural data applied to brownfields or resource expansion projects can add significantly to success. Particularly in brownfields, advances in 3D modelling significantly enhance the probability of success and capability in designing drill programs based on geophysical and structural targets. Applying new modelling and visualisation techniques is at the core of this competency.

This newsletter provides case studies where SRK has contributed significantly, delivering discovery efficiently and improving exploration success in an exploration environment that is increasingly technically challenging.

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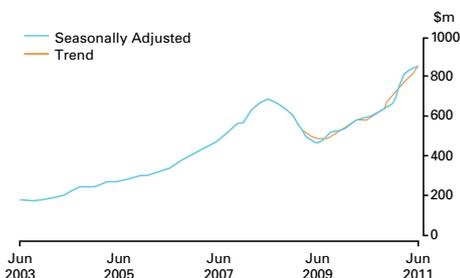


**M**ining and exploration in Indonesia present challenges that are technical, legal and social in nature. The country is currently developing regulations for its new mining law, so there is some uncertainty, albeit within a well-defined legal framework.

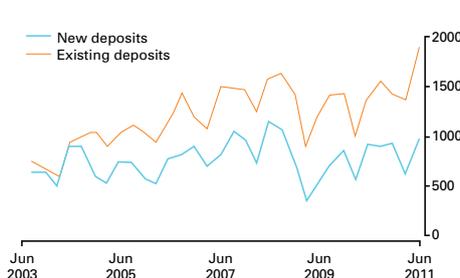
Indonesia provides numerous opportunities for exploration, and SRK is currently involved in several major projects there, mainly concerned with preparing JORC resource statements on coal, gold, laterite nickel and copper deposits. This active tectonic environment with volcanic arcs from the Cretaceous to Recent periods overlying Late Paleozoic to Mesozoic basement rocks, contain some world class orebodies.

Asia Minerals Corporation recently engaged SRK Indonesia to assess the potential of small manganese deposits in Nusa Tenggara Timor (NTT) in West Timor to feed a proposed new, local processing facility to comply with the new mining law. This will require a resource of about 2.5 million tonnes.

**\*Mineral Exploration**  
Seasonally adjusted and trend series



**\*Metres Drilled**  
Original series



\* Source: Australian Bureau of Statistics, September 2011

## Indonesia – exploration on the cusp of development



Typical bedded manganese deposit and artisanal extraction techniques, West Timor (above); Massive chert manganese breccia deposits, unconformity related, with local owners, West Timor (left)

The opportunity is significant; there are more than 50 known manganese sites in NTT, where the ore is currently extracted by artisanal mining techniques and exported as unprocessed product.

The individual deposits are small, spread across extensive areas. Several economically-viable, near-surface deposits are commonly pursued concurrently to provide sufficient tonnes for processing. The advantage is that deposits are generally high-grade with low impurities.

The key to discovering and exploiting such deposit fields is in understanding the deposit genesis for targeting, and following a disciplined exploration methodology. In Timor, the deposits are located in sedimentary rock deposited on the seafloor, subsequently displaced across the region, with numerous thrust faults and remnant mud volcanoes. Currently, there is no model of seafloor manganese deposits that fits well with the Timor occurrences.

### Developing exploration skills

In collaboration with geologists from Asia Minerals Corporation and other advisors, SRK hosted a workshop in Jakarta to advance the understanding of manganese deposits and generate an exploration program that would address the physical and climatic aspects of NTT in West Timor and provide the highest probability of success in defining manganese deposits to about 50m depth along strike from known occurrences.

The workshop identified and mapped those occurrences, and prioritised them for field inspection. The mapping program outlined criteria and methods to determine the characteristics of the deposits and to help develop a genetic model for NTT manganese. It identified remote sensing requirements, geophysical methods, including potential field and active electrical methods, and geochemical methods. The group defined a test area currently accessible under exploration licence, where these techniques can be

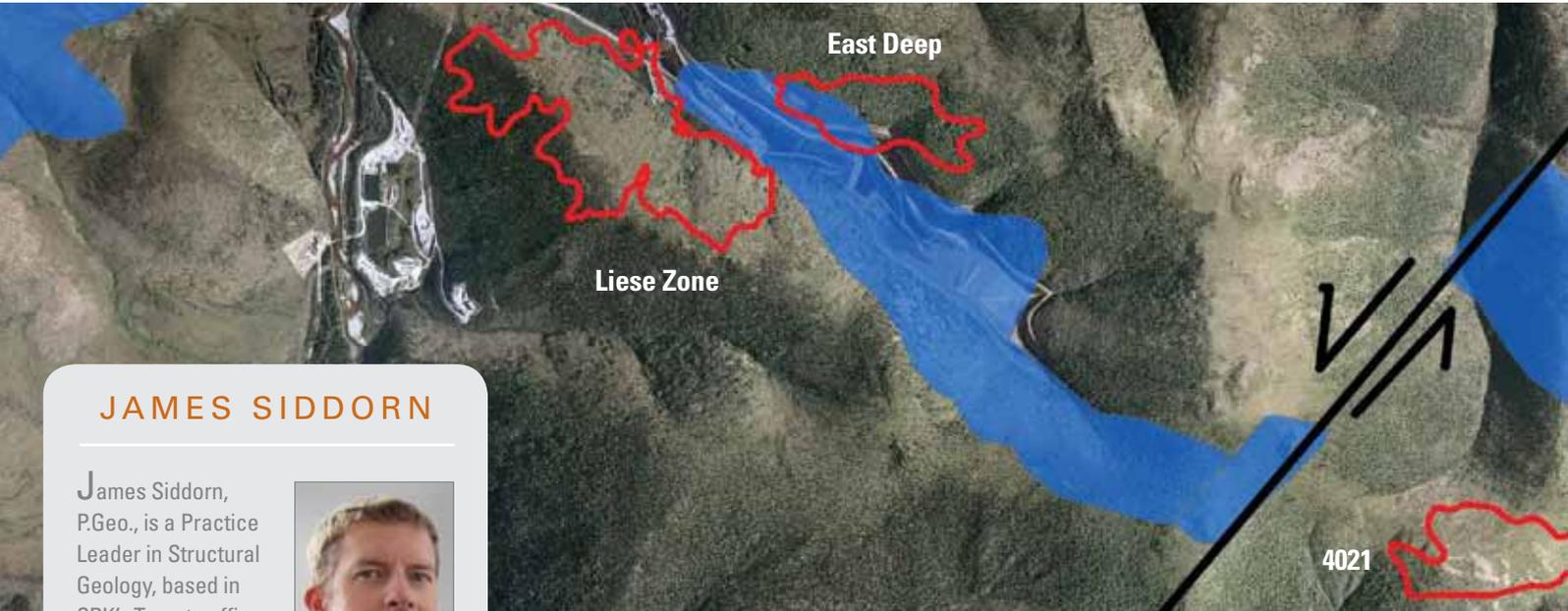
employed and where geometry is either known or can be reasonably inferred. The results from testing these techniques will guide future program development.

SRK will continue its involvement through field reviews, regular exploration program audits, and assessment of exploration results.

Over a 2-day workshop, Asia Minerals Corporation learned about the key data collection required to assess current exploration areas and generate exploration models, adopted a methodology to assess the entire eastern NTT region for exploration potential, and an immediate program to assess its current development licence for preliminary resource estimation. In the process, it gained a committed team aware of the different components that an exploration program needed and the inter-relationships that deliver exploration success.

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## Structural geology collaboration results in new find for Sumitomo



### JAMES SIDDORN

James Siddorn, P.Geo., is a Practice Leader in Structural Geology, based in SRK's Toronto office. He is a specialist in the structural analysis of ore deposits, focused on



deciphering the deposit-scale controls on ore plunge, geotechnical domains, and hydrogeological pathways. James is an expert in the applied geological interpretation of aeromagnetic data, with extensive underground and surface mapping experience, and broad mining experience in conventional and mechanised underground mining. He has spent 17 years in the structural analysis and 3D geological modelling of gold, magmatic sulfide, silver, uranium, tantalum, and diamond deposits covering different geological terranes worldwide. James has taught more than 20 Applied Structural Geology courses worldwide, to over 1000 geologists, geophysicists, and engineers.

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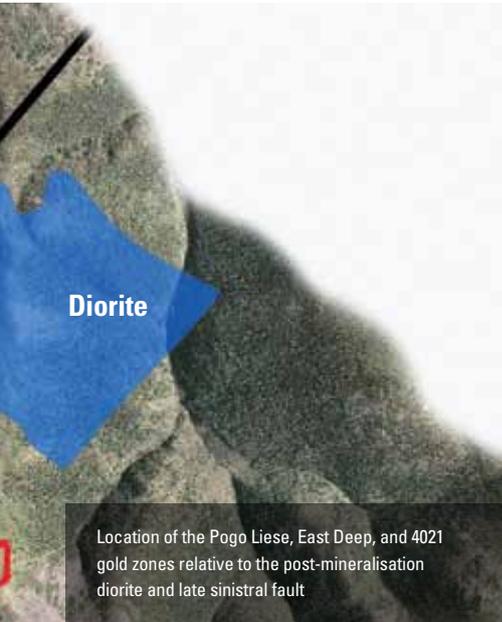
In March 2010, Sumitomo Metal Mining Pogo LLC (Sumitomo) commissioned SRK Consulting Canada to undertake a structural geology interpretation of the Pogo district in central Alaska, to assist ongoing exploration targeting. The interpretation was focused on compiling a structural geology interpretation of recently acquired geophysical data, combined with staged site visits, to examine the structural geology of the Pogo deposit and collaborate with the Sumitomo exploration team.

The Pogo deposit is Alaska's largest producing gold mine. It is underlain by high-grade gneisses of the Late Proterozoic to mid-Paleozoic Yukon-Tanana terrane, which have been intruded by granitoid bodies, mostly belonging to a voluminous mid-Cretaceous suite. The Yukon-Tanana terrane and Cretaceous intrusions extend from west of Fairbanks through the central Yukon, for a distance of over 700 kilometres.

Gold mineralisation at Pogo is hosted within the structurally controlled Liese vein system. Overall, the Liese vein system dips shallowly northwest and is a stacked system of three laminated veins (L1, L2, and L3). SRK and Sumitomo recognised that the lateral extent of the Liese vein system is large, with the L1 vein currently known to have a down-dip extent of greater than 1700 metres. The northeast margin of the Liese vein system is truncated by a post-mineralisation diorite (about 95 million years old). The crosscutting nature of the diorite, combined with the lateral extent of the vein system, indicated to SRK and Sumitomo that the vein system may extend beyond the northeast margin of the diorite, representing a significant exploration target in the shadow of the existing mill.

In 2011, Sumitomo began underground and surface drilling examining the potential for vein systems northeast of the diorite and have since outlined a significant new gold zone, the East Deep zone. The East Deep zone represents

## Providing expert advice to the Canahuire project in southern Peru



the lateral continuation of the Liese vein system beyond the diorite and will represent a significant contribution to the resource inventory of the Pogo deposit. Sumitomo is currently planning a new portal and decline ramp from the surface that will link in with two exploration drifts that have been driven over to this zone.

In addition, a significant outcome for Sumitomo's collaboration with SRK was the ability to start 4-dimensional reconstructions. A great example of this was the realisation that the Liese Creek diorite existed north of the 4021 prospect (figure above). In addition, when overlain with the interpreted structural events, this offset is seen to be from a northeast-trending sinistral fault. By reconstructing this movement, Sumitomo will have a better understanding of targeting gold mineralisation between the Liese and 4021 zones. This has led to the construction of an updated "Liese Zone" model of gold mineralisation.

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In August 2010, Canteras Del Hallazgo S.A.C., (CDH) a joint venture between Gold Fields Ltd. and Compania de Minas Buenaventura S.A.A., commissioned SRK Consulting Canada to provide expert structural geology advice into the exploration and resource delineation programs at the Canahuire Project in southern Peru. This assignment included reviewing and providing recommendations for increasing the understanding of the structural geology of the Canahuire deposit through staged reviews and input (two site visits and one data review meeting) over the course of one year. SRK worked closely with the CDH and Gold Fields exploration teams, in part providing on-the-job training to key project personnel as the study progressed.

The Canahuire deposit is an intermediate sulfidation epithermal gold-copper-silver deposit hosted within breccias of a diatreme complex that crosscuts deformed Yura Group sedimentary rocks. The deposit is located 120km northeast of the city of Moquegua, in the Ichuna region of the Andean fold and thrust belt of southern Peru. This area of Peru has recently received renewed exploration

interest, including the discovery of the Canahuire deposit, in part related to a regional prospectivity analysis that SRK previously conducted.

SRK provided a definition of the regional tectonic history, including the tectonic controls on the formation of the Canahuire deposit and how these may be related to other porphyry and epithermal districts in southern Peru. This regional analysis outlined potential structural trends and locations that are important for exploration in the Ichuna region on a broader scale.

The Canahuire deposit displays a strong structural and geometrical control to the distribution of diatreme facies and also gold-copper-silver mineralisation. A particular focus of SRK's input and analysis was on the controls on the distribution of higher grade (>10 grams per tonne) gold. This included outlining the potential geometry of hydrothermal pathways and traps, and the influence of post-mineralisation faulting on the modification of grade distribution within the deposit.

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## Ground based geophysics

**More and more**, geophysics is becoming an important exploration tool as companies turn their efforts towards hidden and buried deposits. However, it is vital to know the limitations of both the techniques and data when designing, implementing and interpreting the results of a geophysical program. One aspect of this fact was highlighted in a recent SRK ES project involving induced polarisation (IP) and time-domain electromagnetic (TEM) surveys in Oman, in search of copper-gold mineralisation for Gentor Resources.

Following a site visit to audit drilling protocols and logging procedures, SRK ES was commissioned to conduct followup ground geophysics over a pre-defined airborne electromagnetic anomaly in the Oman Mountains, west of Sohar. While a gravity survey to assist in the exploration was initially requested, having seen the very rugged terrain in the prospect areas firsthand, SRK ES considered this impractical. It would require a highly accurate digital elevation model to correct the data. That work exceeded the needs of the project at its current stage and would

add limited geological value, given the time it would take to complete.

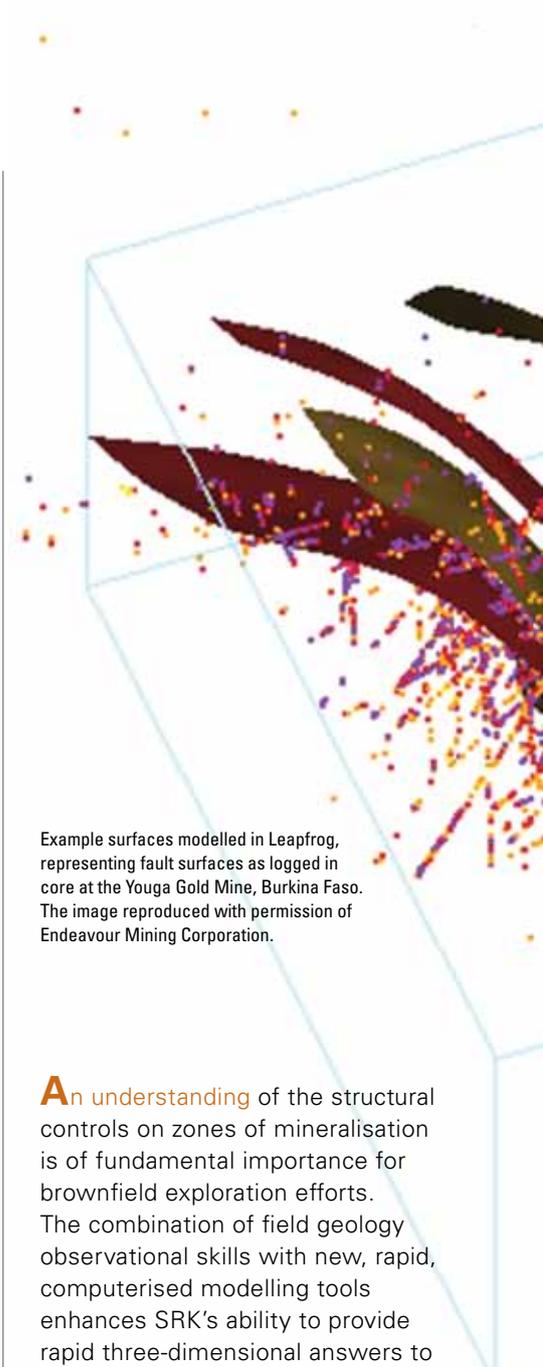
As an alternative, SRK ES conducted an IP and TEM survey over a three-week period, which involved very challenging fieldwork in rough terrain. The process of data collection had to be adapted to the ground conditions, as they proved problematic when trying to obtain good electrical contacts for the IP survey. The TEM survey progressed rapidly, producing results that improved the definition of the conductive anomaly and coincided well with mineralised intersections in previous diamond core drill holes. Due to the speed at which SRK ES completed these survey lines, two further prospect areas were covered with TEM surveys.

The results left Gentor with a number of promising targets to follow up with further studies and scout drilling. In contracting SRK ES, Gentor gained robust geophysical results in a timely manner, despite the obstacles presented by steep scree slopes and exposed environments.

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Time-domain electromagnetic (TEM) surveying for Au/Cu mineralisation in Oman

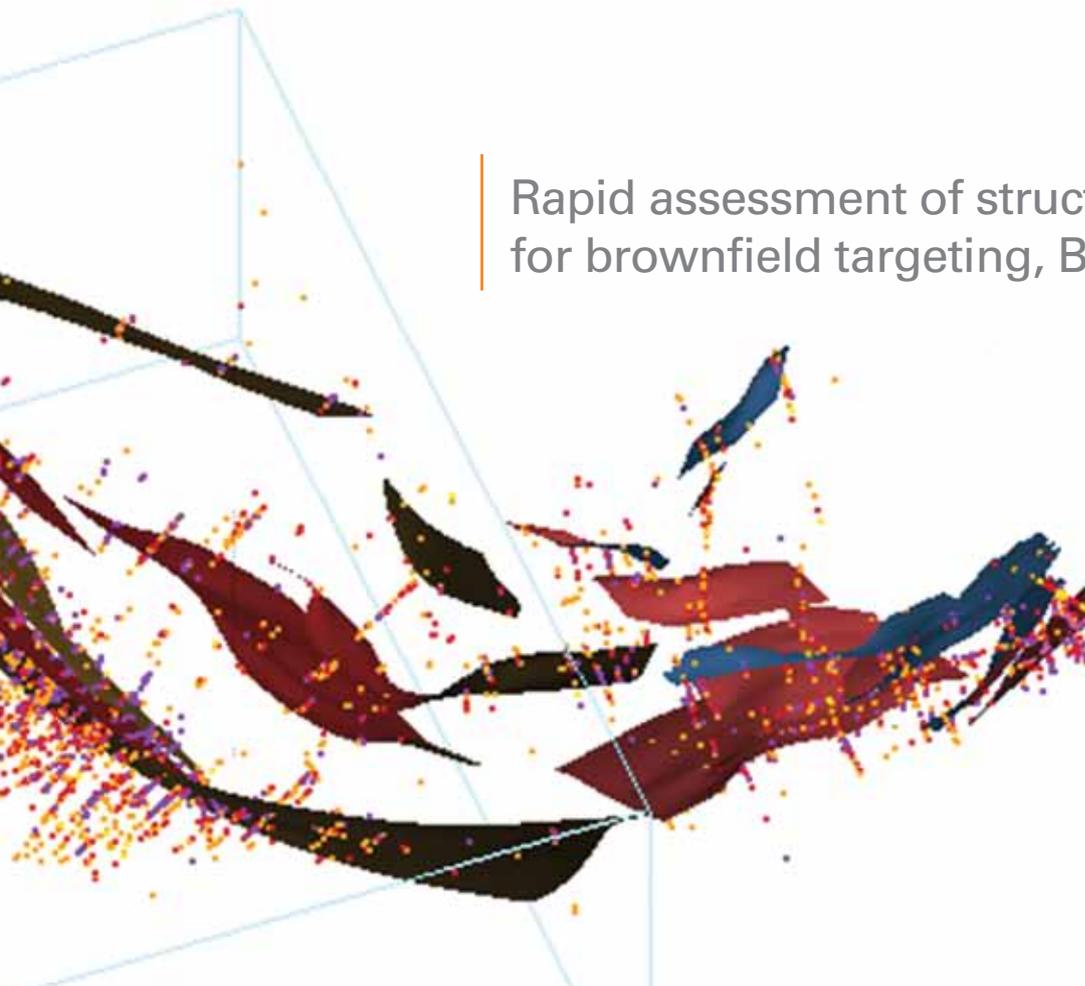


Example surfaces modelled in Leapfrog, representing fault surfaces as logged in core at the Youga Gold Mine, Burkina Faso. The image reproduced with permission of Endeavour Mining Corporation.

**An understanding** of the structural controls on zones of mineralisation is of fundamental importance for brownfield exploration efforts. The combination of field geology observational skills with new, rapid, computerised modelling tools enhances SRK's ability to provide rapid three-dimensional answers to clients. SRK's Vancouver office has been fairly active in gold projects in Burkina Faso, including the Tanlouka project on the Markoye shear zone in the central-east of the country, the Youga deposits in the southeast and the Nami gold zone of the Karma deposit in the Goyen greenstone belt in the western part of the country.

In Burkina Faso, SRK is typically tasked to explain the timing of the possible gold mineralising events relative to the Paleoproterozoic Eburnean deformational history, and to define the controlling structural geometries on the mineralisation.

## Rapid assessment of structural geometries for brownfield targeting, Burkina Faso



Mineralisation often occurs early relative to deformation, and gold may be deposited or mobilised more than once. Fundamental structural observations of deformation timing is key to determining the possible large- and small-scale geometries of mineralisation. Available data varies between projects, but may be derived from mapping and/or drill core. Rapid visualisation of zones of mineralisation and rapid modelling is very valuable before, during and after the site visit, during the post-visit interpretation (see figure above).

We typically use software to evaluate the distribution of mineralisation intersected in existing drill holes before the site visit, in order to select the key drill holes that require observation, based on preliminary interpretation. During the site visit, drill core observations of structural deformation textures, cross-cutting relationships, as well as orientated

core measurements of structural geometries are used to test and continue the interpretation of the mineralisation timing and geometry. The observations are immediately integrated back into 3D to continuously develop and test the 3D models. Leapfrog's Aranz™ (ARANZ Geo Limited) accelerated wireframing capability allows geologists to demonstrate to the client a 3D structural interpretation and a tangible product even before the site visit ends. Preliminary ideas on further drill targeting can be presented and debated with the project geologists.

The integration of structural observational skills and new advanced 3D modelling tools is a successful combination that improves SRK's ability to add value to our clients in brownfields exploration.

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### WAYNE BARNETT

Wayne Barnett has 14 years' experience in the mining and exploration industry. He is a specialist in structural geological analysis and 3D modelling for rock mass



characterisation and geotechnical risk evaluation. Wayne consults in structural and geotechnical drill core logging and quality management, mapping data capture, in rock joint characterisation and the spatial domain-based analysis of structural and geotechnical data.

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### DAN MARSH

Dan Marsh is an Exploration Geologist with SRK ES specialising in exploration geophysics. Dan holds a Master's degree in Geophysics from the University of Southampton and has three years' experience in exploration geophysics, first with Rio Tinto and now with SRK ES. Dan is part of a geophysical team that designs and reviews investigations, including ground magnetic, induced polarisation (IP), time domain electromagnetic (TEM) and radiometric surveys for a range of commodities with a global reach.



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## Target generation and grassroots exploration in Mauritania

### NIALL TOMLINSON

**N**iall Tomlinson (MSc CGeol), is an Exploration Geologist and now an Associate with SRK ES. He has extensive field experience in South America, West Africa and Central Asia. His expertise covers the management and implementation of integrated exploration programs at various stages, from grassroots to feasibility, and in a variety of commodities.



### GARETH O'DONOVAN

**G**areth O'Donovan is a Corporate Consultant (Exploration) with over 26 years experience in mining and exploration projects in Africa, South America, the Russian Federation and Asia. He specialises in the design, implementation and management of exploration projects from grassroots to pre-feasibility in all terrains and environments, mobilising multi-disciplinary field teams. More recently, Gareth has concentrated on reviews, competent person's reports, audits and valuations of exploration and mining properties worldwide and in a variety of commodities. For the past 9 years he has been Managing Director of SRK Exploration Services Ltd based in Cardiff.

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Exploration camp in southern Mauritanides, Mauritania

**I**n 2010/11 SRK Exploration Services was commissioned by Alecto Energy plc to conduct its grassroots copper/gold exploration program in Southern Mauritania. From the outset, SRK's involvement started with visits and meetings with the Mauritanian Ministry of Mines on Alecto's behalf. This culminated in selecting three licences in the Mauritanian Mobile Belt, followed by reconnaissance visits to the licence locations in August 2010, during which we observed areas of copper oxide mineralisation at the surface. A rock chip sampling program returned anomalous copper values, generating a number of targets for follow-up exploration.

Following fund raising based on these results, SRK ES designed a multi-phase exploration program to generate exploration targets and make a decision on the merit of each licence. Work began with a soil sampling program over targets generated in

the reconnaissance phase. SRK ES mobilised an experienced team to a remote location on the fringe of the Sahara to manage the significant logistical requirement, and conduct the sampling program and other activities, such as detailed geological mapping.

SRK ES used a mobile XRF analyser to test samples in the field, thereby allowing for rapid identification of any significant mineralisation and the immediate design of any required infill sampling. This process resulted in a cost saving to the client from reduced laboratory costs and increased efficiency of sampling. All samples generated with anomalous copper values and/or gold pathfinder elements were also submitted for laboratory testing to confirm their content.

We are now planning the next phase for these prospects by assisting Alecto in rapidly advancing their exploration assets towards a drilling

## Evolution of SRK ES



stage. This phase involves ground geophysics and trenching of the targets previously identified; both will be managed by the SRK ES in-house geophysical and geological teams. SRK ES aims to help Alecto establish effective field teams and camps and manage the project's development through office-based consulting services, as well as ground teams and geological supervision.

By contracting SRK ES to manage their exploration portfolio, Alecto was able to engage an experienced and integrated multi-disciplinary exploration team on the ground, developing targets in a time and cost effective manner, while giving potential investors confidence in the management of the program.

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**SRK** Exploration Services Ltd (SRK ES) was established in Cardiff in 2003 as a small group of like-minded exploration geologists with a view to filling a perceived gap in the consultancy market. Initially formed as a subsidiary company of SRK Consulting UK, SRK ES achieved full SRK Consulting Practice status in 2008.

Headed by the Managing Director Gareth O'Donovan, the initial staff comprised of a small number of permanent associates, all of whom believed in the SRK ES philosophy that everything is possible. Over the years the team has expanded to more than 20 permanent staff plus a large team of associates and contractors worldwide. Our philosophy remains "yes, we can do that".

In an increasingly competitive market SRK ES has built a strong team of exploration-focused geologists who are young and enthusiastic, individually skilled but also backed by a wide range of experienced experts in their field. Our Principal Group includes James Gilbertson, Bill Kellaway, Alexandra Akyurek, Tracey Laight and Mikhail Tsyukov. Their experience base is extensive, covering exploration, program design, management and review, project valuation, geological modelling, and input to corporate mergers and acquisitions.

To ensure that the younger exploration geologists joining the team benefit from the broad experience of their colleagues, SRK ES has developed an

in-house training program designed to share experiences and establish a base level of skills that normally require decades to gain.

SRK ES continues to provide traditional consultancy services, technical reviews, valuations, and competent person's reports as well as hands-on exploration management, offering a wide range of exploration skills in various commodities and terrains. Our newest branch office, SRK ES Denmark, headed by Casper Mejer Petersen, was opened in 2012 to support the growing exploration industry in Greenland.

We particularly endeavor to provide assistance to early stage exploration entrepreneurs and junior exploration companies who have ideas but insufficient technical skills to execute the exploration work required. SRK ES provides a package to these companies that includes access to a large team of skilled individuals for a limited period of time, sufficient to execute a field program without having to search for and hire its own staff.

Our services range across target generation, licence acquisition, program design and execution, and we provide an important interface with the upstream departments of the SRK Consulting Group and their resource and mining expertise.

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Part of the Gardar Province, South Greenland. Home to some of the world's largest REE and Ta-Nb deposits

# Applying conceptual geometrical models in evaluating mineral prospects

**C**ontinuity of geology and grade are key traits that must be demonstrable during the process of estimating a reportable Mineral Resource. Too often, however, assay grade takes precedence in interpreting the so-called geological model, while the geology – lithology, structure and alteration – are vastly underused or even ignored during the modelling process. This can lead to a follow-the-dots (grade) geological model in which little or no thought has been devoted to the actual likelihood of the grades being linked according to the model.

Over the years, SRK has encountered numerous projects where seemingly simple geological models, based on grade alone, have become unstuck at a later phase of exploration, evaluation or production. By paying careful attention to the geological structures in drillholes and by applying a relevant empirical geometrical relationship or conceptual geometrical model to the geology of the deposit, the geologist can produce a more accurate reflection of the geology in the 3D models used in Mineral Resource Estimates.

Because SRK's Structural Geologists are highly qualified and have conducted technical evaluations on many deposit types, their experience allows them to draw on conceptual models of

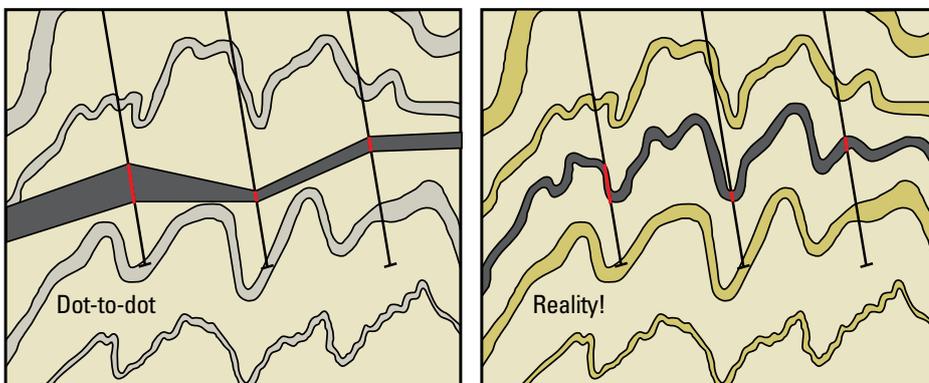
the geometry or controls on mineral deposits and a case book of real-world examples. This breadth of experience is particularly useful in the exploration stage, where geometrical information is scarce.

Knowledge and project experience bring a sound footing for the accurate interpretation of geological data and the means to interpret the continuity of mineralised veins and dykes, folded geological bodies and stratiform deposits with increased confidence, lowering the overall project risk.

Recent examples have included:

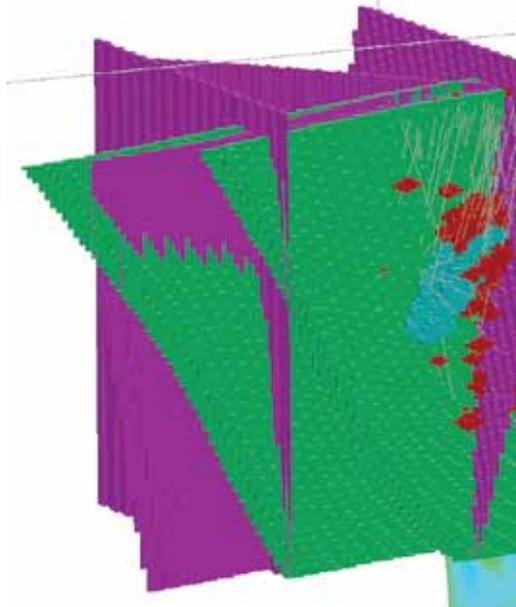
- the interpretation of complex vein-fault relationships in an epithermal Au-Ag deposit to explain the variable exploration intercepts, and to assist in defining geological domains for the Mineral Resource Estimate.
- using conceptual models of vein geometry and growth to assist in the characterisation and likely impacts on mining of a significant gemstone deposit.
- identifying pre-lithification deformation in sediments from drillholes and reinterpreting drill sections in a large, early-stage bulk commodity exploration.

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Schematic diagram of how a dot-to-dot approach can get it wrong, with grave consequences. Recognition at the early stages can mitigate the risk to the project even in highly complex deposits.

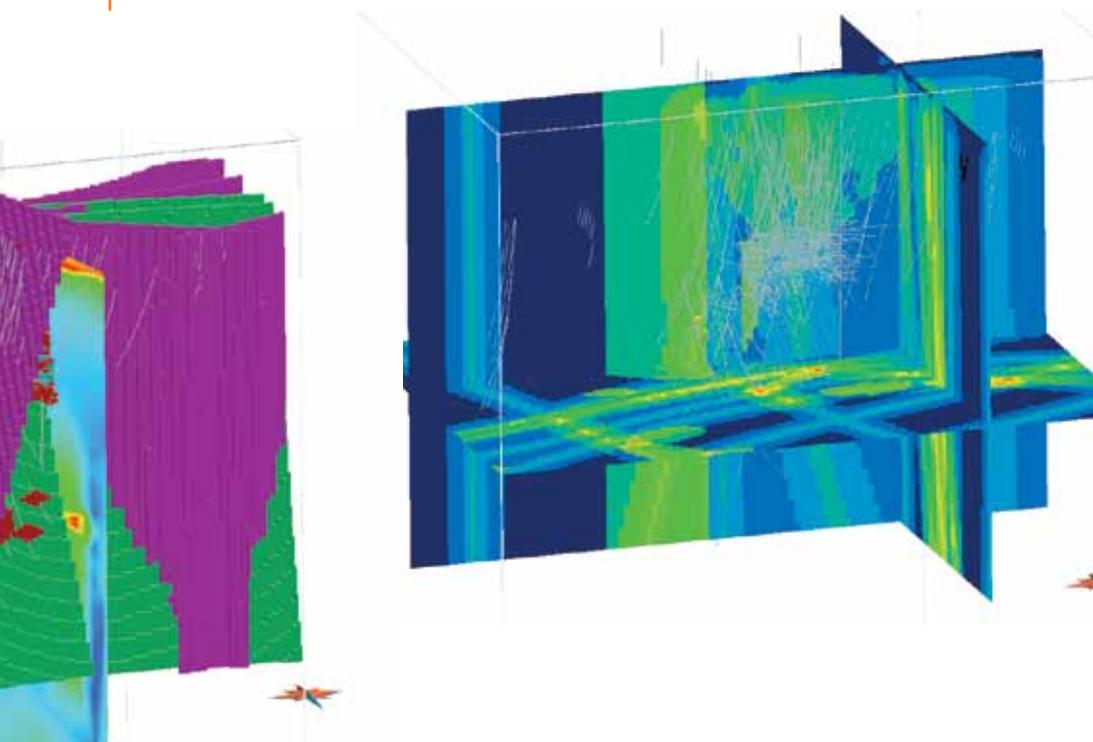
Juno1 (left): Geological block model showing fold axis, faults, assays and ore shoot. Juno2 (right): Sections and plan showing different prospectivity within the geological block model.



**B**rownfield exploration poses many challenges to the geologist: large amounts of data are usually available but often difficult to integrate and use effectively; at the same time old ideas and exploration models often hamper new interpretations and the development of new targets. Traditional interpretation involves a time-consuming and subjective 2D section analysis. In contrast, 3D targeting adds a new approach to the brownfield exploration rebus.

Excalibur Mining Ltd is currently exploring for gold in the Tennant Creek region of Australia's Northern Territory. The company's main focus is the redevelopment of the Juno and Nobles Nob gold deposit (2Moz of mined ore) and the discovery of new deposits in the vicinity of the historical mines. The area has more than 80 years of prospecting and exploration history and a very large quantity of data is available to guide exploration. SRK has applied state-of-the-art 3D targeting to identify new exploration targets in the area.

## Excalibur 3D targeting



3D targeting is a new technique that uses all available geological information to build a 3D block model of the site of interest. The model is interrogated and the most prospective volumes identified. To minimise modelling times rapid 3D modelling software such as GOCAD™, Leapfrog™ and Geomodeler™ are used.

The Excalibur study started with a brain-storming session to identify the characterising features of the Juno and Nobles Nob deposits and define a Mineral System model to be used as the geological framework. All available geological information was then integrated in the model, including lithologies, assays, structures, geophysics (magnetic, EM), mineralised trends, etc. The final 3D model included several million cells, each containing information for the nine geological properties considered.

Three main results were achieved:

- Nine exploration targets were identified, ready to be assessed and potentially drilled by Excalibur

- A rigorous review of the mineralisation model improved the geological understanding of the deposits
- A step-by-step analysis allowed a critical assessment of the quality of the information available and the identification of areas of improvement, where additional or better data could be collected. This new information could possibly be integrated in a revised 3D targeting model allowing the definition of better targets

SRK believes 3D targeting can be successfully applied as an advanced exploration tool when sufficient data are available. The flexibility of this approach allows its application to all deposit styles and geological contexts with a high potential for structurally complex areas. The geological understanding required to perform the analysis helps improve the geological model itself and ensure that all targets identified have strong geological support.

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## FABIO VERGARA

Fabio Vergara, MSc, Structural Geology, is a Geology Consultant with SRK's Perth office. He specialises in 3D modelling and geological mapping and has worked on projects in Australia and West Africa. His expertise includes developing 3D models using Leapfrog™, GOCAD™ and Geomodeler™, geological mapping of structurally complex terrain and GIS targeting studies. He has worked on gold, VMS, iron ore and IOCG deposits from early exploration to the brownfield stage.



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## CHRIS BONSON

Chris Bonson, Principal Consultant (Structural Geology) with SRK Cardiff. His principal area of expertise is characterising and evaluating the structural geology of mineral deposits.



In practice, Chris' work involves the analysis of geological structures from outcrop and exploration data to help in targeting and delineating mineral deposits; along with 3D modelling of geological structures and evaluation of their geotechnical and hydrogeological risk to various mining scenarios. Chris has contributed to technical evaluations of mineral projects around the world at the grassroots to advanced exploration stage, through scoping and feasibility studies, to producing mines.

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## HOWARD BAKER

Howard Baker, MSc, Principal Consultant (Mining Geology), has 15 years of broad geological experience in mineral resource estimation, mine geology and exploration planning. He worked as a senior mine geologist in the iron ore and mineral sands industries in Western Australia before joining SRK in 2007, where he has focused on resource block modelling of iron ore deposits in West Africa, Sweden and Finland. Howard's SRK responsibilities include generating geological models using specialised mining software, producing resource estimates, auditing mining operations as part of Competent Person's Reports and Stock Exchange Listings and technical due diligence reviews.



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## COLIN RAWBONE

Colin Rawbone, MSc, Consultant (Resource Geologist), has over six years' field experience in mineral exploration in west and central African gold and iron ore deposits.



His professional career includes project evaluation and assessment, planning and supervision of drilling activities, 3D geological interpretation and modelling, resource estimation, and preparation of compliant NI 43-101 documents. He has managed the technical aspects of projects from discovery to resource development and bankable feasibility studies. Since joining SRK in early 2011 Colin has focused on mineral resource estimation, including 3D geological models and geostatistical analysis.

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## Maximising drilling to define the mineral resource at the Nkout Iron Ore project



Resource definition drilling at the Nkout Iron Ore project, Cameroon

In September 2010, Afferro Mining Inc. commissioned SRK to conduct the maiden Mineral Resource Estimation (MRE) on their 100% owned greenfield Nkout Iron Ore project in Cameroon. The project is being managed by an SRK Qualified Person for iron ore projects.

Through regional geophysical surveys, Afferro had identified a 20km strike length magnetic anomaly within the Djoum exploration licence and had confirmed the existence of an iron bearing sequence through surface grab samples. SRK assisted in the drillhole planning, assaying, preliminary metallurgical testwork and quality assurance and quality control protocols for the drilling program that enabled Afferro to estimate a 1- billion tonne (Bt) maiden MRE in the Inferred Resource category from 4,359m of drilled meters. Critical to their success was targeting the primary banded iron formation (BIF)

mineralisation from 10 drillholes, and the specific drill targeting of the potential oxidised sequence overlying the BIF with 21 shallow, vertical drillholes. The results of the exploration drill program showed that a high-grade iron concentrate could be generated from the primary BIF after 94 representative samples were selected by SRK for Davis Tube analysis. They showed that Nkout had an oxidised cap with the potential to generate early cash flow from high-grade direct shipping ore (DSO) and a softer, friable BIF that could generate a high-grade sinter fines product through a simple gravity circuit. The maiden MRE covered the Nkout centre target, comprising 3.5km of the 20km magnetic anomaly.

After the success of the maiden MRE, Afferro retained SRK to manage the ongoing exploration drilling with a qualified SRK Exploration/Resource Geologist based on site throughout

# Deciphering structural controls in a greenstone belt in Ghana



In March 2010, Xtra-Gold Resources Corp. commissioned SRK to conduct a structural geology analysis of their Kibi Project that aimed to provide insights to the geological and structural controls on the distribution of gold mineralisation and guide further exploration. Xtra-Gold also commissioned SRK to conduct a structural interpretation of regional airborne geophysical data, with the aim of developing a litho-tectonic framework for the region that could be used for defining conceptual structural targets.

Xtra-Gold's Kibi Project is located in the underexplored Kibi-Winneba greenstone belt in Southeast Ghana. Although SRK has previously conducted numerous geological studies in other belts in Ghana, little is known about the tectono-metallogenic evolution of this belt. SRK investigated Xtra-Gold's drill core and exploration trenches to unravel the geology and controls on gold mineralisation and developed a structural framework that is the first of its kind in this belt.

SRK was able to determine that gold mineralisation at the Kibi Project occurred in quartz-albite-ankerite stockwork veins within quartz diorite intrusions, and quartz-carbonate veins in narrow northeast-trending graphitic shear zones that occur in tightly folded metasedimentary rocks. Gold mineralisation in the quartz diorite intrusions appears to be more widespread and forms the focus of Xtra-Gold's ongoing exploration campaign.

The recognition that gold mineralisation was primarily hosted in quartz diorite allowed Xtra-Gold to focus its exploration drilling, and better define the 3D geometry of these intrusions and the extent of auriferous zones within them. Following further structural analysis of subsequently

acquired drill core, SRK identified several northeast-trending shear zones that bound auriferous stockworks in the diorite intrusions. In addition to controlling the development of stockwork veins in diorite, these shear zones host auriferous fault-fill and extensional veins. Structural analysis of shear zone and vein elements indicated that these developed during protracted SE over NW compression. Moreover, identification of the auriferous shear zones allows Xtra-Gold to better focus regional exploration drilling along this newly-defined prospective structural corridor.

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## IVO VOS

Ivo Vos, PhD, P Geo, is a Senior Consultant in Structural Geology with SRK Toronto.



He has over 8 years of experience in the regional and local structural analysis of mineral deposits and has successfully applied his knowledge to the discovery of new gold deposits in East Africa. Ivo is an expert in deciphering structural controls on the distribution of mineralisation with experience in a variety of commodities, including Gold, Ni-Cu-PGE and Uranium. His other specialties include deposit-scale 3D modelling, structural and geological interpretation of geophysical data, (multi-commodity) regional exploration targeting studies, and GIS integration of geological, geophysical and litho-geochemical data.

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the 2011 program. This allowed a dynamic approach to the drilling and allowed the MRE to proceed with the geological modelling completed as new drillholes are logged and the drill program adapted accordingly. Afferro could now maximise the drilling budget, getting absolute value from every meter drilled and ensuring that international standards are followed.

After the maiden MRE and an additional 5,505m of drilling were completed, Afferro announced an increase in the resource base to 1.4Bt with 700 million tonnes now upgraded to the Indicated category and tonnage to the DSO material increased. Exploration continues and future resource updates are pending as over 9km of the 20km defined magnetic anomaly have now been tested.

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Nugget containing >30 oz gold discovered at Xtra-Gold's Kibi Project in April 2011



# Project diversity and foreign interest spur SRK India's growth and success

**SRK** established its Kolkata, India, presence in 2006. Since then, the office has expanded in response to client needs and an ever-growing client base. SRK India provides a range of services from auditing and competent-person reporting to exploration project advisory, drill program design, and sampling protocol implementation.

While domestic Indian companies are now investing in various mining geographies across the globe, private investments within the Indian mining sector have also gradually increased. These companies and investors look to SRK India to evaluate and audit early-to-advanced stage exploration projects, develop and manage exploration programs, and prepare independent technical reports for potential funding.

## SOUVIK BANERJEE

Souvik Banerjee, a Geologist at SRK's Kolkata office, has nine years of experience. His skills include structural mapping and interpretation, 3D modelling,



exploration planning and managing greenfield to brownfield projects, sampling and assay quality control and mineral resource evaluation. Since joining SRK in 2008, Souvik has worked on base metal, gold, manganese, iron ore and coal projects in India, Indonesia and Southern and Western Africa. Souvik has been involved with projects requiring early appraisal, reviews and audits, exploration development and independent technical reporting following JORC and NI 43-101.

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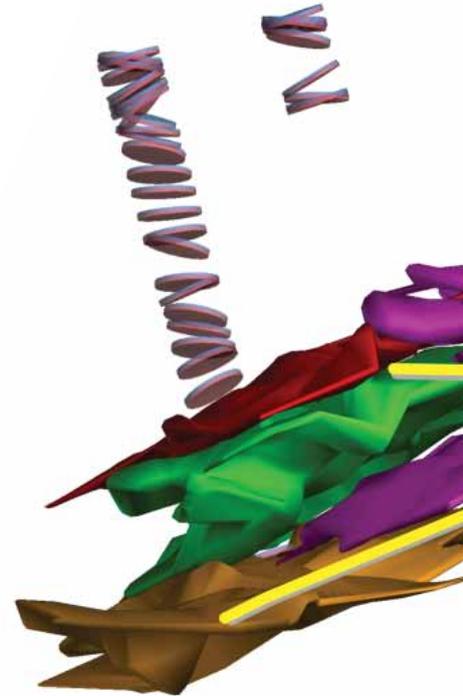
The first step to any geological study is geological mapping. Successful geological mapping includes geospatial documentation, subsurface projection of geological surface features, and accurate identification of geological features and rock types. SRK India has undertaken multiple mapping programs. Some of these have revealed unidentified mineralised bodies, including an iron ore mine in India and a 1000-square kilometer coal project in Zambia.

In 2010, SRK India consulted on an Indian gold project, which involved a data review and field visit, as well as resource potential assessments and exploration planning. As a result of that work, the client further retained SRK India for a scoping study, in which additional field and laboratory test work was recommended so the client could undertake a feasibility study.

SRK India has also provided client training, developed field protocols based on international best practices, and helped design exploration databases. For example, Aryan commissioned SRK India to assist with its exploration program for their Narayanposhi iron ore project and Trimex for their Beach Sand project. In both cases, SRK India provided support to ensure the integrity and reliability of the exploration databases were achieved. Eventually, both companies produced mineral resource reports following JORC code.

Another project also highlights SRK India's growth and success since 2006. When Coal India Limited launched its IPO in 2010, the company appointed SRK India to benchmark its exploration protocols and resource estimation practices according to international best practices. Coal India used this work to report its resources and reserves, which were compliant with the JORC code.

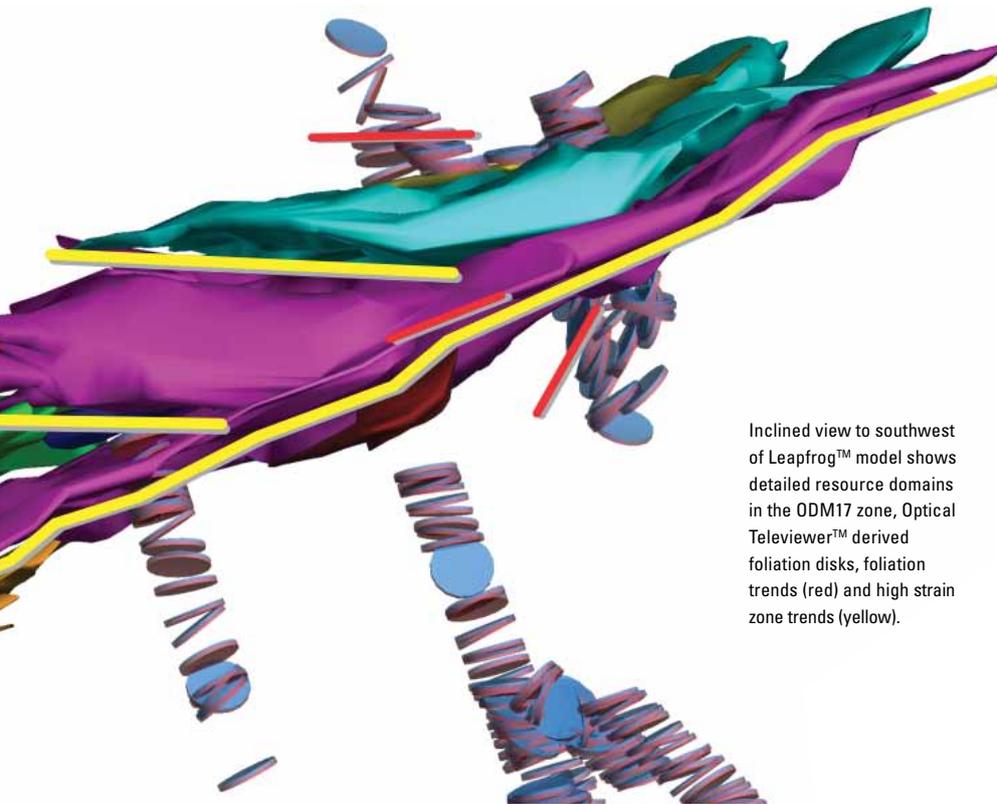
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**SRK** structural and resource geologists work closely with clients to deliver resource estimates that incorporate sophisticated geological and structural models. Since 2007, SRK has assisted Rainy River Resources Ltd. to develop detailed resource evaluations for the Rainy River deposit based on evolving, constrained structural models. The Rainy River deposit is a strongly deformed, gold-rich volcanic massive sulfide-associated gold deposit located in northwestern Ontario, Canada. The deposit consists of a number of distinct resource zones, the largest being the ODM17 zone.

In 2008, SRK was commissioned to undertake a revised resource estimate for the Rainy River deposit. As an integral component of this process, SRK geologists visited the project site and

## Integrating structural geology for improved resource modelling



Inclined view to southwest of Leapfrog™ model shows detailed resource domains in the ODM17 zone, Optical Televiewer™ derived foliation disks, foliation trends (red) and high strain zone trends (yellow).

conducted a structural interpretation based on unoriented drill core. Evidence for a penetrative south-dipping foliation, accompanied by a strong southwest-plunging stretching lineation that overprinted the gold mineralisation, were critical observations. Most styles of gold mineralisation in the ODM17 zone are clearly deformed by this strong ductile deformation, and both sericite alteration halos and gold mineralisation envelopes plunge approximately parallel to the stretching lineation. The initial resource modelling incorporated these structural observations to define a series of geodomains consistent with the foliation and stretching lineation orientations.

In 2010, SRK was commissioned to undertake a further structural study. At this time, SRK was able to integrate recently acquired Optical Televiewer™

and oriented core programs into the geological interpretation. SRK and Rainy River personnel confirmed the strong southwest-plunging lineation and delineated distinct domains, consisting of slightly different foliation orientations within the ODM17 zone. High strain zones at the structural base of the ODM17 zone and bounding internal zones of increased gold mineralisation were traced through the deposit. These observations were used as the geological rationale for constructing better constrained resource domains (Figure 1). The practical implementation of detailed structural analysis resulted in a resource model with increased geological confidence that reduced the level of risk associated with the resource estimate.

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### BLAIR HRABI

Blair Hrabi, M.Sc., P.Geo., is a Senior Consultant with SRK, based in the Toronto office. He is a Structural Geologist with 18 years' experience with the exploration



industry, government geological surveys and in academic settings mapping and modelling the lithology, structure and mineral deposits in deformed Archean and Proterozoic terranes. Blair applies his expertise to evaluating the structural controls on lode gold deposits, to 3D computer modelling of gold, magmatic nickel and VMS deposits for resource evaluation and drill targeting, and to GIS-based structural interpretations of aeromagnetic data for exploration targeting.

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### SHAMEEK CHATTOPADHYAY

Shameek Chattopadhyay, a Senior Consultant (Geology) based at SRK's Kolkata office, has over 8 years of experience. His broad background includes exploration management,



analysing assay quality control data, 3D geological modelling and mineral resource estimation. Since joining SRK in 2007, Shameek has worked on multiple resource estimation projects and technical due diligence studies associated with Stock Exchange Listing. His major commodity specific experience covers base metals, gold, iron and manganese.

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## Effective geological training and data management

### BILL KELLAWAY

Bill Kellaway is a Principal Exploration Geologist with SRK Exploration Services. He has 29 years' experience in the oil, mining and educational sectors. Bill



previously worked in exploration and mine production on a number of tin and gold deposits in South America and South Africa for Gold Fields Ltd before joining SRK Exploration in 2009. Since then, he has managed a number of successful exploration programs coupled with training in West and Southern Africa, Europe and North America.

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### JAMES GILBERTSON

James Gilbertson has over 12 years of experience in mineral exploration and resource modelling, including 7 years as a consultant with SRK. James



has performed many geological and exploration program audits, due diligence reviews, and competent person reports. He now specialises in exploration program design and implementation, technical reviews and data management as a Principal Exploration Geologist with SRK Exploration Services.

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Basic geological training of field geologists, Botswana

In recent years SRK Exploration Services noticed that the fast pace of modern exploration often occurs at the expense of quality data management and geological training.

The current demand for experienced geologists shows little sign of abating and the need for training has never been greater. University curricula are stretched and training in the field is often left to industry, where in-house training programs are now a thing of the past.

At SRK ES, we recognise that many of our clients rely heavily on under-trained staff, supplemented only periodically by expatriate technical managers, and training now forms an intrinsic part in many of our commissions. While geological training is most apt for new and young recruits, SRK ES recognises the need for continual training at every level to ensure competency in all aspects of project work.

SRK ES has developed structured geological tuition programs revolving around a Training Checklist designed to assess current competency and identify training needs. These programs are run as informal workshops for individuals or groups and ideally form part of annual assessments of an individual's continuing professional development. A Training Manual accompanies the workshops, outlining standardised procedures for all aspects of exploration activities ensuring industry best practices.

Recent training programs were run on three levels: basic geological techniques, design and implementation of standard protocols, and exploration management and logistical support. This approach is most effective when pitched at the right level, where there is continual feedback and a proper mechanism for ongoing assistance and support.

In many current exploration projects,

## Exploring for specialty metals in Greenland



SRK ES has identified another area that would benefit from training: effective data management and interpretation. The adage “data rich, but information poor” is particularly true for early stage exploration projects where true geological complexity is yet to be understood.

To address this need, SRK ES has developed specific capabilities for client data storage, management, interpretation and visualisation, along with assistance in selecting and developing tailored in-house programs for effective data utilisation.

As exploration projects are fast-tracked towards resource projects, exploration teams with robust systems and protocols in place, and effective tools to deal with their data, are best positioned to benefit from any corresponding addition in value.

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In 2010, Ram Resources Ltd. commissioned SRK Exploration Services to assist with the review and acquisition of the Motzfeldt tantalum-niobium (Ta-Nb) project in South Greenland. SRK ES undertook an in-depth assessment and due diligence on the data available for this project, which was thought to be one of the world’s largest occurrences of Ta-Nb hosted in altered syenites. Motzfeldt forms part of the Gardar Alkaline Province, located in a remote and mountainous sub-Arctic area with access possible only by helicopter.

In 2010, SRK ES mobilised an Arctic-experienced team to carry out a drilling, trenching and sampling program that highlighted the limited nature of earlier exploration, as well as considerably expanding known mineralisation, and identifying significant rare earth element (REE) mineralisation that had previously been overlooked. Further exploration programs were completed in 2011, along with intensive, helicopter-based, regional geological and geophysical exploration. The area was covered by a new 568km<sup>2</sup> licence that was applied for following review of historical data. This project guided the identification of four new areas of Ta-Nb-REE mineralisation in a range of geological settings.

In cooperation with a range of laboratories, SRK ES also designed specific sampling, assaying and quality control procedures to best assess what are very complex elements and matrix styles, in a most time-effective manner.



Reconnaissance exploration in remote areas of the Igaliko Alkaline Complex, Greenland

Working alongside SRK ES, SRK Consulting (UK) will soon start work on the first Inferred Resource for the project. Further drilling is planned for 2012 to expand this resource and to further investigate the new regional exploration targets identified in 2011.

Ram Resources is a small company with limited in-house geological expertise. By working with SRK ES, they have benefitted from the services of an experienced and multi-disciplinary team that has enhanced their understanding of this unique but challenging geological region.

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### JON RUSSELL

Jon Russell has 11 years’ experience in mineral exploration and geophysics and is a Senior Exploration Geologist with SRK Exploration Services Ltd. He specialises in the



design, management and technical review of exploration programs and has worked on a variety of commodities around the world. Recently, Greenland has been a major area of focus, especially in generating targets for rare earth mineralisation. Jon has also been extensively involved with exploration for gold in West Africa, and he is actively building the exploration geophysics capabilities of SRK ES.

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# Advanced exploration targeting: SRK's approach

**SRK** has a great deal of experience in assisting companies to implement minerals exploration programs from greenfields to advanced projects. The initial stage of any exploration program is targeting. At this stage, exploration activities are focused onto specific areas with the highest potential for discovery, and on developing strategies to systematically explore them. Unfortunately, dedicated exploration targeting is often overlooked.

Ideally, targeting shouldn't create too many false leads, but equally shouldn't be so simplistic that it misses the next big one. When assessing the exploration potential of large areas, decisions should be based on a combination of available data and expert knowledge. Predictive tools use the characteristics of known mineral deposits to identify similar features in exploration datasets such as geochemistry, geology, structure and geophysics. Expert-driven and data-driven are the two different approaches used in predictive targeting.

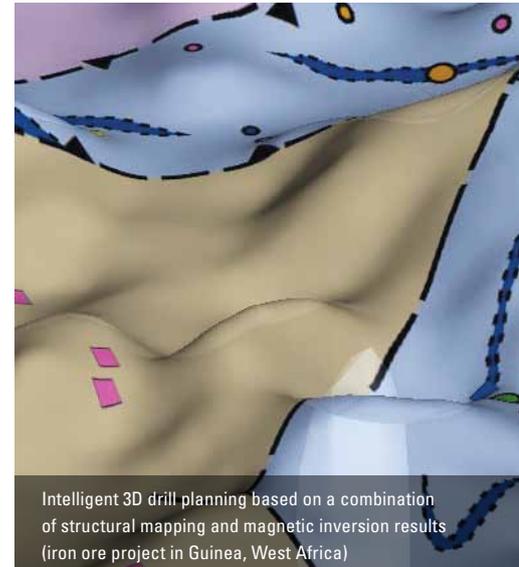
The expert-driven approach to exploration targeting relies on understanding the mineralising system or potential for a minerals system to occur. It is useful in greenfield areas where information regarding mineralisation is limited. The areas can be compared with similar geological settings with known mineralisation, where an exploration model or rationale for future exploration can be developed on sound geological reasoning. This approach uses the

concept of geological processes, in which mineralisation, moving from a source along a pathway, is focused and becomes localised in a trap. Each element is ranked, based on the geologist's judgment, and the features are combined in a 2D or 3D GIS package. The cumulative effect of intersecting features of interest highlights target areas.

Data-driven targeting methods provide a robust and repeatable technique for investigating regions with large amounts of data, particularly in brownfield exploration. The data-driven approaches require little understanding of the actual mechanism of mineralisation, but use empirical evidence to rank each element. The most common approach is the Weights of Evidence technique, where a spatial feature (e.g. fault, geochemical anomaly, specific rock type) is assigned a statistical weighting based on its statistical relationship with identified mineralisation. This approach allows even very large and complex datasets to be integrated in an unbiased manner. In many cases, features related to mineralisation can be identified, allowing exploration to focus on prospective regions, independent of past interpretations.

The targeting processes SRK has developed provide a robust geological framework and mineralisation models on which companies can base exploration programs.

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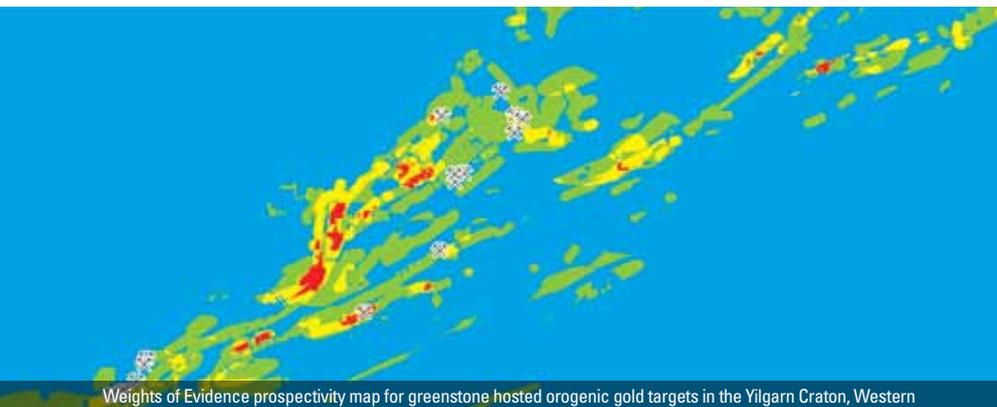


Intelligent 3D drill planning based on a combination of structural mapping and magnetic inversion results (iron ore project in Guinea, West Africa)

**H**aving worked for SRK on a wide variety of exploration projects, I'm sad to report that geological and structural mapping continues to be a largely undervalued exploration tool in the industry. Finding a geological map in the display booths at explorer's conferences is a bit like the industry itself: high risk – low gain!

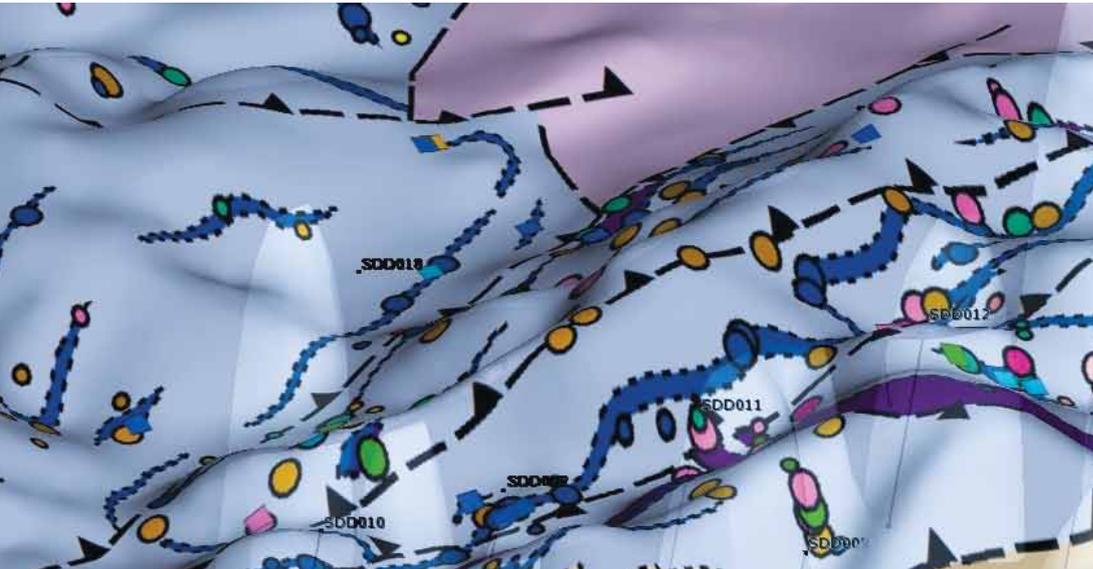
This lack of interest in mapping in part reflects the fact that market appetite is focused on vague declarations of "mineralised corridors" and "prospective structures". And the fast pace at which exploration projects operate allows little time for mapping, which is perceived to be slow work. As a consequence, mapping skills are dying out, and many younger geologists lack the mapping skills needed to make sensible interpretations.

SRK believes that geological and structural mapping should be conducted early in any project, to form a solid basis for a cost-effective exploration campaign. The cost of



Weights of Evidence prospectivity map for greenstone hosted orogenic gold targets in the Yilgarn Craton, Western

## Cheap and dirty, but essential: geological/structural mapping



initial geological mapping fades into insignificance when compared with drilling or regional geochemical or geophysical surveys. What's more, the understanding gained by geological mapping allows a better definition of meaningful and cost-effective drill hole planning, defining target areas for geochemical or geophysical work and establishing a testable geological/structural model.

In recent years, the SRK Geology Team has developed advanced mapping capabilities using GPS-enabled tablet PC's and mapping protocols that allow the digital capture of mapping data in the field, producing maps more quickly than ever before. A geological map in digital form and all attached databases are usually finalised within a week of finishing field work. The mapping data is integrated into a 3D environment (LeapFrog™) to assist in cross-section generation and drill planning, and is presented to the client in GIS and LeapFrog format. SRK also works with a set of reputable laboratories to allow for quick sample returns

for petrographic, chemical and even geochronological analyses, which may assist in geological interpretations.

Recent mapping work conducted by SRK Perth include iron, base metal and gold projects in Australia, West Africa, Southeast Asia and North America. The mapping has ranged from regional (1:50,000) to prospect scale (1:5,000) projects, sometimes incorporating 3D drilling data to aid interpretations.

SRK mapping has assisted clients to identify target areas, by recognising outcropping mineralisation, or structural interpretations, and where data are sufficient, has provided a testable geological model, in some cases, with exploration target sizes. Often, SRK is able to incorporate the surface mapping data into 3D geological models once drill data become available. This in turn leads to better constrained geological domains, and a more reliable resource estimate further down the line.

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### BERT DE WAELE

Bert has over 20 years of structural mapping experience, mostly in African Precambrian terranes. He has consulted on base metal and gold prospects, setting up and running exploration programs or interpreting regional geochemical data. Bert has conducted Independent Technical Assessments on various mineral assets including gold, porphyry copper, iron ore, manganese, diamond, mineral sands, phosphate, evaporite and uranium. He has developed both expert and data-driven exploration targeting systems for gold exploration projects.



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### MATT GREENTREE

Matthew has some 15 years of experience in mineral exploration geology, and has international experience working on numerous deposit styles, including lode gold, IOCG, sediment-hosted Cu-Co and base metal deposits, magmatic nickel, and BIF-hosted iron ores. He has worked on various grassroots and advanced nickel exploration projects in China and Central Australia and regularly consults in the management and interpretation of geological and exploration data within geological and GIS computer packages.



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# Overview of uranium exploration and the nuclear industry in Argentina

## PABLO NAVARRA

Pablo Navarra, Principal Geologist in SRK's office in Mendoza, Argentina, has had a long career with the National Atomic Energy Commission of Argentina, specialising in the fields of uranium mining feasibility and operations, related environmental studies and exploration. Milestones included the Cerro Solo prefeasibility project, and the re-engineering of the Sa. Pintada Mine. He completed and published studies about gamma logging for uranium deposits evaluation, and took part in International Atomic Energy Agency activities related to world uranium resources. He was designated Mining Director of the Province of Mendoza (October 2008 - May 2010).



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## ERNESTO JARAMILLO

Ernesto is a Principal Geologist in the Santiago office with more than 20 years of professional experience. He has spent 14 years in lithological, alteration, mineral zone and metallurgical modeling, specifically in resource modeling and estimation. He also has a background in underground and open pit production geology. As head of the resources/reserves group in Santiago, Ernesto's projects have taken him to locations throughout the Americas as well as to Turkey.



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General view of the uranium mine-mill located in the Sa. Pintada Range, Mendoza Province, Argentina

Argentina's long experience in the nuclear industry is evident not only in continuously generating electricity, 10% on average of Argentina's national consumption since 1974, but also for the companies associated with the government-owned National Atomic Energy Commission (CNEA) that supply nuclear reactors for research and radioisotope manufacture for the international market. CNEA's technical teams began exploring and mining-milling uranium in the 1950's, but only a few geologically appropriate areas have been explored since then.

Now, based on results from exploring sedimentary basins and granitic and volcanic related areas, further developing uranium resources beyond national requirements seems feasible. Meanwhile, investigating areas that could be mined using in-situ leaching, are just beginning, and some interesting surficial deposits were discovered in recent years.

Indigenous uranium production fueled the operating nuclear power plants for

20 years, until 1997, when the Sierra Pintada Mine-Mill Complex, Mendoza Province, was put on stand-by for economic reasons. Then, five years ago, the government launched a reactivation program, by completing the construction of a third nuclear power plant and, effectively reinitiating development of a national, low-power technology reactor.

These measures conform with proposals of energy experts directed at increasing nuclear participation in the energy sector, reducing dependency on oil and gas imports. At the same time, CNEA's teams, along with junior and senior private companies, are taking new initiatives in uranium exploration, spurred on by rising international uranium prices. Reactivating uranium production and increasing resource exploration are relevant activities for minimising dependence on foreign uranium supply for fuel in the long term.

At present, CNEA has plans for re-starting production in Sierra Pintada, and reaching the production stage in the Cerro Solo Project in Patagonia, although

## New life for an old mine – Carmen, Chile



both projects face difficulties related to obtaining permits. Waste remediation is being carried out or is under study at former mining-milling sites. The efficient completion of remediation will be very important for obtaining social licenses for new production, as the social perspective on nuclear and mining activities is as controversial here as in other countries.

SRK may play a role in future nuclear activities in Argentina by supporting uranium exploration and production, both private and government-run. SRK's experts have experience in all stages of uranium production, in environmental studies, and mine closure and remediation. SRK is currently involved in selecting consulting companies for remediation of a closed uranium production center. In furthering exploration activities performed by private companies, SRK's Santiago, Chile office carried out some advisory studies, and maintains contacts for continuing services involving the Mendoza Office.

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The Carmen iron mine is located in the northern Chilean Province of Chañaral and lies approximately 50km east of the coastal port city of Chañaral. Since May, 2010, Minera Santa Fe has been producing a dry magnetite iron concentrate from old stockpiles originally derived from the open pit, idle for 40 years. SRK recognised the possibility of adding resources at the Carmen project by exploring the iron potential of the alluvial gravels east of the old pit, as well as the potential of the mineralised material in the pit, either by extending the depth of the high grade zone in the old underground workings or by expanding the pit itself. Drilling has been conducted on these targets and considerable new resources have been added to the project.

Minera Santa Fe (MSF) has used SRK in Santiago as a consultant to do the geological exploration on most of their projects and they contacted SRK to work at Carmen on this brownfield exploration program. SRK is constructing a new geological model based on additional infill drilling and will produce a new resource estimate. Once this is completed, a mining scoping study will be performed. SRK has already done a preliminary economic study of the project for MSF. The results are very positive and MSF plans to move the project ahead as quickly as possible.

MSF is currently producing from a new plant, which will treat all the ore types at Carmen. The plant will process 500,000 tonnes of material per month.

Carmen is one of the few iron mines in Chile where a massive magnetite ore zone is well exposed in the underground

workings. The workings consist of three levels that are located behind the south wall of the open pit. The levels extend for about 50m vertically and the lowest level, number 3, is about 10m below the lowest point of the pit bottom at 800masl. A I-Site scanner survey was conducted in the open pit and all the underground workings.

SRK's Santiago geologists are able to design and run exploration programs, construct geologic models and perform resource-reserve estimations, as well as integrate their services with the mining department. This has allowed SRK to continue working on this project through the early engineering phases.

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### GEORGE EVEN

George Even is a Principal Geologist and Partner in SRK's Chile office. His 39 years of experience range from grassroots exploration programs



to open pit stability design. After spending 10 years in exploration and mining in North America, he has based his operations over the last 29 years in Santiago. His project experience includes designing and implementing exploration programs and developing structural and geotechnical models. He has conducted numerous technical and due diligence reviews throughout South and Central America.

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Carmen Pit looking north

## Applying the box plot method

Since footwall alteration zones are related to volcanic-hosted massive sulfide (VMS) deposits, their unique features provide likely targets for exploration. Of these, the chloritic footwall alteration pipe is the most characteristic of VMS deposits. This feature is identified geochemically by a strong relative enrichment in aluminium and magnesium, coupled with depletion in calcium and sodium, giving rise to chloritic rocks. During metamorphism such rocktypes are replaced by rocks containing magnesium-rich cordierite, phlogopite, orthoamphiboles or orthopyroxenes and aluminium-rich minerals, such as sillimanite and corundum. As such, the unusual geochemical features of the alteration zone, retained during

the deformation and metamorphism, may be recognised in exploration by studying the geological and chemical composition of their rock formations.

The massive sulfide deposit in the eastern part of South Africa's Namaqua Province, at Areachap, Kantienpan and the defunct Prieska Cu-Zn Mine are hosted in the Areachap Group, formed by volcano sedimentary layers of the mid-Proterozoic era. These deposits were affected by a complex deformation and metamorphic history.

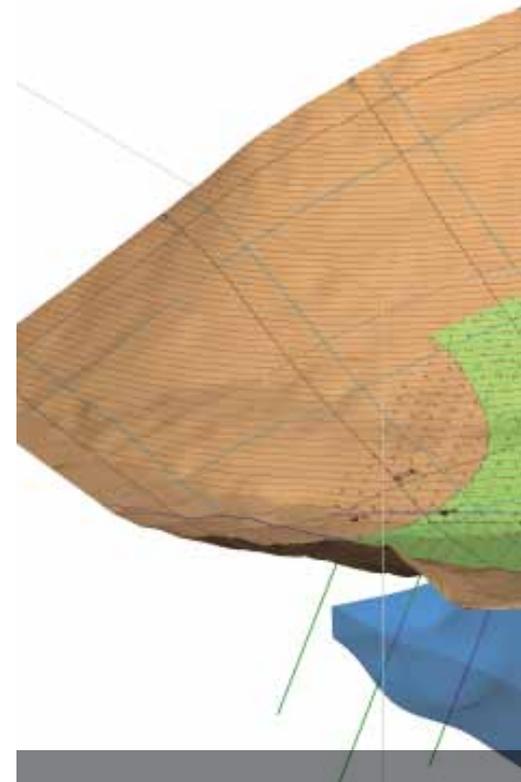
Applying known lithogeochemical methods is especially complicated where the geology is not well understood, due to the poor rock exposure, as in the eastern part of the Namaqua Province.

The box plot presents a method that can readily be used to identify the alteration process, but it was designed for relatively un-metamorphosed environments. This study demonstrates that the box plot may also be applied to high-grade metamorphic terrains, replacing the low-grade metamorphic mineral assemblage with its high-grade equivalent. The trends in mineral composition themselves may be used in defining the box plot. These include, for example, the transition from annite to phlogopite and hornblende to gedrite or cummingtonite.

Conclusions based on using the graphic solution known as the isocon method demonstrated that primary footwall alteration zones in the Areachap Group's VMS deposits are characterised by the predicted depletion and enrichment of elements, as expected. The whole rock compositions that were independently identified as the equivalents of altered rocks plot in the correct place in the box plot for high-grade regionally metamorphosed terrains, establishing the box plot as an effective and practical exploration tool for VMS deposits.

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## The future of 3D modelling consulting



Historically, SRK has been at the forefront of developing advanced geological and mine modelling methods from the early Gemcom days until the development of Leapfrog Mining with ARANZ. SRK consultants saw the need for a rapid grade modelling tool to replace CAD early, and our strong relationship with software developers continues.

The ability to generate logic-based geological 3D models for exploration with speed and accuracy, seems not that far away. There is healthy competition from GoCad, Leapfrog and Geomodeller for this type of solution.

SRK's business unit in Perth – our Advanced Modelling Laboratory – uses the latest rapid modelling techniques to solve geological, hydrogeological and geotechnical problems from early stage exploration to resource estimation and advanced mine design.

### Quo Vadis?

Leapfrog recently developed general geological modelling that responds

### HENNIE THEART

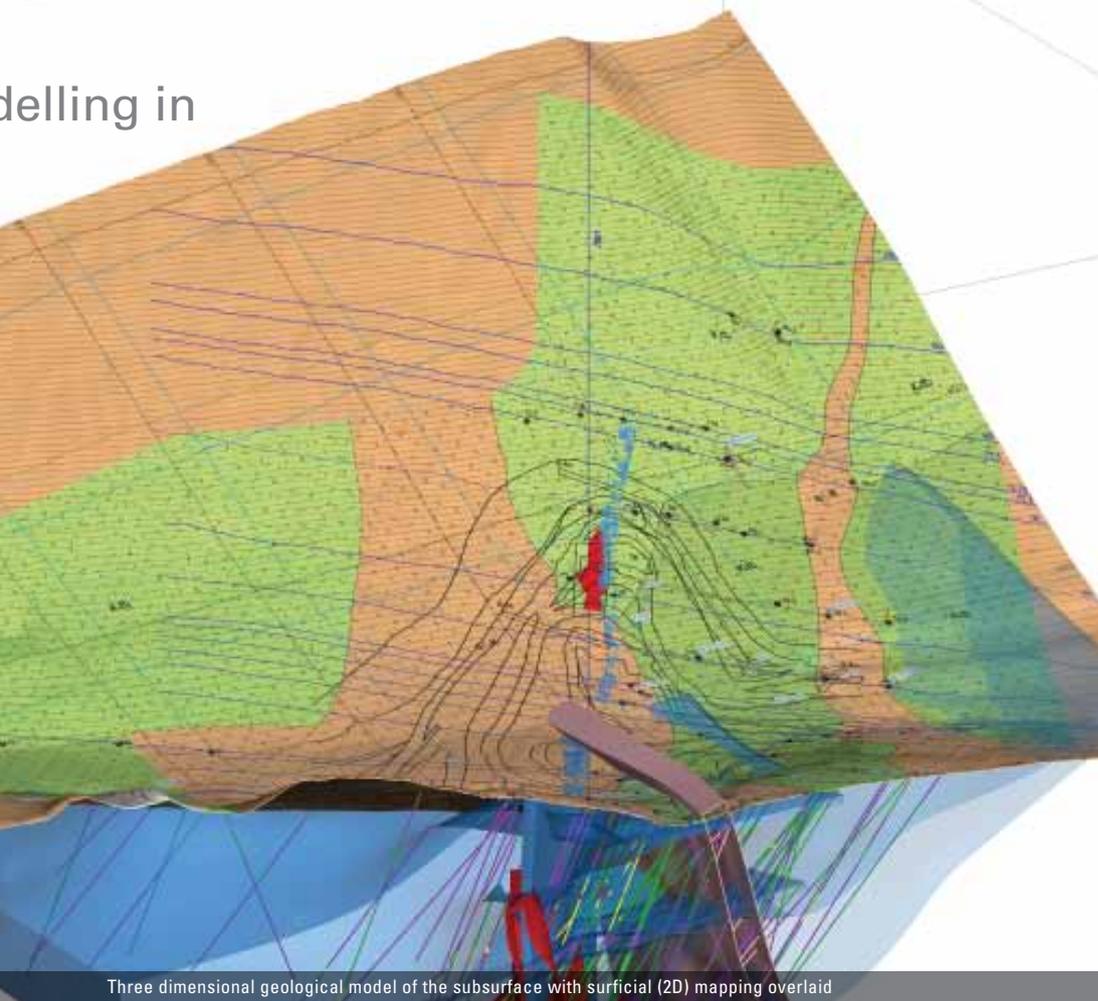
Hennie Theart, a Principal Geologist with SRK Consulting (SA), has over 30 years experience in exploration geology, economic geology, mineral valuation, exploration methodology and mining geology.



His expertise includes the genesis of volcanic base metal sulfide deposits, exploring for, and the mining of various base, rare, and precious metals, industrial minerals and gemstones. Hennie specialised in geochemistry including both soil and lithogeochemical exploration. As a Professor he taught Economic Geology and Mineral Evaluation for eight years at under-, and post-graduate levels and supervised various post-graduate studies on base metals, nickel sulphides, gold, diamonds, coal, and platinum group elements.

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# Modelling in



Three dimensional geological model of the subsurface with surficial (2D) mapping overlaid

to industry needs and can produce effective solid and surface models of faults, intrusions and geological formations, using the same intuitive interface and work flows that made previous Leapfrog capabilities so powerful. Where Leapfrog's model was difficult to validate, new software tackles this problem with relatively simple geological models quite successfully. However, these packages are either expensive or still in development and have not gained wide acceptance.

ARANZ has developed geological modelling for less complex requirements (Leapfrog Hydro and Leapfrog Geothermal). These more simplistic, stratigraphically-controlled geological models do not compare with sophisticated models for multiple-deformed gold deposits. They work, however, for many minerals modelling problems, such as iron ore, bauxite, and coal. The Quo Vadis question, then, is how to build on this capacity to solve more generalised modelling problems.

## SRK Advanced Modelling Laboratory

The SRK Advanced Modelling Laboratory focuses on providing solutions that move away from 2D to 3D geological models to explore at ever-increasing depth. Currently, 3D GIS2 is in its infancy; 3D map products that drive research and data collection are costly and lack specialised expertise. And scale depends on explicit modelling techniques, complicated by the inability to validate models in 3D against multiple datasets.

Applying more general geological modelling has a low cost-to-benefit ratio, with potential to generate rapid 3D maps, ease of validation against 3D data, and scale independence of the modelling process. The ability to model numerous geological domains rapidly and effectively will allow clients to generate regional- and tenement-scale exploration models, reducing risks inherent in resource estimation on poorly domained deposits.

The SRK Advanced Modelling Laboratory intends to use new software technologies to:

## PETER GLEESON

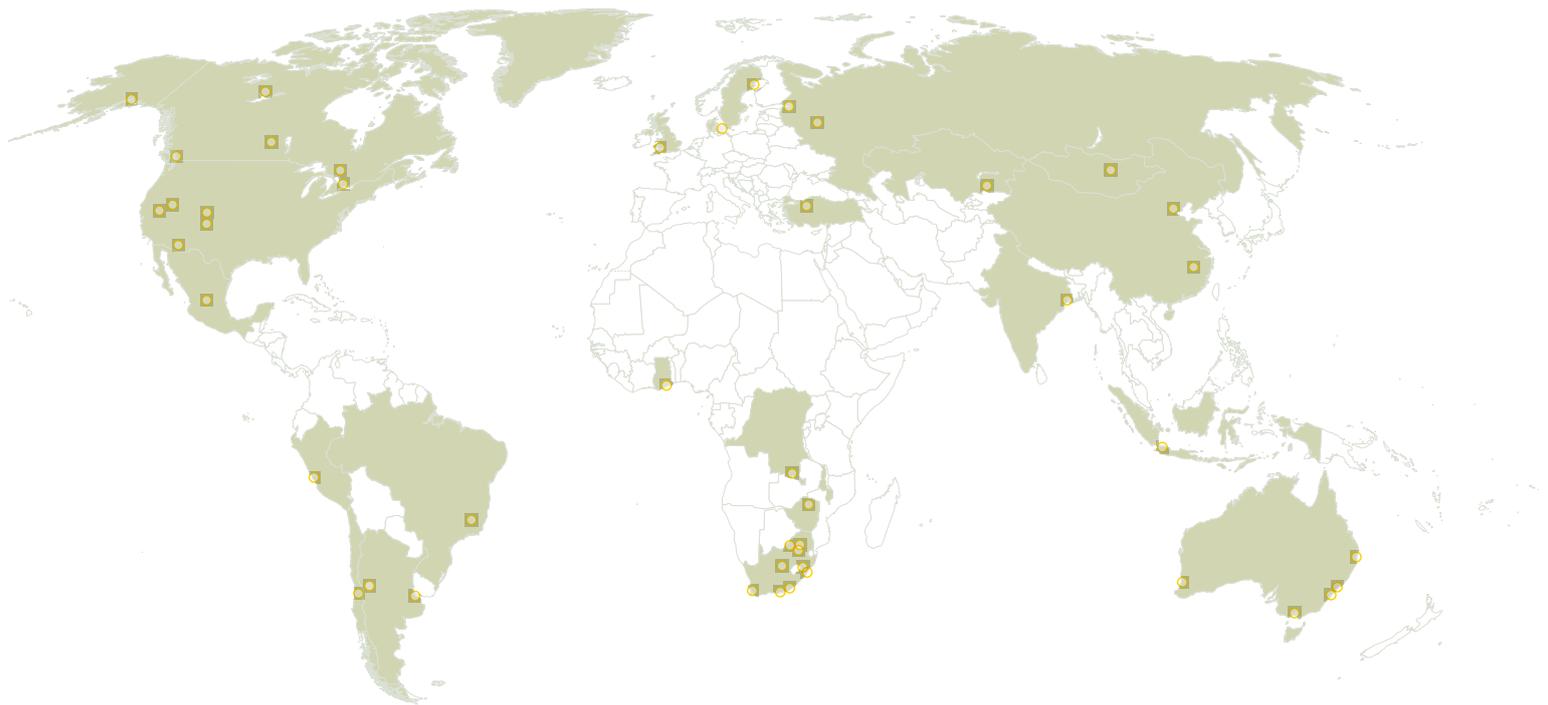
Peter has over 29 years of experience in both consulting and production roles. He has worked on resource estimation projects, project evaluations and 3D modelling studies for a variety of different geological environments and commodities, ranging from precious, base metals, and uranium through to iron ore. Peter has implemented several innovative geological modelling technologies which have helped to improve their effectiveness and the way in which companies produce 3D geological models and interpretations to facilitate the exploration and evaluation of mineral deposits. He is an expert user of several mining and geological modelling software packages such as Vulcan, GOCAD, Geomodeller, FracSIS, Leapfrog and Datamine.



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- Provide workflows for domain definition from regional to resource scale and geological control for resource domains and regional/tenement maps
- Incorporate 3D GIS to search for buried deposits
- Build complex geological models for clients quickly at significantly lower cost
- Use model simulation to reduce risks, providing many scenarios instead of a single model

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