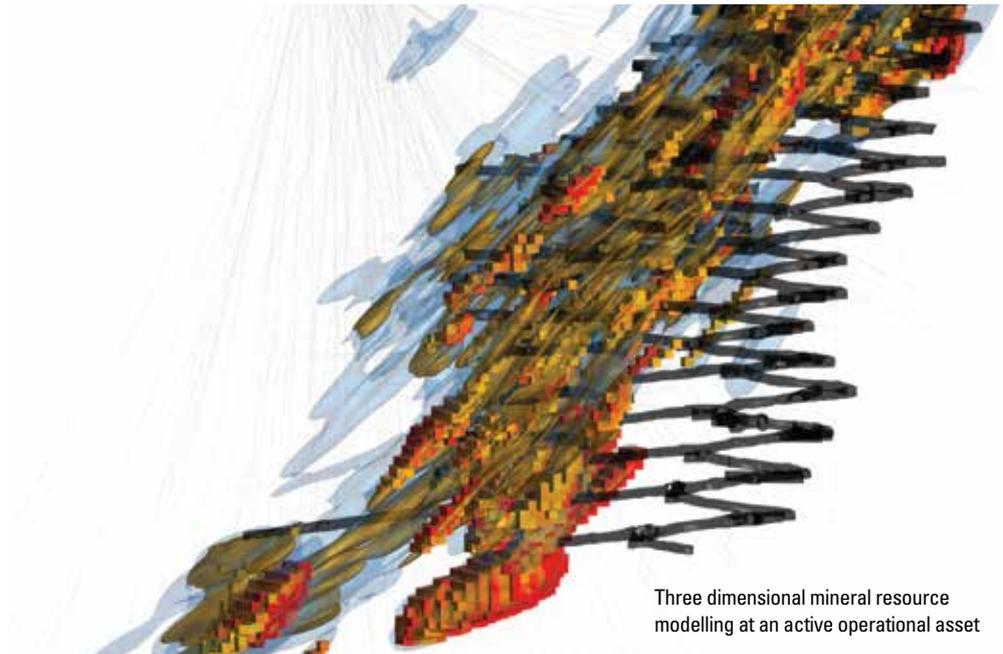


Recent advances in mineral resource modelling

No. 51
SRK Consulting's
International
Newsletter



Three dimensional mineral resource modelling at an active operational asset

In this dynamic and challenging time for the mining industry, SRK Consulting's mineral resource consultants continue to stay up to date. Using the latest technological advances and considering regulatory developments, we can help our clients derive the most value from their mining assets.

Challenging market conditions have led to increased competition for cost-effective mineral resource modelling solutions. In response, SRK is applying advances in implicit three-dimensional geological modelling associated with innovative interpolation algorithms within specialised and traditional modelling software to provide faster and more accurate cost-effective modelling solutions.

The availability of increased computing power has allowed us to apply powerful geostatistical mineral resource estimation techniques. SRK is able to incorporate complex data sets and geological spatial controls of mineralisation into the mineral resource modelling methodology. The result? More accurate and robust mineral resource models. By combining underground and surface exploration data sets, we can provide mineral

resource solutions to operational assets as well as to developing projects.

Due to regulatory developments in recent years, the mineral resource discipline has consolidated reporting codes and standards to ensure consistent and accurate reporting of international mineral resources. SRK contributes to and supports this consolidation, taking advantage of its global footprint to provide seamless services to clients in all jurisdictions.

This newsletter documents case studies that highlight how SRK applies technology advances to meet evolving market demands, adding value to international multi-commodity exploration and operational projects.

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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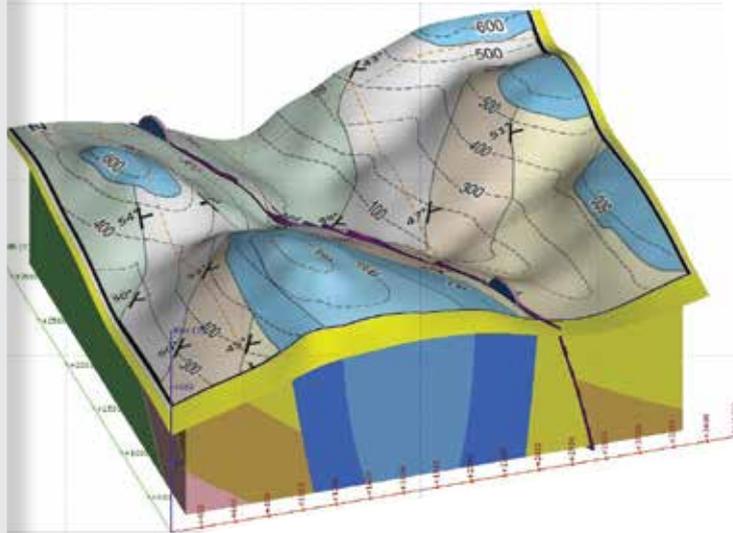
JF RAVENELLE

Dr Jean-Francois Ravenelle is a Senior Consultant (Structural Geology) and has over 14 years of experience in structural analysis of precious and base metal deposits hosted in various parts of the world. His specialisation includes deposit- to regional-scale structural mapping, generation and optimisation of 3D resource domains, structural interpretation of aeromagnetic data, and field- and classroom-based structural geology training. Jean-Francois is an expert in deciphering structural controls on mineralisation and develops new methods to generate 3D models that are sound and structurally constrained.



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Leapfrog Geo developments and the future for 3D modelling



Leapfrog Geo, 3D model of surface geological interpretation based on surface mapping and structural data (left)
3D model section through an overturned Stratiform Base Metal Sulphide model and fault network produced in Leapfrog Geo (right)

Implicit Software Modelling

technologies are designed to improve 3D geological modelling for exploration and resource definition. Since 2005 when SRK consultants in Australia sought to replace CAD-based, wire-framing tools, SRK has actively promoted these implicit technologies, because of their scientific, commercial and economic benefits.

Implicit Modelling defines an approach to 3D modelling that is fundamentally different from CAD-based, semi-manual software, using a mathematical function to profile 3D geological surfaces directly from primary observations without laborious manual manipulations. The main advantages are: speed, cost, better use of complex data sets and repeatable models. SRK got involved with innovative software vendors to provide them technical feedback from end users and independent market insights, such as ARANZ Geo the provider of Leapfrog Mining software.

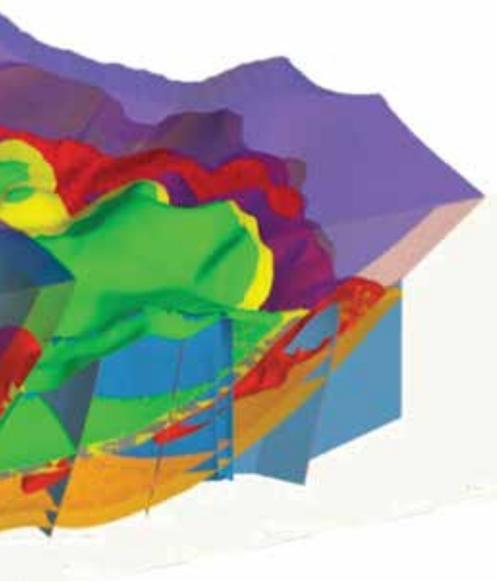
With Leapfrog Mining's tool box approach users began developing models of

stratigraphy, veins, faults, intrusions and other geological formations. Other developers – GOCAD-SKUA and BRGM-Intrepid GEOMODELLER – tackled this problem with varying degrees of success using a workflow-based approach. So I asked the question:

“Can Leapfrog Mining expand into this area and provide rapid modelling of complex general geology for the minerals industry in a workflow style?”

ARANZ Geo eventually produced the commercial products Leapfrog Hydro and Leapfrog Geothermal for the water and geothermal resource industries, and now, based on this success, ARANZ released Leapfrog Geo, its first commercial version of a general geological modelling package for the mining industry, in February 2013. Geo provides an integrated workflow approach to building complete geological and resource domain models. Geologists can use the software to construct a complete, integrated, 3D geological model from fault systems to grade shells, and making it possible to build complete geological models of a mine.

Rigorous geological input in gold mineralisation models



Robust and reliable, cost-effective geological models enable clients to realise cost savings in modelling as well as geological control that previously were not practical. These models can help clients perform risk analyses quickly, avoiding a single static model, producing a wide range of scenarios instead.

These new software technologies open up Leapfrog's capabilities in a wide range of industry applications. For SRK, using Leapfrog Geo expands our ability to bring geology back into resource estimates. In the past only large corporations could afford to engage SRK to build these complex geological models. Now, juniors can benefit from having projects underpinned by robust geological models.

Introducing such new technologies can result in a win-win situation for all. It can spur other mining software companies to compete – healthy competition among vendors in this new and exciting area will benefit the geologist and industry in general.

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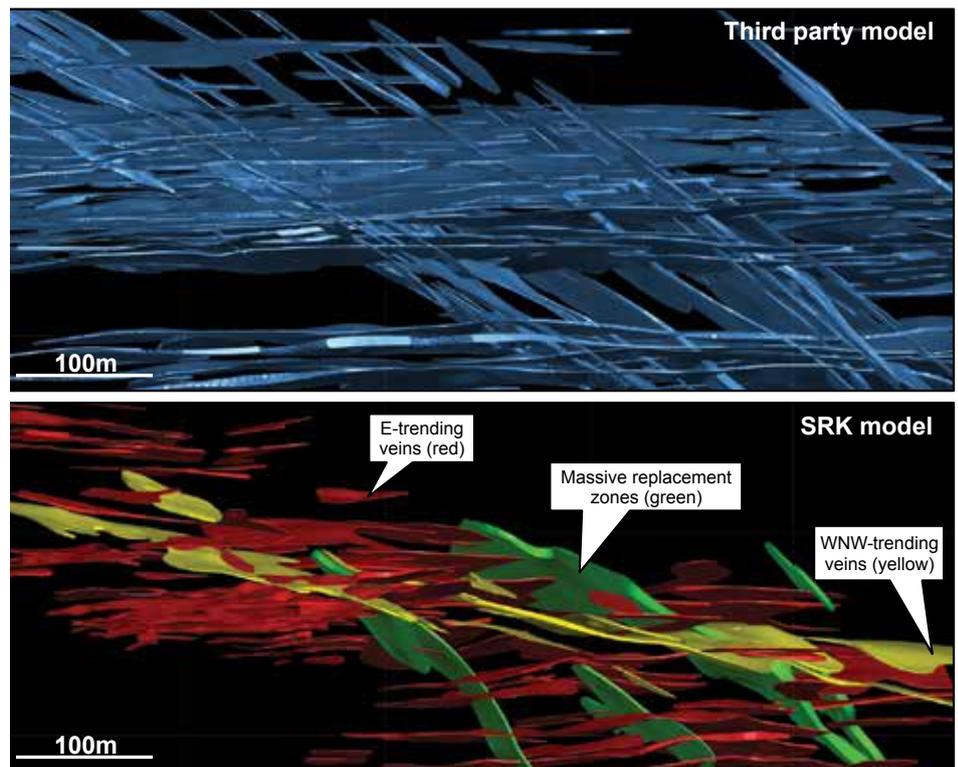
Despite the intention to include geological controls during the wireframing phase of the mineral resource estimation process, modelling methodology is sometimes reduced to connecting grade data along trends judged to be geologically valid. This is specifically the case for precious metal vein deposits where the grade distribution is controlled by complex vein systems. This case study exemplifies how such models can be enhanced by incorporating structural geology analysis into the modelling process.

Eastmain Resources Inc. commissioned SRK to construct a mineral resource model for its Eau Claire gold deposit located in James Bay (Quebec). Gold mineralisation at Eau Claire occurs primarily in metre-scale quartz-tourmaline veins associated with massive actinolite-tourmaline-biotite alteration of their host rock. A wireframe model for the gold mineralisation was previously constructed by a third party but was discarded as it failed to honour factual geological observations.

SRK conducted rigorous structural analysis using surface mapping, drill core analysis, and 3D litho-structural modelling to define and understand the geometry of the auriferous vein system. Three sets of mineralised structures were identified including east-trending and west-northwest-trending sets, as well as a series of older northwest-trending massive replacement zones. Individual veins were modelled independent of grade by diligently reconciling logged vein intervals with vein intervals mapped at surface.

The final modelling stage involved constructing gold mineralisation wireframes that incorporate assay data located within both the veins and their altered selvages. This methodology ensured that the resulting wireframes honoured the vein system geometry, adding considerable confidence to the mineral resource modelling process. This increased confidence will prove invaluable as the project advances to conceptual mining studies.

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Comparison between third party gold mineralisation model (top) and SRK model (bottom)

JAY PENNINGTON

Jay Pennington has over 30 years of international experience, including 18 years consulting. His expertise includes mineral exploration, open-pit and underground mining geology, mineral resource estimation and operations strategic planning. Mr. Pennington has been the QP and primary author of NI 43-101 compliant Technical Reports in resource geology, and has authored or co-authored technical studies to Feasibility level. Jay has been the lead on multi-disciplinary, due diligence teams assessing metal mining operations for investment and banking institutions. He has teamed with stakeholders and regulators to develop innovative solutions for mine closure.



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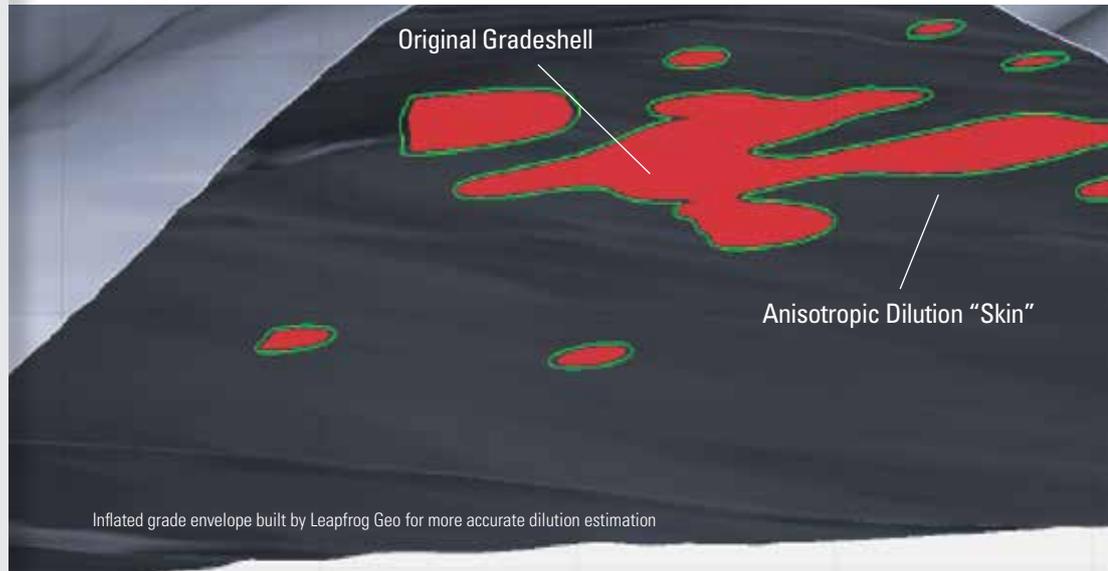
BEN PARSONS

Ben Parson, BSc, MSc, MAusIMM (CP), is a Principal Resource Geologist with SRK. He has over 15 years of international experience, including eight years working on open pit and underground Gold Mines in Africa, before joining SRK in 2008. Ben's responsibilities have included the authoring and auditing of mineral resource estimates, as part of technical studies, independent assessments, due diligence/technical reviews, Competent Person's Reports and Stock Exchange listings. He acts as a Competent/Qualified person for a number of commodities and styles of mineralisation.



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Dilution: GEO's get some "skin" in the game



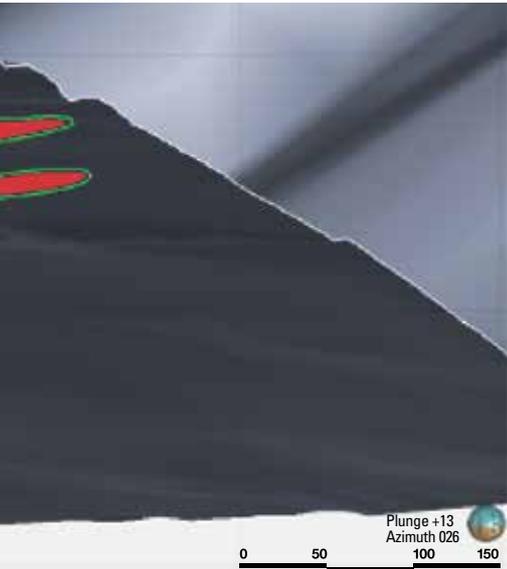
Typically, conversions from mineral resources to mineral reserves are handled by mining engineers, rather than geologists. One of the key concerns in reserve conversion is how to apply dilution so that the grades sent to the process facility meet expectations and the metal mined reconciles with the amount produced. In preparing technical prefeasibility and feasibility studies, SRK commonly prepares both resources and reserves. Clients benefit from having two disciplines apply the best possible tools to complete the task.

PROBLEM: How can dilution be determined in a narrow-vein deposit? Is there a more accurate way to estimate the amount of mineable ore on the perimeter of the model compared to the full block volume when global assumptions drop grades below cut-off.

SOLUTION: In a recent case study, the best means of estimating dilution came from the geologist's toolkit. Using Leapfrog Geo, SRK created an inflated gradeshell to simulate the predicted "over-mining" in an open pit operation. We applied this method in a structurally-controlled, epithermal gold-silver deposit containing seven mineral domains. The SRK project engineer and geologist worked closely to define the dimensions of the dilution envelope or "skin" by considering the geometry and thickness of mineralisation, mining methods and equipment limitations.

In areas of tabular shallow dipping mineralisation, SRK modelled dilution with a thin vertical and broad radial envelope. In more massive areas of the deposit, we built the dilution envelope to a fixed radius outside the interpreted mineralised shell. We applied structural controls and measurements from the original gradeshell interpretations and

Vein modelling using Leapfrog, leads into drillhole planning



adjusted them to mimic mining, using GEO's "Interpolant/New Distance" function. The speed and flexibility of the software allowed us to run several iterations, achieving the desired domain-specific outcome.

Generating the original gradeshells in the same software facilitated the development of the dilution envelopes, but the approach is also valid with outsourced wireframes. In this case, the skin was assigned a zero grade, but we could have used envelope composites to estimate fringing contributions to the reserve. In that application, capping fringe composites to the mining cut-off grade is recommended.

With the case study a success, it appears this technique can be applied beyond epithermal gold into tabular or complex seam geometry.

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Historically the modelling of narrow vein deposits has relied on classical two dimensional methods to estimate tonnage, grade and thickness in narrow vein deposits. The use of three dimensional models has been limited by complexity of this style of mineralisation leading to difficulties generating valid wireframes, associated with linking issues.

Recent developments in implicit software modelling enable geologists to model complex veins, dykes and individual strata with ease and speed directly from drill logs using Leapfrog's interval selection tools in combination with advanced 'vein' modelling workflows.

The advantage of the software is that it provides reasonably quick interpretation, conducts active validation to avoid the classical issues of potential wireframe cross-overs, users can specify a minimum thickness and easily visualise variations in thickness of the veins.

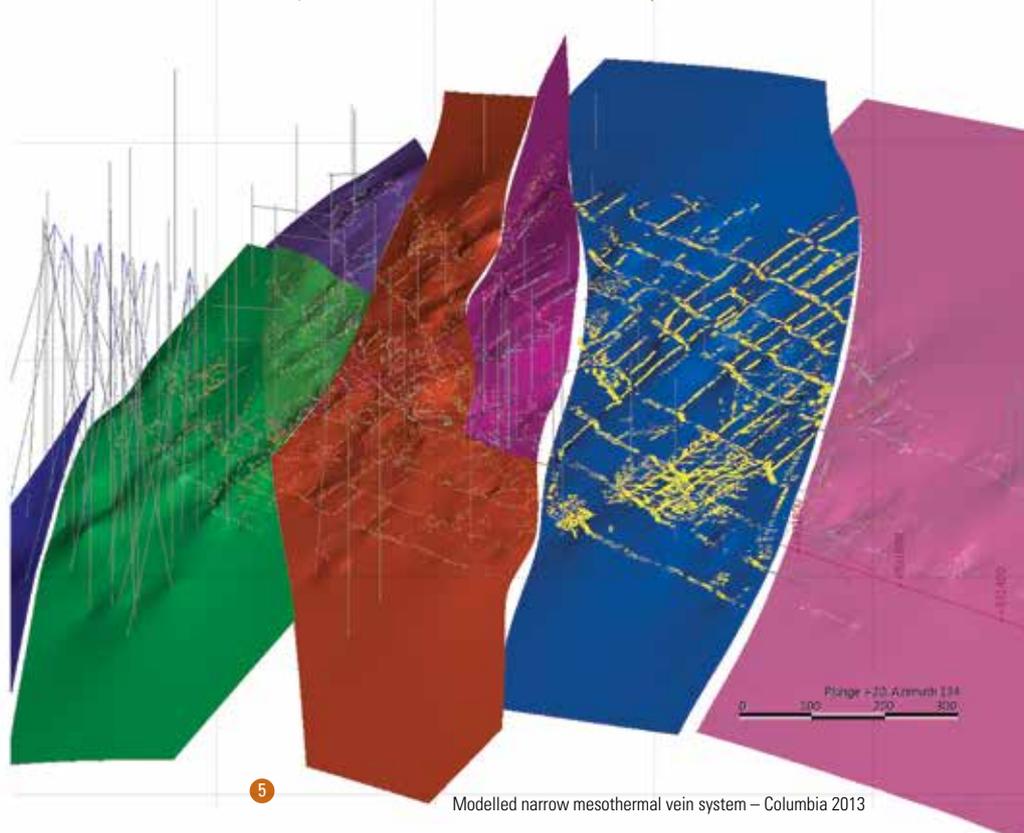
To complete the process different approaches can be used to achieve the same goal from coding of the main vein domains in the geological database, to manual selection of intervals as an alternative to sectional interpretation.

Guide strings allow further refinement to tie into potentially existing features such as underground development or stopes.

The selection of the mineralised intersections ensures accurate definition of hanging wall and footwall contact points with the "known" data in the sampling database, which can be extracted within Leapfrog Geo. Using the extracted datapoints, surfaces can be generated using predefined orientations or existing structural trends to model surfaces. Surfaces can be combined into a single solid with use of a minimum thickness to produce validated wireframes which can be exported to any Mining Estimation Software (such as Datamine/Vulcan) for use in the downstream workflow.

SRK has implemented this process on a number of projects which have enabled the clients to increase the understanding of grade/thickness relationships to more regional structural information, or interaction between veins in cases of epithermal systems which may have been missed using more traditional 2D methods.

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Cut-off grades for mineral resource reporting: going the extra rare earth mile

Resource Geologists are geologists who can value the basic underlying economic attractiveness of a mineral deposit. This means knowing the costs and practicalities of mining and processing for a particular product.

A cut-off grade (COG) is an industry-accepted standard expression used to determine what part of a mineral deposit to include in a mineral resource estimate (MRE). For MRE reporting, COGs tend to be rounded down to ensure that material of no economic significance is excluded from the resource.

To calculate a COG, we can gauge the likely extraction costs and operating efficiencies using benchmarks from analogous mines, and determine commodity prices from public reports or price forecast research notes.

A COG is expressed in grade units that may require conversion from market pricing units. For the COG, the price needs to be expressed in grams.

$$\frac{\text{Ore denominated operating cost } 60 \text{ \$/t}}{\text{Grade denominated revenue } 34.7 \text{ \$/g}} = 1.73 \text{ g/t}$$

Sometimes we face complicated cost, recovery and revenue concepts in deriving a COG for resource reporting. These may stem from:

- Mineralogically different ore types
- Multiple process routes
- Deleterious elements
- Stockpile strategy
- Blending constraints
- By-product credits & metal equivalence
- Net smelter returns

With the recent popularity of rare earth element (REE) projects, SRK developed a complex COG estimation method to assess "reasonable prospects of eventual



economic extraction” using specific studies and generally-held concepts. The COG calculation integrates multi-staged costs and efficiencies from extraction through to refining, all of which are required to realise quoted market prices.

Ore operating cost reflects multiple concentrating stages whose unit costs are measured in different denominations, such as: process costs per tonne of mill feed, mining costs per tonne of ore, transport costs per tonne of concentrate and refinery costs per kg of product. These measures need to be back calculated and expressed in terms of cost per ore tonne in the ground.

Revenue is normally derived from several REE co-products, with very different individual prices that occur in varying proportions. The REE “basket” price is a weighted value per kg of REE co-products. There may also be by-products with different process recoveries whose revenues need to be incorporated in the COG calculation and expressed as recoverable revenue on a REE-equivalent basis.

Using COGs based on complex technical and economic parameters, SRK demonstrated “reasonable prospects of eventual economic extraction” which enabled geologists to estimate and report REE-project mineral resources using an appropriate cut-off grade.

The technical aspects of extracting REE products are complex and vary from one project to the next. Most of the extraction cost occurs in downstream refining, which is mineralogically sensitive. We conclude that early stage projects should not be quoted as Mineral Resources until their mineralogy is sufficiently known to conceptualise the extraction method with reasonable confidence.

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and mining geology, specialising in geological modelling, grade estimation, mine project evaluation and reporting according to international reporting codes. He has worked with SRK since graduating, contributing to the growth, management and mentoring of the 30-strong Cardiff-based resource geology team. Martin is particularly experienced with former Soviet Union projects, African gold projects and tantalum/REE-bearing deposits. He has managed due diligence studies for debt funding and undertaken resource estimates for exploration, development and mining properties.

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Dig line separating ore from waste using a cut-off grade



Multi-element ratios to define estimation domains: Kvanefjeld



Greenland Minerals and Energy Ltd's base in Narsaq, South Greenland

Kvanefjeld is the flagship orebody of Greenland Minerals and Energy Ltd's (GMEL) Northern Ilimaussaq project. Kvanefjeld contains the world's largest mineral resource of rare earth elements, as defined by the reporting standards of the JORC Code or NI 43-101.

In 2011, SRK Australia prepared a Mineral Resource estimation for the project. SRK updated this estimation in 2015. The resource inventory is 1,010 Mt @ 1.1 % Total Rare Earth Oxide (TREO): lanthanide series plus yttrium, and 266 ppm U_3O_8 . Based on SRK's resource model, a feasibility study was completed and the maiden Ore Reserves were reported in June 2015.

The host rock for Kvanefjeld mineralisation is lujavrite – a form of nepheline syenite unique to this complex in southern Greenland. The lujavrite occurs in a layer about 250m thick, shallow dipping, and extending laterally for several kilometres. The visual contrast between the dark lujavrite, and adjacent, lightly coloured host makes it easy to identify from surface mapping.

A challenge for GMEL was to identify higher grade zones within the lujavrite that could be accessed early in the mining schedule, to improve the economic viability of exploiting a very large but essentially low-grade orebody. Defining subdomains would also be critical for focusing

metallurgical studies developed from the resource model.

Early work to establish criteria for subdividing the lujavrite, based either on core logging or statistics from the uranium and REE assays, yielded inconclusive results.

By the time SRK became involved in the project, GMEL had made substantial additions to the drill hole database, including reassaying historical core and broadening the analyses to include 14 rare earth elements, yttrium, uranium, zinc and 23 more elements.

SRK worked with GMEL to test the usefulness of elements, singly or



combined, to define estimation domains. SRK's skills using Isatis software for statistical analysis and Leapfrog software for 3D visualisation were particularly suited to this task.

The key breakthrough came when we divided mineralised samples into subpopulations, based on the ratio of zirconium or hafnium to heavy rare earth elements.

The hafnium to ytterbium ratio was adopted as a geochemical marker for dividing the lujavrite into five layers that became the estimation domains. Analysing multi-element ratios justified estimating these domains separately with

hard boundaries between them.

Of particular financial importance for GMEL, the upper two layers that will be accessed first when mining starts are the highest grade: mean TREO is about 50% greater than the lower layers. The improved domain definition in the SRK resource update meant that these high grade zones were not obscured by the influence of lower grades during estimation.

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ROBIN SIMPSON

Robin Simpson, MSc (Mineral Resource and Environmental Geostatistics), MAIG, Principal Consultant with SRK, has over 15 years' experience in resource



estimation, mining and exploration. In 2004, Robin completed an MSc in Geostatistics at the University of Leeds in the UK and graduated with Distinction. His dissertation topic was a conditional simulation study of a gold deposit in New South Wales. Robin is a fluent user of Surpac, Isatis and Leapfrog, and has substantial experience in setting up and maintaining grade control and resource databases. Robin's specific commodity experience includes gold, iron ore, uranium, rare earths, phosphate, bauxite, copper, nickel laterite and nickel sulphide.

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Grade capping for mineral resource estimates

High grade drill intersects are often a welcome occurrence for a mining company, its shareholders and/or potential investors. They represent the potential for even greater metal content in the deposit. However, from a resource evaluation perspective, they may present complications in generating a realistic resource estimate, by overestimating or underestimating grade.

Capping high grades by lowering the outliers to a 'reasonable' level can, by itself, affect the analysis of the economic viability of a project. Still, this arbitrary choice is often made more by art and tradition than by sound technical analysis.

Two major reasons for grade capping are to guard against overstating the true underlying average grade, and against an overly optimistic assessment of local block grades located near some very high grade assays. For these reasons, capping is often considered a "better-safe-than-sorry" practice on most mineral resource models.

We propose a procedure that can deal with outlier data in two phases. The first phase analyses the data before estimation is performed and focuses on identifying true outliers and an appropriate cap for them. The second phase focuses on restricting high grade assays that would likely be capped to further mitigate the influence of high grades during estimation without capping.

Outlier data, or extreme high values, may significantly skew simple summary statistics like the mean grade, variance and coefficient of variation. To determine the impact of a potential outlier on these statistics, first assess the actual average grade in a mineralised domain. This could lower the risk of distorting the average grade. Once the risk is lowered to acceptable levels, further capping may not be

necessary. This process usually results in fewer capped assays than a typical process. Any undue influence of high grade assays can be further corrected during estimating.

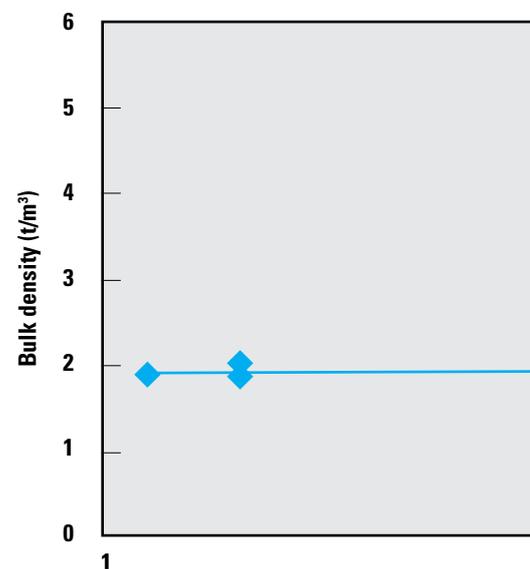
The following procedure is recommended for treating outliers during resource estimation:

- Determine data validity. Are the data free of sampling, handling, measurement and transfer errors
- Review geology logs for samples with high grade assays. Capping may not be necessary for assays where the logs clearly explain the presence of high grade
- Capping should not be considered for deleterious substances that have negative impacts on project economics
- Decide if capping should be considered before or after compositing
- Keep capping to a necessary minimum. If high grade assays unduly affect overall grade average, cap them. Bootstrapping or cutting curve plots could help determine capping levels
- Restrict influence of very high grade assays. Commercial software is well designed for this approach
- Visually and/or numerically assess the effect of high grade assays to be sure they don't affect estimated block grades
- Check the effect of capping on final resource estimates and document the differences

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This article represents an excerpt from a "Suggestions for Good Grade Capping Practices from Historical Literature" Paper.

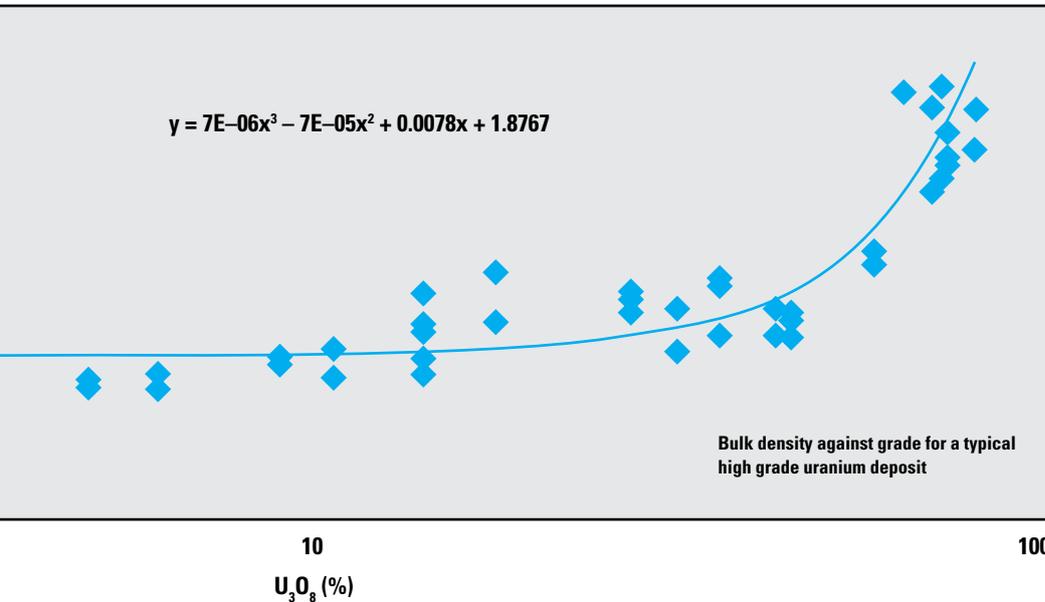
Authors: Marek Nowak (SRK Vancouver), Oy Leuangthong (SRK Toronto) and Mohan Srivastava (Independent).



Mineral resources are reported in tonnage and grades. While great care is placed on generating a reliable estimate of grade, determining bulk density for resource estimation is often overlooked. Instead, a simple average value of bulk density is used. While this estimate can work for some deposit types, an overly simplistic estimate of bulk density can cause serious errors in tonnage estimates and an over or under estimate of metal content. Constructing a reliable bulk density model requires developing a good understanding of how bulk density varies with grade and geology. A reliable bulk density database is essential in determining the appropriate modelling technique to minimise the errors in mineral resource statements.

Modelling bulk density for resource estimates can be complex and intricate, and each deposit type needs to be carefully evaluated to determine the most appropriate methodology to best model bulk density. In a survey of 50 publicly filed technical reports on SEDAR, 29 precious metal, 10 base metal, 7 porphyry

Estimating bulk density for mineral resource reporting



and 4 rare metal deposits, bulk density is only marginally considered when preparing resource estimates. The reports were selected at random and included 6 pre-feasibility (PFS) reports, 6 preliminary economic assessment (PEA) reports and 38 mineral resource reports. Nine of these reports failed to mention bulk density or to indicate how bulk density was assigned to the resource estimate. Of the reports that included bulk density sampling, most used the water displacement method for calculating it. On average, bulk density was measured for less than 20% of the assay data and 29 reports used a simple average value. Of the 10 base metal deposits examined, 4 used a simple average, and 6 estimated bulk density geostatistically with 2 reports including bulk density weighting in the estimate. All reports indicated that multiple geological domains were present, yet most used the same bulk density value to estimate the resource tonnage for all domains, ignoring the multiple geological domains that indicate multiple bulk density domains.

Bulk density is a critical component of the resource estimate. For mineral deposits with low metal content and simple mineralogy, calculating an average of all bulk density measurements can be adequate with sufficient data and a meaningful average. However, each geological domain must be examined individually with a separate bulk density value calculated for each.

For deposits with more complex mineralogy, where a relationship exists between density and grade, simply averaging bulk density for each geological domain will produce errors in local estimates and errors in resource tonnage. A better approach is to apply similar interpolation parameters for grade estimates. For deposits with high grade and density variability, weighting grades by density and estimating grade times bulk density can produce a more accurate resource estimate.

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GILLES ARSENEAU

Dr Gilles Arseneau has over 25 years of experience in exploration project management and has extensive knowledge of geostatistical mineral resource estimations and reserve audits. He has worked for major and junior mining companies as well as with consulting engineering groups in North and South America, China, and Europe. He has also served for three years as manager of geology for the TSX Venture Exchange in Vancouver. He has a BSc from the University of New Brunswick, an MSc from the University of Western Ontario and a PhD from the Colorado School of Mines.



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MAREK NOWAK

Marek Nowak, a Principal Geostatistician with SRK, has over 30 years of experience in the mining industry. He specialises in natural resource evaluation using classical geostatistical techniques like kriging, and risk assessments based on various simulation techniques. Marek has also been involved in assessment and risks analyses of diamond resources. He has optimised drill hole spacing on advanced exploration projects and has been involved with grade control studies for producing mines.



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MultiGaussian kriging for grade domaining – an uncertainty based approach

The place for MultiGaussian kriging for grade domaining

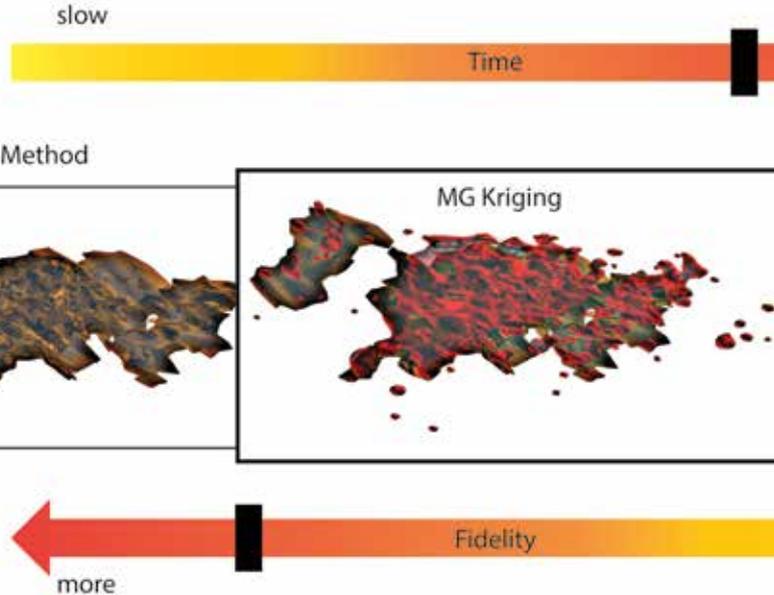
OY LEUANGTHONG

Dr Oy Leuangthong is a Principal Consultant (Geostatistics) and has over 10 years of teaching and consulting experience in geostatistics



for resource characterisation and uncertainty assessment. Prior to joining SRK, she was an Assistant Professor in Mining Engineering at the University of Alberta in Edmonton. Oy has authored and coauthored 2 books, 18 journal papers and over 30 conference articles. Her areas of expertise are resource estimation, conditional simulation and uncertainty assessment using geostatistics.

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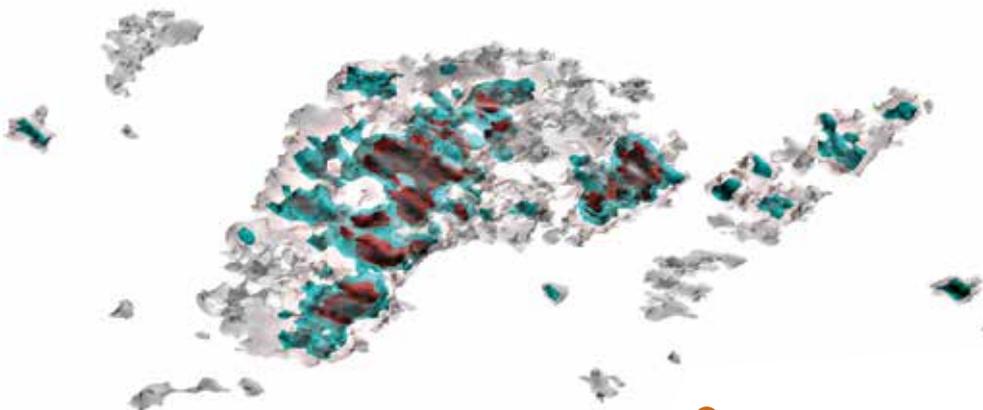
Grade domains are often considered, following the modelling of geologic domains, to further control the distribution of grades during resource estimation. This is usually achieved by wireframe modelling on sections displaying grade assays or composites, indicator kriging, and/or implicit modelling using radial basis functions. The latter approach is often facilitated by using commercial software such as Leapfrog, making it a

fast, semi-automatic alternative to the more traditional manual approach to wireframing. Unfortunately, modellers must enter parameters that indicate spatial correlations, for which they either do not have the time and/or the expertise to suitably calculate or model the required variograms.

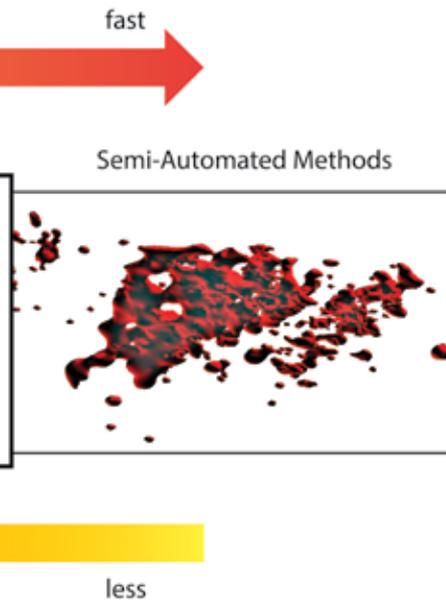
As an alternative to an implicit modelling approach, we propose the use of MultiGaussian (MG) kriging to establish grade domains. The method consists of estimating grades using MG kriging; however, instead of back transforming to obtain a grade estimate at each location, we determine the probability to exceed certain grade thresholds and categorise grade domains accordingly. This block model approach can then be imported into any commercial package to generate iso-probability contours for any grade thresholds of interest. This permits the uncertainty assessment of grade domains by post-processing for various grade thresholds and iso-probability shells, and permits the user to assess confidence in the grade shell for that threshold.

Grey – 20% probability or higher
Cyan – 30% probability or higher
Red – 40% probability or higher

A comparison of iso-probability shells for 0.90 gpt gold



Ordinary kriging vs localised uniform conditioning



This method was applied to the Rainy River gold deposit in Northern Ontario, with visual comparisons to grade shells used for the previous resource model. The resource shells were manually generated with guidance from Leapfrog shells. While results showed the MG kriging approach to grade domains can yield shells comparable to existing implicit modelling methods, they also showed better conformity to the manually digitised wireframes accepted for resource modelling.

The MG approach provides a balance between the more time intensive manual approach to grade domaining and the fast, semi automatic modelling using implicit methods. It also provides greater fidelity to the data by requiring that spatial correlations are calculated and modelled. Finally, this alternative MG kriging approach is attractive because the method and model parameters are data-driven, tractable and repeatable, with the added benefit of quantifying a measure of confidence associated to the resulting grade shells.

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Linear Estimators, such as Ordinary Kriging, can produce smoothed assessments in the results of your resource estimation. The conventional Uniform Conditioning method estimates a tonnage and grade of mineralisation that can be recovered using the Selective Mining Unit (SMU) of size at the chosen cut-off value. A set of grade tonnage distributions is constructed for each panel under study by applying several cut-off values. A new method called Local Uniform Conditioning (LUC) enhances the Uniform Conditioning approach by localising the model results. The LUC algorithm then estimates the mean grade of the grade classes in each panel at the given SMU support level. The grade class is the portion of the panel whose grade is higher than a given cut-off, but lower than the next cut-off.

The next step is to rank the SMU blocks in each panel in their grade, distributed in increasing grade order. Finally, the mean grades of the grade class which have been deduced from the UC model are assigned to the SMU blocks whose rank matches the grade class. Thus, the key advantage of the LUC approach is the ability to calculate the mean grade of the grade class and assign these mean grades to the SMU size blocks, which have been ranked in each panel in increasing grade order (Abzalov 2006).

SRK used a Local Uniform Conditioning method to calculate an Iron deposit in the

north of Chile. The results revealed there was an improvement in representing the grades pertaining to the distribution group close to the average. But, because this project had a high amount of information overall, final results are quite similar to the results obtained in the Ordinary Kriging approach.

SRK plans to continue using this technique in exploration projects with a smaller amount of information to reduce the impact of smoothing that linear estimation methods produce.

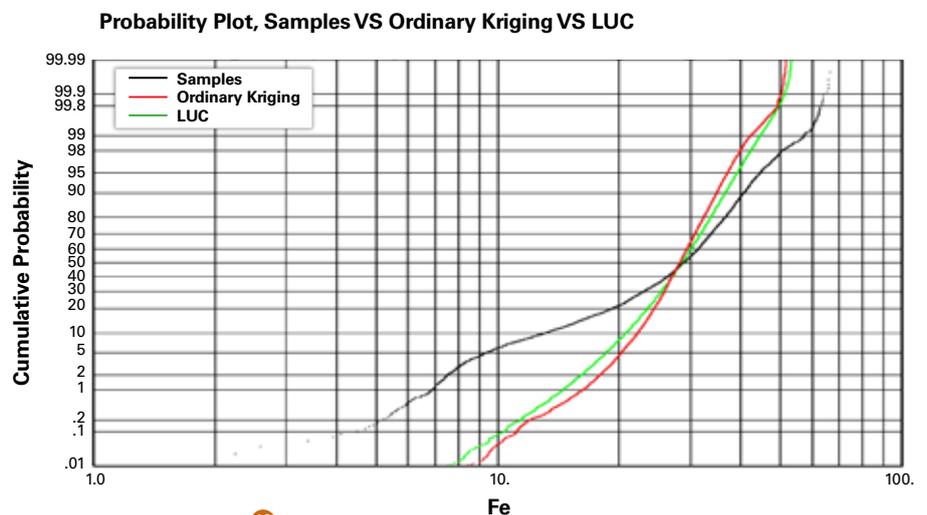
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ERNESTO JARAMILLO

Ernesto is a Geologist with more than 25 years of professional experience and a specialist with wide-ranging experience in geological modelling, resource estimation, lithological and alteration modelling, geologic units, metallurgy and database management for copper, iron and gold projects. He is an expert user of Gemcom, Vulcan, Gslib and Leapfrog.



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Update on geostatistical advances

Most recent developments in resource estimation have taken place in the following fields:

- Geological modelling: 3D modelling has become much faster and more accurate, by implementing fast interpolation algorithms within specialised software like Leapfrog, GOCAD, Geomodeller. More traditional mining packages have added implicit modelling to their capabilities (Minesight, Micromine, etc.). The advantages of these methods are well known: a true 3D approach (as opposed to the traditional wireframing technique), a very fast creation of models, eliminating the tedious tasks of working section by section and allowing for tests of alternative geologically plausible solutions.
- Domaining: the definition of “homogeneous” (stationary) 3D zones is made easier by the availability of good statistical methods and software (clustering techniques, contact analysis, border effects).
- Geostatistical techniques: while no radically new techniques have appeared in the last few years, progress in computing power has led to a significant increase in the use of non-linear methods like uniform conditioning and conditional simulations for geological variables, such as lithology and grades.

The combination of the modern 3D geological modelling approach and powerful geostatistical resource estimating techniques is illustrated by SRK’s recent evaluation of the Miriam Uranium deposit in Niger for GoviEx.

The Miriam deposit was discovered in 2012, at 400m drill spacing, within the

Madaouela 1 exploration license of the GoviEx Uranium Madaouela Project. Since then, the deposit has been drilled intensively (from 200m to 50m grid). The latest drilling phase, at 50m center grid, delivered the current resources used in preparing the preliminary feasibility study of the complete Madaouela Project.

The presence of mineralisation linked with a ‘vertical’ redox front was confirmed and, at the 100m center grid, it became clear that there was more than one vertical, structurally-oriented ‘redox front’.

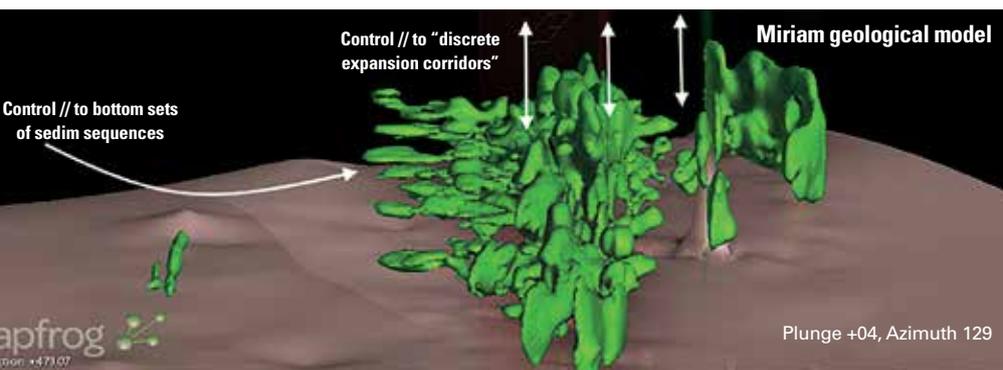
After the 50m center grid was completed with controls by oblique core drilling, the interpretations showed that the high-grade zones are related to the intersection of discrete expansion faulting with favorable sedimentological units, resulting in the ‘Christmas tree’ aspect of these high-grade zones.

The ore envelope was constructed three-dimensionally, using the interpreted sedimentological controls and the vertical interpreted structures. The model was built within Leapfrog software with two cut-off grades defined shells.

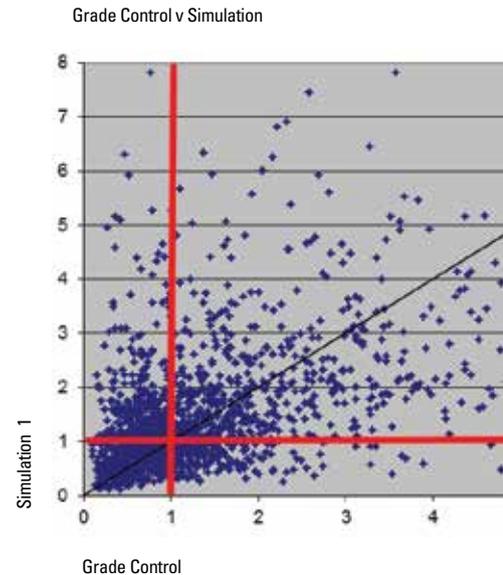
The estimation within the Leapfrog envelope was carried out using a uniform conditioning method, reflecting both the data density and the potential mine selectivity in an open pit. The method is well adapted to estimating the resource for open pit projects at this PFS or FS stage, particularly in cases of relatively complex geometry.

The Miriam deposit appears to be the only one of this type in the region and it opens new ideas for further discoveries in a similar geological context.

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Scatter plots of optimal kriging against grade control and a single simulation against grade control. Note the distributions with respect to the misclassification quadrants and the increased dispersion of the simulated values.

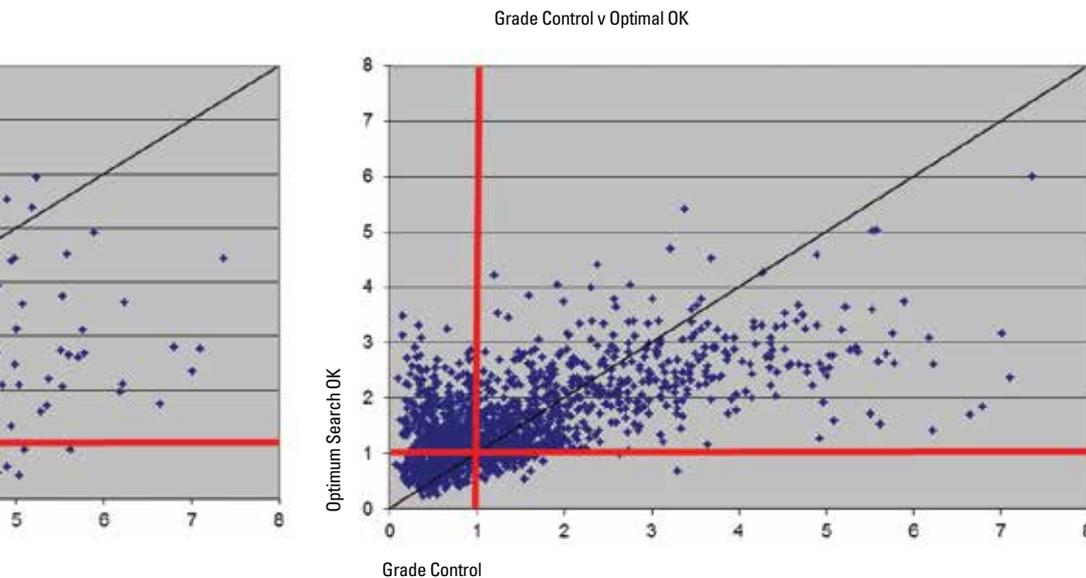


A fundamental concept of geostatistics that is often overlooked or misunderstood in resource estimation during the early project stage is the relationship between the global grade tonnage curve and the quality of the local block by block estimate.

Kriging, with a properly optimised set of search parameters, will always give the best local block estimate with the data available. That means misclassification errors resulting from local block selection compared to reality are minimised.

The trade-off is that the less data you have, the higher the so-called smoothing effect on the local blocks becomes. Consequently, the overall tonnages and grades estimated at higher cut-offs can still be significantly different from the actual tonnages

Selectivity – local vs global



and grades at those cut-offs. Grades at higher cut-offs are typically underestimated and tonnages overestimated.

Reducing the smoothing by introducing increased variability into the block estimation in an attempt to match the actual block variance is an alternative. This produces local block estimates that are worse than those of optimised kriging. Misclassification of ore and waste would be more extensive if mining were to take place with selection based on those blocks. However, on a global grade and tonnage basis, the overall nonselective grades and tonnages at higher cut-offs are closer to reality, if the smoothing is reduced by some appropriate method.

It is therefore critical to understand the purpose of early stage resource

estimating and to understand any differences between the best local block estimate and the theoretical global grade tonnage curves.

At the early stage of a project the accuracy of the local block estimate is often not critical but the overall tonnage and grade at a specific cut-off are critical. The differences between the best local estimate and the theoretical global estimate for an early stage project are most pronounced with commodities with highly skewed distributions, such as gold.

In early stage projects, techniques for obtaining a global estimate that is closer to reality, compared to optimal kriging, include global change of support, sub-optimal kriging (reduced sample search), uniform conditioning and simulation.

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DANNY KENTWELL

Danny Kentwell, a Geostatistician and Engineer, has a background in geological modelling, mine planning and surveying. He has 25 years' international experience with varied commodities including gold, copper, mineral sands, iron ore, nickel laterites, nickel sulphides and phosphate. Danny's skills cover 3D modelling, resource estimation, open pit design, scheduling and optimisation, independent technical expert reporting, fatal flaw analysis and due diligence. He understands the advantages and limitations of different resource estimation techniques and their use in mine planning. Danny is a Competent Person for JORC Code and NI 43-101 reporting.



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With over 35 years' experience in resources, Daniel's expertise includes resource estimation, resource classification (JORC), recoverable resource evaluation and risk analysis, sampling theory, mining simulation, open pit optimisation and training of professionals in statistics, geostatistics, sampling and grade control. Daniel's range of deposit types studied includes gold, copper, iron, tin, nickel, lead-silver-zinc, uranium, mineral sands, phosphate, coal, diamonds and bauxite.



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Estimating metallurgical variability: a case study

SÉBASTIEN BERNIER

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mineral resource estimation. Proficient in CAE Datamine Studio 3, he has co-authored several National Instrument 43-101 technical reports and worked on numerous projects around the world. Sébastien's expertise includes a variety of commodities like base metals, precious metals, uranium and lithium in a variety of deposit types, from unconformity-type uranium deposits to narrow gold veins and volcanic massive sulphides. Sébastien is also the co-instructor of SRK NA's Geostatistics and Resource Estimation Workshop.

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After discovering a mineral deposit, delineating the drilling, and developing a geological framework, the next step is usually estimating metal content by quantifying the grade and tonnage of the mineral occurrence. To support mine design and the economic analysis of the project, a geometallurgical model can also be generated by bridging the gap between the geostatistics and the metallurgy. SRK generated such a geometallurgical model for Royal Nickel Corporation's (RNC) Dumont nickel deposit, located in the established Abitibi mining camp, 25km northwest of Amos, Québec, Canada.

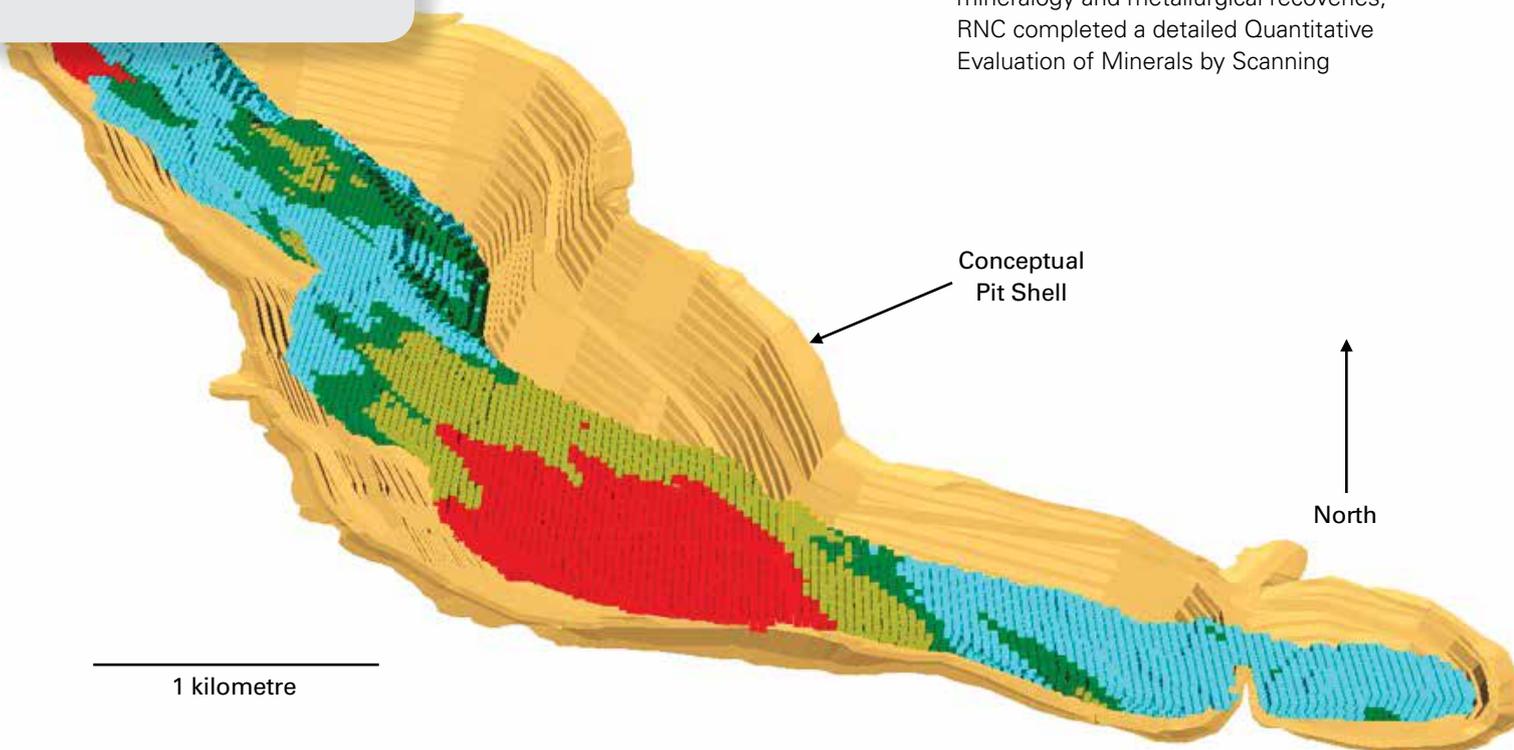
In 2013, RNC commissioned SRK to produce a mineral resource model to support a feasibility study. The model estimated 9.7 billion pounds of nickel resources in the Measured and Indicated category and 2.9 billion pounds of nickel the Inferred resource category. The feasibility study concluded that the Proven

and Probable reserve categories contain approximately 6.9 billion pounds of nickel. Once in operation, the mine is expected to rank as the fifth-largest nickel sulphide mine in the world by annual production, and to last more than 30 years.

The deposit comprises pervasively serpentinised olivine + sulphide cumulates which make up differentiated layers of the Dumont sill, a komatiitic intrusion contained within the Archean Abitibi Greenstone Belt.

Nickel mineralisation within the deposit is characterised by disseminated blebs of pentlandite ($(\text{Ni,Fe})_9\text{S}_8$), heazlewoodite (Ni_3S_2), and the ferronickel alloy awaruite ($\text{Ni}_{2.5}\text{Fe}$) occurring in various proportions throughout the sill. These minerals can occur together as coarse agglomerates, or as individual disseminated grains. Nickel can also occur in the crystal structure of several silicate minerals including relict olivine and serpentine. This mineralogical variability must be accurately modelled in order to calculate recovery for the feasibility study.

To investigate the correlation between mineralogy and metallurgical recoveries, RNC completed a detailed Quantitative Evaluation of Minerals by Scanning



Block variance validation

Electron Microscopy (QEMSCAN) study. They analysed 1,420 samples to provide detailed mineralogical information on mineral assemblages, nickel deportment, liberation, alteration and the variability of these factors. Mineralogical samples were also taken to characterise the metallurgical domain composites and for mineralogical mapping.

The results were used to construct estimation models of mineral abundances. SRK modelled the abundance distribution of awaruite, brucite, coalingite, heazlewoodite, serpentine, low-iron serpentine, iron-rich serpentine, magnetite, olivine, and pentlandite.

In conjunction with defining the nickel grade, the models were used by RNC to establish four distinct metallurgical domains: heazlewoodite dominant, mixed sulphide, pentlandite dominant, and high-iron serpentine. A separate regression recovery equation was determined by RNC for each domain, and was applied to the resource on a block-by-block basis to calculate a net smelter return per tonne, which was subsequently used to support a feasibility study.

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Geometallurgical Domains

-  Heazlewoodite Dominant
-  Mixed Sulphide
-  Pentlandite Dominant
-  High-Iron Serpentine

Generally speaking, grade interpolation can be validated by VMS (visual assessment, mean assessment, swath plot validation) and block variance validation. These methods are easily understood and applied, except for the block variance validation.

When applying kriging to grade interpolation, the theoretical block variance adjustment ratio (f) and the actual block variance adjustment ratio (f^*) can differ by a large measure that is not reflected in the VMS methods. Block variance validation is important for a kriging interpolation, but is not relevant to a non-kriging interpolation, so, the question is how to apply it?

One way is to examine which interpolation is most robust. As we know, the block variance is a measure of how far a set of numbers is spread out. It is one of several descriptors of a probability distribution, describing how far the numbers lie from the mean. Usually, different parameters produce almost identical global mean grades, but obviously different variances. This difference can produce different tonnage-grade curves. All the curves show the same level of confidence at the minimum reporting cut-off, but different levels of confidence at increasing cut-offs. Using a kriging method, the most robust choice is the one with the minimum difference between f and f^* , which indicates that the estimated result follows well with the operator's expectation. For a non-kriging method, the f cannot be calculated, so the confidence levels of f^* and tonnage-grade curve cannot be assessed.

Another application is to find outliers in a borehole dataset. During grade interpolation, the smoothing effect happens inevitably as the support enlarges. The term support at the sampling stage refers to the characteristics of the sampling unit, such as the size, shape and orientation of the sample. At the modelling stage, the term support refers to the volume of the blocks. As support increases, the data is gradually distributed more symmetrically, and the spread of the data is reduced, as the

variance shrinks. The only parameter that is not affected is the mean; it should stay the same regardless of support changes. Theoretically, the distribution presented by the sample data should vary more than that presented by the blocks. But in actual practice, the block variance is occasionally larger than the samples variance when all the reasonable interpolating methods and parameters are considered. Therefore, it is preferable to remove outliers that still exist in the borehole dataset before re-estimating the resources.

Finally, we can answer the question of how to apply block variance validation:

1. Use it to decide which result is the most robust among kriging interpolations
2. Ignore it in non-kriging interpolations
3. Use it to mark the presence of outliers in the borehole dataset

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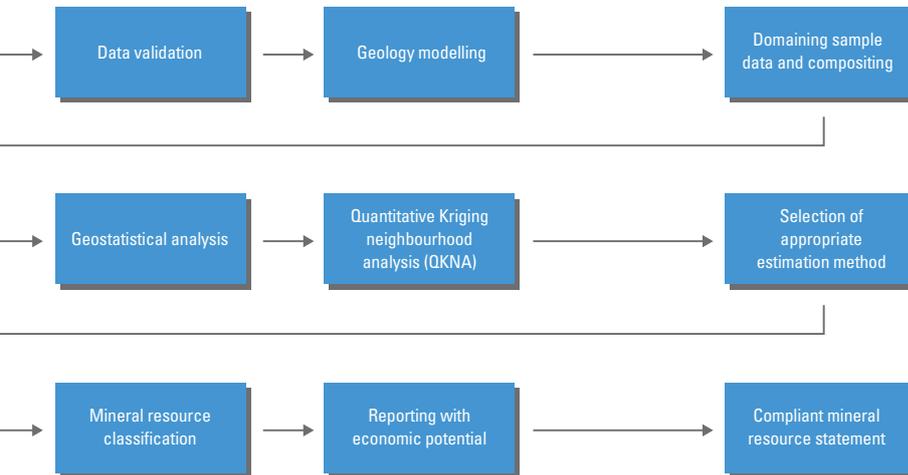
Yonggang Wu, M.Eng, is a Senior Consultant (Mining). He joined SRK after graduating from Jiangxi University of Science and Technology in 2007.



With specialised knowledge of mining engineering and MineSight software; he began training mine technical staff in MineSight while still a student. Yonggang's projects involve the minerals Au, Pb, Zn, Mn, Cu, Fe, fluorite, potassium salts, alum, and more. He has extensive experience in resource/reserve estimation, pit limit optimisation and design, underground mining design, long-term production planning, and due diligence studies, with his expertise in modelling and specialised software.

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External mineral resource audits



will be presented in the public domain and be reviewed and interrogated by a third party. The Resource Geologist must remember that the results of the MRE are the culmination of an often extensive and expensive exploration campaign, the results of which mean everything to the success of the client company.

It is therefore essential that the quality of SRK's work on the MRE is comprehensive and that the results are not influenced by client expectations regarding tonnages and grades. In reality, additional drilling expenditure does not always result in additional tonnes and metal in the ground.

Producing an MRE is a complex process that requires a diligent and well structured approach, and SRK has developed robust process workflows to guide the geologist through the critical decision points. No two deposits and projects are the same and MRE workflows allow the geologist to consider project-specific requirements, ensuring that correct data checks are undertaken before moving to the next step in the process. Furthermore, SRK recognises that multiple techniques

and procedures (such as selecting the composite length, grade capping theory, interpolation method, etc) and built-in validation checks are undertaken to assess the materiality and relevance of each step. This is critical to the successful completion of an external audit and enables the geologist to defend the selected methods. Individual geologists will have different opinions about the correct approach and methodology, so these built-in checks make an external audit a smoother process. Remember that these are estimates and not precise calculations.

SRK prides itself on the quality of the MRE's we undertake. We are front runners in developing and applying modern resource estimation practices, using cutting edge technology described in this newsletter.

External audits can be daunting, but by following the correct workflow to guarantee the quality of the work, they can be stimulating and rewarding.

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MARK CAMPODONIC

Mark Campodonic, BSc, MSc, FGS, MAusIMM, is Head of the Geology department, and a Principal Resource Geologist with SRK (UK) and has over 12 years of international experience. Mark's responsibilities have included the authoring and auditing of mineral resource and ore reserves, as part of technical studies, independent assessments, feasibility studies, due diligence/technical reviews, Competent Person's Reports and Stock Exchange listings. He acts as a Competent/Qualified person for a number of commodities and styles of mineralisation.



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SHAMEEK CHATTOPADHYAY

Shameek Chattopadhyay, Senior Consultant (Resource Geology) has over 12 years of experience in exploration and mineral resource estimation. Since joining SRK in 2007, Shameek's responsibilities include producing 3D geological models using specialised mining software, resource estimation, undertaking technical due diligence studies associated with fundraising and Stock Exchange Listing, and preparing technical reports following various international reporting codes.



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Application of the JORC code to a complex Mozambique coal deposit



Coal mining in Mozambique

ANNA FARDELL

Anna Fardell is a Resource Geologist with SRK, specialising in various aspects of coal and stratiform modelling, resource estimation and applied geostatistics.



She has 6 years' experience in the resources sector. Since completing an MSc in Mining Geology and joining SRK in 2009, Anna has undertaken resource estimates for various bulk commodities and worked on coal projects in Canada, Russia, Southern Africa and Colombia and assisted in the generation of Competent Persons' Reports for various international exchanges. Key skills include knowledge of geological and mine planning software including Vulcan, Minex, Datamine and Isatis geostatistical software.

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Classifying coal deposits in recently explored basins to internationally recognised reporting codes requires close attention to data quality and a comprehensive understanding of the geology.

The coal basins and sub-basins of the Zambezi coalfield are structurally complex, affected in varying degrees by intrusive bodies, with centimetre scale inter-bedded coal and shale comprising the target coal zones which are between 5 and 30m thick.

A recent Coal Resource Estimate of a Mozambique deposit was sampled with boreholes spaced between 100 and 1000m apart. In well sampled areas, the coal zones could be correlated between drillholes and faulted blocks and major structures could be modelled confidently. Intrusions and the extent of burning were modelled, extrapolated between drillhole intersections through the coal zones. However, in poorly drilled areas there is high ambiguity and little confidence in the interpretation.

Structural interpretation was primarily based on remote sensing data and recognisable coal zones. Intrusions could not be confidently correlated between fault blocks or the quality and thickness of contained clean coal estimated.

SRK used density, ash and thickness cut-offs to define the "clean" coal within the zone. This approach assumes that although the drill spacing does not support the delineation of individual coal bands, selective mining can separate them from the waste. Hence, the coal qualities and densities were only counted on the composited clean coal bands.

Clean coal quality grids show significant variations laterally across coal zones, indicating that coal quality cannot be inferred across sparsely drilled areas. In terms of sedimentology, the coal zones have high variability vertically but are less variable laterally. Where the whole coal zone was not sampled, a high level of variability introduces significant bias in the resource estimate.

Block modelling in the CIS and alignment with the GKZ



SRK classified the deposit by considering each coal zone individually, assessing the quantity and quality of the data influencing the coal quality and thickness within and between individual fault zones, including availability of downhole geophysical logs and full seam intersection and analysis. Where intrusions appeared in the coal zones, SRK downgraded the area's classification.

The coal model was tested for economic potential with a Pit Optimisation using a range of coal prices for high level fixed costs to ensure the resource was economically viable. The model used the ratio of clean coal within the zone to washability yield (processing recovery) to quantify the saleable coal. This excluded coal from depth, at the licence boundaries and in areas where the strip ratio was too high to support extraction.

SRK reported the clean coal (with associated partings) that fell within the pit optimisation shell as the Coal Resource.

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The CIS countries inherited the resource estimate code from the Soviet era that was originally created and is still updated by the Geological Commission for Reserves or GKZ. The official method of the resource estimation is still based on sections and plans.

Now the GKZ body in Russia plans to implement the block modelling approach; however, it faces serious methodological differences.

The main problem is this: the GKZ approach requires an estimate within a hard boundary based on an economic cut-off that excludes any material below the stated cut-off grade. If the boundary includes lower-grade material, the resource figures should be corrected, using the ore-waste coefficient, to exclude any possible dilution in the estimate. In contrast, the international approach uses the mineralisation boundary to define the zone of estimate.

This block modelling approach allows for some dilution, depending on the style of mineralisation, geostatistical characteristics and block size. Comparing the results of the two estimates, using a cut-off grade, reveals this difference: the GKZ approach excludes any possible dilution below the stated cut-off grade, while block modelling allows some dilution in the model.

The current GKZ requires the estimate to be made strictly according to the existing code, using hard boundaries. If block modelling is used, it should compare closely to the polygonal estimate results, but it is seldom possible to achieve results comparable to the sections method. Therefore, to use block modelling following international standards, some GKZ requirements need to be changed.

SRK is part of the group currently working on adopting the block modelling approach in GKZ. The group is trying to explain the main difference in the two methods and to propose the possible solutions and changes required to adopt the block modelling technique. SRK is trying to prevent the usage of a mixed approach when the block model is only used to honor the polygonal method, since this could not provide a reliable and unbiased estimate according to the international approach.

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LIUBOV EGOROVA

Liubov Egorova has 10 years' experience working in mining's geological sectors. Her varied background has enabled her to build expertise in many topics concerning mineral resource estimation and exploration activities for a broad range of commodities.

Liubov's responsibilities have included geological modelling, mineral resource estimation and QA/QC, as well as preparing NI 43-101's, geological chapters in Scoping Studies, CPRs and FS reports, supervising drill and exploration programs and many other geological activities. Liubov has developed a deep understanding of the Russian system of mineral resource estimation and reporting. Currently, she is actively participating in developing a method for harmonising international and GKZ systems for resource estimation.



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Satisfying the “reasonable prospects for economic extraction” requirement

International professional organisations in Australia, Canada, South Africa, USA, UK, Ireland, and many countries in Europe have adopted comparable codes, guidelines, and standards for mineral resource reporting. The definition of a mineral resource usually includes the requirement that “reasonable prospects for economic extraction” exist.

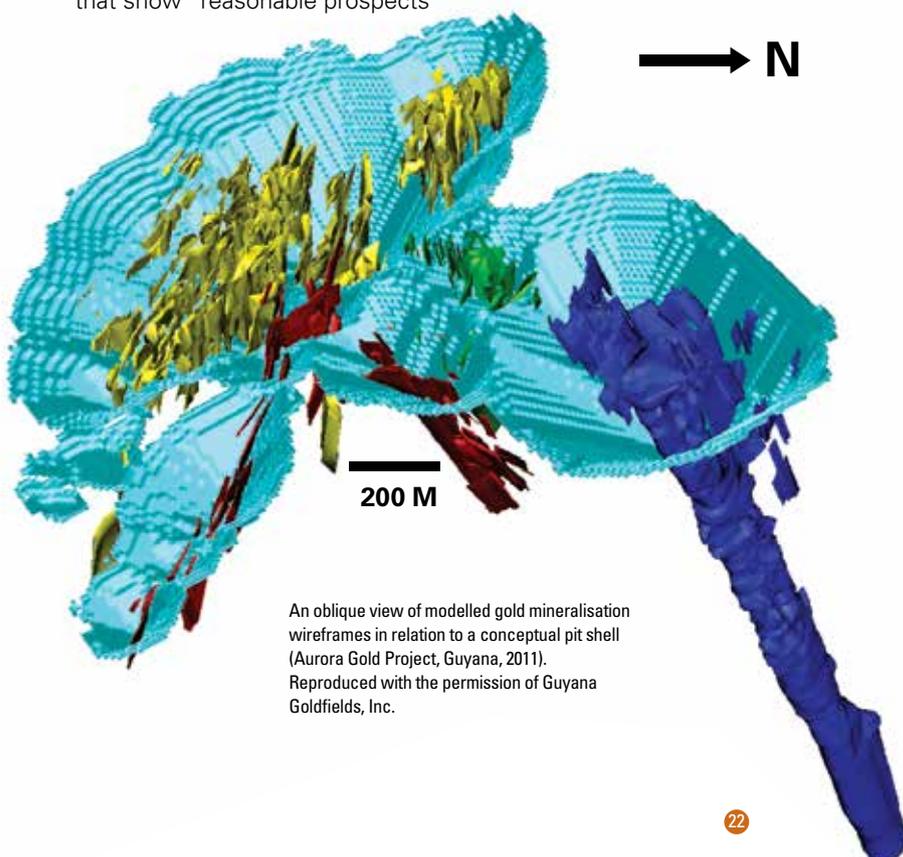
This requirement implies a judgment by the Qualified Person regarding the technical and economic factors likely to influence the prospect of economic extraction. This in turn implies that the quantity and grade estimates meet certain economic thresholds and that the mineral resources are reported at an appropriate cut-off grade that considers economic inputs, extraction scenarios and processing recoveries.

It is important to apply a consistent methodology when assessing the “reasonable prospects for economic extraction” for mineral resource reporting. SRK applies the Lerchs-Grossman optimising algorithm to develop the conceptual pit shells within which the portions of the block models that show “reasonable prospects

for economic extraction” by open pit mining are defined. Portions of the block models that are external to an open pit, but satisfy the cut-off grade criteria for an appropriate underground extraction method, are considered to show “reasonable prospects for economic extraction” by underground mining. Optimisation parameters used to derive the conceptual pit shells are generally optimistic, aligned with standards used in recent comparable studies, and are usually determined in collaboration with an SRK mining engineer and the client.

It is important to state that the results from the pit optimisation are used solely for assessing those portions of the block models that show “reasonable prospects for economic extraction” and do not represent an attempt to evaluate mineral reserves. Mineral reserves can only be estimated based on the results of an economic evaluation as part of a preliminary feasibility study or a full feasibility study.

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The Committee for Mineral Reserve International Reporting Standards (CRIRSCO) has consolidated reporting codes and standards to produce a consistent definition of a Mineral Resource.

“A ‘Mineral Resource’ is a concentration or occurrence of material of economic interest in or on the Earth’s crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are subdivided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.”

This definition raises two key questions: first, what is considered “reasonable” and second, what is the time scale for “eventual economic extraction”?

Following CRIRSCO’s, the eventual economic extraction can be stated clearly. The Template continues: “The term ‘reasonable prospects for eventual economic extraction’ implies the Competent Person [judges] the technical and economic factors likely to influence the prospect of economic extraction, including the approximate mining parameters. It is a realistic inventory of mineralisation which might become economically extractable.”

The Competent Person (CP) makes preliminary judgments on factors used when converting a resource to a reserve (see Figure 1) including: mining, metallurgical and processing, economic, marketing, legal, infrastructure and environmental and social.

Reasonable prospects for eventual economic extraction (RPEEE)

In defining eventual, the CP might ask: what will the resource price be 30 years from now? Will there be sufficient electrical power to grow the minerals industry? How will power be generated? The CP has to wrestle with such questions, even at this early stage.

Why, then, are resources declared when, at best, they should be in Mineral inventory? First, at this stage, the Resource Geologist usually estimates resources to meet the stringent QA/QC requirements and assess the level of geological confidence. Would he need to involve an engineer or economist now? Second, client pressure. With an ambitious exploration target and sizeable investment, the client needs results. The client may suggest the chance of follow up work for the geologist's company are slim without results.

How then does the CP decide what is reasonable? The geological confidence is the primary consideration but not the only one. This multi-disciplined decision must consider all the modifying factors.

As Erich Fromm said, in part:

"What the majority of people consider to be 'reasonable' is that about which there is agreement, if not among all, at least among a substantial number of people; 'reasonable' for most people, has nothing to do with reason, but with consensus."

After considering the modifying factors and geological confidence, would the decision stand the scrutiny of the majority of your peers? That's the benefit of a multi-disciplined peer review process in the preliminary stages of declaring a resource.

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ROGER DIXON

Roger Dixon, Corporate Consultant, is Chairman of SRK South Africa.



He has 43 years' experience in mining engineering, with projects relating to engineering studies, mineral reserve estimation, due diligence, and feasibility studies on open-pit and underground operations. Roger helped formulate the Mine Health and Safety Act of 1996. In 2000, he helped prepare the South African Code for reporting mineral resources and reserves (Samrec Code), and mineral asset valuation (Samval Code) in 2008. He represents South Africa on the Committee for Mineral Reserves International Reporting Standards (CRIRSCO), which represents the major mining regions around the world.

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GLEN COLE

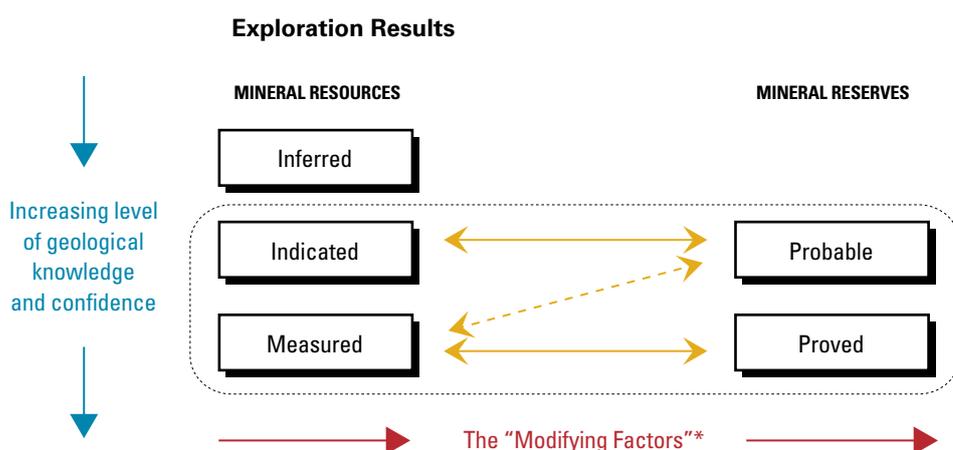
Glen Cole, Principal Consultant (Resource Geology) has over 20 years of experience in mine geology, precious and base metals exploration, resource geology, mine feasibility



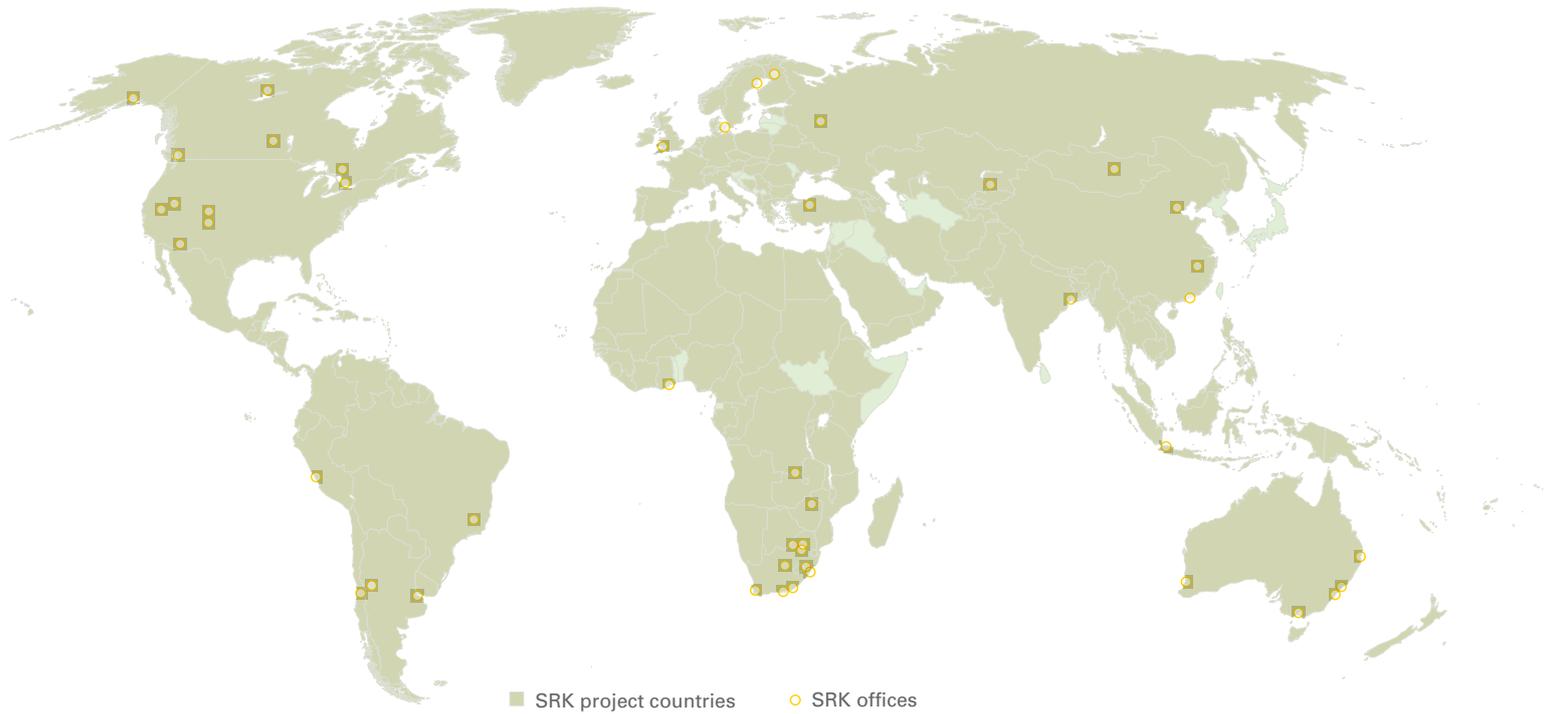
and due diligence. He worked as a Chief Geologist and Chief Resource Geologist on various underground and opencast gold operations in South Africa and Ghana before joining SRK in 2006. He has worked on multi-commodity projects in South America, North America and Africa producing resource estimates, auditing mining operations, undertaking due diligence studies and technical reporting for Competent Person's Reports and Stock Exchange Listings.

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Figure 1



*The "Modifying Factors":
Consideration of mining, processing, metallurgical, economic, marketing, legal, environmental, infrastructure, social, and governmental factors



Specialist advice for mining projects in all global environments.

To learn more about SRK and how we can help you with your next challenge, visit our website:

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