

# Using Technological Advances to Improve Resource Estimates

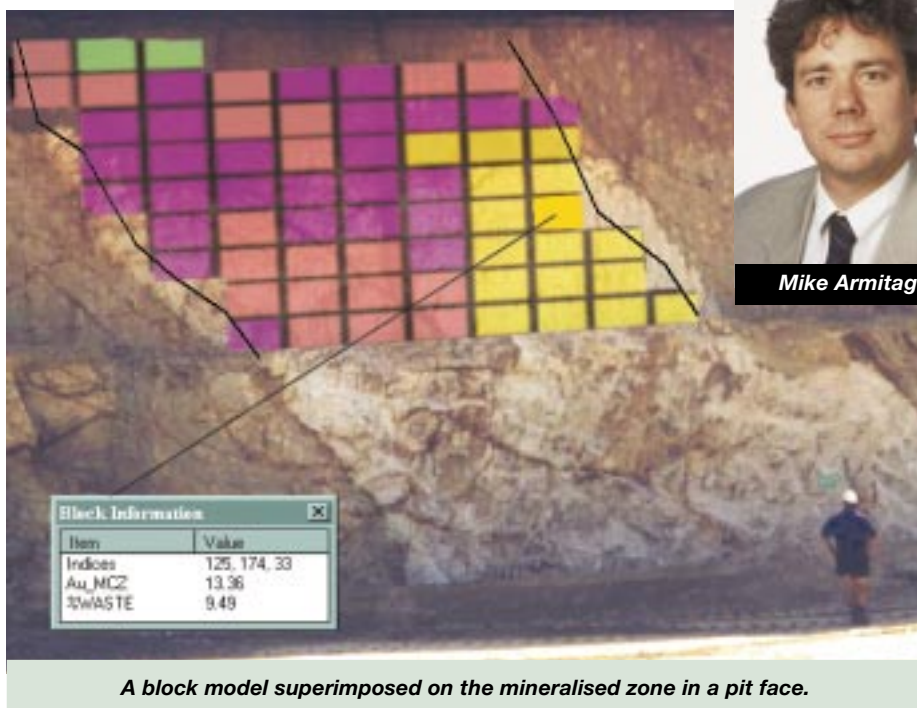
Resource estimation is the science of determining the amount and quality of a given material in the ground that has the potential to be mined at a profit. Methods have changed significantly since SRK was formed in 1974. This is because during this time computers have become more widely available and more powerful and software packages have become more comprehensive and user friendly.

As a result of these technological advances, manual methods such as polygon and section based grade estimation have gradually been replaced by more mathematical techniques such as kriging. This has provided an opportunity to make maximum use of data with the more complex mathematical methods now readily available to the user; however, these techniques are often applied without having a thorough understanding of the geological controls on metal distribution.

Unfortunately, the increased use of these mathematical techniques over the last ten years corresponds, to some degree, to a decrease in both the amount of deposit mapping and, in particular, structural interpretation. Geologically defensible, fault and stratigraphically bounded orebody models have been replaced by the all too common “grade shell”.

As a consequence, despite the increased geological understanding of orebody geometry and controls, the advances in geostatistical thinking and the availability of appropriate software packages; it would be a bold person indeed who believed that the resource estimates produced worldwide during the Year 2000 are, on average, any better than those produced worldwide in 1974.

The articles presented in this publication largely emanate from an SRK conference



**A block model superimposed on the mineralised zone in a pit face.**



**Mike Armitage**

held in Cardiff in 1999 which is referred to in “Standardising on an SRK way”. This conference was organised to bring SRK’s international resource team together, to pool our knowledge of the latest advances in resource estimation techniques and to set a basis for improving our resource estimation methods. The two themes of the conference, *geological understanding*, and *geostatistical understanding*, are reflected in this newsletter. The first theme is exemplified by submissions such as

“Integrating Geology into Resource Estimations for Chile’s Lina Deposit” and “Identifying Mines within a Deposit in West Africa”, while the second theme is exemplified by “Global versus Local Estimates for Platinum and Gold Deposits in Africa” and “Multiple Indicator Kriging: Is it Suited to My Deposit?”

Resource estimates produced today *should* be better than those produced in 1974. At SRK we believe ours are, how about yours?

# Major Cost Savings Through Improved Grade Control

Open-pit grade control is an area where enormous financial efficiencies can be gained by implementing better geostatistical practices.

SRK's geostatistical teams work closely with operational staff on mine sites around the world to improve grade control practices in areas such as ore-waste allocation and bench height/selectivity.

Programs usually involve integrated training aimed at transferring skills to company staff so that site 'ownership' of improved grade control is achieved.

The improvement in ore-waste allocation efficiencies can be measured and the opportunity cost of sub-optimal grade control estimation quantified. One recent example – a large porphyry gold-copper operation – saw improvements of the order of hundreds of thousands of US dollars *per shift*.

Improvements may be gained from changing methods, but often startling benefits can be realised by simply refining the existing approach.

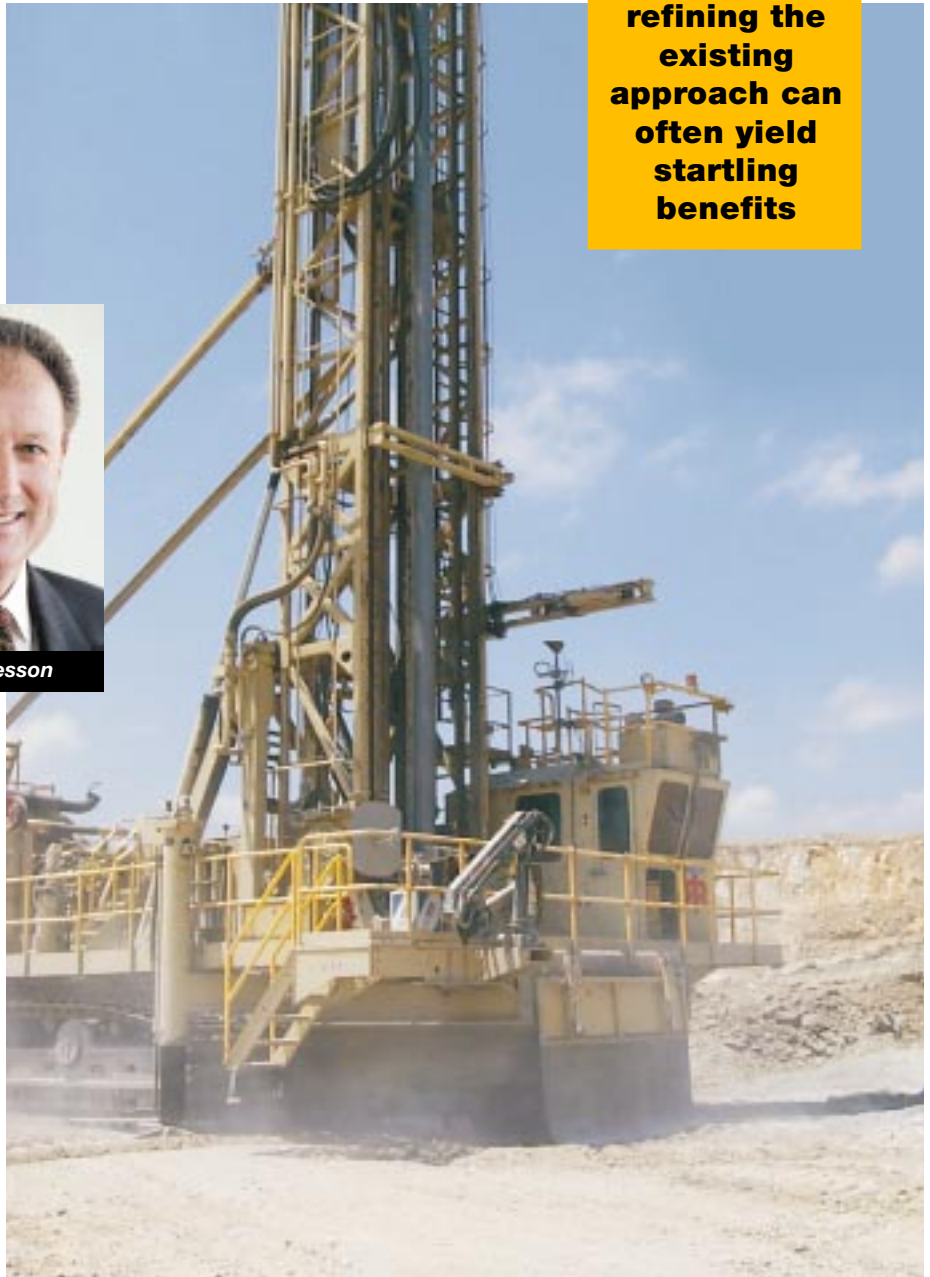
In the arena of selectivity, SRK for many years has used the discrete Gaussian method to perform selectivity studies to predict the impact of a change in mining selectivity on grade-tonnage curves.

SRK has applied this method to a wide range of projects and commodities to study the effect of changing bench height on grade tonnage curves.

"One of the benefits of good open-pit grade control practices, especially for



**Tony Wesson**



**refining the existing approach can often yield startling benefits**

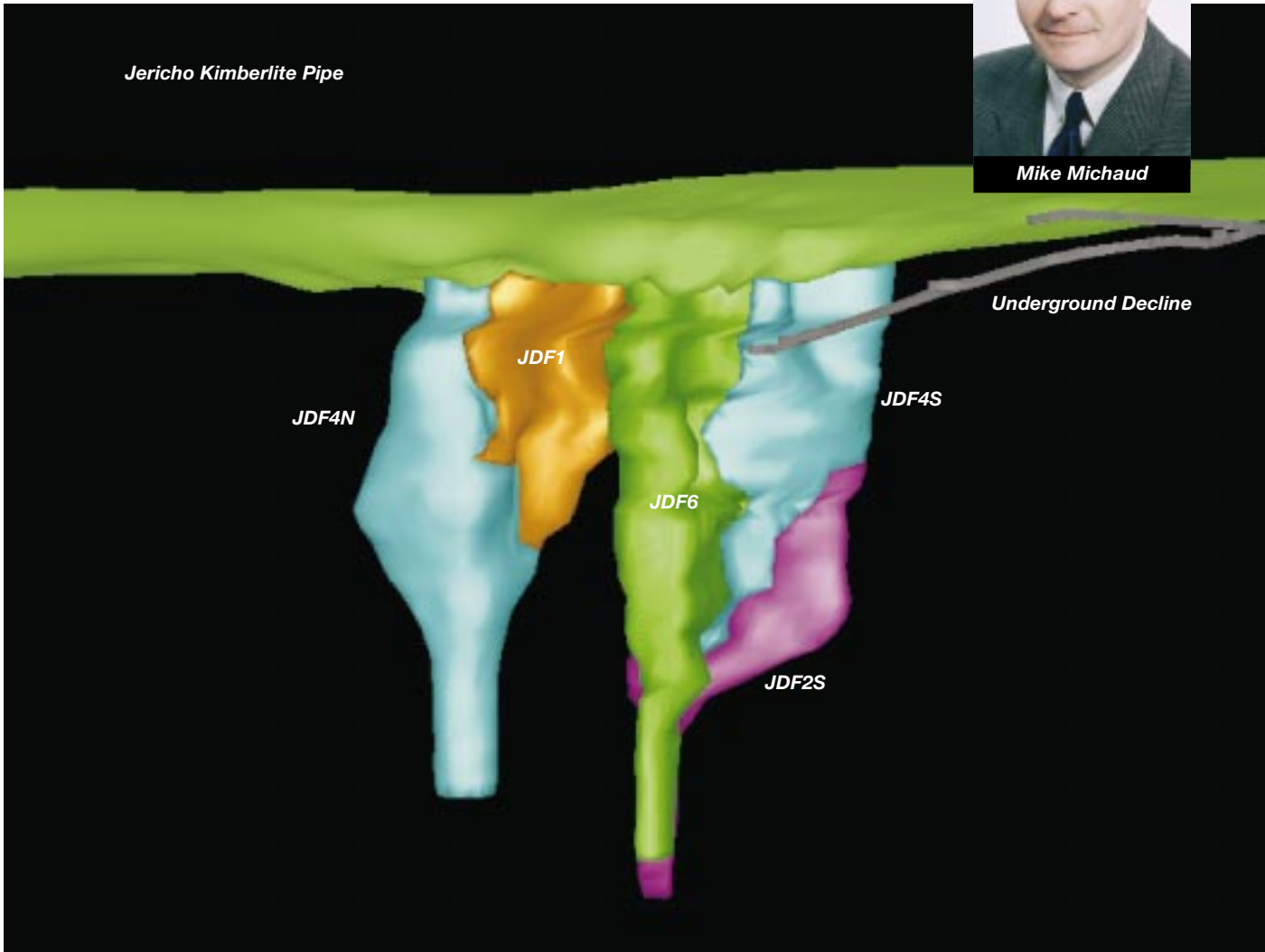
**Many mining companies are not aware that several methods exist to predict and quantify the impact on grade-tonnage curves of a change in mining selectivity**

bulk commodities, is that it creates opportunities for optimising cash flows in the early years of a project through the ability to high-grade a deposit and to stockpile lower grade material for later beneficiation",

summarises Tony Wesson Manager of the Perth geostatistics team.

"SRK has the right team of specialised geostatistical consultants to help deliver improved outcomes around the globe."

# Resource Modelling in Canada



Three-dimensional view of the various phases comprising the Jericho Kimberlite Pipe

As part of a bankable feasibility study, SRK used its extensive experience of diamond deposits to construct a resource model for the Jericho diamond project located in Nunuvut Territory, northern Canada.

The Jericho project, part of the northern portion of the Slave Structural province of the Canadian Shield, is owned and operated by Tahera Corporation. The Jericho kimberlite was formed from multiple emplacement phases, or events, including a precursor dyke (JDF2) and three main kimberlite lobes (JDF4S,

JDF4N and JDF6), each having distinct diamond distribution characteristics.

After an extensive review of the available drill core, SRK identified a correlation between geologically distinct phases of the kimberlite and diamond distribution that could be used to better define the geometry of the various phases of the kimberlite pipe. This geological model was used as a foundation for resource and reserve estimation, thereby providing a much more accurate estimate of the grade, tonnage and value of the deposit.

Michael Michaud of SRK's Toronto office and Martin St. Pierre, Vice President Exploration for Tahera Corporation agree, "we defined a correlation of diamond distribution between the core samples and underground bulk samples, which provided a mechanism to assess the quality of the various sampling methodologies. This correlation also helped to increase the level of confidence in the resource to be used for evaluating various mining and processing scenarios for the completion of the feasibility study."

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## Fresh face in Cardiff

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**A**lwyn Annels, a specialist in resource evaluation and geostatistics, joined us in April 1999 after 26 years at Cardiff University.

Alwyn began his academic career in 1961 at Kings College in London where he gained an honours degree in geology. In 1964, he went on to Imperial College where he gained a PhD in volcanic geology and in 1967 he took up employment with RST Technical Services as an exploration geologist in Zambia, initially in the Copperbelt and then in the Northwestern Province. Later, he transferred to RCM Ltd's Mufulira Mine as Assistant and Acting Chief Geologist.

In 1973, Alwyn returned to the UK to take up a lecturing post at University College Cardiff, where he developed undergraduate courses in mineral exploration and resource evaluation while continuing his research interests in resource evaluation and geostatistics. This led to the publication of his textbook *Mineral Deposit Evaluation: A Practical Approach*. In 1994 he developed, and was the first course director for, a new MSc-taught course in mineral resources, which has rapidly gained international recognition.

Alwyn is currently involved with offshore diamond projects in southern Africa, heavy mineral deposits in Kenya and lateritic nickel projects in Albania.

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## Standardising on an 'SRK Way'

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**SRK resource estimates should reflect a standard approach**



**Several participants of the recent SRK Resource Conference in Cardiff**

**T**he first internal SRK Resource Conference in Cardiff offered an opportunity for SRK's resource teams in Australia, UK, Africa and North and South America to meet and discuss the practice of resource estimation and auditing.

SRK is conscious that its reputation and standing in terms of resource estimation is a function of work done by all of these teams collectively, but that the maintenance of this position is dependent upon work done by each of the teams individually.

SRK's Mike Armitage says: "The aim of the conference was to engender an approach which ensures that all relevant issues are addressed and accounted for."

"In addition, discussions were held on the practical methodologies used at each office to deal with specific issues and specific circumstances. We envisage that these discussions will form the basis of an SRK reference booklet."

While the conference agreed that few areas of resource estimation are amenable to prescriptive guidelines, it also agreed, that all could be appropriately addressed if the team undertaking the work has an understanding of the deposit geology and envisaged exploitation plans, as

well as a knowledge of estimation theory and practical experience.

One outcome of the conference is that the attendees, and in turn the groups to which they are attached, benefited – and now continue to benefit – from each other's experience and specific knowledge.

"Regardless of the SRK office commissioned to undertake or review a resource estimate, the approach used should be similar," Mike concludes. "Key areas should all be identified and addressed with the benefit of the experience and knowledge not just of the members of that particular office but the other SRK practices worldwide."



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# Integrating Geology into Resource Estimations for Chile's Lina Deposit

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**SRK's** ability to apply principles of structural geology to assist with resource definition is demonstrated by its input to the Lina copper project in the Atacama Desert, northern Chile.

The Lina deposit is a satellite of the Michilla mine, discovered and evaluated by Minera Michilla, a subsidiary of Anaconda Chile.

The main Michilla orebody consists of copper mineralisation hosted within shallowly dipping favourable beds (mantos) and breccia pipes, and less important mineralisation along fractures and faults.

An initial resource estimate at the Lina 'daughter' deposit was based on a geological interpretation that most mineralisation occurred as mantos limited by ENE-trending faults.

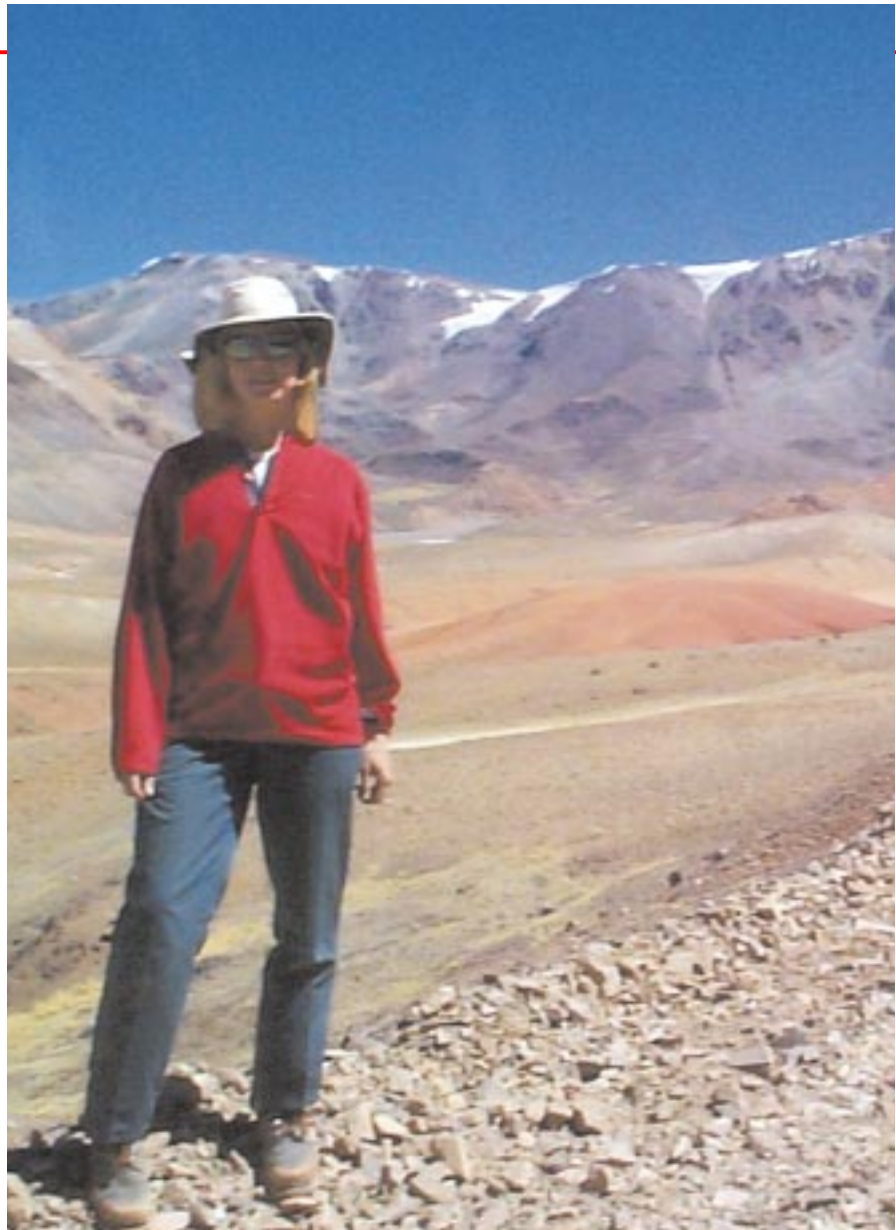
This estimate yielded a demonstrated (measured plus indicated) resource of approximately 500,000 t at 1.53% Cu using a 0.5% cut-off.

"However," says Dr Jacqueline Windh of SRK's Santiago office, "an initial attempt at mining showed that the oreblocks were not located as predicted by the manto model."

Reviewing the geological logging of the 85 drill holes over the Lina deposit, Jacqueline aimed to create a geological model independent of the grade information, then use this model to interpret the direction and degree of connectivity between mineralised intersections.

While a coherent stratigraphy was difficult to develop in any one section alone, by working simultaneously in parallel and perpendicular sections a coherent stratigraphic model was developed.

With a robust geological model in place, Jacqueline was able to relate mineralisation to specific beds and structures. Working with a Michilla



**Jacqueline Windh, Senior Associate Geologist**

geologist, she overlaid grade data on the geological interpretation, and was able to correlate which mineralised drill intersections correspond with mineralised mantos, and which are related to mineralisation hosted along discordant faults.

"Together, we defined oreblocks and calculated grades for them. This allowed

us to calculate a demonstrated (measured plus indicated) resource of 334,000 t at 1.55% (using a cut-off of 0.5% Cu), including 190,000 t at 2.25% (1.0% Cu cut-off).

"The geological input to the definition of the oreblocks provides a result with a greater degree of confidence than the previous estimations."

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## SRK Welcomes World Renowned Sampling Expert

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**Francois-Bongarcon**

**SRK** is very pleased to welcome Dominique Francois-Bongarcon, internationally recognised consultant, researcher and teacher, as an associate.

A long-time SRK collaborator, Dominique has been involved with numerous sampling projects including Vaal Reefs, Harmony, Mount Todd and Cadia/Ridgeway. In addition, he has presented several of his sampling courses through SRK's Perth-based geostatistics group (formerly Geoval).

Holder of a doctorate for research at the geostatistical centre of the Paris Mining School in Fontainebleau, France, Dominique has an impressive CV that stretches over a quarter century. His work in the fields of sampling, assaying, QA-QC programs, geostatistics and specialized ore heterogeneity (sampling and sample preparation assessment, sampling regime optimisation) has been acclaimed around the world.

In addition, his approach to open pit optimisation forms the theoretical basis of one of the more common commercial methodologies available today. Dominique has also pioneered the modern applications of Pierre Gy's sampling theory to mining and exploration problems.

When not in the field, Dominique works from his office in San Mateo and may be contacted through Nick Michael in SRK's Denver office or e-mail at: [dfbongarcon@srk.com](mailto:dfbongarcon@srk.com).

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## When is a Resource Audit 'Successful'?

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### A generic case study of a successful resource audit

The first words uttered by the enthusiastic project financier over the telephone were "Everything's OK. The feasibility study is complete and it all looks good. We'd like your company to do a quick fatal flaw analysis of the available documentation and give a preliminary sign-off so we can proceed with the financing arrangements in parallel with full due diligence. The company has several operating mines in Australia that have been performing well and there's a likelihood of future financing opportunities."

Thus began an odyssey carrying this geologist through the depths of the company's project exploration data and the client's resource and reserve group's inner workings. My initial considerations were that the data were collected appropriately and analyzed by highly qualified people and laboratories. The core logs and chip logs were first rate and the geology well transferred to the sections and plans. There had been several studies of the esoteric aspects of the deposit and the company's geologists had participated directly in the construction of the drillhole/deposit geology database. As with any geologic interpretation, there were areas where I disagreed, but in general, the deposit geologic model was, in my opinion, well done and a good reflection of the evaluated data.

As I continued to review the basis of the estimate, however, I received a call from a

colleague responsible for reviewing the mine production schedule. He said: "Take a look at the grades in the first two years of the mine plan. They appear to be quite high and, further, our financial auditor has informed me that the success of the

project depends on the quantum of early metal production." Needless to say, I took a quick – hard – look and lost a lot of sleep in the next several days. Those high grade intercepts, tightly constrained as they were, still contributed an inordinate amount of metal and that amount of metal expected was quite clearly suspect, or at best, highly uncertain.



**Bill Crowl**

My subsequent telephone call to the project financier had a downbeat theme. "I think there's a problem with the amount of metal in the first two years of the mine plan. I suggest we ask the company to examine the findings and get back to us quickly."

An examination was made, explanations were tendered all around – and ultimately the mine plans and schedules were re-cast to reflect the new findings. The cooperative efforts of the sponsor company's team, SRK's mining geologists and the financier resulted in a more robust project. Thus, we were all participants in a successful resource audit. The value of a peer review was once again re-affirmed. Success is discovering the true nature of a deposit at an early enough stage so that no serious mistakes are made.

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## From Mineralisation to Mining: Ensuring All Options Are Uncovered

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**Chris Page**

**A**t what stage does the word ‘mining’ get into the resource estimation?

Too often a mine is outlined after a single resource estimate becomes public. Frequently only one mining option is considered, and sometimes that is an optimistic option. As knowledge builds, the resolution of the mineralisation invariably demonstrates more challenging conditions.

But one has to remain a ‘balanced enthusiast’; playing the devil’s advocate while not prematurely damning the project.

People are right when they say that mines are made; they seldom leap out at you. But so often one is looking only at the opportunities and not considering

the uncertainties (and the costs of managing these).

The trick is to keep all options open, to delay making that final choice of a mining scenario until all options have been properly explored, to keep doors open to alternatives until the last moment, to maximise flexibility.

No project should go to final feasibility until there is reasonable certainty that the outcome will be positive without going back to basic concepts to redesign the mine or re-estimate the resource.

The final feasibility is all about detail; the scoping study is about how many deposits and mines there might be; the

conceptual study is about ensuring the alternatives are feasible; and the pre-feasibility is about ensuring that the project is ready for the final feasibility. By this time the intellectual wrestling should be complete. The rest is ‘simple’ engineering.

We are too often lulled into a false sense of security by the detail of a final feasibility. But there is no certainty of outcome if the basis for design does not recognise the inherent uncertainty of a deposit – the ‘deposits within a deposit’ and ‘mines within a mine’.

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## Probability-Based Resource Estimate for Nevada Mine

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**M**ining specialists from SRK’s Denver practice, successfully used a probabilistic technique to complete a resource estimation for an operating open-pit silver-gold mine in Nevada.

A special feature of the deposit is the presence of multiple structural orientations significant both as conduits for ore fluids and as locations for higher-grade mineralisation.

“In any given volume of rock, three or more intersecting structural trends can be seen,” elaborates Bill Tanaka from SRK’s Denver office. “The complexity is such that separation of each into individual domains is not possible.



**Bill Tanaka**

“This condition poses serious problems in resource estimation, as a weighting ellipsoid orientated for one trend will ‘smear’ grade from another trend at a different orientation.”

PACK (Probability Assigned, Constrained Kriging), a probabilistic method developed by Gordon Seibel of AngloGold North America at the similarly-constrained Cresson Mine, was applied by SRK with significant success.

“PACK relies on the estimation of ‘probability’ values to blocks from indicators assigned to composites,” explains Bill.

“Indicators were assigned by setting a value of 1 to each composite greater than or equal to some threshold and 0 below. Variograms were run on the indicators to establish estimating parameters. Values between 0 and 1 were then estimated to the blocks.

“Distribution of the values in blocks was then compared with geologic cross sections as well as with actual ore and low-grade outlines within a mined volume. A value was selected that best represented the shapes observed. This was repeated at two thresholds for each metal.

“The volume defined was used to locate and tag composites for inclusion or exclusion from grade estimation. Similarly, the blocks are coded, and control established over which blocks are allowed to receive grade during estimation.”

## SRK Consultant Profile: Daniel Guibal

Daniel Guibal, technical director (geostatistics) in SRK's Perth practice, is one of the most respected geostatisticians in the world, with more than 25 years of theoretical and practical experience covering nearly all commodities and deposit styles.



**Daniel Guibal**

Before moving to Australia in 1983 to found Siromines (the precursor of Geoval, which merged with SRK in 1998), Daniel was in charge of advanced research in geostatistics and applied software development at the Centre for Geostatistics at Fontainebleau in France.

There he made major contributions to the development of conditional simulation and non-linear geostatistical methods. In addition, Daniel was involved in the practical evaluation of important mining projects in Europe, North America and South America, in particular Peru, where he lived for several years and met his wife, Juanita.

Daniel has conducted a large number of conditional simulation studies, including multivariate simulations for geologically complex deposits in both open-cut and underground situations.

Daniel has also delivered lectures, seminars and technical courses to professional associations, private companies and universities. He has written many technical papers for journals, conferences and books in the field of geostatistics and ore reserves.

Daniel graduated with a degree in civil and mining engineering from the Nancy School of Mines in France and later obtained an MSc (Mathematics) from the University of Paris VI. He is a Fellow of the AusIMM and was recently awarded honorary life membership of the Geostatistical Association of Australasia. He is fluent in English, Spanish and French.

## Global Versus Local Estimates for Platin

In 1999, SRK completed a feasibility study for Barnex, investigating near-surface gold mineralisation discovered at the Prestea Mine in southern Ghana.

The mineralisation occurs as podiform disseminations around discrete shear-zone hosted quartz veins that occur within Birrimian shales and greywackes. The quartz veins have been the traditional mining targets, and the discovery of bulk mineable material on surface had the potential to extend the life of these mature operations.

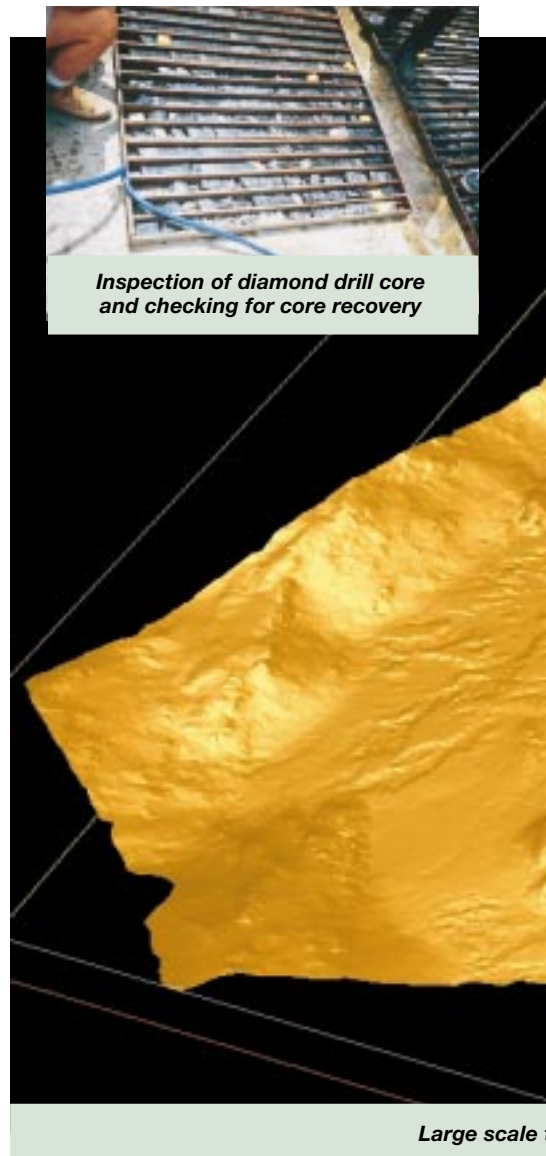
SRK Principal Geologist, Michael Harley, comments, "As part of the feasibility study, SRK considered that infill drilling was needed to upgrade the sampling database in areas that were poorly covered by the earlier campaigns. We were considering a highly selective mining option and needed the local precision in the block estimates to allow realistic modelling and planning to be achieved. SRK also devised a series of tests to check for sampling and sub-sampling biases that may be generated by the sample splitting process. These tests indicated that the sub-sampling program generated insignificant biases."

SRK also directed the collection of further density determinations and the surveying of the surface topography in critical areas to significantly improve on the existing sample and topographic databases. SRK then generated three separate geological models to describe the three main orebodies that formed the focus of the feasibility study. These models were then used as the basis of a detailed geostatistical modelling process to provide a grade model on which to base selective mine planning and design decisions.

"Magmatic platinum deposits, in direct contrast to shear-zone gold deposits, present far fewer opportunities for selective mining, with subtle lateral



**Inspection of diamond drill core and checking for core recovery**



**Large scale**

variations in reef grade being displayed by these deposits."

Michael's observation follows work undertaken on a project situated close to the original discovery site of the Merensky Reef and containing both the Merensky Reef and the underlying UG-2 orebody.

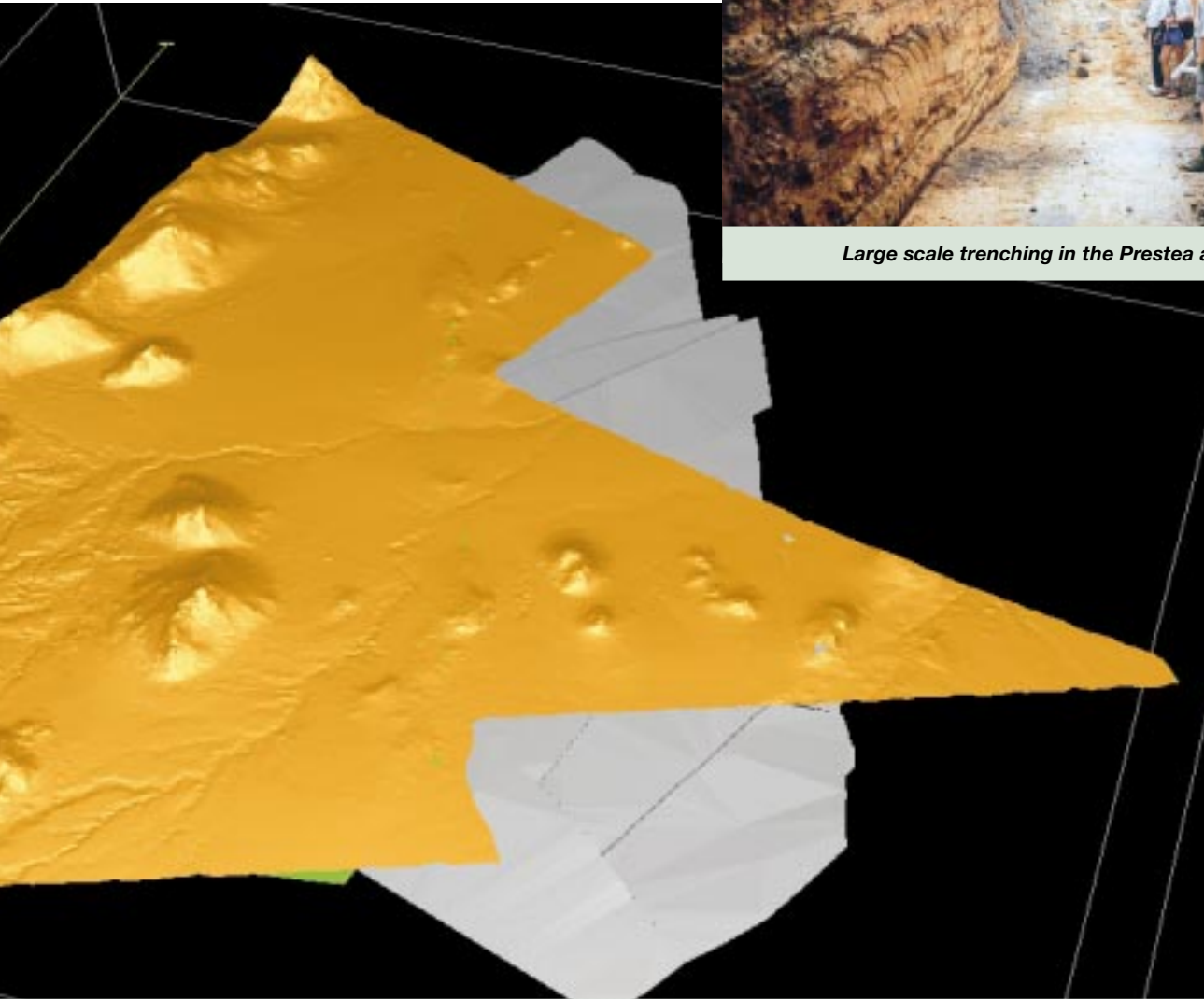
SRK generated valid reef selections from the more than 160 drilled intersections within the Merensky Reef. Holes that intersect non-representative features such as potholes, faults and a dunite pipe have



# um & Gold Deposits in Africa



*Large scale trenching in the Prestea area, Ghana*



*Topographic and reef structure models form the basis of the global grade estimates*

been excised from the base data used in the compilation of the Mineral Resource.

Additional sample data are available from channel samples cut into the sidewalls of development adits with diamond saws. These data permit the modelling of the variogram of metal accumulations with close spaced samples. The drillholes alone do not adequately sample the variogram at suitably close spacings to allow a reliable variogram model to be constructed. Only a combination of both data sets achieves this objective.

Grade variation within the UG-2 is even more restricted than in the Merensky Reef. Local estimation of block grades is not feasible at this stage in the project. Individual block estimates based on the wide-spaced drillhole data are imprecise, and detailed modelling of the grade variation on a block-by-block basis is not possible or necessary at this stage, given the low degrees of lateral variation in grade within these deposits.

SRK has generated global estimates for the grades of the two orebodies using

Simple Kriging in the case of the Merensky Reef and Ordinary Co-kriging of Accumulation and Channel-width in the case of the UG-2. Within the UG-2 these variables show a linear correlation that is honoured by this type of estimation process. The grade models, coupled with structural models deduced from drillholes and remote-sensing data formed the basis of an ongoing mine planning and design process.



**Michael Harley**

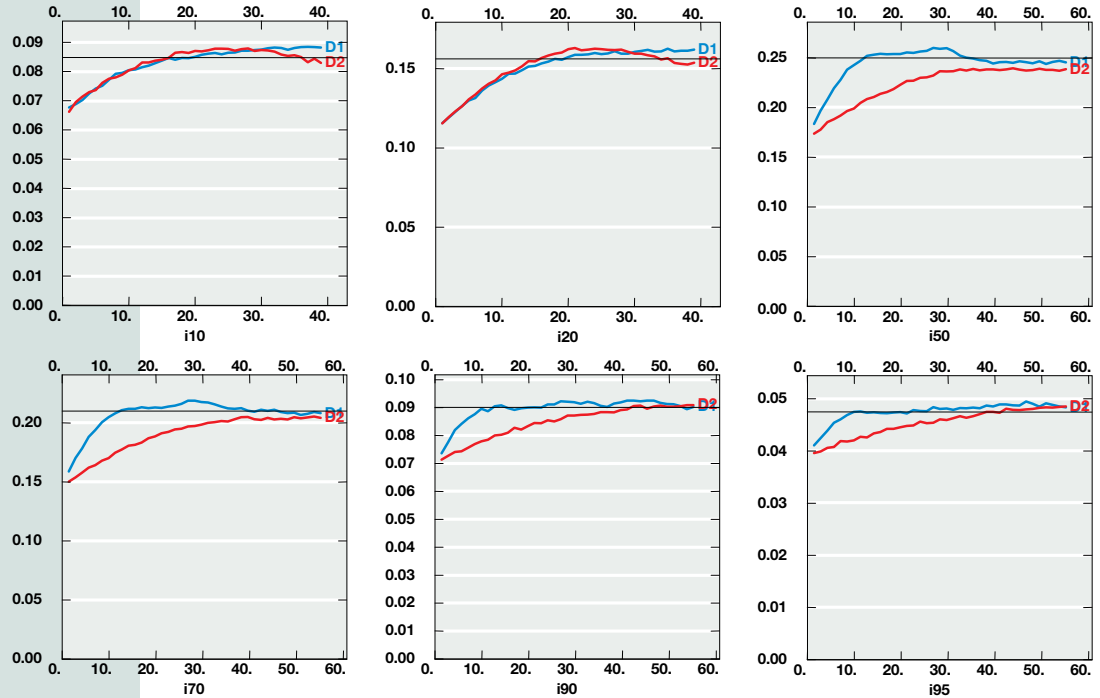


Michael Harley

# Multiple Indicator Kriging: Is It Suited To My Deposit?

**SRK lets  
the geology  
guide the  
choice of  
geostatistics**

*Indicator variograms for a range of cut-offs: If we are to avoid serious order relationship errors, these should all be "proportional", i.e. have the same nugget/sill ratios and ranges. In this and other examples the authors have encountered, such proportionality is not observed.*



Sample grade distributions are often highly skewed, with high nugget effect and/or short range variograms. This is the case for gold, uranium and many other metals.

Consequently, significant deskewing of the histogram and variance reduction occurs when considering blocks rather than samples.

The selective mining unit (SMU) is the minimum size/support upon which ore/waste allocation decisions are practically made. The SMU is normally smaller than the sampling grid dimensions, especially at exploration/feasibility stages.

For many years, geostatisticians have warned against trying to estimate small (SMU) blocks directly, as this distorts the grade tonnage curves and provides a poor basis for mine planning.

Non-linear estimation is the solution to the 'small block problem'. It reduces distortion

of grade-tonnage curves, and provides a better basis for mine planning and economic decision making.

At present, Multiple Indicator Kriging (MIK) is the most widely used technique for performing estimation of recoverable resources. MIK has some potentially serious

limitations:

- It presumes that the indicator variograms at various cut-offs can be modelled independently. In most mineral deposits, this is clearly false.
- It presumes there will be a reasonable approximation if the variograms have very similar shapes, regardless of cut-off.

Again, this is rarely observed.

- The change of support (mainly affine and lognormal) has practical limitations.

Simple tests exist, which allow us to determine the suitability of different estimators for a given deposit. These tests are rarely used in industry, but are well understood by SRK geostatisticians and used routinely.

We let the geology guide the choice of geostatistics. In cases where MIK is not appropriate (which is often the case), SRK have found a simpler ordinary kriging-based method, called Uniform Conditioning (UC), to be faster, very robust and lacking many of the problems highlighted here.



Daniel Guibal



John Vann

# Resource Estimation for Ghanaian Gold Project

Normandy Ghana Gold Limited requested SRK to prepare an independent resource estimate for the Sefwi Belt gold project in Ghana, potentially one of the largest new gold mining operations in West Africa in the next 5 years.

The deposit, as delineated to date, consists of 10 shear zone orebodies situated along a 40 km strike length. Normandy specifically required a team of resource geologists from one consultancy to ensure a consistency of approach.

Key aspects of SRK's work included geological review, 3D computerised structural modelling, statistical and geostatistical analyses, 3D block modelling and reconciliation with previous estimates.



**John Arthur**

Martin Pittuck (UK), John Arthur (UK) and Danny Kentwell (Australasia) spent 5 weeks on site producing geological models for each orebody, taking into account all the interpretive work done by Normandy and check-logging the core where appropriate.

Three months of statistical and geostatistical work was then undertaken in Cardiff during which some 45 geological domains were assessed separately. Michael Humphreys (Australasia) joined the team to assist with the neighbourhood optimisation, variography and Ordinary Kriging. In addition, Inverse Distance 'check' models were

created and at two deposits, MIK check estimations were undertaken.

Once the grade block models were completed, a detailed reconciliation with previous estimates was made. This helped quantify the benefit of the interpretive work done on site to model the geological structures identified in a year-long core re-logging program.

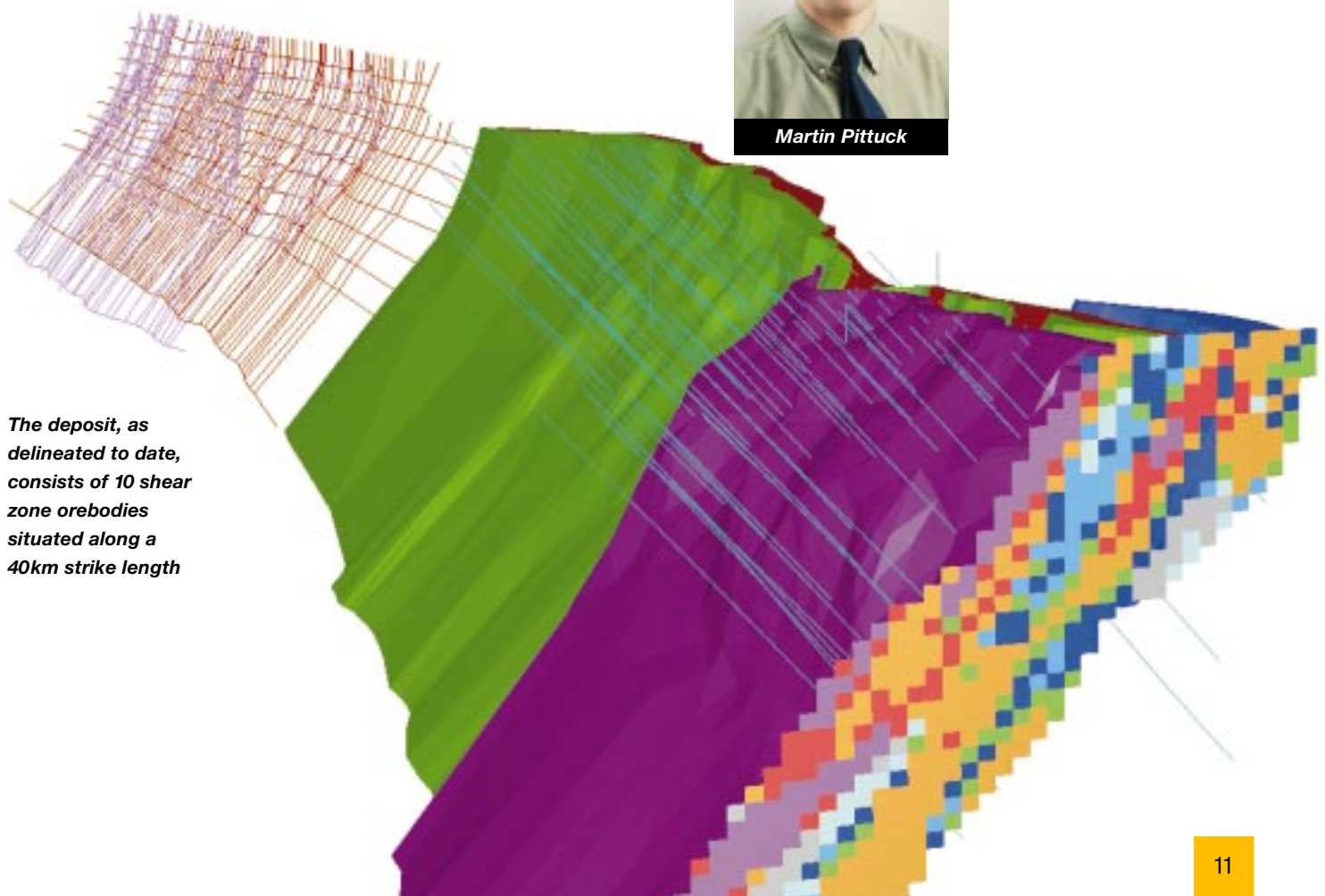
The structures proved to have a significant control on the mineralisation and most importantly, were demonstrated to have good continuity, which allowed resource estimates to be derived with an increased level of confidence.



**Danny Kentwell**



**Martin Pittuck**



**The deposit, as delineated to date, consists of 10 shear zone orebodies situated along a 40km strike length**

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# Are Your Grade-Tonnage Curves Distorted?

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Application of more advanced techniques such as those in non-linear estimation help prevent significant distortion of grade-tonnage curves, which could make the assessment of project economics or other critical decision making riskier than necessary.

Michael Humphreys, Senior Consultant in SRK's Australian practice, explains: "In some cases available data are too sparse to obtain an estimate on the desired block size through linear methods, such as Inverse Distance and Ordinary Kriging, without distorting the grade tonnage curves."

"As the grade continuity deteriorates, distortion is exacerbated. There is ample literature warning strongly against estimation of small blocks by linear methods" Michael adds.

"With non-linear estimation, the proportion of the block above a cut-off

grade is estimated, based on a given selectivity or selective mining unit – SMU.



Michael Humphreys

"Herein lies the solution to the problem of estimating 'small blocks' i.e. units which are considerably smaller than the average drilling grid (say, appreciably less than half the size, though in higher nugget situations, blocks with dimensions of half the drill spacing may be very risky). Though we *cannot* precisely estimate small (SMU-sized)

blocks by direct linear estimation, we *can* estimate the proportion of SMU-sized blocks above a specified cut-off, within a larger panel."

"There are tests that can be carried out to check the quality of estimation (see papers quoted below) and these should be run as standard procedure."

"Non-linear estimation encapsulates the concept of change of support – estimating the histogram of grade for

blocks from what we have on samples. We expect the distribution to deskew as we go from samples to blocks."

The most common non-linear estimation methods are Multiple Indicator Kriging, Median Indicator Kriging, Uniform Conditioning, Disjunctive Kriging, Residual Indicator Kriging, Multigaussian Kriging and Lognormal Kriging. There are tests used for finding the appropriate methodology for a given orebody. These tests are generally based on the correlation of indicator variograms at different cutoffs and should also be run as standard procedure. Conditional Simulation is also being used more and more to present maps of expected grades and probabilities of being above cut-off.

"Non-linear estimation has been around for many years with many published papers including a number by members of SRK's geostatistics team." Michael concludes. "It has become an essential tool in resource estimation for advanced geostatistical practitioners."

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## Identifying “Mines Within a Deposit” in West Africa

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**Staff of SRK Consulting and High River Gold Mines examining surface trenching program at the Taparko Gold Project**

**W**ith the recent advancement in extraction technology and cost efficient mining methods, there has been a tendency to focus on large, low grade deposits. However, some deposits present an opportunity to selectively extract and process a higher grade portion, thereby improving the overall economic viability.

SRK, as part of a feasibility study, identified the Taparko deposit as being one such deposit. This orebody, estimated to contain in excess of 1-million ounces of gold, is an advanced project operated by High River Gold Mines Ltd.

The Taparko project is underlain by predominately Lower Proterozoic, Birimian metavolcanic and meta-volcaniclastic rocks. Gold mineralization of the GT, 3 and 5 zones is hosted within a north to northwest trending broad shear zone (Taparko shear).

“Our detailed structural analysis revealed that the highest gold grades are associated with quartz veins that are localized in dilational jogs forming plunging high grade shoots within a broad, low grade, halo of the Taparko shear zone,” reports Michael Michaud, Senior Resource Geologist.

“Hydrothermal fluids and gold mineralization were focused within these dilational structures. This understanding of the gold distribution made it possible to define the geometry, grade distribution and physical characteristics of the deposit to be used as a foundation for the resource estimate.”

“Based on this estimate, we were able to choose a mining and processing scenario which would optimize the resource and provide a longer life project.”

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## SRK Opens Office in Toronto

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**SRK** Consulting has opened a Toronto office and formed an association with long-time local consultant David G Wahl of Southampton Associates to assist in the growth of the fledgling practice.

Coordinator of the initiative is Michael Michaud, formerly of the SRK Vancouver office. Michael is highly regarded for his due diligence and resource/reserve estimation abilities. Before joining SRK in 1996, Michael was chief geologist at the Lac des Iles PGE mine in Ontario.

Contact details for the new office are:

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**Audits require technical knowledge & experience of the audit process itself**

## Auditing Resource Estimates for Project Finance and Stock Exchange Listing

**SRK** has developed considerable global expertise in the auditing of resource estimates for project finance and stock exchange listings.

These assessments are usually one part of an overall project audit, the end result of which is the derivation of an audited technical-economic life of mine plan and annual cashflow projection. It is this cashflow projection that subsequently drives the loan agreement and project or company valuation.

“Undertaking audits requires not only technical knowledge and experience but also experience of the audit process



**Richard Clayton**

itself,” explains Richard Clayton of the UK office. “It is the assessment of the achievability of the predicted mined and milled tonnes and grade presented in the life of mine plan which is key to these audits rather than a detailed critique of the estimation methodology.”

It is critical to identify key areas of risk and assess how the resource estimation process used deals with these, together with the likely impacts of alternative approaches.

Critical areas usually include geological continuity, grade interpolation, density determination and resource classification.

The approach to the audit is also dependent on the purpose. Project finance audits should err on the side of conservatism as the banks require technically robust cashflows for use as the basis for interest calculations and repayment schedules. Listing documents, on the other hand, need to inform shareholders equally well of any upside potential.

“Understanding that the resource audit is part of an overall project audit is important,” Richard concludes. “Use of balanced, experienced teams ensures that the various disciplines work together to the same plan and understand the impacts of other disciplines on their aspect of the audit.”

## SRK Offices Join Forces for Lateritic Deposit Evaluations



**Andrew Vigar**

**SRK’s** Brisbane, Perth and Denver offices have pooled their considerable resources to successfully complete geological and mining evaluations of lateritic mineral deposits for a number of high-profile clients.

Projects over the past 2 years cover the full range, from remote sensing techniques deployed in early exploration for suitable geological terrains on a regional scale, through to feasibility studies and due diligence audits for mining clients and financial institutions. Deposit types include bauxite and both wet and dry nickel laterites.

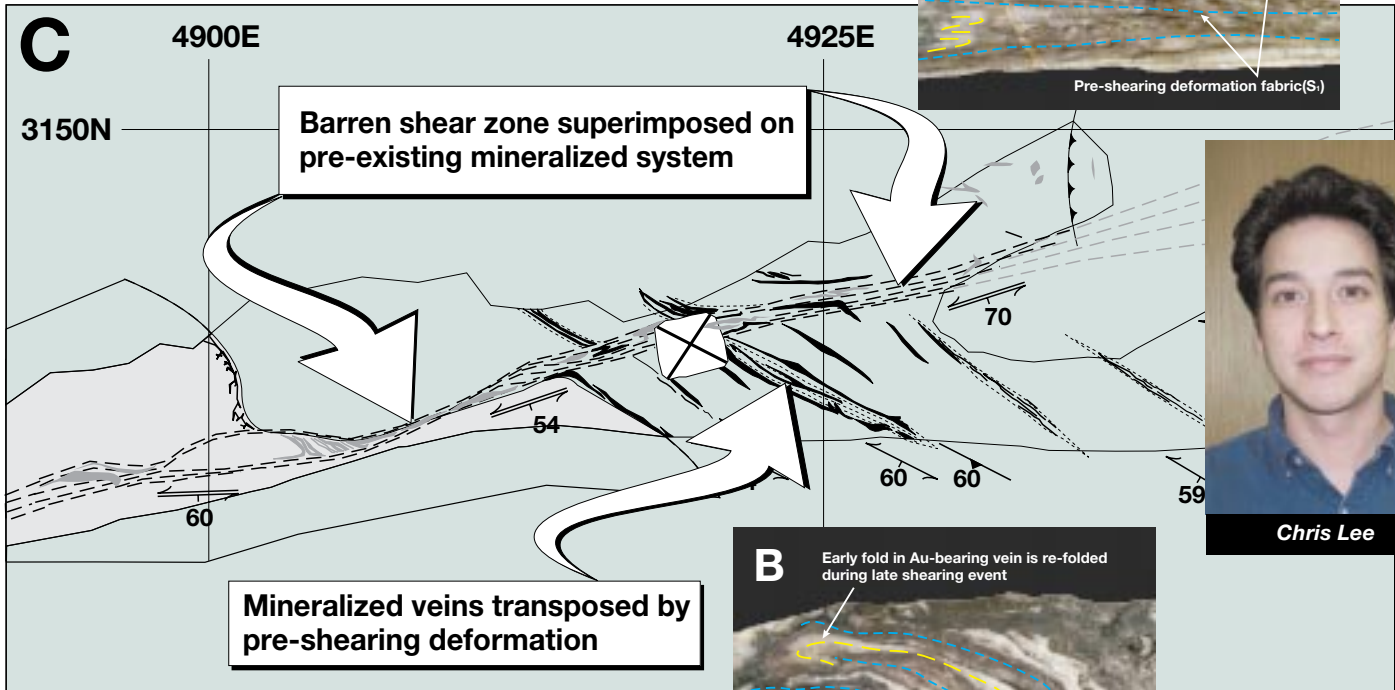
Client	Project Name	Commodity	Commission
Anaconda Nickel	Cawse	Nickel	Pre feasibility
Comalco	Weipa	Bauxite	Geostatistics, Resources & Grade Control
Falconbridge	Confidential	Nickel	Exploration
INCO	Goro	Nickel	Feasibility study
Pechiney	Project Sun	Bauxite	Due diligence
Highlands Pacific	Ramu Nickel	Nickel	Feasibility study

### *Selection of evaluations of lateritic mineral deposits undertaken over the last 2 years*

“Based on our wide-ranging experience, we believe we have a uniquely nuanced understanding and appreciation of the complexities of laterite geology, resource

estimation and mine development considerations,” comments Andrew J Vigar, Associate Principal Resource Geologist, Brisbane.

# Grade Control: Getting it right...



**A**lmost every deposit has unique features that control the mineralization. “Hydrothermal mineralizing systems, in particular, are generally long-lived and protracted events, which commonly result in the overprinting of both mineralized and barren systems within a single deposit.” says Chris Lee, Structural Geologist, SRK Vancouver.

Misidentification of the structural conduits, active during the critical mineralizing stage, can therefore lead to debilitating errors in resource estimation and grade control. The example provided here, from an unnamed ‘shear zone-hosted’ lode gold deposit, illustrates the critical importance of understanding the timing and structure of a mineralizing event, to getting the resource model right.

In this example, resource estimation and stope development both relied on the assumption that, as in most other shear zone-hosted lode gold deposits, the main

shear structure acted as the primary control on gold bearing veins, and thus grade distribution. However, detailed observations of fabric-vein relationships (e.g. A & B) show that the mineralized veins actually *pre-date* the deformation associated with the principal shear zone. The mineralization is therefore governed, *NOT by the principal structure*, but by the architecture of an earlier vein emplacement event that was modified during subsequent deformation. In less-deformed regions (e.g. C), it can be seen that the geometry of the mineralized vein system bears little resemblance to that of the main shear zone. This oversight led to a number of problems during the mining stage, including: *delayed production*, as production stopes had to be locally modified to incorporate the unexpected

geometries, and *excessive dilution*, since the main target of the mine was essentially a

barren structure, where it did not intersect the earlier vein system.

The lesson to be learned is that key geological controls are not always what they appear to be at first glance, and that a rigorous geological analysis, at the earliest possible stages of a project, is critical to its success. The error made here lay in the assumption that all deposits within a certain deposit class can be treated with the same resource model and estimation techniques. Detailed structural geology, unencumbered by model-driven deposit characterization, can therefore provide the key insights that will add confidence and value to every subsequent stage of resource evaluation and ore production.



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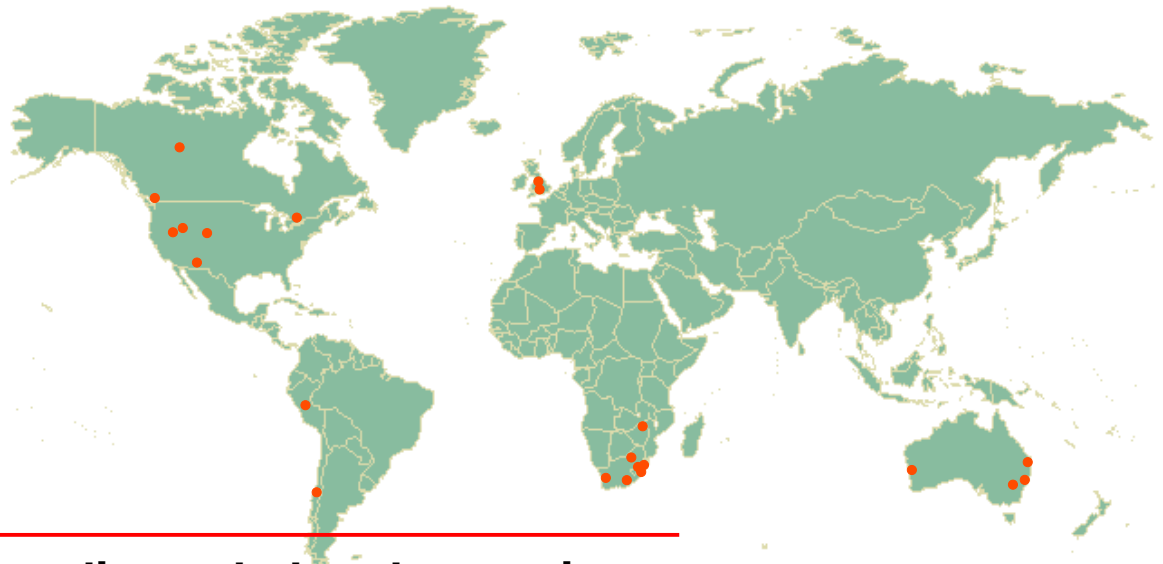
## SRK consultant profile: Chris Lee

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**C**hris Lee joined SRK Vancouver's Mining and Geology group in February 2000. Chris is a broad based, classical geologist, who recently specialized in the structural geology and genesis of lode gold deposits for his PhD dissertation. With more than 10 years experience in structural geology, tectonics, and ore deposit research, his skills are equally well-suited to a wide range of SRK projects, from grassroots exploration, through resource estimation and geotechnical risk assessment, to

characterization of contaminant pathways in groundwater studies.

Together with Cam McCuaig and Jun Cowan (SRK Perth), Chris is a semi-finalist in the "Goldcorp Challenge" – a global competition for exploration and mine geologists (for details, see: [www.goldcorpchallenge.com/homepage\\_static.html](http://www.goldcorpchallenge.com/homepage_static.html)), and is currently awaiting announcement of the top 3 finalists, with judging based upon their geological models and proposed targets.



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**For more information, contact us at: [www.srk.com](http://www.srk.com)**

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**Issue No. 27**  
**Feb 2001**

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