



## Mining for diamonds worldwide

photo: courtesy of De Beers

The Arctic of Northern Canada and Siberia, the jungles of Africa and South America, and the deserts of Southern Africa and Australia: these are the locations of today's diamond mines.

Diamonds are being recovered from primary deposits such as kimberlite and lamproite pipes and dykes but also from alluvial gravels and seabeds. From exploration to mine closure, the variability facing today's diamond miner almost certainly exceeds that which is faced by the producer of any other commodity.

The diamond itself – the simplicity of the chemical composition – contrasts sharply with the complexity of assessing the diamond's value; the price for a single-carat stone could vary in value by an order of magnitude depending on quality and market.

Then there is the variation of the kimberlite host rocks and pipe geology. Kimberlite can be as tough as granite or as weak as soil; the strength can alter significantly with short exposure to moisture.

The process of identifying a valuable deposit and estimating that value is unique to diamonds; large samples might be required to get a reliable estimate; size, color and quality are all critical. Many of the statistical and geostatistical methods used for other minerals might not be appropriate.

Mining methods are as variable and complex as the product itself. Very few mining methods have not been used, from large

open pits and caves, to narrow vein methods and state-of-the-art deep-sea mining.

The political, social and economic responsibilities placed on most diamond producers require extensive and complex impact assessment studies before mines can go into production. The requirements of various regions, provinces and countries make the permitting process very complex.

Profitable and safe mining of diamonds is very complex and challenging. However, these complications and challenges can be overcome using knowledge and experience from a range of disciplines.

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Jarek Jakubec

## Geology and diamond projects

It is not uncommon to discover significant gaps in understanding the nature of the deposit during the later stages of projects. In many cases such gaps result in development delays and cost overruns. Such “surprises” could be avoided if geological investigations are integrated into all levels of project development.

In the early stages often the geological data is limited to the resource model and very little is known about the country rock geology or pipe contact zones. In order to reduce the risk of selecting the “wrong” mining method or raising “unrealistic” expectations for the particular mine design, it is important to understand all aspects of geology, such as regional structural geology, kimberlite pipe as well as country rock geology.

Structural geology is fundamental. In the Canadian Arctic, where many kimberlites are being discovered under the lakes, understanding of structures can have a major impact on the mining concept and strategy.

The pipe emplacement mechanism could influence pipe size and geometry, internal structures, rock mass competency and the character of the pipe contact zones. All these parameters could directly affect pit wall stability, underground mining method selection, dilution, treatment plant process, or dewatering strategies.

The petrology and mineralogy model could be crucial to factors in a diamond resource estimate but also in diamond damage and liberation, slope stability of the pit wall and underground excavation, support design, mine safety (mudrush risk assessment), mine dewatering and environmental issues. Characterizing the clay provides important clues to the

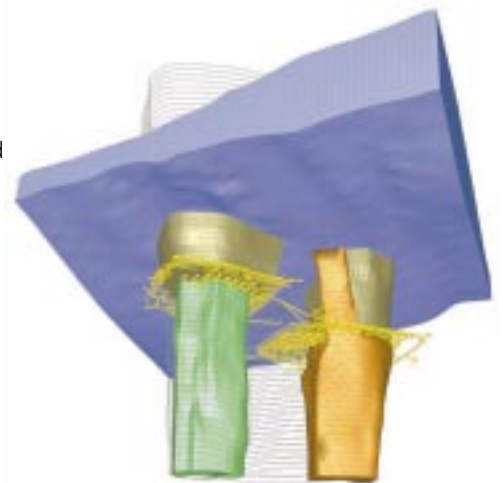
weathering susceptibility of the kimberlite rock types.

The knowledge of country rock geology is at least as important as the geology of the kimberlite pipe. Pit slopes, underground access development and mining infrastructure are mainly located in the country rocks. Often, during the kimberlite delineation program, holes are terminated as soon as they leave kimberlite. This can and does lead to erroneous interpretations of pipe geometry because the assumed “country rock contact” is only a country rock xenolith.

For a mining operation to be successful, it must bring fundamental and applied science together. The mining engineer must understand the importance of geology, mineralogy and petrography and the geological scientists must be familiar with project development from the exploration stage through mine design and operation to mine closure.

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**3D visualization of pipe geology helps with fundamental decisions on mining strategy and layout**



# Contribution of structural geology



Chris Lee

In most mineral systems, applied structural geology is about understanding “pathways.” Pathways include the crustal scale plumbing systems that facilitate the emplacement of kimberlitic magmas, as well as the pipe scale fault/fracture networks that control groundwater flow and alteration during and after emplacement. Understanding these pathways can profoundly affect the success of diamond projects at all stages.

Today’s common diamond exploration tools consist primarily of airborne geophysics and quaternary geology (soil sampling). In many cases, both techniques – whether used together or in isolation – have proven to be highly successful means of locating kimberlites and diamonds. However, where kimberlites have no distinct magnetic signature or traceable dispersion train, understanding the crustal architecture and its structural-kinematic evolution can provide valuable insights into their location and distribution. Using existing aeromagnetic data, crustal scale geology and the tectonic history of a given area, structural analysis can help identify favourable sites for pipe emplacement.

Effective management of ground stability and groundwater issues are two critical elements underpinning the success of any mining operation. Structural analysis of faults and fracture systems outside and within the kimberlite can help predict zones of instability and groundwater risk. Groundwater flow is not only an immediate impediment to development, it can also lead to progressive weakening of the groundwater pathways over time. Structural geology is an important tool in

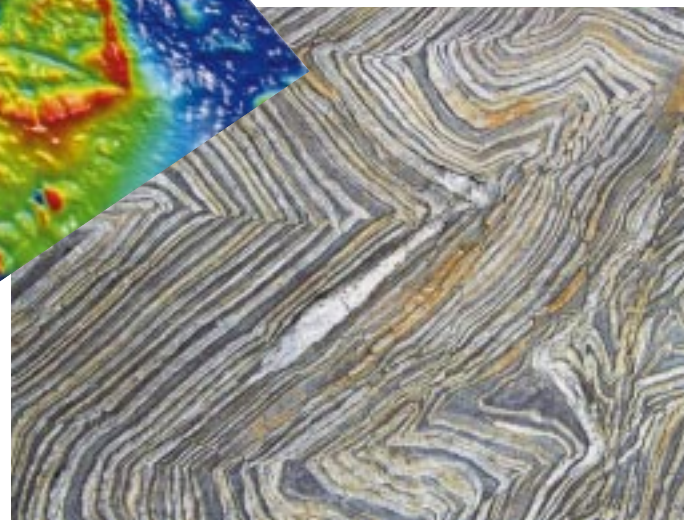
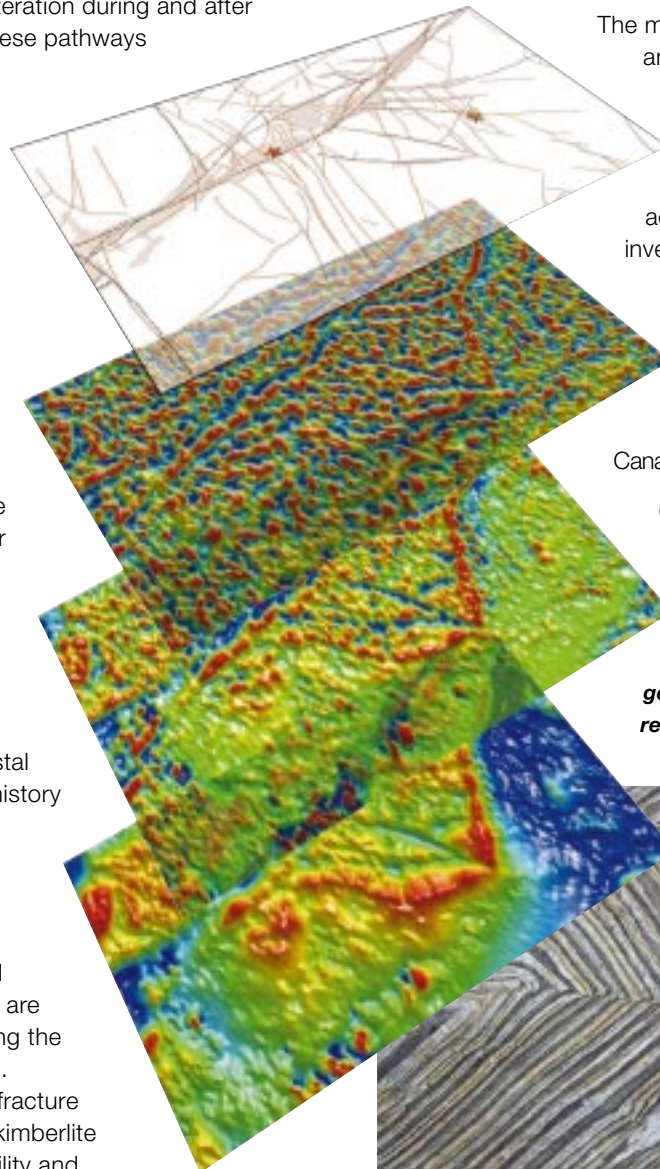
the early stages of mine design, mine planning and mine safety, and its application to groundwater studies further extends its relevance for mine closure and remediation.

The maximum benefit of structural analysis is realized when it is introduced early, during the initial assessment stages of a project, when it can be used to considerable advantage in focusing subsequent investigations, and thereby saving significant amounts of both time and money.

Structural interpretations have been successfully conducted by SRK on several Canadian diamond projects.

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***Successive filtering of geophysical data, combined with geological knowledge, results in a reliable structural geology image.***



***Understanding micro structures often provides insights to large-scale structural geology***

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## Unique aspects of waste rock management

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Open pit diamond mines typically have high stripping ratios and therefore result in generation of large volumes of waste rock. As a result of experience at other types of mines throughout the world, the expectation from regulators and the general public is that the waste rock can generate severe environmental impacts through oxidation of sulphide minerals, the worst result of which can be acid rock drainage (ARD).

SRK's Vancouver office has been involved in pre-mine and operational geochemical characterization of waste rock at several new diamond mines in Canada (Ekati Diamond Mine,<sup>™</sup> Diavik<sup>™</sup> Diamond Mines Inc., Jericho Project and Victor Project), and is at the forefront of demonstrating to stakeholders in the mine permitting process the importance of understanding the geochemistry, mineralogy and geological model for emplacement of kimberlite, and how these features affect the long term chemical stability of the waste rock and tailings. Some important features that distinguish waste rock and

tailings at diamond mines from waste rock and tailings at metal mines are described as follows:

- Kimberlite pipes are emplaced rapidly at relatively low temperatures. Unlike most metal deposits, this results in little, if any, alteration of the surrounding country rock. Unless these rocks are mineralized as a result of another process, the sulphide minerals that can have negative environmental impacts are typically very rare.
- Kimberlite itself is comprised of a complex suite of mantle-derived magnesium silicate minerals along with carbonate minerals. Sulphide minerals are often present in trace amounts, and are more likely to be associated with the country rock entrained in the kimberlite during emplacement, or by collapse of the crater. Due to the relatively high amount of carbonate and low amounts of sulphide, kimberlite ore and tailings are not likely to generate ARD.



**Kelly Sexsmith**

- Natural high weathering susceptibility of many kimberlites (a combination of physical and chemical degradation) leads to rapid exposure of any sulphide

minerals present in the rock, and consequently rapid rates of sulphide oxidation. The presence of magnesium in the rock supports high sulphate concentrations possibly resulting in a need to manage elevated total dissolved solids (TDS) in seepage and runoff.

An understanding of these properties is the key to developing waste rock management plans that meet the specific needs of the diamond mining industry.

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**General view of Panda open pit at the Ekati Diamond Mine<sup>™</sup> with waste rock storage area on the right**



## Kimberlite weathering – complex issues



Jarek Jakubec

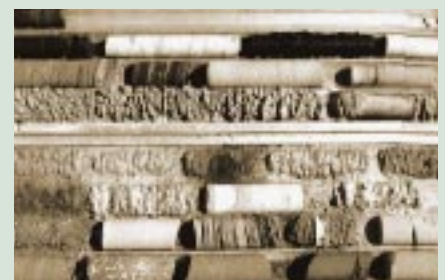
## Indicator testing of kimberlite weathering

**SRK** is using a simple qualitative “accelerated” weathering test to establish the degree of weathering of various kimberlites. The core or rock lump specimens are subjected to wetting and drying cycles and the deterioration of the core after each cycle is documented and photographed. The results are then compared to known kimberlites from other mining projects, which allows the impact on slope design or support requirements to be assessed. The two photos below show the extent of the deterioration of various kimberlitic rock types after several wetting and drying cycles. Note that some kimberlites completely disintegrated while others stayed intact. Although the test does not provide quantitative results, it can be performed on site, quickly and on large quantities of samples.

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**The kimberlite core samples above are shown below after only 3 wetting and drying cycles – many with extensive deterioration**



### **Kimberlite weathering can cause rapid pit slope deterioration**

“It is not a rock” somebody at a diamond mine said about kimberlite. Of course, technically speaking, he was not right, but sometimes I wonder if we really are dealing with rocks. The physical properties of kimberlite can be extremely variable and geotechnical issues of the kimberlite pipes very complex. Failure to characterize such issues could have significant consequences for mining projects.

One of the fundamental geotechnical issues to consider in selecting the mining method and design is the strength and deformation characteristic of the rock mass in which mining takes place. Not only can various kimberlite rock types have variable properties, such properties can change rapidly with time. Most kimberlites fall into the category of weak to moderately strong rocks. In the context of mine design this would not pose a challenge. The problem arises if kimberlite loses strength within days of exposure.

This can happen if the “wrong” clays are

present in the rock matrix. If clays from the smectite group are exposed to moisture or – even worse – to wet and dry cycles, they swell and disintegrate the rock matrix, dramatically reducing the strength of the rock mass. The stability of excavations, supportability of the rock mass, and trafficability are all in jeopardy. To combat kimberlite deterioration many underground diamond operations apply sealant to prevent moisture from entering the exposed rock. Failure to do so can result in rapid tunnel deterioration. Preventing kimberlite weathering could pose particular challenges in the Arctic where low temperatures or condensation could prevent effective application of most sealants.

It is important, therefore, to characterize the weathering susceptibility of the various kimberlite rock types in the early stages so these factors can be built into the mine design to forestall a “surprise” during the development.

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## Coarse kimberlite rejects at Ekati Diamond Mine™

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The environmental effects of weathering and leaching of kimberlite recently came under the microscope with the successful development of diamond mines in northern Canada. BHP Billiton and Diavik™ Diamond Mines Inc. (a subsidiary of Rio Tinto) operate mines located in a pristine arctic wilderness area where lake water is exceptionally pure and highly sensitive to impacts. SRK's Vancouver office is involved in the environmental assessment, permitting and development of these mines.

At BHP Billiton's Ekati Diamond Mine,™ SRK geochemists Stephen Day and Kelly Sexsmith worked closely with mine staff to evaluate the unusual weathering behaviour of coarse kimberlite rejects

(CKR) – the fine gravel-sized material that results from processing kimberlite. In 1999, routine monitoring of shallow pools along the toe of the CKR pile showed that drainage from the pile resembled acid rock drainage, even though testing of the CKR had clearly shown that the potential for acid generation was negligible. The drainage was also quite different from process water entrained in the CKR.

Identifying the source of elevated concentrations of the total dissolved solids in the water was a high priority. BHP Billiton's engineers design waste management plans, and the company had applied for permits to mine several new kimberlite pipes in the area.

Through detailed investigations, SRK and BHP Billiton have determined that CKR are leached by contact with natural, strongly-acidic soils. To counteract this, BHP Billiton now designs its waste kimberlite storage areas so that the foundation does not come in contact with acidic soils, and so that the extremely cold conditions in the region are harnessed to freeze the soils.

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**Stephen Day**

*SRK's Kelly Sexsmith sampling seepage from coarse kimberlite rejects at the Ekati Diamond Mine™*



# Diamond resource estimation



The estimation of the resource content in kimberlite pipes – primary host rocks for diamonds – entails a number of aspects that are unusual, compared with the resource estimation for other minerals. Diamonds occur as discrete particles, each with its own size and quality. Combination of highly variable values per unit-weight and relatively low occurrence makes sampling and resource estimation very complex.

In kimberlite, diamond sizes range from dust-size particles to diamonds larger than 100 carats per stone. The real value of diamonds lies in particles larger than approximately 0.1 carat per stone; smaller diamonds are normally not recovered. The diamond recovery is related to the characteristics of the treatment facility in terms of cut-sizes, crushing sizes and re-crush sizes, and these characteristics are often different in a sampling treatment plant, a bulk-test treatment plant and a production treatment plant.

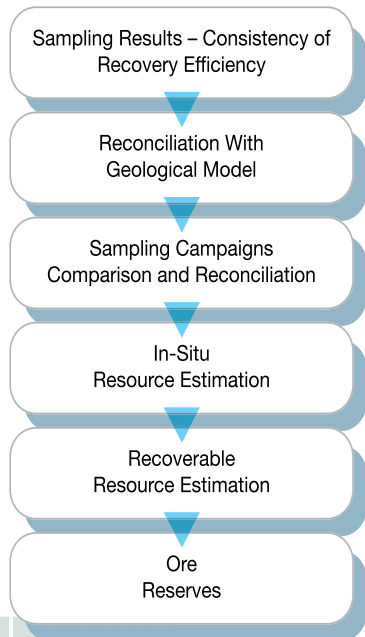
Diamond-size frequency analysis is an important tool that helps compare the recovery in different treatment plants and relates it to revenue obtained. The diamond-size frequency is normally obtained by sieving the diamonds on round aperture sieves. The tools used for interpreting diamond-size frequencies are cumulative carat plots on logarithmic probability paper. The distribution of diamonds in kimberlite is close to log-normal and a plot on logarithmic probability paper shows as a straight line. Deviations can signify recovery efficiency problems. Another graph of grade-by-size plots can be used to compare treatment plants and to check for recovery efficiency.

Another aspect of diamond resource estimation is diamond value. The value of individual diamonds can range from a few US\$ per carat to

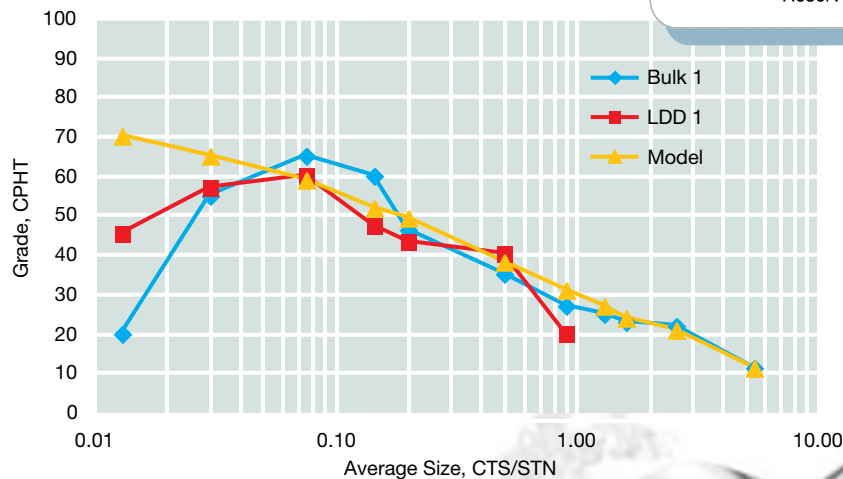
over US\$10,000 per carat. Normally a parcel in the order of 5,000 carats is required and a valuation-per-size class is requested for valuation. This information is used to model the value per size class and this information together with the expected diamond size frequency during production is used to estimate revenue.

Knowledge of statistical and geostatistical methods combined with sound practical experience is essential for realistic in-situ estimates. To correctly evaluate the recoverable resource, the geology, mining method and process plant type has to be taken into the equation. Jarek Jakubec and Mike Michaud from SRK Canada are working closely with Tinus Oosterveld, the world's leading authority on diamond resource evaluation, on resource estimates for a North American client.

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Diamond Recovery Model



**Bulk sampling gives a better representation of larger stones.**

**Large Diameter Drillhole (LDD) provides a better sample throughout the entire orebody, but a limited representation of larger stones.**

**The most accurate model is based on a combination of both methods.**



photo: courtesy of De Beers

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## Permafrost and mining

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**W**hile the impact of permafrost on soil stability is well documented, there is a relative shortage of information in the public domain dealing with open-pit or underground mine design criteria for orebodies located in permafrost. SRK Canada has been involved in several mining projects situated in the high Arctic where the issue of permafrost had to be evaluated.

The Nanisivik underground mine is located in Nunavut on northern Baffin Island approximately 750 kilometers north of the Arctic Circle. The lead/zinc/silver orebody was mined partly as a room and pillar operation. SRK helped to develop a mine layout that would take the strengthening effect of permafrost on the rock mass into account.

Open-pit diamond mines located in Siberia also illustrate the impact of permafrost on the rock mass. Most of the open-pit slopes are steeper than those located in “warmer” climates. Although good blasting practices are still required some of the pits could achieve slope angles of 60 degrees and more.

Clearly the effect of permafrost needs to be taken into consideration when designing an open-pit or underground mine. The economic benefit, however, cannot jeopardize safety, which should be the highest priority of the mining project.

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## Diamond mining in an Arctic context

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*Steep slopes of Aikhal diamond mine are only feasible because of permafrost.*

**C**anada's SRK team is involved in development of diamond projects in the Arctic for several reasons. These include experience with kimberlite mining in Southern Africa and Russia, worldwide experience with caving and non-backfill methods typical for underground diamond operations, and extensive experience with operations in the far North.

Primary diamond resources in the Arctic are mainly associated with kimberlites. Kimberlite rocks are known for the variability of their geological, chemical and physical properties that distinguish them from other rocks encountered in underground operations. Kimberlites can weather extremely rapidly (some operations must proceed without water); they can “absorb” blasts that make them difficult to break; they can be extremely

weak. A number of mining challenges must be faced in the mine design. But most important the differences in rock mass must be recognized and carefully assessed. Add the harsh Arctic environment and the location of most diamond-bearing pipes under lakes and you have some idea of the complexity of the mining difficulty.

SRK's experience with Arctic diamond projects includes:

The Snap Lake project. The first diamond project to mine a shallow-dipping, diamond-bearing kimberlite dyke on a large scale. Most diamonds mined from primary sources have come from kimberlite pipes; kimberlite dyke mining in South Africa is limited, such dykes dip steeply and the operations are



## Diamond mining expert: Jarek Jakubec

Jarek Jakubec, principal engineer with SRK Canada, is based in the Vancouver office. He has more than 18 years of operational and consulting experience in geology, rock mechanics and mining; his personal focus areas are block caving and diamond mining.

After spending eight years in geology and mining in Europe and Canada, Jarek joined De Beers Consolidated Mines in South Africa in the capacity of senior geotechnical engineer. Soon he moved to Botswana, where he was given responsibility for leading the Geotechnical Section for large open-pit diamond mines. "Botswana produces approximately one-third of the world's diamonds by value," says Jarek. "And it was exciting to be involved with such an important diamond producer." Besides geotechnical engineering, he was also involved in the geological modelling of diamond pipes and participated on several research studies, such as kimberlite weathering effects on mine design.

Jarek joined the SRK office in Vancouver in 1997 and started actively promoting consulting services for the diamond industry. He has been involved in a wide variety of underground and open-pit projects, as well as several training programs for clients' geotechnical and engineering staff. His wide experience with mining diamonds led to his being chosen as project manager on the feasibility study for the Jericho Diamond project in Northern Canada. He has also participated in diamond resource evaluation, with Tinus Oosterveld, the world's leading authority in the field.

Over much of his professional career, Jarek has had the opportunity to work on exciting diamond projects; this has allowed him to visit most of the diamond producing mines around the globe, including those in Siberia, southern Africa, Brazil, Australia, and Canada.

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### cause of permafrost conditions and good blasting practices

small-scale. The Snap Lake dyke in the Canadian Arctic is located mostly under a large lake at depths ranging from 100m to 500m.

The Jericho project. A comparatively small kimberlite pipe on dry land, Jericho is located in permafrost, which, in fact, may produce better ground conditions. It will start as an open pit and convert to "open benching" at depth.

The Victor project. Victor pipe already presents some complex issues for mining in the North; extensive dewatering is required and some challenging materials must be excavated from this large open-pit operation.

The Ekati Diamond Mine™ operations. Includes several underground projects for

BHP Billiton. Most of these projects are open pits converting to underground as the strip ratio increases. Many are likely to be mined by non-backfill methods, a major departure from typical operations in Canada. Plans for the Ekati Diamond Mine™ are well advanced; their first underground operation at Koala North uses the "open benching" mining method.

Underground operations in kimberlites present challenges that can be managed as long as the technical concerns are recognized and evaluated correctly.

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## Diamond mining at great depth

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**P**remier Mine near Pretoria, South Africa, produced the world's largest diamond gem – the famous Cullinan – which weighed 3,106 carats. Since operation started in 1902, more than 113 million carats of diamonds have been mined.

The current plan is to replace existing production with operations at deeper levels through two new vertical shafts that will provide ore to a new treatment facility built on the surface. This would significantly increase the processed tonnage. The extension would take mine workings down to more than 1,000m below the surface. That would make it one of the deepest underground diamond mines in the world.

SRK Consulting is part of the multidisciplinary team that is helping De Beers with its geotechnical and hydrogeological investigation for the Premier Centenary Cut project. Jarek Jakubec from the Vancouver office and Fred Harvey from the Johannesburg office are working along with experts from the HClTasca consulting

group. Dr. Dennis Laubscher, the world's leading expert on block caving, is also involved in the mining aspect of the project.

Underground mapping and additional drilling data provided a basis for the comprehensive rock mass characterization and geotechnical assessment. Based on this assessment a 3D geotechnical domain model was built in Gemcom software.

The model was then converted to a block model to set up the FLAC numerical model. Calibrating the numerical model to existing conditions will help us understand rock mass behavior at greater depths. The model can then be used to simulate different mining scenarios and layouts.

Correct assessment of the stress conditions for the various strategies will be critical for the successful development of the undercut and production horizons. Knowledge of the water regime is important, not only from the operational point of view but also to investigate the potential risk of mudrush and support deterioration.

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***Dr Loren Lorig (Itasca), Alan Guest (De Beers), Jarek Jakubec (SRK) and Dr Denis Laubscher – members of the multidisciplinary team for the Premier Centenary Cut project***



***Premier is one of the deepest diamond mines in the world***



## SRK Australasia and the Argyle diamond mine



*The Argyle mine yields more diamonds than any other mine in the world - 30 million carats/annum*

**A**rgyle Diamond Mines Pty. Ltd. own and operate an open-pit diamond mine in the Kimberley Region of northern Western Australia. The AK1 ore body consists of a volcanic intrusion of Lamproitic tuff and magmatic Lamproite. SRK Consulting was commissioned to undertake a pre-feasibility study to assess the economic viability of extraction of the orebody by underground caving methods.

Studies were first undertaken to gain an understanding of the geotechnical characteristics of the ore, the surrounding rockmass cavability and ultimate fragmentation during caving. The study then investigated alternate mining, material handling and ventilation options. As a part of the study, SRK were also asked to

review mass stoping methods for the footwall of the AK1 resource, to undertake a study into mining of the Southern Tail resource by underground stoping methods and then develop it to the detailed engineering stage.

Several mining scenarios were developed and evaluated involving sublevel caving, block caving and a combination of both mining methods. The individual scenarios also included various ore delivery options, such as staged and trim lift conveyor and shaft.

With SRK's help two options were selected for full feasibility study, which is scheduled for completion in 2004. It was also decided that an early exploration decline should be developed to allow

access into the AK1 orebody at depth. SRK has provided all engineering design input to a detailed engineering level.

Unlike the diamond projects in the Canadian Arctic, the AK1 orebody will face many ventilation challenges as a result of heat load from groundwater and impact of extreme tropical climate conditions. The ambient air temperature and humidity levels at Argyle are high and cooling of the air before circulation underground will be essential.

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**Campbell Baird**

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## SRK works with De Beers in Botswana

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The Orapa diamond mine is located in central Botswana, approximately 220km west of Francistown. The climate is semi-arid; temperatures range from above 45°C in summer to below 0° at night in winter, while the annual rainfall averages less than 450mm. The morphology of the surrounding area is flat, apart from a few low hills and ridges; it supports low savannah-type vegetation.

The A/K1 kimberlite pipe, with a surface area of 118ha, is the largest of a group of more than 60 known kimberlites in the area. Included among these are Orapa A/K2 and Lethakane D/K1 and D/K2 pipes. Like A/K1, they are mined for diamonds.

Orapa A/K1 kimberlite was discovered in 1967, and since 1971, more than 121 million carats have been extracted. The bottom of the open pit currently lies 150m below the surface, at 810m above mean sea level. To date, all mining faces of Cut 1 are confined within the kimberlite pipe boundary. The plan is to exploit the Orapa pipe by the open-cast mining method until 2030, increasing the rate of production as number 2 plant is commissioned. Ultimately, the pit depth will extend more than 500m below surface.



For such a large pit, the slope angle design has enormous economic consequences. As a result, every aspect affecting the open pit must be examined to minimize the stripping ratio and meet safety requirements.

SRK has worked on the slope design and optimization at Orapa for 20 years and is currently evaluating the effect of weathering on mudstones in the pits and the need to pre-treat them to achieve steeper overall angles and save on stripping costs.

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*Orapa A/K1 diamond open pit is located in a semi-arid region of Central Botswana*



## SRK Offshore



*Undersea mining unit used to extract sediments from the sea floor*



Since 1998 SRK has been developing methodologies for the exploration, evaluation and exploitation of offshore diamonds. To aid exploration we have identified eight different types of “feature,” which can be detected by geophysical survey. On the continental shelf off South Africa and Namibia, sediment-filled depressions on the sea floor bedrock are known to contain diamonds and range from open basins to narrow channels and gullies. Each feature is assigned a prospectivity rating based on its proximity to diamond source, the ease of transport and potential for entrapment, concentration and preservation of diamonds. The rating also reflects operating experience and the presence of positive sampling results. Prospectivity may be downgraded if water and sediment depths fall outside acceptable ranges for current mining techniques. This classification system led naturally to the development of a sampling strategy for each feature type.

SRK uses the prospectivity rating and the success rates of exploration and exploitation programs to estimate the resource potential of each feature type and the global potential for all the licence areas held. The rating only indicates the potential value of the licence areas, not the resources from which mineable reserves could be determined.

Developing a resource evaluation methodology, which relies on a strong understanding of geology, was SRK’s next goal. We selected one that company geologists could use with current stand-alone software and without the need for a deep understanding of statistical theory. The method identifies “negative” sample information reflecting the margins of diamondiferous sediments, the apparent lack of internal continuity of grade (reflecting sample size) and “technical failures.” Once these technical failures are removed, we estimate the planar grade

(cts/m<sup>2</sup>) by using indicator kriging to determine the probability of zero values and then combine the results with kriged planar grades. Block modelling was constrained within digitized areas, whose limits were defined by sampling with the Wirth drill and Vibrocorer, and through geological interpretation based on comprehensive geophysical data.

The method proved very successful in predicting the distribution and grade of potentially economically viable diamond concentrations without resorting to statistical methods remote from geology. Failure to take valid zero grades into account in the past had produced misleading resource estimates, particularly for deposits considered economically marginal using current mining technology.

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## Due diligence at Archangel, Russia

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**SRK**, assisted by a representative from Société Générale de Surveillance S.A. (SGS), took on due diligence of drilling, drill core sampling, processing and



**Mike Armitage**

diamond recovery at a diamondiferous kimberlite pipe in northwest Russia.

The pipe, located about 100km NNW of Arkhangelsk, is only accessible by semi-submersible tracked vehicles, travelling

over waterlogged logging roads and large peat bogs. This made the logistics of the drilling operation very difficult, and the midsummer insects made the fieldwork extremely taxing.

A SRK senior geologist travelled to the site to supervise the entire process of drilling and sampling. He accompanied the sample as it was transported to the Pomorye kimberlite processing plant, kept the core sample under constant supervision during processing and maintained the sample in strictest security at the processing facility and during sorting of the concentrate. Finally, the diamonds recovered from the concentrate were described, weighed and independently verified by SRK and SGS.

According to project director Mike Armitage "It was extremely important that we provided a completely independent and impartial assessment of the competence of the drilling, sampling and processing operations, as this enabled us to confirm that the highest standards, methods and levels of security were being employed by our client and it's joint venture partner and that the reported diamond grades and qualities could therefore be relied upon by shareholders and potential investors."

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## Groundwater investigation at Victor

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**Winter logistics... one challenge of working in cold climates**



**Michael Royle**

**SRK** has been involved at the De Beers Victor Project in the James Bay region of northern Ontario for the last five years. Initially, the scope of work covered the rock mechanics of the pit wall area. However, in partnership with HCltasca a preliminary groundwater investigation was integrated with this program to assess pit dewatering and water treatment requirements. In the first year, deep geotechnical drillholes were hydraulically tested (packer tests) and instrumented using grouted vibrating wire piezometers and thermistors to collect data on groundwater flow to the pit area. Next, a phased program was carried out using large-diameter airlift tests, followed by two seasons of dewatering and well-pumping tests. As the scale of the investigation increased, the monitoring system design was expanded to collect data on the effects of local lithology and large scale structures over a larger area of impact.

In 2003, two dewatering wells were tested separately, for 10 and 30 days, to assess large scale dewatering impact and potential effects on the local river system respectively. A significantly enhanced monitoring system with numerous

collection points away from the kimberlite body measured the well's effects and its potential impact on the local water courses. Geochemical monitoring has been employed to model environmental discharge and to comply with environmental permitting.

Conventional wells were planned to dewater the main pit area. However, a deep glacio-fluvial sediment filled depression posed problems that had to be evaluated by several unconventional methods: by "freeze-wall" technology using deep thermosyphons and deep cut-off wall construction. Both systems are currently used on other projects, but not to the depth required at Victor.

Dewatering system design will play an important role in the economics of the mine due to the significant costs for providing power at the site. This aspect applies to most of the Canadian diamond projects, and to all of the northern mining projects SRK is involved with.

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## Underground diamond mining in Canada

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**Jarek Jakubec**

Following South Africa and Russia, Canada has become the latest country to open an underground diamond mine. BHP Billiton's Koala North is being developed as an open-benching, mechanized, trackless operation. Dr Chris Page and Jarek Jakubec from SRK's team in Vancouver helped BHP Billiton's engineering team select the mining method and basic design criteria. Although the method was successfully used at several De Beers diamond operations in South Africa, it has never been tested in an Arctic environment. Consequently, Koala North will serve as a learning experience for underground

kimberlite mining in the Arctic, where a project has to deal with a unique set of mining conditions in a harsh environment.

The mine is accessed from a ramp developed at the surface. Because of the presence of permafrost, all of the granitic country rock is drilled using a brine solution. Production access routes branch off the ramp at regular intervals to reach the kimberlite pipe. These levels provide access for stope production, exploratory diamond drilling, and mining infrastructure, including sumps, refuge bays and electrical installations. Production tunnels are developed into

and across the kimberlite pipe for slot access, stope drilling and production mucking. Due to the geo-mechanical and weathering characteristics of kimberlite, development and production blast hole drilling must be completed dry.

SRK is proud to be involved, together with BHP Billiton's team of engineers, in identifying and solving some of the challenges of mining in the Arctic.

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*Development at Koala North – the first Canadian underground diamond mine*



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## SRK UK's Bruce Evans

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**Bruce Evans**

**B**ruce Evans together with Neal Rigby and Roy Barfoot, started the company's UK consulting practice in 1988 where he pioneered due diligence of mining projects for London Banks and Stock

Exchange Listings, a business that has grown in scope and size and spread to several other SRK offices.

He has many years of experience in hands-on operation, project evaluation and implementation at senior levels with Gencor (now BHP Billiton), both in South Africa and other countries on four continents. As CEO of Gencor's Gold and Uranium Division, he headed a 100,000-employee business with fourteen listed mining and process plant companies, producing 100 tons of gold a year.

Bruce specializes in interpreting orebodies, their mineability, overall mine feasibility and mining economics, especially in gold, base metal underground mining and alluvial diamonds. He has been involved in alluvial diamond sampling, mining and economic assessments of properties in the Congo and Guinea and in the statistical and geostatistical analysis of a diamond mining property in West Africa.

He led a multi-disciplinary team of six experts in performing the technical-economic due diligence analysis of a significant diamond pipe in Angola.

Bruce has consulted extensively on off-shore diamond deposits and the mining of them, in particular for Namibian Diamond Corporation during its heyday. SRK seconded him as chief operating officer as the company depleted its known reserves and struggled unsuccessfully to catch up on its exploration and feature definition backlog.

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## Alluvial diamond reserves in areas of artisanal mining

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**Allan McCracken**

**C**alculating the value of alluvial diamond resources and reserves is a challenge in normal circumstances, considering variations in grade, distribution, stone size, diamond value and recovery constraints. Still, good techniques have been established, based on reliable sampling methods, an understanding of geology, statistical evaluation and sound practical experience. But when artisanal miners have previously worked the deposit, especially over many decades, all of these variables need close attention as well as an estimation of the amount of the deposit they have extracted.

Artisanal mining is usually more expert than many would expect and can easily account for 50% of the grade worked. This, however, may represent far more than 50% of the value of the stones as the larger, better quality stones are mined preferentially.

SRK Consulting has evaluated several such diamond deposits, each with their own individual features, and has developed a series of relevant rules and tests to apply.

Good maps and recent aerial photographs are essential along with local knowledge and understanding of the mining context. The extent of artisanal exploration and mining has to be established and the artisan's cut-off grade estimated. In this context, a good history of the water table and its movements and whether the miners have used pumps, is very important.

Once it is possible to estimate the percentage depletion in different areas of



**Central African artisanal miners**

the deposit, the remaining resources and reserves can be determined by classical methods. However, exploration sampling in active artisanal mining areas needs a higher degree of security and vigilance. Co-existing with artisanal miners requires specific environmental considerations, and the project must recognize the conflict of interests that exist and work towards accommodation at an early stage.

While there are challenges in mining in such areas, the projects are potentially viable. SRK has been able to obtain reliable estimates that should achieve the same bankable status as any other project.

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