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The road to NPV +

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Synopsis
When the slope angles of the southern side of the Venetia open pit were required to be flattened by some 20 degrees after an analysis completed by De Beers geotechnical engineering in conjunction with SRK, the additional waste stripping tonnage generated was in the order of some 70 million tons. The potential cost of having to move this tonnage had a significantly negative effect on the Net Present Value of Venetia Mine, challenging the viability of the third pushback and rendering a potential fourth pushback completely uneconomic.

This paper details some of the innovation that went into the design and planning process undertaken to virtually negate the instantaneous effect of the flattened slope angles and the associated waste tonnage as well as further improve the NPV of Venetia Mine and bring the fourth pushback back into economic viability. This process has become known as NPV+ and is an ongoing exercise in waste reduction/deferment and revenue advancement.

Introduction
Venetia Diamond Mine is situated in the Northern Province of South Africa some 35 km due south of the joint border between South Africa, Botswana and Zimbabwe. It is the largest South African producer of rough diamonds, and the first major diamond mine to be developed in South Africa in 25 years. It was opened by former De Beers chairman Harry Oppenheimer on 14 August 1992, and represents one of De Beers’ biggest single investments in South Africa.

Venetia inherited its name from the farm on which it is situated, while its emblem, the guardian lion, is the biblical symbol of Saint Mark, the patron saint of Venice.

The Venetia story begins on the farm Seta, 35 kilometres north-east of the present mine, where as early as 1903 diamond-bearing gravels had been discovered close to the Limpopo River. In 1969, De Beers began a reconnaissance sampling programme to locate the source of these river deposits. The trail led to a farm called Venetia, where a cluster of kimberlite pipes was discovered in 1980. A thorough evaluation began the same year, and the two largest pipes proved to be economically viable. A full feasibility study was commissioned in 1988 and approval for the project was granted in 1989. Construction of the mine began in January 1990, with full output being achieved in 1993. Running for a brief period on continuous operations, Venetia has run predominantly on a five-day processing week and a seven-day mining week up until October 2000, when full continuous operations were once again introduced. The mine is South Africa’s largest producer of diamonds, thus maintaining the country’s position as a prominent world producer.

Geology
Diamonds were formed many millions of years ago in the mantle of the earth more than 150 kilometres below the present surface. Carbon, present in the mantle, was subjected to very high pressure and temperature and crystallized to form diamonds. Much later, melted rock or magma formed in the mantle forced its way through the Earth’s crust and burst through to surface in volcanic eruptions. The magma carried diamonds with it—and when it eventually cooled in the pipes the diamonds became trapped in the rock that was formed. This became known as kimberlite. For millions of years erosion has been taking place and large quantities of diamonds were washed away. It is believed that such erosion of the Kimberley pipes formed the resource base for beach and marine mining operations along the West Coast of Southern Africa. The same happened to Venetia’s cluster of pipes but so far the geologists have not been able to find the diamonds from the upper section of Venetia’s kimberlites.

There are 12 known kimberlites, which form the Venetia cluster. Of the 11 pipes and

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Erosion model of Venetia
one dyke system, only two of the kimberlites, K1 and K2, are currently being mined. Some of the pipes were formed in multiple intrusive events, which have resulted in a variety of kimberlite types being encountered during mining operations. The kimberlites are clustered over approximately three square kilometres, while the total surface area of the kimberlites themselves is 28 hectares. Open cast mining is expected to carry on for some 20 years and, as the mine becomes deeper, the feasibility of underground operations will be investigated.

**Mining**

Venetia Mine is an open pit mine, exploiting the major...
kimberlites known as K1 and K2. The mining method employed is a conventional open-pit mining with hard rock drilling and blasting combined with a shovel and truck load and haul operation. After the surrounding earth and rock have been removed to expose the kimberlite, the ore is blasted and loaded into trucks, hauled to a crusher, reduced in size, and conveyed to a primary stockpile. From the stockpile, the crushed ore is conveyed to the main treatment plant for processing. The mining activity is a continuous, round-the-clock operation, and mining operations in the open pit are supported by workshops using the most modern vehicle maintenance equipment. What makes Venetia mine unique within the De Beers group and amongst other open pits world-wide is its high-level application of the most modern computer-based technology.

Ore processing

After primary crushing the kimberlite ore is fed into the main treatment plant where it undergoes further crushing, screening, scrubbing, dense medium separation and a final diamond recovery process. Inside the treatment plant, the kimberlite is further crushed, washed and screened into different sizes. A special feature of the pipe conveyors used on the mine is their ability to carry sealed loads and negotiate bends and steep gradients. A process known as dense medium separation (DMS) further reduces the volume of diamond-bearing material by separating light from heavy material. Diamonds are heavier than most of the material mined, and they separate into a concentrate which is passed through X-ray sorting machines which detect fluorescence and divert the diamonds from the stream by means of air.
jets. After drying, a final sorting by hand ensures that all the non-diamond material is discarded.

The plant is highly automated and has the first in the world installation of an expert system to control all treatment operations. This has had the effect of increasing utilization and maintaining the plant under steady conditions. The implementation of such technology lends itself to the higher productivity in terms of tonnes per man-hour.

Diamond mining and recovery is a clean operation. Processing of the ore uses no toxic chemicals and produces no chemical pollutants.

The Venetia Mine planning process

As the open pit at Venetia has developed from a 'young' pit in cut 1 and 2 into a 'mature' pit in late Cut 2 and Cut 3, the mine planning process has had to undergo a major phase of change development. Since 1997, some of the initiatives and innovations implemented in this area have seen some significant value and major benefits accrue to the operation.

Pre-2000 planning process

The initial pit slopes at Venetia were originally designed at a constant angle of 54 degrees all the way around the proposed pit. This constraint was applied in the mine design process for Cut 1 and Cut 2 and the pit was planned and mined accordingly. However, during the process of mining the second cut, some significant failures occurred during 1997 and 1998 in the planes of the rock making up the southern highwall. These events ultimately led to the failure of the southern access ramp on the same highwall.

A new geotechnical investigation programme was started in 1998 involving intensive drilling of the southern country rock within the designed limits of Cut 3 in an attempt to re-quantify the slope requirements for future cuts at Venetia. Because of the very short lead time, mining of the waste in Cut 3 was already started before fully optimized designs and plans could be produced making use of the new geotechnical data. This highlighted some of the lessons to be learnt in terms of the workflow and the timing of designs and plans as well as the criticality of having full geotechnical parameter information well in advance of the planning and subsequent mining process.

The split shell mining process (detailed later), which required some major redesign work for Cut 2, was applied in the 1999 strategic business plan year and even in this first year, significant savings were made in capital as a result of not having to expand the waste mining fleet significantly.

In late 1999, early 2000, the new geotechnical study (SRK report number 173849 revision 1 and 2 March 2000) was completed and the data collated into a full report on the way forward with all the design parameters and recommendations.

The new planning structure and workflow

The planning section was re-engineered in early 2000 and focused on a very clear structure of work with the primary objective of reducing or delaying the amount of waste stripping to be carried out and advance as much revenue as possible by accessing sustainable sources of quality kimberlite as early as possible for feed to the plant.

The three main pillars of the planning process at Venetia are design, plans and reconciliation. Software tools were set up to enable this capability and the first order of business in the form of the redesign of Cut 5 was started on this basis using the newly published geotechnical criteria.

Mine design

The process of mine design makes use of several important criteria primarily the geotechnical parameters which constitute essentially the slope angles for the design of the different sections of the pit high walls and the economic criteria which are optimized in Whittle 4X to determine a general guideline limit in the form of an outline within which a pit design can be built. Other factors such as bench height, haul road width, ramp gradient, etc., are also included in the set-up for the design. At Venetia, design is done using Gemcom software. The ore reserve and geological models are also done in the same package. Once a design is complete, it is checked and audited both internally and externally and is then approved and signed off.

Planning

The pit shell design is then exported to the Venetia planning system. The design shell is then analysed for suitable opportunities to apply the split shell methodology as described below, which generally looks for opportunities to minimize the waste stripping peaks.
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The split shell principle

Concentric mining—Until 1999, open pit mining at Venetia was carried out in the traditional concentric manner which is a system of mining where waste stripping of ore takes place all the way around the pit shell in successive waste cuts ± 100 m in width each. The ramp geometry consists of independent ramp systems tracking all the way around the circumference of the pit in concentric rings.

The only access to the ore in a concentrically mined pit is through the waste cuts and this creates production inefficiencies as well as safety hazards from rock falls from the upper benches where waste stripping is taking place. If for any reason one of the concentric ramps is cut off by a geological or operational problem, the entire ramp system is lost as there is no alternative access point.

Split shell mining—The split shell mining concept effectively creates two or more splits in the mine along an east–west or other axis allowing smaller independent waste push backs to take place thereby highlighting the following benefits:

➤ Unobstructed ore haul route access due to waste mining taking place on the opposite side of the pit to that of the ore ramp
➤ Little or no effect of the waste spillage from blasting and loading operations taking place on the upper operations of the new cut on the lower ore mining areas
➤ Improved cycle times, reduced safety hazards and other operational efficiencies as a result of less equipment congestion in the working areas
➤ Alternative access via another ramp system in the event that any of the main access ramps is rendered non-operational for various reasons. Essentially a failure of a ramp section only renders that section inaccessible and not the entire ramp system as would be the case in a concentric design
➤ Smaller waste cuts resulting in a reduced peak waste tonnage profile across the life of the mine and hence reduced fleet and other capital requirements.

In summary the split shell mining method is highly efficient in that it firstly enhances safety in the open pit environment by separating the upper and lower mining operations to opposite sides of the mining pit allowing each operation to continue independently without adversely affecting the other one and secondly improves the overall mining economics, specifically the Net Present Value, of the mining operation by eliminating the peak of waste tonnage stripping and the subsequent fleet capital requirements.

Splitting the shell

Once the design is in the planning system and the geometry of the potential splits has been evaluated the splits are positioned on the shell. The design is then split into one or more interim shells. From the interim shell, the position of the first bottleneck is determined. Briefly, a bottleneck is the...
point at which the ore that has been stripped of waste and is being fed to the plant is approaching the point of exhaustion and the new waste stripping cut that will open up the next section of treatable ore must be down to the point where that next section of ore is becoming available for feed to the plant. This, just in time, period is known as the bottleneck and is a critical time in the operation of the mine. Timing of the bottleneck is usually planned such that there is at least a six to twelve month overlap between the two different sections of ore feed. The golden rule is clearly to always preserve the integrity of quality plant feed. The amount of waste tonnage that is required to be moved to meet the first bottleneck is then calculated and scheduled within the same time that the stripped ore tonnage can be treated. The second bottleneck is then calculated in a similar way. These tonnage figures then constitute the amount of tonnage that needs to be moved within the bottleneck time frame and are used as the targets for the planning process that follows.

From the present face positions, the entire design is planned through to the final limits in three-month plan sections. This process is done by the planner giving due thought and consideration to the practicalities and operational limitations of the equipment and mining infrastructure. From each plan a complete product flow is produced detailing the tons and content of all the sources of ore by rock type and by bench as well as the tons of waste by bench and position.

All the three-month plans are compiled into a book which is circulated to all relevant personnel within operations and management, and details complete information of the mining plan and physical mining positions at any point in time.

Reconciliation

Once the mining plans have been issued and the faces are being mined it is important that the actual mining positions are following the plan and that the faces are being achieved in the correct sequence. In order to measure this, a process of reconciliation takes place at the end of each quarter. The as-mined faces are superimposed on the planned faces and the over-/ and under-mined areas are measured and calculated. From these measurements, the net mining position is determined against the plan by bench and by material type and an equivalent waste audit and an equivalent carats audit is produced. The equivalent waste audit measures whether sufficient waste has been stripped in relation to the amount of ore that has been mined thereby ensuring that planned stripping ratios are being complied with. The equivalent carats audit checks whether the mining of the ore has taken place according to plan and that lower grade material has not been sacrificed for earlier mining of high grade material. A report is then compiled detailing the findings of the reconciliation and also highlighting and recommending potential adjustments that need to be made to the mining calls in order to catch up tonnages or grades. The summary of the report is a diagram of the plan showing the areas of over-/ and under-mining.

These three main pillars constitute the long-term strategic mine planning process at Venetia and to date has proved extremely successful in ensuring planning and mining alignment and the realization of major waste savings that have dramatically increased the Net Present Value of Venetia.
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The cut 3 redesign process

Background

Although Cut 3 had been designed previously, it was done without the new geotechnical information. Once this information became available in March 2000, a major redesign exercise was required to be undertaken in order to encompass the new requirements. The major changes required were firstly the flattening of slope angles on the southern wall of the pit to reduce the probability of wall failure and, secondly, the requirement to design the pit with multiple slope angles as the orientation of the rock structures varied with the pit limits within newly defined rock domains. With slope angles as previously designed at 54 degrees the probability of failure on the southern wall was sitting in the 50% range. The new slope angle required was 37 degrees for this wall to bring down the risk factor into the 5 to 10% range. The first run of designs was carried out and as a result of this slope flattening, the amount of waste tonnage to be stripped increased by some 70 million tons over the previous Cut 3 designs. In order to ensure the same amount of kimberlite tonnage from the cut, the surface limits for the cut had to be moved out further than the originally anticipated 100 m pushback.

It was decided earlier in the life of the mine that the two main orebodies namely Kimberlite K1 and Kimberlite K2 would be mined. It was further decided that the two orebodies would be depleted on an ‘average grade’ principle thereby maintaining a steady sinking rate for the two pits. As a result, when the initial designs were done for Cut 3, the K2 pit was incorporated into the waste stripping calculations. With the flattening of the slope angles, the amount of waste that was required to be stripped around K2 was very high and further analysis was done to determine a more suitable way of extracting the K2 kimberlite in Cut 3. At about this same time, it was decided that more detailed notional revenue information would be released to the operations for planning purposes. This information, together with the new slope information, was compiled into an input for new Whittle and planning runs.

The results from these new runs indicated a major shift in the economic mining outline for the Venetia kimberlites. The outline became more elongated on a north–south axis and shortened on an east–west axis in line with the new slope and revenue information.

The birth of NPV+ as a philosophy

An overall analysis of these new developments clearly suggested that an alternative approach to the design and planning of Cut 3 was required if this cut was to be economically viable against an underground extraction method. High waste tonnage for no additional kimberlite was challenging the viability of this cut and rendered future open pit cuts totally unviable.

At this point, it was proposed to analyse the alternative of mining the orebody to best Net Present Value (NPV) instead of average grade. The new Whittle results were used as a basic guideline but more importantly a revenue per ton contour plot was developed to more representatively highlight where the mine design should be centred around. The initial results were encouraging and suggested that high waste tonnages could be significantly reduced by applying the split shell technique and that the NPV could once again be boosted. Approval was obtained to pursue the new proposal and it was labeled NPV+.

Application and results

The revenue per ton contour plot indicated that the obvious target was K1 with its higher grades driving the higher revenue profile. Although the K2 revenue was marginally higher than that of K1, the grade of the material was significantly lower. This meant that the mining rate in K1 needed to be stepped up and slowed down in K2.

Because of this difference in grade and revenue between the two orebodies, it was clear that the pushback requirements for each orebody needed to be differentiated. An analysis of the mining positions showed that the cut position of K2 was in fact beyond its economic limit for Cut 2 and was actually already in the Cut 3 position and the stripping that was about to take place was for the Cut 4 position of K2. K1 was clearly in its Cut 2 position ready to be moved to Cut 3. The effect of this was that the mining positions in K1 were effectively required to catch up with those in K2 and therefore the new mine design for Cut 3 was built up.

Effectively the waste stripping for K2 was already completed and only the stripped kimberlite was required to be mined and moved to the plant. The major portion of waste stripping required was from K1. The new design was rebuilt accordingly and in this process the power of the split shell technique became very apparent. A three way split was applied to the design, K1 south, K1 north and K2. If these splits were not applied, the clearances around the cut 2 limits would not have been possible thereby necessitating additional waste stripping. The design was then planned through in quarters from current face positions and the product and cash flows analysed.

These results showed that the 95% of the initial waste tonnage increase for Cut 3, as a result of the slope flattening,
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had been negated and that the waste tonnage to be moved was back to 1999 Cut 3 design levels. By planning the mining sequence of the ore to the best NPV based on the revenue per ton contours, the grade of the ore flow improved by 16%. With the impact of the waste reduction, the higher grade profile and the positive effect of being able to extract all the planned kimberlite from this cut in the planned sequence, the result was the Net Present Value of the Cut 3 cashflow being improved by R310 million. Some of the initial reactions to these results were that high grading had taken place and that the viability of future mining cuts had been compromised. To analyse this effect, a Cut 4 was designed and planned down a further 12 benches below the Cut 3 using the same philosophies of NPV+. The results of this analysis showed that, by adopting the new approach and changing the mine design and plan sequence, the Cut 4 viability was enhanced more than had ever been achieved with previous analyses.

The proposal to move the mine into NPV+ mode was presented to Venetia and De Beers management on 28 June 2000 and was unanimously approved. The new design and plans were formalized and the system was implemented in the July 2000 planning month.

Benefits, learning points and conclusions

The clear benefit of the application of the NPV+ philosophy is the large NPV improvement to the mine that resulted. Since the time of application, further initiatives have been implemented to save on further waste and advance kimberlite extraction thereby bringing revenue forward. In October 2000, continuous operations on the Venetia plant were introduced, stepping up plant throughput by an additional million tons per year. A re-plan along the same basis further enhanced the NPV of the operation and as a result another project has been opened to investigate increased production scenarios.

The major learning point from the whole exercise is the importance of timing in the whole mining planning process. In the case of Venetia, further optimization could have been realized if more detailed information to plan Cut 3 had been available prior to the start of mining it. Already, because most of the Cut 4 information is in place, a large number of iterations have been performed on the various scenarios for this and it has been possible to further enhance the NPV of Cut 4 significantly more than was achieved with the first exercises. Another major learning point has been the development and application of relevant software that can be used to determine the iterations required efficiently and speedily so that there are no long lead times in the delivery of designs and plans. A set of workable plans for the whole cut must be producable within two to three days from the completion and approval of a design shell.

In conclusion, the combination of the innovation of the split shell technique, software development and application, and a focus on the business output has enhanced the Net Present Value of Venetia Mine by some R600 million (excluding capital) over the last 36 months. Further development and applications that have been applied to developing costing models, waste dumping optimizations and the integration and scheduling of multiple ore sources (satellite orebodies and low grade dumps) are showing promising results that will continue to increase the value of Cut 4 as a viable open pit project as well as add value to Cut 5 in its conceptual stages and further delay the planning and implementation of an expensive and potentially risky underground mining operation.

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References


INFACON 10—Research and development needs in the ferro-alloy and stainless steel industries*

Local R&D in Ferroalloys and to a lesser extent in stainless and alloy steels has declined over the past ten years. South African papers accounted for a major part of the programme at Infacon 6 in Cape Town in 1992. Infacon 10 is only three years away and there is some concern that the contributions from South Africa R&D activities will be disappointing.

We need to encourage Industry and relevant Government Departments and Institutions such as Universities and Technikons to give more support to appropriate R&D projects to demonstrate the level of commitment this important area deserves. It is recognized that some R&D carried out by Industry is confidential and thus is not open to a wider audience.

Current and new R&D projects started over the next two years should provide a significant quota of papers for Infacon 10. Suitable topics for Infacon 10 include the following: Ore/raw material sources and
geology/mineralogy, pre-treatment processes (e.g. pre-heating and pre-reduction), melting and smelting processes, refining, casting and granulation, unit operations (e.g. furnaces, kilns, fluidized bed reactors), process flow sheet development, environmental, health and safety aspects, stainless steel process technology and alloy development, quality of ferro-alloys and stainless steel, modelling, simulation and control and economic considerations including the potential benefits of new technology. The announcement of Infacon 10 will be issued early in 2002. Mintek would like to play a leading role in assisting to establish current and future needs for R&D and to explore ways for finding funding to address these needs. We would like to have feedback on this suggestion.

* Please respond to either Nic Barca or Tom Curr at Mintek with your comments and/or suggestions at ncb@mintek.co.za or jonc@mintek.co.za
GeoInside starts online trading in mineral commodities*


The core business of GeoInside is a moderated matchmaking between supply and demand. Via the GeoInside Website, buyers and sellers can anonymously present their sales and supply requests, exchange information via internet, fax, phone, and finally make personal contacts or visits. GeoInside monitors the matchmaking process between business partners and gets a commission after successful completion of a deal. As GeoInside takes an independent market position, it is able to provide frank and fair information about products and business partners.

Small-to-medium scale mining and processing companies in particular benefit from the Internet and can enhance their market position through online trading. The first mineral commodity sales offers are, for example, for tantalite, chromite, vermiculite, bentonite, mineral pigments, natural stones and gemstones. Trading has now started and several transactions have successfully been completed. GeoInside provides samples, assists in controlling the quality, arranges transport, and guarantees payment to the seller. GeoInside also visits mine operators as well as the interested buyers, thus being able to give valuable recommendations for the trade.

GeoInside also helps to streamline the transport of mineral commodities to make mineral products more competitive and trading more economic. On request, GeoInside can also carry out exploration, mining and processing consultancies, or can advertise tenders for such services.

Apart from the trade in mineral commodities, the Market Place includes the invitation for tenders for private and public sector projects in the field of earth sciences. A job market and product catalogue complement the information and trading platform.

GeoInside is directed by two geologists, Dr Peter Hanstein and Dr Peter Buchholz, who have over 10 years experience in mineral commodities and management of international projects. The Head Office is located in Berlin, Germany, with branches in Zambabwe and Brazil.

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Gearing up for the professional mobile radio expo*

With only two months to go, the Professional Mobile Radio Association is gearing up to deliver an event targeted specifically at fulfilling visitors’ needs. The PMRA Expo’01 is the show that will reaffirm the place of radio and mobile communication technology as a reliable and innovative communication tool. This year’s expo promises to be a unique business-to-business event attracting decision makers from a variety of industries. In addition, the show is already sold out, further indicating a success for exhibitors and visitors alike.

Exhibitors on board include big names such as: Siemens, Sentrech, Webb Industries, Marconi Communications, E.A.D.S. Multisource, Alcom systems, Global Communications, Vertel and Grintek Telecom, among many others.

Being held at the Kyalami Convention on 16 and 17 October, the PMRA expo will bring together a targeted group of users and suppliers to interact and network. The exhibition will showcase diverse categories of communication technology, including two-way radios, radio paging, satellite and microwave technology, radio data, control centres, network and computer applications, mapping, components, accessories and services.

There is a huge market for these communication services with industries from emergency services, to hospitals, mining and construction, all relying on radio or microwave technology for their communication needs.

‘In addition to exhibitors, we will also highlight a number of speakers addressing seminars on topical subjects—including the Tetra vs Tetra Pol debate, making for a comprehensive event not to be missed by anyone with an interest in Professional Mobile Radio communications equipment and networks,’ says Dave Koller, Chairman of the PMRA.

For more information on the PMRA Expo please contact Bronwen Lambert on blambert@pmra.co.za or Tel: (011) 706-5457.

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