Ultra-deep level mining—future requirements

by D.H. Diering*

Synopsis

The paper deals with the technologies required for opening up a new idealized ultra-deep level mine. First the overall philosophy of accessing ore at ultra depths is discussed. Then the individual technologies which will be required are explored. Finally a detailed overview on one of the key technologies, namely tunnel support, is given.

Because this project is still in its infancy, few definitive answers are provided; instead each of the envisaged technologies are briefly discussed, with emphasis on those which require the element of speed for rapidly accessing the ore body.

Introduction

Ultra-deep level mining is once again in the forefront of the South African mining fraternity's minds. This has come about both because of the need to go deeper as existing shallower reserves are depleted, and also because of the advances that have been made in ultra-deep level mining practice during the past twenty years.

A fact that is often forgotten is that Western Deep Levels got down to 3 500m below surface back in 1977 and that a significant proportion of their mining operations since then have taken place between 3 000 and 3 500m below surface.

Now the South Shaft is set to beat that record with their recently launched R1,1 bn deepening project. They will reach the 4 000m mark in 2002.

Towards the end of last year, Anglogold's Chairman, Bobby Godsell announced that Anglo was looking even deeper, and that the possibility existed that one or two new 'mega shafts' could be commissioned to the south of Elandsrand and Western Deep Levels, down to a depth of 5 000m.

In this paper, I will be looking at a hypothetical shaft system, and will be taking a broad look at the technologies involved in getting to 5 000m. I am thus specifically not talking about Western Ultra-Deep Levels in particular, but ultra-deep level mining in general.

Access philosophy

The key word here is 'rapid'. A new major shaft system down to 5 000m could cost in the region of R5 bn or more, and there could be a 10–14 year lead time before revenue is generated. Clearly therefore, speed is of the utmost importance in any project of this nature. Actually mining at 4 000–5 000m underground is going to present all sorts of technological problems, but let's assume that these can be overcome (if they can't, there wouldn't be much point in going there). Unless we can find innovative ways of *getting* there, and getting there *quicker*, it is unlikely that anyone will get a project of this nature off the ground. There are two keys required therefore in order to unlock the treasures that lie between 4 000 and 5 000m

i) the ability to mine the ground at those depths, and
ii) the ability to get there quickly.

As I've already mentioned, we're looking at a hypothetical shaft system from surface to 5 000m below surface, and I'm assuming that mining down to 3 500m is already taking place via existing infrastructure. The objective here therefore, is to exploit the ore reserves between 3 500 and 5 000m. Figures 1 and 2 show two possible alternatives. In both cases, the existing mine is stoping Carbon Leader down to 3 500m, and VCR down to 3 000m (less than Carbon Leader simply because the crosscut to reef distances would be too great at ± 4km).

Figure 1 shows a new shaft system to open up the reserves of both reefs down to 5 000m. The new main shaft extends to 3 000m. As can be seen, no ore reserves are accessible from this shaft. Now the sub-shaft has to be sunk down to 5 000m (or less if it was to be done in stages) and there are two shaft pillar inter-sections.

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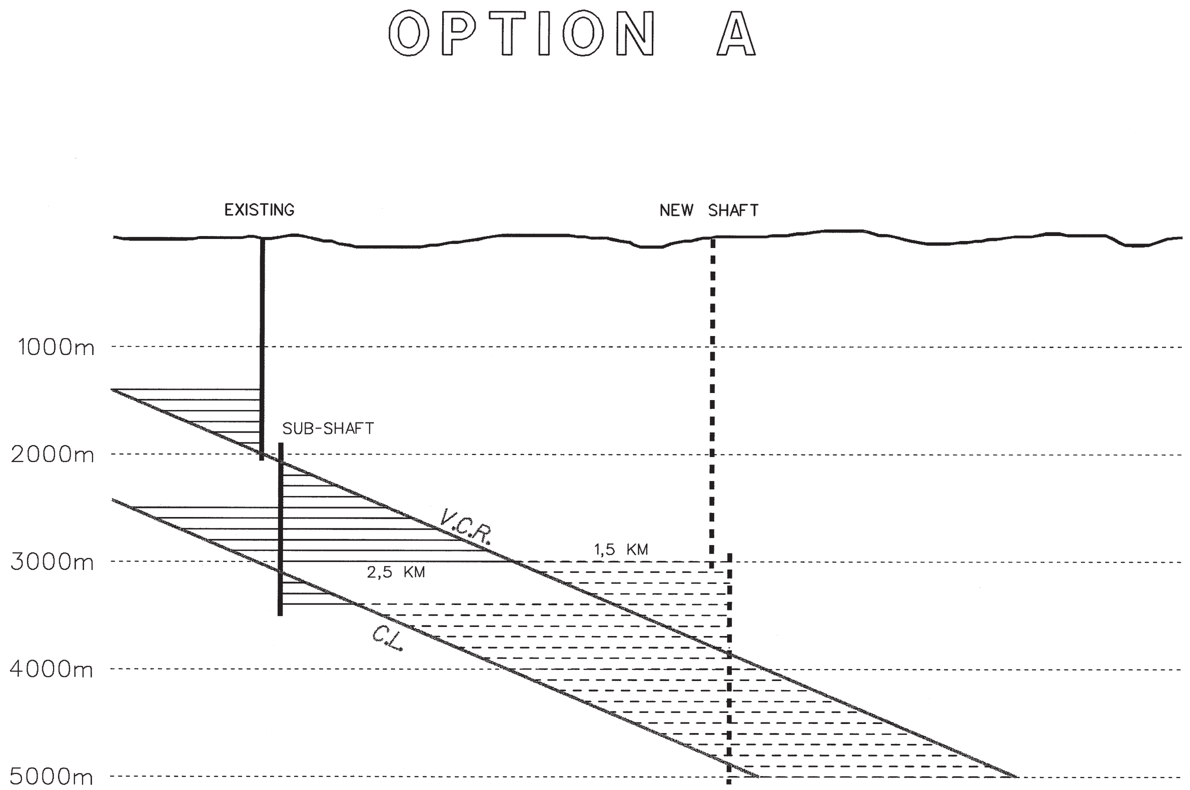

Figure 1—Schematic layout of new shaft system—no ore reserves accessible from main shaft

Depending upon what sinking and development rates are used, stoping will only commence 13–15 years after commencement of the project. At the current gold price and with realistic grades, the rate of return on a R5bn investment would be hopelessly unacceptable to investors; they would preferably put their money into a building society, or better still, buy the building society!

Figure 2 shows the new main shaft being sunk straight down to 4 000m below surface. A totally different picture now emerges: 50% of the VCR reserves (including the shaft pillar) and 33% of the CL reserves become available before the sub-shafts are commissioned (or indeed, even started).

There is a four year gain to start of production using this approach, and approximately 50% of maximum production (or ±150 000 tpm) could be produced from this deep main shaft until the sub-shaft is commissioned. There are two reasons for the limited production:

i) the length of wind, and
ii) the fact that the sub-shafts' sinking waste rock has to be hoisted up the main shaft.

Full hoisting capacity can only be achieved from a shorter wind, possibly 3 500m or even less. This means that the sub-shaft gets sunk from well above 4 000m and that there will be at least 500m of 'sacrificial' shaft. The 4-year shorter lead time will more than compensate for the additional expenditure, and this is the only way that we can see realistic rates of return being achieved.

This then is our overall access design philosophy: sink to 4 000m in one go, gain access to 40% of the reserves, start stoping 4 years sooner albeit at reduced capacity for the first 5 years, and then 'sacrifice' some of the main shaft and hoist at full capacity from a balanced main and sub-shaft system.

The question is, 'can it be done?'

Critical technologies

I've just shown that the single most important criteria for rapidly accessing ore at ultra-depths is the ability to access sufficient ore out of the main shaft. The only other ways of getting there sooner is to sink faster and to develop quicker. As I've already mentioned, mining at ultra depths has two requirements,

i) the ability to stope at these depths, and
ii) the ability to get there quickly.

There are 10 technologies involved in getting there (quickly) and in being able to mine at these depths.

They are:

- 4 000m Shaft Sinking
- 4 000m Ropes
- Hoists
- Shaft Design
- Refrigeration and Ventilation
- Access Development
- Stoping Method
- Stope Support
- Management of Seismicity
- 3-D Underground Imaging.

I will go through the issues involved with each very briefly, with emphasis on those directly related to *rapid access*, namely 1, 2, 3, 4, 6 and 10.

I must also emphasize that most of the technology which

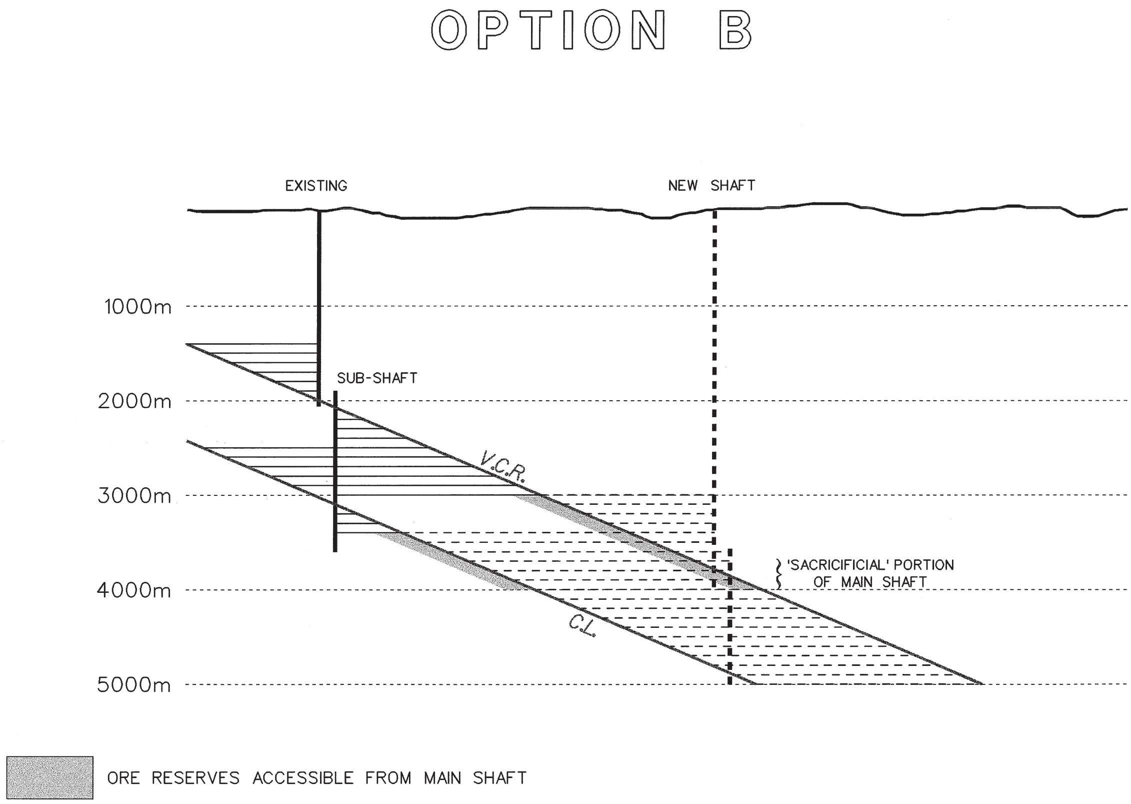

Figure 2—Schematic layout of new shaft system—ore reserves partially accessible from main shaft

I will discuss is available right now or could be within a few years. This is not to say that ultra-deep mines of the future won't be radically different from what we know today; I believe we have to be in a 'constant state of readiness' to proceed with an ultra-deep mine should the financial circumstances permit it.

Shaft sinking

As I've already pointed out, the ability to sink a shaft to 4 000m in one hit is the key to the overall rapid access of the ore body. We already have the capability of sinking down to ± 2 800m, so what are the issues involved in sinking to 4 000m? Clearly ropes, and in particular stage ropes, will be the limiting factor, but this will be discussed in the next section.

Ground support is going to become an issue as 4 000m is approached, and I envisage some sort of initial support being required prior to concrete lining such as bolting and shotcreting. This could have the effect of slowing down the sinking operation.

Other issues are pumping and cooling—intermediate bulk cooling chambers will have to be cut on the way down. Perhaps one of the most important issues is mechanized drilling—we really do need to be able to sink at 4m or more per day instead of 2-3m. Concurrent equipping is another important issue to be resolved.

The only real stumbling block to sinking to 4 000m that I can see is the ropes.

4 000m ropes

If someone asked the question 'what would stop us going to 5 000m today, assuming there was an ore body worth going to and enough money to pay for it?,' the simplified answer would be 'ropes'.

There are three requirements here:

i) Changes in the current regulations
ii) Some innovative new methods of rope construction
iii) Winders which can accommodate this length of rope and impose the minimum amount of shock loading on the rope.

Conventional triangular strand ropes are almost certainly not going to be suitable. Instead, ropes which are torsionally neutral will be required, such as the non-spin 'fishback' construction used for kibble and stage ropes. What is not known is how these ropes would behave in a conventional hoisting situation, and what the expected life would be.

This is an urgent research and development area, and several of our deepest existing shafts are going to have to be equipped with these ropes during the next few years so that the rope manufacturer and our engineers can come up with the right answers.

Concessions in rope factor of safety legislation will not be forthcoming without a very thorough, well-considered engineering programme to address all the technical issues from an analytical and test point of view. Good progress has already been made, and to answer the question 'can it be done?', I think the answer is definitely 'yes'.

Winding

This is a fascinating area of new technology. Winders which are going to have to handle 4 000m of ropes are going to have to be BIG and motors, controls and braking systems very sophisticated. We could be looking at 9m diameter Blair winders and because the width, most probably electrically coupled (i.e. no shaft), which means two motors per winder. Braking systems are going to have to be very sophisticated, and one envisages a computer controlled 'thinking' hoist.

The price of a winder such as this could be in the region of R100 000m, and a large twin shaft system would probably have two rock winders and three men and material winders, so you would be needing R500 000m for the winders alone. These hoists don't as yet exist, but there is little doubt that there is sufficient expertise to manufacture them if the need existed.

Shaft design

It could take up to two years to equip a 4 000m shaft with conventional steelwork. The need exists therefore to go for larger bunton spacings; however with higher pay loads and higher speeds, this presents potential major problems. Our engineers are going to have to come up with some very innovative designs that facilitate faster equipping whilst at the same time permitting safe, low maintenance, high speed hoisting.

One of the options being considered which would have a major impact on equipping time is rope guides. The mere mention of these two words raises scepticism in most people, but because of the potential saving in equipping time and hence speeding up the whole process of accessing the ore body, research and development of rope guides in ultra-deep shafts is warranted.

Refrigeration and ventilation

It goes without saying that this is a key technology when considering mining down to 5 000m. However I do not see any fundamental differences in the requirements for Western Deep Levels South which is already on its way to 4 000m and our new mine which will go to 5 000m. The VRT at 4 000m will be ± 62°C (incidentally, the same as President Steyn No 4 shaft right now), and at 5 000m it will be ± 70°C.

There are three issues here:

1. Providing the cooling power
2. Distributing the coolth effectively
3. Minimising the cooling requirements.

The first is essentially not a problem—almost any amount of cooling can be provided on surface, using ice plants, ammonia water chillers, or whatever. The real issue is initial capital cost and project-life cost. The major advantage in using ice is the reduced volume of water that needs to be re-circulated; the disadvantages are mechanical reliability and the inability to recover the potential energy. Both of these problems could be overcome, the latter using some kind of pelletized ice transport system.

I've no doubt that our environmental and mechanical engineers will come up with the right answer as far as cooling plant is concerned. What is more important is how we distribute and utilize this cooling—this is an area that is often sorely neglected.

I'll be dealing with access development and stoping method in the following sections, but one of the key issues is level spacing and consequently the length of stope back that is created and has to be ventilated and cooled. 150m level spacings enable 1 in 3 levels to be cut out, which is very desirable and will certainly speed up the overall process of ore access, but this creates a 400m stope back that has to be serviced, ventilated, and cooled. A great deal more work is required in this area but I suspect that the answers that Western Deep Levels South are going to have to come up with in order to stope at 4 000m will be essentially the same as those required for mining down to 5 000m.

The third and vital issue is reducing the amount of cooling that is required. Here I take 'total' backfilling of the stopes as a given; the real issue therefore is haulage insulation. This topic has been debated for decades, but I am not aware of any fundamental successes as yet. My view is that we have to come up with a material that can be added to the shotcrete (or equivalent) for the sidewalls and hanging wall, and the concrete for the footwall which will have good thermal insulation properties. Unless we can achieve a one-pass operation of support and thermal insulation combined, I do not see great progress being made. This technology needs to be urgently researched and developed, as the implications on the overall cost of cooling could be enormous.

Access development

Next to the ability to sink (quickly) to 4 000m in one go, clearly rapid horizontal access development is the most important issue as far as rapidly accessing the ore body is concerned.

South African mining engineers have been rapidly accessing tabular ore bodies for many decades so one might ask 'what's changed, what's the issue?'. The answer is simple—support requirements, and these can play havoc with conventional multi-blast high-speed development cycles.

There are therefore two separate sub-issues as far as rapid access development is concerned:

i) the methodology to be used
ii) tunnel support.

A good benchmark for twin-end multi-blast development *with* support using conventional equipment (i.e. hand-held drilling and rocker-shovel cleaning) is 160m per month or 80 linear metres per month. Talking to the experts, it seems as if 600m, or 300 linear metres per month is possible. Now when one is talking of up to 50km of initial access development, the difference between these two rates is 1 year versus 3 years, which is very significant. Clearly therefore, we have to progress beyond conventional development methods, and there are four basic alternatives:

1. Tunnel Boring
2. Track-Bound Mechanized
3. Trackless Mechanized
4. Future (Non-Explosive) Methods.

Although we have relatively little experience with TBM's in hard rock tabular ore body environments, I'm sure it can be done. TBM's, once started, like to continue tunnelling and not to be dismantled and moved from one level to another. They therefore require radically different underground layouts. I personally would discount TBM's as the way to go, purely from the point of view of risk—you've literally got 'all your eggs in one basket'.

Mechanized track-bound development is currently being carried out at Elandsrand; the suite of equipment comprises a

Hagg-loader, overhead conveyer, 'special' hoppers, and a twin-boom electro hydraulic drill rig. Time will tell whether or not this is faster and/or cheaper than conventional trackless development. One of the main reasons put forward for this particular method is that it doesn't require the extensive infrastructure (and expertise) required to support a large fleet of diesel vehicles. It is also 'environmentally friendly'.

High-speed trackless development using LHD's (and trucks?) and drill rigs is probably the most tried and successful method; incidentally, the trackless refers to the up-front portion of the tunnels only—tracks are installed in the haulage behind the last connecting cross-cut. However, when you're going to develop between 3 500m and 5 000m underground, we feel that diesel-powered equipment becomes a very real issue because of heat and fumes. Electrically powered (cable) LHD's will be far preferable in this environment, but they must be able to move under their own 'steam' from haulage to RAW to mobile workshop etc. This implies an electric LHD with some sort of on-board diesel-driven power supply (or battery) which will enable the machine to be driven from point A to B. I'm not aware of any machine that is readily available 'off the shelf', but I'm quite sure that it is well within our capability to produce such a machine. An electric cable/battery LHD prototype was built back in 1984. More recently, TDS has developed a cable (AC) hydrostatic-drive LHD powered via an overhead trolley line, although I personally don't believe this system will provide sufficient mobility. An interesting alternative is a rubber-tyred electric Hagg-loader, loading onto an overhead extensible conveyor—no heat problem.

In time there may well be continuous, non-explosive tunnelling methods (other than TBM's) which capitalize on the highly fractured nature of the rock at depth. These need to be researched and developed, and if in time they can out-perform mechanized drill, blast and clean, then they would be used. I do not however see this as a pre-requisite for rapid development of tunnels at depth.

Whichever method is chosen to carry out rapid access development, the one issue which is common to all, and absolutely fundamental, is support. By support I mean shotcreting (or some equivalent fabric). This is the single most important issue to understand, plan, design and manage when developing at depth, and regrettably in my own experience, the one that is least understood, planned, designed and managed. Because this is such an important issue, I have set aside the next section to discuss it in a bit more detail. Suffice to say here that next to ropes, this is the most important technology requirement for rapidly accessing the ore body at ultra-depths.

Stoping method

'Longwalling is dead—long live sequential grid'!

We believe that the only viable mining method at ultra-depths is partial extraction with dip stabilizing pillars which as far as is practically possible, will 'tie up' all of the major geology, and where overall favourable face shape (i.e. always mining down towards solid, and never mining into a corner at the top) is achieved through the 'sequential grid' method as practiced at Elandsrand and now being used at Western Deep Levels - South.

If we could find an ore body that was virtually free of geological discontinuities, then longwalling is a super mining method in many respects. However, in the very disturbed ground that is typical in the Carletonville area, it becomes a nightmare—we will not design another deep level shaft with longwall mining layouts—period.

The other aspect here is, of course, how we break the ground; well, until some viable alternative method is found, we will drill and blast and scraper clean. This is not to say that is what we'd want to do well into the next century, but I'm merely pointing out that an explosive-free, people-less, mechanized stoping environment is not a pre-requisite for mining down to 5 000m.

Stope support

Until something better comes along, we will stay with 'total' backfill (i.e. every panel from gully to gully) not more than 3–4m from the face and pre-stressed yieldable support units not more than 2m from the face. Early results after 9 months of use at Western Deep Levels are very encouraging and I'm sure that this stope support philosophy and methodology will find much wider application in the years ahead.

The most serious unresolved support issue in a deep, geologically disturbed, seismically active environment remains the support of gullies. Timber packs on their own on either side of the gully (which is what were used in one form or another for the last 100 years) are simply no good. New methods have to be found immediately. An exciting new concept which could have huge benefits is the spray-on flexible 'membrane' type support, currently being developed by the CSIR - Miningtech.

Seismic management

This is a subject which would require a paper on its own, and is really outside the scope of this paper. Suffice then to say we're talking about

- ➤ the elimination of seismicity through partial extraction, avoidance of mining through structure, and mine design and layouts
- ➤ the minimization of seismic damage through backfill and appropriate stope and tunnel support
- ➤ the prediction of seismicity, if indeed this ever becomes reality. We have progressed well in terms of space prediction, but not in terms of time prediction.

Prior geological knowledge, or 3-D underground imaging

Here we are talking about being able to 'see into the rock ahead of us' for at least 300–500m so that our development can be correctly placed with respect to the geology that we want to 'tie up' inside our dip stabilizing pillars.

The results from surface 3-D seismic surveys are amazing, and we would like to be able to create a similar picture to that which is being created now, except on a much smaller scale so as to pick up more detail. Incidentally, as a technology for rapidly accessing the ore body, 3-D surface seismic surveys are invaluable in terms of the correct positioning of the surface geological boreholes, and the ability to produce far more meaningful initial mine designs from the very clear pictures that are produced.

My understanding is that this surface technique will not work in the underground environment, and ground penetrating radar is limited to ± 30m at best, so something new is required. This is an absolutely vital technology both for rapidly accessing the ore body, i.e. we put our cross-cuts and raises in the right places, and for minimizing seismicity (and hence our ability to mine at ultra-depths) because we are able to accurately place geological structures ahead of time and integrate them into our stabilizing pillar network.

Tunnel support

So much has been written over the decades about shotcrete in the underground environment, both in terms of its effect on rock mass behaviour and its physical parameters. Huge advances have been made in the past twenty years in terms of shotcrete material and in the pumping/application equipment. However my own view, based on experience, is that we in the deep-level gold mining business have not kept pace with these developments. The basic problem as I see it is as follows: mines are opened up at shallower depths where generally shotcrete is not required. Certainly the rapid access development programmes down to 2 500–3 000m are almost all devoid of any shotcrete. Bolting and wire-meshing and lacing (usually installed much later) are the order of the day. Now the mine has to go deeper—the shaft is deepened to say 3 500m, and a new access development programme is commenced. It is in this new environment that the need for shotcrete as a support medium quickly becomes apparent; however the ability to apply it on a large scale becomes a major problem because of the effect that it has on the planned development rates (around which the whole project feasibility was based!), and because of serious logistical problems. In other words, we wait until we encounter poor ground, and then we set about trying to manage a large shotcreting programme.

Most large shotcreting programmes around the world are applied in a concentrated environment (often only one tunnel) and close to surface. Our environment is exactly the opposite—far from surface (possibly down three shaft systems) and in a widely distributed network of tunnels; up to 10 levels, going east and west (i.e. twenty ends), and up to 3km from the shafts. The logistical engineering and management in this environment is very different to most underground civil engineering applications.

There are 4 prerequisites before embarking on a major shotcreting programme:

1) Why are we shotcreting—what work is the shotcrete going to do?
2) What kind of shotcrete material and pumping equipment will be used?
3) How will we meet the logistical requirements?
4) How will shotcreting be integrated into the treble-shift, high speed access development cycle?

To do justice to this topic would require a full paper on its own (and possibly a SAIMM colloquium on the subject). I will deal very briefly with each prerequisite.

Why are we shotcreting?

The answer is very often 'because the tunnel is falling in!'. There are three conditions which require shotcrete-type support:-

➤ Deterioration of the tunnel hanging and/or sidewalls (i.e. scaling) caused by high stress, weak geological strata, or both. I call this 'NOW support'.

➤ Future deterioration due to stress changes (and possible seismic damage) such as those that will be experienced with all tunnels traversing a sequential grid (or scattered mining) layout at depth. I call this 'THEN support'

➤ Preservation of large, long life excavations, even when they're not in poor ground.

Shotcreting is never cheap, but the most expensive support is that which is applied after the damage has already taken place. It is far more preferable to apply the shotcreting immediately behind the face, and thus prevent deterioration taking place either now or in the future, i.e. support for then, now!

Once the rock engineer knows exactly what work the shotcreting has to perform over its life-cycle, he can specify the physical parameters of the material.

What kind of shotcrete material and equipment?

There are 3 issues here, namely:

a) Shotcrete material
b) Application mode
c) Application technology.

a) Volumes have been written (and will no doubt continue to be written) on the subject of shotcrete material. Whilst this is important, and in some cases could be critical, I think it is more important that we get *area* coverage, in the *right places*, and at the *right time*, of a good quality material. I've no doubt that for deep level applications, commercially available steel-fibre re-inforced shotcrete is the answer.

b) In the past, we used to talk about pre and post shotcrete, with or without meshing and lacing. The options were pre shotcrete only, pre shotcrete and mesh and lace, mesh and lace and post shotcrete, and pre shotcrete, mesh and lace and post shotcrete. The first is good in most static environments, the second a good product, but expensive, the third usually a waste of money, and the fourth a brilliant support medium but a logistical nightmare. A one-pass operation using fibrecrete is the obvious answer. Depending upon what work the fibrecrete has to perform, different 'spec' materials can be used.

c) Essentially, we're talking wet or dry. In the past, most underground shotcreting was done dry due to the simplicity of the equipment and the lack of time constraints. Today, with fibrecrete and the need to apply it in as short a time as possible so as not to hold up the development process, the answer appears to be wet. The real issue now becomes logistics—i.e. how to feed this machine with sufficient material.

How do we meet the logistical requirements?

The first and obvious answer is to put the required amount of pre-bagged material down the shafts in timber/material cars. In a busy shaft already producing 30–40 000m^2 in the upper levels this can be a major problem. The next problem is how to get the material to the machine (can be a problem in a trackless development environment), and then how to feed the machine fast enough.

Logistical engineering and management have taken a 'back seat' all too often. Our mining engineers, mechanical engineers, rock engineers, and the contracting company must put their heads together and engineer out the problems in advance. It is unreasonable to expect production line personnel to manage all the problems as and when they encounter them.

Integrate shotcreting into the development cycle

Often the planners who put the metres into the feasibility development schedule, and the managers who accept them, have not experienced the 'horrors' of development at ultra-depth. The result is that the line manager doing the development is faced with a horrible dilemma—how to achieve his call while at the same time trying to get a shotcrete programme off the ground. The rates must include shotcreting and the multi-blast cycle must be built around the shotcreting process—simply because this is the primary bottleneck.

We know we have to develop rapidly at ultra-depths in order to make the project viable. We also know that we have to support our tunnels so that they can adequately perform the function for which they were designed (i.e. safe and efficient transport of men, materials, rock and services, over their life-time). There seems to be a notion that says we can't develop quickly enough if we have to shotcrete up-front—therefore catch up later as and when conditions permit.

This is the reason for adding this section to this paper. Simultaneous shotcrete-type support is as much of a pre-requisite for access development at depth as is speed. If we know this up-front, and we engineer the systems' requirements, do our planning properly, and manage it, I don't see any reason why the necessary rates of advance cannot be achieved. If we don't, we place an impossible burden on line production personnel 'down the road'.

Conclusions

$2^1/_2 + 2^1/_2 = 5$. We know we can sink two 2 500m shafts to get to 5 000m, and provided we had all the time we needed we could adequately support our tunnels to get to the ore body that we are going to mine. If Western Deep Levels has been stoping at 3 500m for twenty years, and is going to stope at 4 000m within the next 10 years, then I have no doubt that we can stope at 5 000m. So we as mining engineers know that we could mine down to 5 000m, but the question is will we?

Unless people can work down there in an environment which is at least as safe as the top third of our current gold mining operations, we should not mine down there, nor I suspect, will society permit us to. If we can mine down there safely, then we will only get there if we have an attractive enough project proposal to put to the investors—'R 5bn down now and your money back in twenty years' won't 'rock the stock exchange'.

In the paper I've tried to give a very general, brief overview of the technologies involved in mining at 5 000m, and specifically those involved in rapidly accessing the ore body at these depths. The time taken to sink two 2 500m shafts down to 5 000m will in all probability preclude a project of this nature ever getting off the ground because of the very long lead times involved. If it has already cost your company billions of Rands and 5–20 years to get to 4 000m below surface, then the cheapest and quickest way of getting to 5 000m is through either a tertiary shaft or a re-deepened sub-shaft. However, for the purpose of this paper, 'our' new mine was below someone else's mine and this option was not available.

I have shown that the key to getting there is to be able to sink to 4 000m in one go. Then we have to adequately support our ultra-deep level tunnels so that they stay open once stoping operations commence. The next critical issue is that we have to be able to 'see into the rock' well ahead so that our mining layouts and actual development avoids all major geology, i.e. we tie up discontinuities into our stabilizing pillar network.

Then, provided we can adequately cool our workings, and with 'total' backfill and pre-stressed elongate-type support on the face, we ought to be able to mine at 5 000m.

I've also shown that most of the above is possible using existing technology—the only possible exception being the ropes themselves, and the ability to 'look into the rock ahead of us'. This is not to say that the quest for new technology must not proceed with much greater urgency than before—it must, but not only so that mining can take place down to 5 000m. The entire gold mining industry stands to benefit most from technology that will bring about productivity improvements and minimize the human risk involved in mining at depth.

I'm confident therefore, that we can design 'our' mine down to 5 000m. What is as important as the technology involved is the competence, or excellence, of our mining engineering, and here I coin a phrase 'FUNCTIONAL ELEGANCE'.

We must design and engineer out the systems, inefficiencies inherent in so many of our shaft systems, that make line production personnel's lives so difficult. Mining at depth is problematic enough—we can make it easier through engineering and design excellence—and the use of appropriate new technology.

In conclusion, I would like to thank Anglogold for granting me permission to publish this paper. ◆

UCT engineers at the cutting-edge of mineral processing research*

International Conference, 'Minerals Processing '97', the 16th Annual Minerals Processing Symposium, was organized by the Western Cape Branch of the South African Institute of Mining and Metallurgy in collaboration with the Universities of Cape Town and Stellenbosch, and the Cape Technikon.

The 'Process Control Workshop' was held in Stellenbosch on 6 August, and 'Minerals Processing '97' was held at the Graduate School of Business at the Victoria and Alfred Waterfront in Cape Town on 7th and 8th August.

The conference was privileged to be addressed by Dr Victor Philips, President of the IMM, Dean of the Faculty of Engineering, University of Exeter. He was hosted by the SAIMM (which is the daughter institute of IMM). Plenary speakers were Dr. N.A. Barcza, Vice-President of Mintek, and M.A. Reuter and J. Villeneuve of TU Delft, The Netherlands. A large contingent of Australian researchers from the Julius Kruttschnitt Mineral Research Centre, University of Queensland, Australia, were present at the conference endorsing the strong collaboration between the two countries in the field of Minerals Processing.

Following on from the SAIMM Conference was the mid-year AMIRA P9L meeting (Australian Mineral Industries Research Association) held on 10th and 11th August which was organized by AMIRA (Melbourne) in conjuction with the departments of Mechanical and Chemical Engineering, UCT. It was the *first* AMIRA meeting held in South Africa. Approximately 60 delegates from Australia, Canada, South Africa and the USA attended the meeting.

UCT are sub-contracted by the Julius Kruttschnitt Mineral Research Centre (JKMRC) in Brisbane to co-ordinate the South African component of the AMIRA (Australian Mineral Industries Research Association) P9L project, which has been running for 34 years and been funded by 27 industrial sponsors, including some of the largest mining companies in the world.

The P9L project is an extensive research programme in the field of minerals processing aimed at understanding and ultimately simulating entire industrial mineral processing operations.

The UCT Flotation and Comminution Research Groups, have undertaken to complete a four-year cycle of P9L research programmes for the South African mining companies Amplats, Gencor, Goldfields and Lonrho. The South African mining suppliers Bateman Process Equipment, Outokumpu, Senmin and Weir-Envirotech have also joined the P9L project as project observers. ◆

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