Improved technologies in longhole blast hole drilling, applied to dropraising and longhole stoping as well as the application of a small twin boom mechanized drillrig

by P.H. Ferreira*

Synopsis

'Longhole blast hole drilling' techniques are not new to the mining industry. Appropriate mechanization and improvement of the techniques and application has evolved from the industry requirements.

Today safety and economics play a larger role in the excavation of ore passes, ventilation passes, and relatively small inclined excavations in the conventional gold and platinum industry.

The application of dropraise drilling from the top or from the bottom is discussed investigating the current techniques available, DTH application, advantages and disadvantages, limiting factors, typical layouts and proposals, the drop raising technique and future applications. Similarly, the application of longhole blast hole drilling in tabular and massive orebodies is discussed with emphasis on the DTH application, advantages and disadvantages, limiting factors, typical layouts, the long hole stoping techniques and future applications.

Dropraising

Dropraising also known as 'Longhole Raise blasting' or 'Upside down Raising', whereby an excavation is completely pre-drilled over the full length and then charged from the top and blasted from the bottom in practical lengths for an effective advance per blast.

This technique has been practised in South Africa for many years and perhaps even longer in the First World mining countries.

Why dropraising

Some prominent benefits are:

Safety

The raise needs never to be entered once blasting commences, thus avoiding hazards posed by falls of ground, fumes, poor working conditions, etc.

Speed

Drilling of the raise is much faster than handheld operations. Once drilling has been completed, blasting can take place without the interruptions of making safe and drilling the next round.

Economy

The inside of the raise is never equipped eliminating the cost of equipping.

Improved safety and speed result in early availability of the raise.

Available techniques

Independent rotation drifter longhole drilling has been practised over many years utilising relatively small diameter blast holes (±50 mm). Accuracy constraints limited the lengths to shorter holes, i.e. generally around 40 m. Longer holes can be drilled but accuracy is not guaranteed.

Drilling accuracy is partially determined by geological and operator competence factors. It can however be greatly improved by using more rigid drilling equipment such as 'down the hole' or 'in the hole' drills.

The plant typically used for this type of drilling is a DTH mini rig with an electro-hydraulic power pack, control console and 1000-cfm x 21 bar mobile compressor.

These units have been modified to fit in most modern shaft cages for the ease of transporting between levels and into the workings. However the assistance of a rigger is required at times.

A machine is capable of drilling approximately 40 metres of dropraises per month under normal conditions.

Dry drilling in the hole is preferred in down drilling and dust is controlled using a water quench at the collar of the hole. Water in the hole reduces the effectiveness of 'chip' removal and re-grinding in the hole bottom reduces penetration speed and bit life.

The introduction of large diameter holes and recognition of a crater retreat breaking (as opposed to that based on a cylindrical cut) has led to changes in drilling patterns and the method of charging holes. Considerable success has recently been achieved in this field.

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The introduction of slurry blasting agents has proved advantageous as not only can these high density waterproof compositions be fully coupled in blast holes to provide maximum blasting effect, the hazard of misfires or cut-offs is significantly reduced.

It is thus felt that the earlier limitations of dropraising have been largely overcome by technological innovation and longer raises can now be undertaken more confidently.

'DTH' (down-the-hole hammer) long hole drilling is another technique utilized and offers some advantages over drifter drilling. Some advantages could be:

- Hole accuracy is much improved due to larger blast holes, hammer action down the hole and more rigid drill pipe
- Hole lengths of up to 60 m can be drilled with acceptable accuracy
- Drilling speed is improved as fewer but larger holes are generally drilled
- Hole diameters can range from 58 mm to 200 mm
- The DTH drill string is much more rigid.

Both machines can drill down or up, although down drilling is by far the most common.

Limiting factors (DTH drilling)

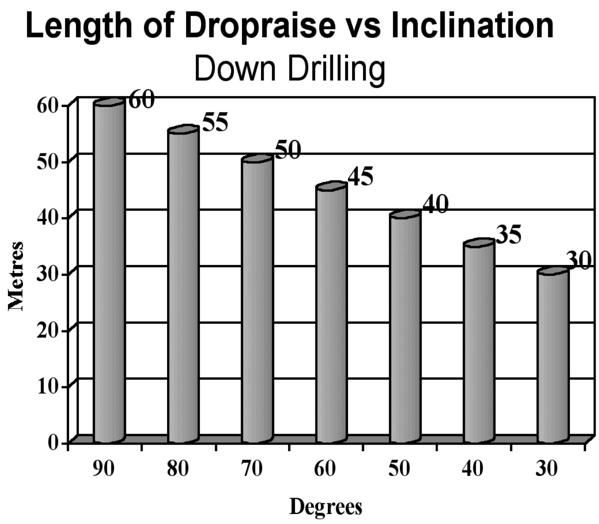
Factors to be considered in designing a dropraising layout are given here.

Hole length vs drilling angle

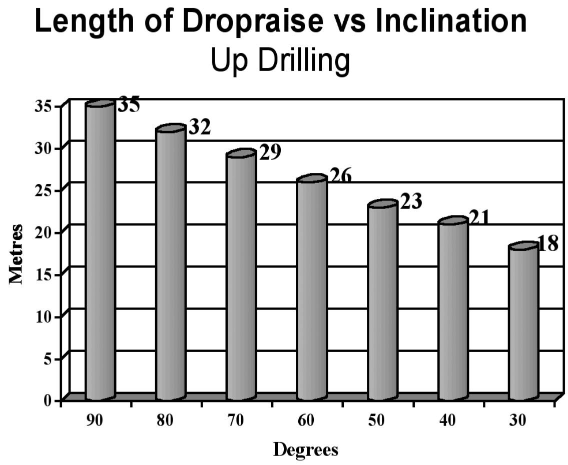
A 90° hole can be drilled to a length of 60 m but hole length will reduce to approximately 30 m at 30° to remain accurate. (This for down drilling).

Up drilling can theoretically deliver the same performance in length and angle but modifications are required on a standard machine to supply adequate power.

Refer to graph numbers 1 and 2 for more detail on in-hole lengths vs. inclination.



Graph 1



Graph 2

Excavation dimensions

Excavations ranging from 1.0 m in diameter to 20 m or more can be excavated using the dropraising technique and is very well suited to vertical settlers, dams, silos, bunkers, orepasses, ventilation passes and travelling ways.

The size of the required excavation will determine the size of the chamber at the top and bottom of the excavation.

Refer to Figures 1 and 2 for more detail on cubby and layout sizes.

Blasting

Blasting is generally performed by charging the holes from the top. Retreat blasting up the hole is used for safety and practical reasons.

Bottom blasting is possible provided only one blast is taken from the bottom.

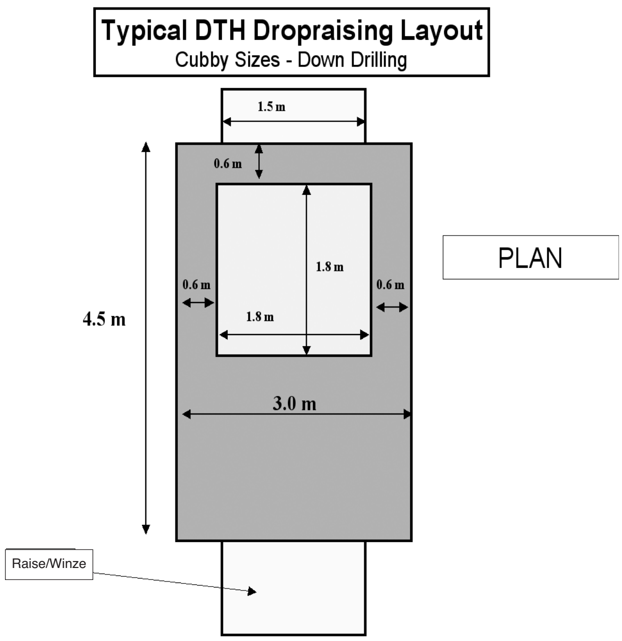


Figure 1

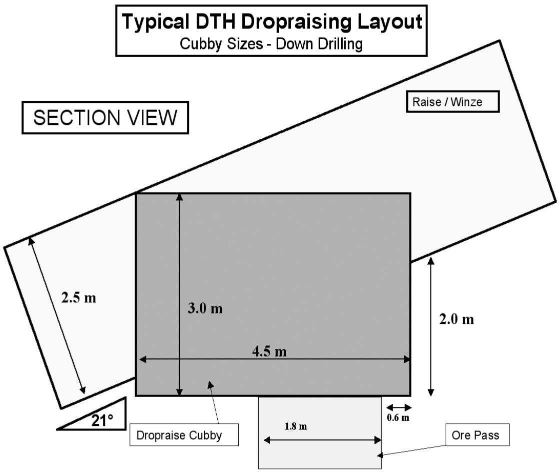


Figure 2

Advance per blast is constrained by the space at the bottom of the hole and the concussion generated by the single blast.

Blasting can also be carried out in a raise with the box front installed to assist with the cleaning directly into hoppers, conveyor belt, etc.

Dropraising is well suited to multi-blasting so permitting rapid safe excavation.

Up drilling

Although not normal, it is becoming more common. Hole lengths are generally shorter and a machine cubby is required at the bottom of the raise.

Down drilling

Is the most common technique because of the ease of operations.

Longer holes can be drilled than is the case with up drilling. A machine cubby is required at the top of the excavation.

Typical layouts

Some typical layouts depicting up and down drilling techniques are shown for orepass layouts.

Refer to Figures 3, 4, 5, and 6.

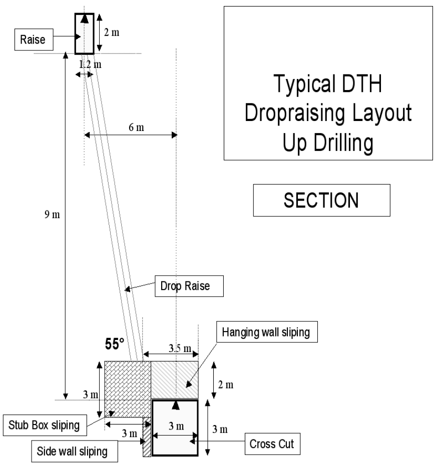


Figure 3

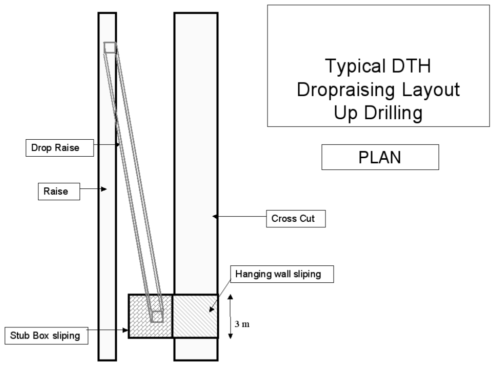


Figure 4

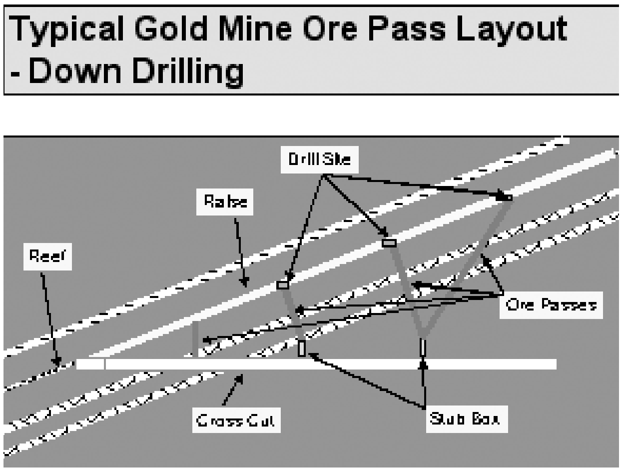


Figure 5

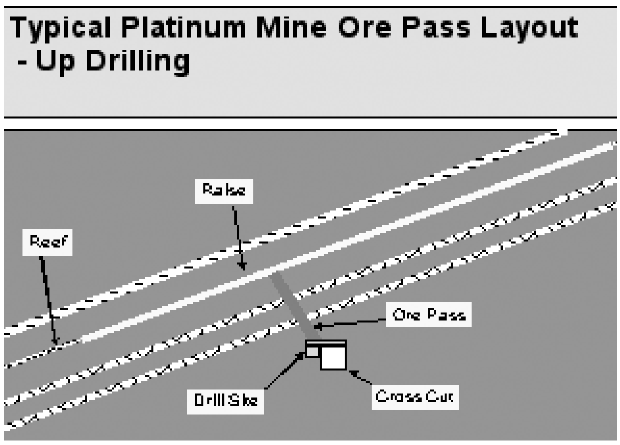


Figure 6

Typical Round

A typical round design will be as per Figure 7 consisting of approximately 9 holes for a 1.0m diameter excavation. It is essential to pay close attention to explosive charge levels as not to cause damage to the excavation sidewalls.

Refer to Figure 7.

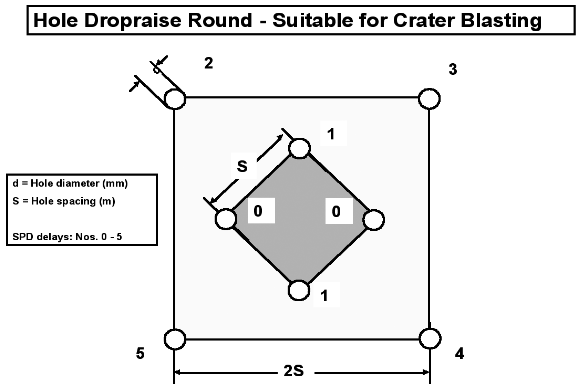


Figure 7

The DTH drilling technique

Mobile compressor

The mobile compressor is usually parked in a cubby as close to the site as possible to reduce pressure drops. A cubby should be provided where the compressor will be out of the way of tramming equipment and therefore protected against possible damage.

Drill site and facilities

A typical drill site for the machine and power pack will be approximately 3.0 m wide x 3.0 m high and 5 m long.

25 MPa x 200 mm thick concrete pad must be constructed on a clean and solid footwall after it has been examined for misfires.

At least six survey pegs should be installed, forming three direction lines, i.e.

- A centre line and two lines on the sides of the required excavation. This is essential for raises longer than 30 metres in length.

Drilling

Rigging

The drill rig is moved into position and lined up from the survey pegs. It is levelled and secured using Camlock props or holding down bolts. The direction is finally checked and the mast is then raised to the required dip and secured. Care is taken during collaring to prevent deflection. After the hammer has been drilled away the line direction is checked again.

Operation

The operator monitors the feed pressure and rotation speed. Feed pressure increases with the depth of the hole. This minimizes possible deflection. If deflection does occur, it is likely the holes will deflect at the same dip and direction, should they all traverse the same ground and geological features.

Deflection

Deflection is a function of hole length and drilling accuracy, beyond a depth of 50 metres, cannot be guaranteed, although reasonably accurate holes have been drilled up to 75 metres. Holes in the range of 50 and 75 metres should be a shared risk between contactor and client and should be a negotiated well-planned operation. Holes tend to deflect clockwise and to tend towards the normal, i.e. to cross the strata perpendicularly.

Holing

The holing position of the dropraise has to be examined and free of explosives/misfires.

The excavation in which the holing takes place must be ventilated to prevent any build-up of gasses. Where up-dip probe holes are required, the excavation should be clear of any accumulations of water and/or mud.

Charging up

On the completion of drilling, each hole is examined from the bottom and plotted to form a 'picture' of direction and orientation of the holes in the round. Before charging up the drill pad is cleared of loose rock. The length of each hole is measured, using a tape measure, tied off-centre to a 30 cm iron rod. Each hole is checked as clear. Blocked holes are re-opened, usually by blowing out with a 25 mm compressed air hose or barring out by throwing a jumper attached to a bell wire down the hole.

Once the holes have been measured and cleared it is checked whether the face has broken out and not only blasted out large sockets or craters.

The length of the bottom stemming is calculated for each hole to re-create a 'face' for the charge to ensure that the charge is on the same elevation. The hole is plugged using a conical plug or sandbag tied to a polypropylene string and anchored to a bar at the collar of the hole. After the bottom stemming has been placed, each hole is measured again to check that the stemming was placed correctly. Thereafter the explosive charge is placed in position. It is preferred to spread the volume of the charge over the length of the hole using single full-length tube cartridge to ensure the correct coupling. Cartridges of these dimensions are not usually standard items and may have to be specially made. It is important to ensure that the specific explosive charge in the area is not too high and will not result in freezing.

The preferred initiation system is electric detonators. It is the most reliable for the firing sequence and also causes the least damage.

Cordtex exploding on the 'wall' of the hole causes damage and increases the diameter of the hole. In long holes the hole may eventually become oval and the volume of the hole becomes uncertain.

Cordtex often damages structures in the hole that can cause scaling in the hole, especially at 'white spar tracers' and mylonite fillings on fault planes. This can cause permanent blocking of holes that require re-drilling to re-open them.

After each charge has been placed, the depth is measured to ensure that the charge is at the right elevation.

The preferred aggregate for bottom stemming is 10–16 mm crusher stone, but for top stemming a tube filled with water is used. Aggregates like sand and crusher stone can be used as top stemming but tend to be compacted with large charges and cause blockages.

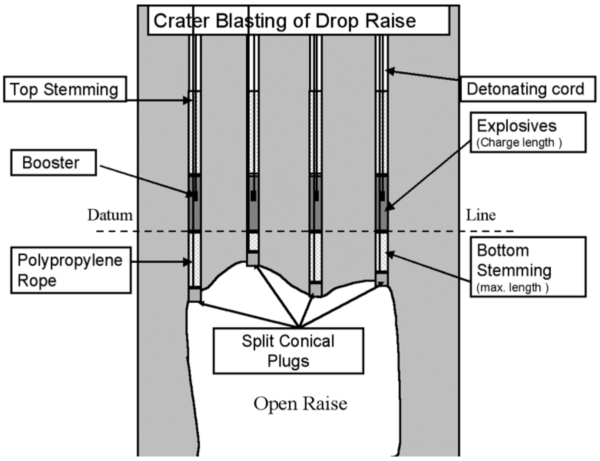


Figure 8

Finally a top stemming is placed to complete the charge. Top stemming reduces 'back blast' and encourages the crater effect. A shot exploder is used to set off the blast.

Rock handling

A dropraise box or excavation is to be cleared after every blast. This is to allow for the bulk of the concussion energy to escape through the bottom of the dropraise box or excavation and reduce 'back blast' through the holes. Back blast is caused when limited space is available below the blasted face and the dirt pile. It can cause extensive damage when the concussion energy cannot escape via the bottom. Typical damage that can be caused by 'back blast' are:

- ➤ When aggregates are used for top stemming, back blast can compact it to such an extent that it can freeze the hole so as to require re-drilling for re-opening.
- ➤ Back blast energy will penetrate the hairline fractures, especially at soft/hard rock intersections and geological formations. It can break out pieces of the formation that can scale out into the hole and so block the hole high remote from the face position.
- ➤ Back blast energy penetrates into the fractures close to the collar of the hole and can badly damage the collar area or the footwall at the top of the raise.

This is extremely dangerous in areas where ledging has already been done and stope induced fractures occur. It can badly damage and lift out large blocks of the stope footwall.

- ➤ Back blast can have a cannon effect out of the hole and destroy support and services such as ventilation pipes in a raise that is not holed.

DTH equipment

Drill rig

The rig comprises five independent, free–standing modules of which four are interconnected by hydraulic hoses with quick-release type couplers:

- ➤ Base frame and mast - 225 kg
- ➤ Valve bank - 100 kg
- ➤ Power pack unit - 180 kg
- ➤ Tank module - 150 kg
- ➤ Lubrication module - 50 kg

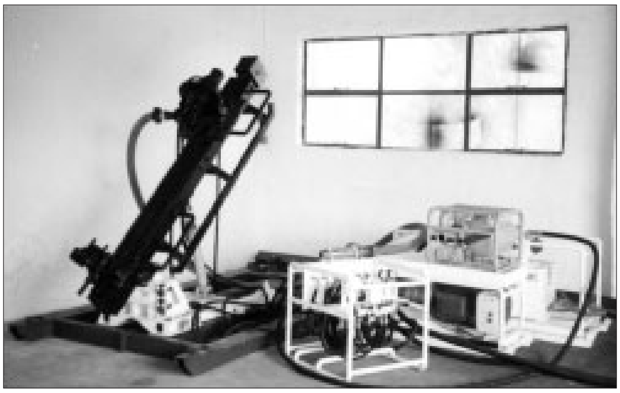


Figure 9—DTH drop raise drill rig

High Pressure Compressor

The compressor unit is a bogey-mounted unit with slinging lugs and fittings to allow transportation through shaft systems and along haulages.

Under normal circumstances the compressor unit will fit into a cage in a vertical shaft and will not have to be slung.

Future applications

With the emphasis more and more on safety in the mining industry, the search continues for better and safer means to excavate inclined excavations.

Up drilling of boxholes and orepasses has become essential and saves time in the overall excavation cycle.

Methods and techniques are continuously being modified to satisfy the needs of the industry.

Longhole stoping blast hole drilling rig has evolved from the experience gained in dropraising and research and development.

Longhole stope blast hole drilling

Definition:

'Longhole stoping' can be described as:

- ➤ Blast holes drilled parallel to an advancing tabular orebody stope panel or face and blasting the reef into a gully for cleaning.
- ➤ Long blast hole drilling in a larger or massive orebody in extracting the ore.

Typical applications

Tabular narrow ore-bodies

Typical layouts are depicted in Figures 10 and 11.

Holes are drilled parallel to the advancing face approximately 15 to 20 m long with burdens around 50 to 70 cm (ground dependent) and hole diameter of 58 mm.

An ASG (advanced strike gully) or dip gully must be pre-developed at a width of ±3.0 m and a height of ±1.5 m from where the drilling and charging-up occurs.

Ideally, a stoping width equal to the channel width can be removed with very limited or unnecessary waste thus managing grams per ton. Ideally the stope panel should not be entered.

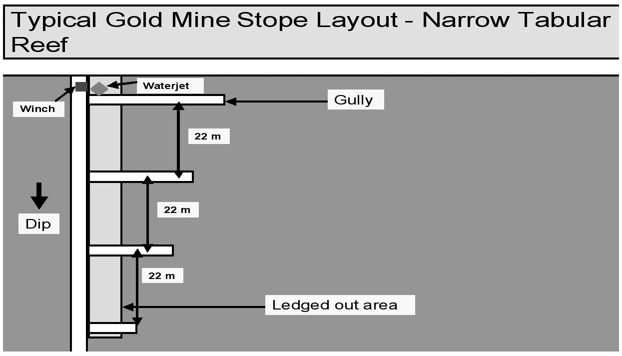


Figure 10

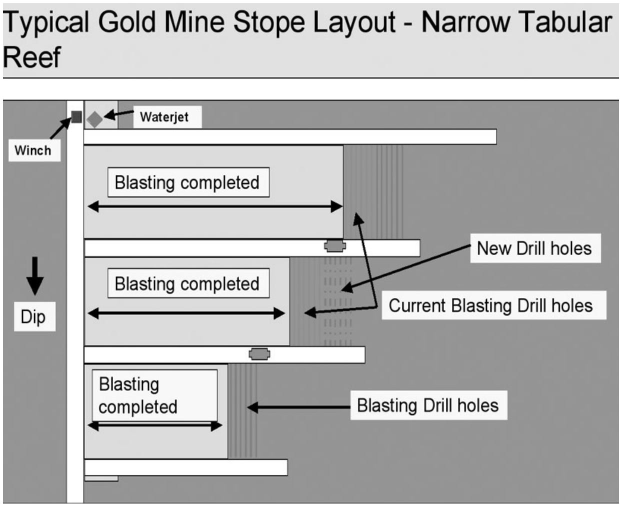


Figure 11

Larger massive type orebodies

The long blast hole drill rig can also be used in larger and massive orebodies where holes of 15 to 20 m need to be drilled. Applications such as drawbells, undercut stoping in blockcaves and sub-level caving can be drilled.

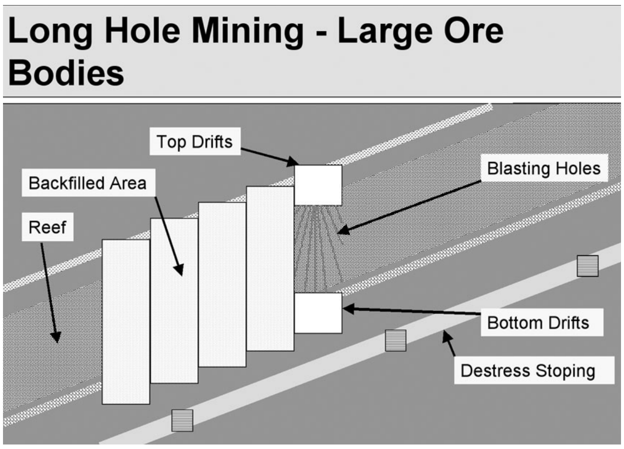


Figure 12

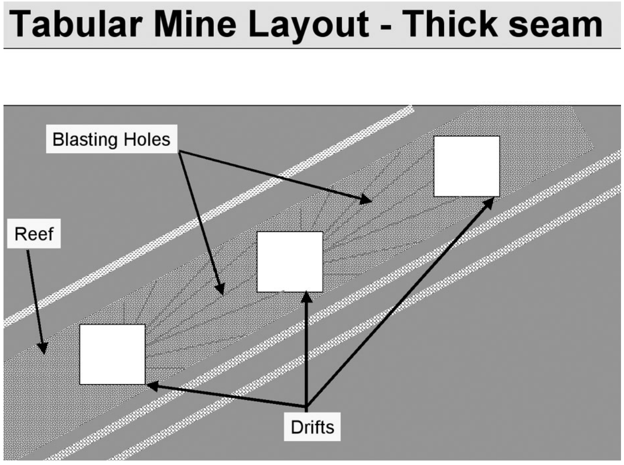


Figure 13

Advantages of long blast hole drilling with a small drill rig

- Small unit with dimensions of:
  - 2.8 m in length and
  - 1.45 m in width and
  - 1.32 m in height
  - 2.55 m boom length
- DTH (down-the-hole hammer technique)
- Accurate drilling
- Limited capital outlay compared to other mechanized units
- Relatively small unit that can be pulled into existing stopes
- Cost-effective unit
- Well suited to narrow tabular reef orebodies.

Disadvantages

- Requires a high pressure (20 bar) compressor unit with high pressure piping
- Current unit is suitable for narrow tabular reef orebodies (different unit required for steep drilling)

Figure 14—Longhole stope drill rig

Limiting factors

Length

This unit can accurately drill between 15 and 20 m in a relatively flat dipping orebody and stabilizers are used to assist with drilling accuracy.

Dip/Inclination

The current drill rig model can drill at angles from –25° to +25° without modifications. Modifications will be made to the unit required for steep dipping orebodies.

Longhole stoping is ideally suited to steep dipping narrow reef orebodies where it is not essential to install support in the back area.

Gully dimensions

The drill gully dimensions should be:

± 3.0 m wide
± 1.5 to 2.0 m high

Drilling

This unit can drill up and down from within the drill gully reducing moves to another gully.

Drill hole diameter is currently 58 mm utilizing the DTH technique.

Stabilizers are used to assist with drilling accuracy.

Drill speed is again a factor of the type of rock to be drilled, geological discontinuities, ground conditions and operator skill.

Blasting

Blasting of long holes takes place with millisecond delays between holes. Only ± 4 holes are blasted at one time.

The type of explosive used is a matter of opinion, economics and blasting success but generally used components are:

- Detonating cord
- Boosters where applicable
- Anfo or cartridges
- Electric detonation or fuses.

Future applications

This DTH long blast hole drilling on crawler-mounted tracks shows great potential in narrow tabular reef orebodies.

Low grade orebodies can now be extracted more cost effectively by reducing the mining of waste and possibly a reduction in stope support.

The drilling unit has proven DTH technology.

Drilling can be modified to suit individual needs regarding:

- Stoping widths
- Dips
- Excavation heights and widths
- Traction unit, i.e.
  - Crawler mounted
  - Track bound
  - Rubber tyred

This unit can be a great success in reducing safety risks and reducing mining costs.

Small twin boom drilling mechanized development

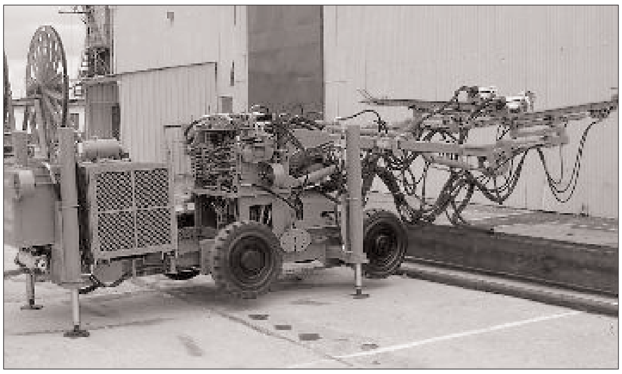
Appropriate mechanization of conventional development ends has become more and more important in conventional mining.

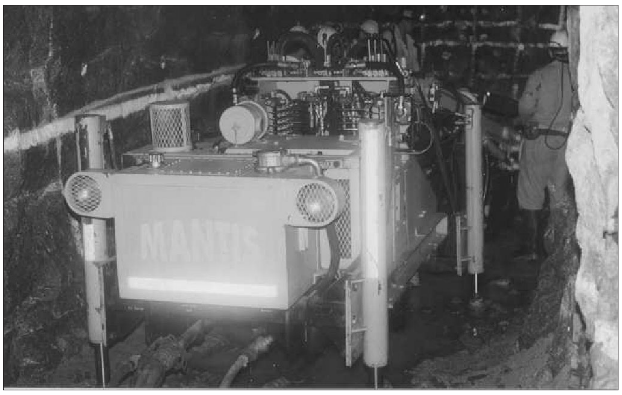
People must be removed from high risk areas in the development cycle such as the handheld drilling of support holes and the development end face.

Machine specifications

A relatively small and lightweight twin boom drilling has been modified to suit some South African mining conditions. Typical specifications are as follows:

Total machine length	=	6.35 m
Total width	=	1.50 m
Total machine height	=	1.60 m (potential min = 1,47m)
Total weight	=	4000 k g
Drilling range	=	4.5 m (W) x 4.5 m (H)
Turning circle	=	2.85 m radius
Self propelled diesel or electric or pneumatically driven	=	1.5 to 3.0 km/h
Boom controls (Twin)	=	Hydraulic system (pneumatically or electrically driven)
Drifters	=	small pneumatic or other
Total boom length	=	2.7 m (standard) can be longer
Feed length	=	2.2 m (standard) can be longer





Figures 15 and 16—Small twin boom drilling

Improved technologies in longhole blast hole drilling

Small twin boom drilling

Implementation

This unit has been successfully introduced on gold and platinum mines resulting in increased productivity due to reduced number of people and improved safety.

Support

Drilling of support holes in large ends, i.e. 3 m x 3 m is done by the machine. The installation of support components is still by hand.

Productivity and safety

This drill rig can compete with a crew of four hand held rock drill operators with improved safety.

Rig capability

The drill rig is equipped with a small diesel engine allowing it to be self-propelled.

Different traction types such as small rubber tyred wheels, allows the unit to operate in a 'trackless' environment at the face from where it can move backwards over the rail tracks. Four outriggers are pushed out and a rail bogey is pushed in to allow the unit to run on rail tracks to another end or workshop.

Various types of small drifters can be fitted to suit individual requirements.

Conclusion

This unit shows great potential in mechanizing the development end face and support drilling activities and especially with ends of varying sizes due to versatile booms.

General

Appropriate mechanization and technology improvement in conventional South African mines has become more important than ever before. ◆

Mineral liberation analyser for Mintek*

Mintek and BHP Billiton recently signed an agreement to facilitate the purchase of a Mineral Liberation Analyser (MLA) from JKTech, Australia. The instrument will be located at Mintek's laboratories in Randburg, South Africa.

BHP Billiton's support is part of its anticipated ongoing relationship with Mintek in mineralogical investigations—particularly through BHP Billiton's Johannesburg Technology Centre.

The MLA, which was developed by Philips Electron Optics, a world leader in electron microscopy, and the Julius Kruttschnitt Mineral Research Centre in Brisbane, is a new tool for rapid and accurate mineral liberation analysis.

The system consists of a highly automated Philips XL40 scanning electron microscope, which provides high-speed, high-resolution back-scattered electron (BSE) images, and an embedded energy-dispersive X-ray (EDX) detector with automated EDX analysis. State-of-the-art image analysis techniques enable accurate mineral identification for particles ranging from 2 to 1000 μm in diameter.

The results from the MLA include the mineral species present, mineral abundance as volume and weight percentages, elemental assay, particle or phase size and surface area, mineral associations, mineral liberation, and false-colour images. These data can be expressed in terms of the sample as a whole, or limited to selected particles, such as those containing an element of interest.

The resulting information as to where and how the valuable minerals are distributed throughout a sample of milled ore or plant stream is of great benefit in designing and optimizing mineral processing circuits. ◆

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Erratum

SAIMM *Journal* Vol. 103, No. 2, pp. 113–118

One of the author's of the paper published in the above *Journal* was mistakenly omitted—N. Kornelius. The paper was entitled 'The use of neural network analysis of diagnostic leaching data in gold liberation modelling' and the authors, of the paper should read K.R.P. Petersen, L. Lorenzen, D.J. Amandale, and N. Kornelius. ◆