Preparation for Mining the No 2A Sub-Shaft Pillar at the Hartebeestfontein Division of Avgold

I N SINCLAIR
Manager
Production South

J D BOSMAN
Rock Mechanics Engineer
Hartebeestfontein Division of Avgold

SYNOPSIS

Preparation for mining a shaft pillar where the integrity of the shaft needs to be retained both during and after the pillar has been extracted, must take cognisance of the following factors.

- Sequence and method of stoping so as to minimize risk and damage.
- Support in the Shaft barrel and environs to cater for anticipated movement.
- Modification to shaft steelwork so as to cater for both lateral and vertical displacements.

This paper also analyses the impact of delays during the preparation for mining due to unforseen circumstances. This will facilitate the preparation of more realistic schedules when planning for the mining of other shaft pillars in the future.

INTRODUCTION

Sinking operations at the Hartebeestfontein No.2A Shaft commenced in the middle of 1957 and were completed early in 1959. The shaft, which is circular, has a lined diameter of 7.32m. This was the first shaft to be sunk at Harties to exploit the ore reserves in the deep block lying to the west of the Kromdraai Fault (Figure 1A). The Kromdraai Fault has a throw of approximately 900m.

The shaft, which has a total length of 1 153m, was initially sunk from transfer to 29° Level. In 1971 it was deepened to 31° Level. An approximately square pillar was left to protect the shaft and its infrastructure. The Vaal Reef intersects the shaft just above 28 Level at a depth of 1 850m and has a mean dip of 10°.

The shaft was served by three 1 715kW winders situated on Transfer Level and is sub-divided into six compartments, four men and material and two rock hoisting compartments. Two of the winders were used for men and material, utilising the north and south compartments while the third was a rock winder with conveyances running in the outer east and west compartments. The rock hoist compartments are the smallest and each had one of its guides attached directly to the sidewall of the shaft.

This is the third shaft pillar to be extracted at Harties, however, it is the first shaft which will remain fully operational during the extraction process. It is vital that the integrity of the shaft be maintained not only during the extraction period, but also after completion, as this shaft will be used for the extraction of the No.4 Shaft Pillar. In addition it will continue to pump the water, which is being drained through the boundary with Stilfontein Gold Mine until the end of the life of the mine.

The No.2A Shaft pillar contains approximately 150 000m^2 of reef and is situated some 1 850m below surface. The decision to prepare the shaft pillar to commence mining in the first half of 1997 was taken as a result of:

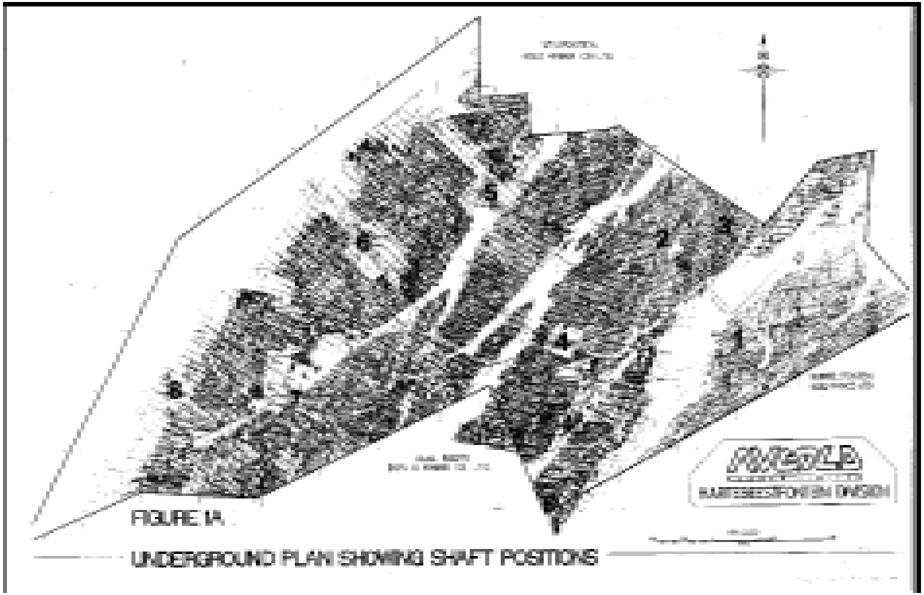

5
6
2
3
4
1
FIGURE 1A
UNDERGROUND PLAN SHOWING SHAFT POSITIONS

Figure 1A

- Mineable ore reserves in the No.2A Shaft area, which consisted of:
  - The No.3 Shaft pillar
  - The satellite pillar to the cast of the shaft.
  - The HB 1 8 fault zone.

Having become largely depleted. All other shafts are independent of 2 and 2A Shafts for the handling of men, material and rock.

No.'s 4 and 5 Shafts which are connected to No. 2A Shaft would serve as second outlets during mining of the pillar. Return airways to No. 3 Shaft would not be affected by the pillar mining operation.

It is essential that the shaft be stable by the time that it is to be used for the removal of the No. 4 Shaft pillar in 1° years time.

The levels interconnecting the above shafts are shown in Figure 1B.

PREPARATION OF THE SHAFT

The amount of work required to be carried out in the shaft prior to the commencement of mining was fairly extensive. It was realised that if this work was to be done at weekends only, mining of it's pillar would not take place ahead of mining the No. 4 Shaft pillar. In order to expedite this phase of the operation, it was decided to close No. 2A Shaft down so that preparatory work could be carried out on a continuous basis.

As the shaft was producing some 2 000m^2 per month from outside the shaft pillar as well as 170m of development, much of it, necessary to prepare the shaft pillar for mining, access for men, material and rock was effected via the adjoining No. 5 Shaft, situated 2,8km to the west of No. 2 Shaft. The time scheduled for this work was 10 months. In reality the time taken exceeded this by almost 50% so that mining of the pillar commenced 5 months later than planned. The last section of this paper analyses the reasons for the time overrun.

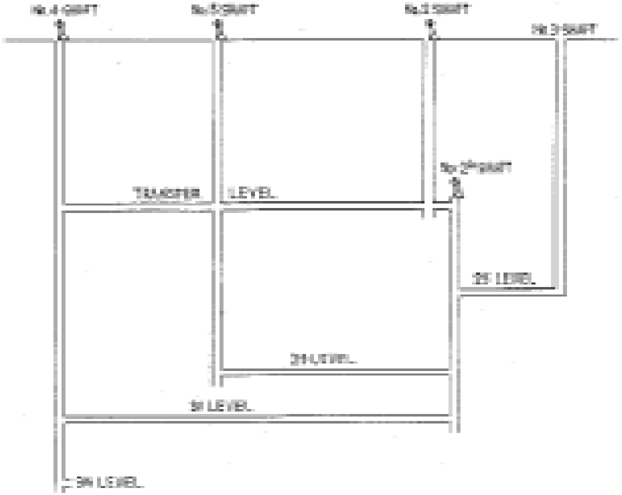


FIGURE 1B

SCHEMATIC REPRESENTATION SHOWING LEVELS ON WHICH Nos 2, 2A, 3, 4 AND 5 SHAFTS ARE LINKED

Figure 1B

SEQUENCE AND METHOD OF MINING

Geology

The pillar is intersected by a number of geological features which effectively divide it up into four distinct blocks (Figure 2). All of these features are approximately dip aligned. The most significant features are:

- A 10 metre wide vertical dyke with a throw of 75 metres. This dyke traverses the pillar some 45 metres to the southeast of the shaft.
- A smaller dyke, either splaying out of or cutting out onto the large dyke and which intersects the shaft in two locations. The multiple intersections are due to the undulating nature of the dyke.
- A 20 metre normal throw fault which can be seen further to the south-cast of the dyke.

A section through the shaft and the pillar shows the relative positions of the various blocks of reef (Figure 3).

Mining Sequence

Bearing in mind the necessity to preserve the integrity of the shaft both during and after the extraction of the pillar, a mining sequence which would inflict the least possible damage to the shaft and its immediate environs was of paramount importance.

Initial investigations showed that in order to achieve the above objectives, it would be essential to mine in a symmetrical fashion from the shaft outward. A detailed mining sequence was created with the idealised plan as a guideline. This mining sequence was used to determine the expected strain and stress changes on the shaft and it's vital excavations by means of numerical modelling (Figure 4).

The expected strain changes were calculated using MINSIM-D and MINSIM-W numerical analysis software. A safety factor of 2 was applied to the maximum expected strains obtained from the numerical modelling prior to designing the shaft steelwork. This was done to compensate for inelastic deformation such as bed separation, as the numerical model was capable of calculating elastic strain changes only.

The mining sequence had to be planned such that mining proceeded away from the shaft in a symmetrical fashion. This limited the available options in terms of approaching the dyke. The dyke will be approached at the most oblique angle possible. Mining will stop 10m short of the dyke leaving an excess shear stress reducing pillar along the dyke. The excess shear stress reducing effects of the pillar were simulated with MINSIM-W.

The design catered for a 60m x 60m inner window around the shaft barrel, holing into a slot already blasted in the shaft barrel. Mining would then proceed further in a symmetrical fashion from the barrel. Mining of the inner pillar and panels adjacent to it was hampered as a result of numerous holings into 28 Level shaft infrastructure excavations.

The presence of a geological feature with significant dimensions increases the probability of seismic activity during the extraction of the pillar. The rockburst prevention strategy adopted for the pillar includes rockburst resistant support in both on- and off-reef excavations, optimising the mining sequence, employing bracket pillars along the dyke and monitoring the rockmass response to mining.

Dyke intersections with access and service excavations were identified and cone bolt support was installed with wiremesh and lacing. Where regarded necessary, this support was supplemented with 6m cable anchors. On-reef support consists of three lines of 200/400kN rapid yielding hydraulic props with 600mm load spreaders. The props are installed lm apart on dip and 1.5m apart on strike and the support to face distance will not exceed 3.5m after the blast. All hydraulic props will be supplied, installed, moved forward and maintained by a contracting firm. Gully ledges are supported by 2 rows of 1,lm x 1,lm solid mat packs installed on a checkerboard pattern. Gully hanging wall is supported by 3 rows of 1,8m shepherd crooks

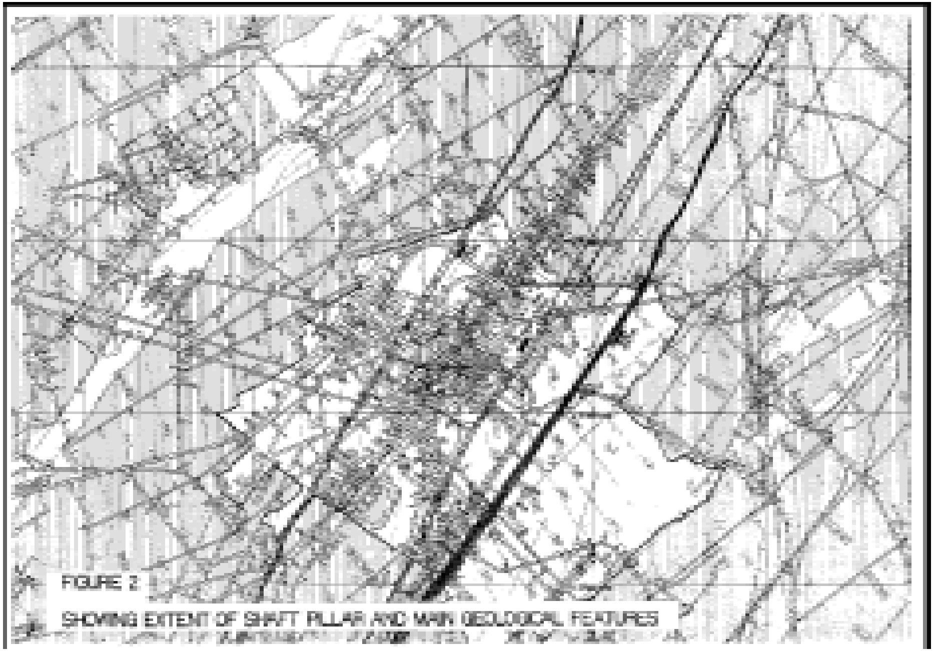


Figure 2

Showing Extent of Shaft Pillar and Main Geological Features

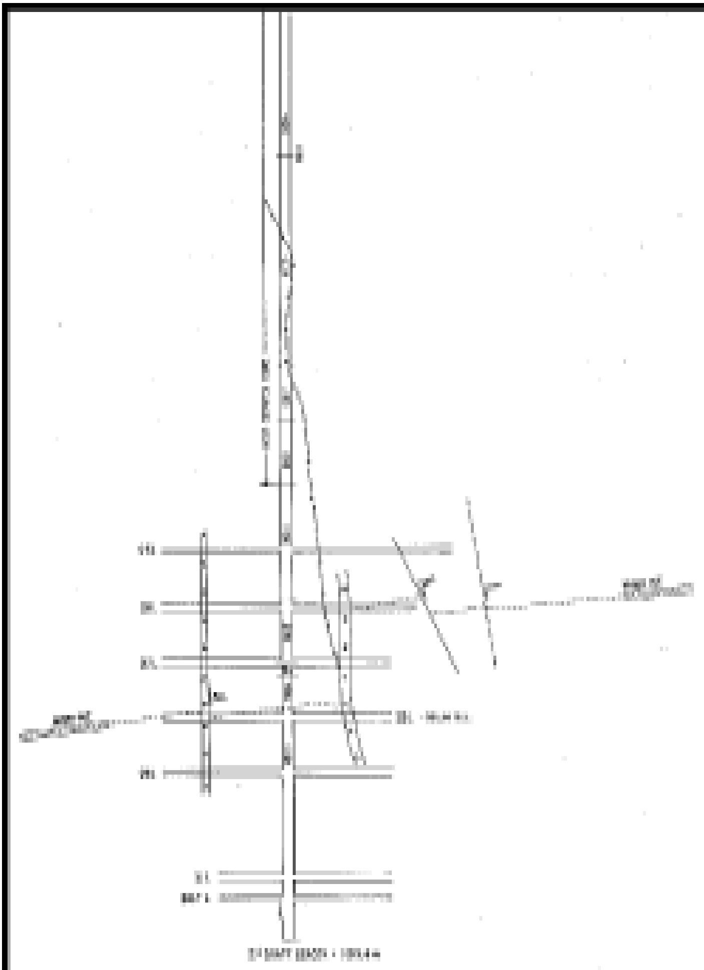


FIGURE 3

SECTION THROUGH SHAFT PILLAR SHOWING GEOLOGICAL STRUCTURE & REEF DISPLACEMENTS

Figure 3

spaced a metre apart in both directions. This method generates support resistance in excess of 200kN/m^2.

The 25 Level Pump Chamber, responsible for handling the Stilfontein water is situated approximately 90m above the reef on the edge of the shaft pillar. Mining will also start at an early stage under the chamber to enable the least possible stress changes during the extraction.

Reef Intersection

The reef was expected to cut through the shaft some 8 metres above 28 Level station. The concrete lining in the area would have been moiled away prior to the installation of Support with the holing into the shaft being effected during the mining on the inner pillar.

As it turned out, the reef intersection was located in the immediate hanging wall of 28 Level station. Consequently it was decided to deck off the shaft on 28 Level footwall and cut a reef slot from the shaft.

Some 100m^2 was mined out in this way, which was sufficient to install a line of quick crush packs on the edge of the shaft and a second line of solid mat packs inside the slot as well as a ventilation seal consisting of pumped aerated cement (Figures. 5 & 6).

Broken rock was removed by a scraper pulling across the platform in the shaft up a fabricated ramp/chinaman box and tipped into a hopper on 28 Level station.

The station concrete lining had to be stabilised once the slot was removed, preventing pieces of concrete from collapsing into the shaft. A dense pattern of 6m long pre-stressed cable anchors were installed in an attempt to not only stabilise the concrete lining but also to consolidate the rockmass, improving safety when stoping of the inner pillar holed into the station.

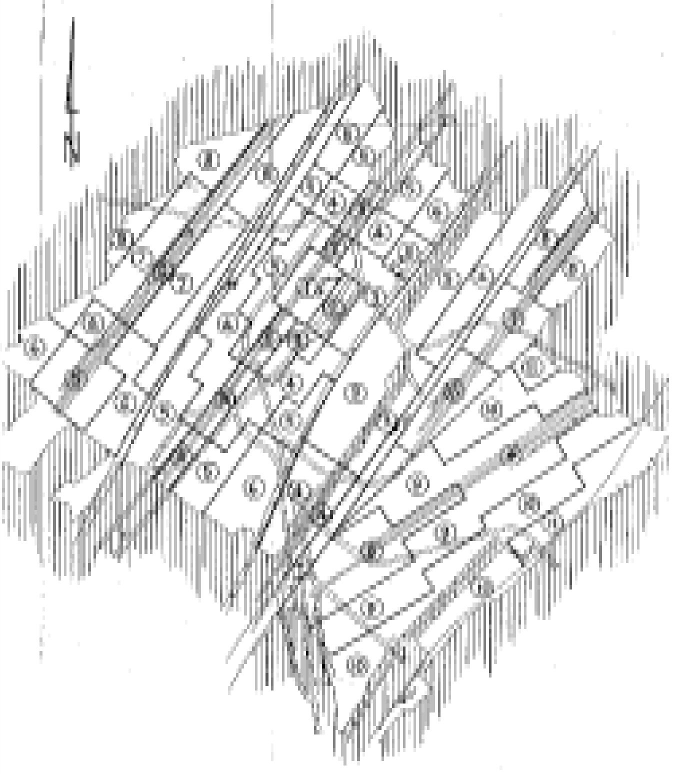


FIGURE 4

SEQUENCE OF MINING STEPS USED FOR MODEL

Figure 4

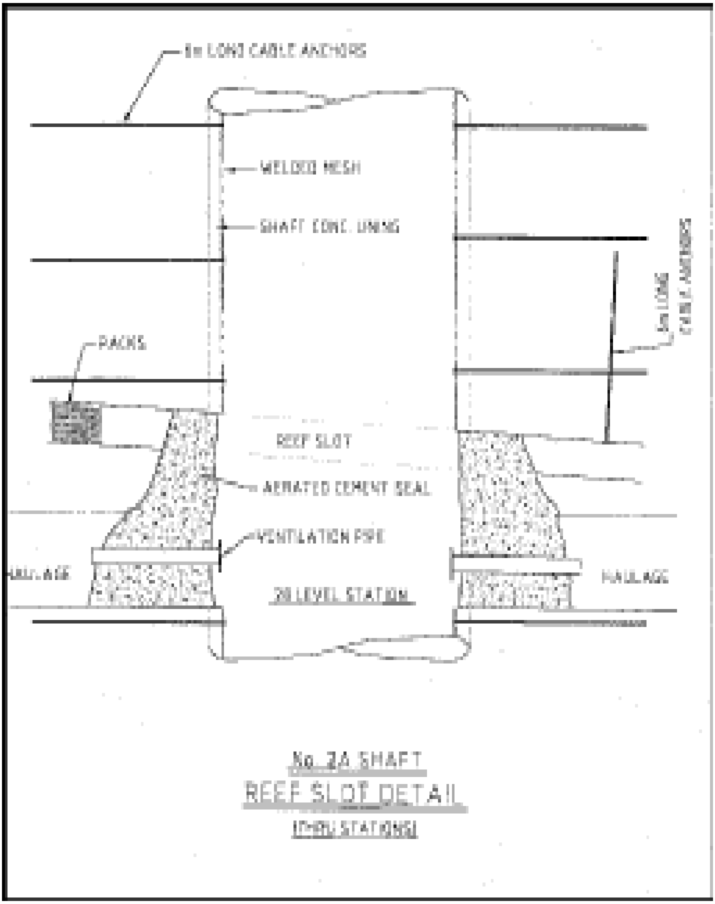

5m LONG CABLE ANCHORS
WELDED MESH
SHAFT CONC. LINING
5m LONG CABLE ANCHORS
PACKS
REEF SLOT
AERATED CEMENT SEAL
VENTILATION PIPE
HAULAGE
28 LEVEL STATION
HAULAGE
No. 2A SHAFT
REEF SLOT DETAIL
(THRU STATIONS)

Figure 5

Shaft Orepasses

With the reef cutting through 28 Level, it was accepted that this level would at best suffer severe damage, and, at worst become totally inaccessible. The shaft orepasses would be mined through at an early stage during the excavation of the inner window. However, once stoping progressed beyond the major 75m upthrow dyke with tipping taking place on 27 Level, the shaft passes would no longer be of use. To this end an intertip-system was developed between 27- and 29 Level to handle ore from this upthrow block of ground.

A traveling way linking 28- and 29 Levels, also forms part of this system (Figure 7).

Due to the anticipated loss of 28 Level, all development to access the pillar for stoping was done from 27- and 29 Levels (Figure 8).

Monitoring Rockmass behaviour

A seismic network consisting of eight three component geophones was installed before mining commenced. The network was designed to record all events of magnitude-1 and greater. The network will be utilised to monitor the rockmass response to mining and to update and improve strategies as the behaviour becomes apparent. The measurements taken by the seismic network will be supplemented by physical measurements in the dyke obtained with the aid of vibrating wire stress meters and creep meters.

SHAFT BARREL SUPPORT

Anticipated mechanisms to be countered by support

The shaft was expected to be subjected to a number of different and changing loading conditions. Support had to be designed to cater for these conditions. The following are detailed descriptions of the loading conditions expected in the shaft:

Vertically Induced Tensile failure

When the shaft was sunk, the rockmass was elastically compressed commensurate with the vertical virgin stress and the rigidity of the rockmass. As the shaft pillar became isolated due to mining over the years the vertical stress in the pillar increased and therefore the rockmass containing the shaft was compressed. The shaft concrete lining and the shaft steelwork have therefore been compressed by a value equal to the total vertically induced strain. Past studies by Wilson and Moore O'Ferrall, and Esterhuizen have shown that maintenance to shaft steelwork and concrete lining starts increasing at a vertically induced compressive strain of approximately 0,4mm/m.

When shaft pillar mining commences the vertically induced stresses are gradually removed causing the rockmass to deform elastically into the void created by mining. The rockmass and therefore the steelwork and concrete lining, which are attached to it, experience a vertically induced strain commensurate with the mined out span around the shaft, the rigidity of the rockmass and the depth of mining. If available, backfill or satellite pillars can be used to reduce the vertically induce tensile strain.

Vertically induced tensile strain in excess of 0.2mm/m is expected to cause tensile fracturing of the shaft concrete lining. The fractures are expected to be horizontal and sub-horizontal. Depending on the competency of the lining and the degree of fracturing blocks may be formed and once isolated have the potential of dislodging into the shaft.

Radial closure due to increased horizontal stress.

During the initial stages of inner pillar extraction, the horizontal stress acting on the shaft barrel is increased. As mining proceeds, the high horizontal component of stress will decrease and migrate higher up and lower down the shaft. The increased horizontal stress is expected to reactivate the fracturing process in the sidewalls of the shaft, which will naturally be associated with radial dilatory

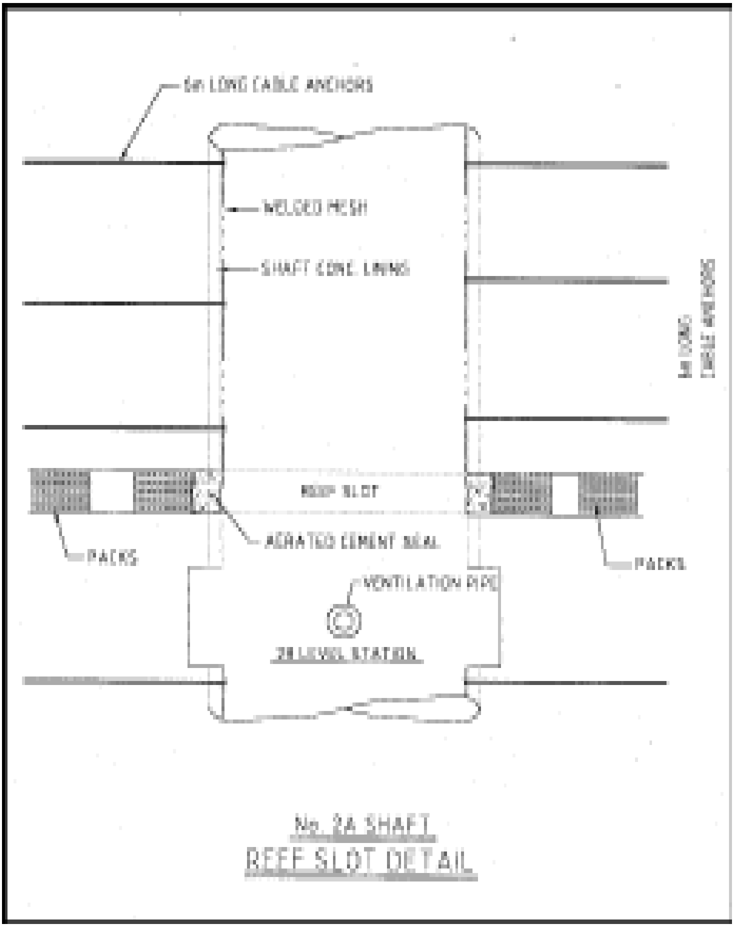

6m LONG CABLE ANCHORS
WELDED MESH
SHAFT CONC. LINING
6m LONG CABLE ANCHORS
REEF SLOT
PACKS
AERATED CEMENT SEAL
PACKS
VENTILATION PIPE
38 LEVEL STATION
No. 2A SHAFT
REEF SLOT DETAIL

Figure 6

displacement into the shaft. This is most likely to result in bulking and flaking of the concrete lining. The effects of these stress changes were anticipated to be most severe in the area thirty metres above and thirty metres below the shaft reef intersection.

Rockburst loading

The presence of a geological feature in the shaft barrel increases the associated rockburst risk during mining operations. The risk will depend on the type of structure, the nature of the structure, its orientation in space and the distance between the reef and the location where the feature intersects the shaft. Numerical modelling was used to determine the value of excess shear stress acting on the feature at the point of intersection. It is suggested that positive excess shear stress at the point of intersection must be avoided as far as possible. Positive excess shear stress would indicate the potential for shear displacement on the fault and therefore dislocation in the shaft. The mechanisms of rockbursts and their associated damage are a complex field of study. To predict the mode of failure in the shaft would be near impossible. Nevertheless, all precautions must be taken to prevent concrete or rock from being ejected into the shaft.

Support design

Considering the numerical modelling results and the geological structure the following areas in the shaft were identified for supporting. Table 1 indicates the location and extent of support requirements in the shaft as well as anticipated failure mechanisms. Figure 9 depicts the four support areas in the shaft.

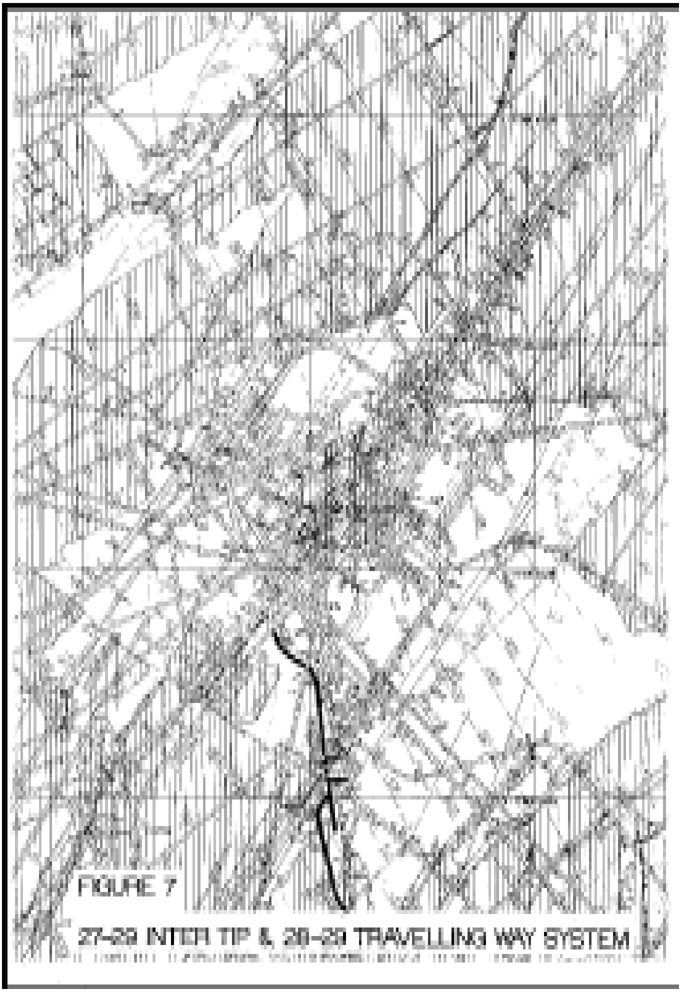


Figure 7

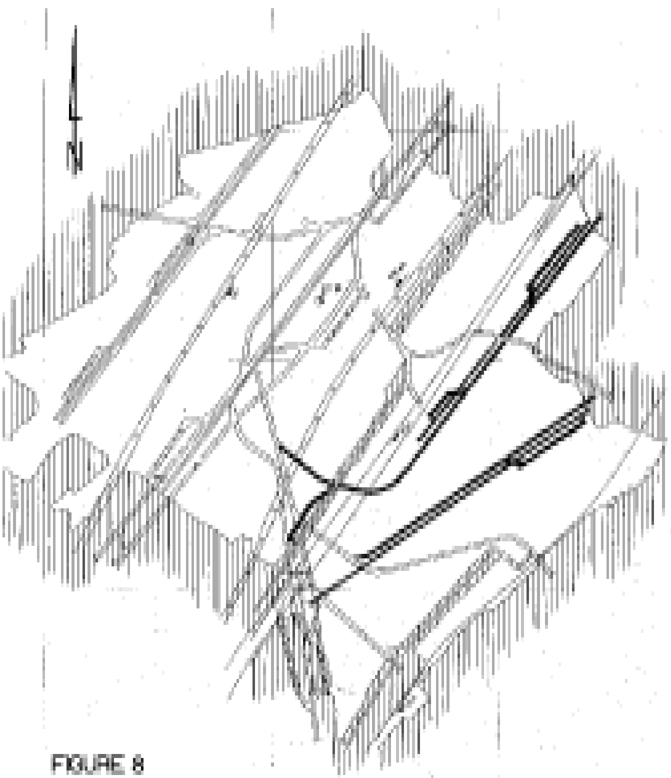


FIGURE 8

2A# SHAFT PILLAR SHOWING PLANNED DEVELOPMENT TO ACCESS THE ORE BODY

Figure 8

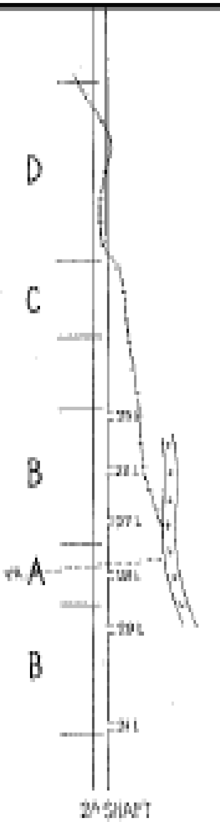


FIGURE 9

SUPPORT AREAS IN NO. 2A SHAFT

Figure 9

Table 1

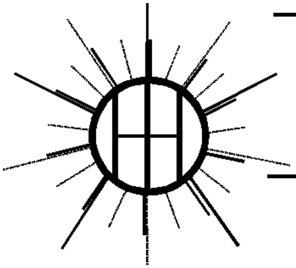
Area	Location	Distance	Anticipated failure mechanism
Area A	From 3m above the reef to 30m below the reef.	60m	Inelastic movement driven by deflationary forces and dislodging of sections of the concrete lining which have failed under tensile loading.
Area B	From 25 Level elevation to 30m above the reef intersection and from 30m below the reef intersection to 5m below 31 Level.	215m	Dislodging of sections of the concrete lining that have failed under tensile loading.
Area C	From 1 628m BS to 1 697m BS	64m	Potential rockburst damage in section of shaft exposed to dyke.
Area D	From 1 418m BS to 1 562m BS.	144m	Potential rockburst damage in section of shaft exposed to dyke.
TOTAL		**483m**	

The support layout took the following factors into consideration:

1. The anticipated deformation mechanism;
2. Time required for installing support;
3. Availability of space in the shaft due to the presence of columns and cables;
4. Restrictions due to cage clearances.

Once all these factors were considered, the following support layouts were adopted.

Area A



Legend

— Row A of 6m long 400kN full column grouted pre-tensioned cable anchors with 75cm bearer plates. Five cables per row spaced 2m apart vertically.

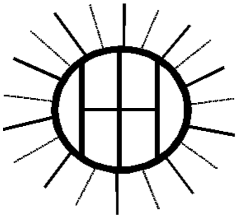
— Row B of 6m long 400kN full column grouted pre-tensioned cable anchors with 75cm bearer plates. Five cables per row spaced 2m apart vertically.

— Row A of 3m long x 19mmÆ left-hand thread rock studs full column grouted. Ten bolts per row spaced 2m apart vertically.

— Row B of 3m long x 19mmÆ left-hand thread rock studs full column grouted. Ten bolts per row spaced 2m apart vertically.

○ Welded mesh 50mm x 50mm x 3.1mm.

Area B

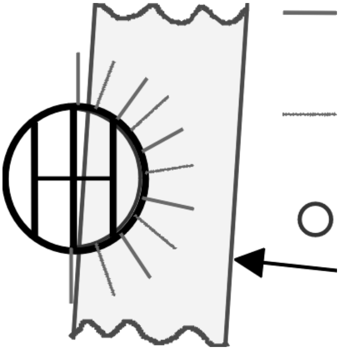


— Row A of 2.2m long x 19mmÆ left-hand thread rock studs full column grouted. Ten bolts per row spaced 2m apart vertically.

— Row B of 2.2m long x 19mmÆ left-hand thread rock studs full column grouted. Ten bolts per row spaced 2m apart vertically.

○ Wiremesh 50mm x 50mm.

Area C



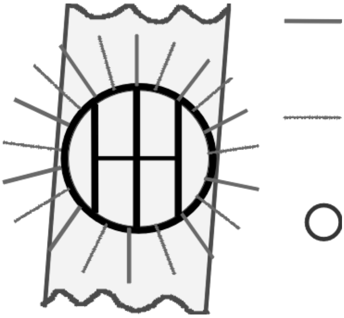
Row A of 2.4m long x 22mmÆ Cone bolts full column grouted. Six bolts per row spaced 2m apart vertically.

Row B of 2.4m long x 22mmÆ Cone bolts full column grouted. Five bolts per row spaced 2m apart vertically.

Wiremesh 50mm x 50mm.

Location of dyke as determined from geological mapping done during sinking stage.

Area D



Row A of 2.4m long x 22mmÆ Cone bolts full column grouted. Ten bolts per row spaced 2m apart vertically.

Row B of 2.4m long x 22mmÆ Cone bolts full column grouted. Ten bolts per row spaced 2m apart vertically.

Wiremesh 50mm x 50mm.

The rationale behind the support optimisation was to reduce the length of tendons where possible and to install support only where it is required. The support in Area A remained unchanged as it was thought that the original design was optimal.

In Area B the tendon length was reduced as the function of the support is to only contain loose concrete lining sections until they can be removed if necessary. The reduction in length will not reduce the effectiveness of the support. Further, the area to be supported was also reduced by not installing support in the area below 31

Level. The inspection cages from which the support work will be performed will not reach below 31 Level therefore making support work virtually impossible.

The support design used for the shaft dyke intersection area remained the same however, only the areas where the dyke is exposed in the shaft will be supported. The support in this area is designed to contain displacement and absorb energy if the dyke bursts. From experience it is unlikely that the quartzite immediately adjacent to the dyke will also burst into the shaft.

From the above it can be seen that optimising the support design did not in any way compromise its effectiveness.

THE SHAFT STEELWORK MODIFICATIONS

This section will not be discussed in great detail as the steelwork and hoisting modifications form the basis of a separate paper to be presented by the Section Engineer who was in charge of the shaft while the preparatory work was being carried out.

Two major changes were made to the layout of the shaft:

Rock hoisting

Initially rock hoisting was done via the 'C' winder with the skips running in the outer east and west compartments (Figure 10). As one of the guides in each compartment was attached to the sidewall, it was realised that these outer compartments would have to be abandoned. Thus the decision was made to convert the A winder to hoist rock. This necessitated modifications to the shaft loading and tipping arrangements as well as the winder itself. The current layout can be seen in Figure 11. A steel tower 115m in length was constructed to cover the area above and below the reef intersection. The tower is suspended from an A frame situated just above 27 Level to below 29 Level station (Figure 12). Once the tower was installed, all buntons were divorced from the shaft sidewalls.

Externally pressurized compensators were installed on the air, water and pump columns and are situated just above 29 Level. The compensators are designed to cater for the full 600mm of closure anticipated over the length of the tower.

Take up guides have been installed on 29 Level station elevation and are also designed to cater for the full anticipated closure. To date it has been necessary to compensate on the guides for 120mm of closure. This closure has resulted from the mining of 16 000m^2 of the pillar to date and is in line with the anticipated rate of closure.

Horizontal displacements are expected to be of the order of 21mm in the north-south direction and 65mm in the east-west direction.

ANALYSIS OF DELAYS

The total time allowed for preparation of the shaft barrel for removal of the pillar was three hundred and eight days. This program was overrun to the extent of 50%. All delays were recorded and summarised. The analysis of these delays and the reasons therefore have provided valuable information which will be used in the planning of shaft preparation prior to the removal of other shaft pillars on the mine viz No.'s 4, 5, 6 and 7 shafts.

Basically the shaft preparation can be divided into the following four distinct phases:

Phase 1	Support of the shaft barrel and environs.
Phase 2	Modification of loading and tipping arrangements
Phase 3	Installation of the shaft steel work tower
Phase 4	Modification of the A winder and commissioning the rock hoist system.

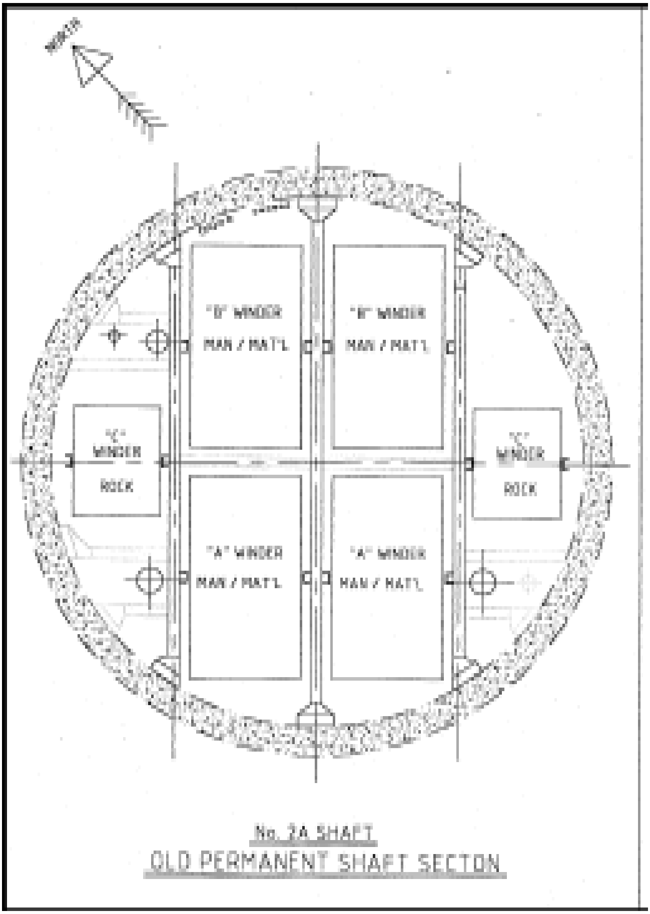

NORTH
"D" WINDER
MAN / MAT'L
"B" WINDER
MAN / MAT'L
"C"
WINDER
ROCK
"C"
WINDER
ROCK
"A" WINDER
MAN / MAT'L
"A" WINDER
MAN / MAT'L
No. 2A SHAFT
OLD PERMANENT SHAFT SECTON

Figure 10

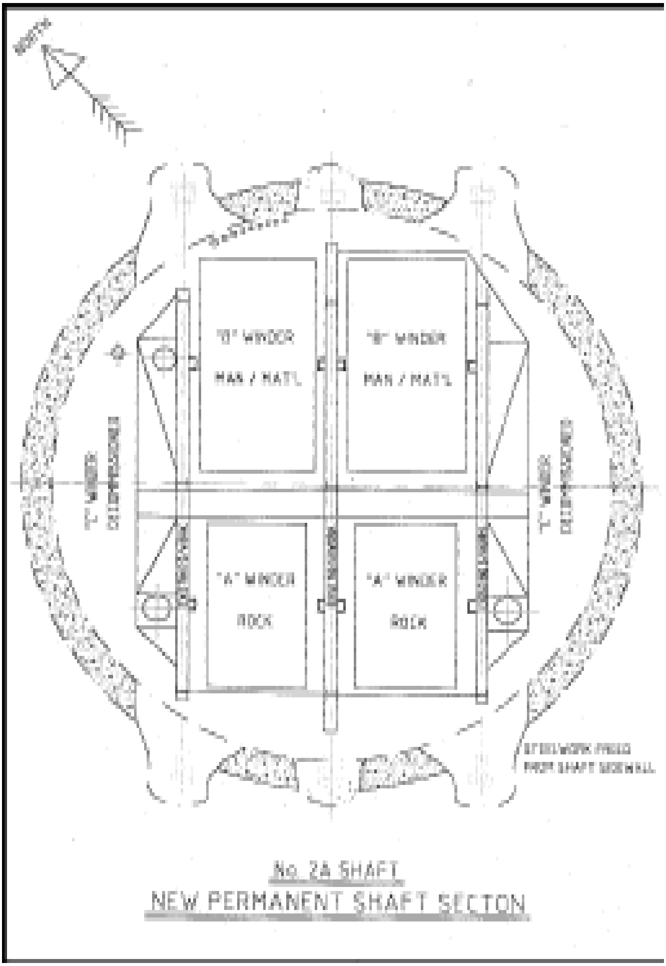

NORTH
"B" WINDER
MAN / MAT'L
"B" WINDER
MAN / MAT'L
"A" WINDER
ROCK
"A" WINDER
ROCK
STEELWORK FREED
FROM SHAFT SIDEWALL
No. 2A SHAFT
NEW PERMANENT SHAFT SECTON

Figure 11

The major delays which occurred during each of the phases are tabulated below.

Phase	Delay in Days	Cause of Delay
Phase 1	17 25	Reef slotting Cleaning shaft bottom
Phase 2	19 11	Steelwork installation Standing time due to mine delays
Phase 3	7 4	Steelwork modification 28 Level station brow Support and ventilations seal installation
Phase 4	20	Loading and tipping modifications, spillage arrangements and winder modifications
Total	**103**	

The remaining delays of lesser duration amounting to 47 days in total were the result of the following:

- Power failures;
- Water problems;
- Statutory examinations;
- Moving of pump crews;
- Interim hoisting.

In many cases assumptions were made during planning which led to major delays once work got underway.

I.e. It was believed that the reef cut through the shaft approximately eight metres above the hanging wall elevation of 28 Level. When it was found that the shaft actually intersects the reef between one and two metres above the hanging wall elevation of 28 Level, it was decided to remove a slot from within the shaft barrel. This necessitated the installation of a platform in the shaft on 28 level to prevent blasted rock from falling down the shaft.

Additional Support in the form of 6m long pre-stressed cable anchors had to be installed on 28 Level to stabilise the station concrete lining. Due to the flat dip, the reef remains close to the station

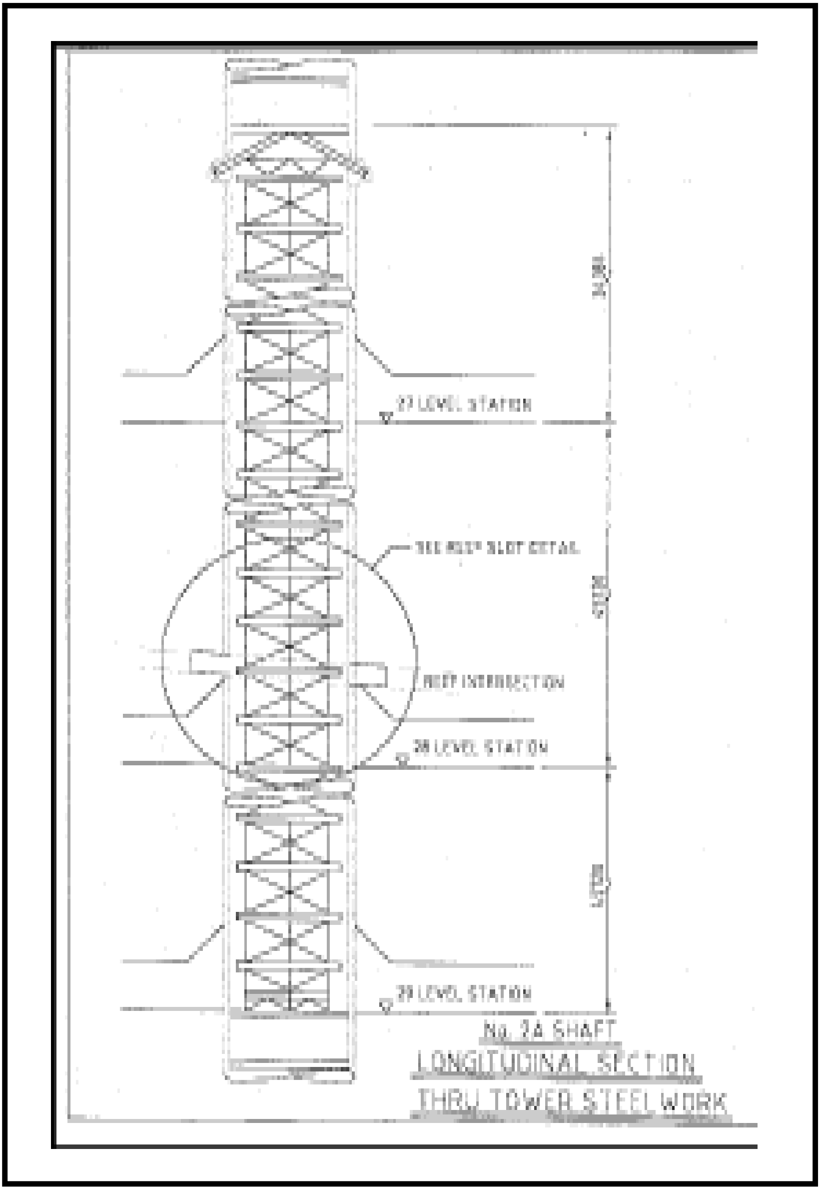

27 LEVEL STATION
SEE REEF SLOT DETAIL
REEF INTERSECTION
28 LEVEL STATION
29 LEVEL STATION
No. 2A SHAFT
LONGITUDINAL SECTION
THRU TOWER STEELWORK

Figure 12

for a considerable distance before an effective brow could be formed.

As a result of the shaft preparation programme running behind schedule, it became necessary to hand the shaft back between phases to facilitate the hoisting of rock. Development within the shaft pillar and limited stoping were taking place concurrently with the shaft preparation work and the shaft ore passes needed to be drawn down to facilitate the continuation of these operations. Clearing the shaft ore passes of fines, which had solidified rendered hoisting a slow process.

As work progressed in the shaft bottom existing steelwork was found to be more severely corroded than originally anticipated, as a result of which more steel had to be stripped, fabricated and re-installed.

Work in the loading and shaft bottom areas was rendered difficult as a result of the amount of water entering the shaft due to mining, support and instrumentation drilling taking place in close proximity to the shaft.

During the installation of the steel tower, a stage was reached where the new steelwork failed to match the existing shaft steelwork. After thorough checking of the shaft steelwork it was found that not all bunton sets in the thirty eight year old shaft were perfectly aligned and equally spaced below one another. From this point onwards, it became necessary to install shorter side plates on certain sets where it was no longer possible to cater for these variances with the built in slotting adjustments. Take up guides were also modified for greater robustness.

The ventilation seal had to be installed on 28 Level station elevation, which due to the height of the excavation became a time consuming and difficult operation, compared to what would have been the case had the reef intersected the shaft between 27 and 28 Levels.

With the benefit of hindsight many of these delays could have been avoided. Production was delayed by some five months in addition to which the project went over budget. The moral of the story is that when preparing an old shaft, particularly one sunk during the era when shaft sinking records were broken, more frequently than face value. The only way is to get into the shaft and take measurements of all the steelwork in the areas where modifications are to be made. Geological information regarding the position of the reef intersection continuation of these operations. Clearing the shaft ore passes of fines, which had solidified rendered hoisting a slow process.

As work progressed in the shaft bottom existing steelwork was found to be more severely corroded than originally anticipated, as a result of which more steel had to be stripped, fabricated and re-installed.

Work in the loading and shaft bottom areas was rendered difficult as a result of the amount of water entering the shaft due to mining, support and instrumentation drilling taking place in close proximity to the shaft.

During the installation of the steel tower, a stage was reached where the new steelwork failed to match the existing shaft steelwork. After thorough checking of the shaft steelwork it was found that not all bunton sets in the thirty eight year old shaft were perfectly aligned and equally spaced below one another. From this point onwards, it became necessary to install shorter side plates on certain sets where it was no longer possible to cater for these variances with the built in slotting adjustments. Take up guides were also modified for greater robustness.

The ventilation seal had to be installed on 28 Level station elevation, which due to the height of the excavation became a time consuming and difficult operation, compared to what would have been the case had the reef intersected the shaft between 27 and 28 Levels.

With the benefit of hindsight many of these delays could have been avoided. Production was delayed by some five months on addition to which the project went over budget. The moral of the story is that when preparing an old shaft, particularly one sunk during the era wehn shaft sinking records were broken, more frequently than most of us have breakfast, original plans should not be taken at face value. The only way is to get into the shaft and take measurements of all the steelwork in the areas where modifications are to be made. Geological information regarding the position of the reef intersection and major geological disturbances must also be ratified during the planning phase.

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