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PMC LIFT II MINING PROJECT OVERVIEW

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SYNOPSIS

Palabora Mining Company was registered in 1956 by Rio Tinto. The mining of the commenced as an open cast mining operations in the year 1965 and the last blast in the pit was taken in the year 2002. At this time the site was a well-established mining complex and a reputable refined copper producer in South Africa. The final dimensions of the pit are approximately 1 600m and 1 900m across in diameter and 825 m deep, ranking as one of a kind mining pit in the country.

The impending uneconomical exploitation of the reserves in the pit resulted in a studying the possibility of mining the orebody from underground. A decision to build an underground mine was reached in the year 1996 and execution commenced shortly thereafter. The result was mining of a 450m high, 700m wide and 200m long block through 332 drawpoints within 20 production drawpoints. This is a fully trackless operation, both secondary blasting and ore hauling. The material is handled through 4 crusher and conveyor belt arrangement. The production steady state of 30kt/day was reached in the year 2005.

Naturally, the depletion of the reserves posed yet another question around business's sustainability. The answer was the Lift II, i.e. construction of a new mining block below the current mining operation. The regional geology knowledge and extensive exploration drilling over the many years of mining in the area revealed that the pipe like nature of the orebody, it extends further down at a near vertical angle.

The Lift II project was approved to extend the LOM by a further 13 years. This decision was made in the late 2013. This made way for a construction of the mining block 430m below the current Lift. The construction entails the shaft systems, i.e. Twin declines, crusher complexes and 434 production drawpoints. The lessons learned with the Lift I design, construction and operation form the base of all the works on Lift II, this from the studies to the execution. The Project is in a full blown execution phase, the development of the decline system is complete and the accesses to both the south and the north of the footprint, the ventilation level and undercutting level has been established. The development is carried out by a contractor under an alliance contract with the owner/client.

This paper seeks to highlight the technical progression made and lessons learned over time in hard rock block caving, especially on design considerations and compliance during mine development. The Lift I construction and operation was/is ground breaking, Lift II pushes the boundaries even further. The underlying theme is largely the marrying of the technical innovation with the safe construction and operation of the Lift II. The fixed plant construction and installation will not be excluded from this paper.

Table of Contents

SYNOPSIS	1
INTRODUCTION	3
The Footprint	3
Dewatering	4
The Drawpoints	4
The Cooling and Ventilation	5
PROJECT EXECUTION	6
The Contract	7
The Mine Development	7
The Resource	7
THE QUALITY	8
The Geotech	9
The Rock Mechanics	11
The Safety Performance	11
CONCLUSION	12
REFERENCES	12

INTRODUCTION

The project is one of two major caving projects in South Africa. The duration of the Lift II project is 7 years, it is currently in its second year of full execution. The schedule is based on activities leading to and the establishment of the hydraulic radius, at which point the caving can be gravity induced. The total mining activities are 10 years long; this is made up of 3 years of 2 600m long twin declines system, 5 years of production level, ventilation level, undercut level, cave initiation and 2 years to complete the footprint and other non-critical path activities.

The approximate total tunnelling will be 39 000m and total undercutting will be 151 000 m²

THE DESIGN

The Lift II design incorporated the effective Lift I features and successes observed over a decade, the technological advancements and technical successes in the Block Caving fraternity over the years, especially in this century. The homogeneity of the rock type and the consistency of the copper grade throughout the extension of the orebody provided a sound base for the general design.

The Footprint

The Lift II production footprint is a third larger than the Lift I. Although it has 3 production crosscuts less, it has 102 more drawpoints. To accommodate these additional drawpoints, the crosscuts are longer with the longest measuring around 400m. The two jaw-gyro crushers will be positioned in the north of the cave, similar to Lift I. However instead of four single tipping point crushers, two jaw-gyratory crushers with four tipping bays each were selected. This increases the tipping wall availability and caters well for the long cycle time brought about by the long production crosscuts. Each of the Lift II crushers is rated at 2000tph.

Drawpoint support will include installation of two drawpoint steel sets, anchored to the rock walls by means of 2.4 m rock bolts. The sets will be shuttered and filled with concrete or shotcrete pumped into the hollows of the legs and crown so that all voids are filled. The bullnose pier construction must be keyed into the bullnose with drilled steel construction rebar or bolts.

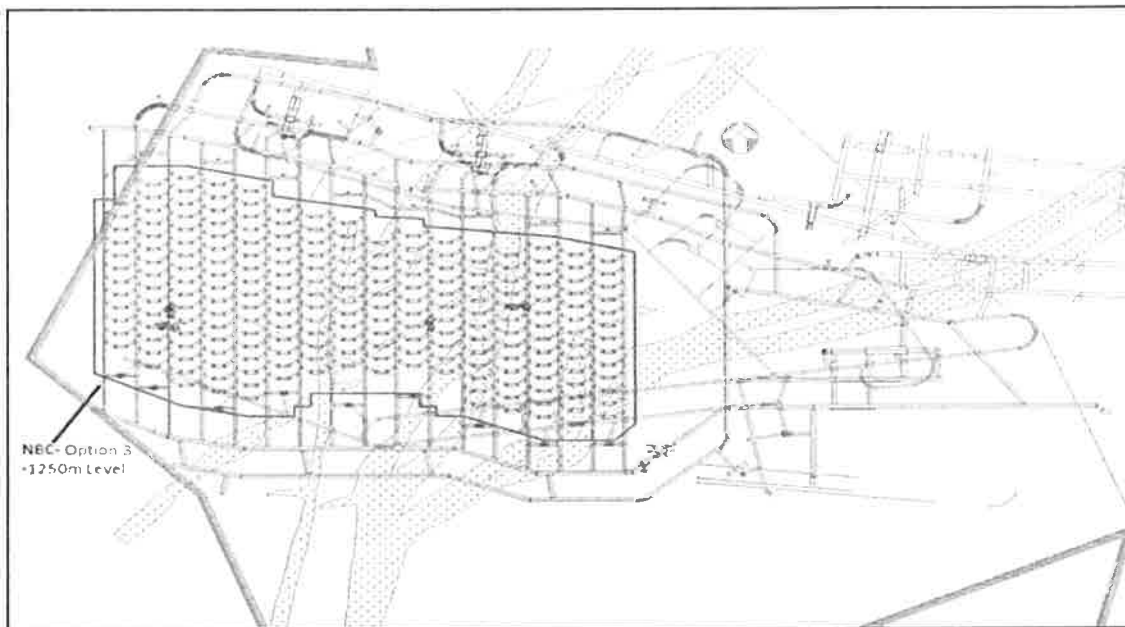


Figure 1 – Lift II Footprint

Dewatering

The Lift I crosscut are sloping to the north, although this ensures that a fully laden Load Haul Dumper travels downhill towards the crushers in the north, so is the water. This advantage is eroded as the by the damages on the roadway in the main crusher access tunnel. The damages negatively impacts the maintenance on both the roadways and the LHDs. The Lift II production crosscuts are inclined to the south at thus removing water and ensuring that the roadways remain dry, especially the main crusher access drives.

The philosophy of the mine dewatering system is such that the mine service water and ground water ingress into the block cave complex is contained on each Lift II level and allowed to gravitate down to the lowest point of the mine through drain holes and ventilation RAP. Clarified water will be pumped from here to the Lift I clear water dams.

The overall philosophy of the underground water management is through means of high rate water clarifiers. Water from mining operations will be separated from solids by use of flocculants and vertical settlers, from which clear water will be recirculated back into the mine service water circuit. Excess water will be pumped out of the mine by a series of five, ten stage, high lift pumps located on Lift I.

The Drawpoints

The drawpoints orientation for Lift II remains the off-set herringbone (figure 2) as laid out in the Lift I instead of the straight through layout commonly known as the "El-Teniente" (figure 3) layout. The layout choice was based primarily on these two reasons:

- Palabora has occasional mud rushes or dry fine material pushes, either wet or dry, rushing out from a drawpoint into the production crosscut. These events can be dangerous and have resulted in fatalities at Freeport's DOZ mine. At DOZ, it was found that in the event of a mud rush, the off-set herringbone layout is safer because when the mud pushes an LHD out of the

drawpoint it hits the opposite rib and swings to move down the production crosscut. With El-Teniente drawpoints mud rushes have been known to push an LHD out of the drawpoint and into the opposite drawpoint, trapping the LHD and operator; and,

- Palabora produces a very coarse ore and experience many more hang-ups than most block cave mines. If there are multiple hang-ups in the drawpoints opposite each other (common at Palabora) then two hang-ups can be washed or loaded simultaneously with an off-set herringbone layout without having to work directly across each other. With the El-Teniente layout, work in one drawpoint would have to be done directly in line with the hang-up in the drawpoint behind. From a safety perspective this is not acceptable work practice. Fines/mud pushes from a drawpoint will flow directly into the opposing drawpoint with possible serious consequences for any activities taking place in that drawpoint.

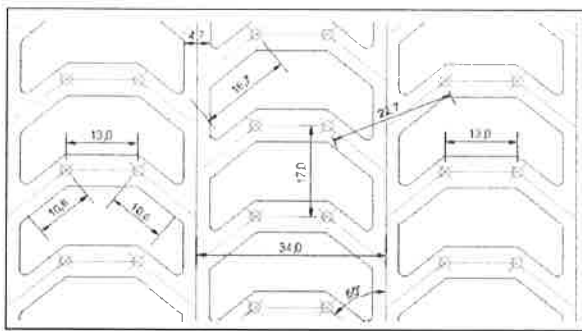


Figure 2 – Off Set Herringbone Layout

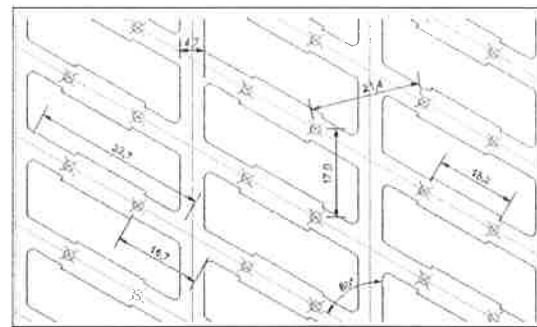


Figure 3 - El-Teniente Layout

The Cooling and Ventilation

The Lift II block cave cooling and ventilation system will tie in to the Lift I infrastructure, as is on many other operational systems on this project. The air will be drawn underground to the Lift I through 2 main shafts, i.e. Production and Service shafts. The air will be then cooled and drawn further down to the Lift II through 3 Fresh Air Passes. The general air flow at the production level will be north to south through the production crosscut. At the south, the air reaches the Return Air Way through a series of Return Air Passes. These RAPs are 2.4m in diameter and on average 40m in depth. The foul air will the make it back the Lift I through the 2 main RAPs and to surface through 2 main ventilation shafts. The air gradient will be maintained by 2 exhaust fans installed at the ventilation shaft. The ventilation infrastructure is depicted in Figure 4 below.

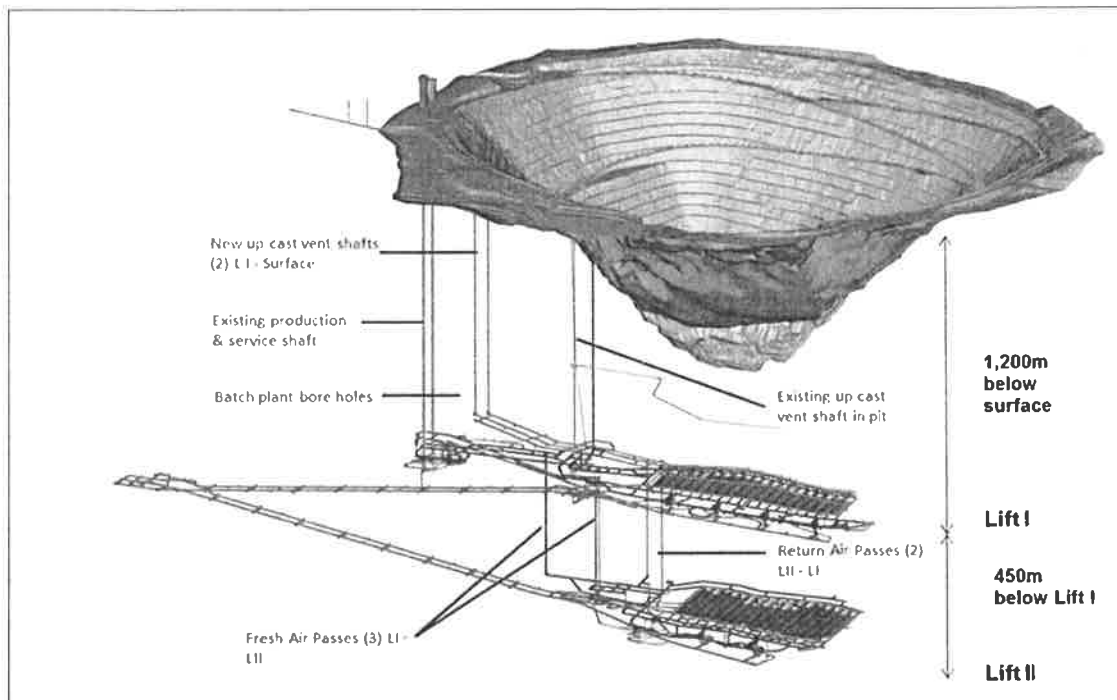


Figure 4 – Ventilation Infrastructure

The table below highlights the Cooling ratings in the Lift II. The average virgin rock temperature at Lift II is 58° C.

Unit	Rating	Position
Surface Air Cooling – Fridge Plant	18.0 MWR	Service and Production Shaft
Underground Bulk Air Coolers	11.0 MWR	FAP 1 & 2
Cooling Cars	2.5 MWR	Decline System
Total	28.5 MWR	

Table 1 – Ventilation Infrastructure

PROJECT EXECUTION

The construction of the Lift II mine commenced in December 2011. This however was two years prior to the full approval of the project. This construction period was known as Early Works Phase. It was primarily instituted to establish the access to the Lift II level, thus Early Works was purely Decline Systems development. A 2,600m long twin decline system and associated temporary infrastructure was constructed during this phase. The actual completion period for this package was just over three years.

The main works or main construction has since commenced in March 2015 and is in its second year of the seven. This phase will fully construct and equip the Lift II.

The Contract

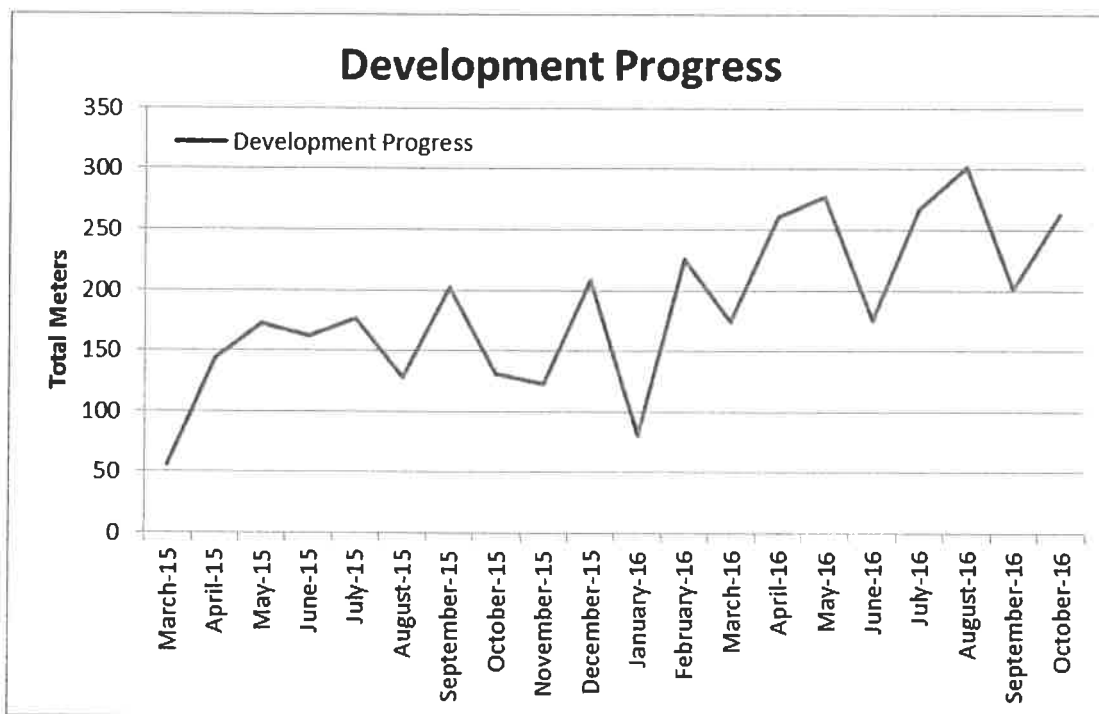
Palabora Mining Company is in an Alliance Contract with the tunnelling contractor. This was the case during the early phase and it still is currently. This arrangement promotes "Pain/Gain" principle equally on both the Client and the Contractor. This is necessary in a brown field project like the Lift II to cater for the interruptions linked to the other operational area, i.e. Lift I.

The current contractor is a fully black empowered South African company.

The Mine Development

The decline system was completed in Q1_2015 at a daily production rate of 7.5mpd. The current workings was progressing at a rate of 5.0mpd since Q2_2015 and the rate has since improved to average of 7.5mpd in the past 7 months and it continues to show an upward trend. The reasons for the improvement are the increased face availability and the High Speed Development program. This program is an efficiency focused intervention that was commissioned to focus on improving the performance. In this programme, a divide and conquer philosophy was adopted. The main development activities were sub divided into work streams made up of subject matter experts, to resolve apparent inefficiencies and streamline the outcomes to improve the overall performance. The focal points were logistics, mobile maintenance, temporary support infrastructure and development cycle times.

Although on the increase, the current performance is still below the expected rates. The main development project progress is depicted in Graph 1.



Graph 1 – Lift II Development

The Resources

The total personnel compliment on the project is 458. This number includes the subcontractors in the development area. This is made up of Administrative and Operational personnel. The recruitment was mainly focused on people around the Ba-Phalaborwa municipality, especially

on the unskilled and semi-skilled level. Some of these are novices in the mining industry and therefore require additional attention on both the safety and productivity fronts.

The mobile equipment is sourced from various Original Equipment Manufacturers; however this is limited to two OEMs with regards to the Drill Rigs, Dump Trucks and Load Haul Dumpers. This enables healthy competition between the suppliers and easier management of support service. A key difference from a typical development fleet is the absence of the roof bolters in favour of drill rigs, which are used to drill and install tendon support (roof bolts and split sets). The other variation is the use of the Integrated Tool Carrier, shortened to IT. This replaces Scissors Lifts as preferred ancillary support units. These are simply a front end loader with the ability to attach and detach implements at an instant. They are used to carry and hoist through detachable forks, basket or jip. This flexible and multi-purpose use is an advantage in the high speed development setting.

The Total fleet size is currently 62 units as per the table below.

Unit Type	Quantity of Units
LHDs	7
Drill Rigs	8
Dump Trucks	8
IT	5
Agicars	8
LDVs	11
Unimog	2
Water Cart	1
Grader	1
Lube Truck	1
Charmec	2
Tyre Handler	1
Service Trucks	2
Tipper Trucks	2
Spraymec	3
Total	62

Table 2 – Mobile Fleet

QUALITY

The development in the Lift II progresses through three main rock types, Micaceous Pyroxinite, Fenites and the Carbonatites, this coupled with intrusions of Dolorite Dykes. These rock types have varying strengths and level of competency. The Palabora orebody is made up of rock of varying compressive strength ranging from 63Mpa to 320Mpa. This rock types are also very coarse with low fracture frequencies.

Rock type	Ave. RQD	Ave. FF/m	Ave. IRS	Ave. IRMR	Min. IRMR	Max. IRMR
DOL	73	11	217	59	27	89
FOS	88	6	121	53	29	82
Magnetite	83	13	88	53	51	55
MPY	89	5	118	55	39	74
TCB	88	5	115	53	27	85
BCB	91	6	117	52	33	82

Table 3 - Geotechnical

Test	Point load tests			UCP tests			UCM tests		
Rock type	Ave. IS (50)	Corr. factor	UCS ptl MPa	Ave. UCS $\delta 1$ MPa	Min. UCS $\delta 1$ MPa	Max. UCS $\delta 1$ MPa	Ave. UCS $\delta 1$ MPa	Min. UCS $\delta 1$ MPa	Max. UCS $\delta 1$ MPa
DOL	6.42	34	218	219	172	269.84	291	135	381
FOS	3.33	38	126	127	66	184.48	122	76	172
MPY	2.97	40	119	120	-	-	123	-	-
TCB	3.26	37	121	121	76	232.32	113	86	138
BCB	3.26	37	121	-	-	-	-	-	-

Table 4 – Geotechnical Tests Results

The Geotech

The project has an extensive mapping programme that ensures that any exposed rock face is mapped. There is an around the clock coverage on the mapping. The team is made up of 4 Geologists and their assistants working contops with the production teams. The Geologist maps the face manually and also uses high definition camera to capture still photos of the face.

AdamTech software is used to stitch together these digital images that are taken from the development ends. A Minimum of 16 images is taken by a digital camera after scaling the face prior to shotcreting. The underground capturing process of the images takes less than 20 minutes per heading. The pictures are converted to a 3D model through AdamTech and then stored in a database.

The mapping report gets generated and distributed to the relevant personnel at the end of the shift. The content of the report include the rock types and their Q rating, any visible structures, water seepage, face advance estimate and an actual picture of the face. Below is a typical cover page on the mapping report.

PMC
PALABORA
MINING COMPANY

TO: GROWTH DEPARTMENT

FROM: MUWANWA VELEVELE

DEPARTMENT: GROWTH

DATE: 17/11/2016

Title: 14M2E

Map/No Report

Location: SVBP Pits #: 4540 Dist. To face: 44.6m

This report covers the mapping that was conducted at SVBP on the 17th November 2016. The tunnel has the following approximate dimensions: a height of - 4.3 m and a width of - 6.0 m. TCB was the main rock type with very small MPV patches scattered in places. Sulphide mineralization was also observed in the heading.

- The profile comprises of three joint sets, and one random joint (refer to the mapping sheet in Figure 1)
- The above mentioned structures had the following orientations:
 - The first joint set is dipping at 75° SE with - 1.5 m spacing
 - The second joint set is dipping at 85° SW with - 1.1 m spacing
 - The third joint set is dipping at 85° NE with - 1.2 m spacing
 - The random joint is dipping at 73° N
- No Ground water was observed in the face
- The ground condition was good with a calculated Q-value of 11.25, an estimated RQD of 80% and an estimated GSI - 85%. (See Figure 2 for the photo of the face SVBP)

Plate 1 – Front page form a mapping report.

At some instances, the 3D simulation is used for geotechnical analysis and as a reference on support recommendation by Rock Mechanics Department. Below is a final output from image stitching through AdamTech software.

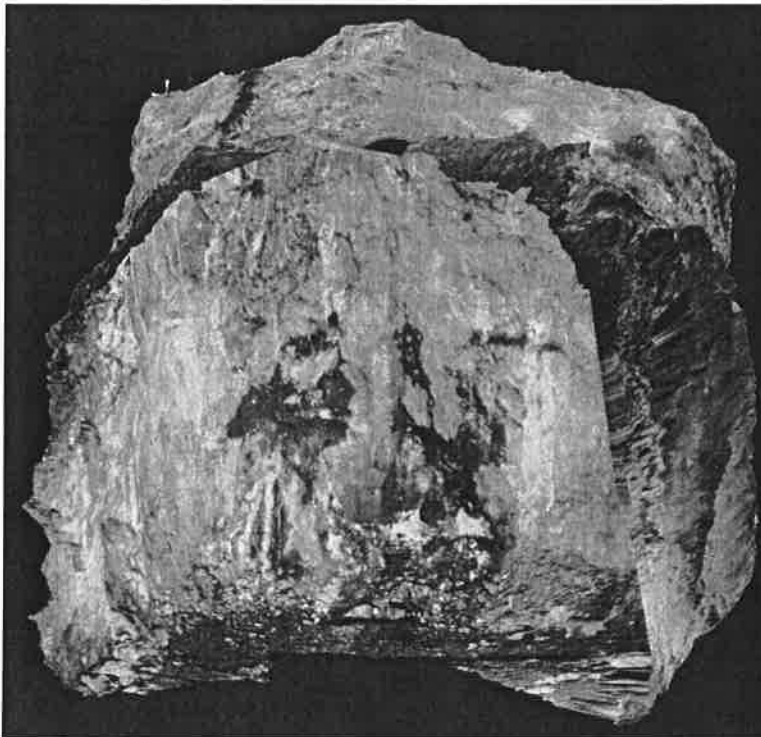


Plate 2 – 3D Mapping Image

The Rock Mechanics

Every blasted face that is mapped by the Geotechnical team is also assessed by the Strata Control Officers ensuring that every blast must pass a technical quality assurance. In case of deviation from the recommendation, the SCO is empowered to issue an "On The Spot" rock support recommendation to rectify and when the face conditions are adverse, to issue a "Stop and Fix" recommendation.

The support system recommended for the Lift II horizon infrastructure and associated capital excavations is based on empirical analysis (Barton, Grimstad and Hoek) and engineering analysis which includes experience obtained in Lift I. Support recommendations are predicated on a support regime system based on the estimated rock strength and expected strain/stress conditions applicable to the specific excavation over its life. The recommended support regime comprises rock bolting and fibre-reinforced shotcreting as the primary support unit with the use of lacing, cable anchors and mesh as additional support. Three major support regimes are specified for Lift II:

- Undercut level: All undercut development;
- Extraction level regime 2: The extraction drives at the cave foot print boundaries where these drives will be affected by cave interaction, cave propagation and the presence of poor rock mass conditions such as in DOL dykes requires a support system to combat the abutment stress impact; and,
- Extraction level regime 1: This area includes all of the remaining development in the extraction level.

All bolts installed for LOM excavations will be full column, grouted with either resin or cement to prevent corrosion of the tendon within the rock mass. Bolt length will be standardised to improve installation efficiency. Bolts are to be placed systematically on a regular square pattern on the crown and sidewalls of all excavations.

Any excavation with a span greater than 6.0 m will be supported with a combination of cable anchors and bolts, based on location specific Rock Engineering Department recommendations. Cable anchors will be used for additional reinforcement at all intersections and brows.

The Safety Performance

The safe delivery of the project is a paramount. Safety performance is closely managed and the strategy is often adapted to cater and address the leading indicators of poor safe practices or conditions. The participation of the leadership in the programmes cannot be over emphasised, therefore the management team members form a core of any safety intervention. The Growth Safety Accelerated Programme or GSAP is one such programme. This is an in-house safety focused programme instituted by the Project Lead.

The GSAP program is borne on the aim of escalating the good safety performance to great safety performance. Such intervention keeps safety fresh in the minds of the employees and needed stimulation in case the project team become complacent with regards to safety.

CONCLUSION

The Lift II project is a major project with a potential significant contribution to the economy of South Africa in particular the host communities. It however remains a significant technical pioneer in the block caving fraternity. Just like Lift I, it will be the hardest rock to cave and still a high block, only this time as the deepest caving operation. Palabora is yet again pushing the mining technical boundaries.

The knowledge preserved during Lift I construction and operation was the base of the Lift II design and construction. The body of knowledge around hard rock caving has increased significantly over the past two decades or so. Palabora provided a learning platform for the industry.

The compliance to design parameters and safe mine construction is never under stated. There is a strong believe that the development will meet all its targets, safe completion of the project on time and on within budget.

REFERENCES

Lift II Feasibility Study Report (Project Team, 2013).

Lift II Technical Services Reports (Tech Services team, 2016).

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