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Assessing the role of stress and geology on mine layout design in Block Caving Mine – A case study

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college of science, engineering and technology

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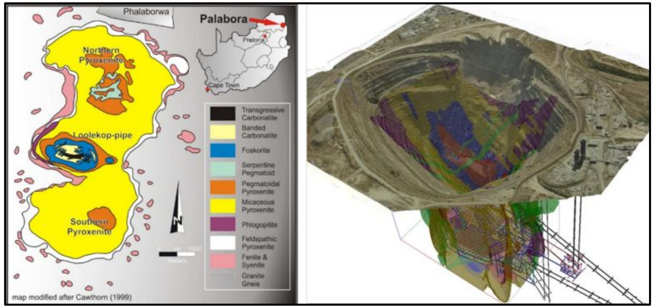
Introduction

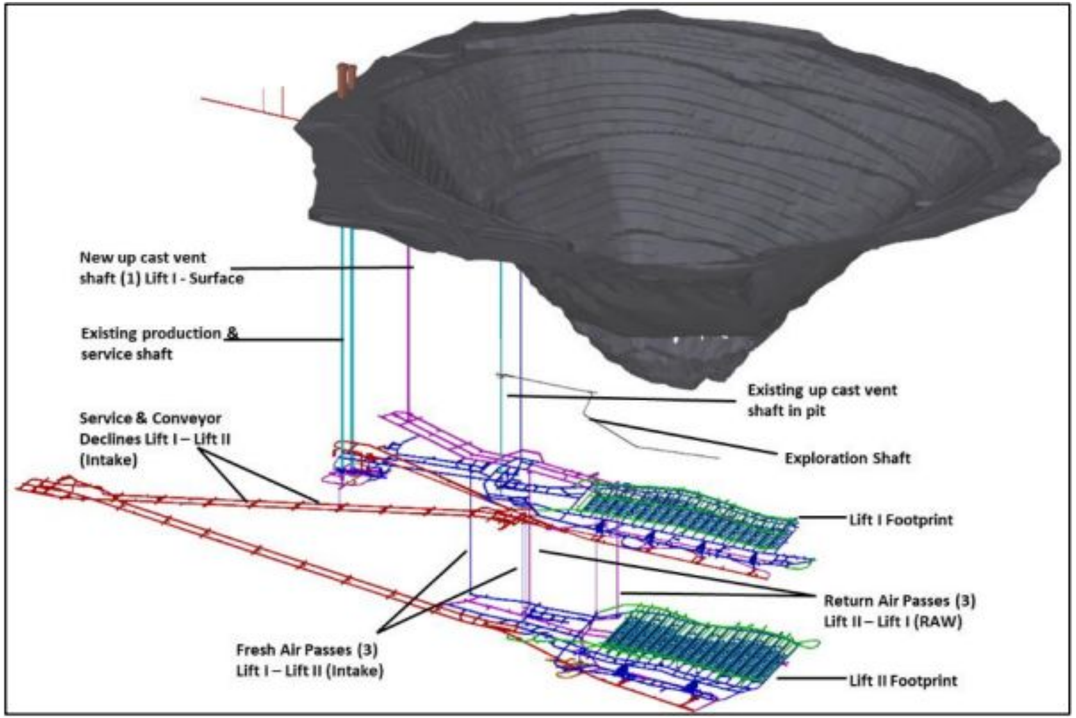
PILLARS OF MoU BETWEEN PMC & UNISA			
#	**Pillar Type**	**Pillar Description**	**Pillar Update**
1	Research and Development for Postgraduate Studies	Support and enable PMC employees to partake in industry-based research through MSc & PhD studies	❖ 10 Employees for MSc ❖ 1 Employee for PhD
2	Work Integrated Learning (WIL)	Assist UNISA students gain practical work experience	❖ 3 Mining Eng Students on-boarded in 2024 & for 2025 plan is 4 ❖ 1 Mine Survey Student on-boarded in 2024
3	Short Learning Programs (SLP) at above NQF Level 4	Accelerate development of employees by elevating their knowledge and skills	❖ 3x SLP's 80% complete (Management Essentials, Mining & Mineral Processing)
4	Higher Certificate in Supervisory Development (NQF Level 5)	Enable Supervisors to properly lead, inspire and guide their teams	❖ Programme may start in Jan 2028
5	Recognition of Prior Learning (RPL)	Provide opportunities for employees who have gained experience with no qualification to obtain formal qualification	❖ 16 employees admitted through RPL
6	Collaboration in Research, Innovation, Commercialization and Technical Support	Drive business sustainability to build strong technical pipeline or internal pool of experts	❖ 4 papers accepted in different journals ❖ 1 JRP call between SA/China (through NRF)
7	Exchange of educators, learners, administrators and advisors to participate in conferences, symposia and seminars	Provide platform for professional development and networking	❖ SAIMM LimpopoTech Event (2024 / 2025) - 3 / 2 PC & 10/2 UNISA presentations respectively ❖ Digital Transformation in Mining Conf (2025) – 1 PC & 1 UNISA presentations

❖ Work being presented in this AfriRock Conference falls in Pillar #6 and #7.

Introduction

- ❖ Palabora Copper Mine's Lift II block cave development (1640m depth) is progressing towards a breakthrough into Lift I (1200m depth)
- ❖ The Palabora Copper (PC) Igneous Complex is an Archaean Foskorite-Carbonatite Pipe complex with an area of 20 km2
- ❖ The copper ore body is an elliptically shaped vertical pipe with an area of 1 km2
- ❖ Four main lithological units occur in the Lift II Cave, those being BCB, DOL, FOS and TCB





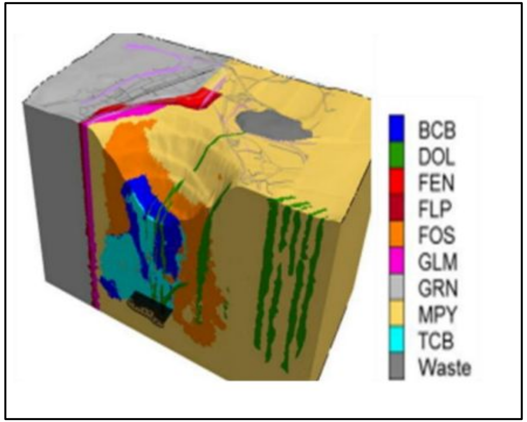
- ❖ The purpose of the study is to evaluate the role of stress distribution and geological structures on block cave mining sequence and the mine layout

Geotechnical Domains

- The rock mass properties of the underground mine were initially determined through the mapping of the previous open pit before underground mining could start.

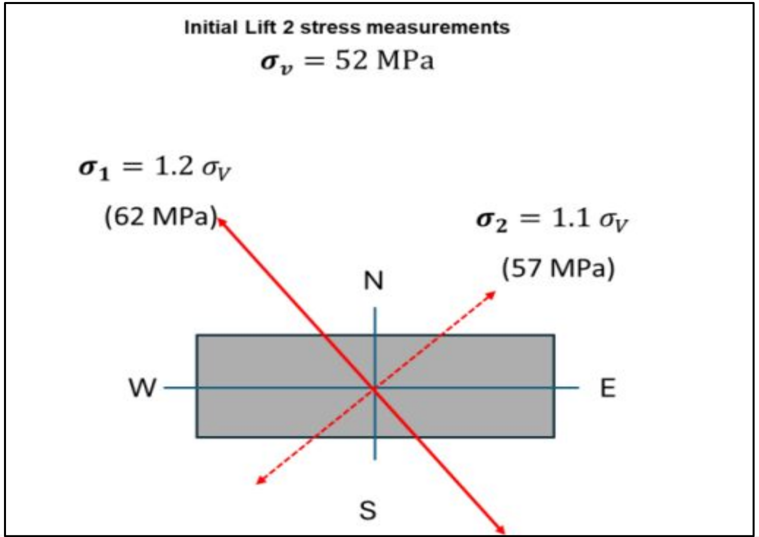
- The geotechnical domains for Lift II are based on lithology~~;~~, namely, the branded carbonatite (BCB), dolerite (DOL), Foskorite (FOS), micaceous pyroxenite (MPY), and transgressive carbonatite (TCB). The properties of the geotechnical domains are summarised in the Table

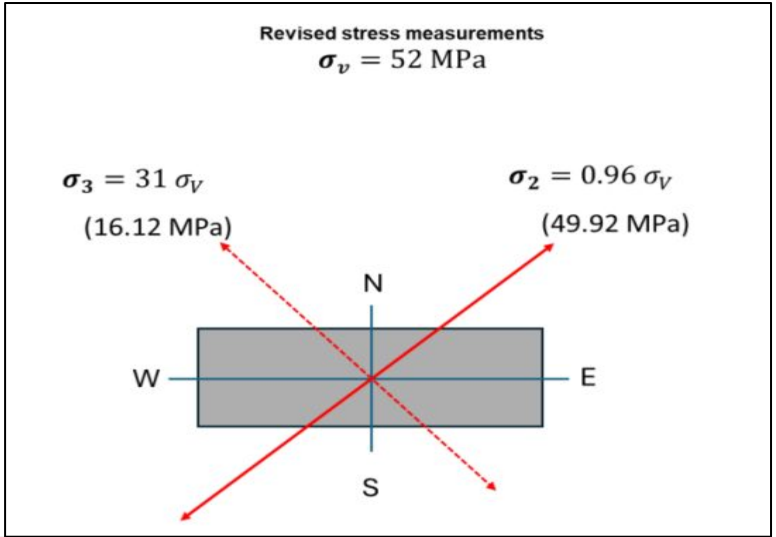
Domain	m_i	GSI	m_b	σ_{ci} (MPa)
BCB	22.9	71	8.2	147
DOL	24.1	73	9.2	406
FOS	25.2	69	8.3	104
MPY	17.4	68	5.5	64
TCB	28.0	71	10.0	122



In situ stress measurements

❖ The stress orientation of the rock mass for Lift II was determined through overcoring in Foskorite on the Lift II Production Level.





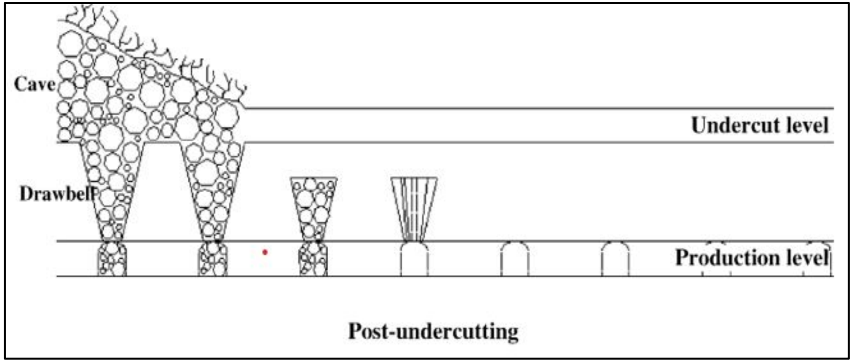
Stress	Magnitude (MPa)	Dip (°)	Dip Direction (⁰)
σ_1	ρgH	90	0
σ_2	0.96*σ_1	0	058
σ_3	0.31*σ_1	0	148

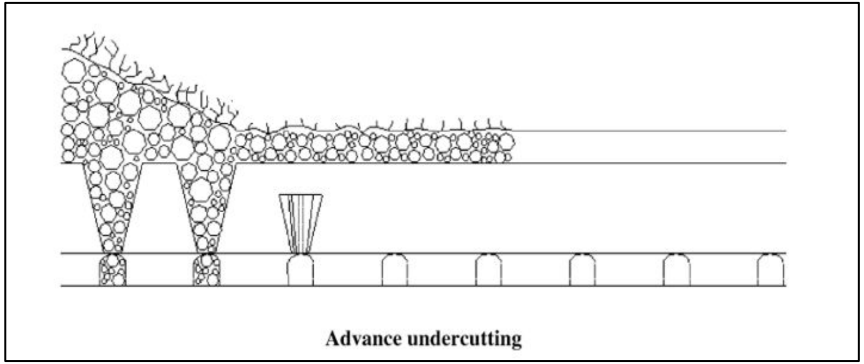
❖ The σ1 and σ3 orientations have been swapped. In other words, σ1 was previously striking NW-SE, it is now vertical. Conversely, σ3 was previously vertical, it is now striking NW-SE.The initial response of the Lift II Production Level and cave initiation supports the revised stress regime (Sainsbury, 2023).

Mining method

This section discusses the influence of the measured stress on the mining layout of Lift II.

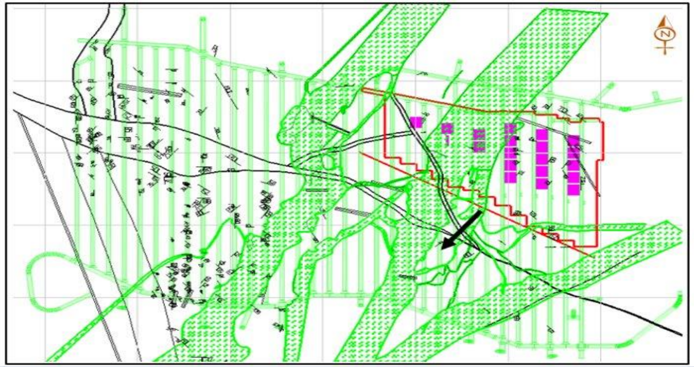
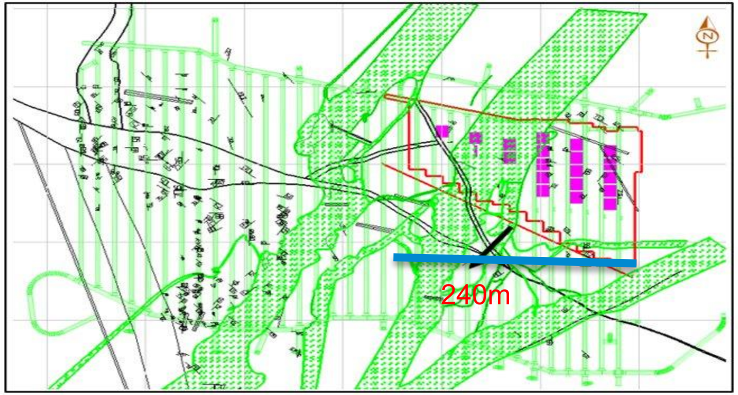
❖ The advantage of advanced undercut over post-undercut is that large unsupported drawbell excavations are not subjected to high abutment stresses, and less support rehabilitation is required in areas where undercutting precedes production-level development.



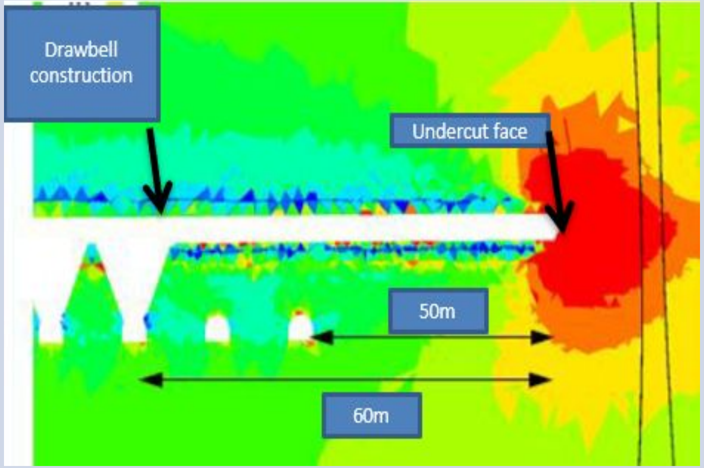


❖ To minimise stress damage and increase rehabilitation requirements in extraction levels, PMC opted for advanced undercutting techniques. In simple terms, the advanced undercut method was selected to ensure the stability of the extraction level for the mine's life.

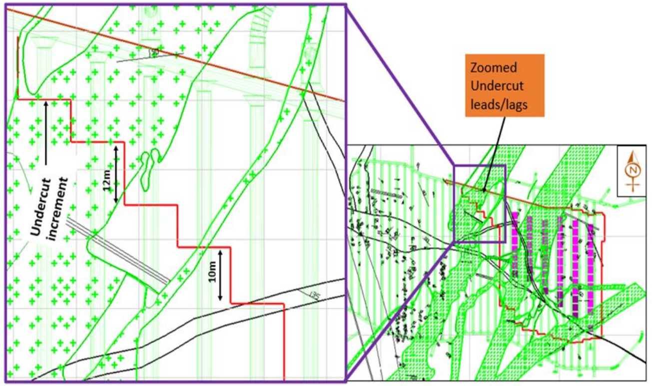
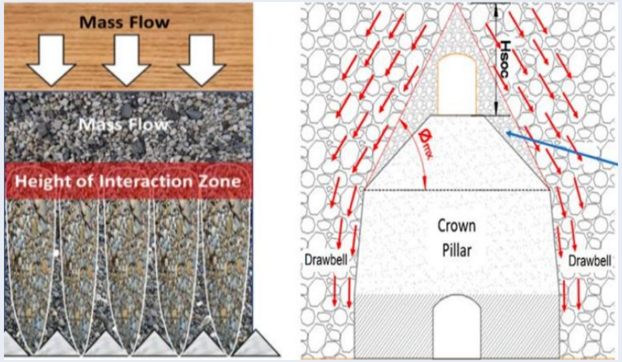
Mining Design

Mine design parameters	Description	Diagram/Annotations
Undercut face angle	Designed based on the initial stress orientation of the Lift II model to be initiated from the SE to NW, with an undercutting face striking **NE-SW** To mitigate against the potential for large seismic risk, an undercut face design change was implemented to ensure that the long-undercut face advance is **perpendicular** to the major principal stress and Dolerite dykes.	
Undercut face length	The length of the undercut face is a function of the undercut face angle. The longer the face, the more difficult it is to construct enough draw bells behind the face to allow it to keep moving. The recommended face length must be less than 300m, at PC the maximum was **240m**.	

Mining Design cont

Mine design parameters	Description	Diagram/Annotations
Undercut face advance rate	Critical as the rock mass ahead of the undercut face is subject to high abutment stresses. The slower the undercut advances, the greater the deterioration of the rock mass, and the more difficult it is to successfully blast the face. Conversely, rapid undercut face advance, where the face is greater than **50m – 60m** ahead of the last line of drawbells, leads to the formation of a 'verandha', and this acts as an abutment stress concentrator which typical results in large drive deformations and rockbursts. The average advance rate of the Lift II undercut was initially planned at around 3,400 m2/month, equating to approximately 11 m/month. The current advance rate is **10 – 15 m/month.**	

Mining Design cont

Mine design parameters	Description	Diagram/Annotations
Lead lags	The differential distances between adjacent faces (drill drives) is known as the leading and lagging distances. The greater the leads or lags between adjacent faces the greater the stress differential. The objective is to minimise the lead and lag distances so that the tangential (hoop) stresses are maintained in the undercut face and thus aid in its stability (adds confinement to the rock mass). In practice a practical operating lead-lag distance is between **10m to15m** (max) and ideally no more than 2 to 3 rings.	
Draw point spacing	The isolated draw zone (IDZ) diameters for the averages of all rock types are approximately 12-13 m. This suggests an optimal drawpoint spacing of 32 m (drive centres) by 16 m (drawbell centres) to ensure an interactive draw. This design choice was primarily driven by two critical factors: the operational requirement to accommodate **large Load-Haul-Dump (LHD) equipment**, and the **geotechnical objective** of improving the stability of the extraction level.	

Conclusion

This study delved into described the effect of stress, geological structures and stability of the undercut and production level on the layout design of a Block Cave Mine. The findings of this the study are summarized as follows:

- ❖ The standard guidelines for mine design cannot be given, as are not one size fit all, as the rock mass properties of each mine are unique. ;
- ❖ For example, it is a standard guideline that the mining sequence advances perpendicular to the major geological structures. This is also the case at PMC where the face advances perpendicular to both the major principal stress and to the dolerite dyke were found to be preferable.;

Conclusion cont

- The mine adopted found that a 45° lead/lag face shape of the undercut to minimized abutment damage to the undercut level; by the abutment stress. The mine also adopted an advanced undercutting method to protect the extraction level from abutment stress from undercutting. The 45-degree method was used.

- The theory of height interaction zone dictates that the drawpoint be closely spaced to allow interactions of the draw zones of the drawpoints whereas closely spaced drawpoints may affect the stability of the major apex and result in manoeuvring difficulties of LHDs.

Acknowledgements

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Thank You