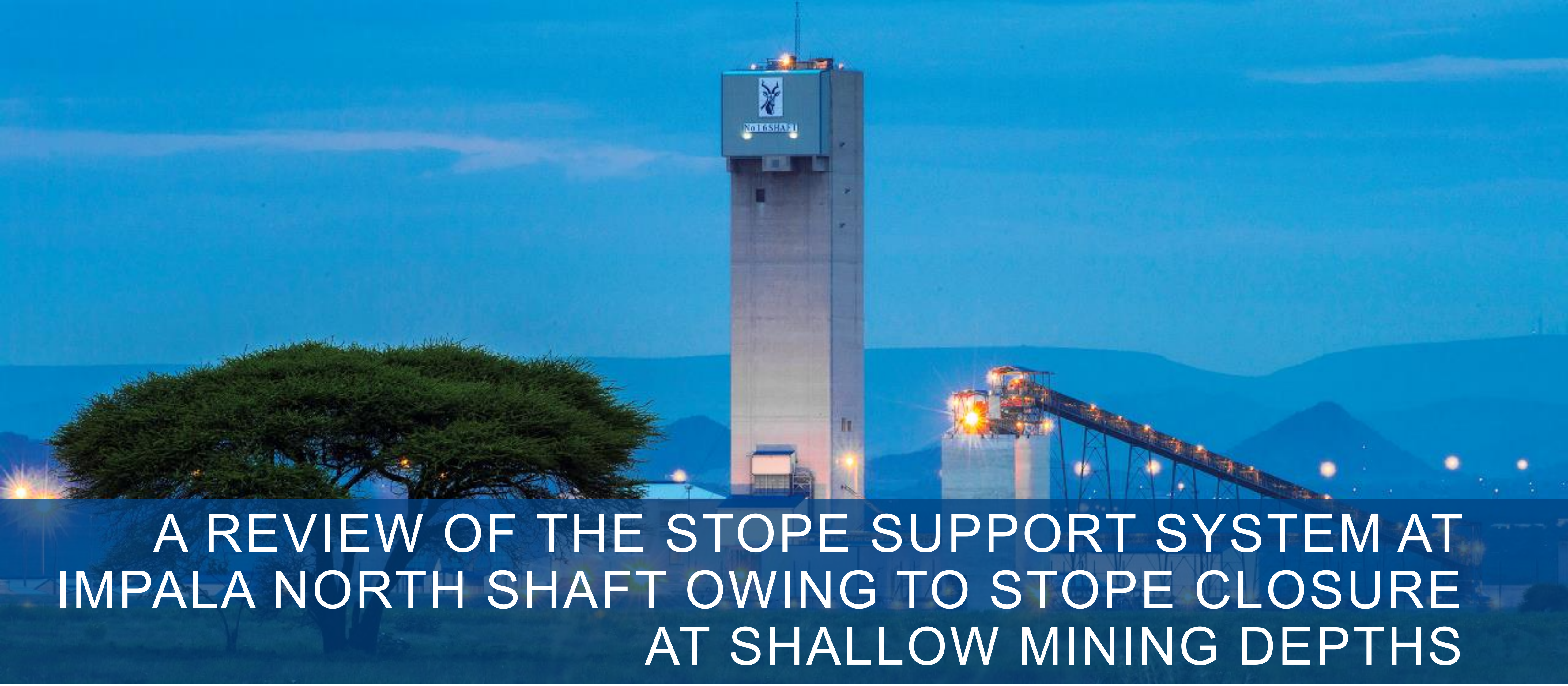


A REVIEW OF THE STOPE SUPPORT SYSTEM AT IMPALA NORTH SHAFT OWING TO STOPE CLOSURE AT SHALLOW MINING DEPTHS

North Shaft

RESPECT, CARE
AND DELIVER

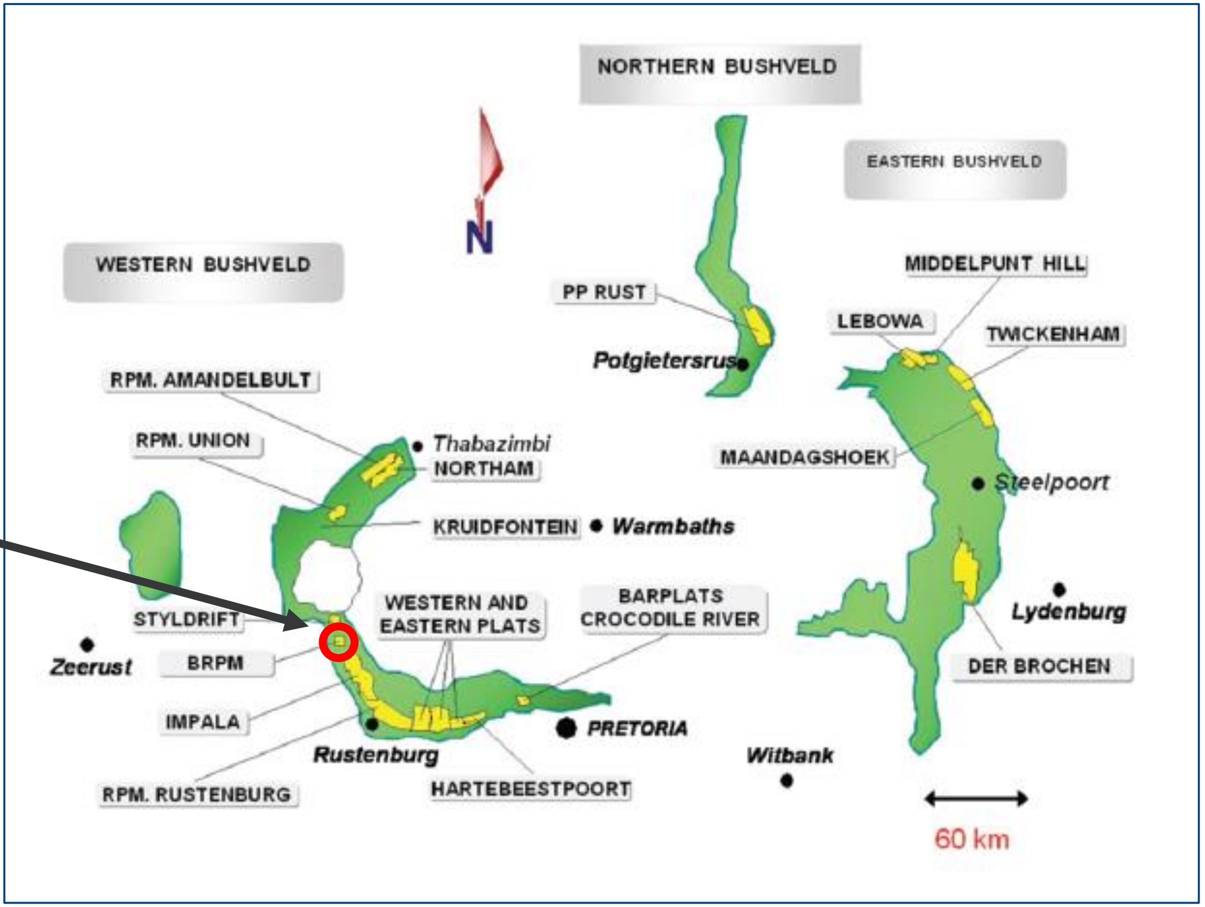
IMPALA
Member of the Implats Group

LOCATION

The Bushveld Igneous Complex (BIC) is a layered igneous intrusion that is mined for Platinum Group Metals.

The BIC spans approximately 350 km from east to west and has three major outcrops, the northern, eastern and western limbs.

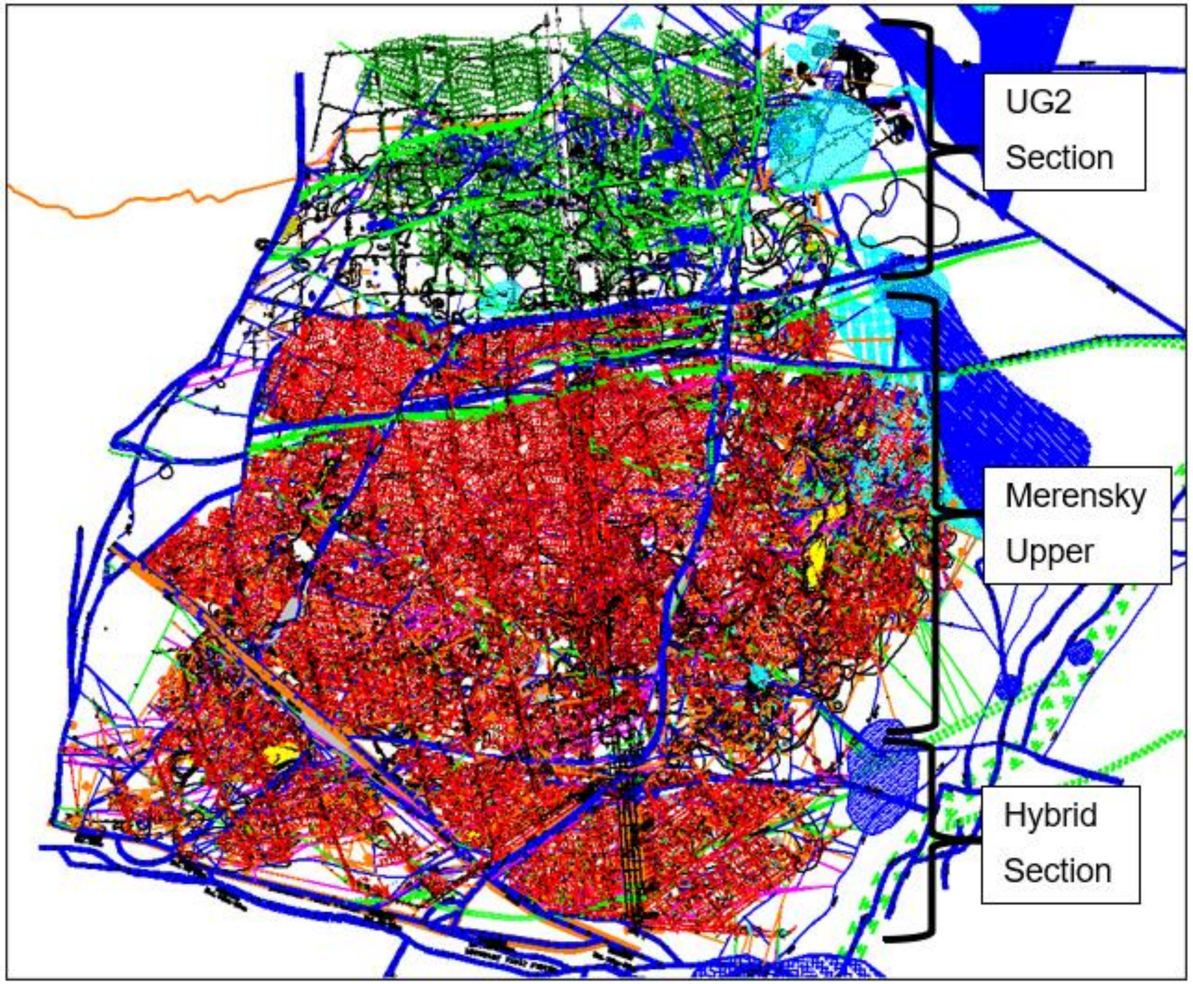
Impala North Shaft (previously BRPM) is located along the western limb of the BIC, approximately 30 km north of Rustenburg in the North-West Province.



MINE BACKGROUND

Shallow tabular hard-rock mine, mining the Merensky and UG2 reefs.

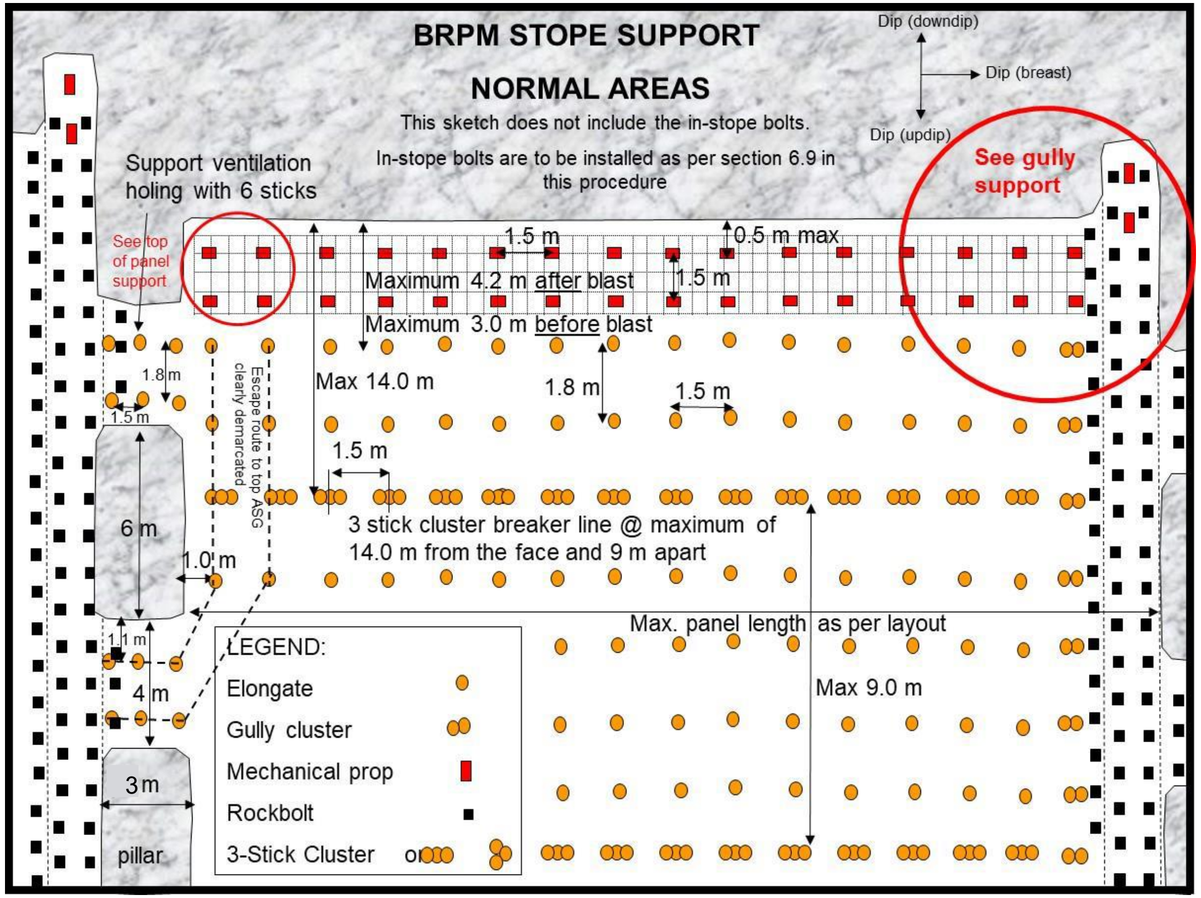
- The **UG2** reef is mined between 100 m and 350 m depth.
- A middling between the reefs of approximately 70 m.
- The **Merensky** reef is conventionally mined between 400 m and 500 m depth.
- The **Hybrid** Section is the deepest portion, mined between 500 and 650 m depth.
- Mechanised on reef development.
- Conventional scattered breast stoping.



SUPPORT SYSTEM

North Shaft's support design relies heavily on elongate support due to the requirements for a stiff support system to prevent any unravelling from taking place.

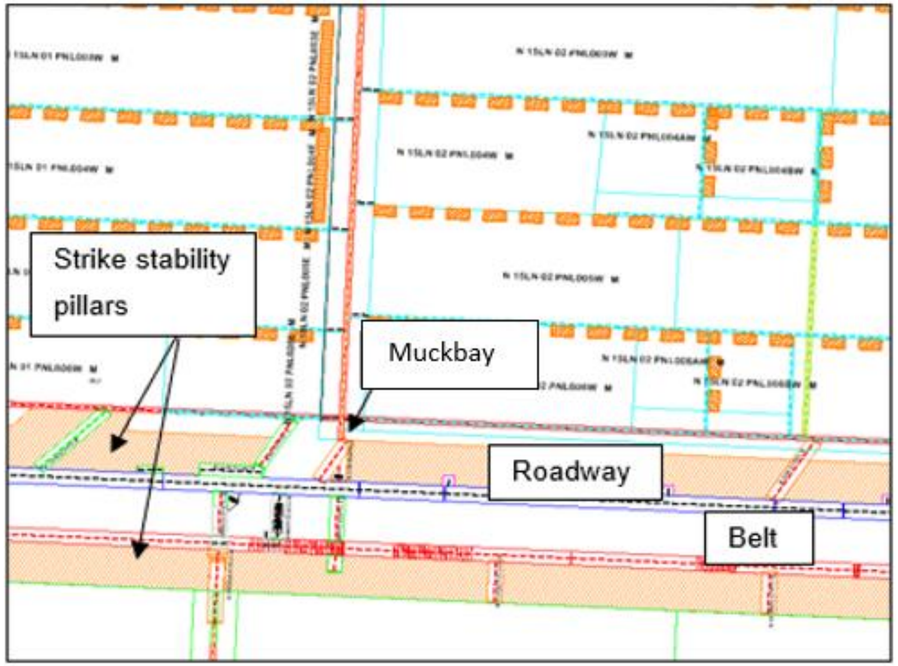
- Shallow mines experience very little horizontal stress which leads to the formation of a tensile zone in the hanging wall.
- The tensile zone interacts with low angled geological structures which can lead to instability.
- The crush pillars are is 6 m long x 3 m wide.



HYBRID MINING

The Hybrid design was utilised to allow for on-reef development and to reduce capital expenditure and time to access the reef.

- The Hybrid Section is serviced with on-reef mechanised roadways that need to remain stable over the life of the mine. Strike stability pillars were designed on either side of the roadways and belts.
- Ore is transported along raise lines using a winch, into a muckbay.
- A load, haul, dump loader (LHD) is then used to transport the ore to the strike conveyor belts.

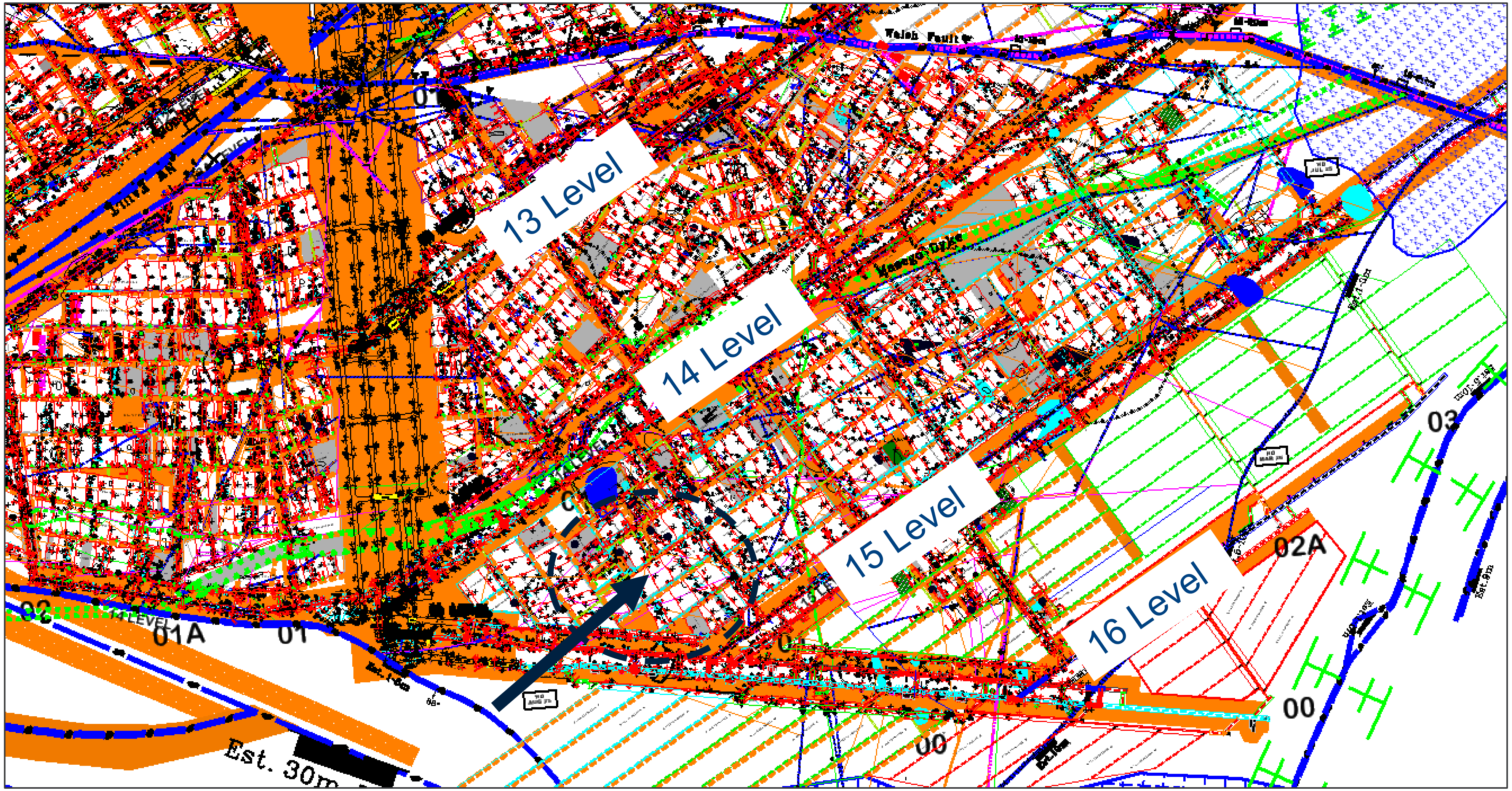


HYBRID MINING

The mining depth characterizes North Shaft as a shallow mine.

- Very little closure had been observed on the mine.
- The first raise line that was established and mined at 15 level, experienced much high closure rates which led to the failure of mine pole support units.
- The mine pole support was found to be splitting and buckling in the back areas of panels from as little as 20 m away from the face.

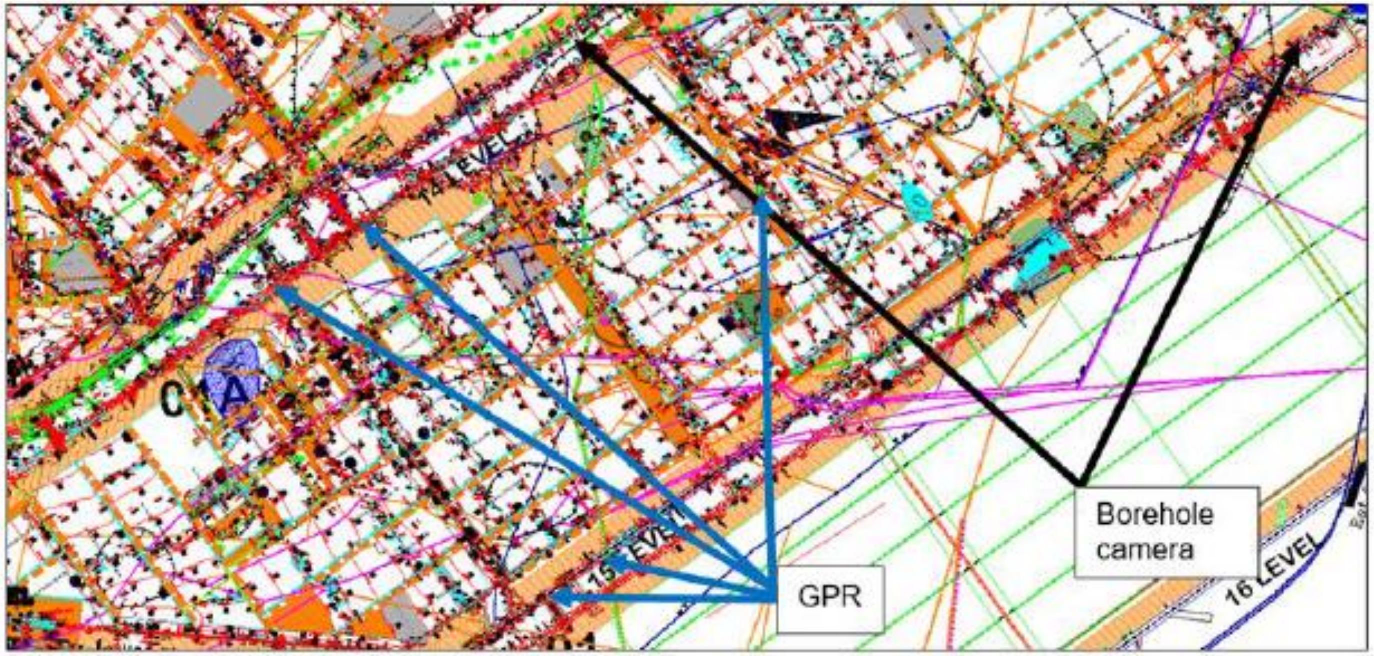
CLOSURE OBSERVED



RESEARCH OBJECTIVES

The main objectives of the study:

- Fully understand the rate of closure and its effects on the support system in use.
- Adapt the support design and layouts to cater for the conditions encountered.

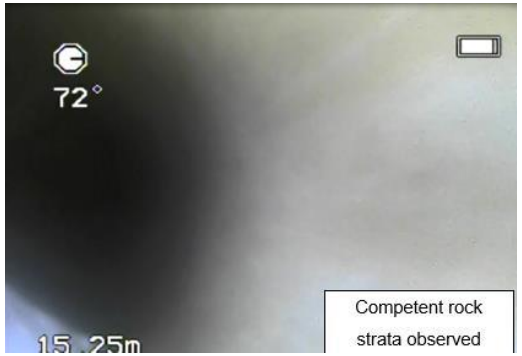


DATA COLLECTION

Borehole Camera

- Borehole camera investigations were conducted along the Roadways.
- The 15 m height was chosen as this was the known depth of the Bastard Reef chrome parting, the contact was examined for any signs of tensile failure.

Hanging wall pyroxenite to Norite contact



Bastard Reef contact

DATA COLLECTION

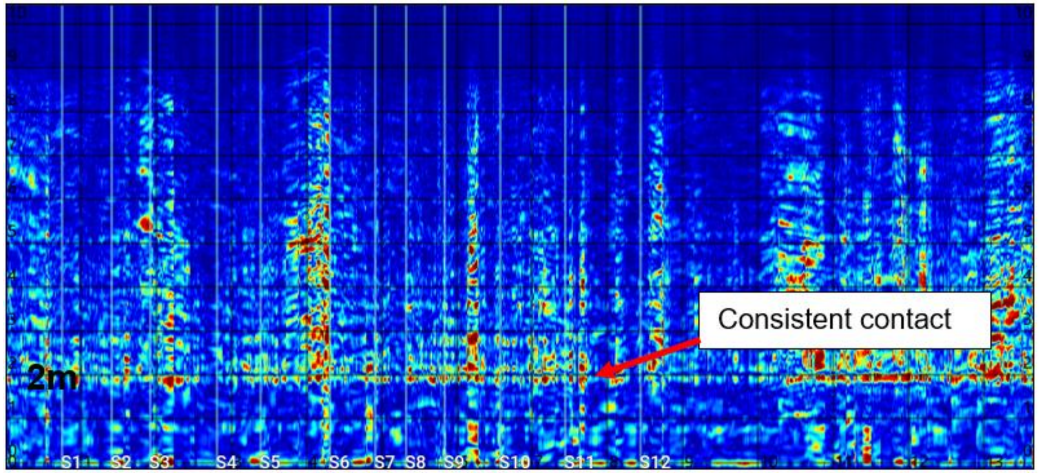
Ground Penetrating Radar

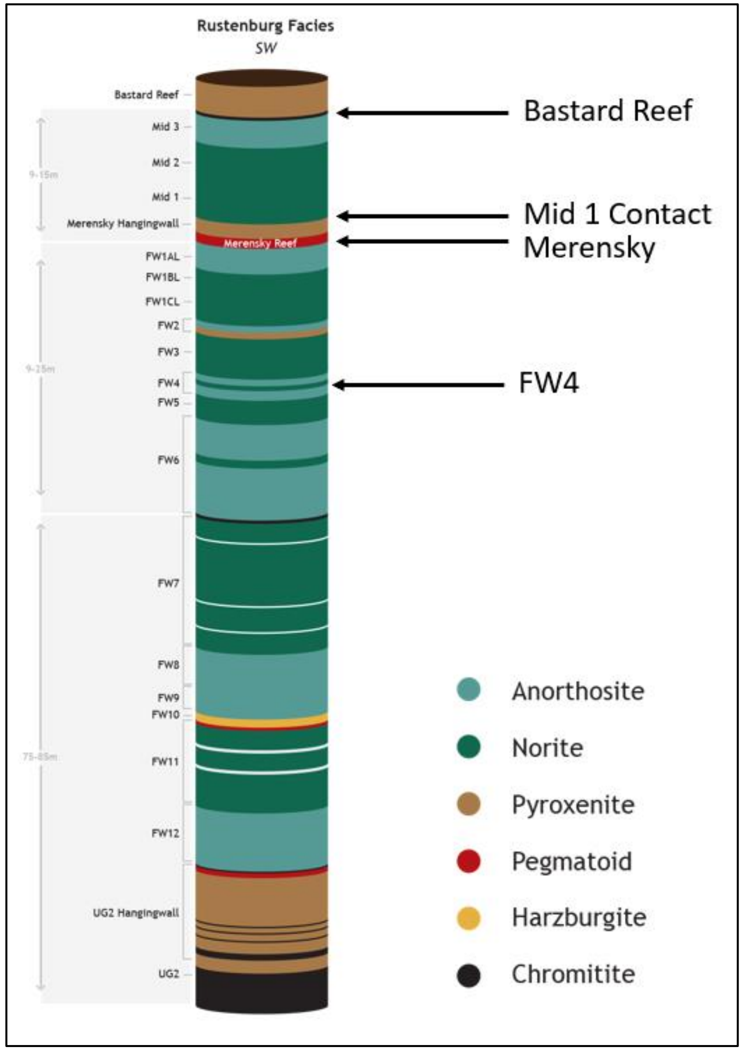
- GPR scans were conducted along the roadways and along raise lines.
- The GPR that was utilised is referred to as a Sub Surface Profiler (SSP).
- The tablet enables the user to check the scans in real time.

FINDINGS

GPR

- The GPR scans show no obvious parting besides the consistent contact at 2.0 m into the hangingwall. The contact was between the Merensky hangingwall pyroxenite and the Mid 1 Norite.
- The borehole camera was used to correlate GPR findings.

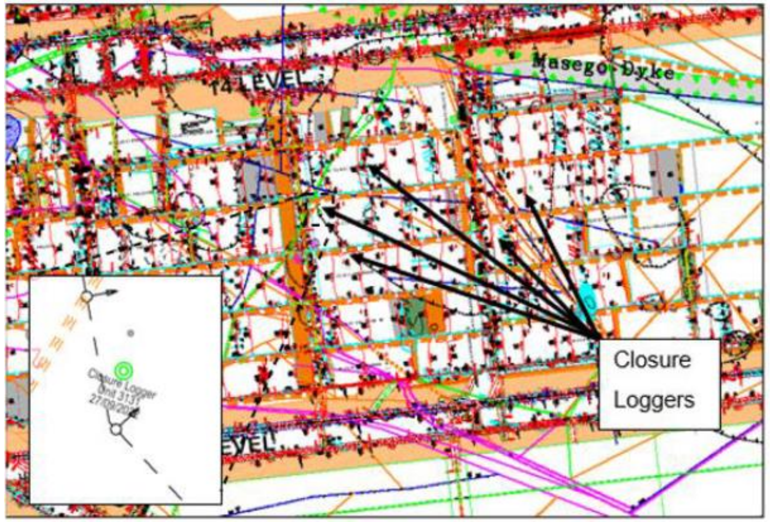




INSTRUMENTATION

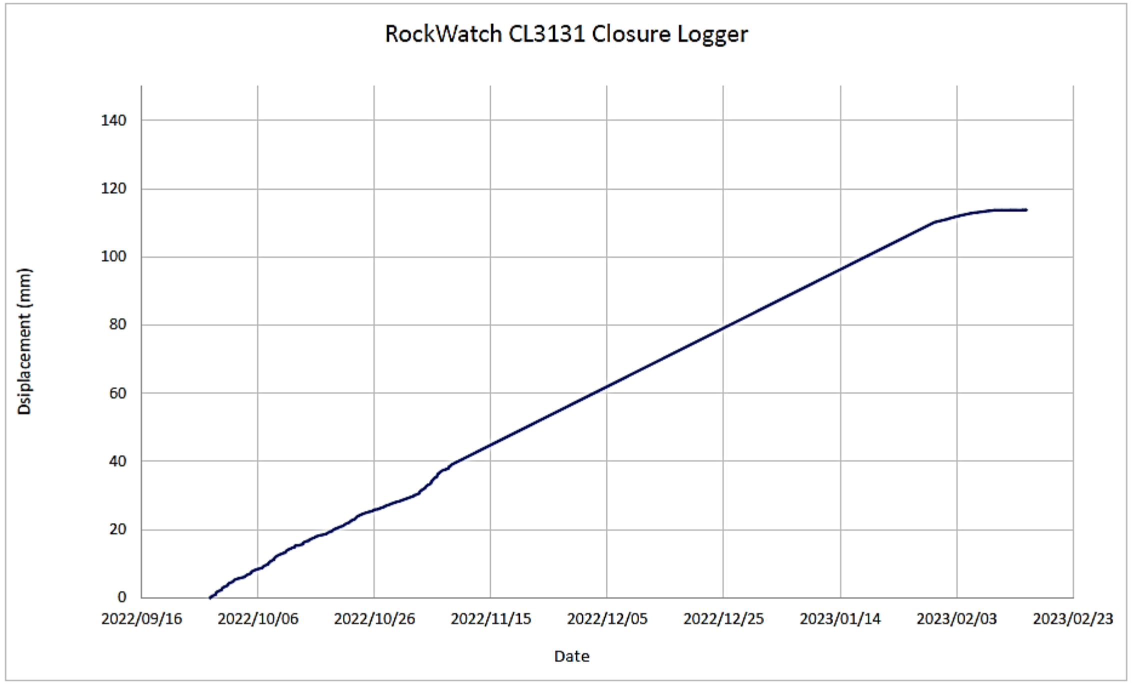
Closure Loggers

- Closure measurement data was recorded with closure loggers.
- The loggers were used to determine the rate of closure per metre of advance.



CLOSURE LOGGER FINDINGS

The closure measured on the loggers was 115 mm. The advance over this period was 64 m.

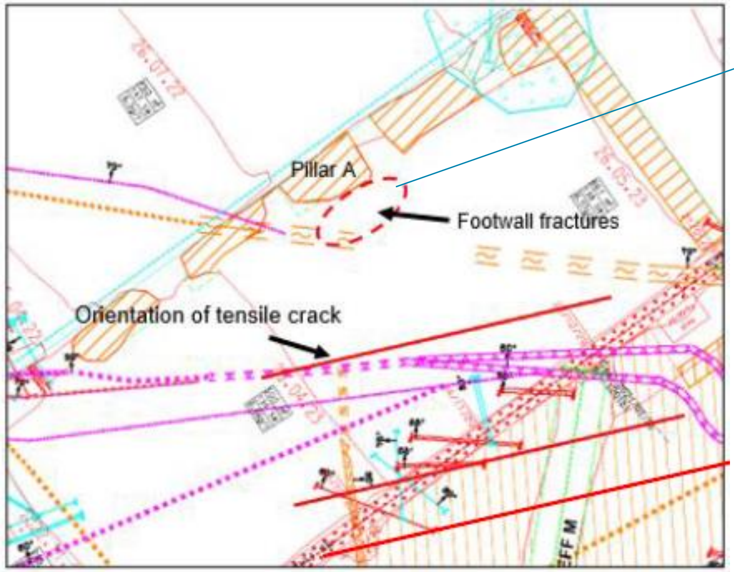


$$\frac{\text{Closure measured } (115\ mm)}{\text{advance } (64\ m)} = \text{Closure rate } (1.79\ mm/m)$$

VISUAL OBSERVATIONS

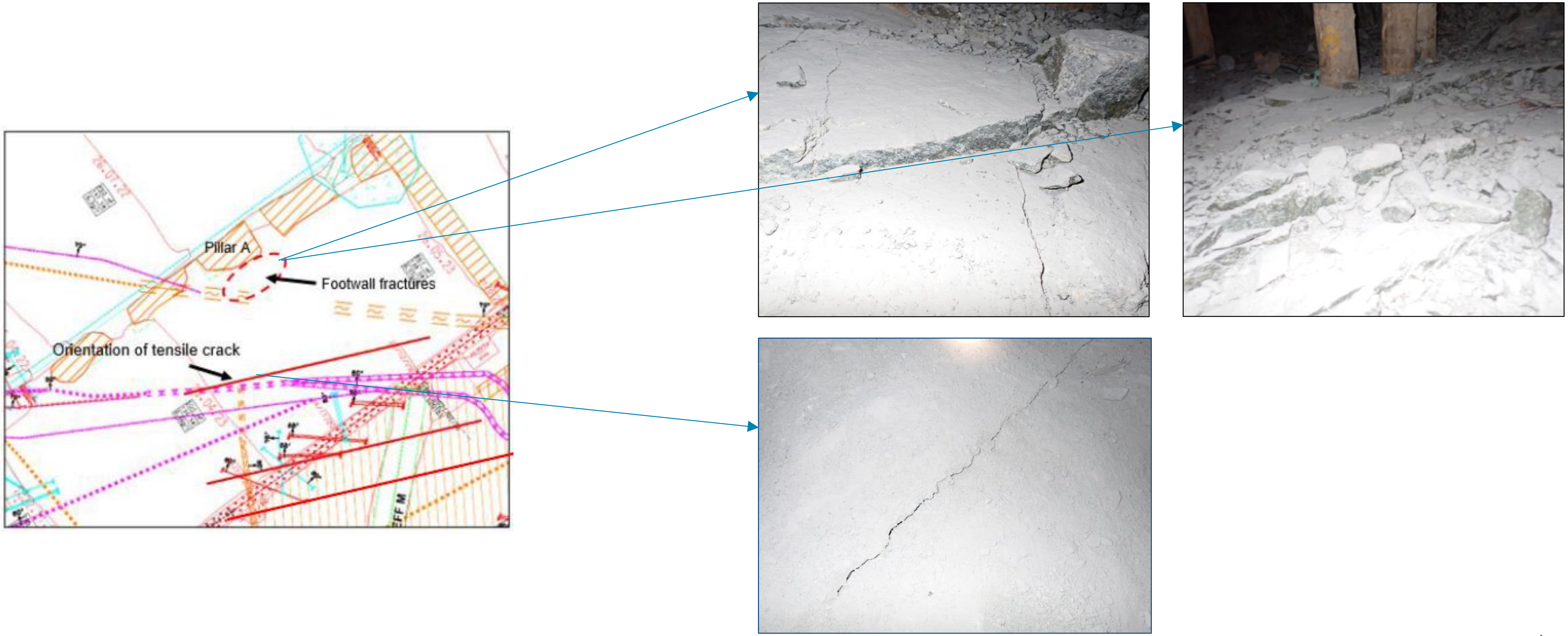
The crush pillars in the back area were inspected:

- The hanging wall around the pillar appeared to be in good condition with no sign of fractures.



PILLAR BEHAVIOUR

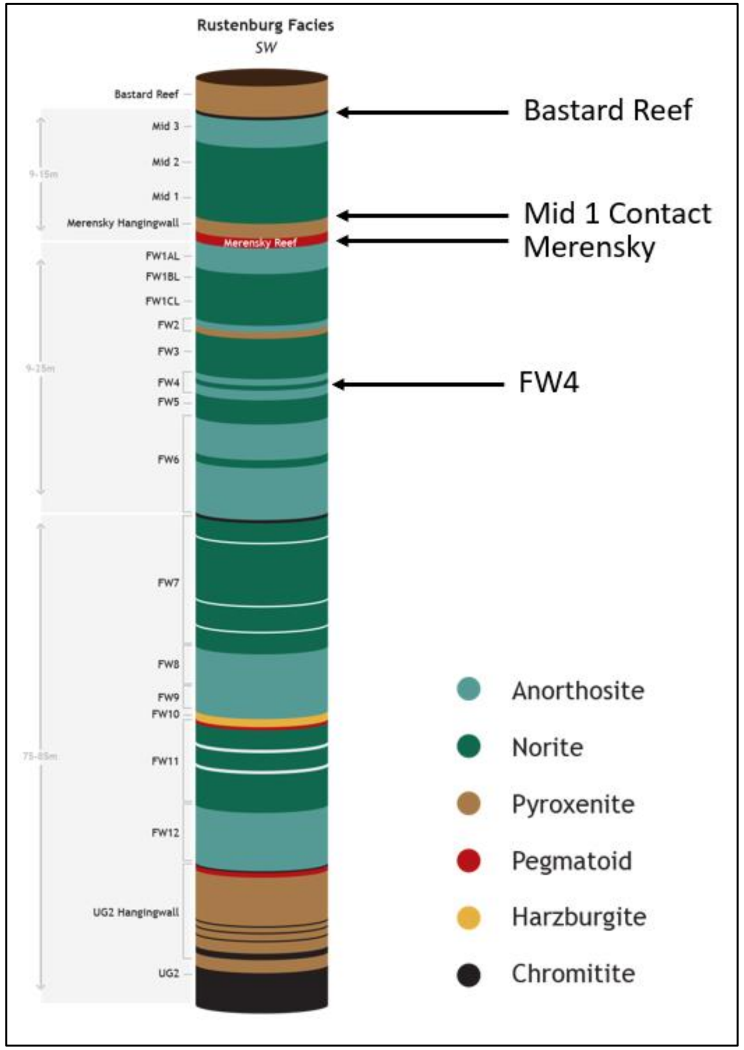
The footwall around the pillars had fractured significantly and footwall heave had taken place around the pillar. Tensile cracks were observed in the centre of the panel along the footwall.



SHEARED FOOTWALL

Footwall 4 contact

- The footwall material is weaker than the hangingwall.
- The Footwall 4 contact was drilled and measured at 4.65 m below the reef.
- The potential for the contact to form a parting plane is high due to its 1 – 2 cm thick slickenside and serpentinized contact.

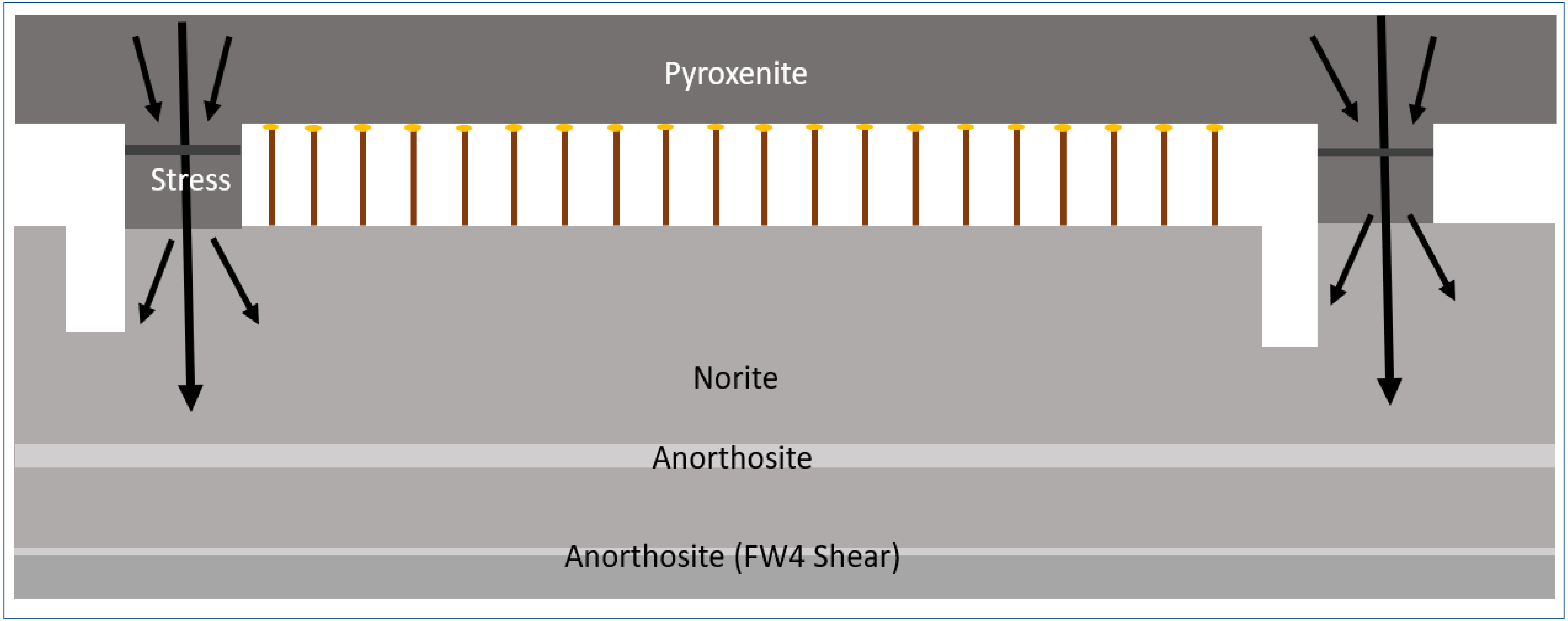


THEORY

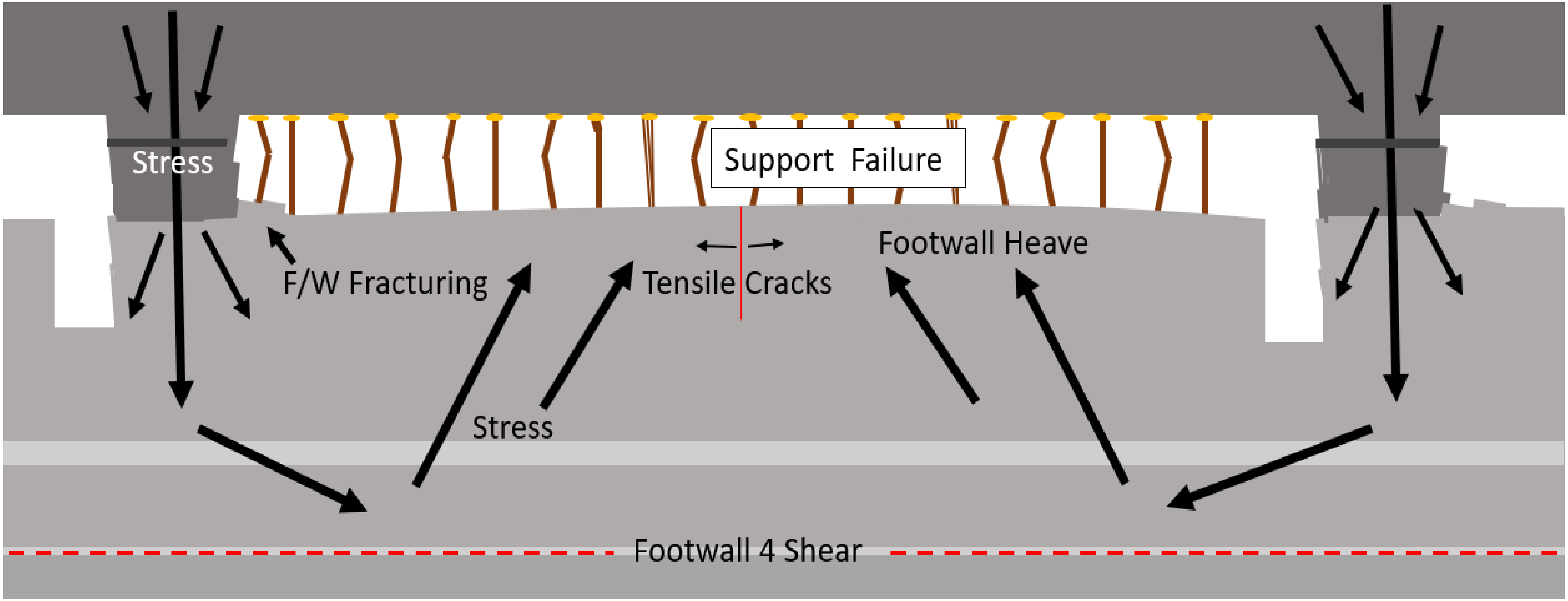
The high closure rate was initially considered to be due to tensile failure of the hangingwall.

- The instrumentation combined with visual observations indicated that the hanging wall was not showing signs of tensile failure.
- The footwall fractures around the in-stope pillars combined with the tensile cracks observed on the panel footwall were indicators of potential footwall heave.

FOOTWALL HEAVE



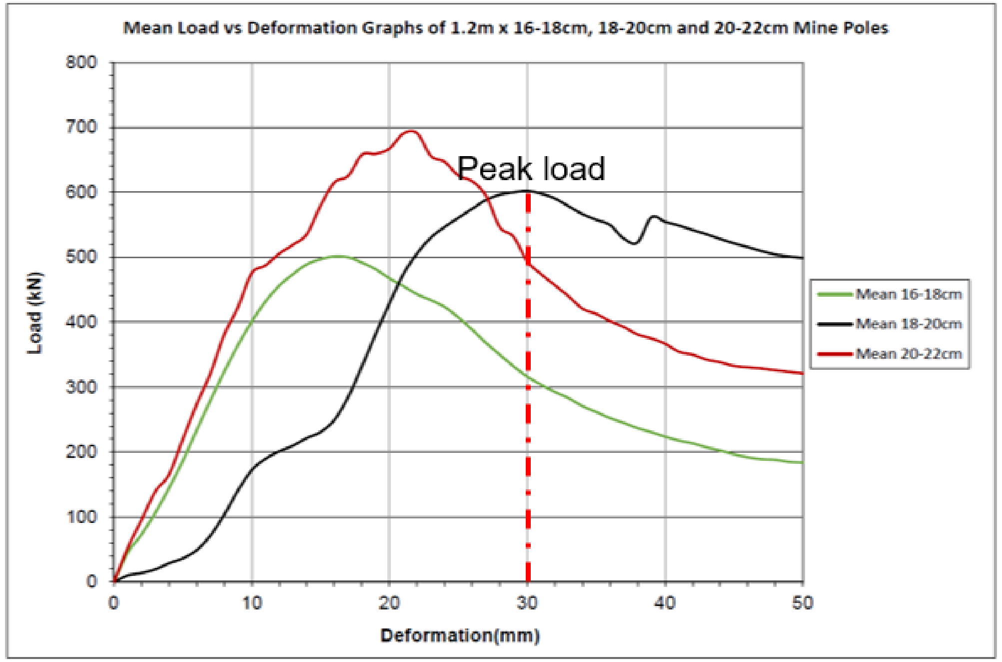
FOOTWALL HEAVE



SUPPORT CHARACTERISTICS

Elongate support

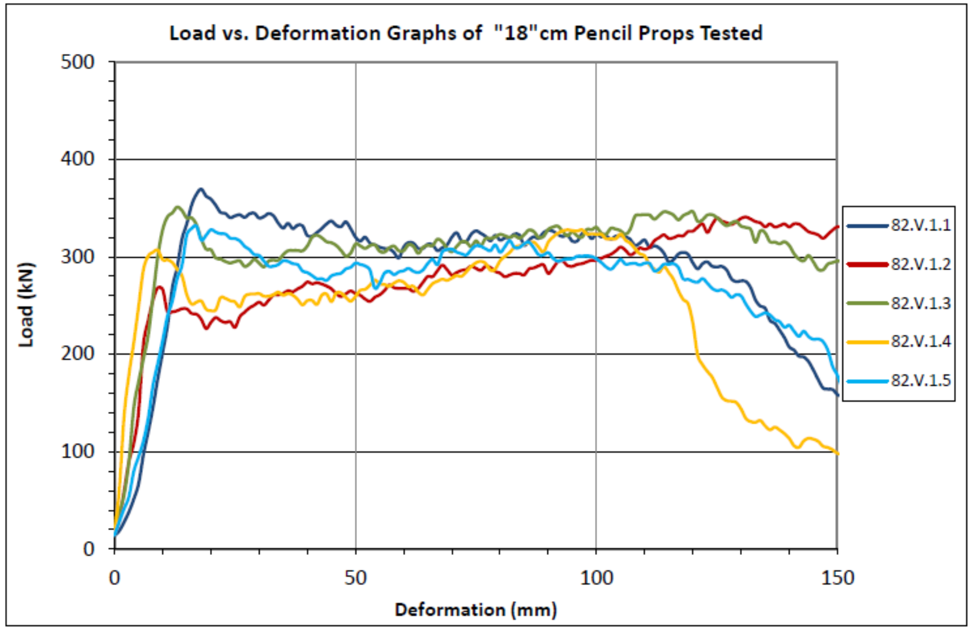
- The mine poles that were being used, reached their peak strength after a displacement of 30 mm. This means that after approximately 18 m face advance, the closure caused the mine poles to fail.



SUPPORT CHARACTERISTICS

Elongate support

- Pencil sticks were introduced as an alternative to the mine poles.
- They provide the benefits of a stiff support system with the yielding capability required for the closure experienced.
- The profiled portion of the stick brushes/yields in a controlled manner to allow the load to be shed whilst maintaining the support resistance.



STRATEGY

The panel length was established as a critical factor in maintaining stability of the workplaces.

- Panel length was reduced to 25 m for all new panel layouts.

The yield capability of the pencil sticks provided suitable support for the high closure rates observed.

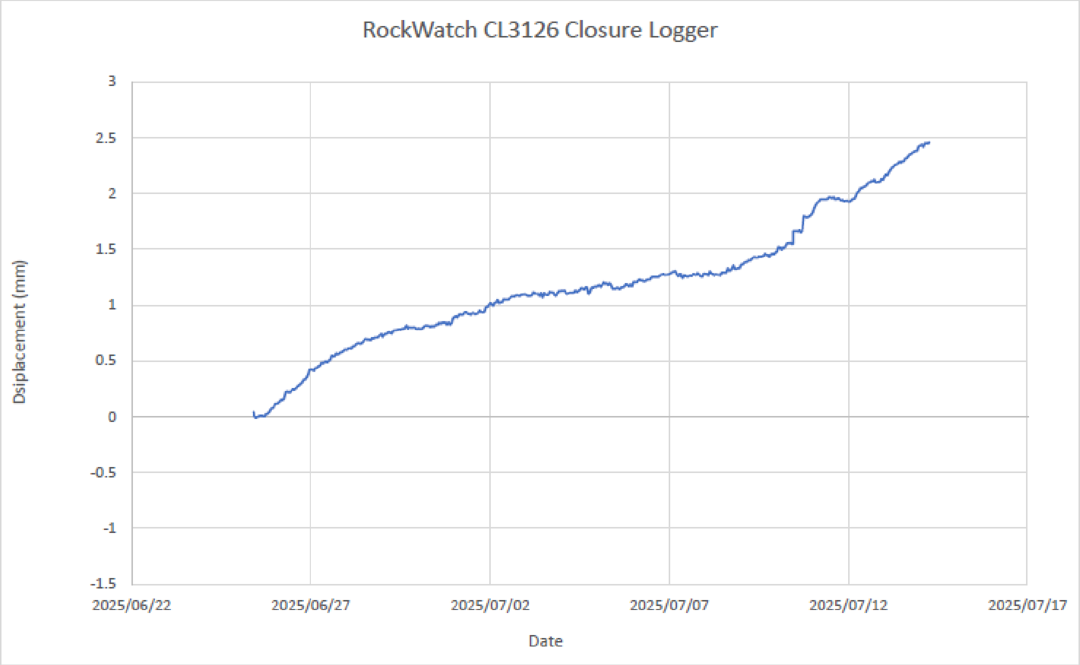
- Pencil stick support continued as the primary support.

- Limit spans between raise lines to prevent excessive closure from taking place with dip stability pillars.

PROOF OF CONCEPT

Closure Measurements

- Two closure loggers installed in 25 m panels.
- Four additional units planned for installation.
- Initial measurements indicate that the design changes have been effective.



$$\frac{Closure\ measured\ (2.5\ mm)}{advance\ (15\ m)} = Closure\ rate\ (0.15\ mm/m)$$

Thank You