



SEISMIC RESPONSE

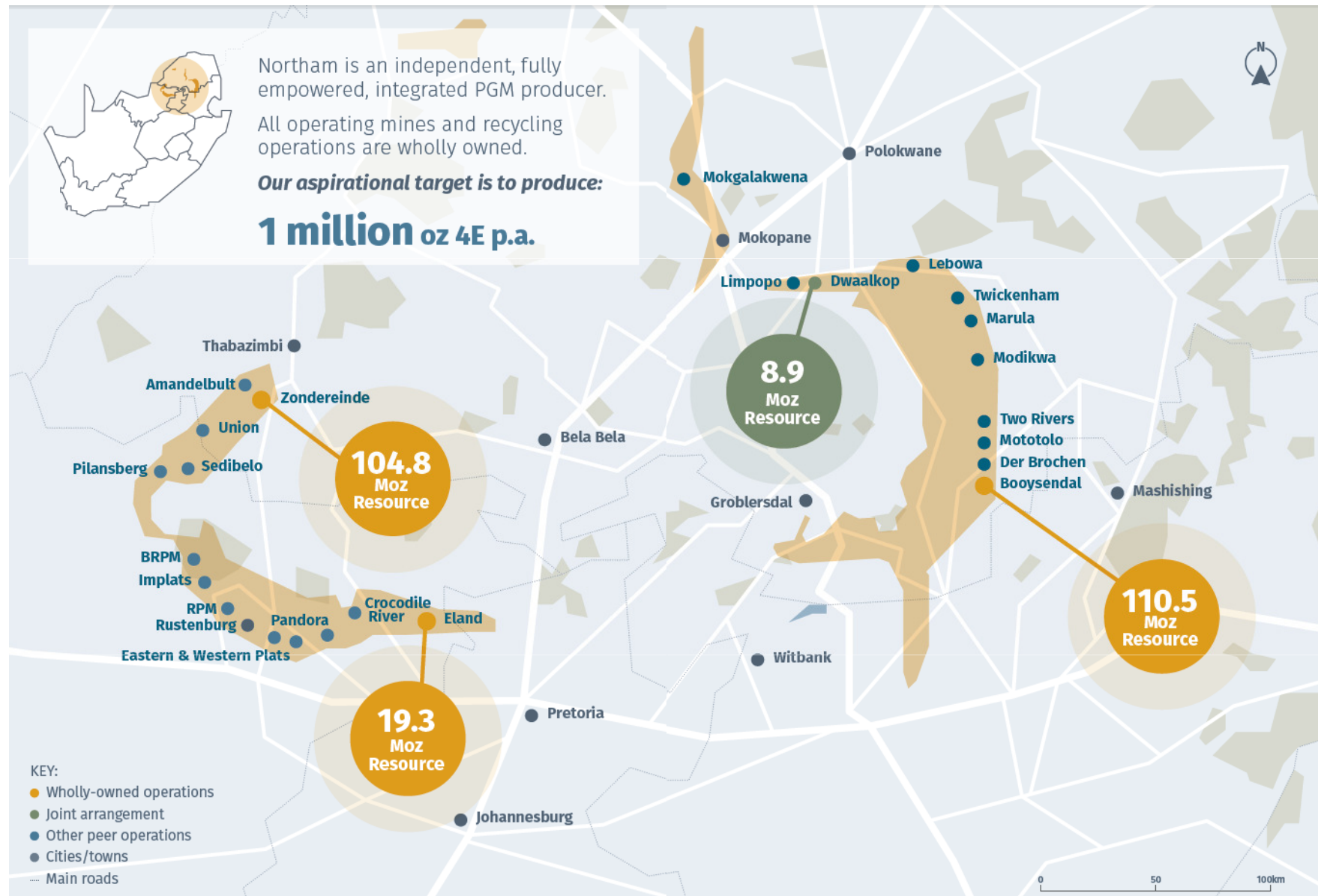
Deep Level PGM Mining



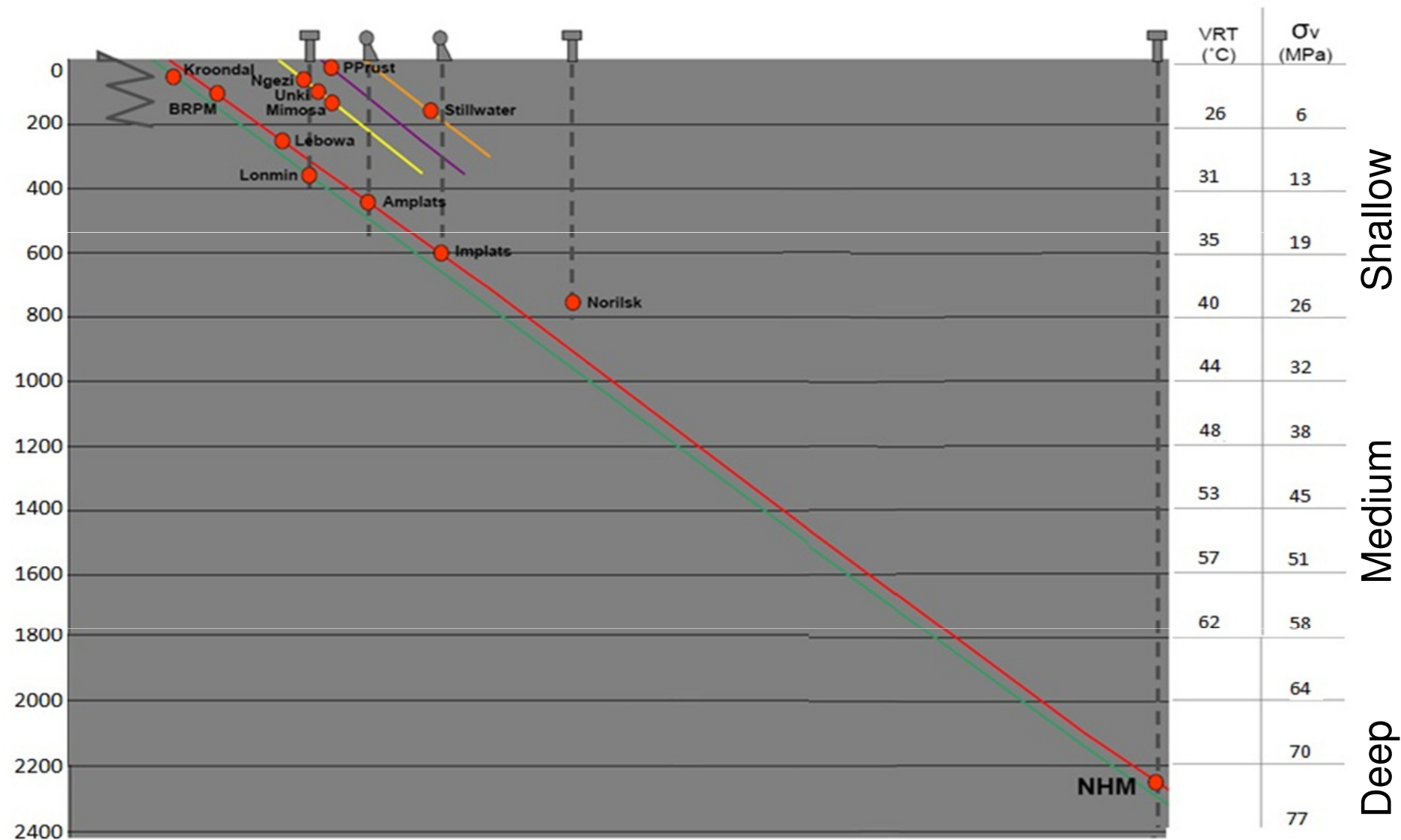
08 November 2019

www.northam.co.za

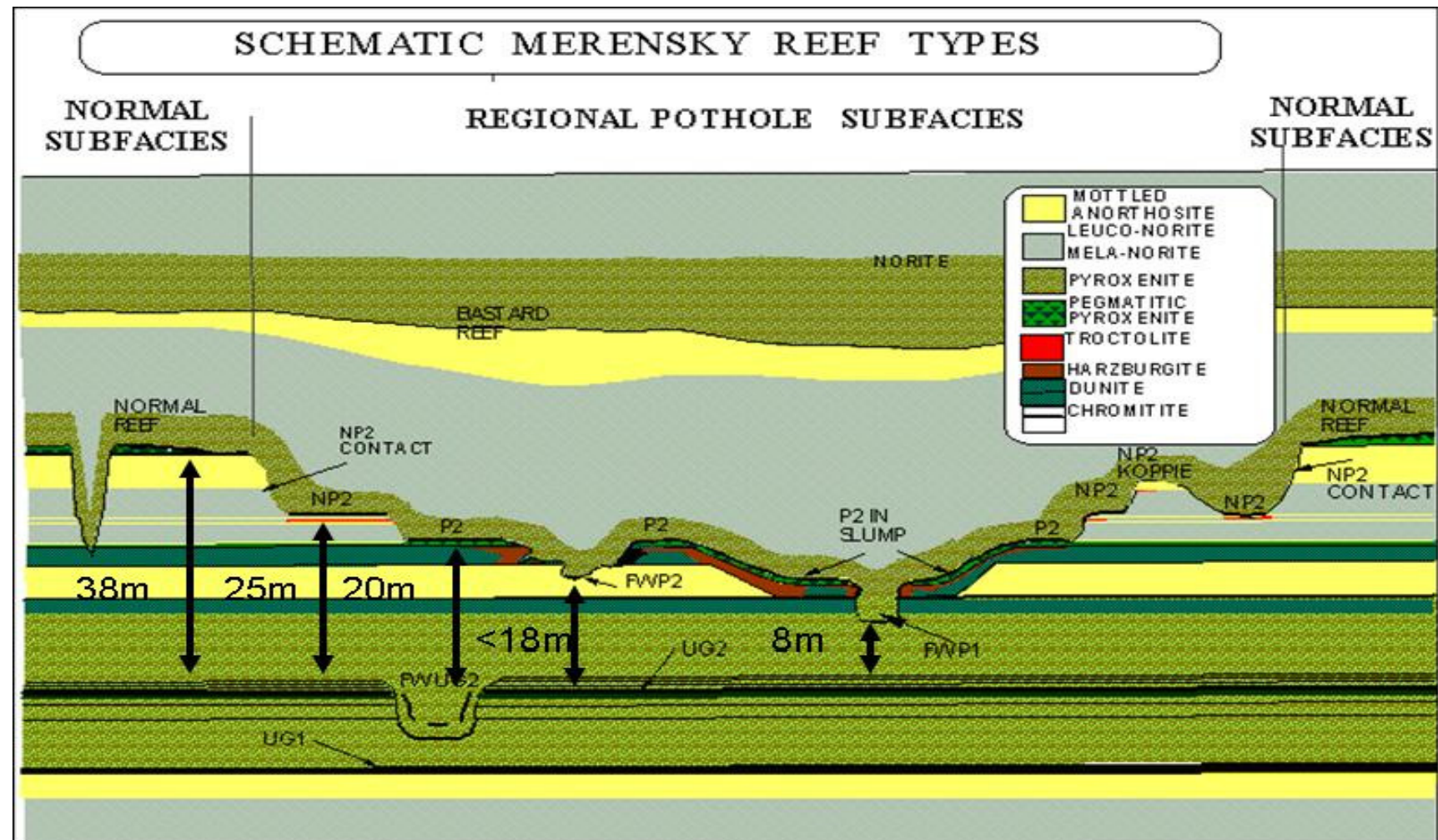
NORTHAM PLATINUM LIMITED



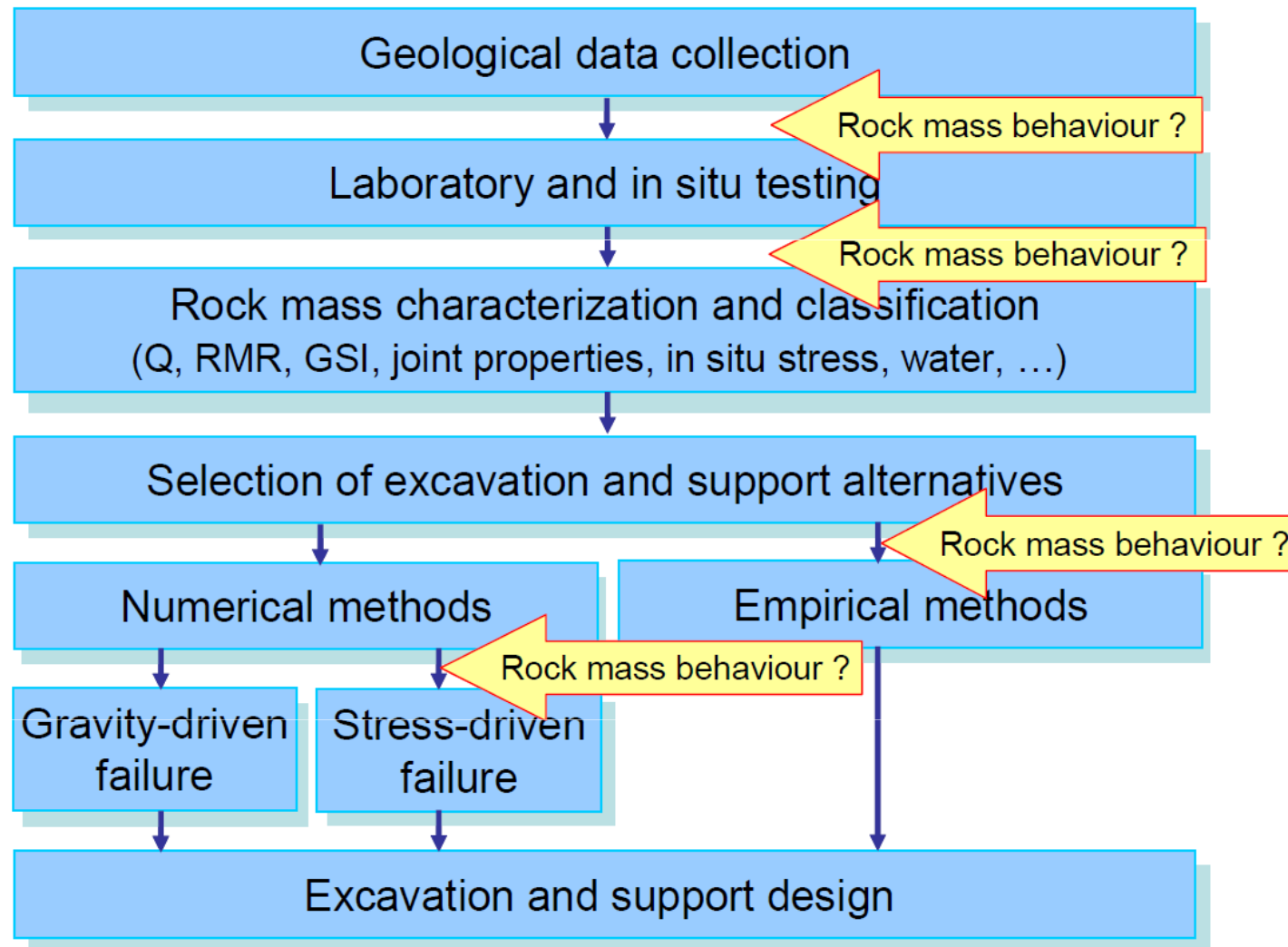
DEPTH BELOW SURFACE



OREBODIES MINED



ROCK BEHAVIOUR CHARACTERIZATION



INTACT ROCK STRENGTH (UCS)

Rock Type	Pyroxenite	Norite	Anorthosite	Dunite	Chromitite
“Deep” Hangingwall	153 – 260	137 – 204	172 – 173		
Merensky Reef Hangingwall	71 – 118	75 – 161			
Merensky Reef	60 - 208				
Merensky Reef Footwall			87 – 152	83 – 93	
UG2 Reef Hangingwall	85 – 148			105 – 140	
UG2 Reef					56 - 112
UG2 Reef Footwall	60 – 138				
“Deep” Footwall	60 – 240	78 – 227	69 – 150	55 – 170	

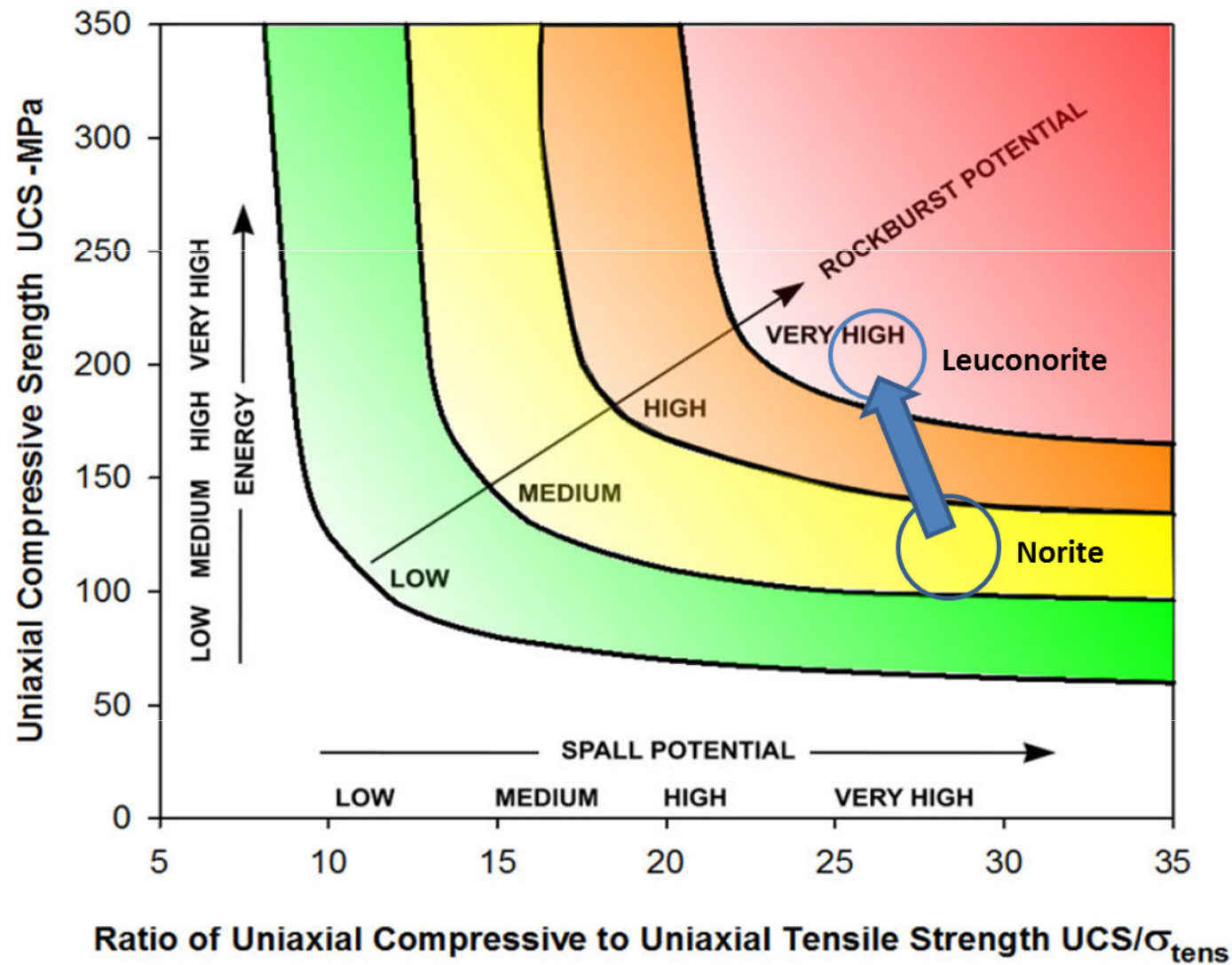
STRESS VS ROCK STRENGTH – NORITE FOOTWALL



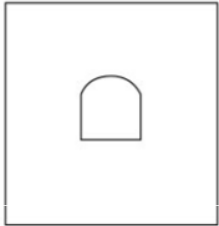
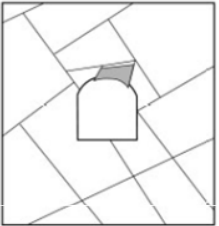
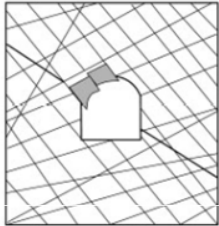
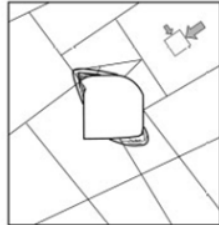
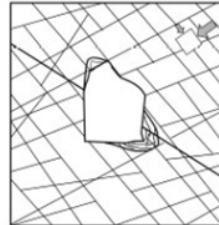
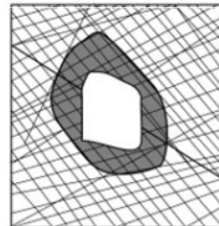
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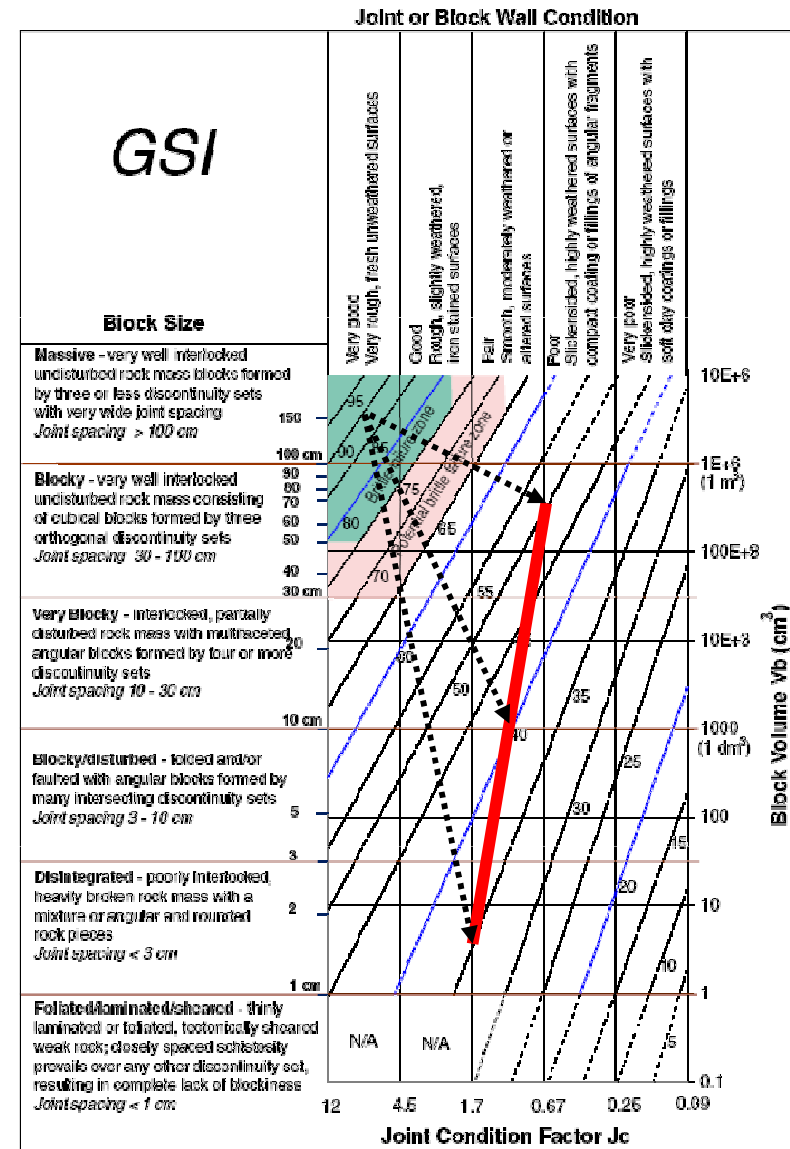
STRAINBURSTING IN FOOTWALL DEVELOPMENT



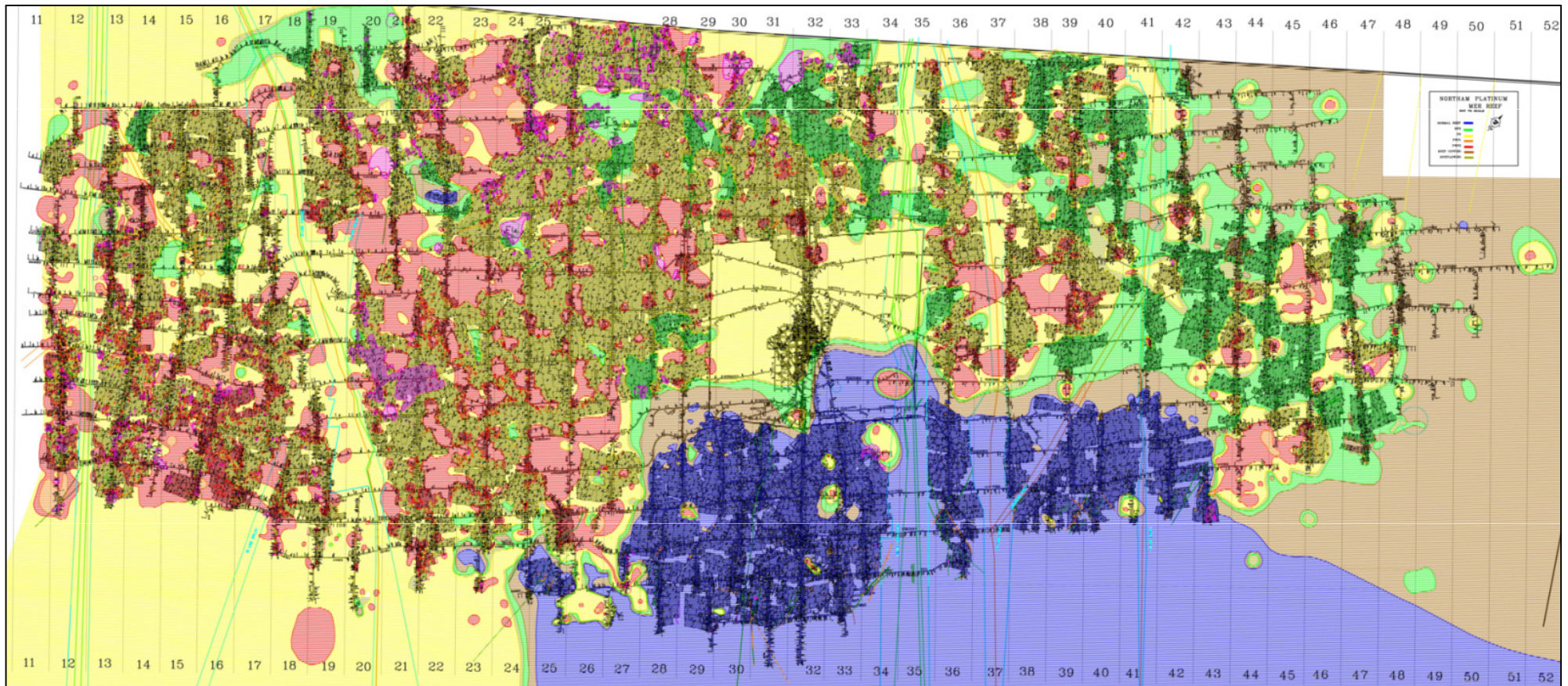
STRESS-DRIVEN FAILURE DOMINATES

	Massive ($RMR > 75$)	Moderately Fractured ($50 > RMR > 75$)	Highly Fractured ($RMR < 50$)
Low In-Situ Stress ($\sigma_1 / \sigma_c < 0.15$)	 Linear elastic response.	 Falling or sliding of blocks and wedges.	 Unravelling of blocks from the excavation surface.
Intermediate In-Situ Stress ($0.15 > \sigma_1 / \sigma_c > 0.4$)	 Brittle failure adjacent to excavation boundary.	 Localized brittle failure of intact rock and movement of blocks.	 Localized brittle failure of intact rock and unravelling along discontinuities.
High In-Situ Stress ($\sigma_1 / \sigma_c > 0.4$)	 Failure Zone Brittle failure around the excavation.	 Brittle failure of intact rock around the excavation and movement of blocks.	 Squeezing and swelling rocks. Elastic/plastic continuum.

ROCK MASS STRENGTH DEGRADATION



FACIES DISTRIBUTION – MERENSKY REEF



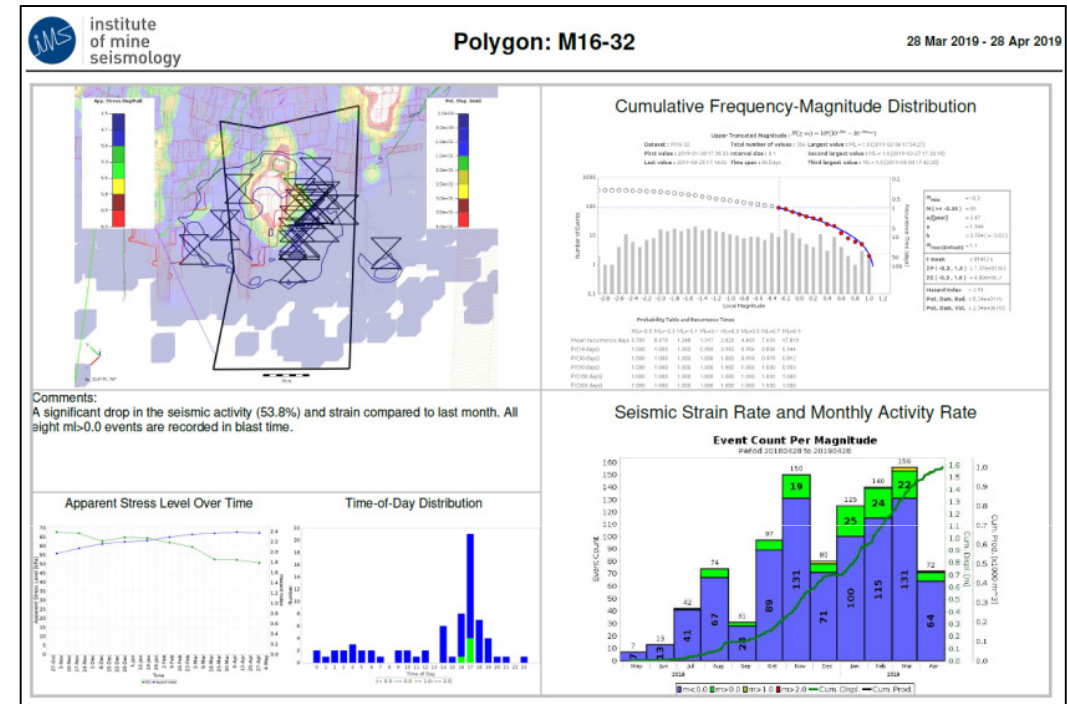
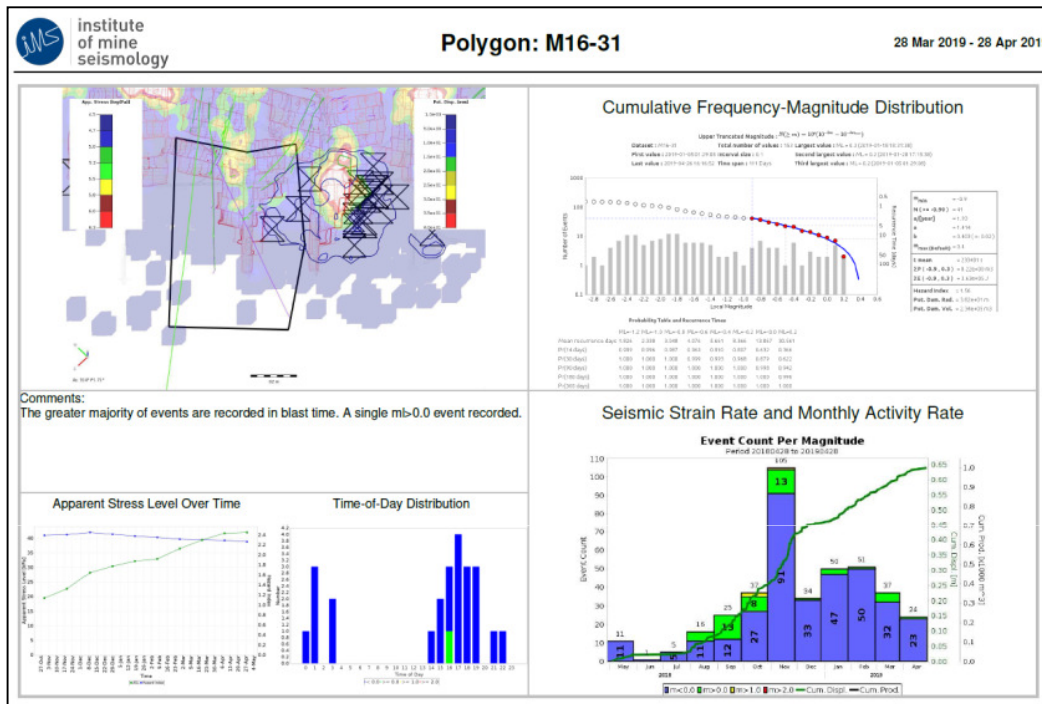
STRESS VS ROCK STRENGTH – MERENSKY REEF



SEISMIC RESPONSE TO ROCK MASS CLASS

RMR = 60

RMR = 70



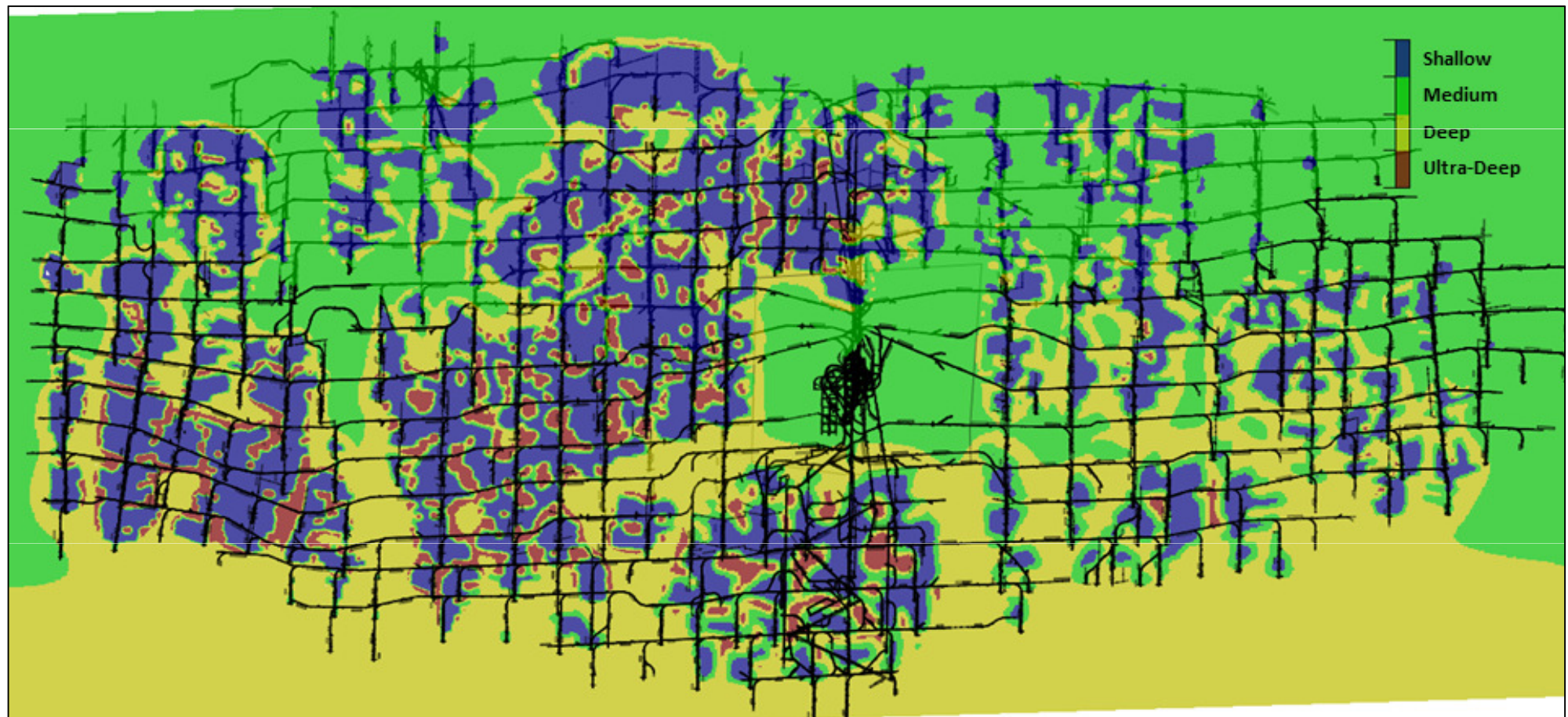
FACE BURST – MERENSKY REEF



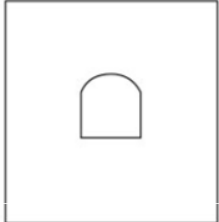
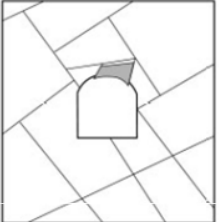
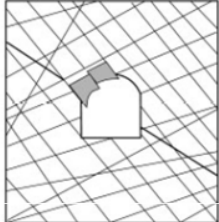
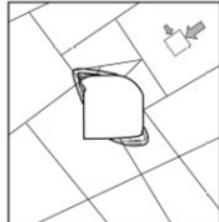
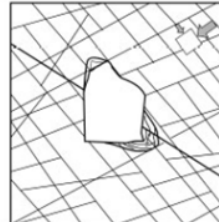
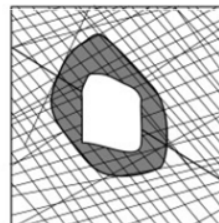
FACE BURST – MERENSKY REEF



MODELLED MINING DEPTH – UG2 REEF

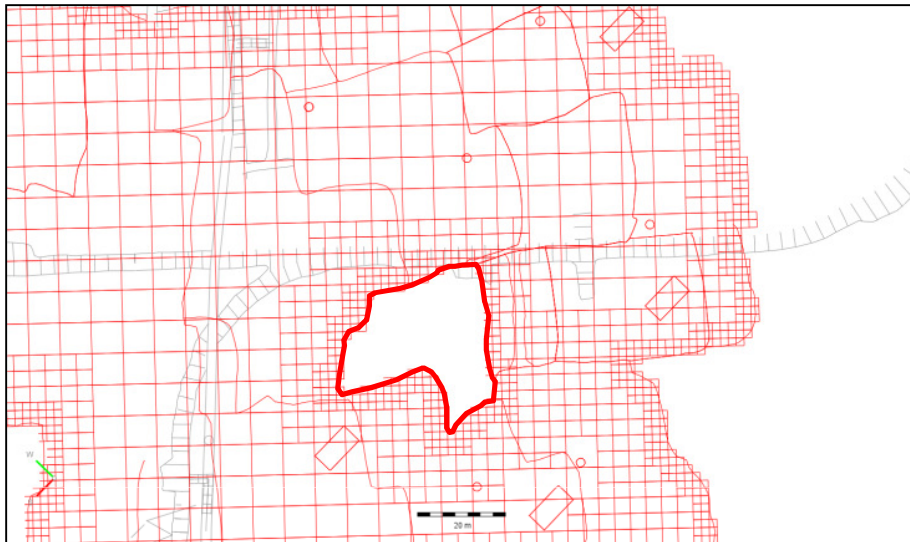


POSSIBLE FAILURE MODES IN UG2 MINING

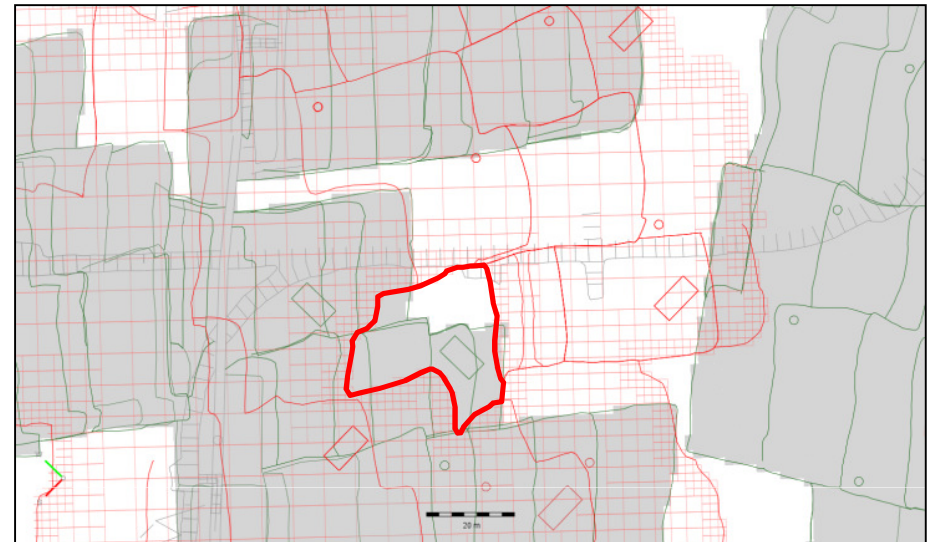
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UNDER-STOPING STRESSED PILLARS

Merensky

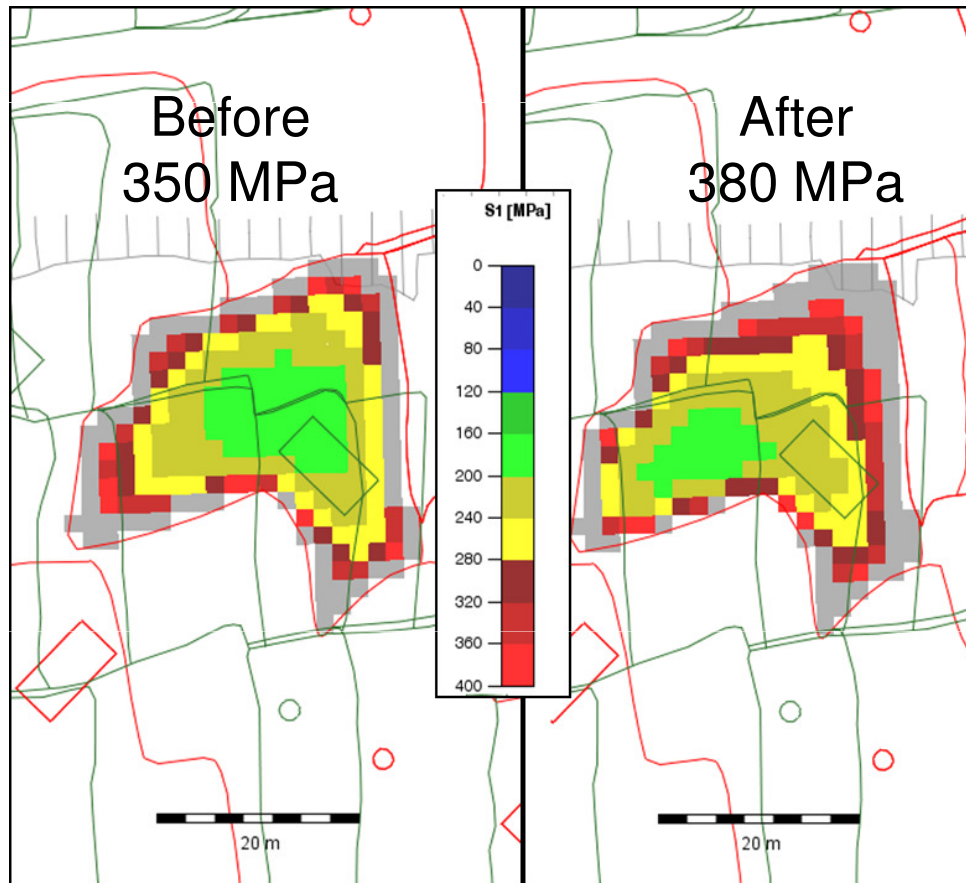


UG2

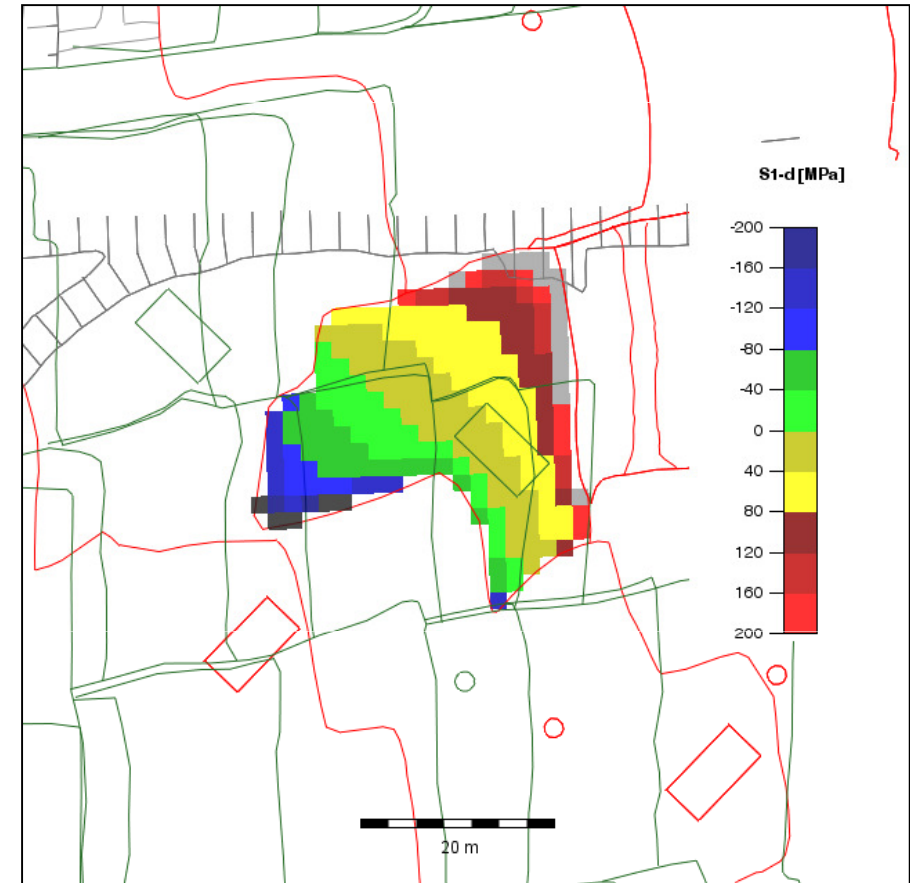


'RAINBOW' PILLARS

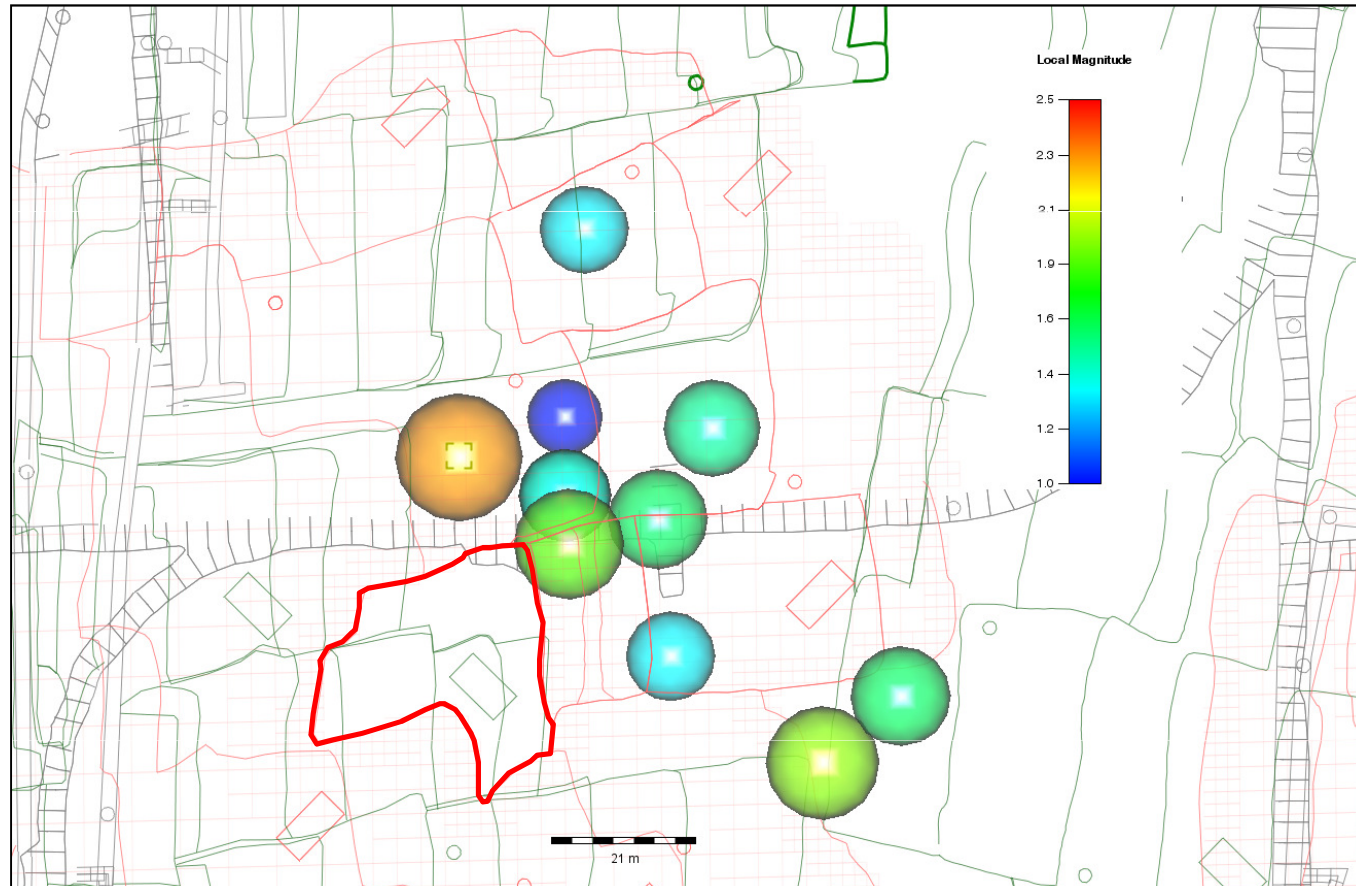
APS



Difference



RECORDED SEISMICITY ($M_{MAX} = 2.3$)



SHAKEDOWN DAMAGE – UG2 REEF



FACE BURST – UG2 REEF



DYNAMIC DAMAGE TO SUPPORT – UG2 REEF



ROCK MASS BEHAVIOUR – UG2 REEF



AMELIORATION STRATEGIES

- Backfill
- Regional support pillars
- Mine design & planning
- Controlling leads & lags
- Preconditioning
- Stress modelling
- Seismic monitoring
- Rock mass classification
- Support design
- Compliance auditing

RISK MANAGEMENT

NORTHAM ZONDEREINDE - Working Place Control Sheet																
LEVEL	X/CUT	PANEL	REEF	SHIFT SUPERVISOR	PLANNING RISK RATING	DATE OF LAST DEPARTMENT VISIT	ISSUES FROM LAST VISIT	CURRENTLY MINING (Y/N)	PLANNED FOR THE NEXT MONTH (Y/N)	PLANNING MINUTES	PERCENTAGE COMPLIANCE PER PANEL	PERCENTAGE COMPLIANCE PER S/BOSS & MO	MOST RECENT RMR	MOST RECENT SEISMIC MEDIUM TERM RATING	MOST RECENT FACE STRESS OR RCF MODELLED	GEOMETRY
14	19	2e	mr	A Mokhali	Low	23-Sep-19	Panel not yet mining crew advancing the gully. No gully winch installed.	Y	Y	No major issues but monitor for and treat keyblocks.	84.6%		80	3	185	0.26
14	19	3e	mr	A Mokhali	Medium	23-Sep-19	The heading was mining off reef. Missing gully pack at the entrance of the gully on south shoulder. Low angle joint forming a brow in the middle of the panel. Moderate stress fractures. Gully and the heading not to standard.	Y	Y	Fix face shape. Fault expected ahead of current face.	76.9%		56	3	220	0.60
14	19	4e	mr	A Mokhali	Medium	23-Sep-19	Some of gully packs were exceeding >2.0 m. The panel was not cleaned. Missing elongates in the panel not replace by camlok props.	Y	Y	Rolling reef reported. Maintaing a steady HW in the heading and gully. Do not follow excessive downward reef rolls. Monitor for and treat keyblocks	92.3%		52	3	258	0.18
14	19	5e	mr	A Mokhali	High	23-Sep-19	Dripping ground water at the top of the panel. Moderate stress fractures on panel face. Sub-standard gully pack. Heading and gully not to standard.	Y	Y	Scaling expected to intensify as panel approaches dip pillar. Potential for overhanging face. Enforce barring + support + good blasting discipline.	84.6%		32	3	323	0.36
No. of W/		4										86.5%				