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Influence of pit wall stability on underground planning and design when transitioning from open pit to sublevel caving

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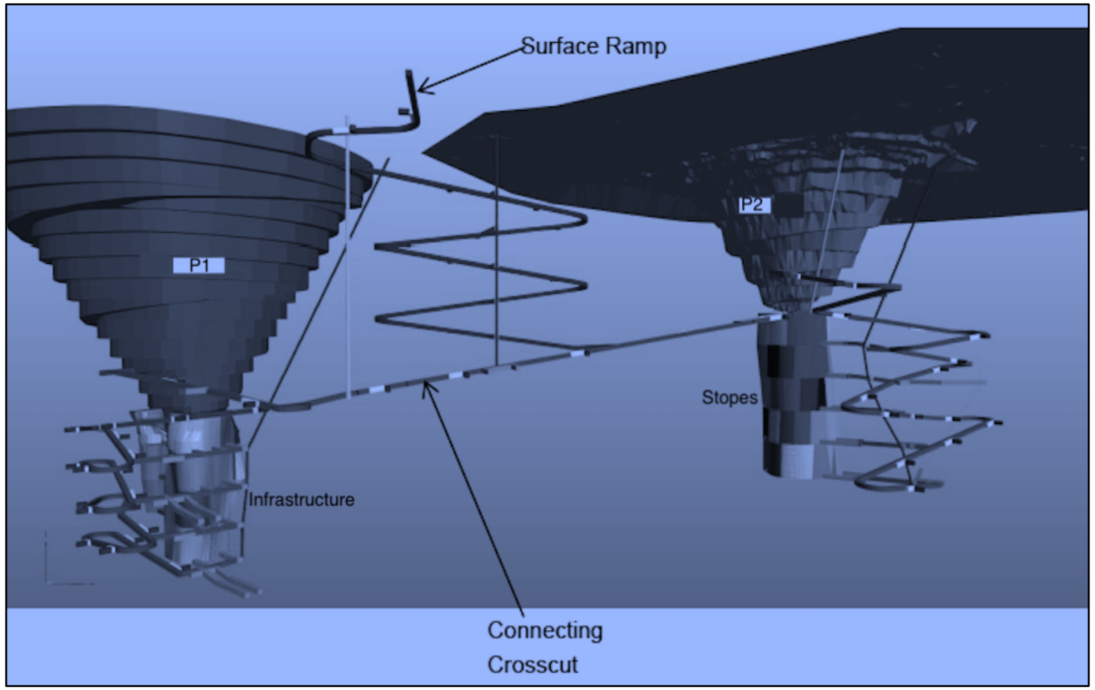
Contents

Introduction

- Beyond economic pit limit, opportunity to transition to underground
- Challenges exist
- Availability of resources/reserves, project economics, geotechnical environment and safety
- Study focuses on the geotechnical environment specifically:
  - Stability/instability of the pit wall
  - Positioning of excavations and infrastructure
  - Role of numerical modelling in assessing stability



Stability and Transition Challenge

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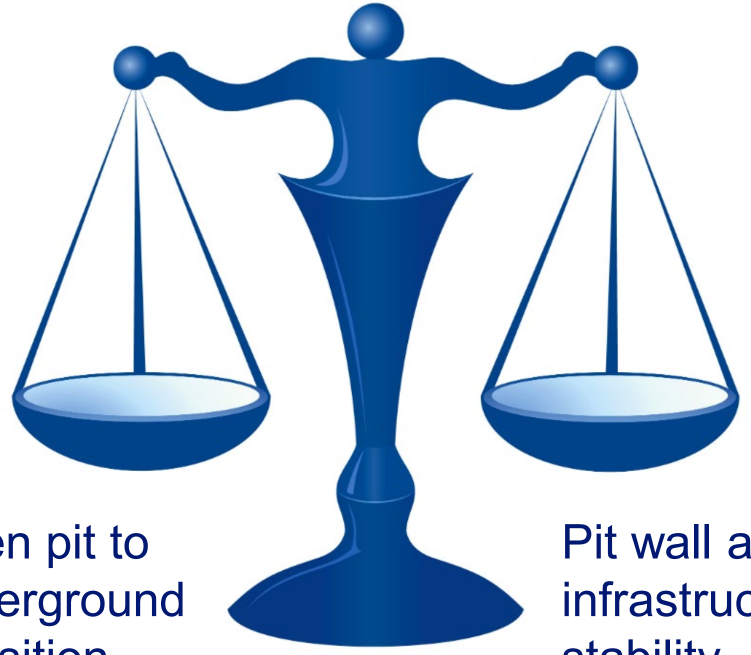

Open pit to underground transition

Pit wall and infrastructure stability

- Stability has to be satisfied and at the same time open pit to underground transition has to occur
- Inadequate consideration of geotechnical parameters can cause:
  - Uncontrolled backbreak
  - Failure of pit walls
  - Loss of lives and equipment
  - Excessive dilution
  - Loss of the mine

Case Study Mine

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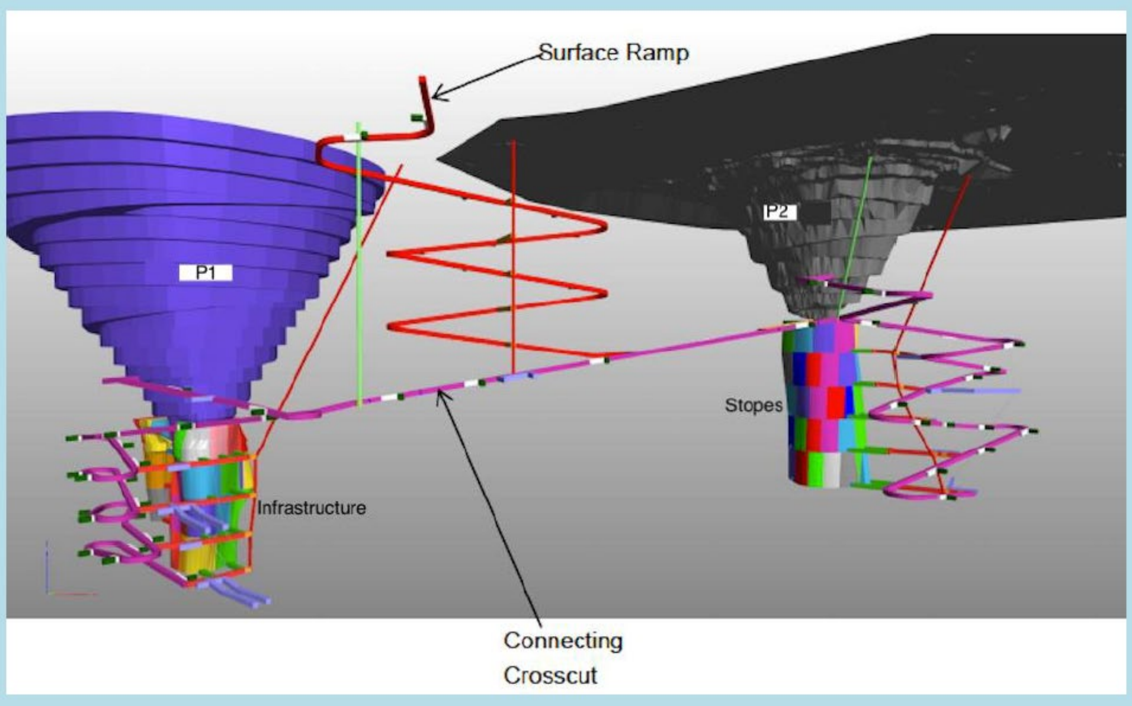
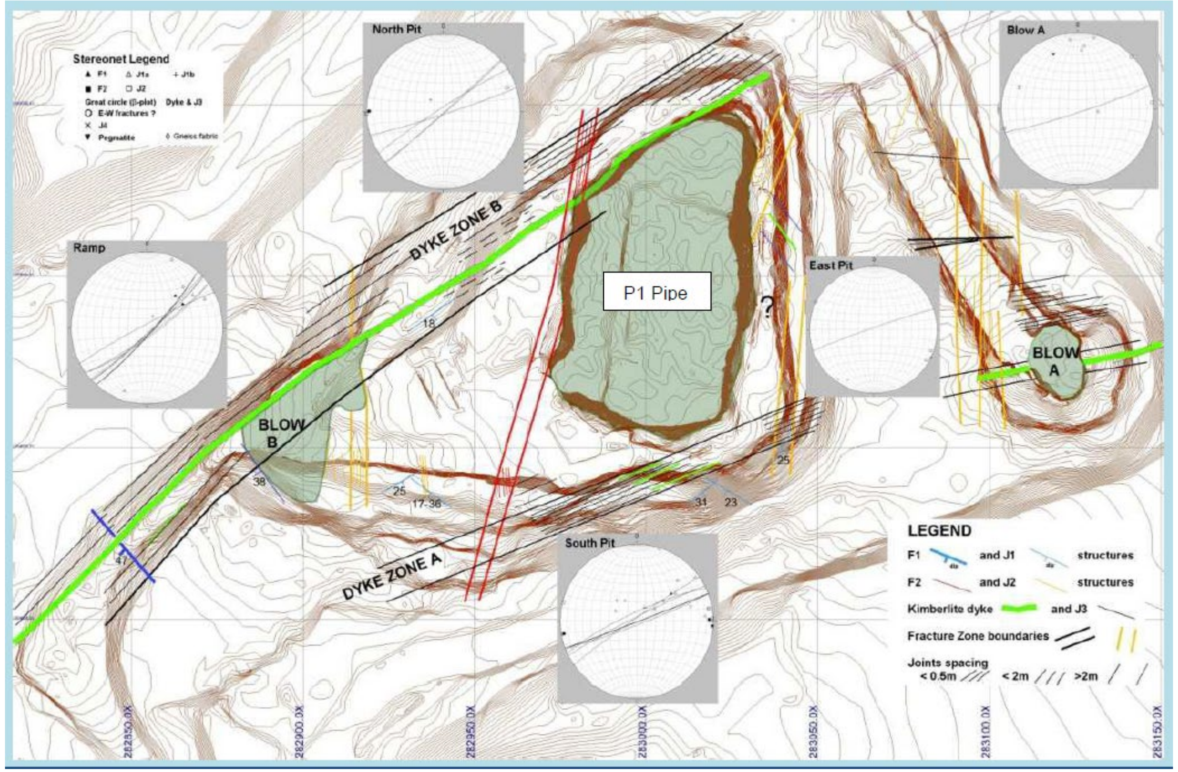
- Located in Africa
- Diamond mine – consists of two kimberlite pipes, P1 and P2
- Spaced at 800m apart
- Several other blow pipes in the vicinity
- Initially mined by open pit until they reached their economic limit at 300m
- Kimberlite pipes intruded the granitic gneiss host rock



Case Study Mine – Geology

- Kimberlites are intruded into the Archean-aged Leonean granitic gneisses of the West African craton
- Gneissic fabric is not obvious everywhere, but appears to define areas of higher strain
- From sight observations and geotechnical investigations, the kimberlite dyke zones are the most prominent structures
- Dykes are not continuous, but pinch and swell, bifurcate and form eastward stepping echelon arrays
- Vary from thin stringers (<30cm), separated by the country rock, to 1.5m wide



Why Investigating Transition?

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- Factors that affect mine stability:
  - Structural Geology
    - Faults
    - Bedding
    - Joints
    - Foliation
    - Dykes
  - Groundwater
  - Rock mass classification
  - Geometry
  - Alteration
  - Stress conditions
  - Weathering
  - Blasting

Underground Infrastructure

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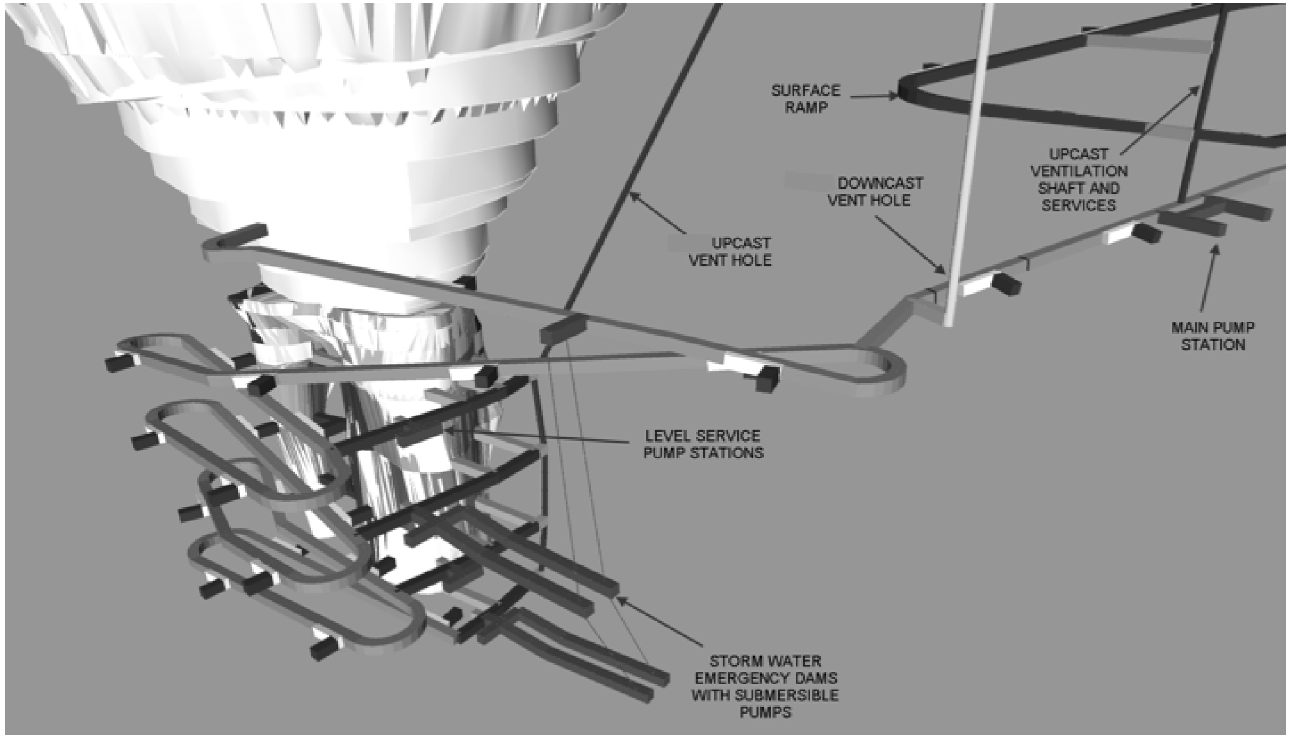
- Considered for the project:
  - Ramp development
  - Connecting drive for the two underground workings
  - Ventilation shafts
  - Underground workshop
  - Drilling water reticulation
  - Dewatering system
  - Electrical system
  - Secondary escape route
  - Level drives

Infrastructure Considerations



- Infrastructure to be placed in stable ground conditions
- Assess stability risk posed by stress concentrations around pit walls
- Haul roads to be open during initial stages
- Stable position for primary access breakaway
- Mining sequence that does not cause excessive slope failures

Numerical Modelling

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- FLAC3D
- Model for predicting the effect of stress changes around the pit wall and underground
- Input parameters include geomechanical properties, initial conditions, boundary conditions, groundwater and mining sequence
- Top down sub level caving through 40m slices
  - ✓ 4 slices for Pipe A
  - ✓ 5 slices for Pipe B
- Hoek-brown failure criterion used
- Informed siting of infrastructure

Rock Property Parameters

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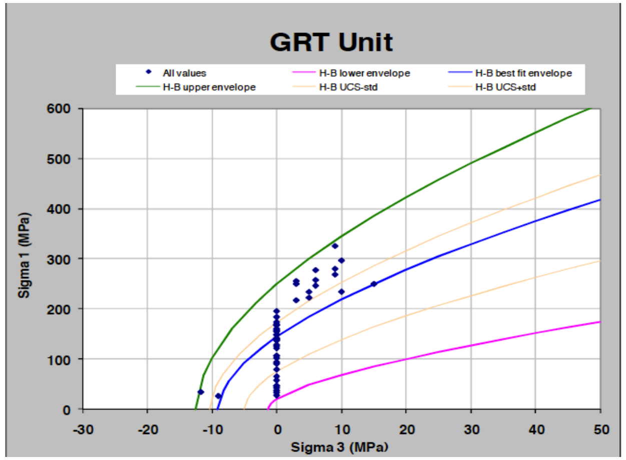
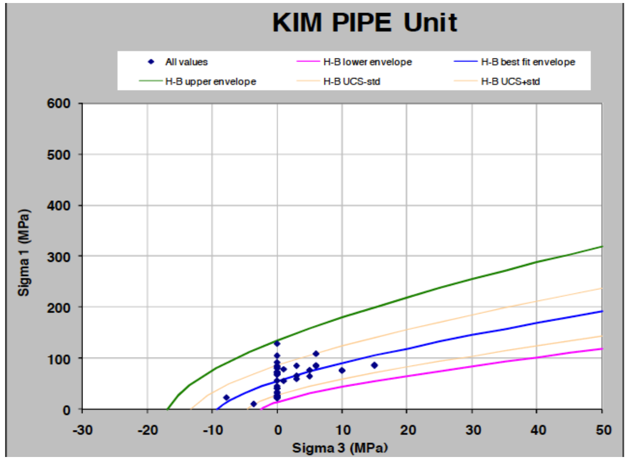
Rock Unit	Breccia	Granite	Kimberlite Dyke	Leached Granite	Translational Dykes
Density (kg/m^3)	2570	2680	2920	2260	2650
UCS (MPa)	64	124	120	24	55
Young Modulus (GPa)	55	65	82	15	32
Base Friction Angle (°)	28	36	30	35	20

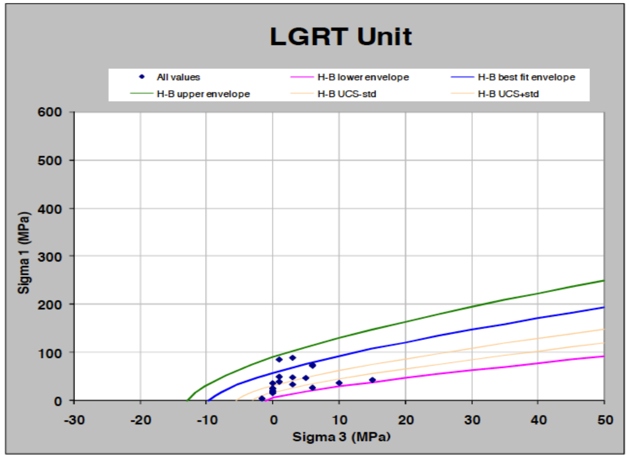
Granite



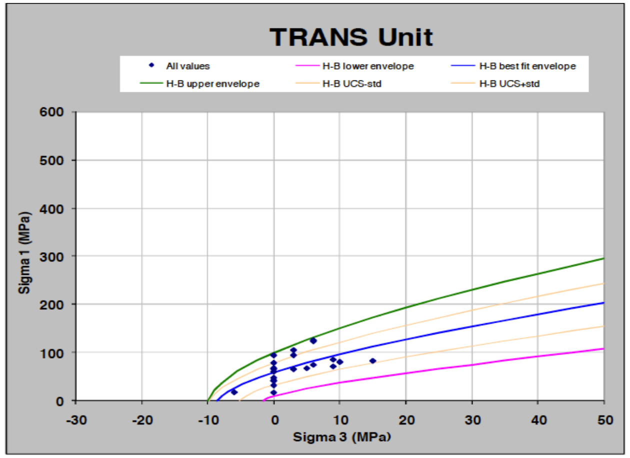
Kimberlite pipe



Leached Granite



Translational dyke



Geotechnical Design Parameters

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Rock type	UCS	RMR	GSI	mi	c	Φ	E
					kPa	°	GPa
Breccia	72	45	40	6	262	34	1.9
Granite	133	63	57	16	1004	55	9.5
Kimberlite dyke	120	61	56	6	977	44	4.9
Kimberlite pipe	65	61	56	6	694	40	3
Leached granite	25	48	43	6	184	27	0.5

Joint Set Characteristics for the Mine

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Set	Dip	Strike	Spacing	Length	Macro planarity	Micro Roughness
P1						
J1	Shallow	a) SW b)E	2 m - 10 m	>5 m	Wavy	Rough undulating
F2/J2	Sub vertical	N-NNE	0.5m	>5 m	Straight	Rough undulating
J3	Sub vertical	ENE	<0.5 m - 2 m	>5 m	Straight stepped at intersections	Smooth undulating, sometimes slickensided
J4	Sub vertical	NW				
P2						
J1	Shallow	a) SW b)SE	>10 m	>5 m	Straight	Rough undulating
J3	Sub vertical	ENE	<0.5 m - 2 m	>5 m	Straight stepped at intersections	Smooth undulating, sometimes slickensided
Dykes						
SJ1	Moderate Sub vertical	60°-80° anti-clockwise from J3			straight, slightly curved	Smooth planar
SJ2	Shallow moderate	N			Wavy	Smooth planar
J3	Sub vertical	ENE	<0.5 m - 2 m	>5 m	Straight stepped at intersections	Smooth undulating, sometimes slickensided

Mechanisms of Slope Failure

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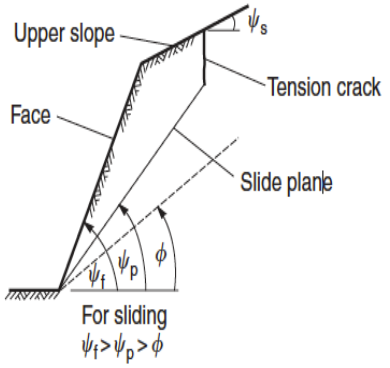

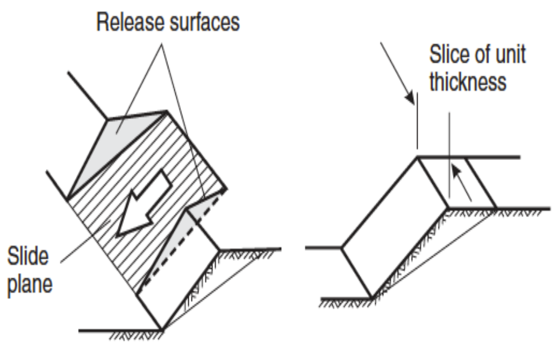

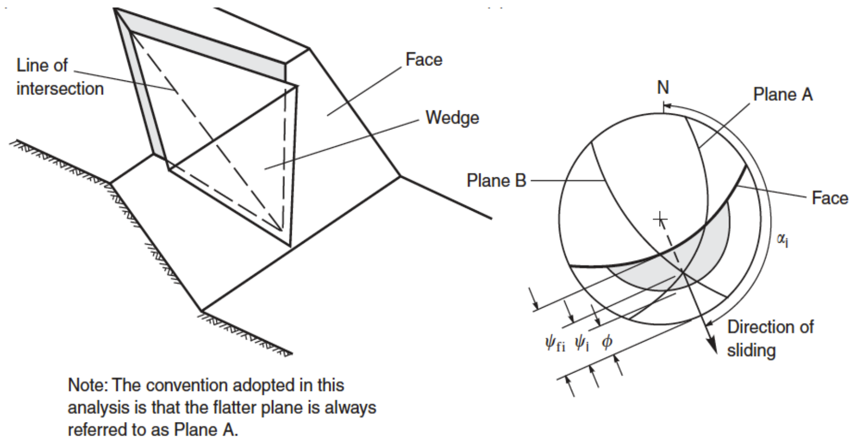

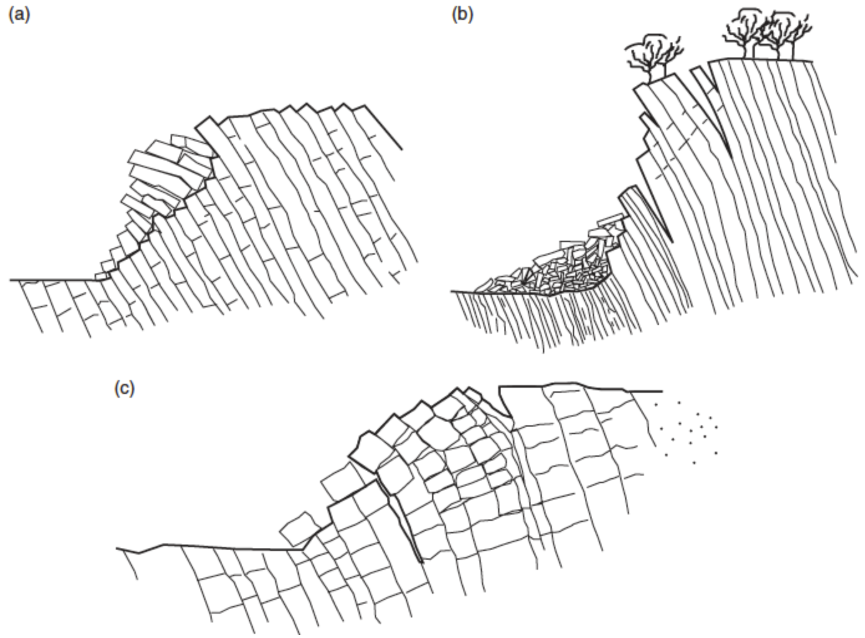

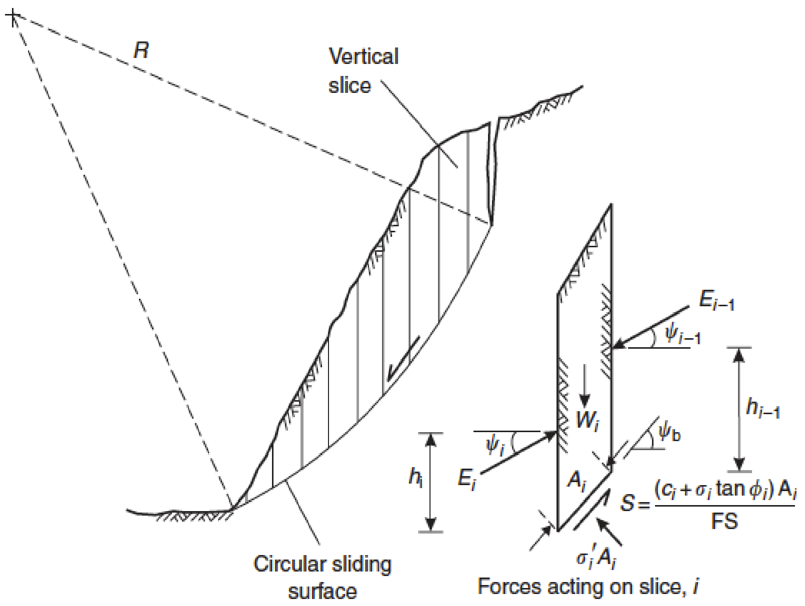

Results and Analysis

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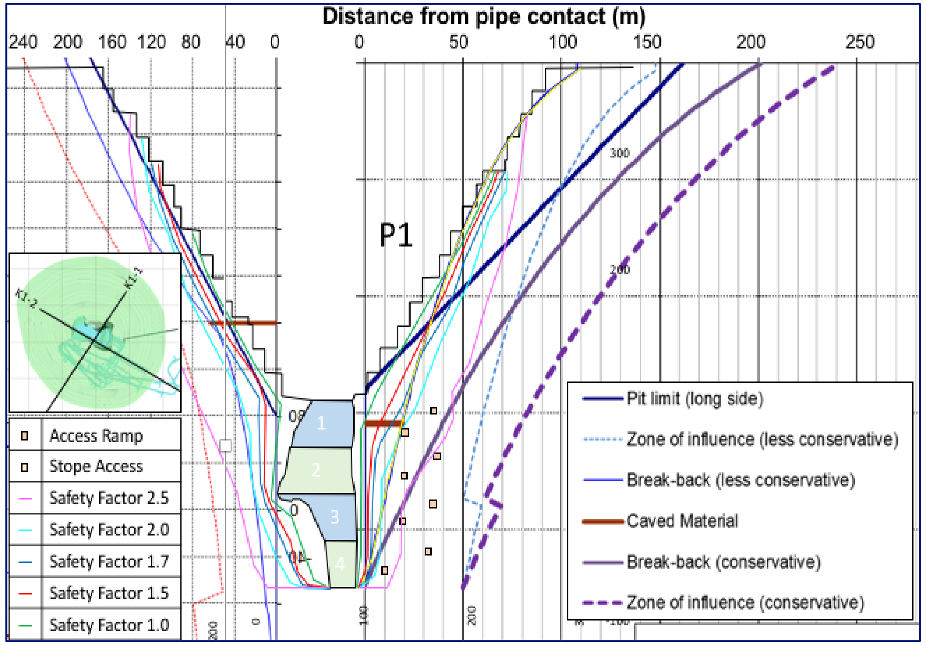
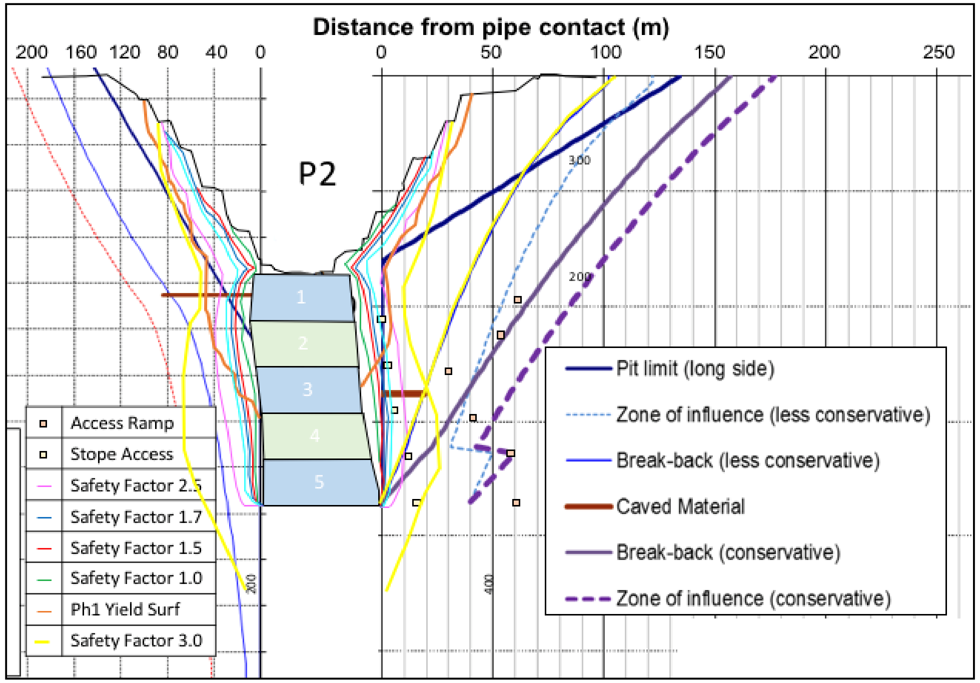


- Factor of Safety iso-shells
- From the modelling, areas of interest were
  - Pit slope behaviour
  - Interaction of pit and underground mining
  - Zone of geotechnical stability and instability



Factor of Safety Shells

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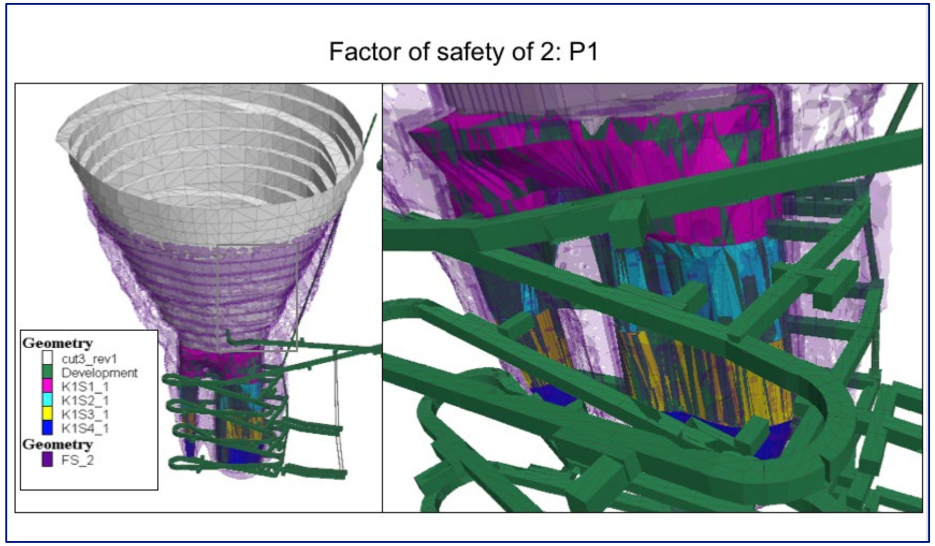

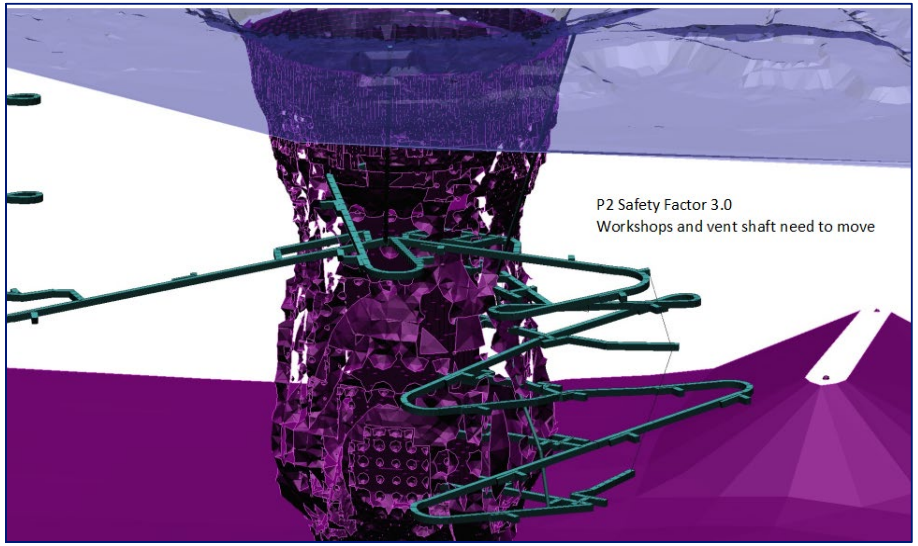

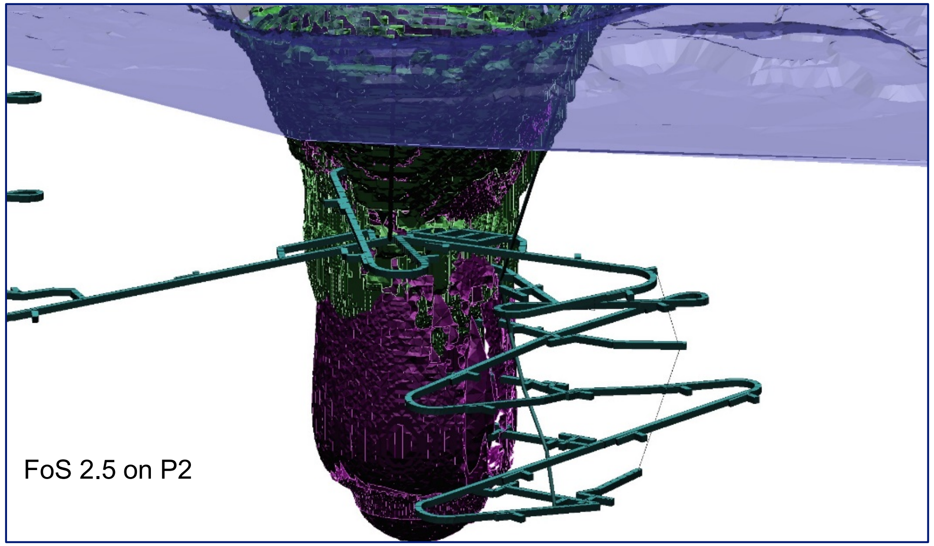

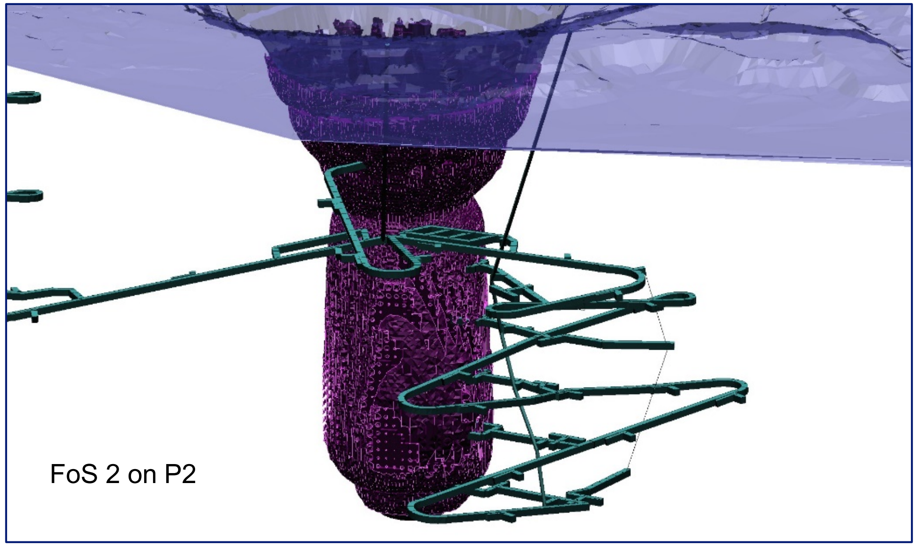

FoS Shells for Pits P1 and P2

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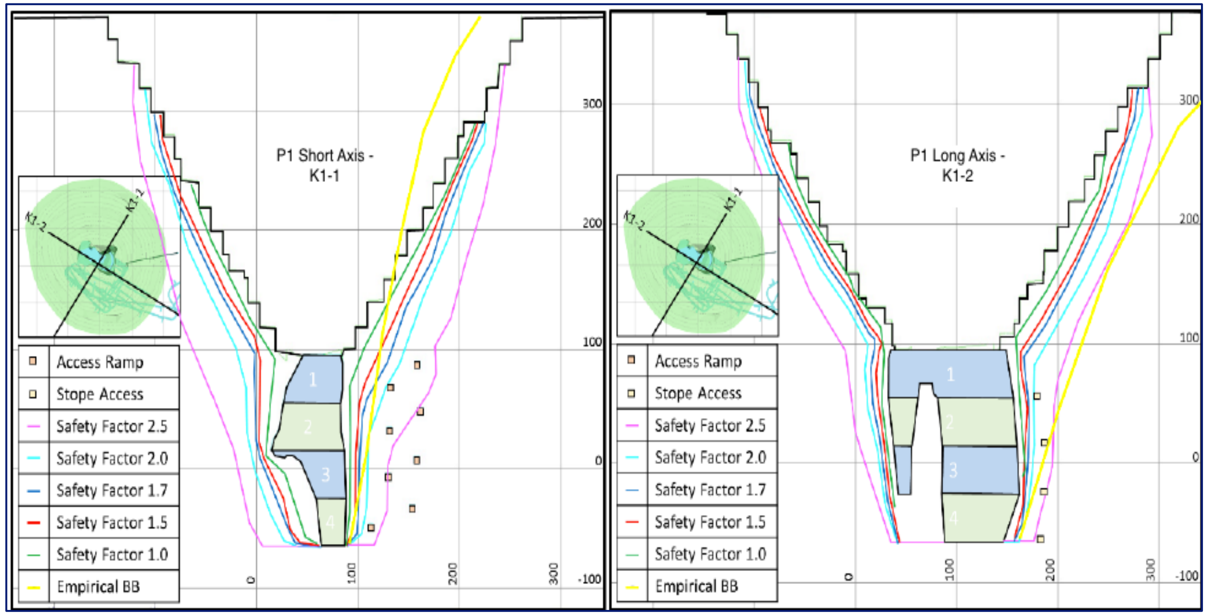

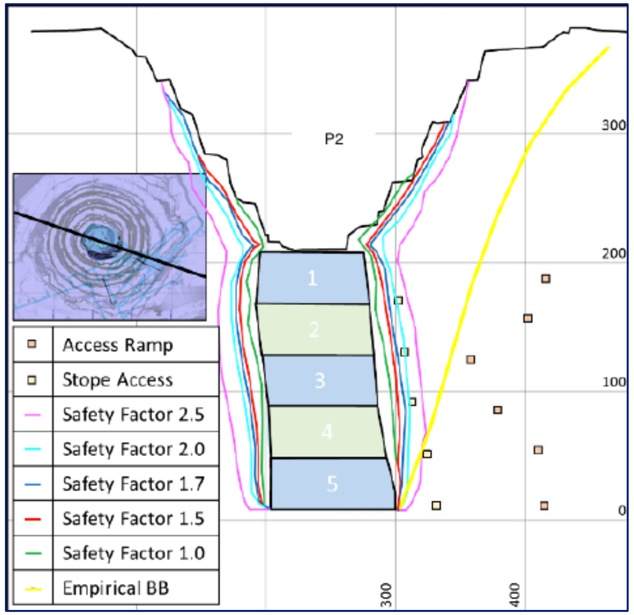

- FoS of 2 chosen to ensure critical excavations are outside failure zone
- Signs of pit instability and slope movement were projected when mining second stope
- Faults and dykes adversely affected pit wall stability

Conclusions and Recommendations

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- FLAC 3D FoS iso-shell used for design outside expected zone of influence
- Conservative FoS of 2 was chosen to cater for the unknown rock mass behaviour
- New conditions discovered during the project should be recorded and added to the numerical model
- Strong cross-functional approach from both the geotechnical and the mine planning departments
- Effective monitoring system is required in place around the pit wall, to continuously assess and evaluate displacement and deformation as mining progresses

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Thank you