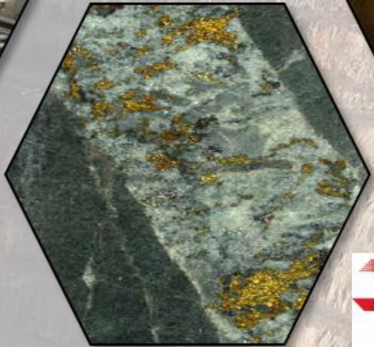
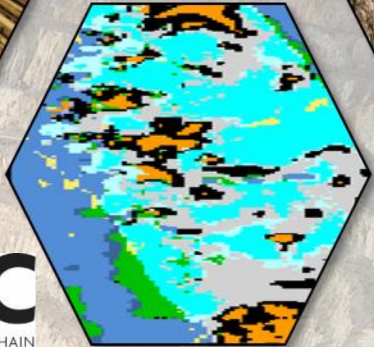
The Use of Automated Core Logging Technology to Improve Estimation of Fracture Mineralogy and Weathering for Geotechnical Index Calculations





TMVC
TRANSFORMING THE MINING VALUE CHAIN

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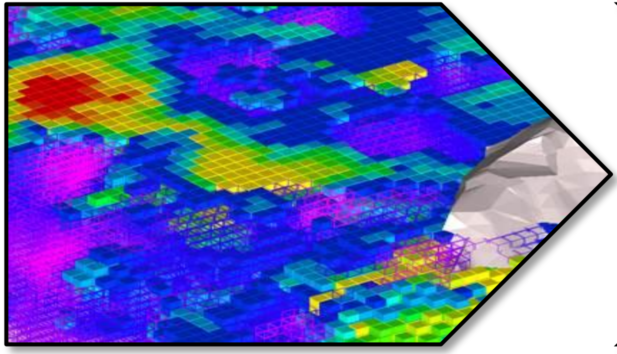
Drilling for Geology II
July 26 – 27, 2017

corescan

NEWCREST MINING LIMITED

Introduction

Geotechnical assessment and modelling vital to mining



Rock mass properties are directly affected by mineralogy and weathering

Successful geotechnical models depend on characterising rock mass

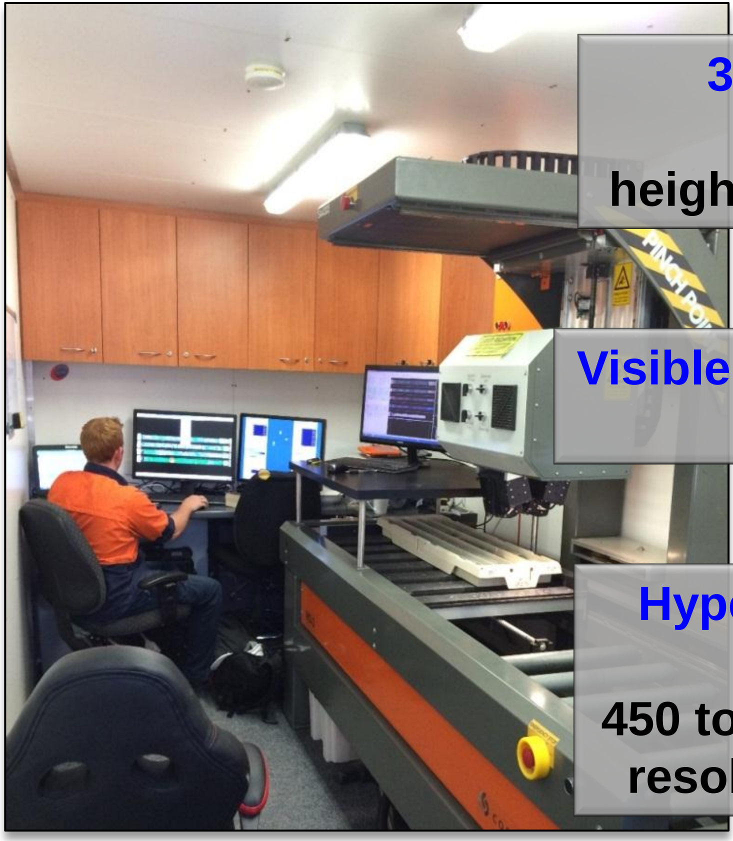
Successful geotechnical assessment = successful mining = *profit*

Current Geotechnical Data Collection

Geotechnical models based on manually measured data

- Successful, but time-consuming
- Prone to inconsistencies

Corescan Technology



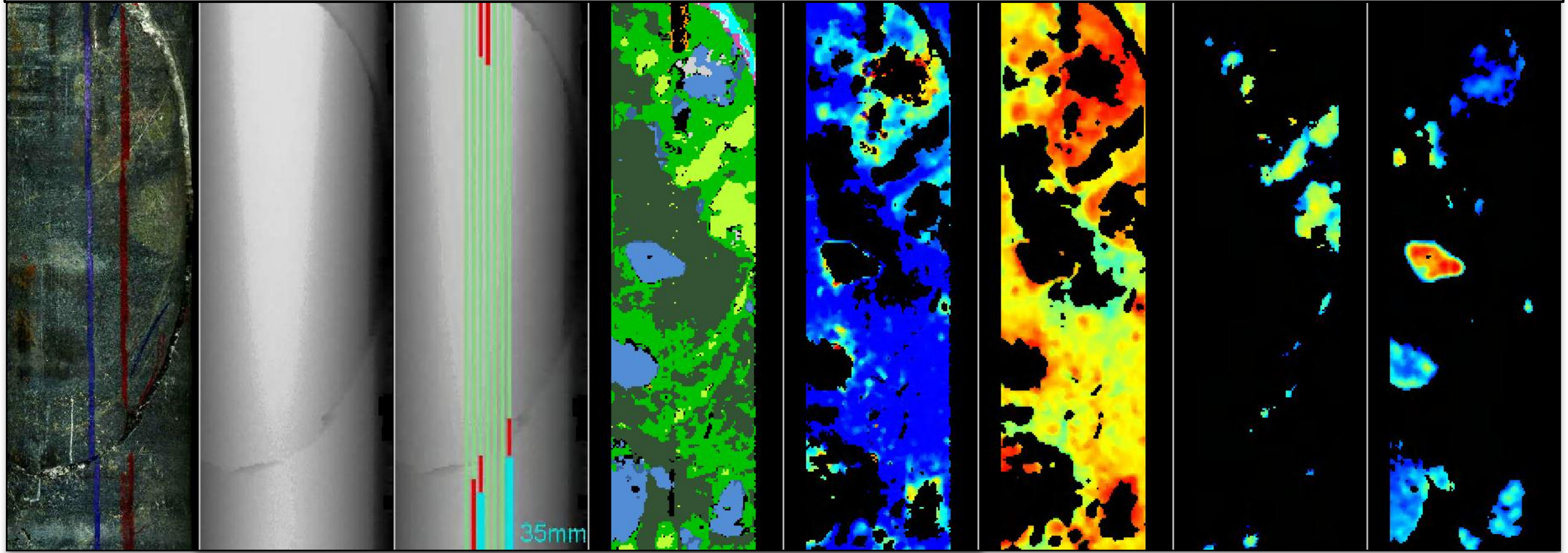
3D Laser Profiler
200 µm pixels
height resolution = 15 µm

Visible Light Camera (RGB)
50 µm pixels

Hyperspectral Scanner
0.5 mm pixels
450 to 2500 nm @ 3.84 nm resolution (VNIR, SWIR)

Corescan Technology

RGB Image	3D Laser Image	RQD Calc	Mineral Class Map	Silica	Clinochlore	Epidote	Sericite



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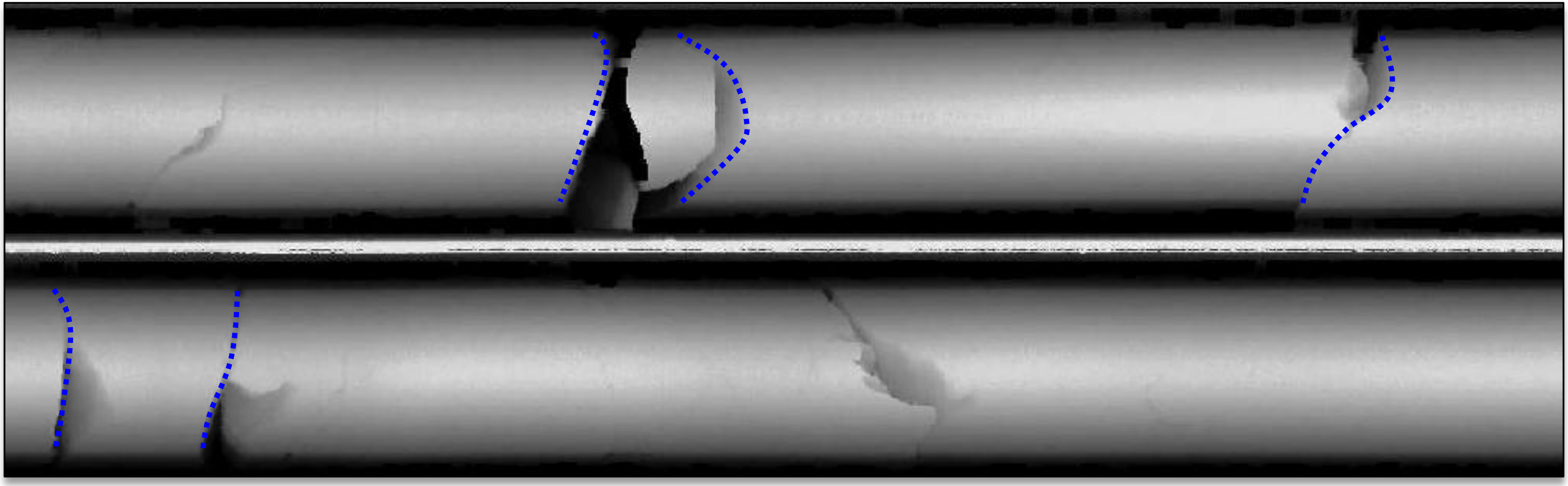
Opportunities for Geotechnical Data

- Continuous down hole core height and mineralogical data
- Opportunity to collect high volumes of consistent data
- Multi-data, integrated geotechnical data collection



Geotechnical Index Parameters

Rock Mass Rating (RMR)

$$RMR = \sum \text{all criteria}$$

Classification Criteria	Rating
RQD	0 – 20
Fracture Spacing	0 – 20
Fracture Condition	0 – 30
Groundwater Condition	0 – 15
Intact Rock Strength (UCS)	0 – 15

(Bieniawski, 1989)

Tunnelling Index (Q-index)

$$Q = \frac{RQD}{Jn} \times \frac{Jr}{Ja} \times \frac{Jw}{SRF}$$

Classification Criteria	Rating
RQD	0 – 100
Sets (Jn)	0 – 20
Roughness (Jr)	0 – 5
Alteration (Ja)	0 – 4
Water (Jw)	0 – 1
SRF	0 – 10

(Barton, Lein and Lunde, 1974)

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(Barton, Lein and Lunde, 1974)

Geotechnical Index Parameters

Uncut HQ drill core

Poor fracture condition

RMR Fracture Condition Guidelines

Separation (aperture)		**Infilling (gouge)**		**Weathering**	
Description	Rating	Description	Rating	Description	Rating
None	6	None	6	Unweathered	6
< 0.1 mm	5	Hard filling < 5 mm	4	Slightly weathered	5
0.1 - 1.0 mm	4	Hard filling > 5 mm	2	Moderately weathered	3
1 - 5 mm	1	Soft filling < 5 mm	2	Highly weathered	1
> 5 mm	0	Soft filling > 5 mm	0	Decomposed	0

(Bieniawski, 1989)

Geotechnical Index Parameters

Poor fracture condition

Q-index Ja Guidelines

Rock wall contact	
Description	Ja value
Tightly healed, hard, non-softening, filling	0.75
Unaltered fracture walls, surface staining only	1.0
Slightly altered fracture walls, non-softening mineral coatings, clay-free disintegrated rock, etc.	2.0
Small clay-fraction (non-softening)	3.0
Softening or low-friction clay mineral coatings	4.0

(Barton, Lein and Lunde, 1974)

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Geotechnical Properties of Minerals

- **Properties of minerals in fracture affect geotechnical behaviour**
  - **Relative hardness**
  - **Low-friction potential**
  - **Swelling potential**

Geotechnical Properties of Minerals

- **Minerals Detected by Corescan System**

Hard, high-friction, non-swelling (H)	Soft, high-friction, non-swelling (SHFNS)	Soft, low-friction, non-swelling (SLFNS)	Soft, low-friction, swelling (SLFS)
amphibole	carbonate	clinochlore	gypsum
apophyllite	iron carbonate	chlorite	laumontite
epidote	iron oxide	kaolinite	montmorillonite
prehnite		phlogopite	nontronite
quartz		muscovite	vermiculite
tourmaline		dickite	

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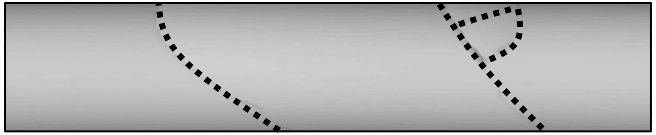
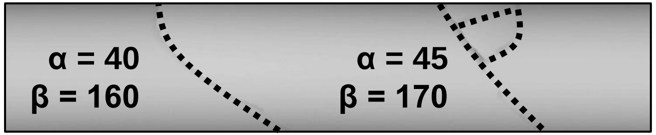
Automated Fracture Condition

1. Automatically recognise fractures



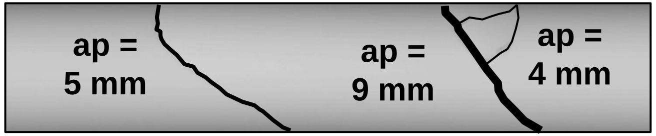
RMR, and Q-index

2. Calculate fracture orientation



RMR

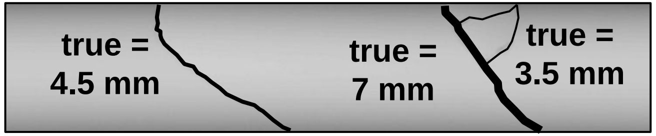
3. Calculate apparent aperture



RMR

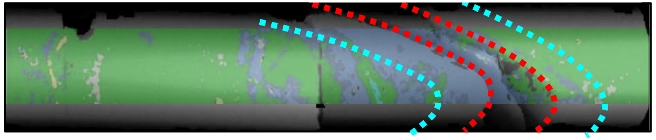
Automated Fracture Condition

4. Calculate true aperture



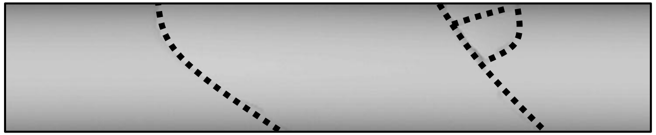
RMR

5. Extract mineralogy



RMR, and Q-index

6. Calculate fracture condition



RMR_{infill} = 4
RMR_{weath} = 2
Ja = 1.0

RMR, and Q-index

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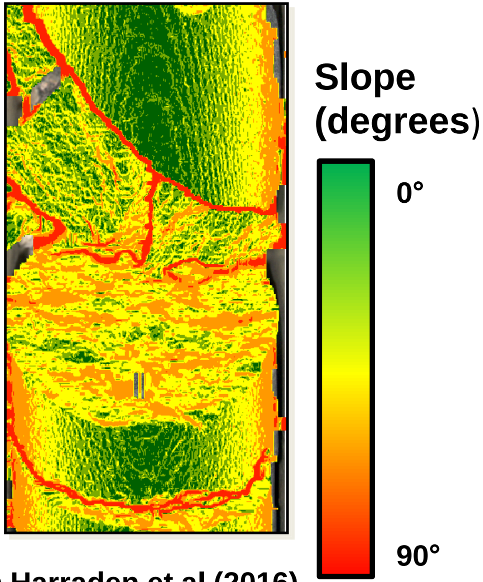
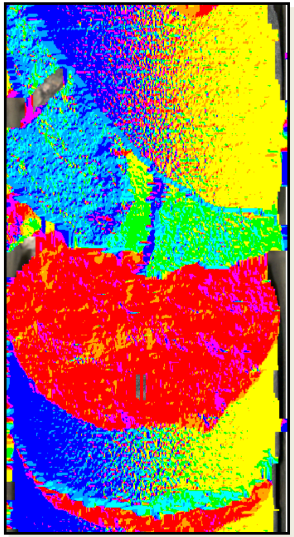
1. Fracture Recognition

Fractures represent discontinuities in cylindrical shape so:

Relative slope to highlight fractures → **Aspect filter to exclude core curvature** → **Fracture recognition**





Aspect (degrees)

- Flat
- 0.0 – 22.5°
- 22.5 – 67.5°
- 67.5 – 112.5°
- 112.5 – 157.5°
- 157.5 – 202.5°
- 202.5 – 247.5°
- 247.5 – 292.5°
- 292.5 – 337.5°
- 337.5 – 360.0°

Uncut HQ drill core - from Harraden et al (2016)

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2. Fracture Orientation

Extract x, y, and z values of fracture points

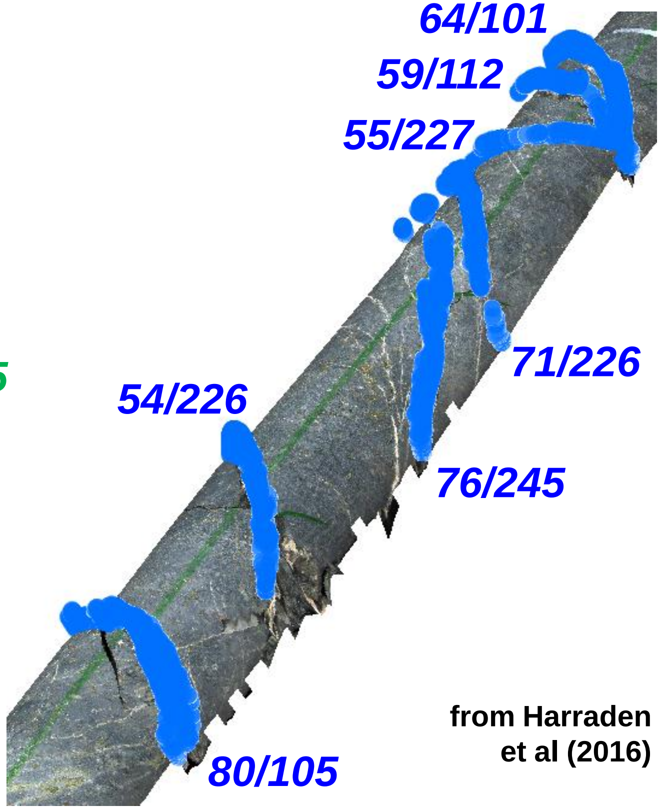
↓

Fit plane to fracture points (least squares linear regression)

↓

Account for drill hole (2D linear transformations)

Apparent Orientation



True Orientation

from Harraden et al (2016)

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3. Apparent Fracture Aperture

- **Pixels cover 200 μm, so:**

Apparent aperture =

 # pixels across fracture * 200 μm

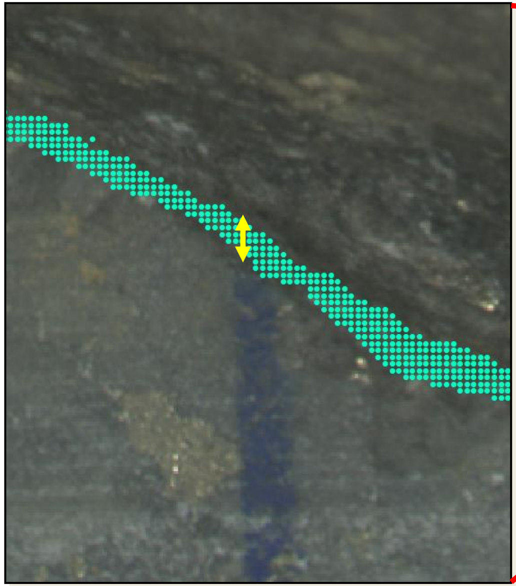
Apparent aperture

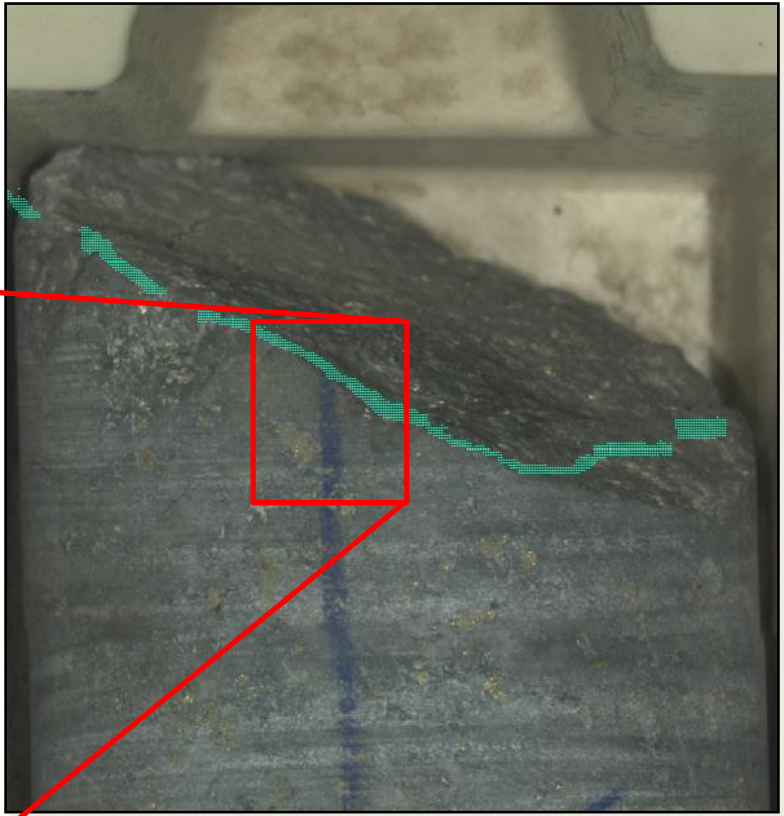
= 5 pixels *

200 μm

= 1000 μm

= 1 mm





4. True Fracture Aperture

- Orientation of fracture and drill hole known

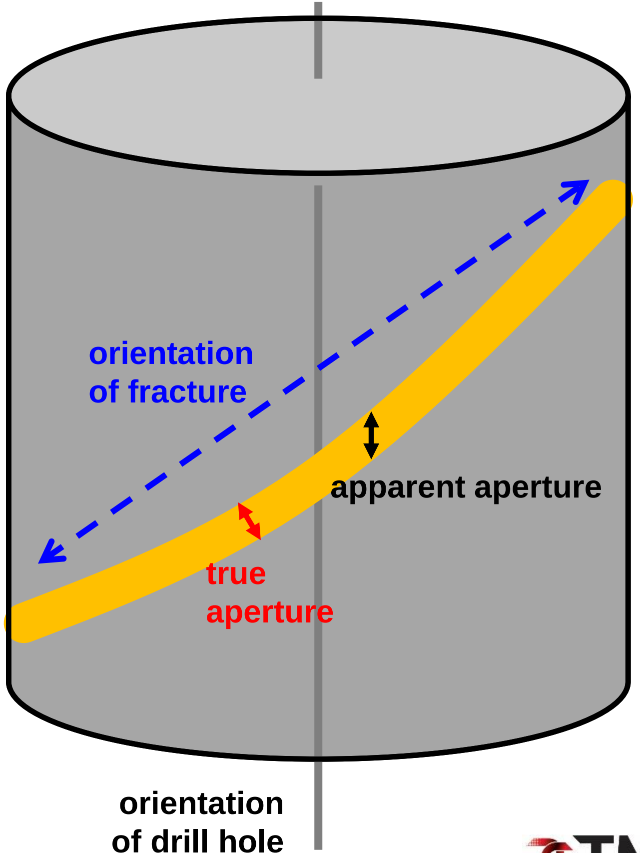
True aperture = L cos (ρ)

where

L = apparent aperture

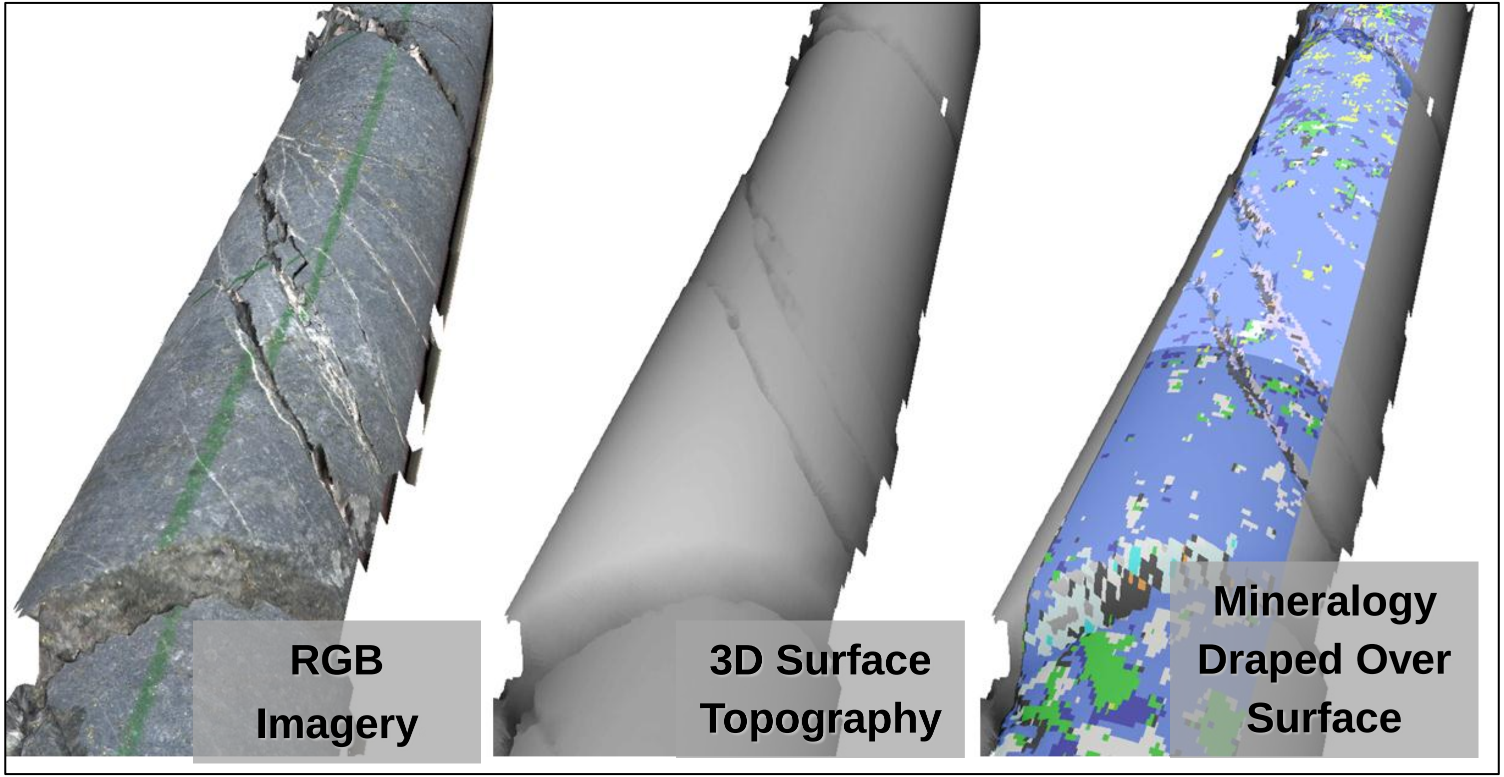
ρ = angle between pole to fracture plane and drill hole

(Charlesworth and Kilby, 1981)



5. Extract Mineralogy

- **Mineralogy co-registered with fracture pixels**



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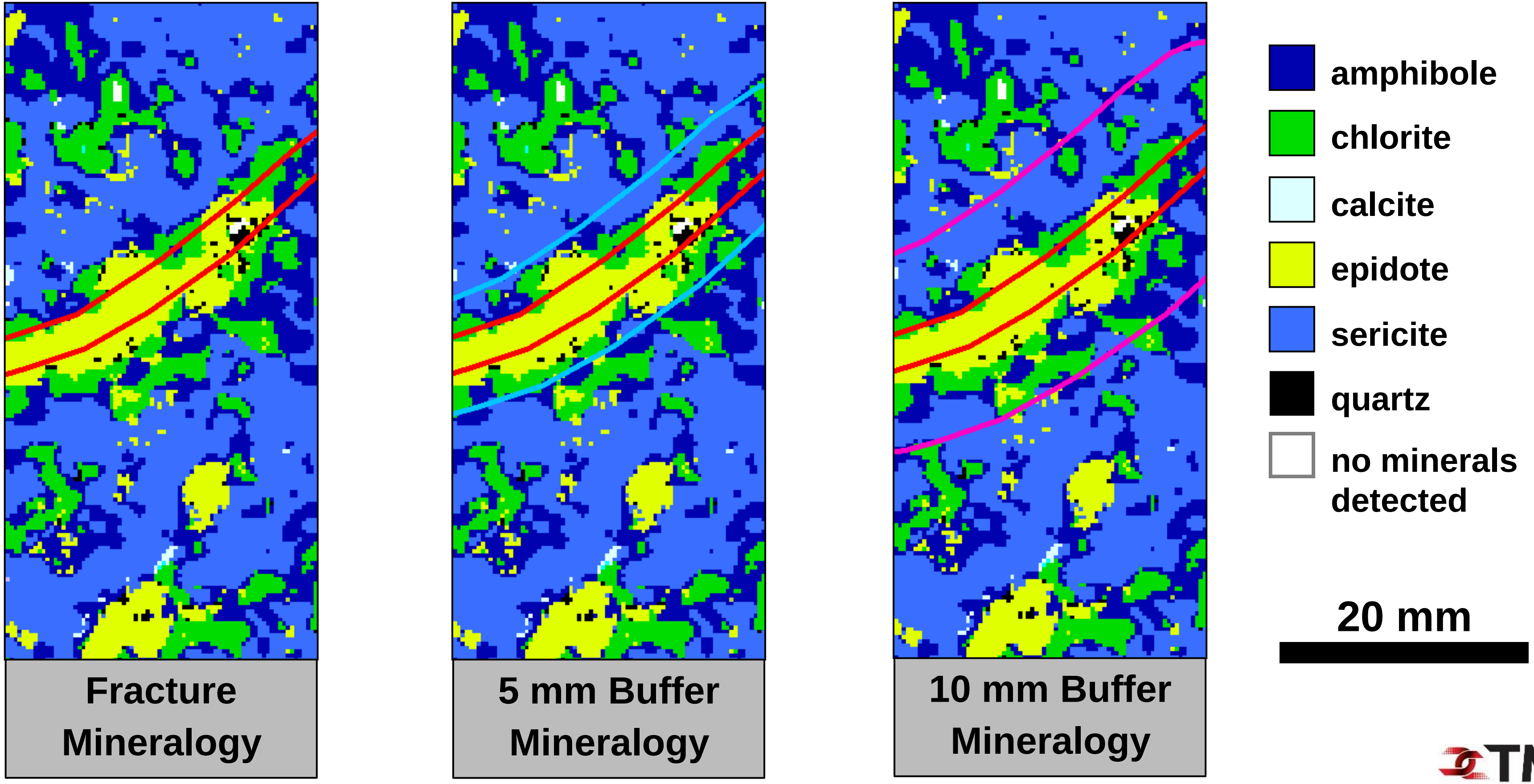
5. Extract Mineralogy



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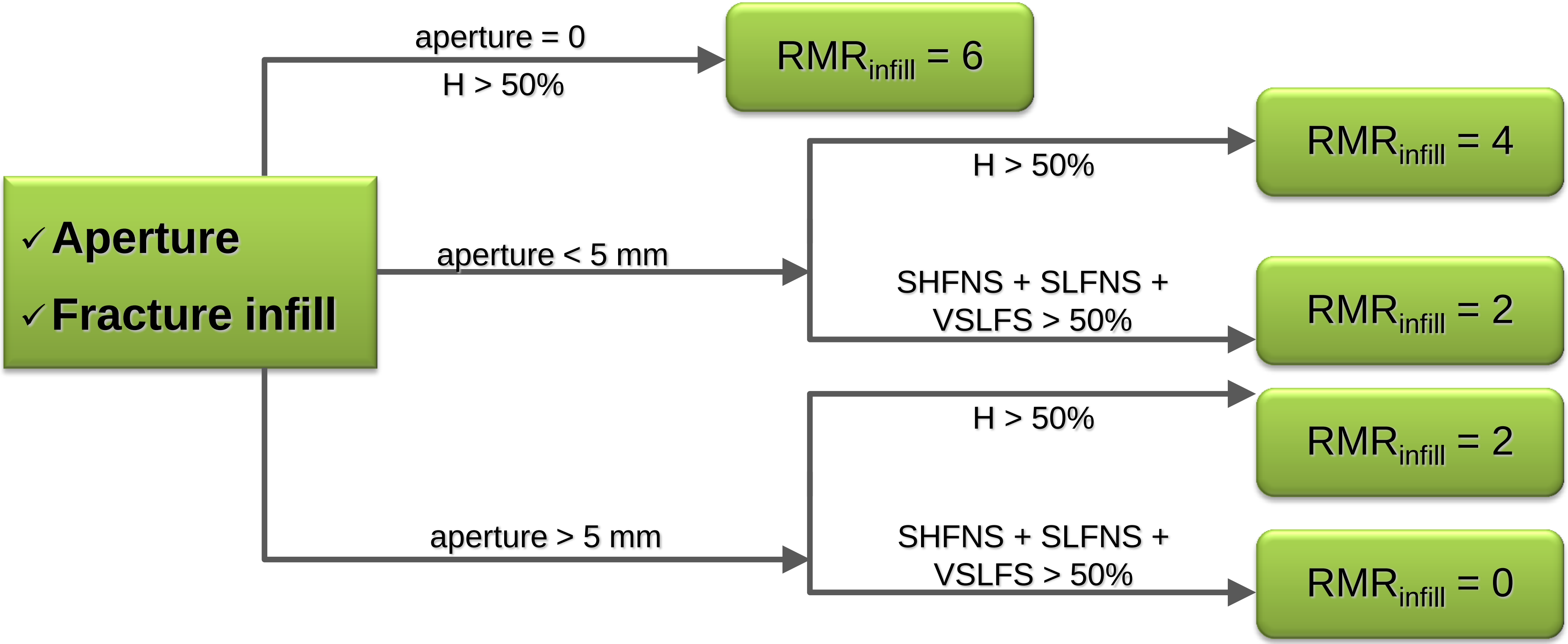
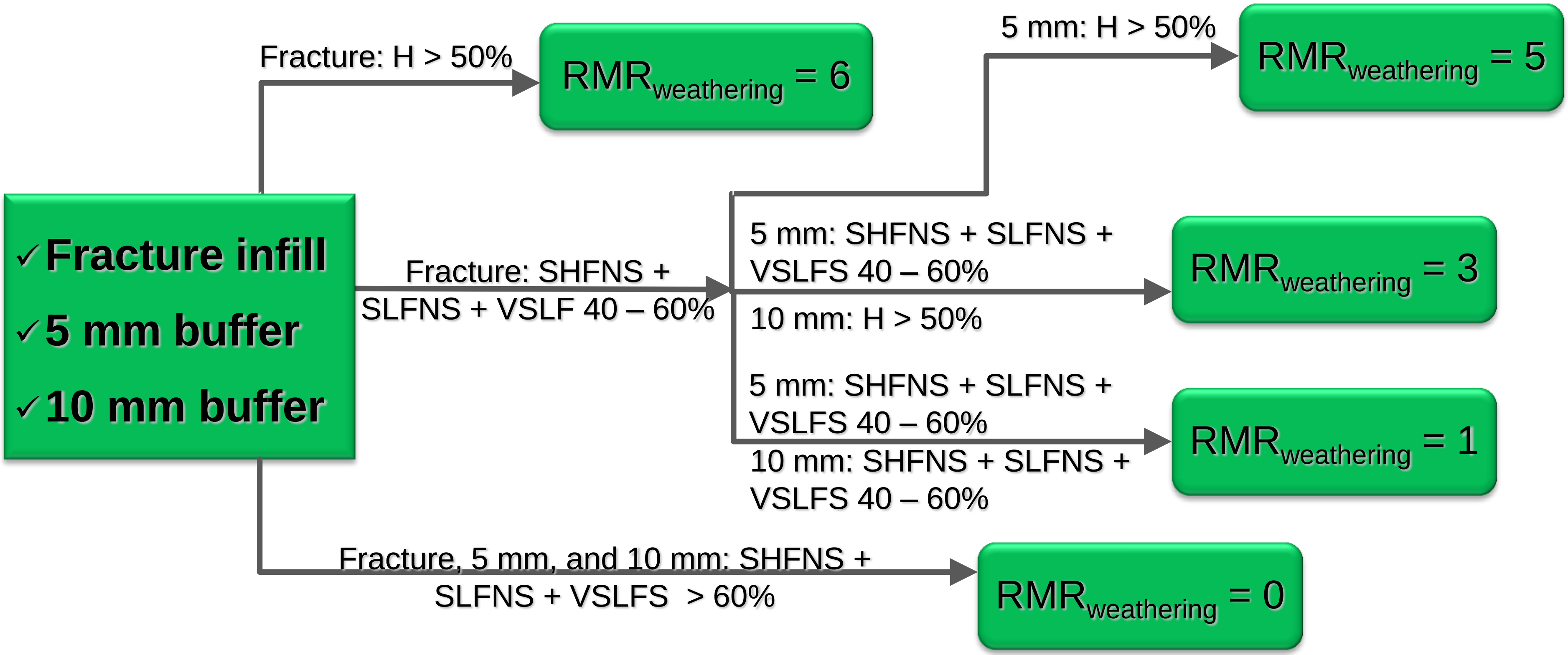
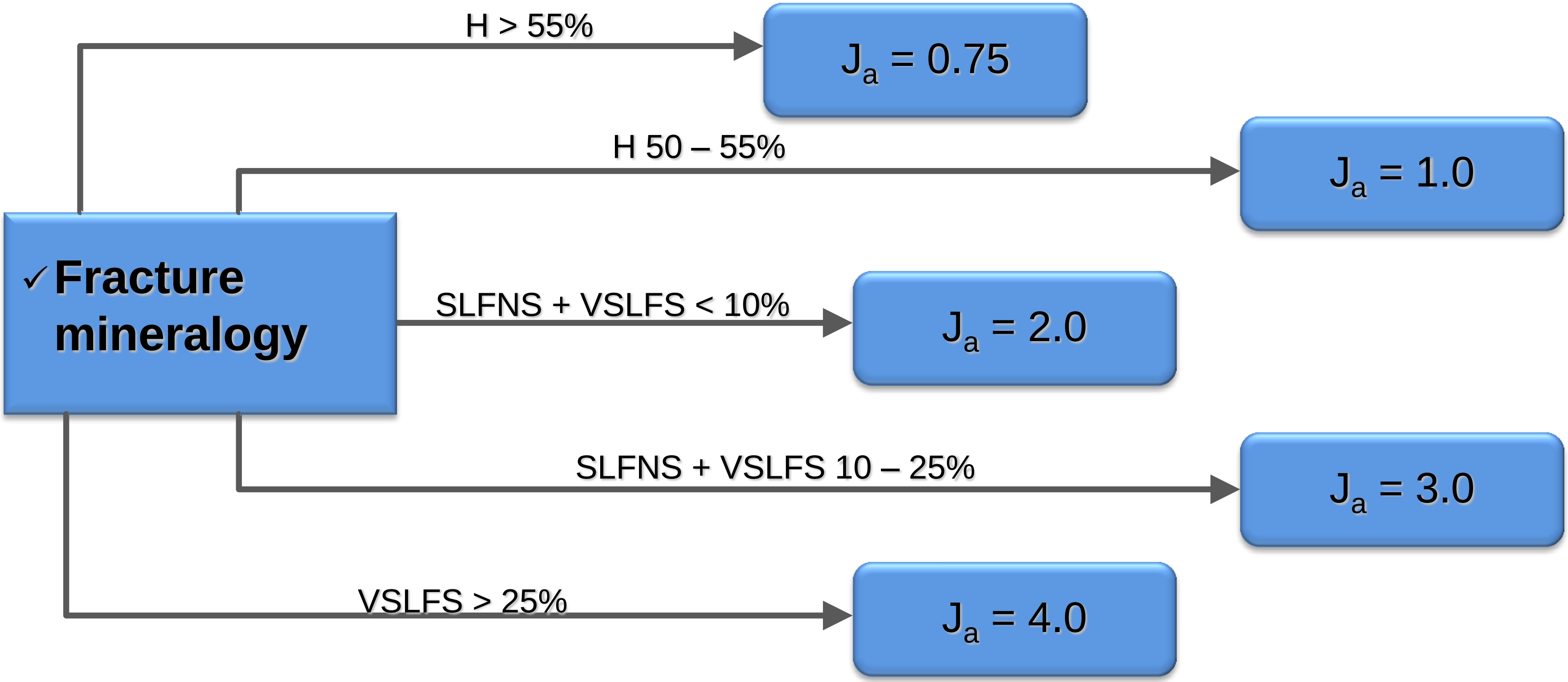
6. Calculate RMR Infill



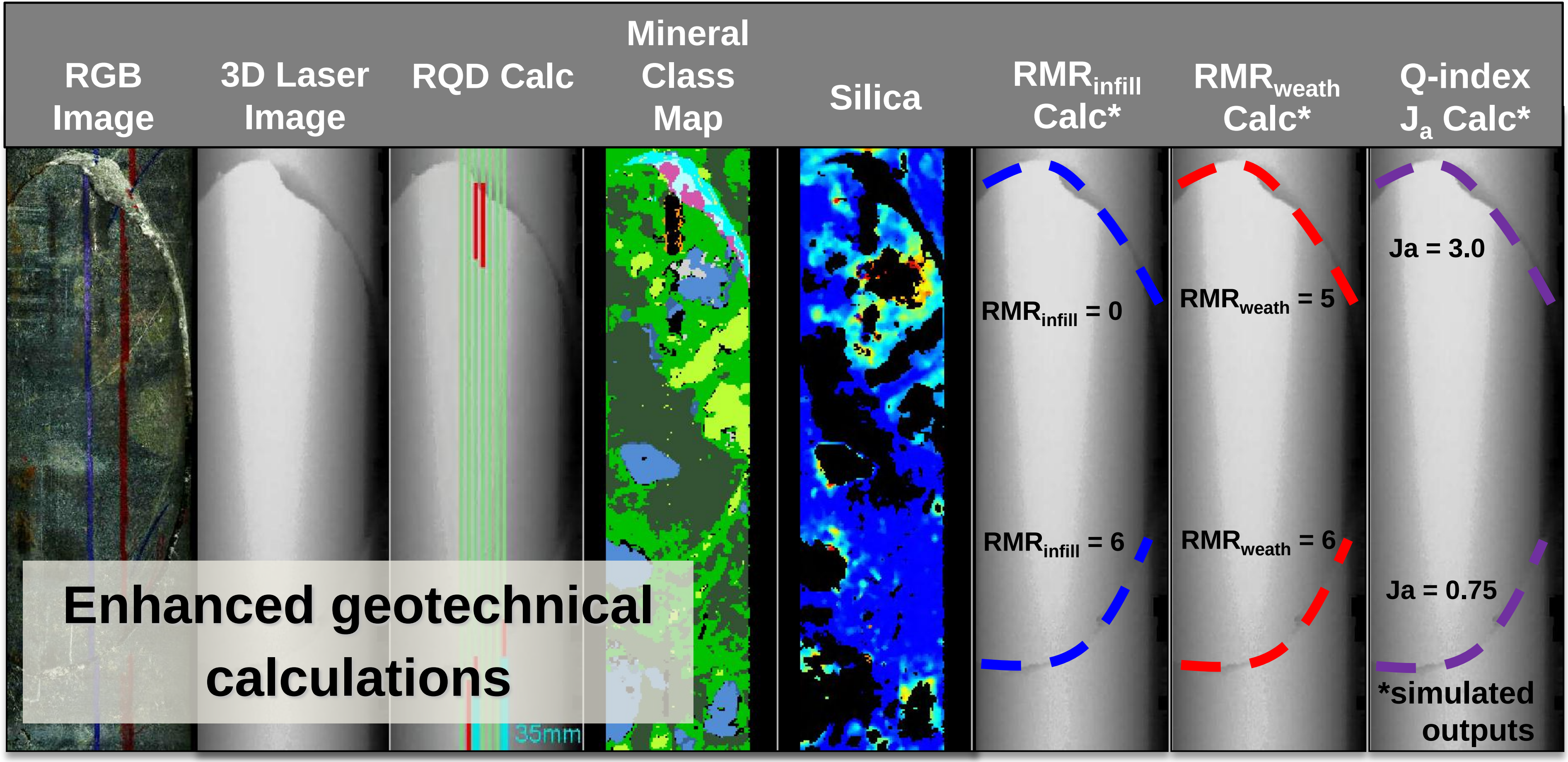
6. Calculate RMR Weathering



6. Calculate Q-index Ja

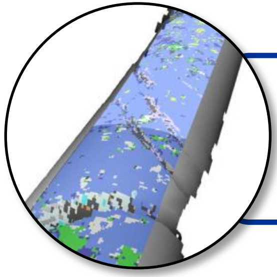


Proposed Corescan Outputs

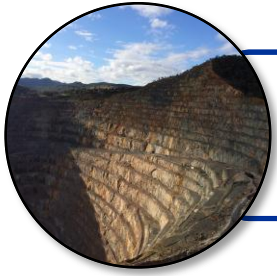


Key Points

Automated core logging technology provides rapid, consistent, automated surface topography and mineralogy



Methods automatically extract key mineralogical and weathering properties to estimate RMR and Q-index



Consistent mineralogy and weathering calculations increases accuracy and efficiency of geotechnical models

Acknowledgements

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- Thanks to Anthony Harris (Newcrest Mining Ltd), Neil Goodey (Corescan Pty Ltd) and David Cooke (University of Tasmania)
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