Fracture Patterns of Hard Rock
– On-site Observations & Mechanics

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Contents

• Fracturing in rock pillars
• Fracturing in mine stopes
• Fracturing in burst rock
• Mechanics of hard rock fracturing
• Summary of fracture patterns
Fracturing in rock pillars

Spalling/slabbing in sandstone pillars
Slabbing – shear fracture

Shear fracture on a weakness plane
A crush pillar in a South African mine  (M. du Plessis 2015)
A crush pillar in a South African mine (M. du Plessis 2015)
Crush pillar fracturing consequence (M. du Plessis 2015)
Facturing pattern observed in a crush pillar (M. du Plessis 2015)
Fracturing in mine stopes

Spalling / slabbing in the wall of a mine drift
- Depth: 1000 m
- Rock: chloritic quartzite
3000 m overburden

- Depth: 3000 m
- Rock: Quartzite

Slabbing in the mining face

(a)
Cut-and-fill mining in a metal mine

At 1000 m:
\[ \sigma_1 = 63 \text{ MPa}, \quad \sigma_1 = 42 \text{ MPa}, \quad \sigma_3 = 27 \text{ MPa} \]
Fracturing in stope E1

- No stress-induced fractures on the face
- Noises in the rock during excavation
Cut 1 in stope E1

- Spalling on the roof of Cut 1
Cut 3 in stope E1

Slabbing on the face (the roof of Cut 2)
Cut 4 in stope E1

- Slabbing on the face (the roof of Cut 3)
Fracturing in stope E2

Cut 1-1 in E2

• No stress-induced fractures on the face
• Noises in the rock during excavation
Cut 1-2 in E2
Slabbing in the roof of Cut 1-1
Cut 1-2 in E2
Slabbing on the face of Cut 1-2 (the wall of Cut 1-1)
Fracturing in stope E3

Cut 3 in E3
Tightly spaced fractures on the face of Cut 3. sub-parallel to the roof surface
Rock fracturing under dynamic loading

Strain burst

Seismic burst
Strain burst

(Li 2000)
Seismic / fault-slip burst

(Simser 2000)
Seismic / fault-slip burst

(Li 2018)
Mechanics of hard rock fracturing

- Extension fracture dominates at low confining pressure
- Extension fracture starts at $\sigma_1 \approx 0.5$ UCS
- Shear failure at high confining pressure
Extension fracture and shear band

Central section of a gneiss specimen
(Li, Prikry, Nordlund 1998)

Shear bands in quartzite
(D. Ortlepp 1998)
Wing crack
Acoustic Emission (AE)

AE in a diorite specimen under uniaxial compression, UCS = 221 MPa

Continuous AE started ~50%UCS
AE events in Kuru granite at different load levels
Extension fracture

- Extension fracture starts at $\sigma_1 \approx 0.5$ UCS
- Extension fracturing lasts for a long time, having a characteristic of “creeping”
Fracture patterns in tunnel wall of hard rock

$\sigma_1$

Final failure in shear

Spalling / slabbing
Fracturing in walls

Fracturing in roof and floor
Fracture patterns in pillar of hard rock

Extension fracture

Extension fracture and shear failure
Conclusions

• Extension fracture dominates in hard rock
• Surface spalling / slabbing / bursting is most severe in the first Cut
• The rock mass is pre-fractured in subsequent cuts
• Strain burst: The rock is finely fragmented and the burst depth is limited
• Seismic burst: Different sizes of rock blocks and the burst volume could be huge