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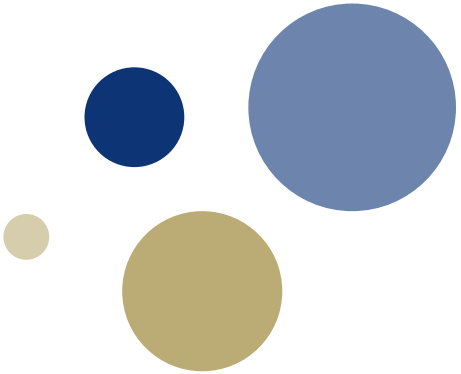
Science and Technology



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

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NTNU, Norway

Jean Mandel lecture CFMR, 6 Dec. 2018, Paris, France

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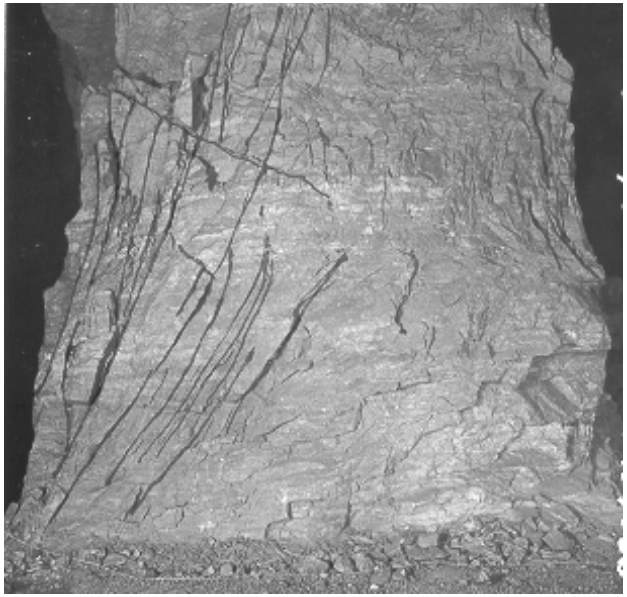
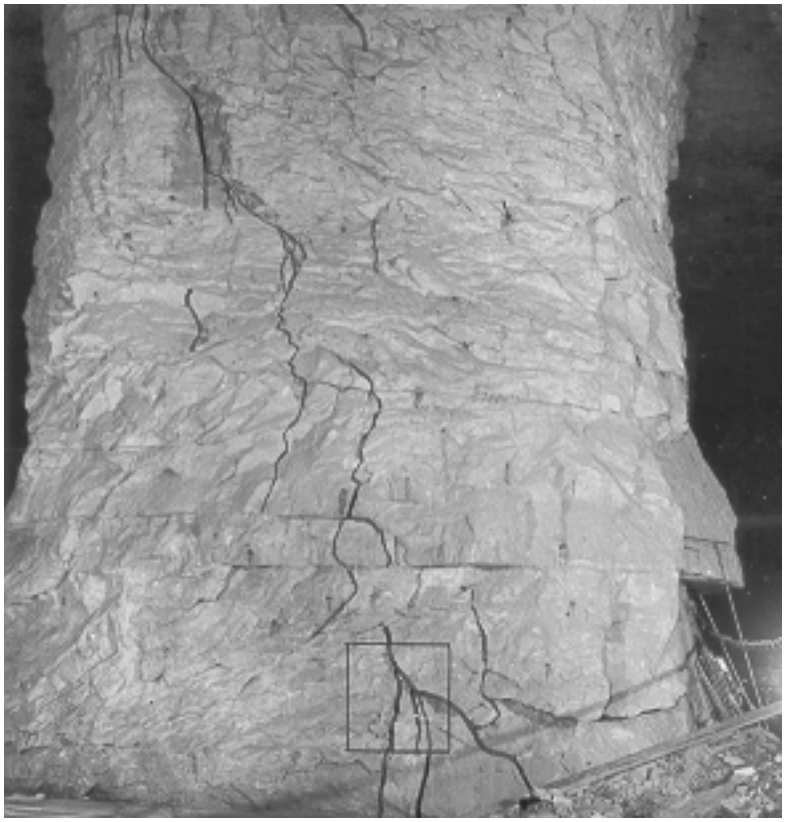
- Fracturing in rock pillars
- Fracturing in mine stopes
- Fracturing in burst rock
- Mechanics of hard rock fracturing
- Summary of fracture patterns

Fracturing in rock pillars



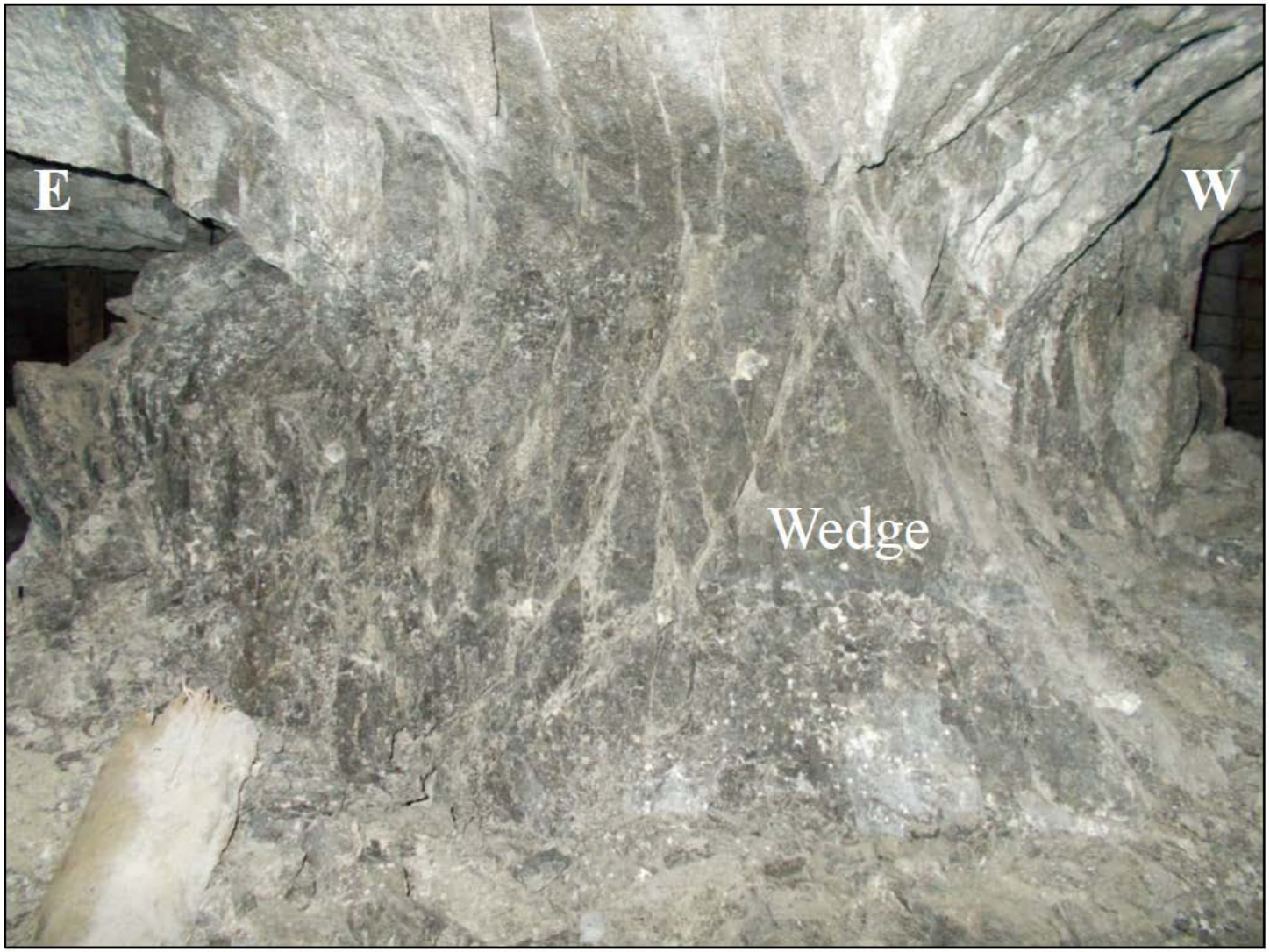
Spalling/slabbing in sandstone pillars



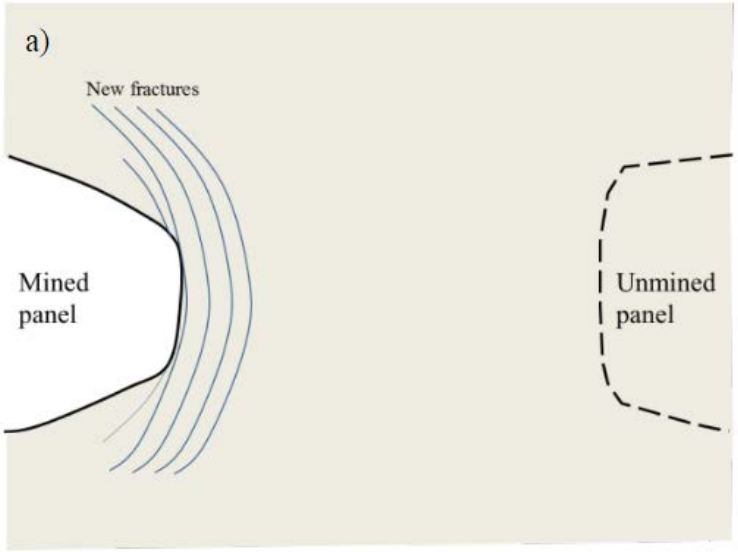
Slabbing – shear fracture

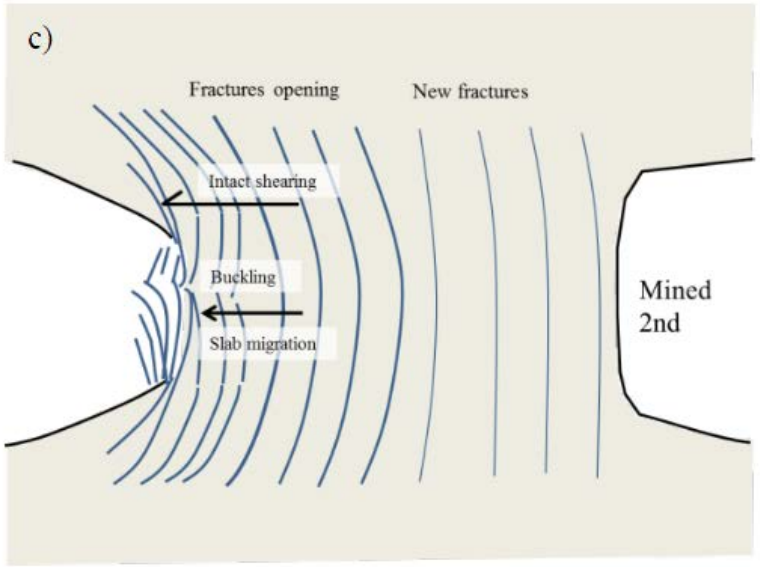
Shear fracture on a weakness plane

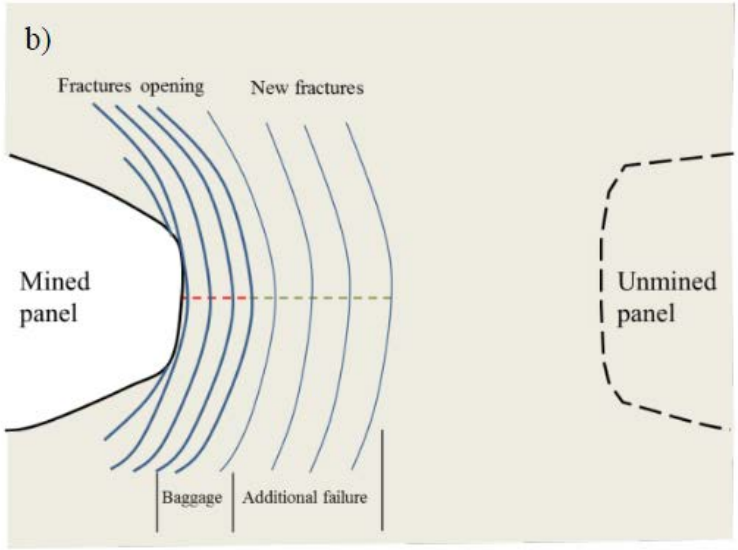
A crush pillar in a South African mine (M. du Plessis 2015)

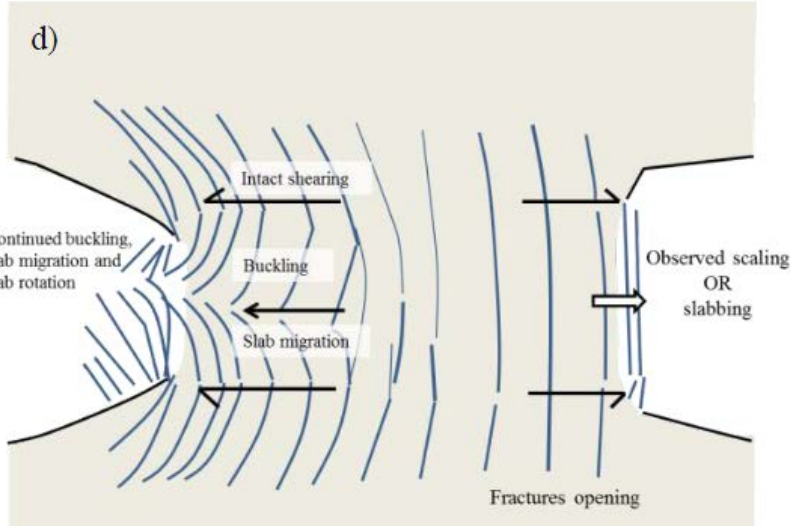


A crush pillar in a South African mine (M. du Plessis 2015)

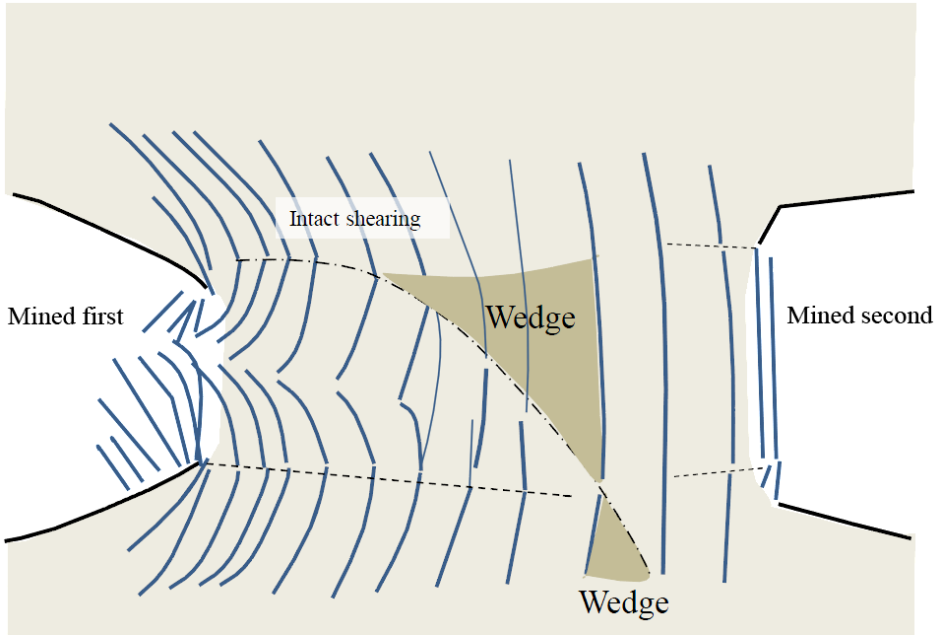


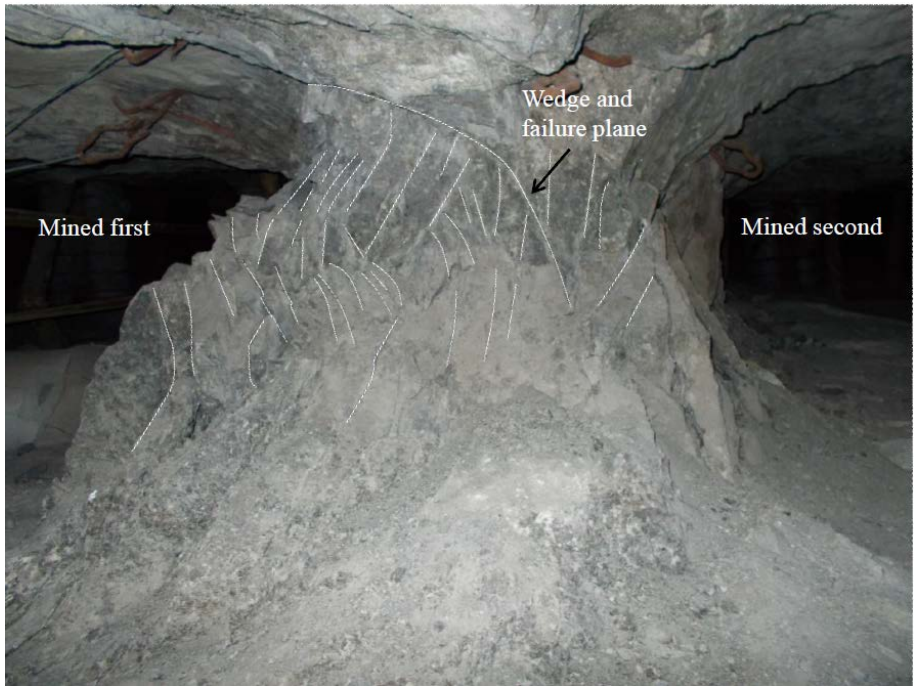






Crush pillar fracturing consequence (M. du Plessis 2015)



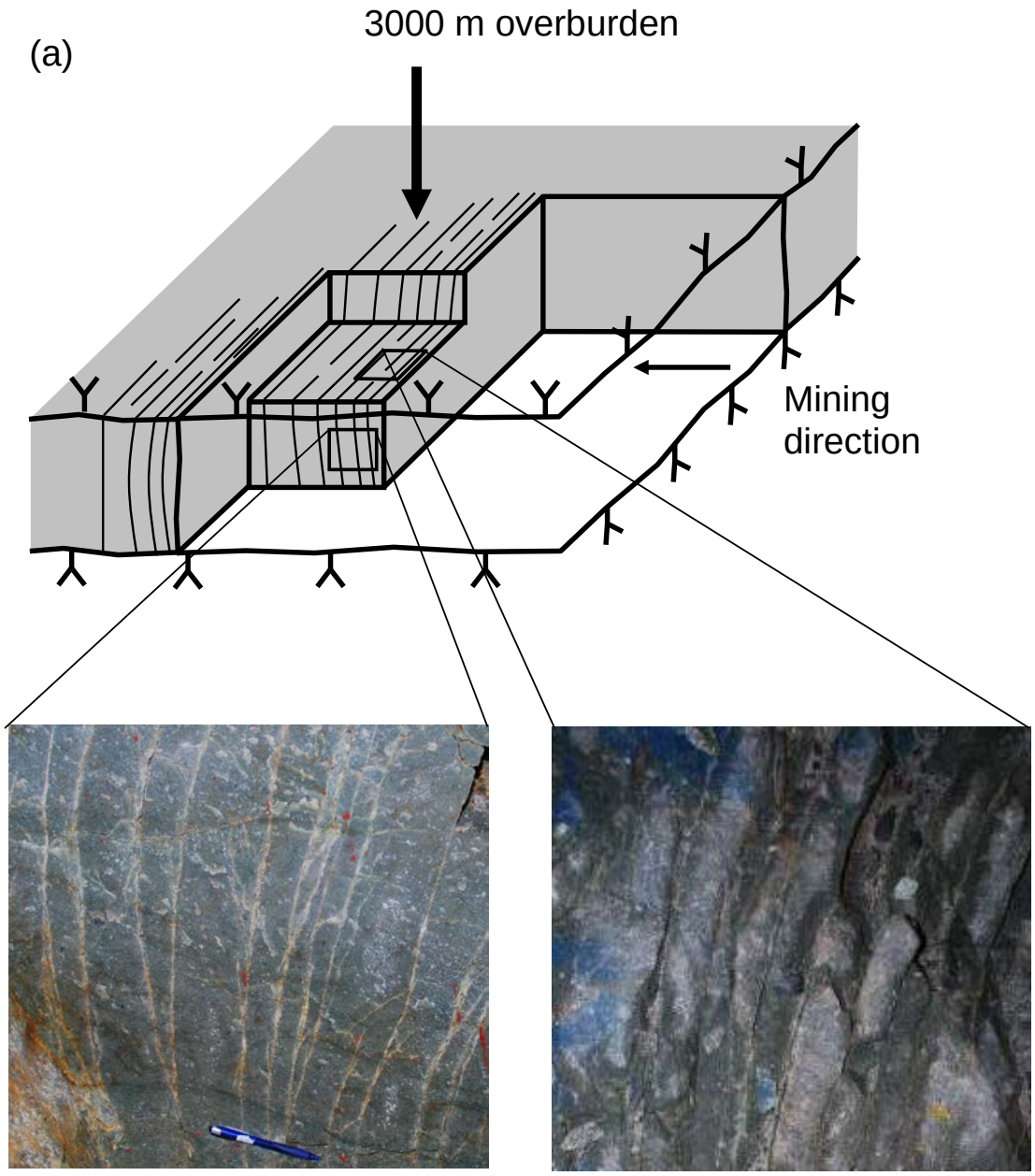


Facturing pattern observed in a crush pillar (M. du Plessis 2015)

Fracturing in mine stopes

Spalling / slabbing in
the wall of a mine drift

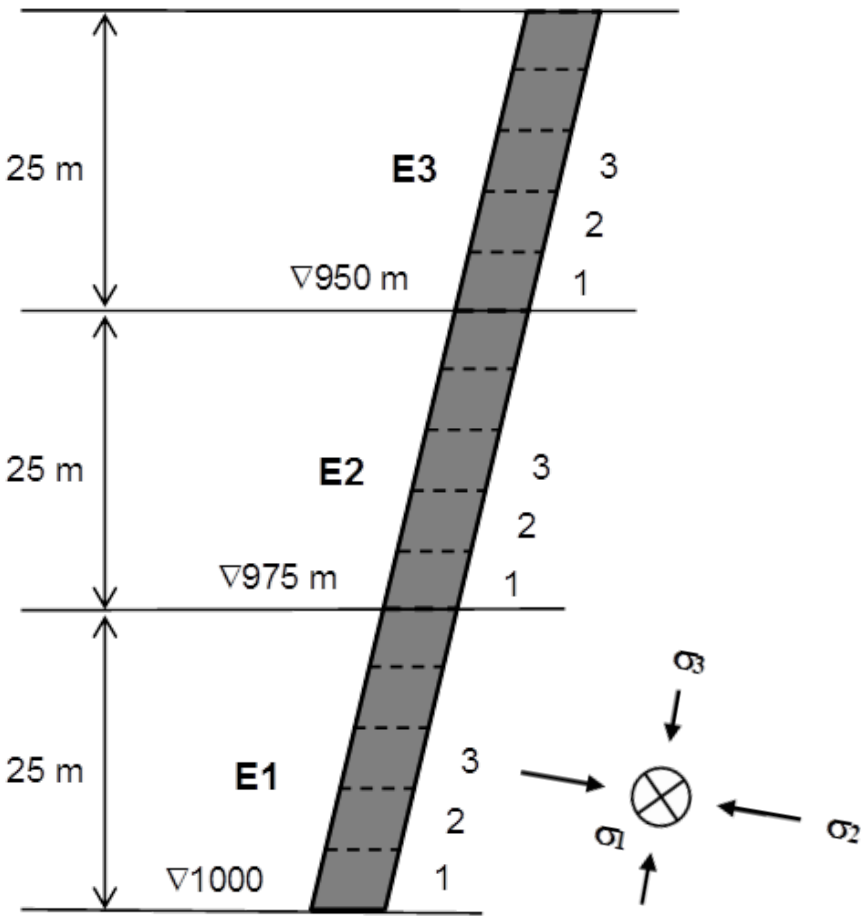
- Depth: 1000 m
- Rock: chloritic quartzite

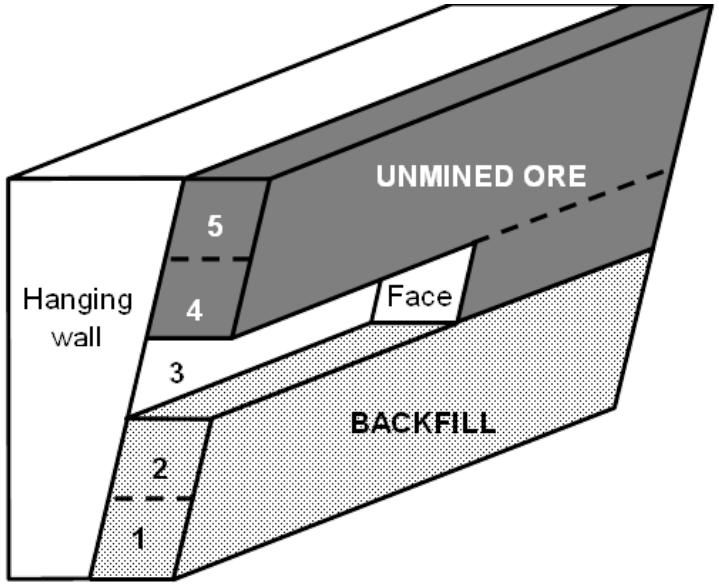


Slabbing in the mining face

- Depth: 3000 m
- Rock: Quartzite

Cut-and-fill mining in a metal mine



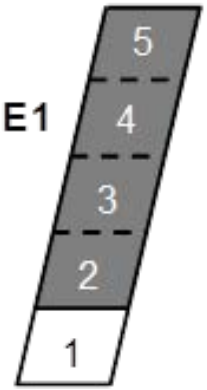


At 1000 m:

σ_1 = 63 MPa, σ_1 = 42 MPa, σ_3 = 27 MPa

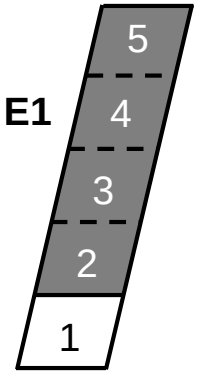
Fracturing in stope E1

- No stress-induced fractures on the face
- Noises in the rock during excavation



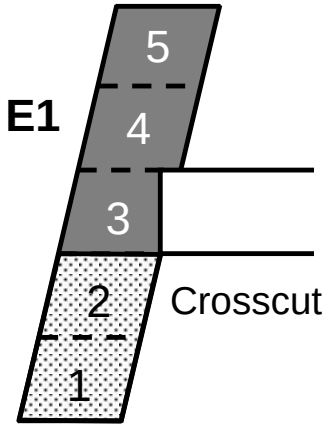
Cut 1 in stope E1

- Spalling on the roof of Cut 1



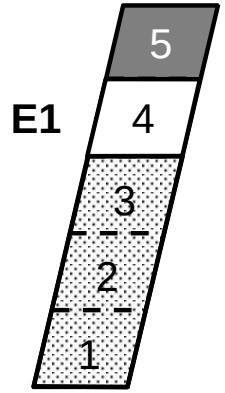
Cut 3 in stope E1

Slabbing on the face (the roof of Cut 2)



Cut 4 in stope E1

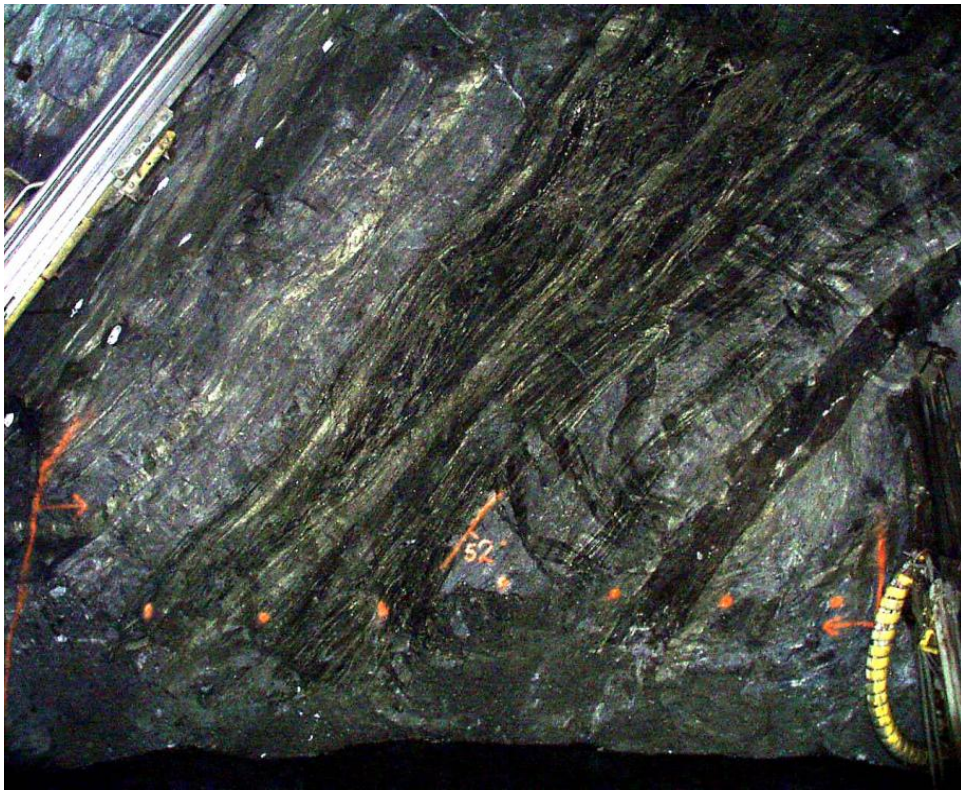
- Slabbing on the face (the roof of Cut 3)

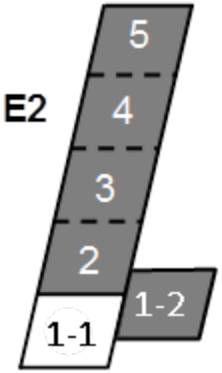


Fracturing in stope E2

Cut 1-1 in E2

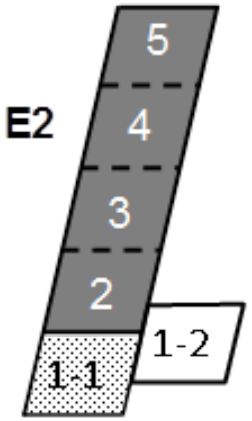
- No stress-induced fractures on the face
- Noises in the rock during excavation

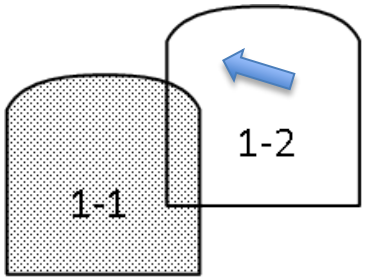




Cut 1-2 in E2

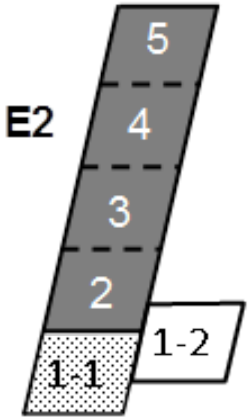
Slabbing in the roof of Cut 1-1

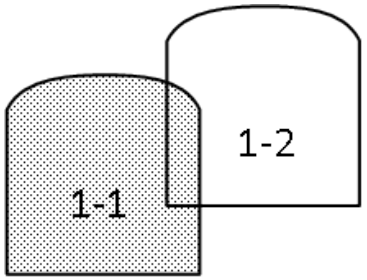




Cut 1-2 in E2

Slabbing on the face of Cut 1-2 (the wall of Cut 1-1)

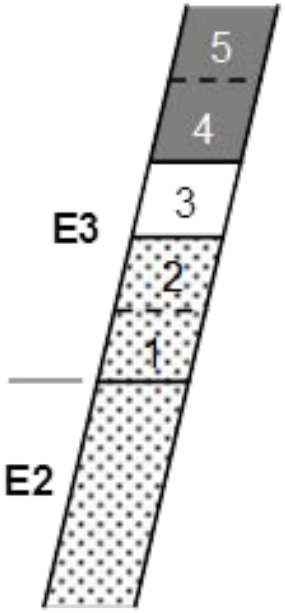




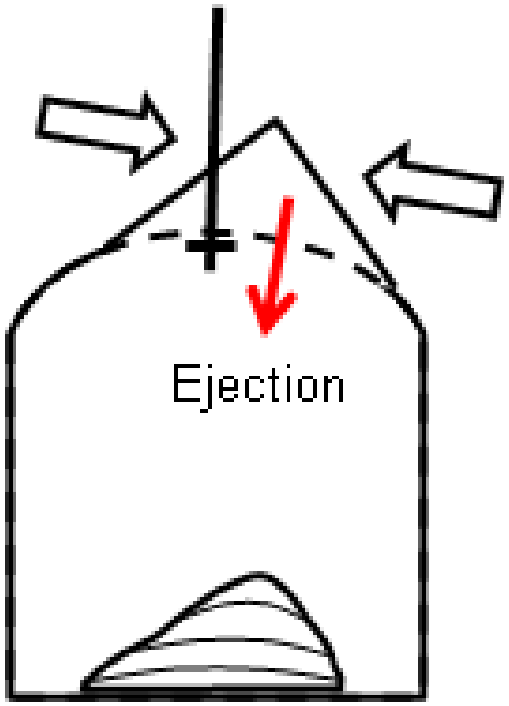
Fracturing in stope E3

Cut 3 in E3

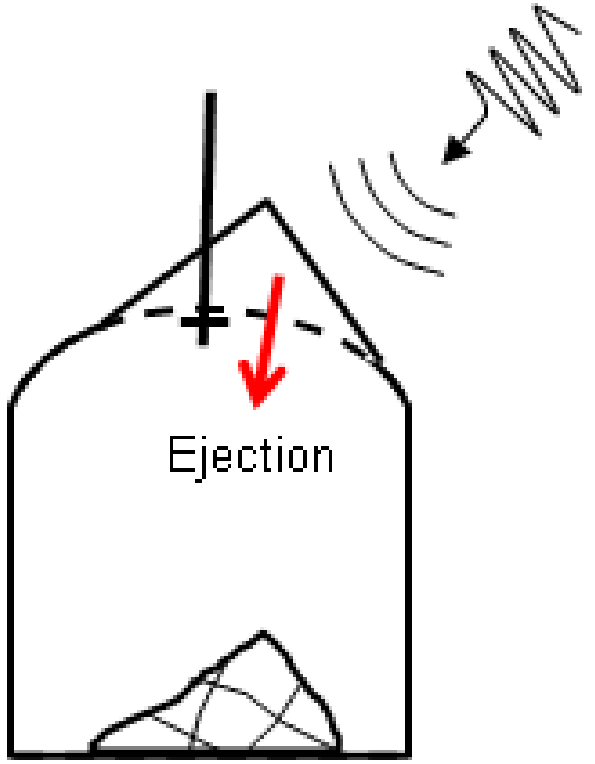
Tightly spaced fractures on the face of Cut 3. sub-parallel to the roof surface



Rock fracturing under dynamic loading



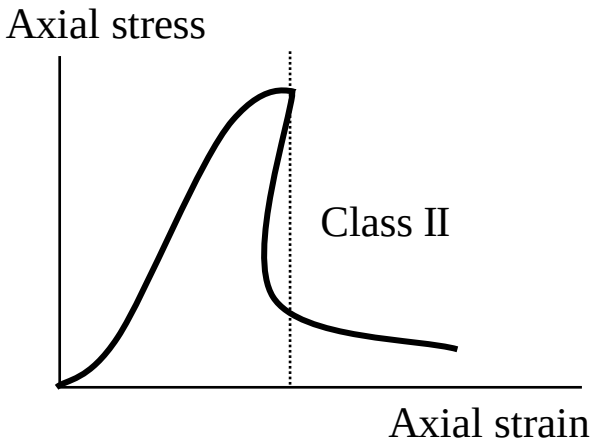
Strain burst

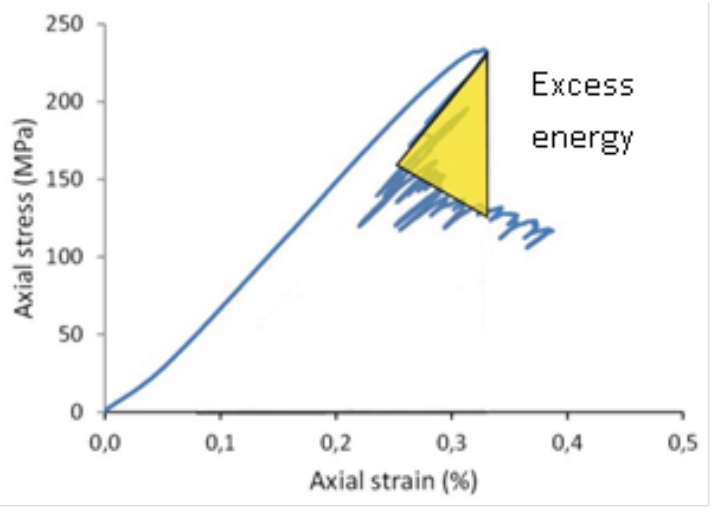


Seismic burst

Strain burst

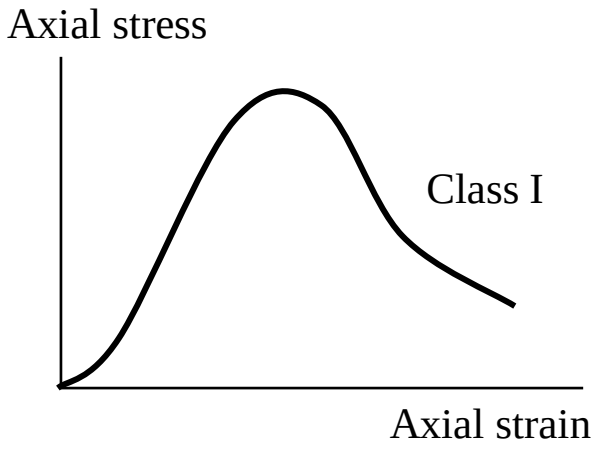
(Li 2000)





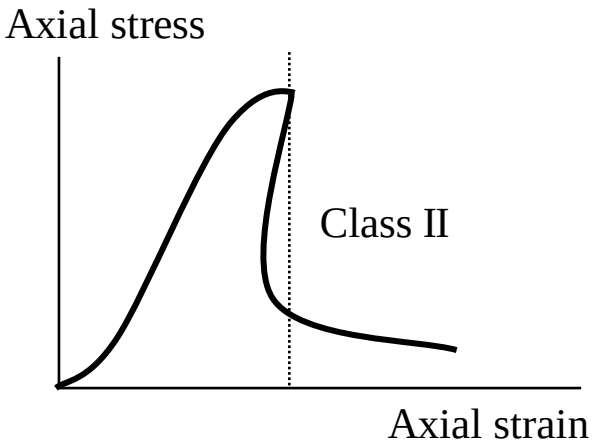
Seismic / fault-slip burst

(Simser 2000)



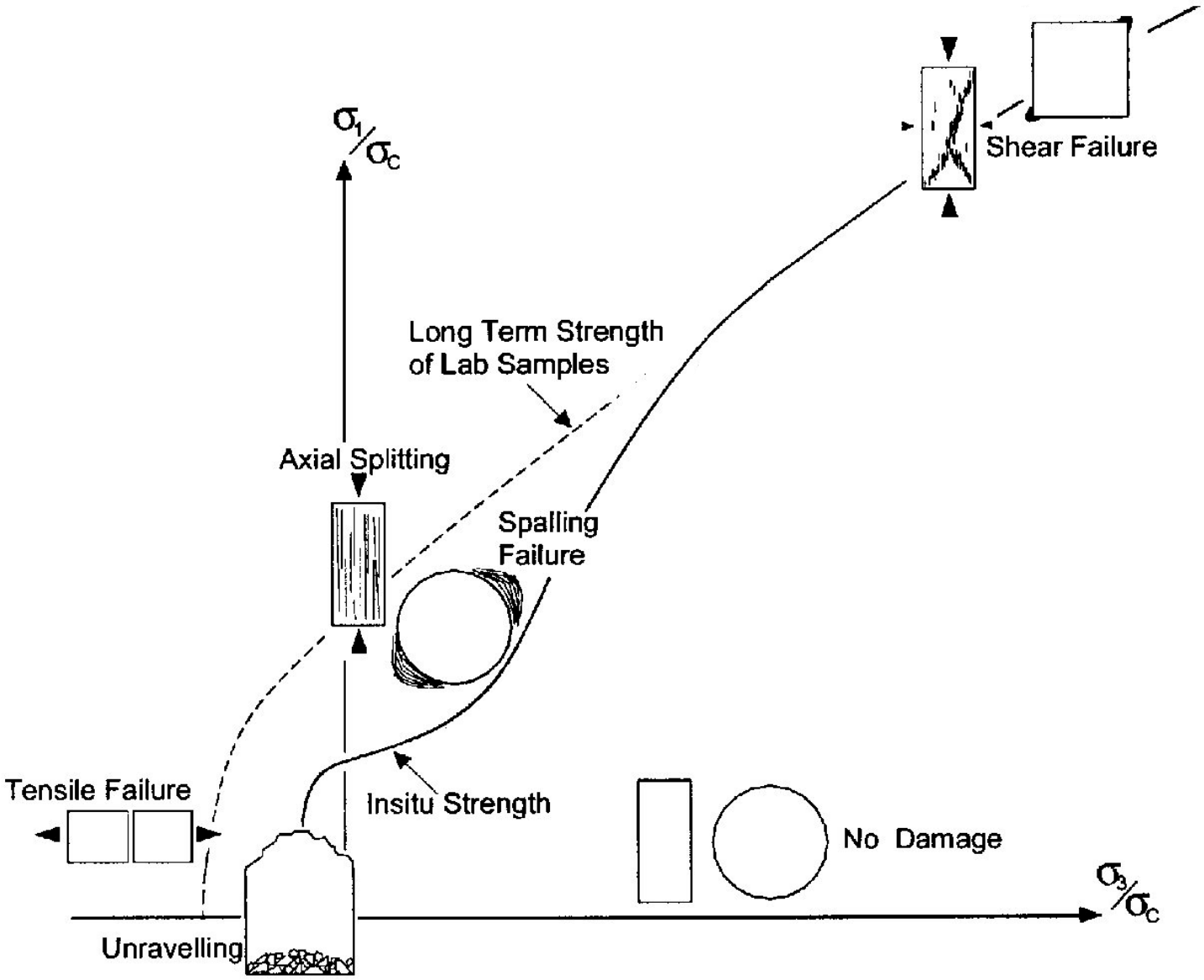
Seismic / fault-slip burst

(Li 2018)



Mechanics of hard rock fracturing

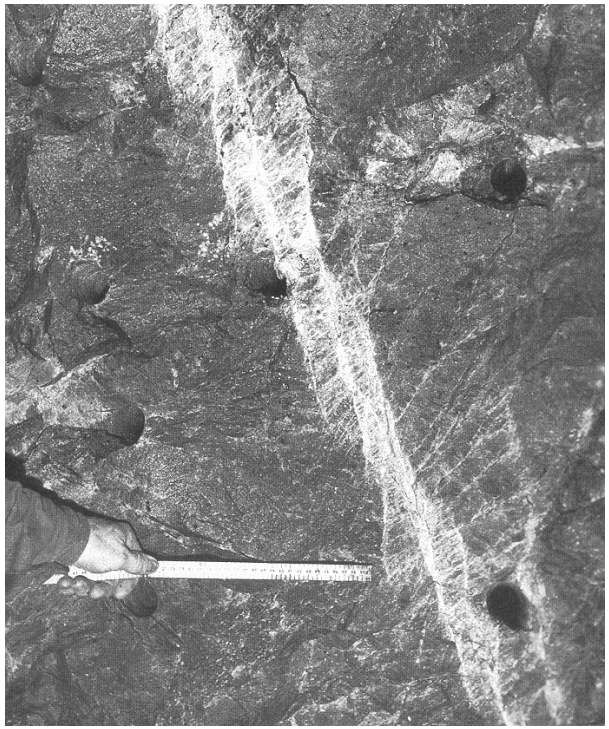
- Extension fracture dominates at low confining pressure
- Extension fracture starts at $\sigma_1 \approx 0.5$ UCS
- Shear failure at high confining pressure



(Diederichs et al. 2004)

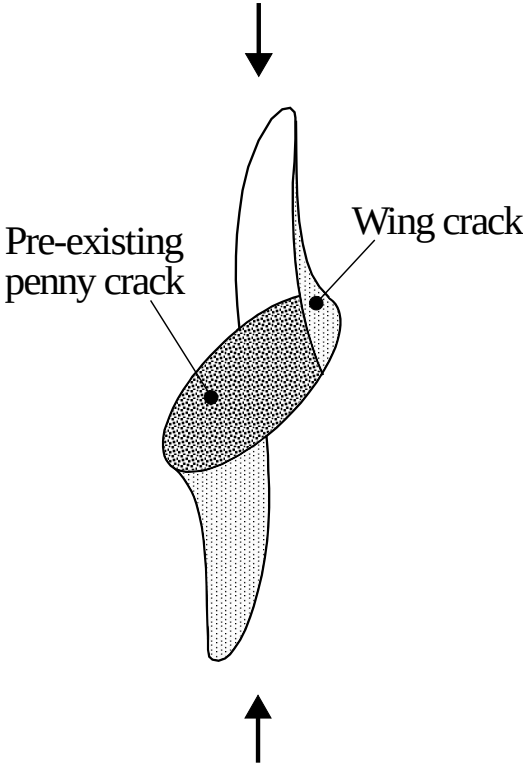
Extension fracture and shear band

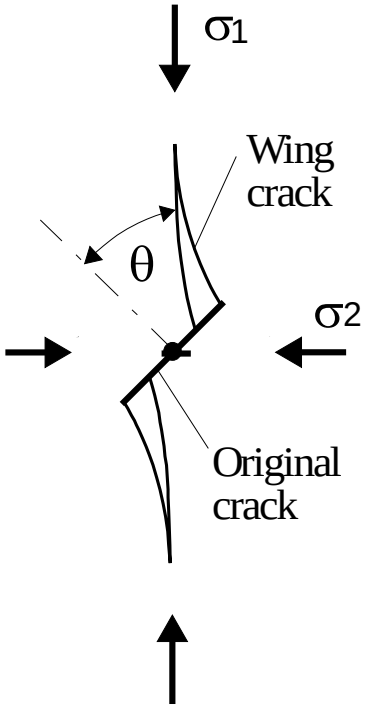
Central section of
a gneiss specimen
(Li, Prikry, Nordlund 1998)



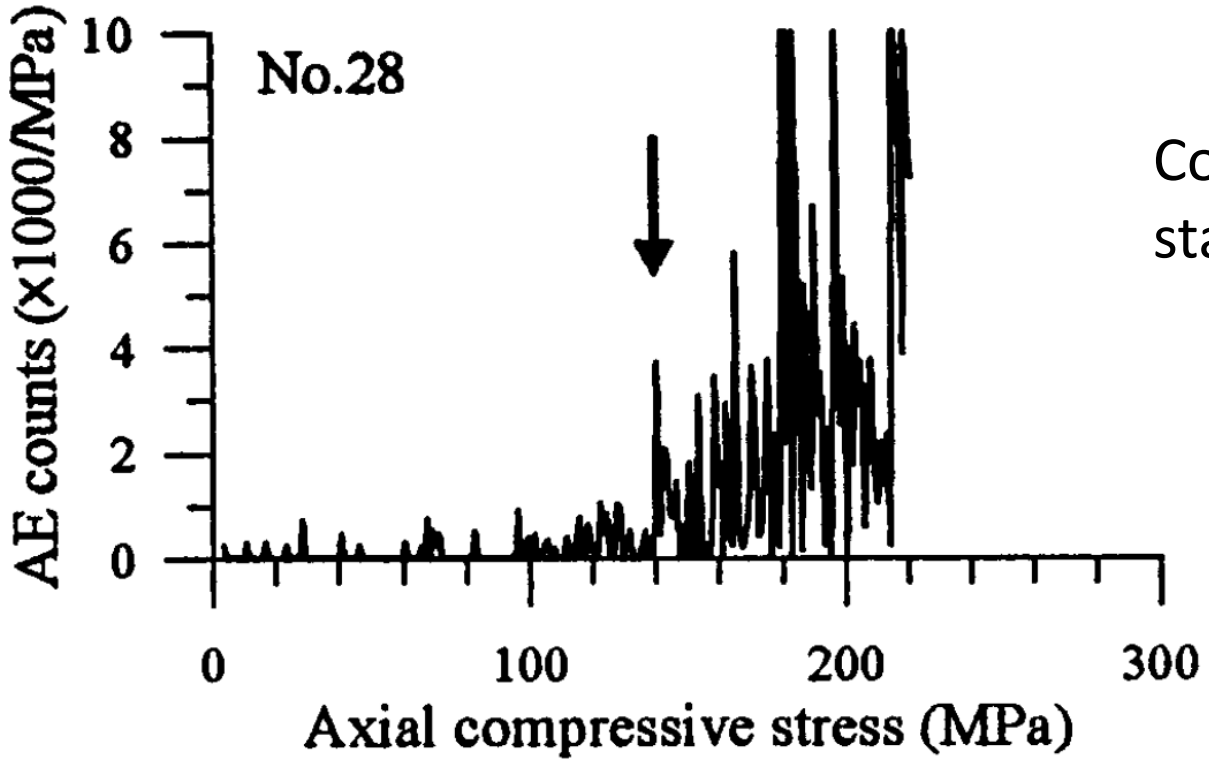
Shear bands in quarzite
(D. Ortlepp 1998)

Wing crack


Pre-existing
penny crack
Wing crack


σ1
Wing
crack
θ
σ2
Original
crack

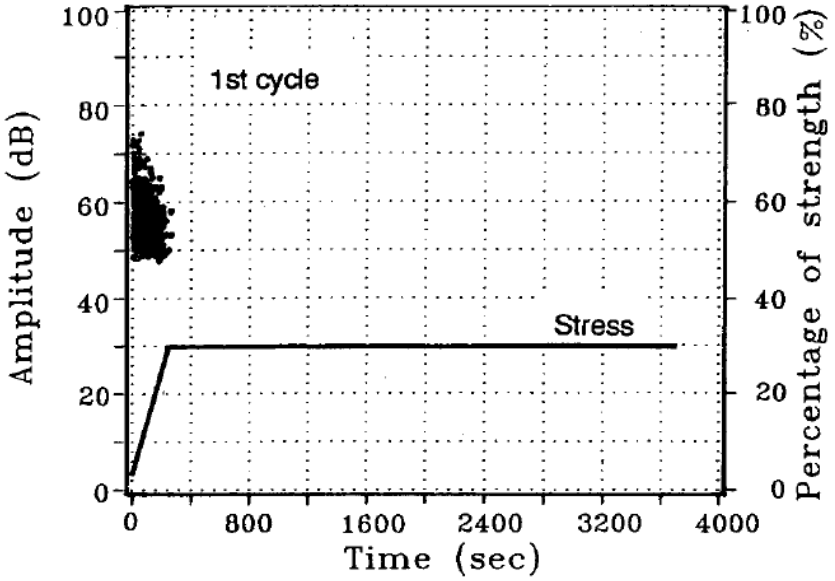
Acoustic Emmision (AE)

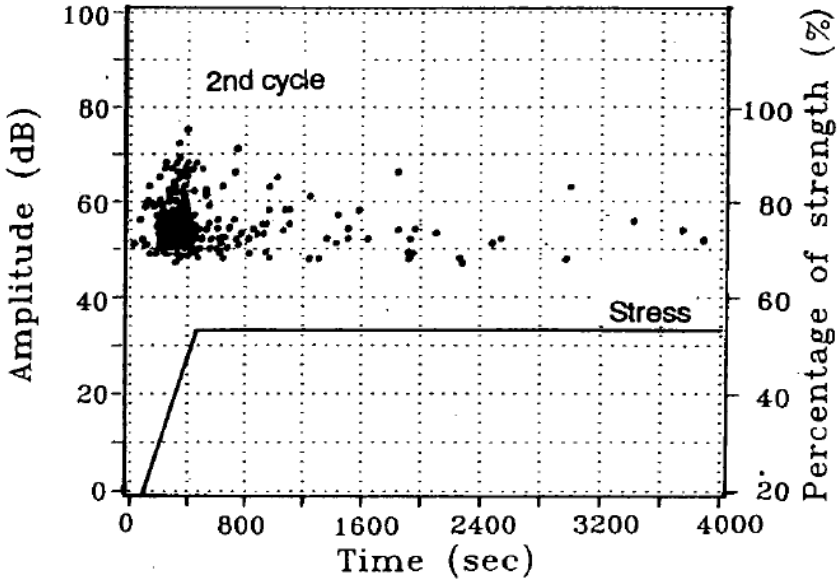


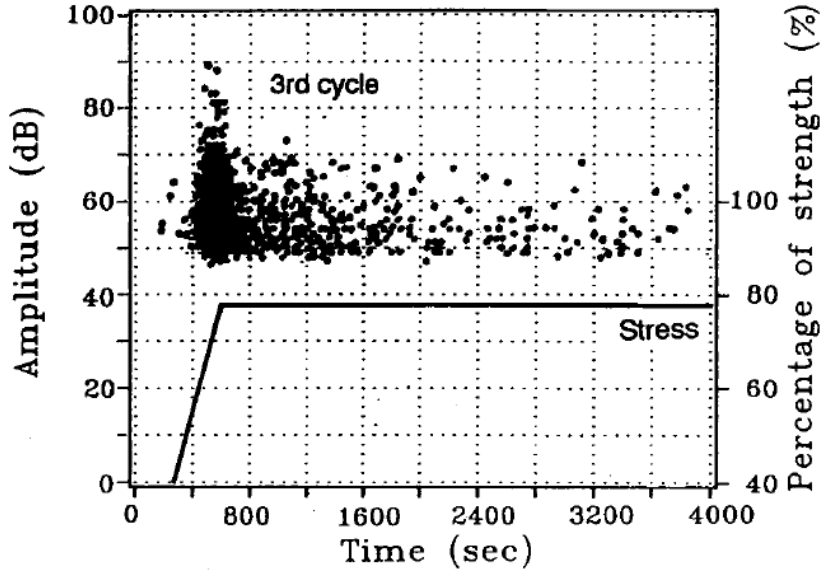
Continuous AE started ~50%UCS

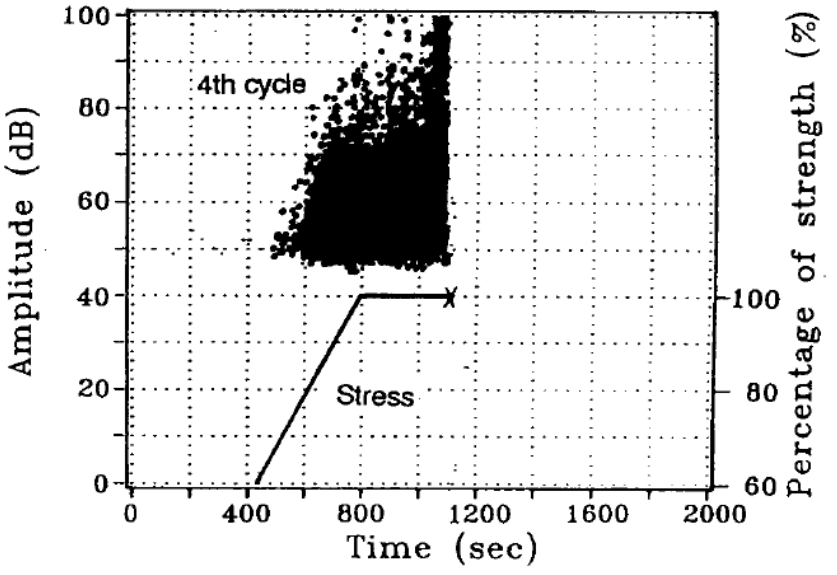
AE in a diorite specimen under uniaxial compression, UCS = 221 MPa

AE events in Kuru granite at different load levels





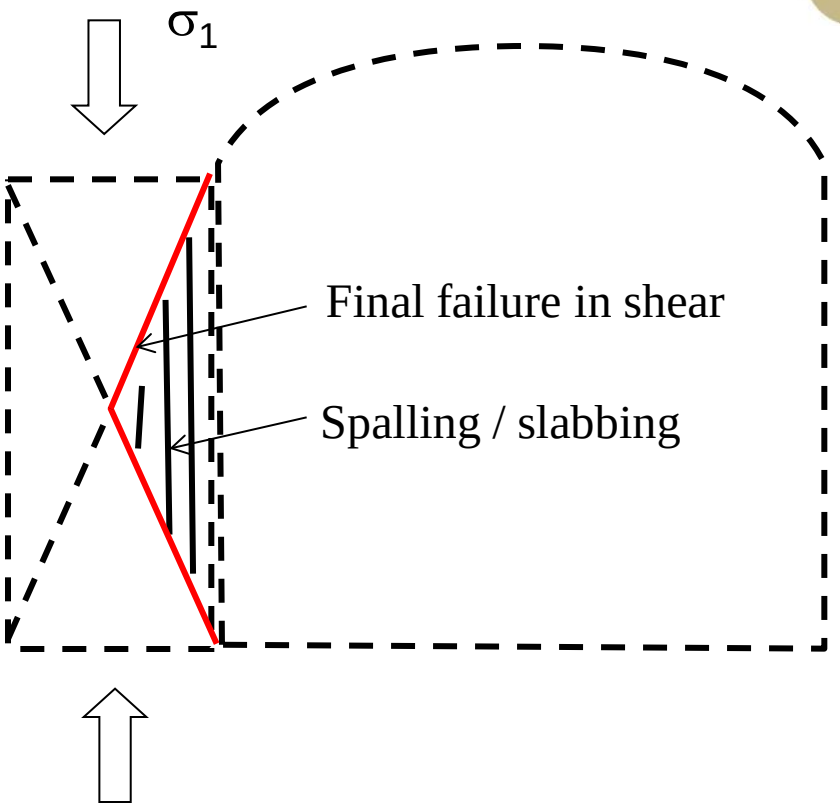


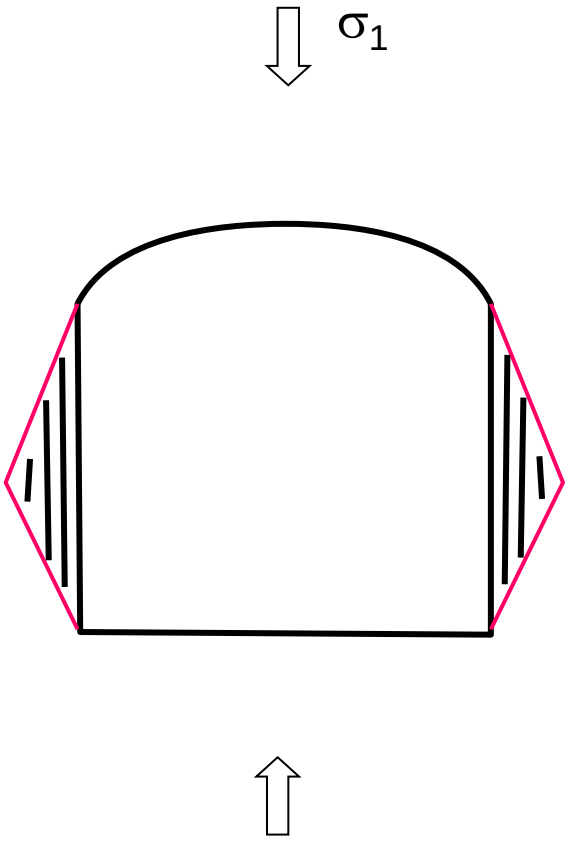


Extension fracture

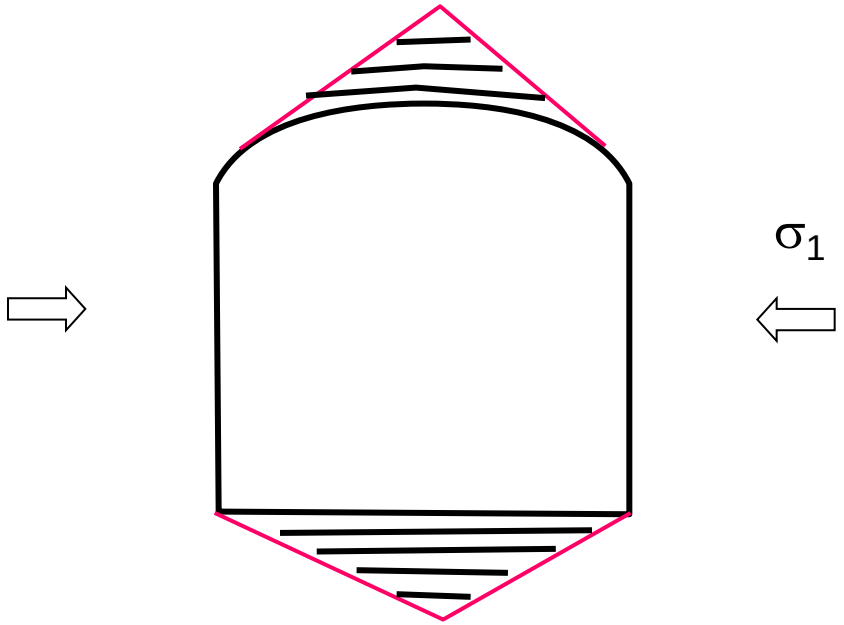
- Extension fracture starts at $\sigma_1 \approx 0.5$ UCS
- Extension fracturing lasts for a long time, having a characteristic of “creeping”

Fracture patterns in tunnel wall of hard rock



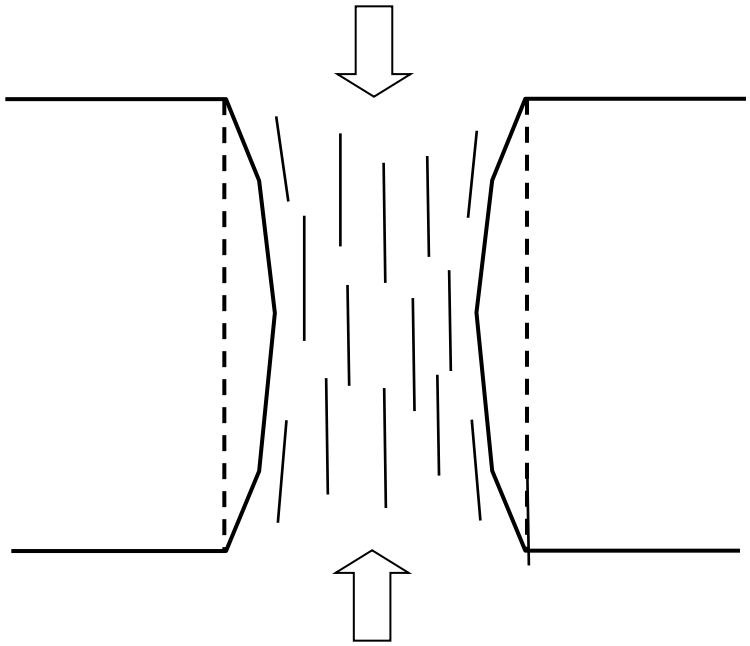


Fracturing in walls

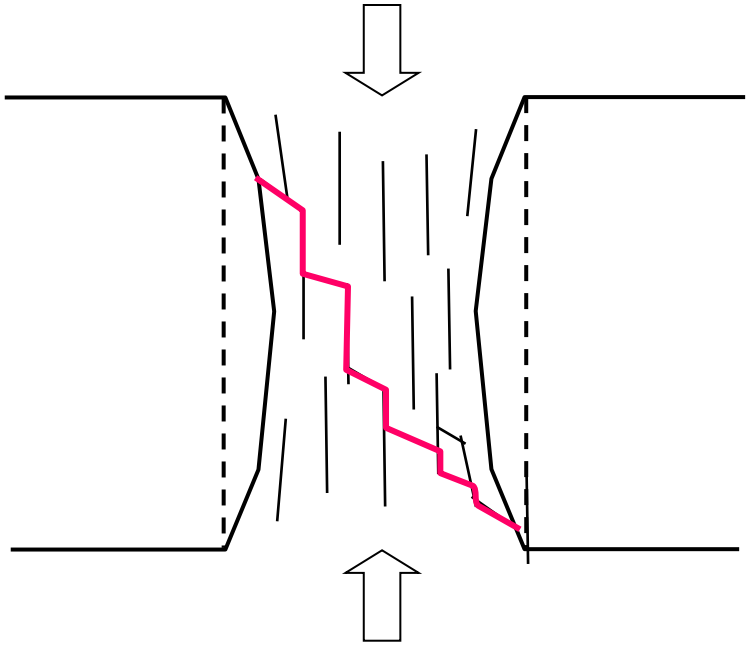


Fracturing in roof and floor

Fracture patterns in pillar of hard rock



Extension fracture



Extension fracture adnd 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