"Unknown Miner" *by Herman Wald*

Symbolic recognition of the contribution by all who worked/work in the South African mining industry and Wits University's educational role

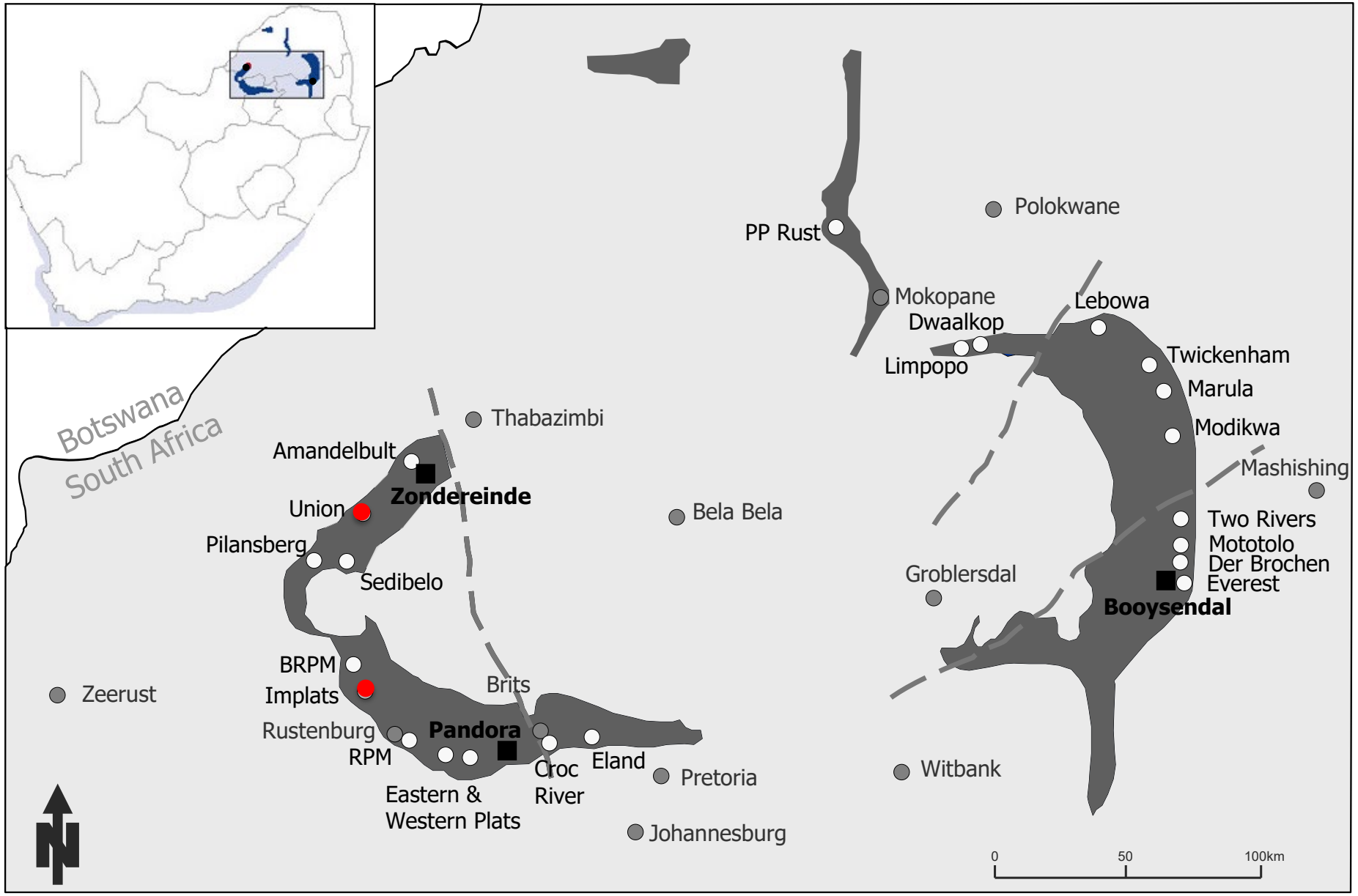
AfriRock Symposium

Crush Pillar Design for High-Stress Mining Environments

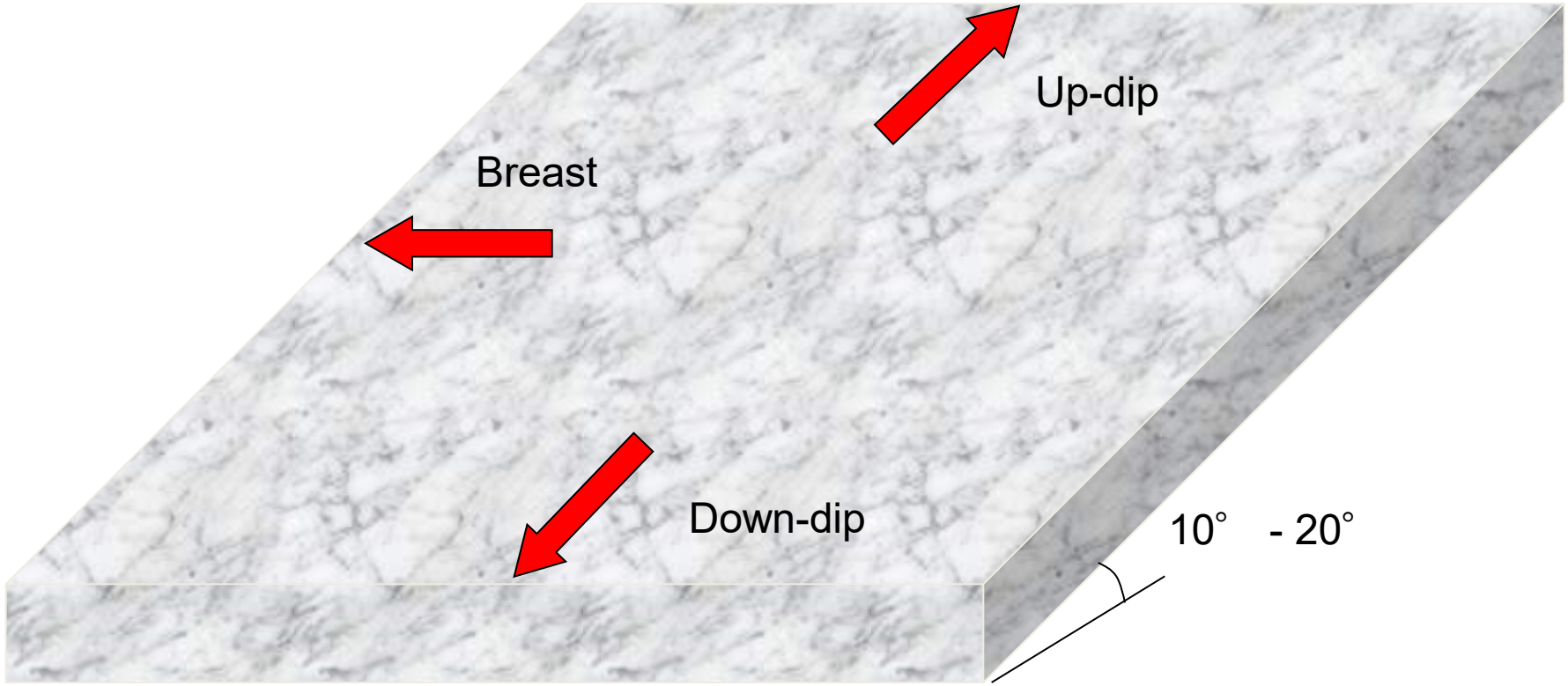
Bryan Watson

22nd July 2025

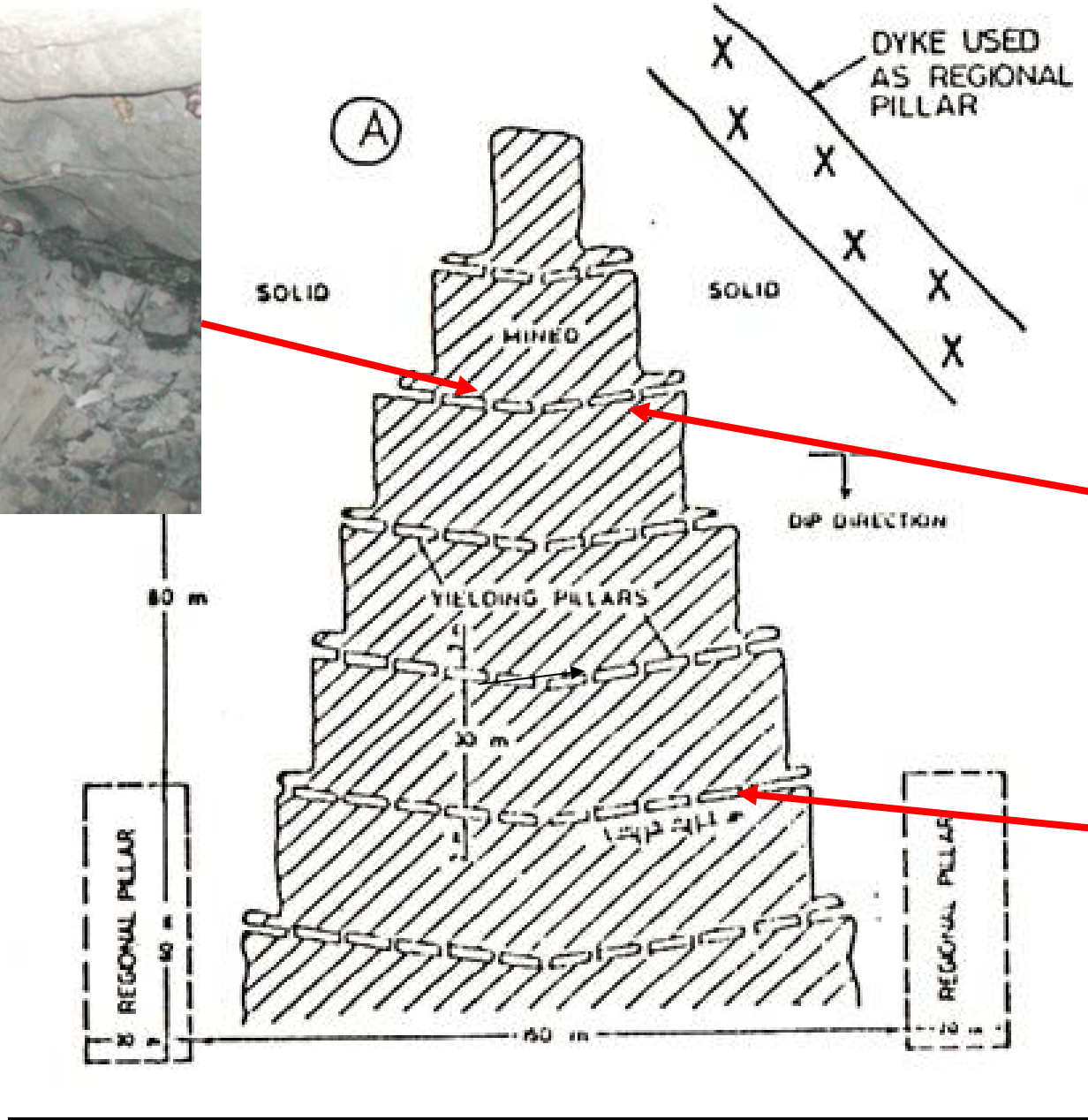
Bushveld complex in RSA



3D view of Bushveld orebodies

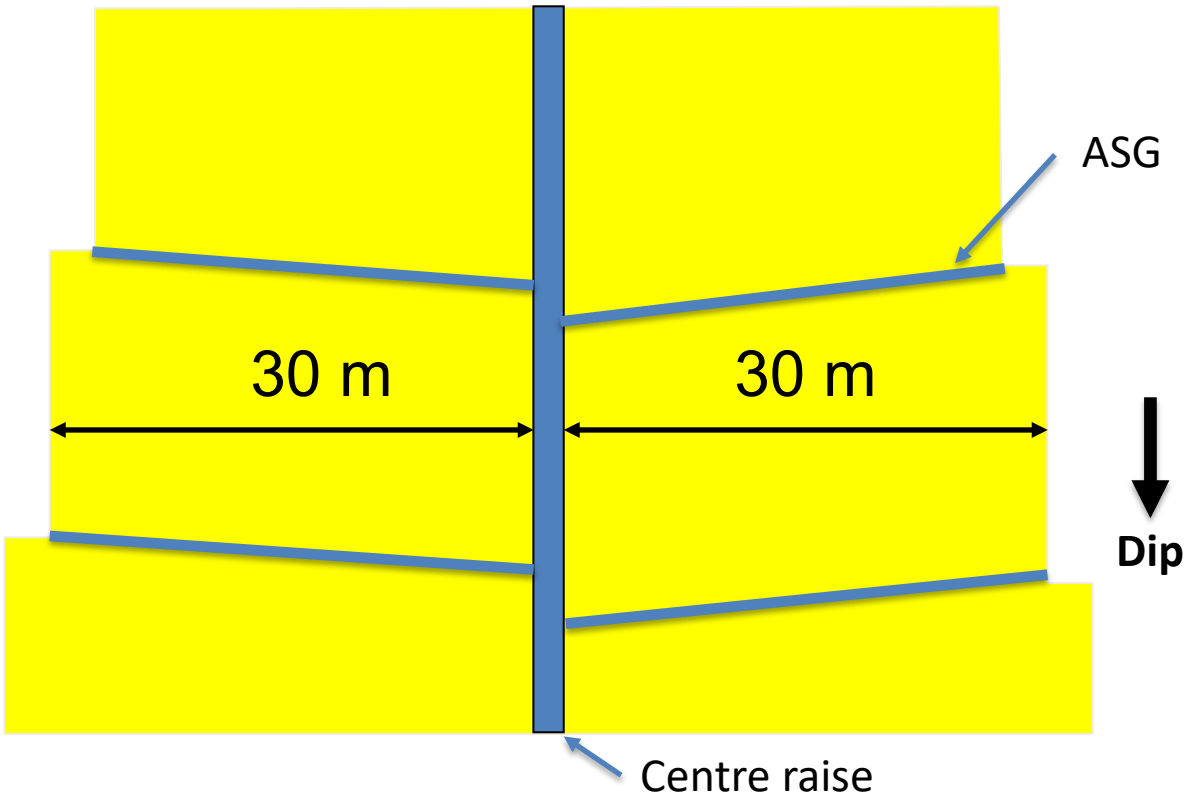


Plan view of a typical Bushveld stope

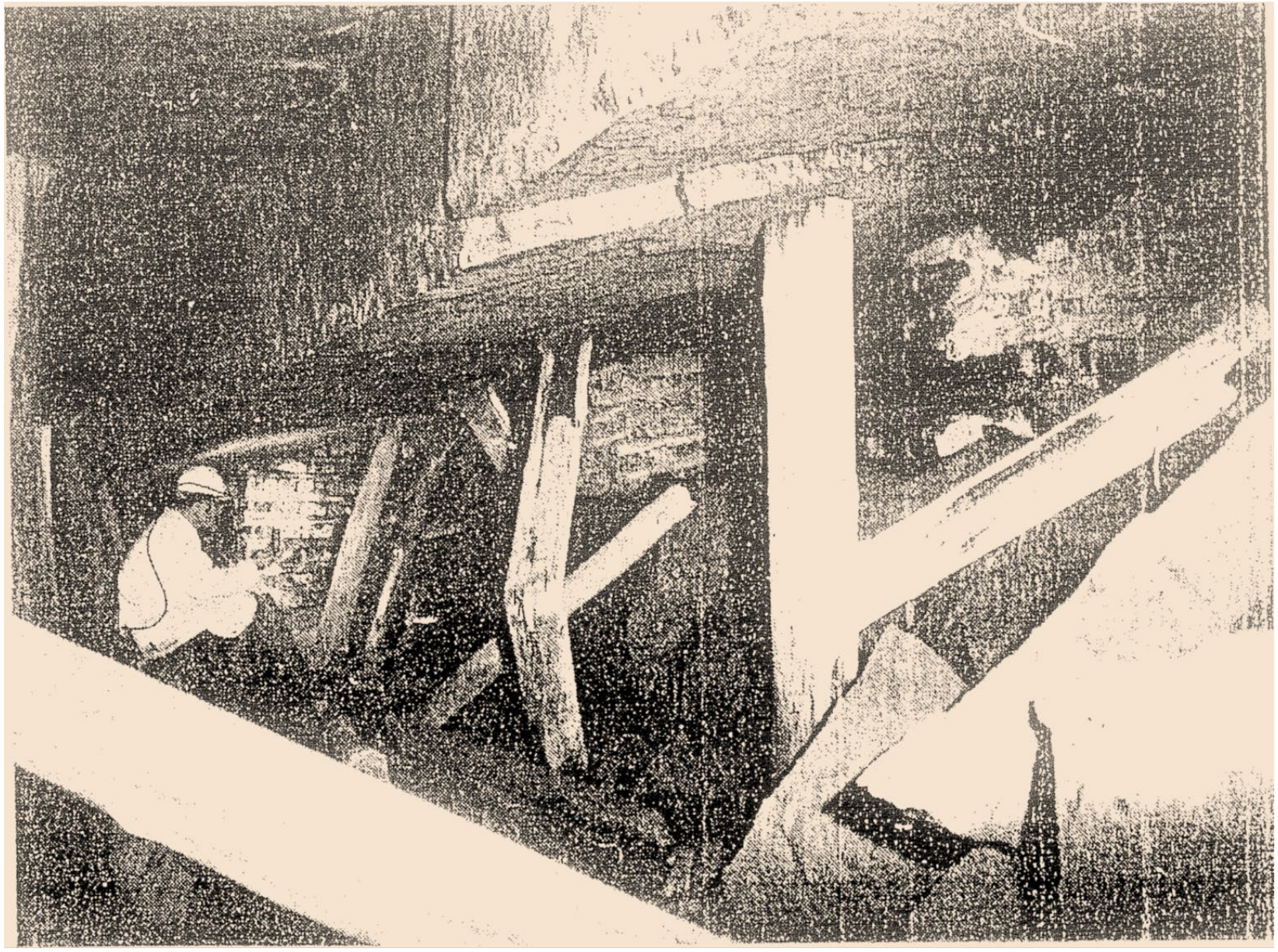


Discovery of crush pillars

- Korf (1978) noted that stope collapses occurred whenever a distance of 30 m was reached on either side of the raise line.

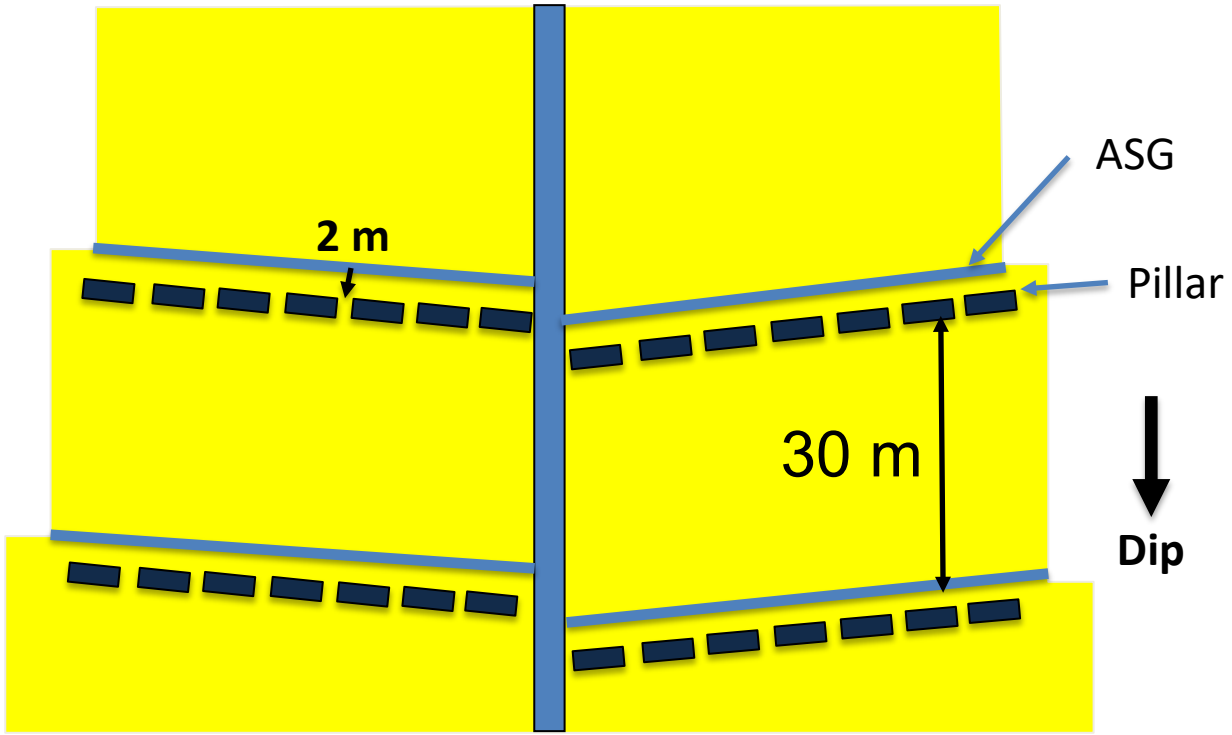


Stope collapse

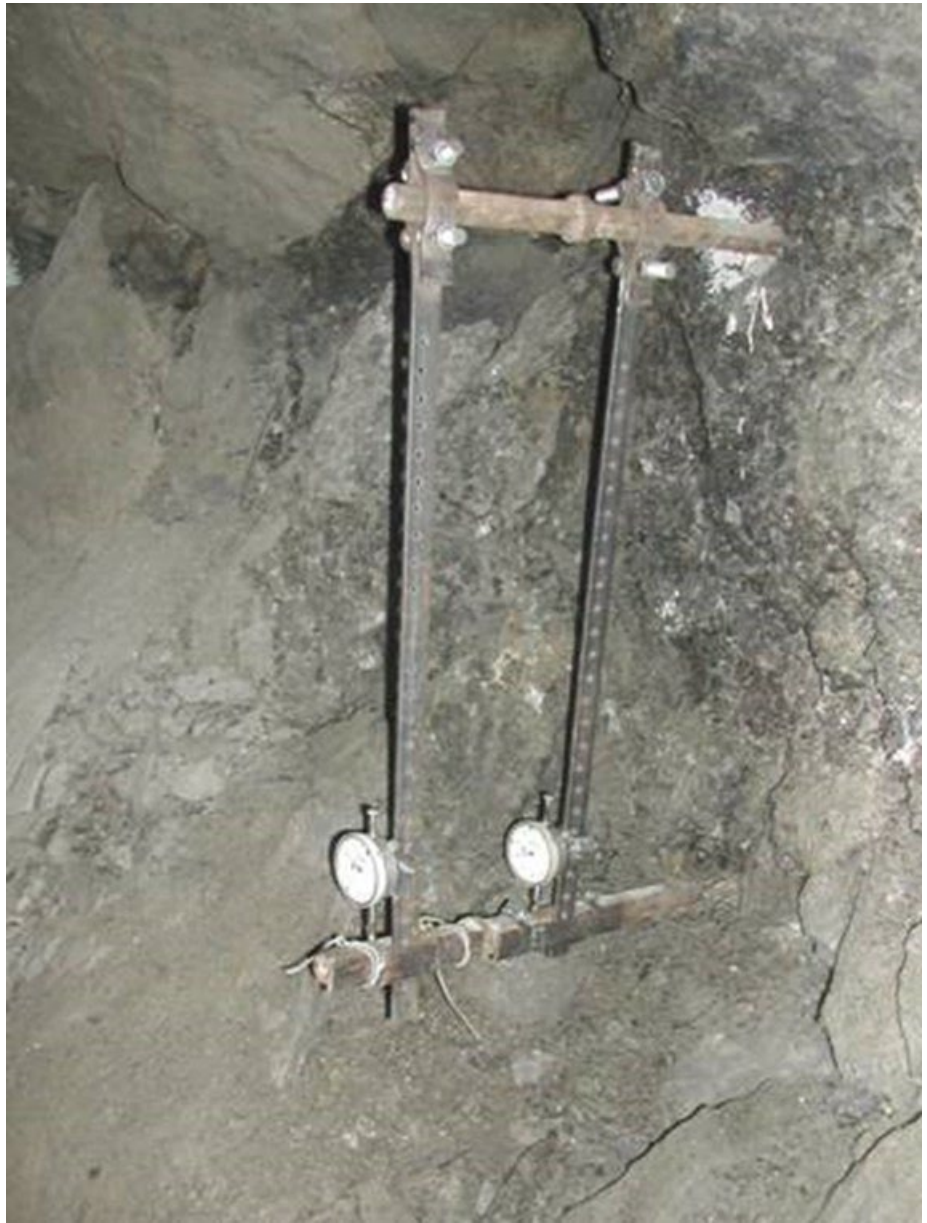


Discovery of crush pillars

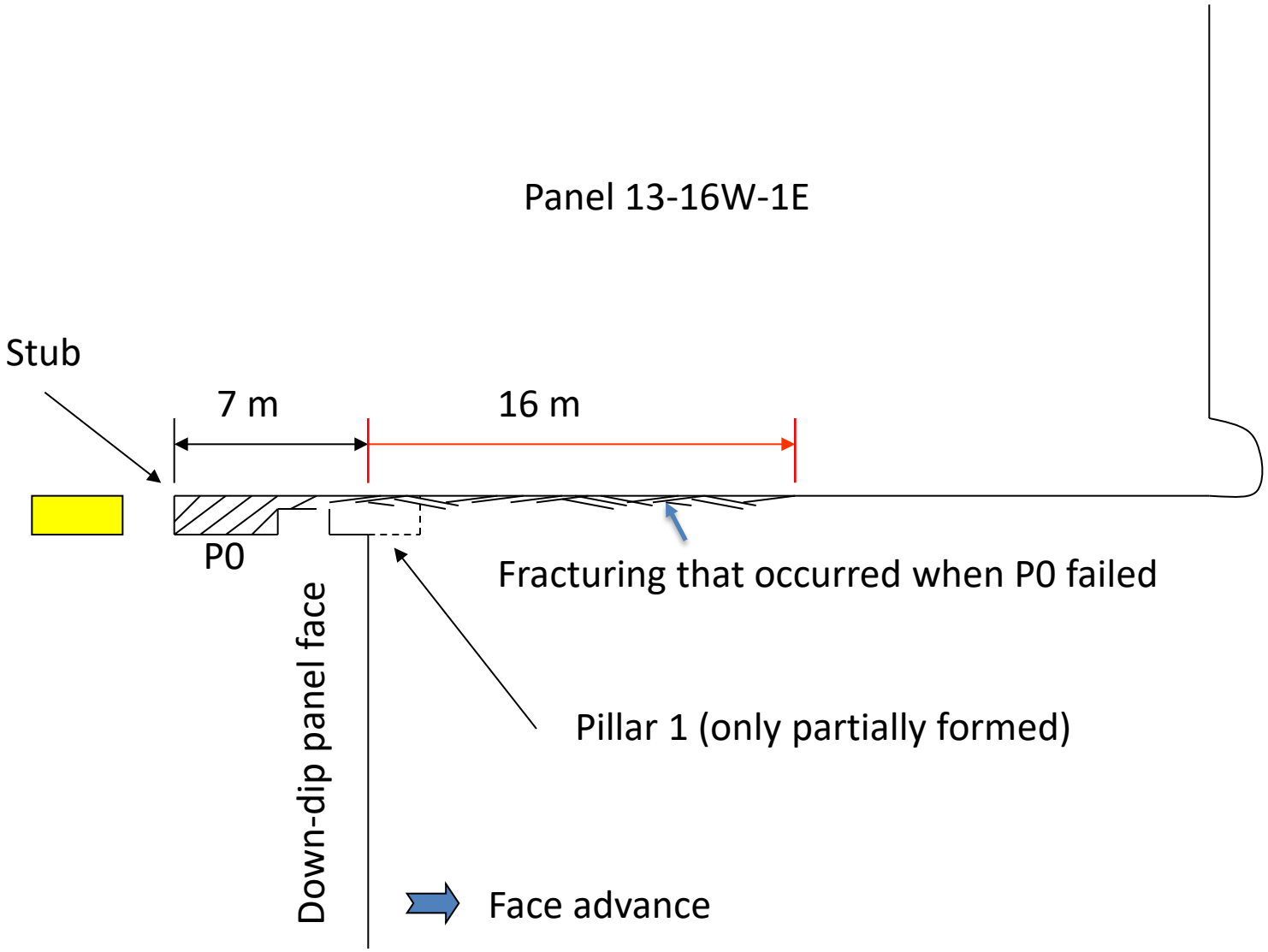
- Pillars with w/h = 1.5 were shown by Korf (1978) to be sufficient to meet the demands if 2 m wide sidings were cut between the pillars and the ASG.



Crush pillar

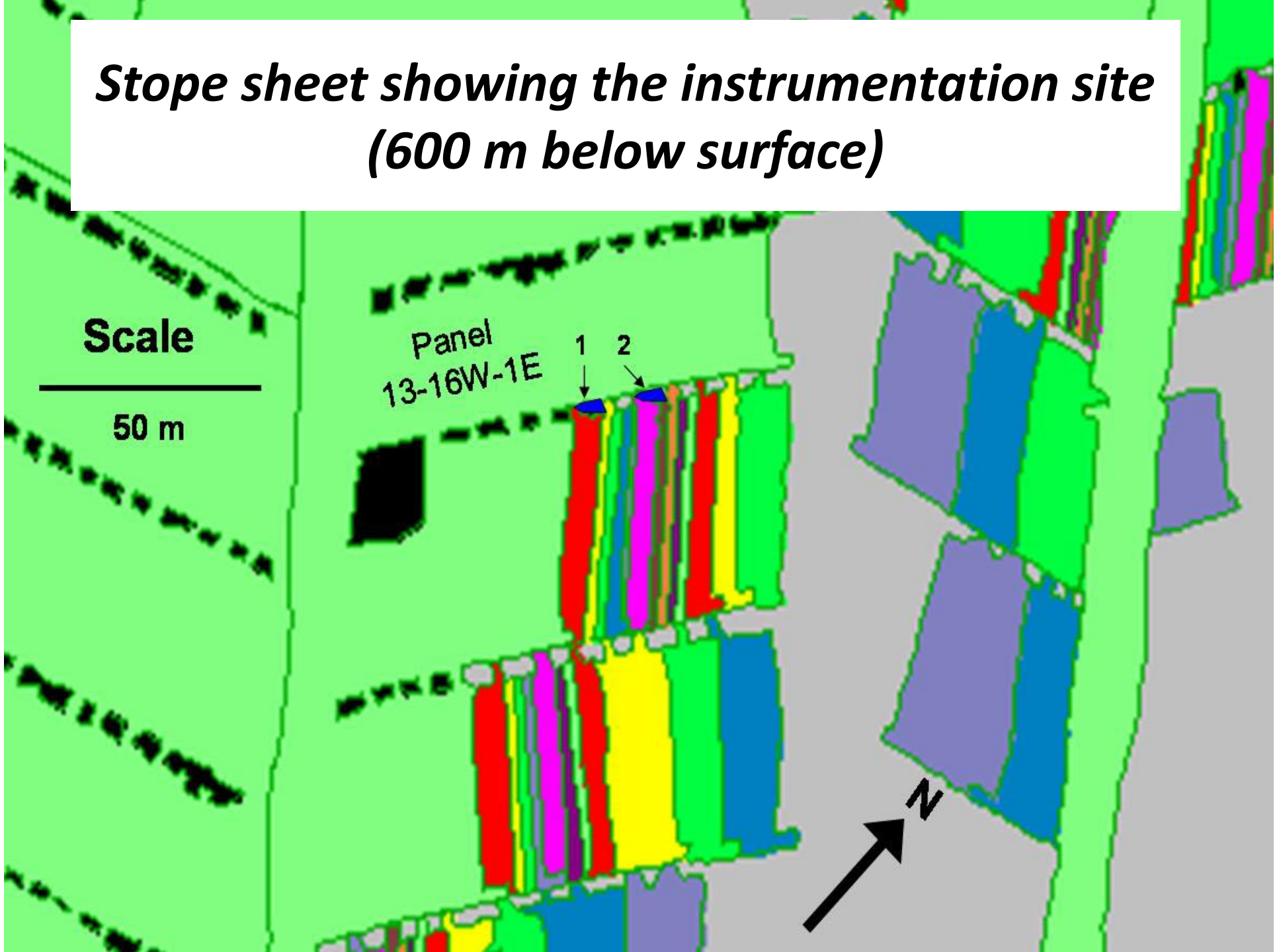


Stable failure
(Significant fracturing observed at failure)

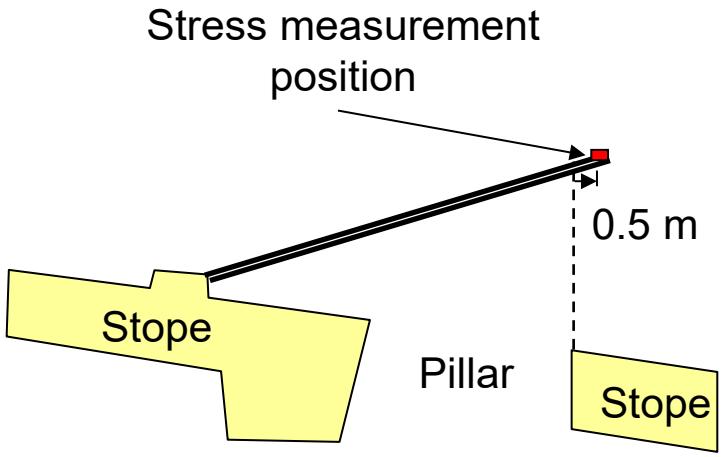


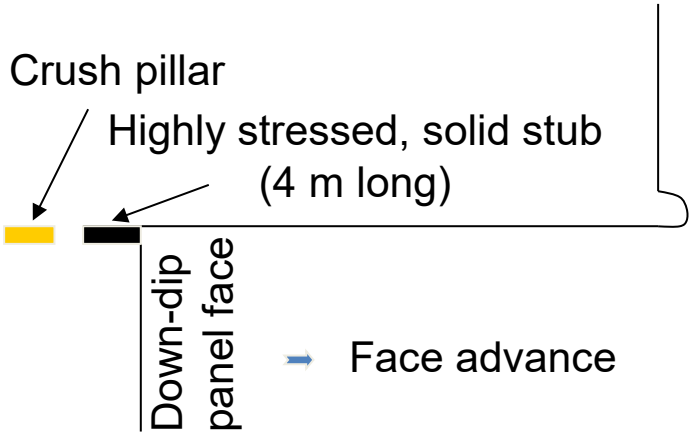
(Watson et al., 2007)

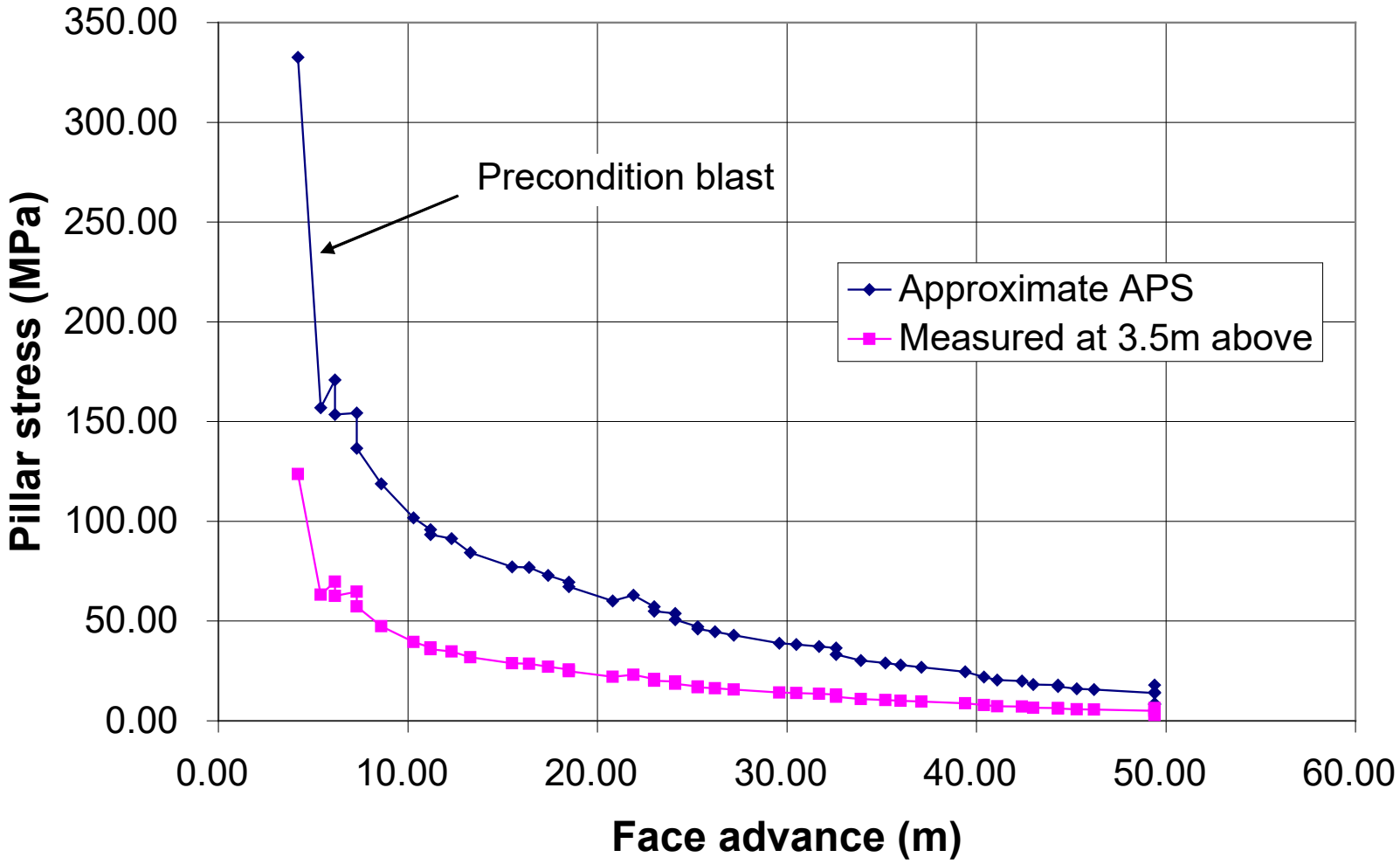
Stope sheet showing the instrumentation site (600 m below surface)



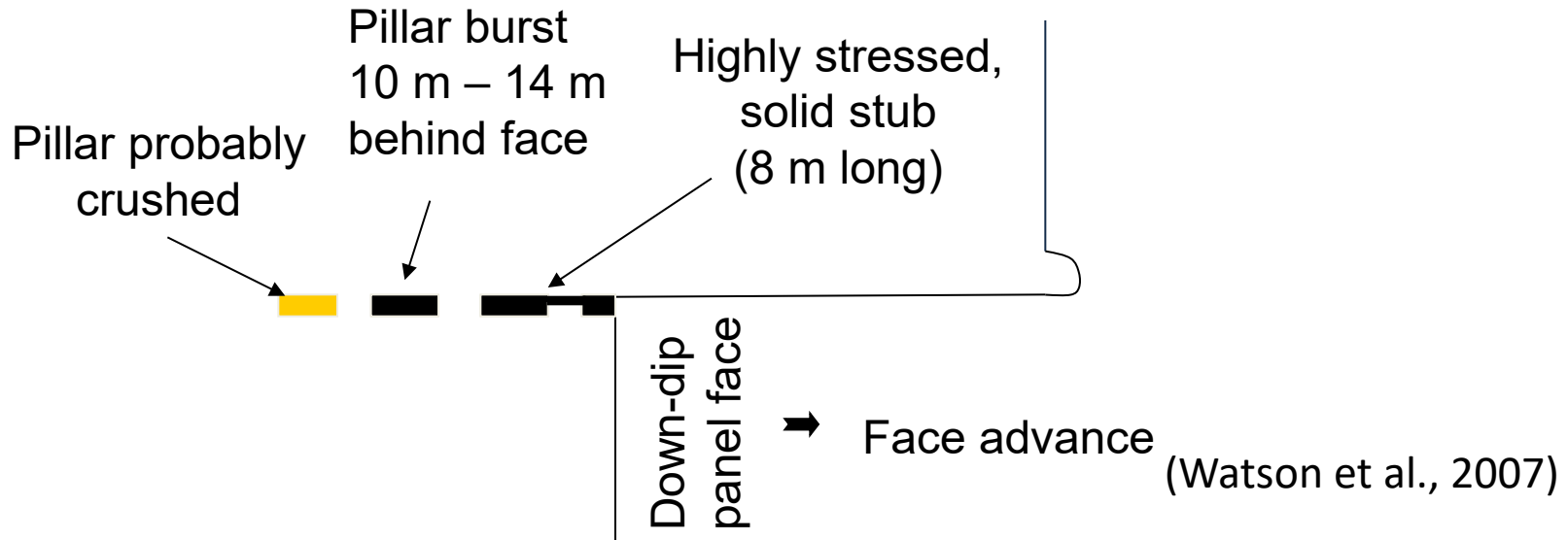
Stable failure of Pillar P1





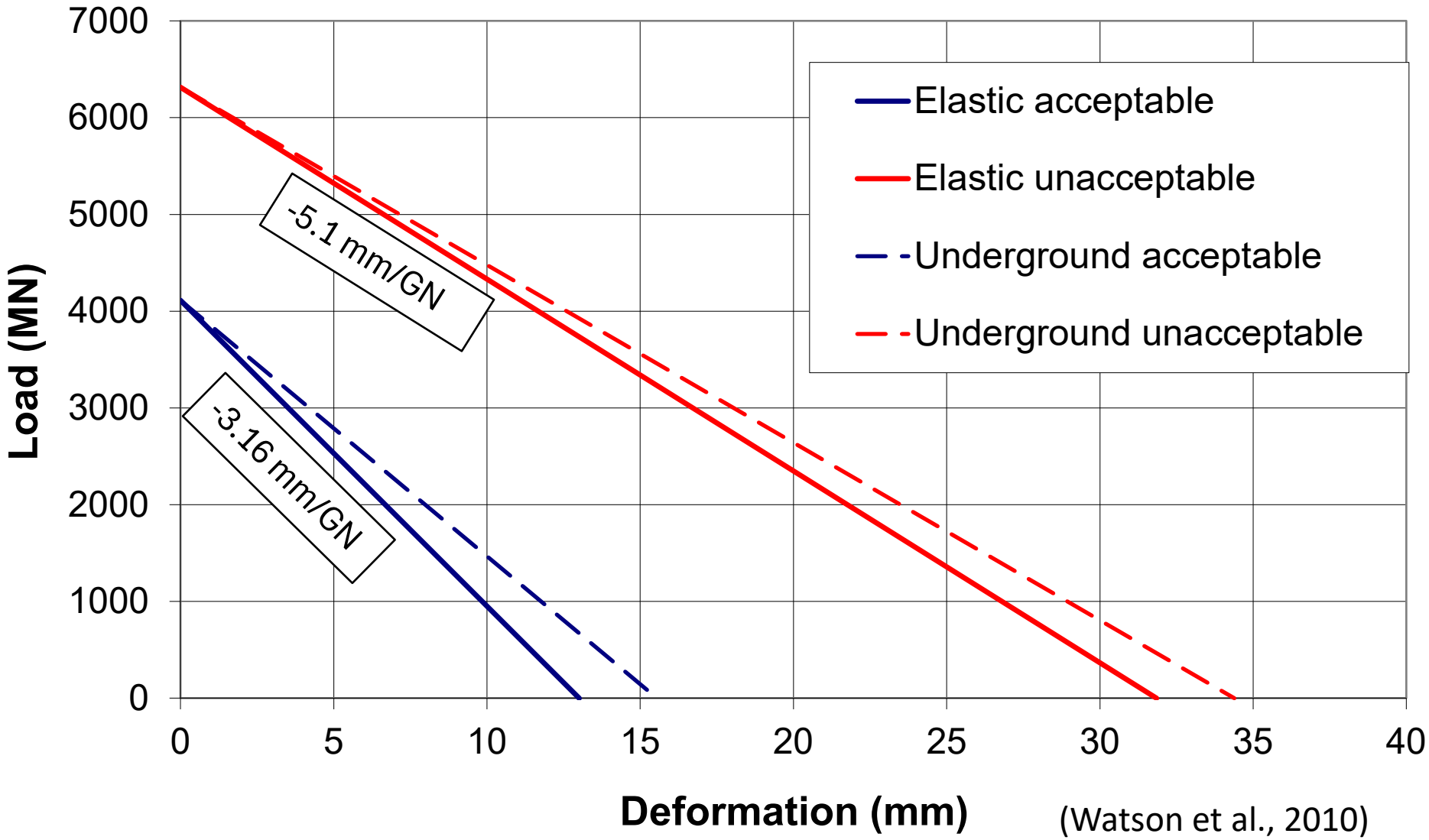


Pillar burst



(Watson et al., 2007)

Unloading stiffness for stable failure (Merensky Reef)



(Watson et al., 2010)

Stiff testing machine

Soft testing machine

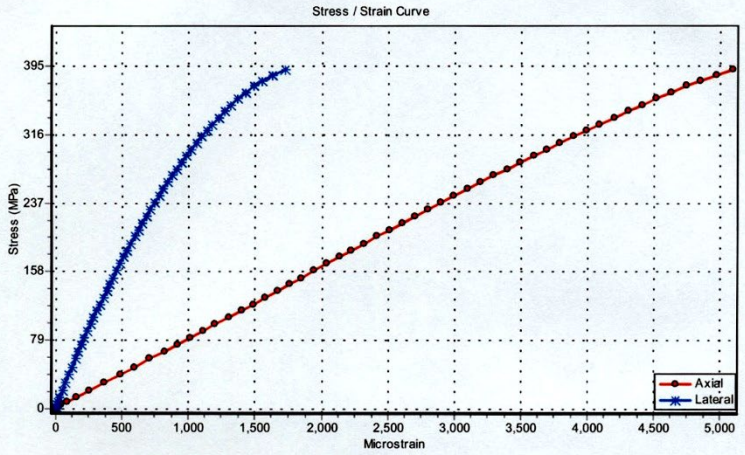
LABORATORY TESTING

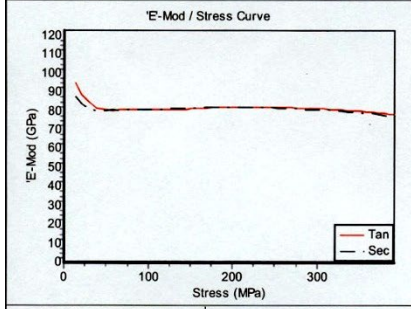
GEOMECHANICS LABORATORY

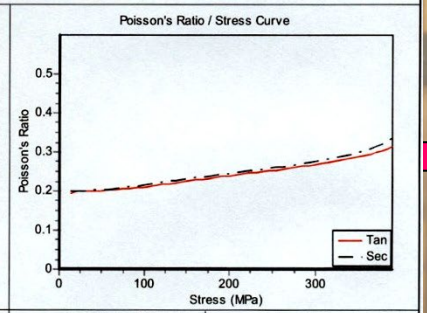
UNIAXIAL COMPRESSION TEST

WITH DEFORMABILITY MEASUREMENTS BY MEANS OF STRAIN GAUGES

CSIR MININGTEK







'E'-Mod @ 30% UCS		'E'-Mod @ 50% UCS	
Tan:	83.3 GPa		82.3 GPa
Sec:	81.0 GPa		82.3 GPa

Poisson's Ratio @ 30% UCS		Poisson's Ratio @ 50% UCS
Tan:	0.257	0.299
Sec:	0.221	0.243

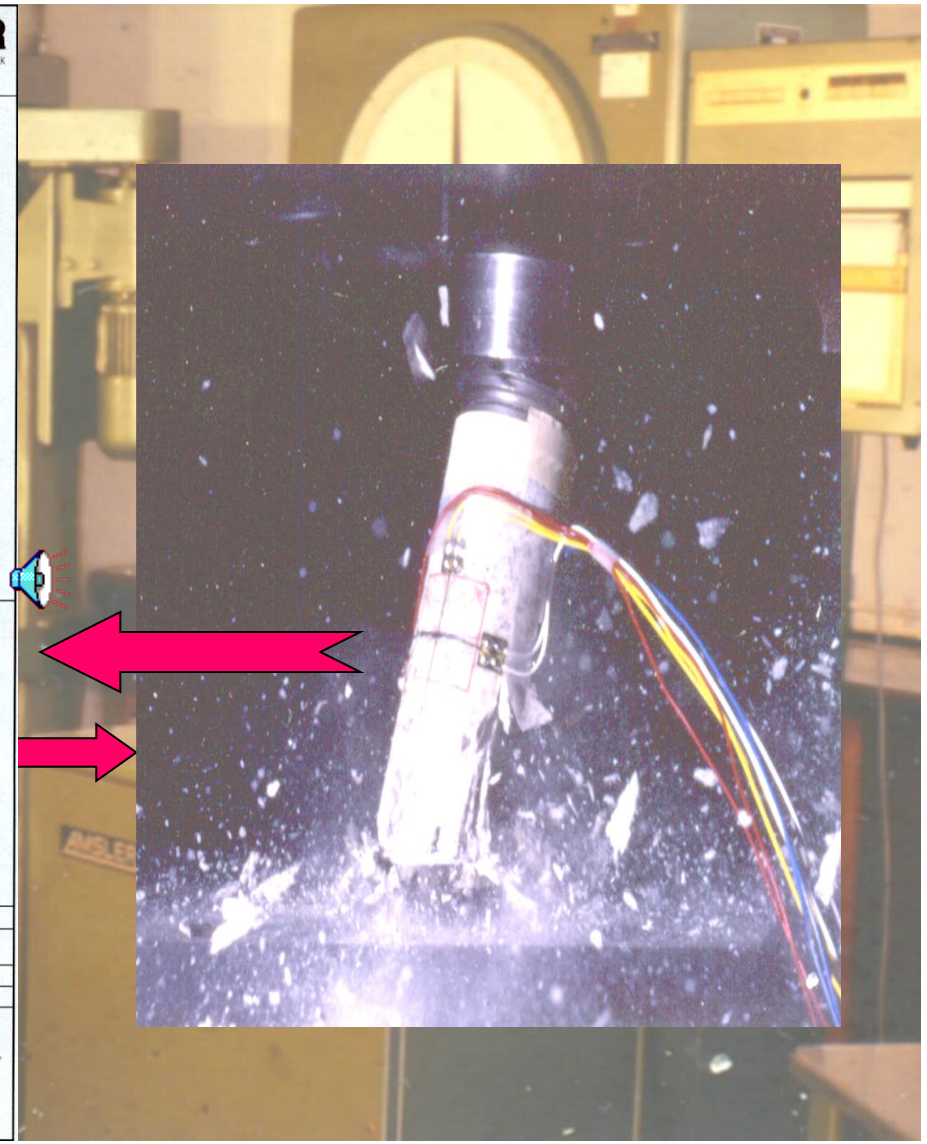
Mod Ratio @ 50% UCS:	UCS (MPa):	Toughness Index:	
208	396	Farmer (MPa): 0.9528	CSIR (MPa): 1.0450

TEST DETAILS

Date: 1994-12-09
Time: 10:58:01
Test Machine: Amsler
Range (kN): 1000
Falure Load (kN): 297
Tester: KD
Client: MININGTEK

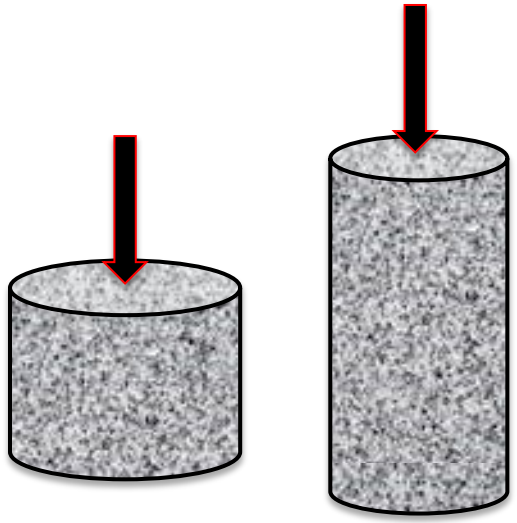
SPECIMEN DETAILS

Rock Type: LAVA
CSIR Number: 1640-UCM-22
Diameter (mm): 31
Length (mm): 80
Mass (g): 172
Density (kg/m³) 2866
Deg. of Sat.: LAB DRY



Pre-failure sample stiffness

$$k = E\frac{A}{h}$$



- Pre-failure stiffness is a function of both material property, *E* and geometry

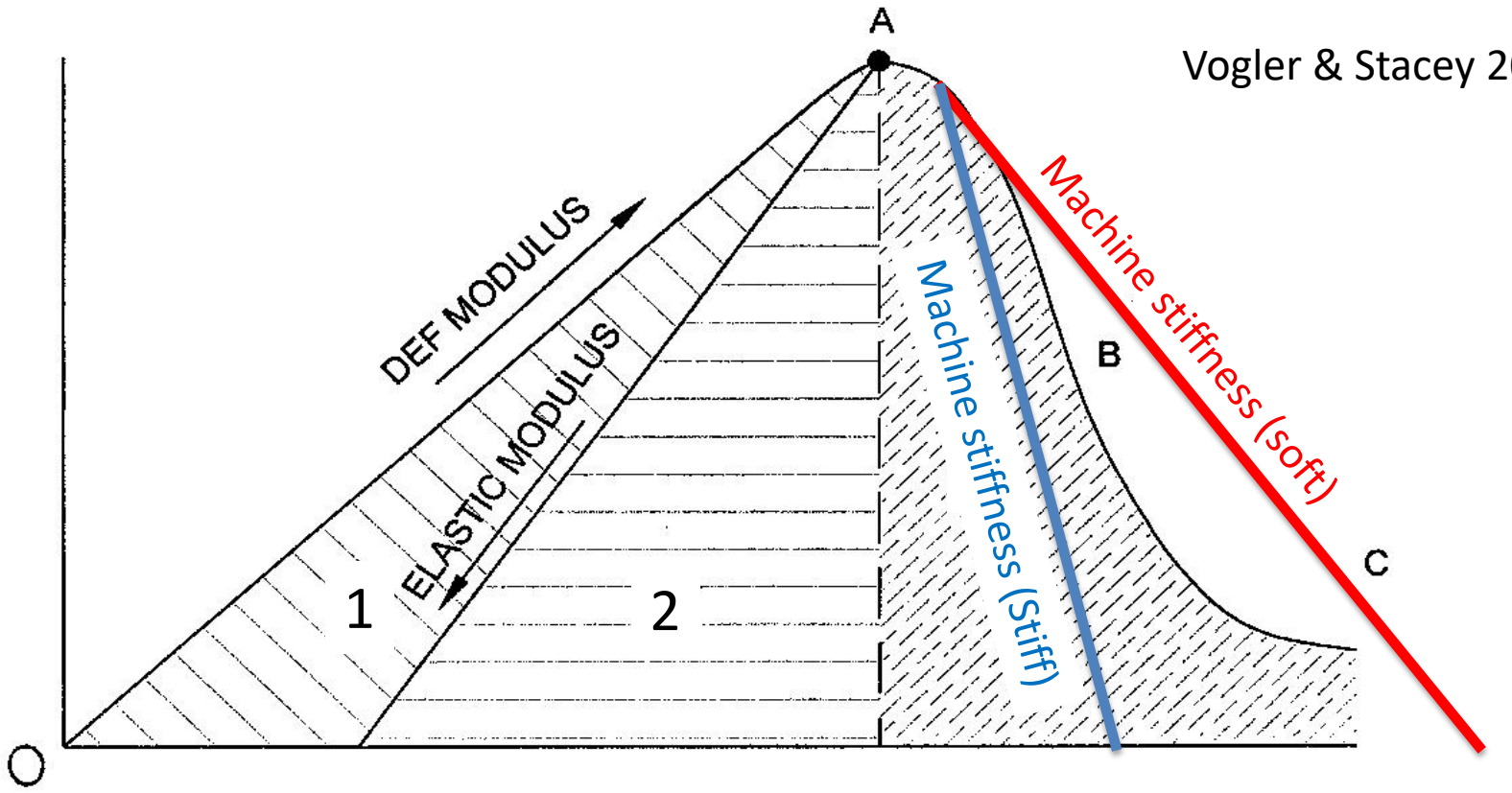
- For a given material, stiffness will increase with an increase in loading area (*A*) and decrease with an increase in length or height (*h*)

Class I unloading behaviour

Area 1 = Non-recoverable energy (energy required for crack formation.

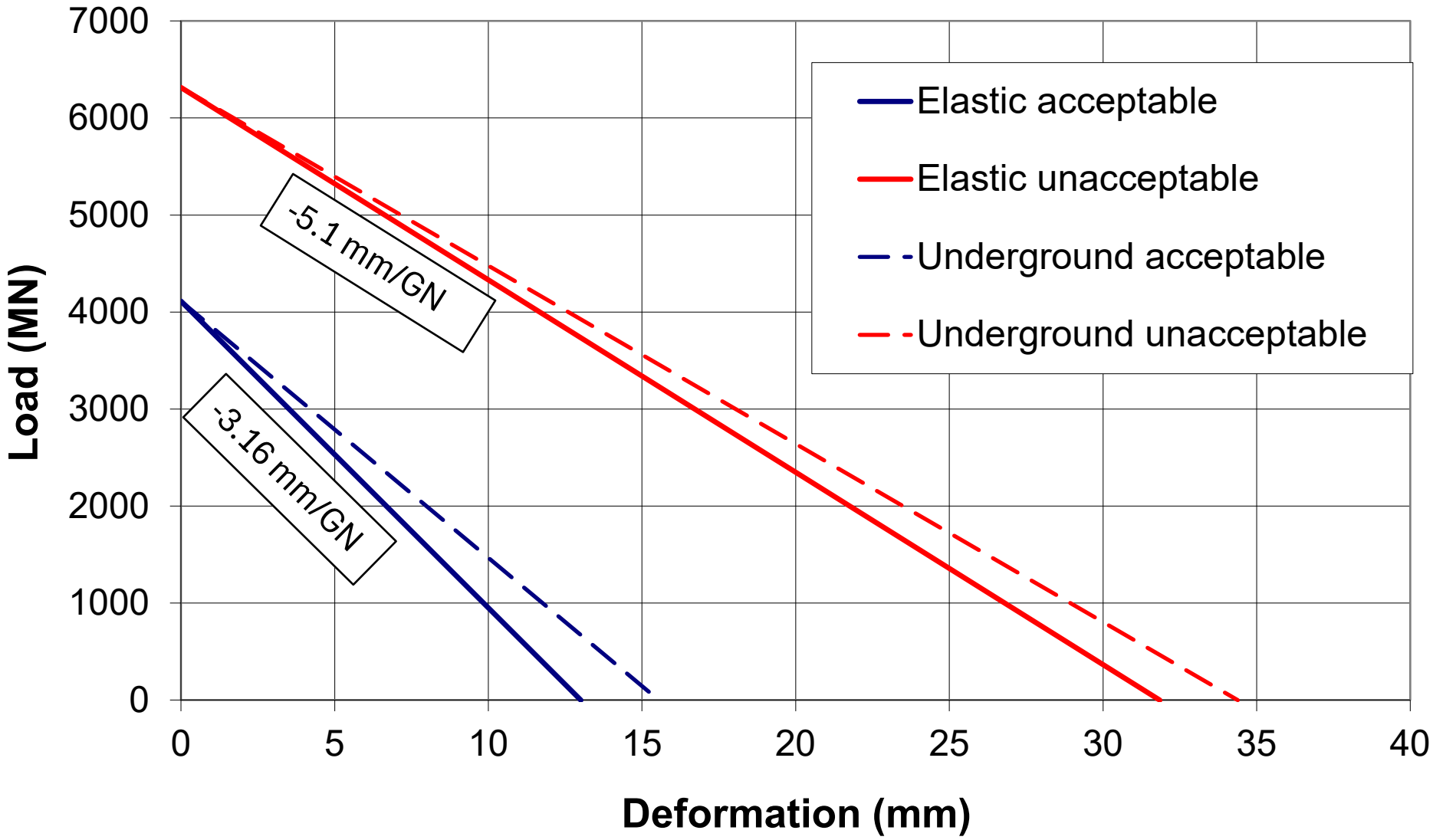
Area 2 = Elastic energy available in the test sample at point A

Area 3 = additional energy to be supplied by the machine

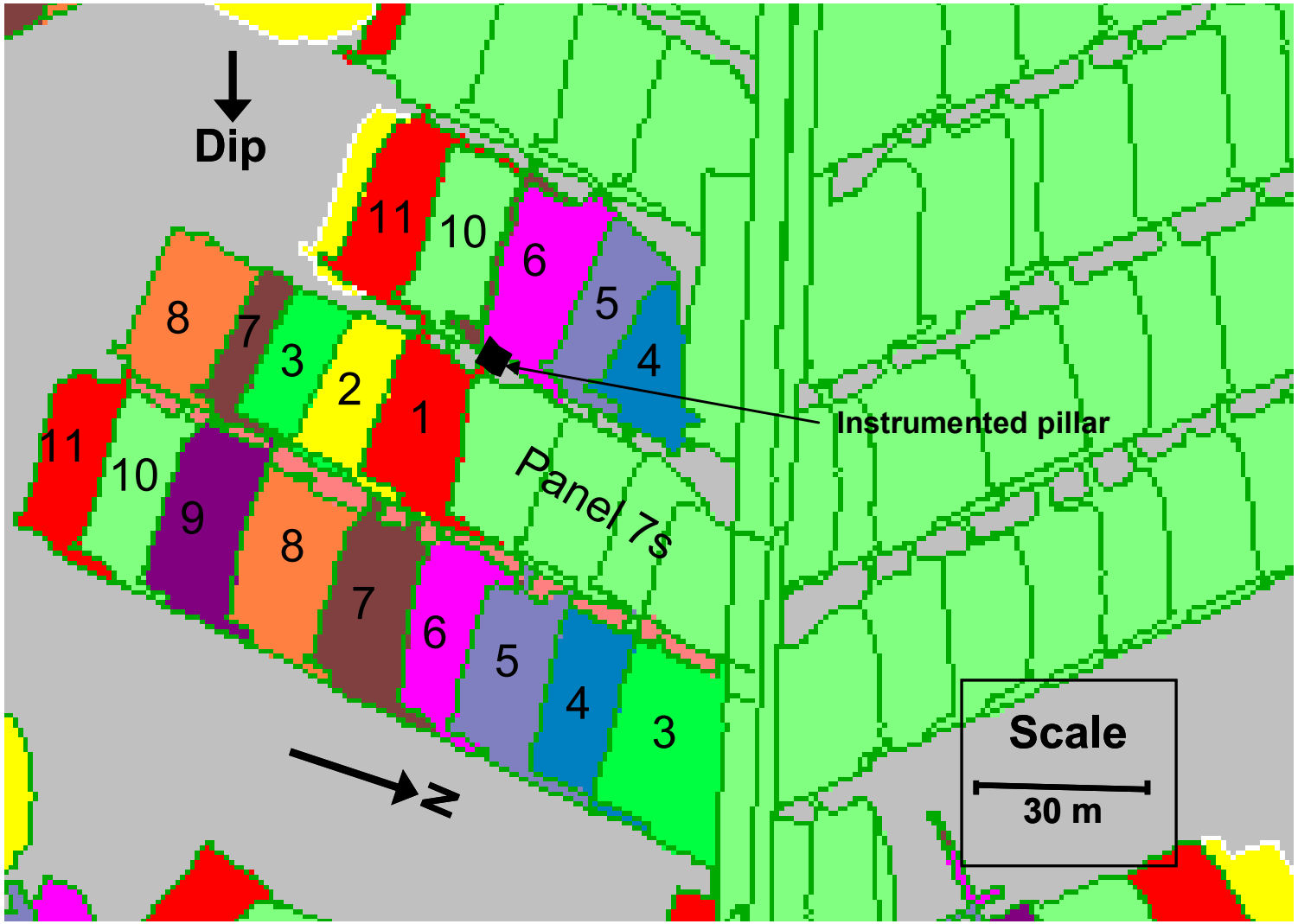


Vogler & Stacey 2016

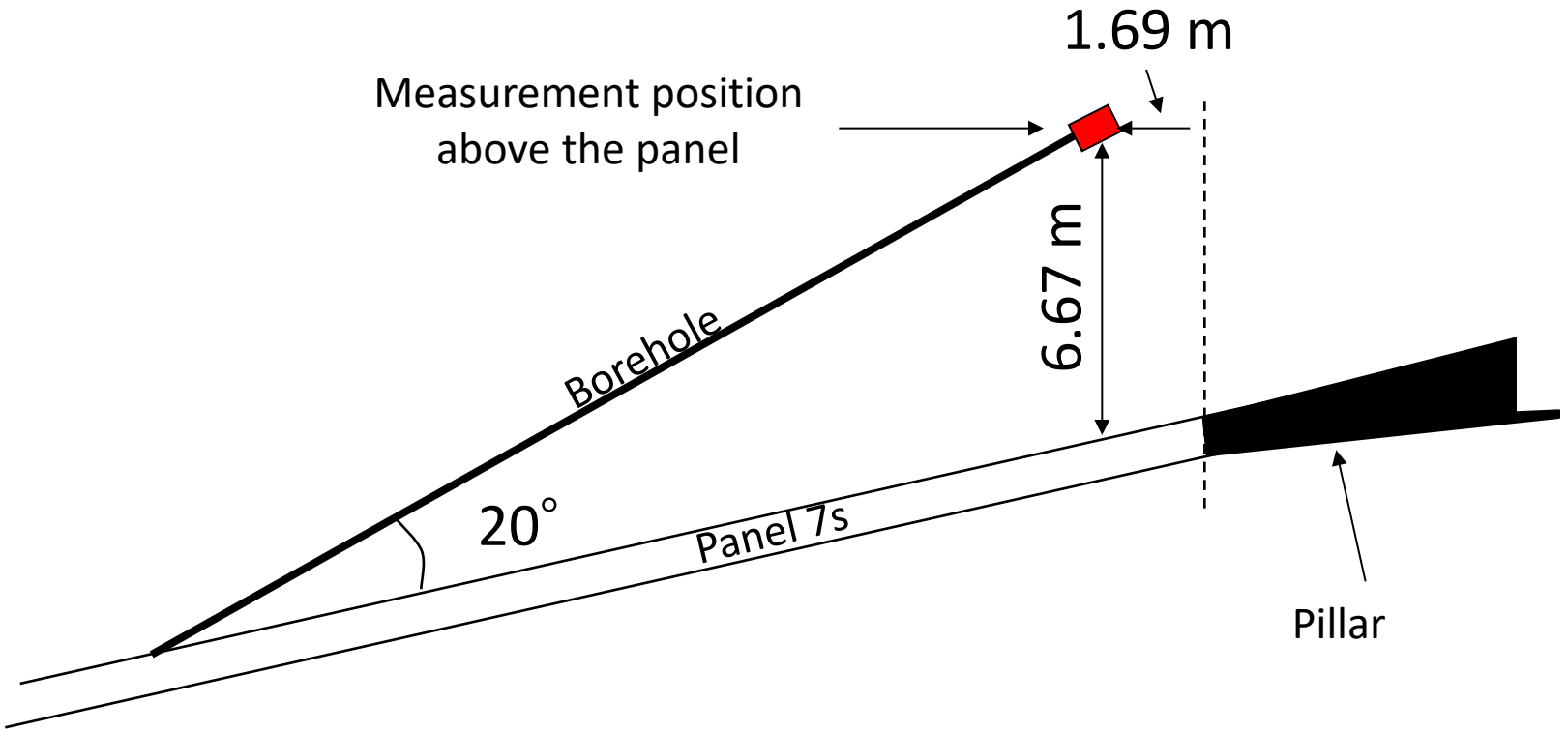
Unloading stiffness for stable failure (Merensky Reef)



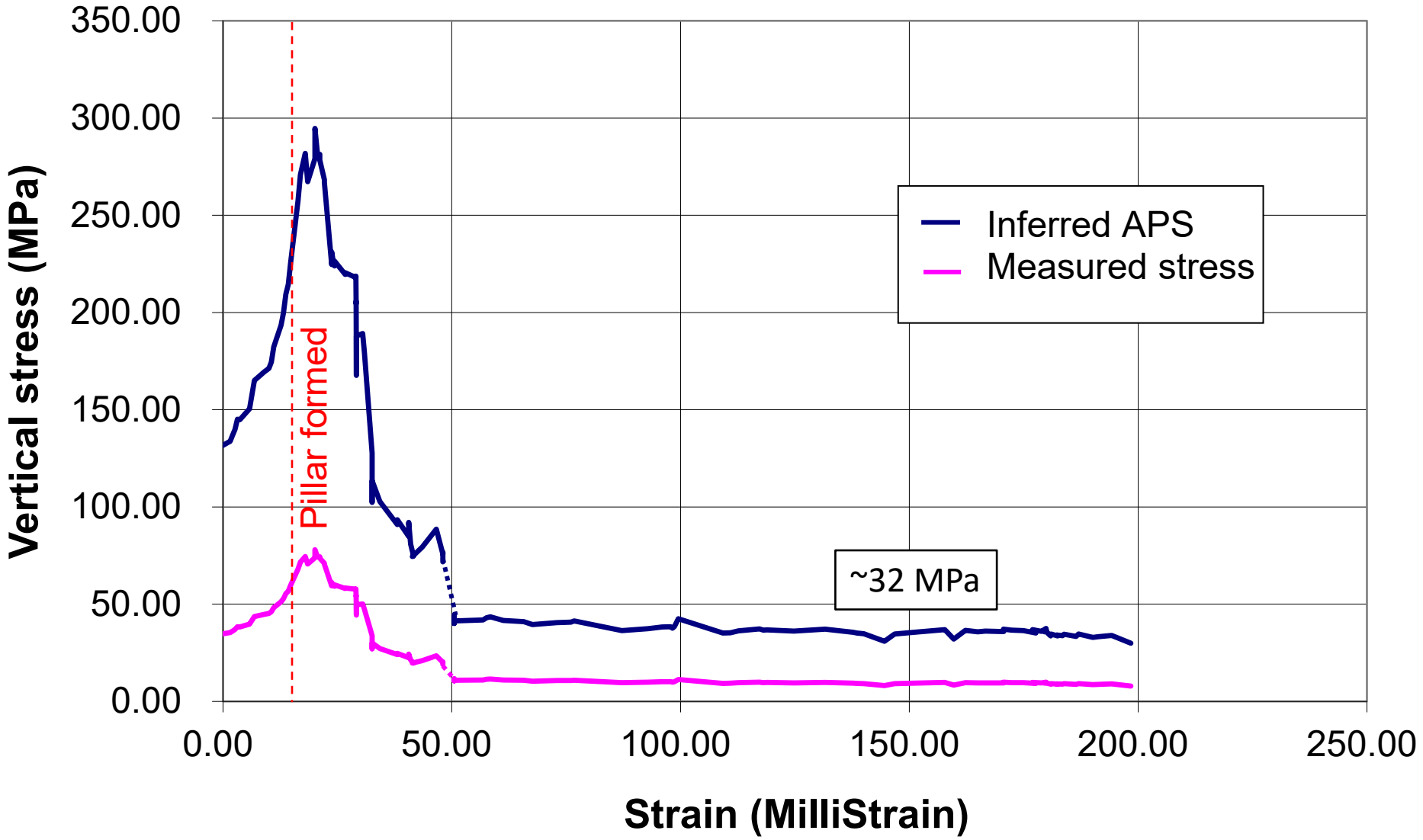
Impala platinum stope sheet (1100 m below surface)



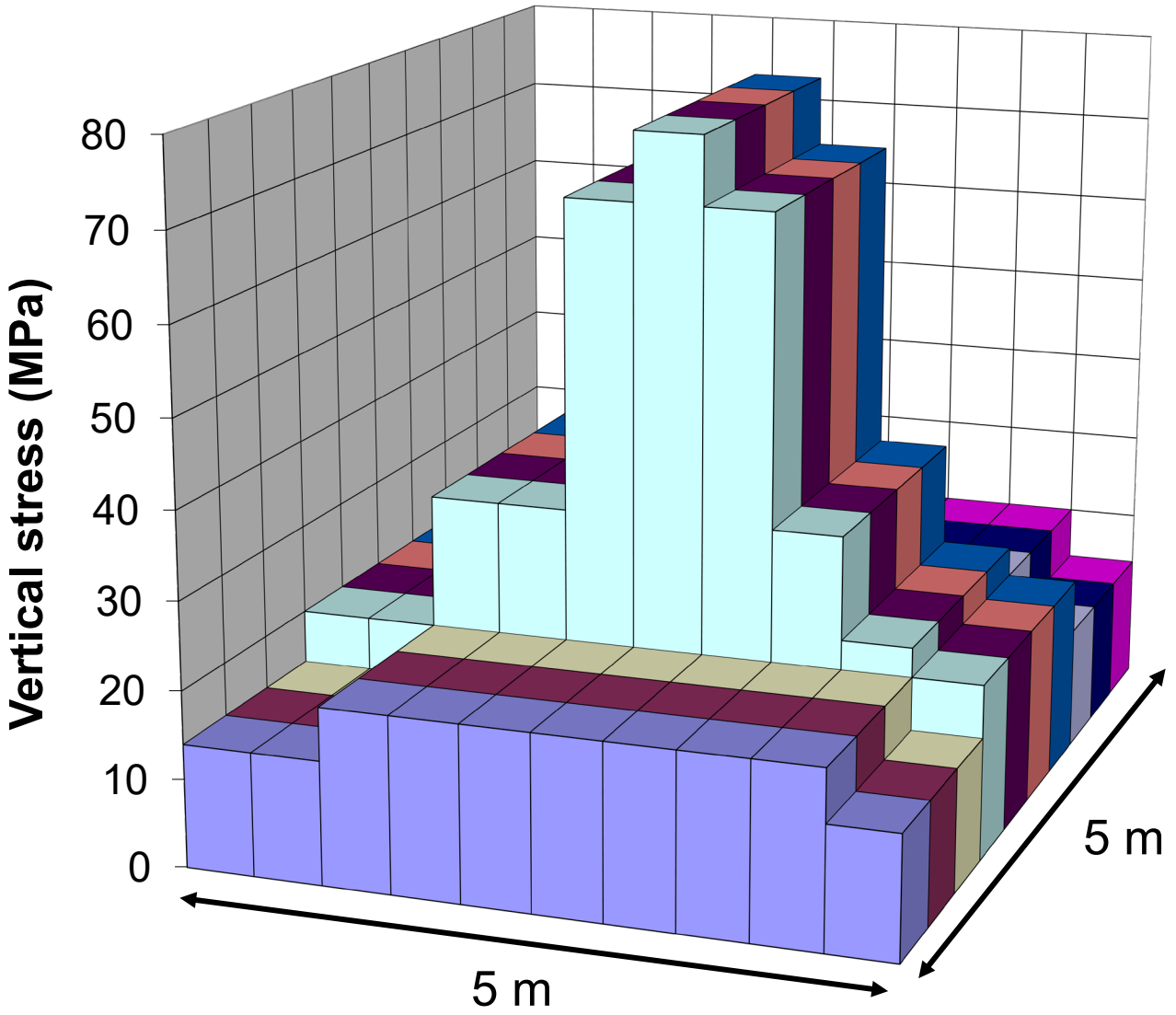
Section view of the measurement site



Stress-strain curve for a 5 m wide pillar

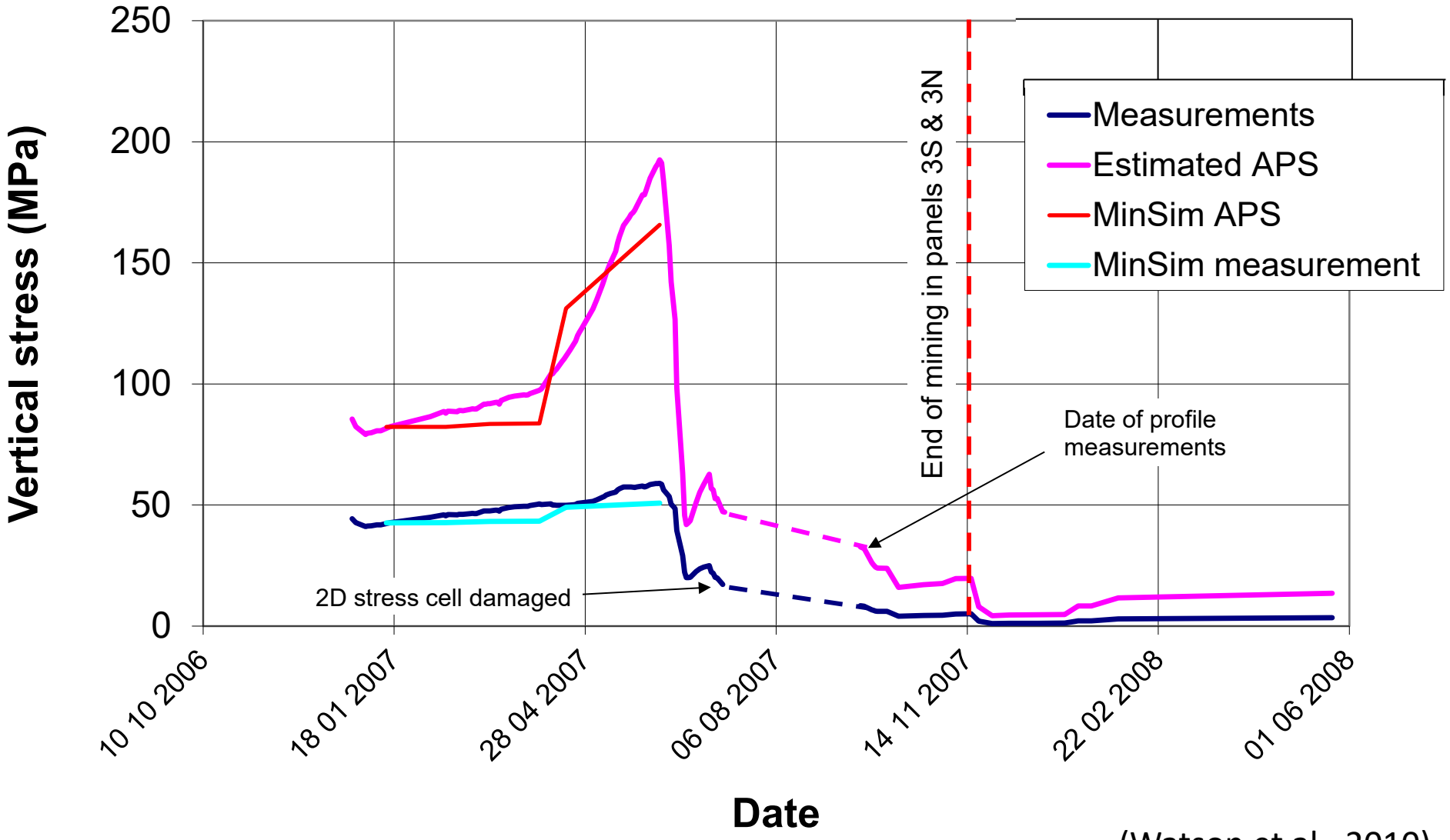


Approximate stress profile (crush pillar)



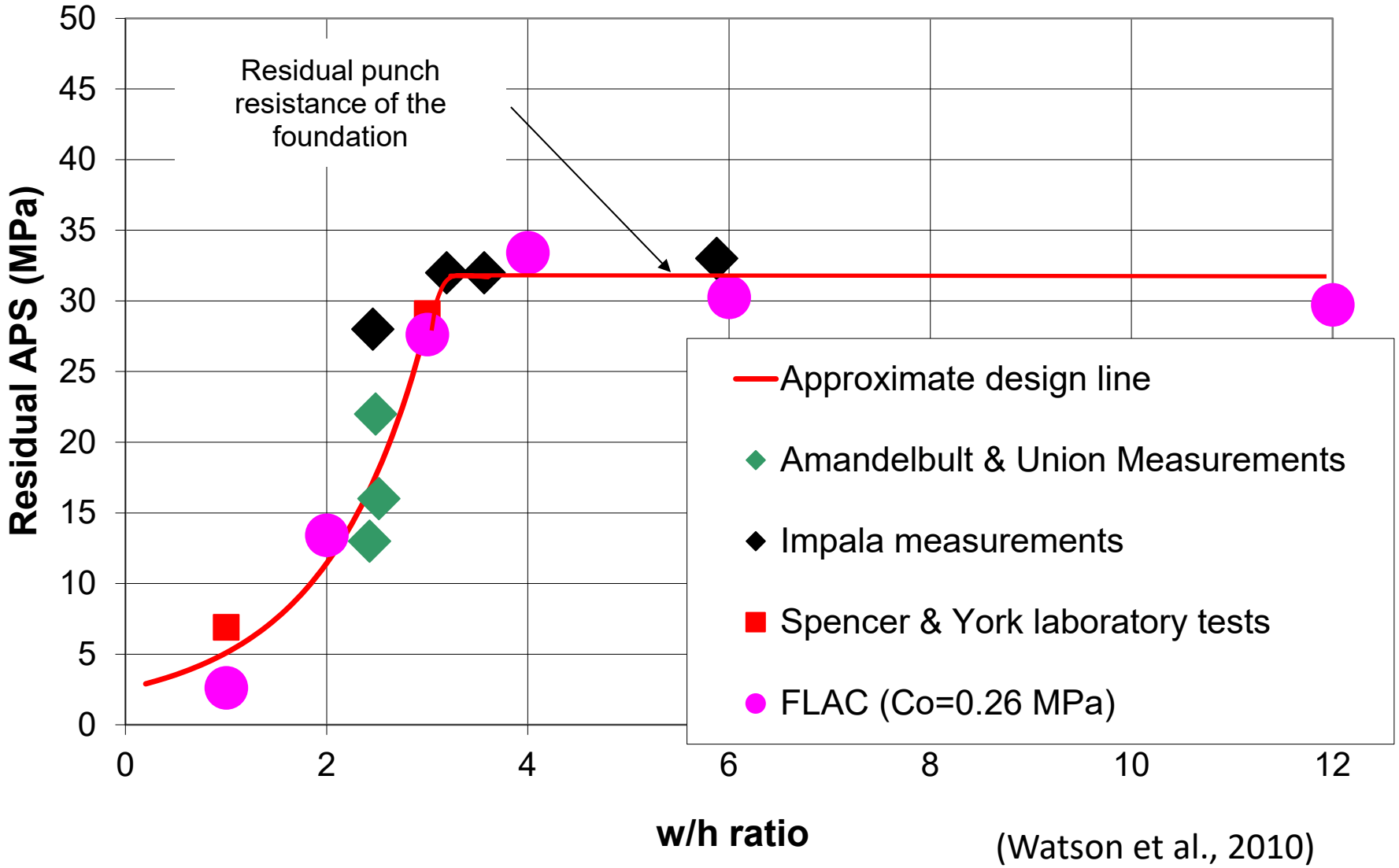
(Watson et al., 2009)

Drop in residual strength with reduced deformation



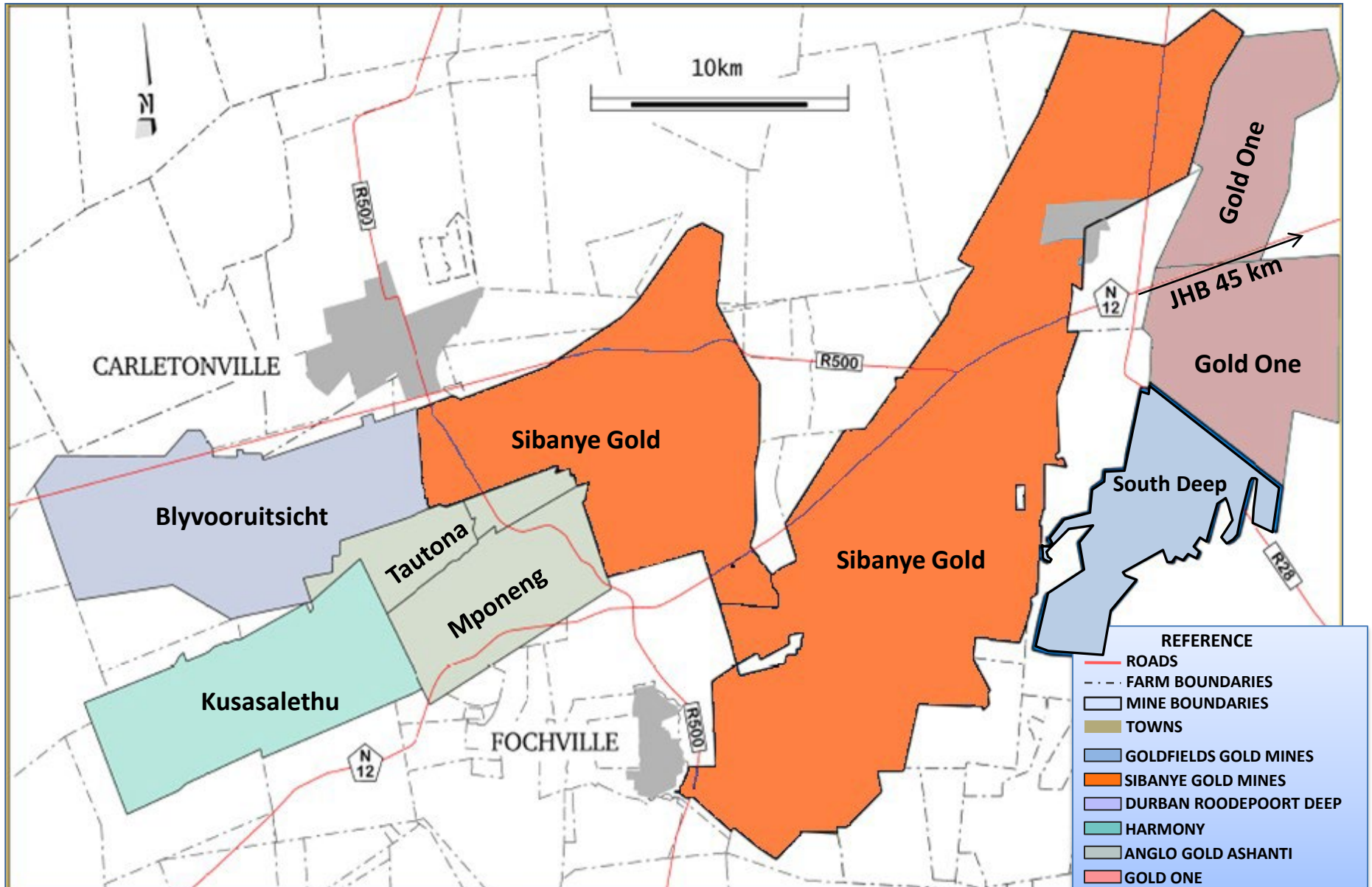
(Watson et al., 2010)

Crush pillar strength as a function of w/h ratio



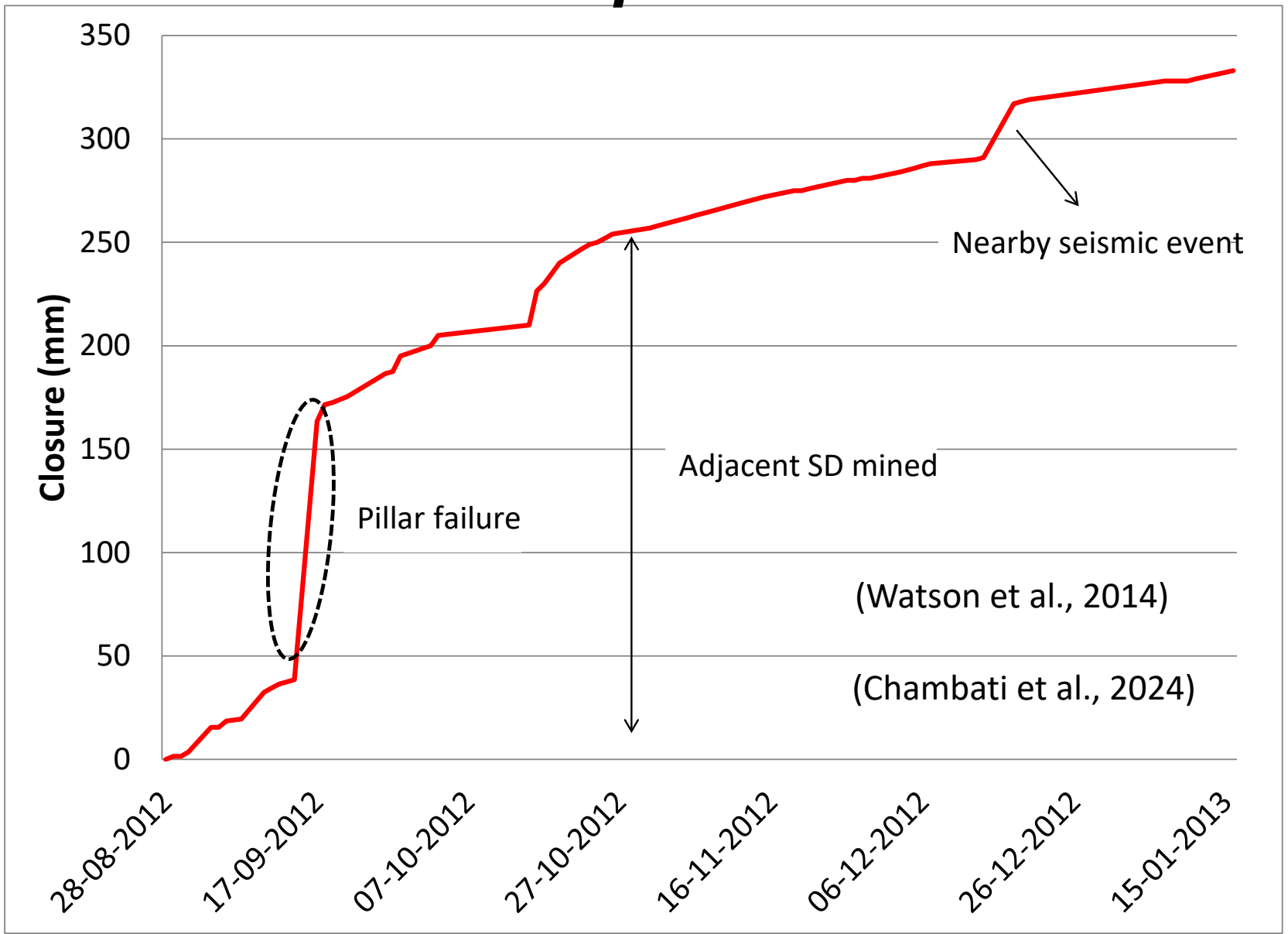
(Watson et al., 2010)

South Deep Gold Mine

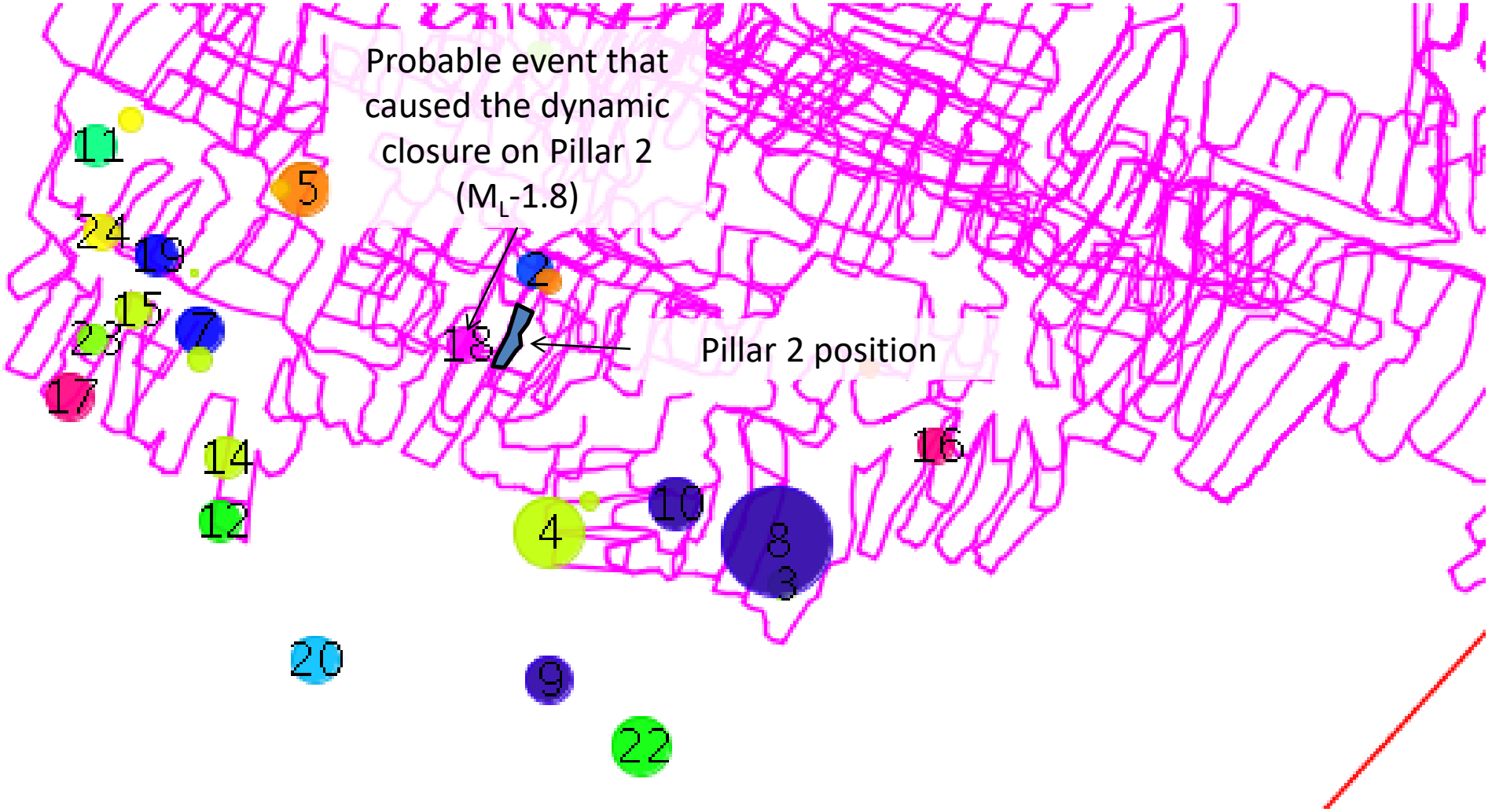


Crush pillars at 3000 m below the surface

Closure in a destress stope at South Deep Gold Mine

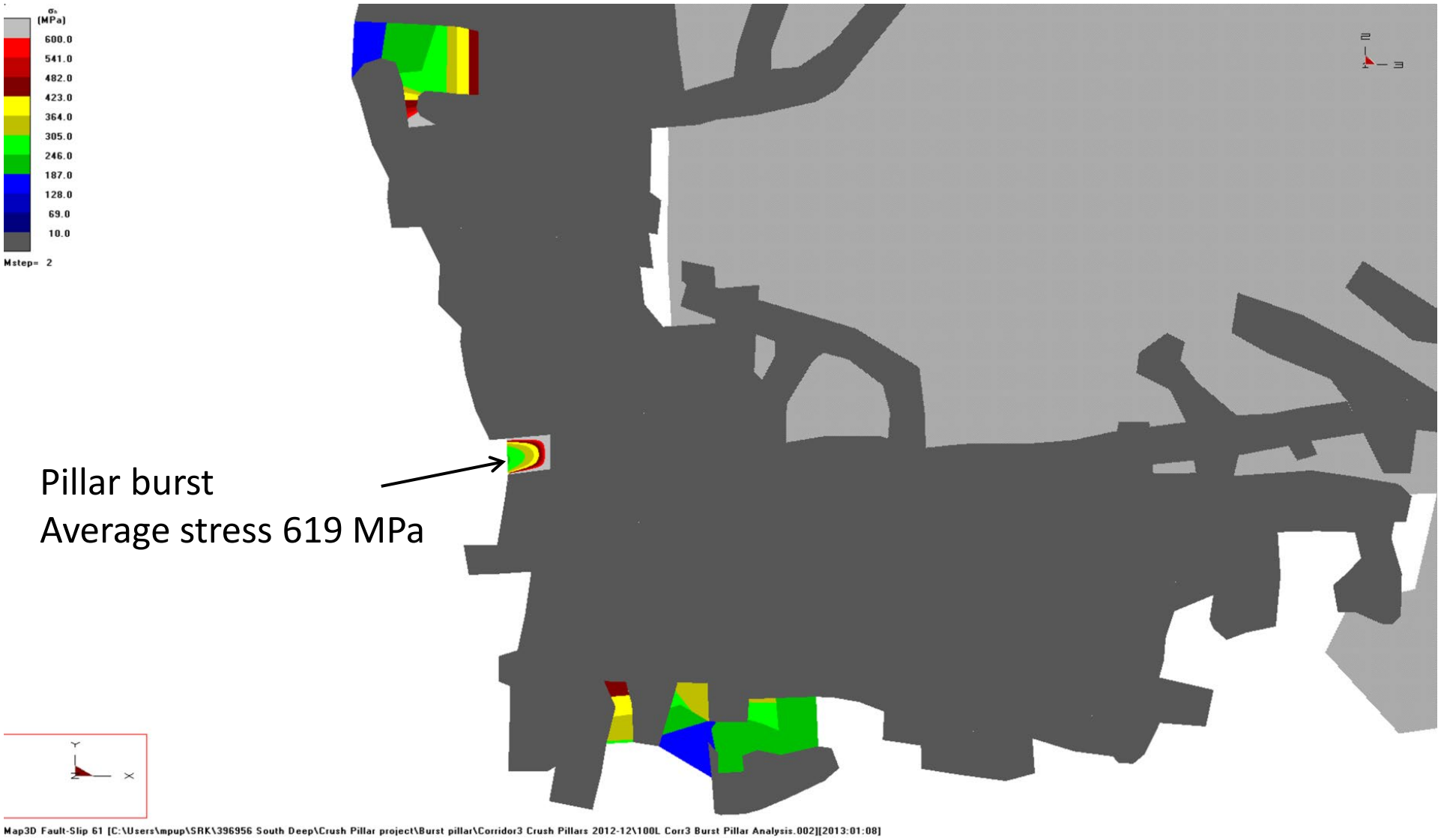


Location of a seismic event (M_L= -1.8)

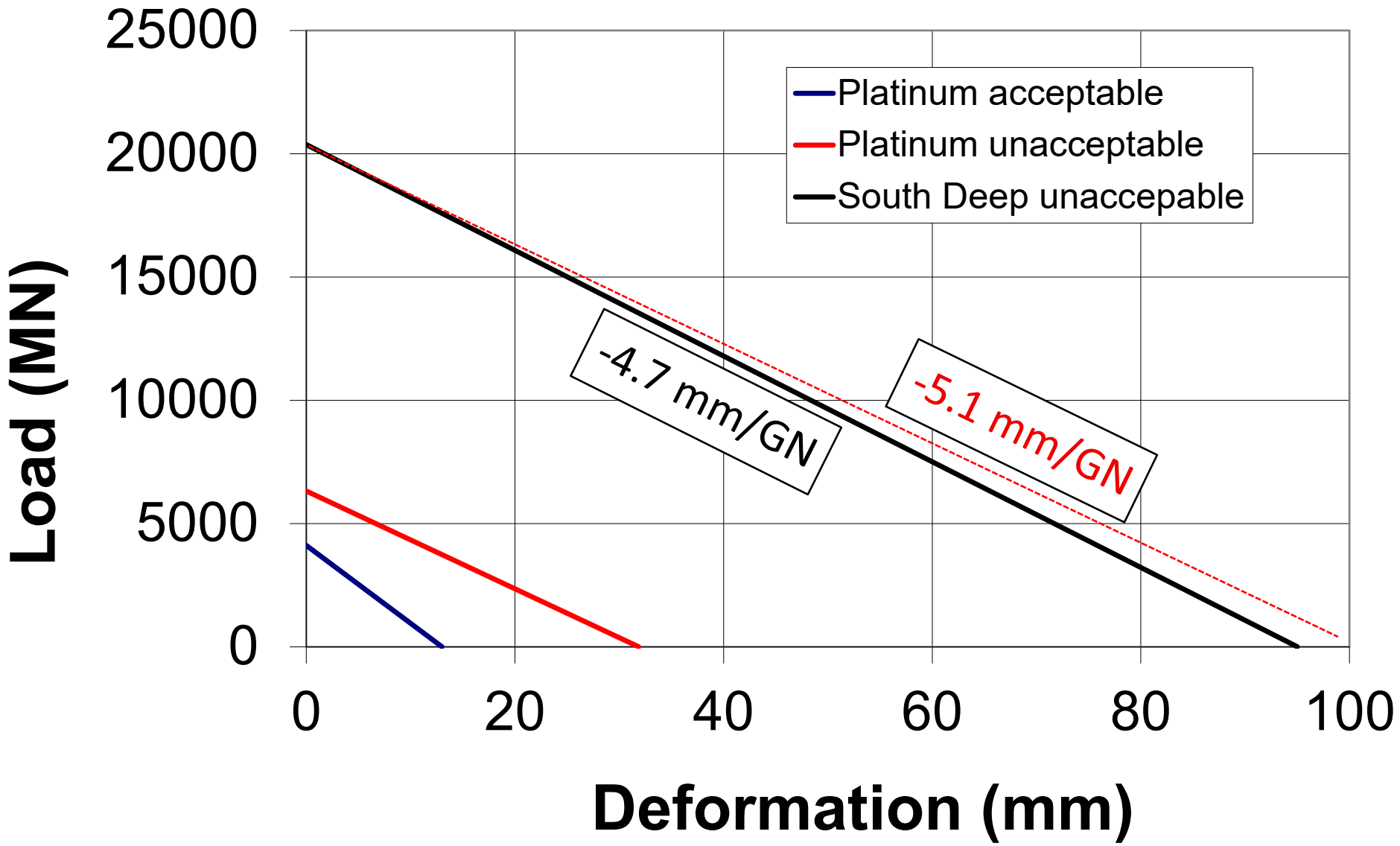



Quartzite pillars
(APS= 37 MPa for w/h= 1.7)
(3000 m below surface)

100 level corridor 3

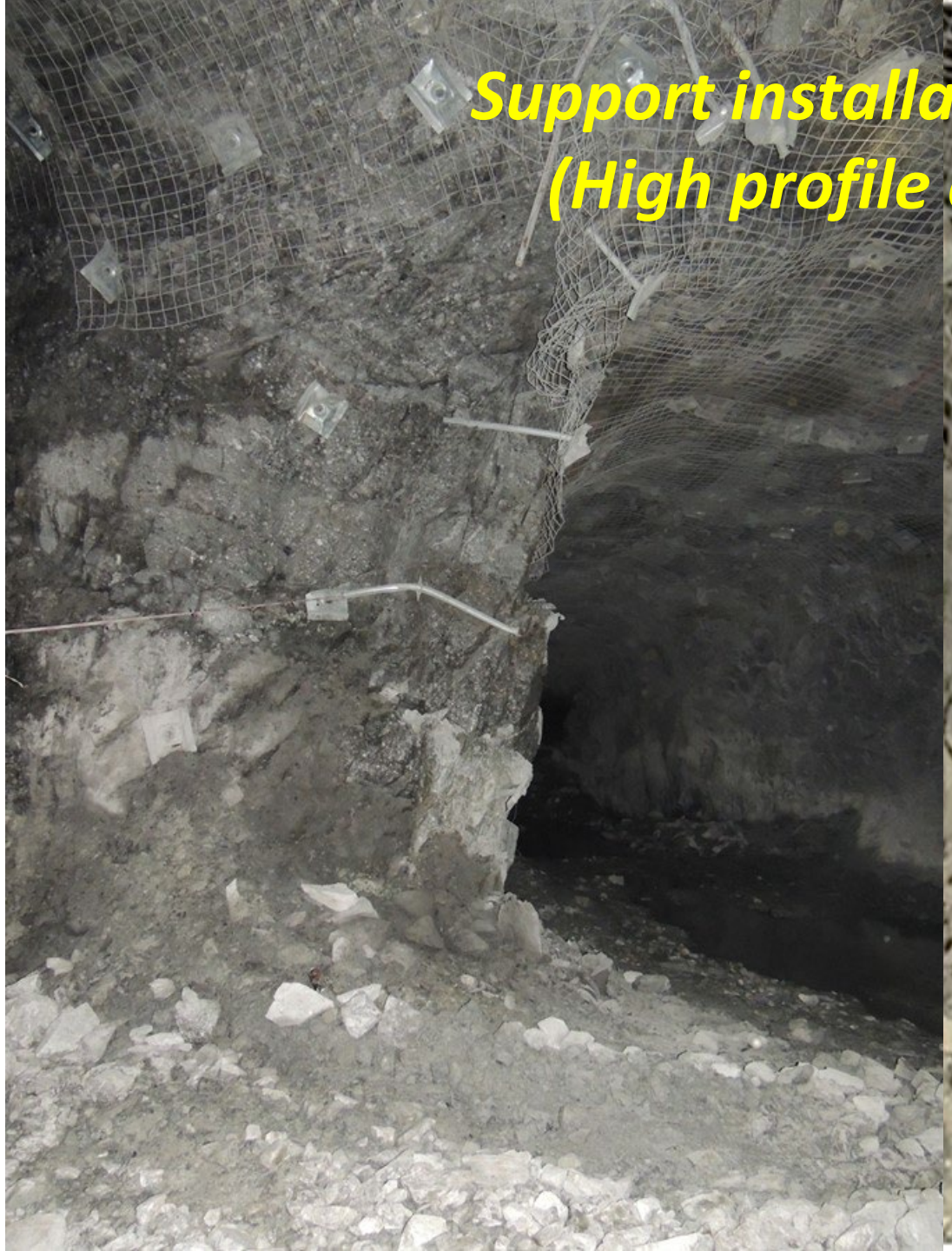


Unloading stiffness measurements (Unacceptable stiffness for quartzite)

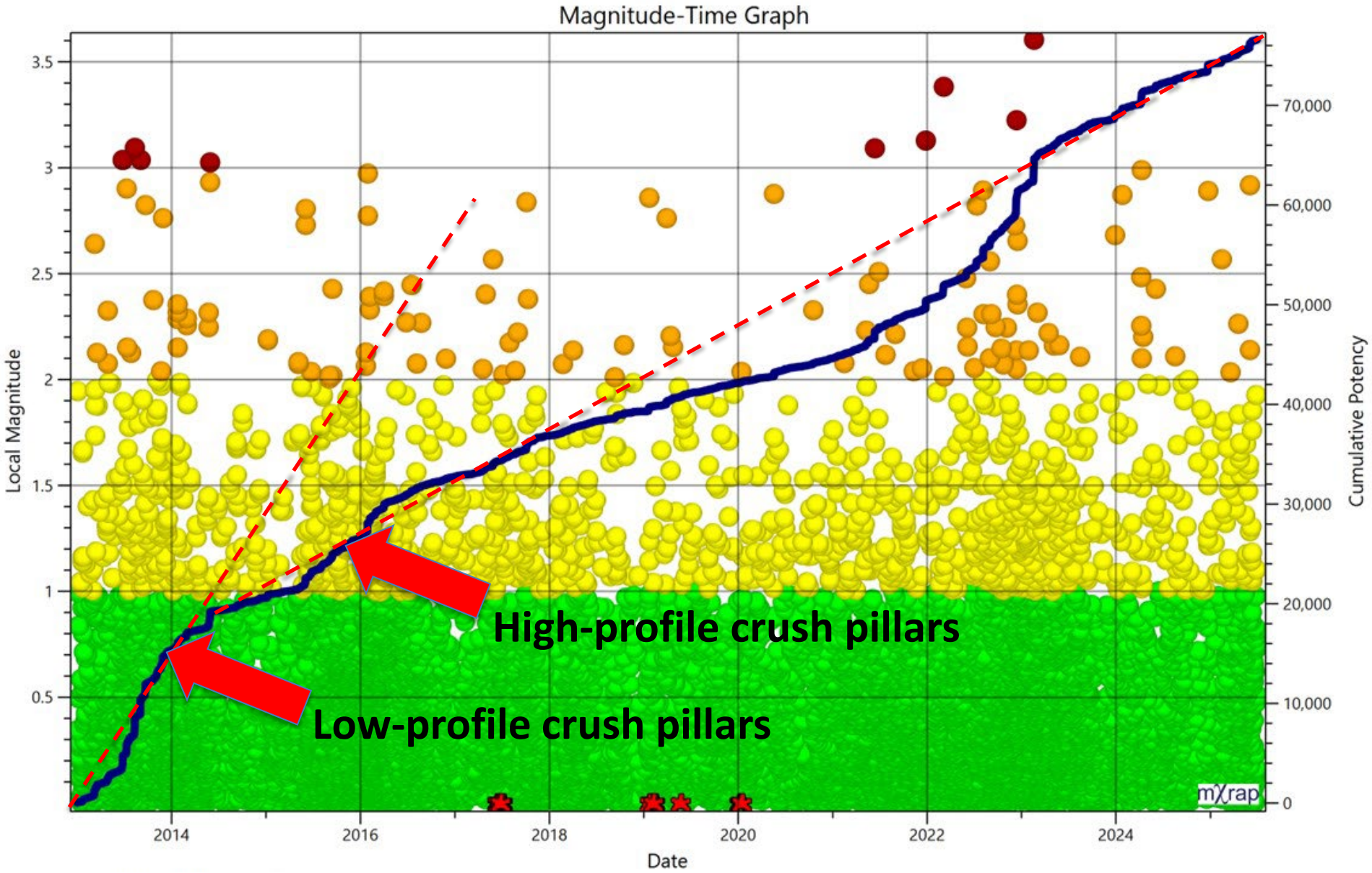


Strain burst
(Pillars too wide)

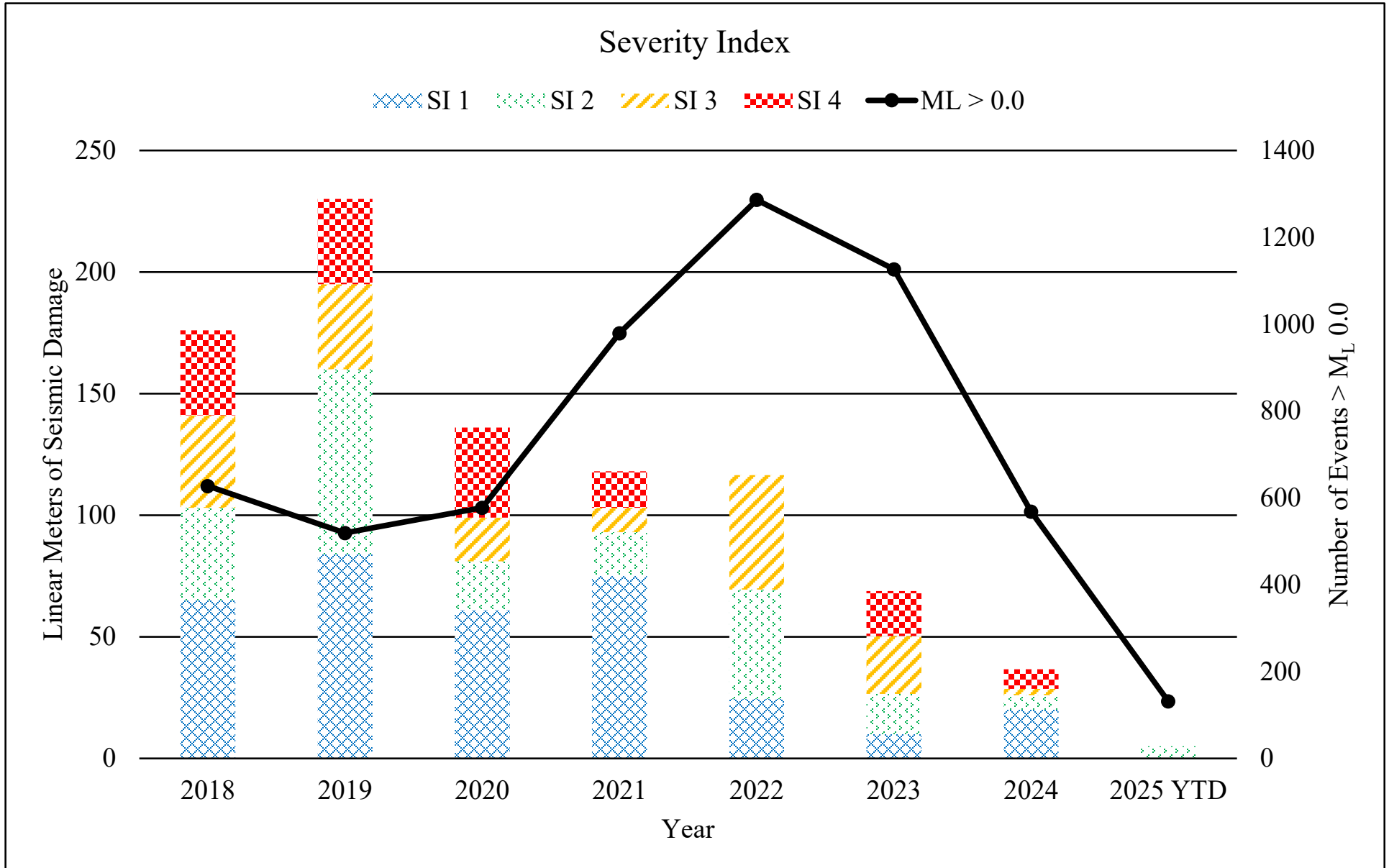
Support installation difficulties (High profile crush pillars)



Mine seismicity
(Before and after the crush pillar introduction)

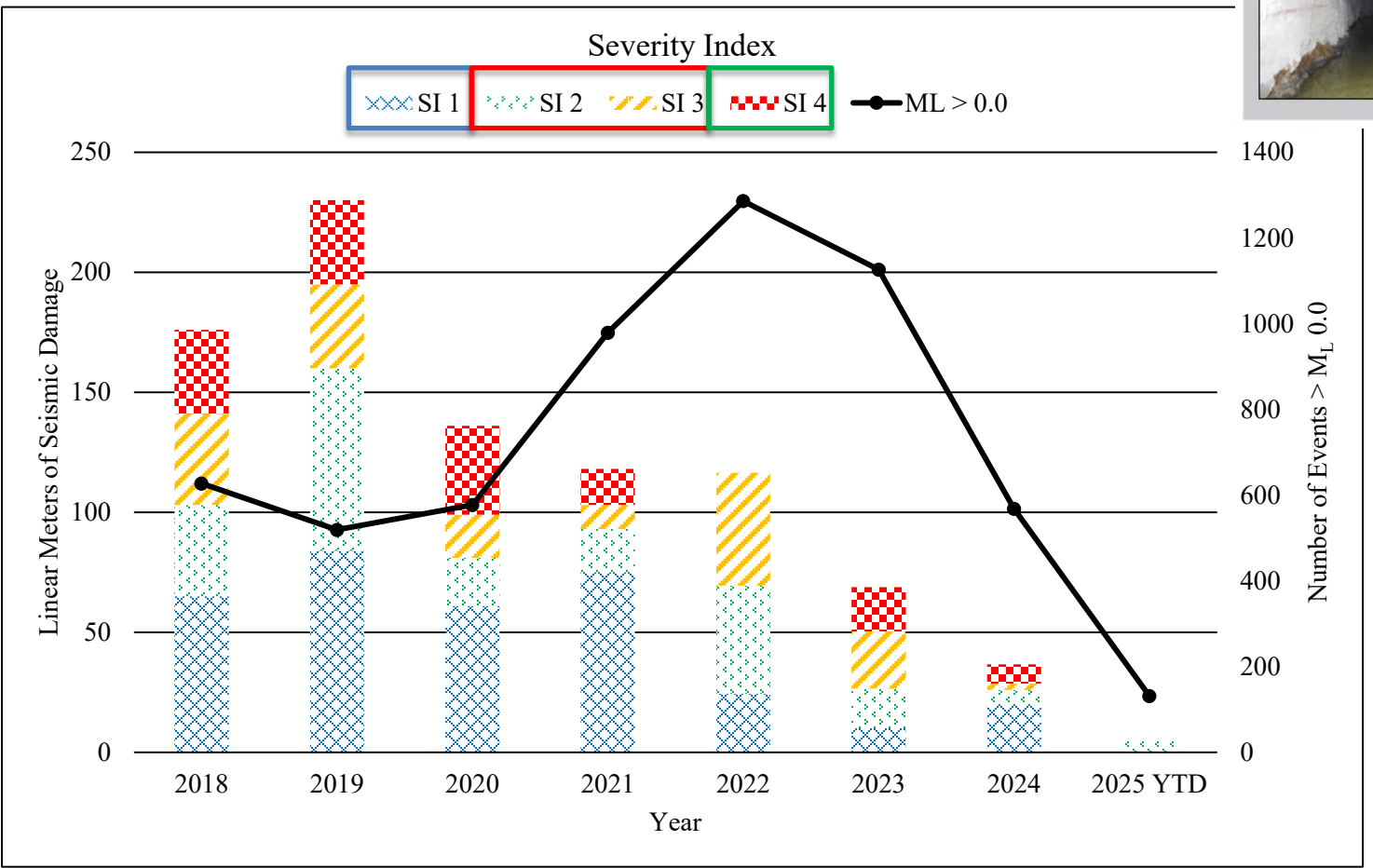


Reduced seismicity (right-size crush pillar)



Reduced seismicity (right-size crush pillar)

1	2	3	4
No Ejection	Ejection thickness < Length of Yielding Support		Ejection thickness > Length of Yielding Support
Support Holding	Bolts Intact Mesh Failed	Bolts Failed Mesh Failed	
			



Ms Banjwa & Mr Sibanda

Reduced damage
(sufficient support & installed correctly)

Ms Banjwa

Questions?