JMConsulting-Rock Engineering

TBM "Boreability" in Hard Rock

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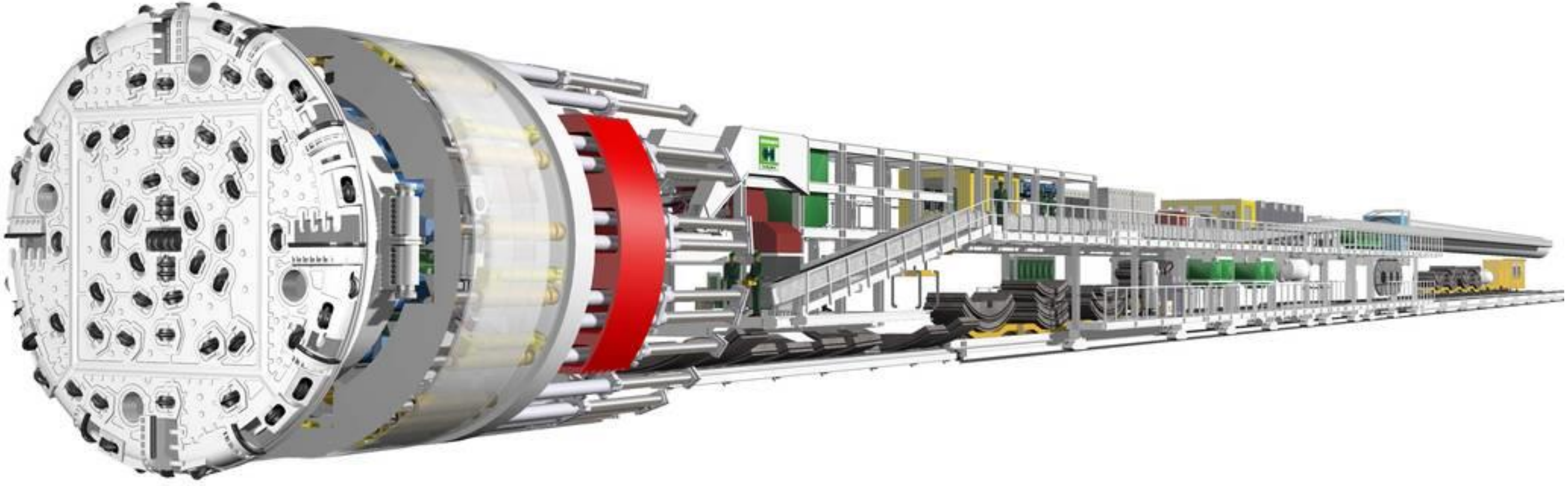
NORSK BERGMEKANIKKGRUPPE

Rock Engineering

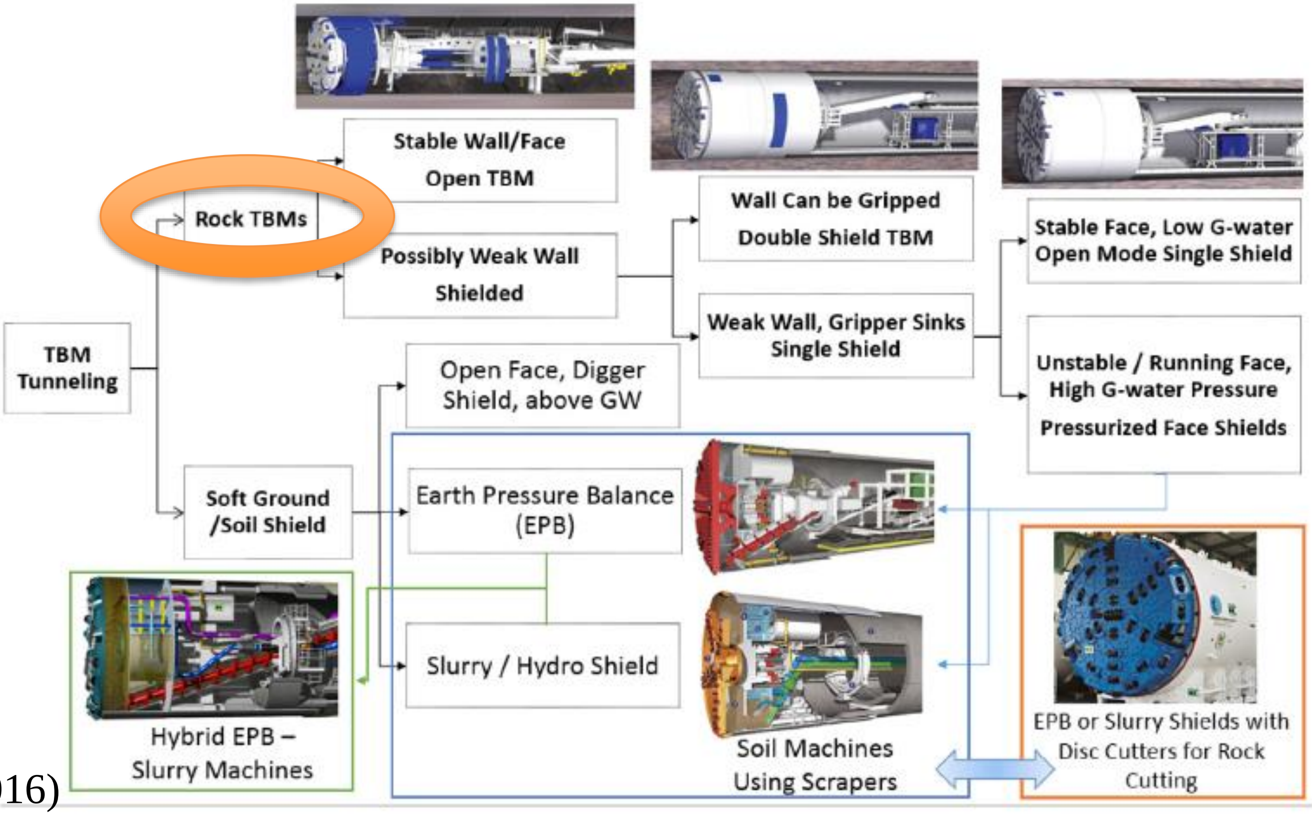
Outline

- Introduction
- What is rock boreability?
- Drillability
- Rock mass assessments
- Conclusive remarks

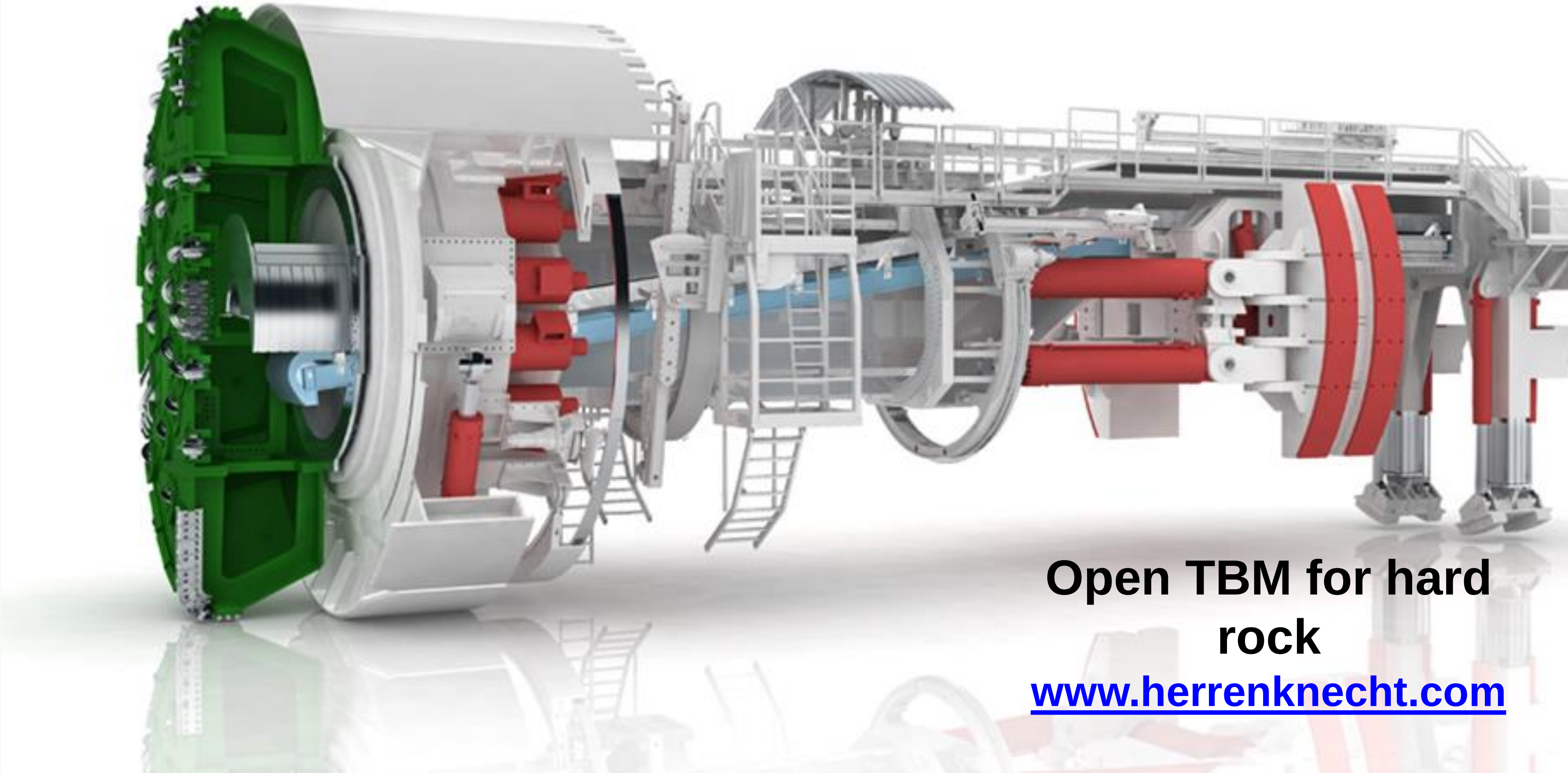
Tunnel Boring Machine (TBM)



TBMs in faulted rock



Rostami (2016)



Open TBM for hard rock

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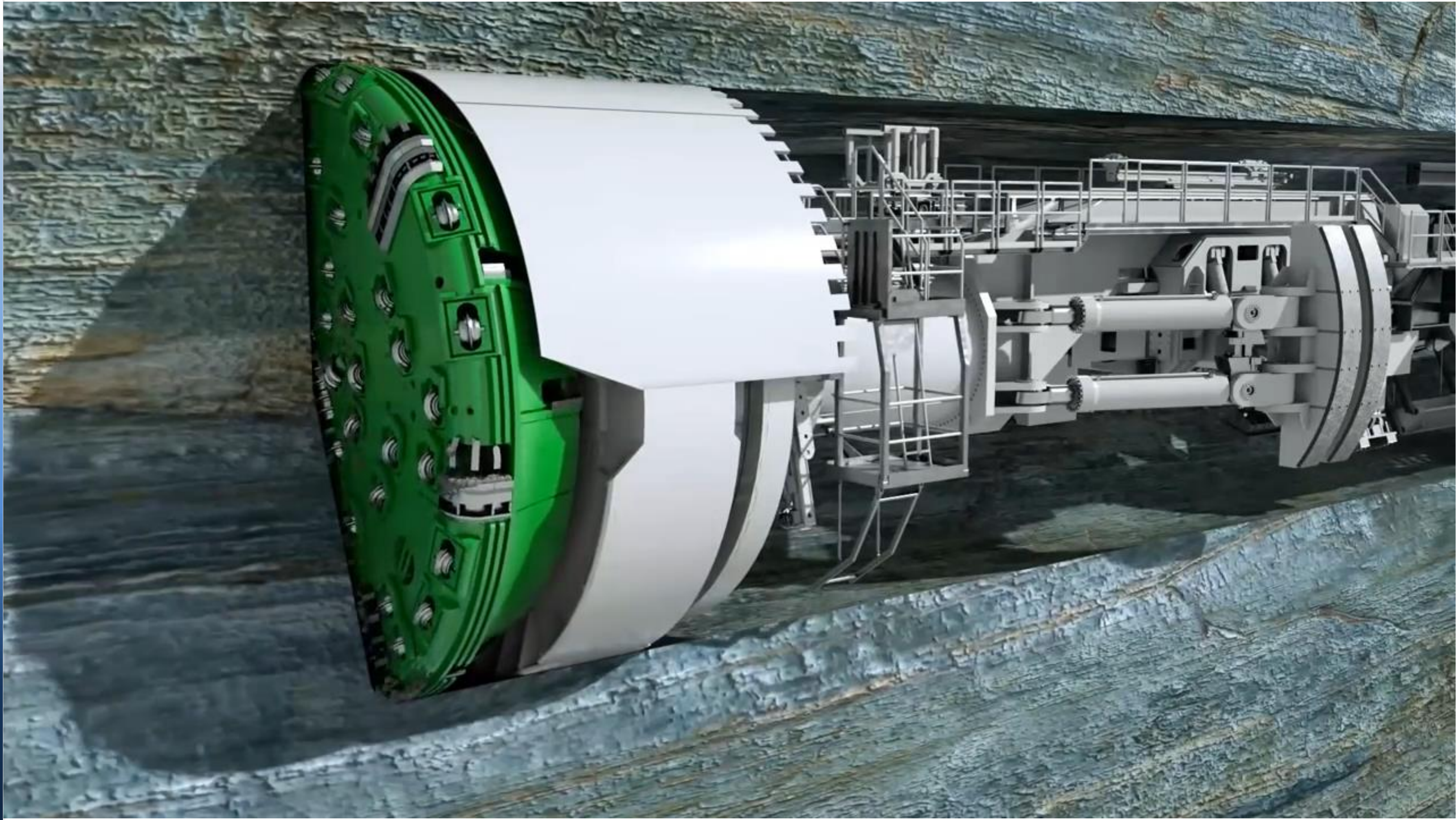
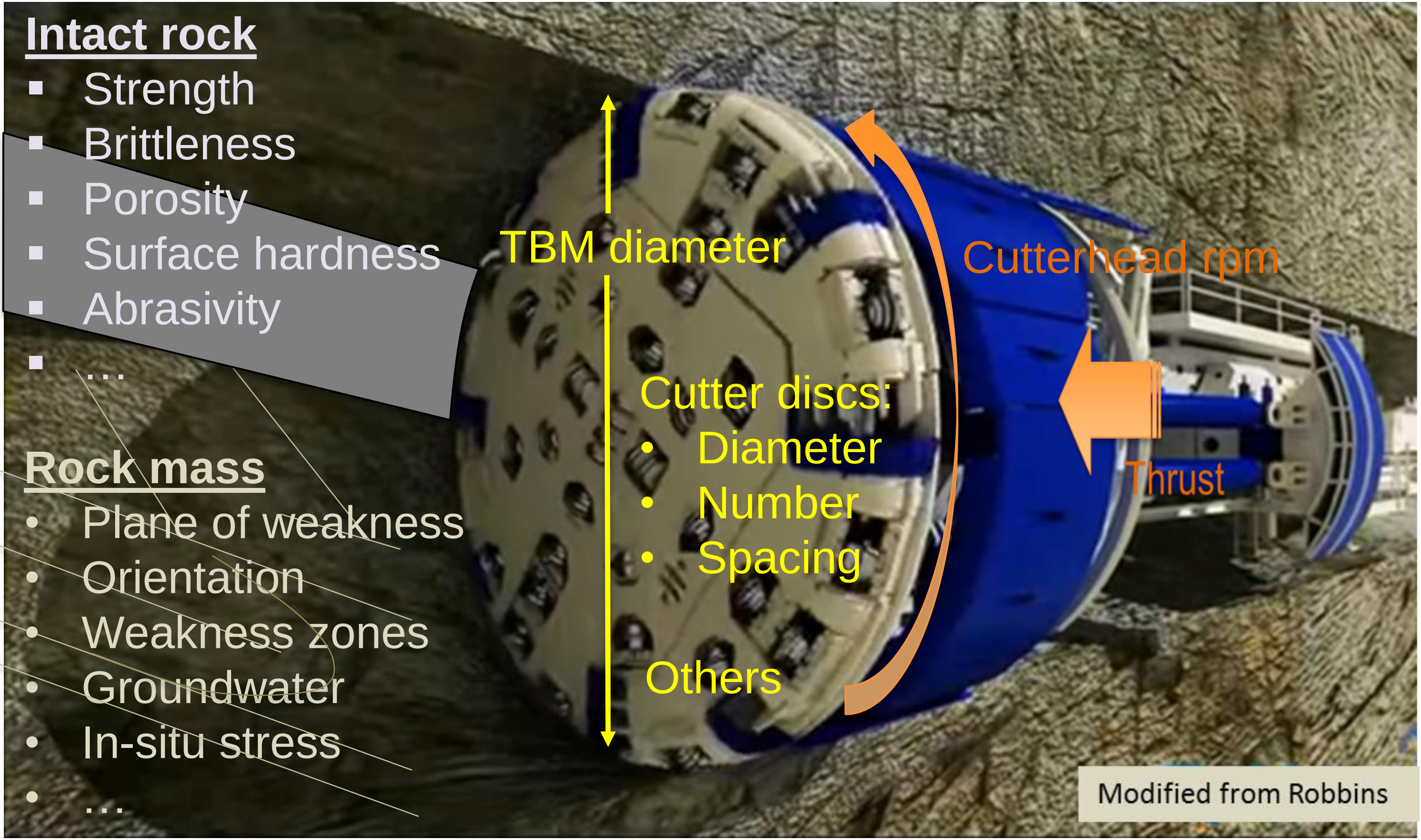


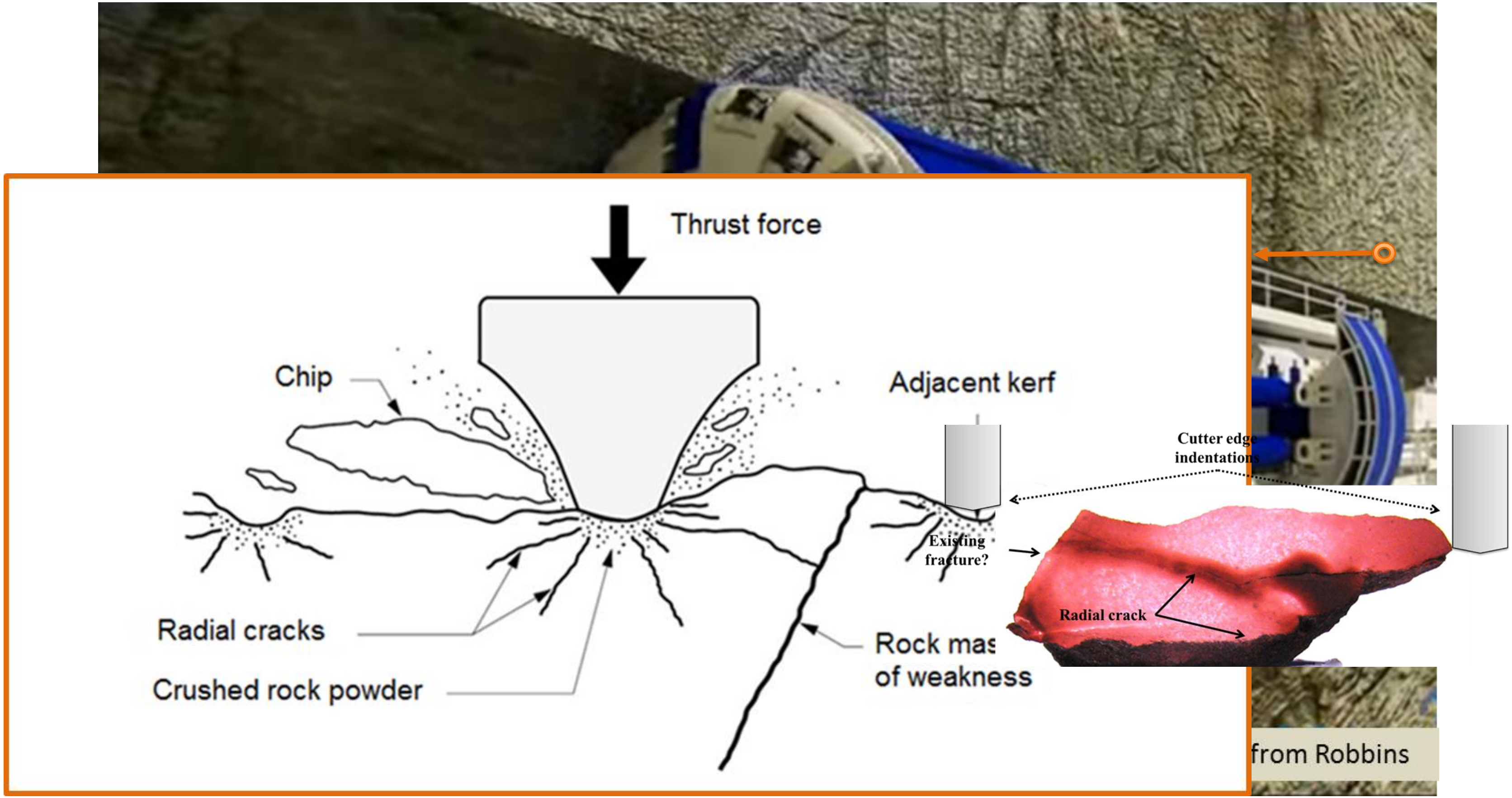
Cutterhead and cutter discs

Cutterhead and cutter discs

Hard rock tunnel boring



Hard rock tunnel boring



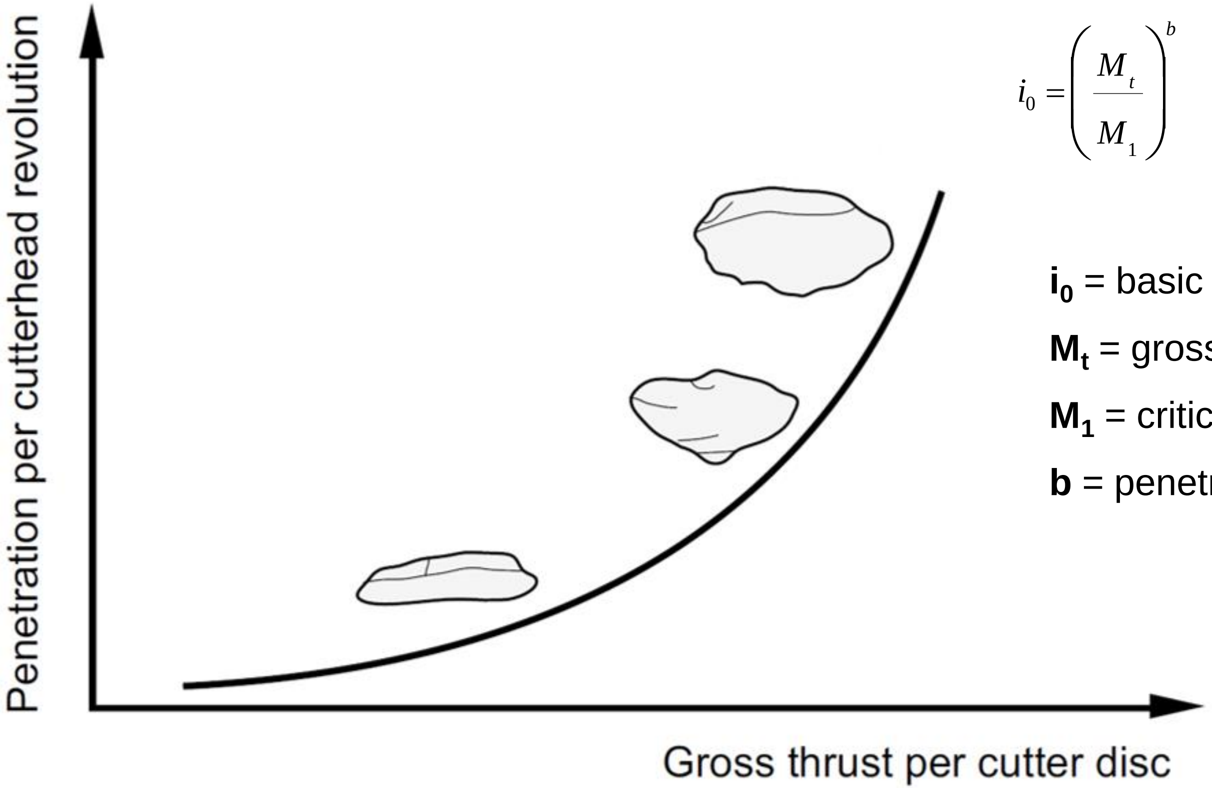
Rock boreability

- TBM boreability can be defined as :

  The resistance (in terms of ease or difficulty) encountered by a TBM as it penetrates a rock mass (intact rock containing planes of weakness)

- Intact rock – Drillability
- Rock mass

Rock boreability



$$i_0 = \left(\frac{M_t}{M_1}\right)^b \quad \text{(mm/rev)}$$

i_0 = basic penetration rate

M_t = gross cutter thrust

M_1 = critical cutter thrust

b = penetration coefficient

Modified from Bruland (2000)

Rock drillability

"Ability of the *intact rock* to be drilled or bored"

"Influence that intact rock properties on performance prediction and cost evaluations"

Breakability

Abrasivity

Rock drillability

Main intact rock properties

- ❑ Strength
- ❑ Brittleness
- ❑ Surface hardness
- ❑ Wear capacity

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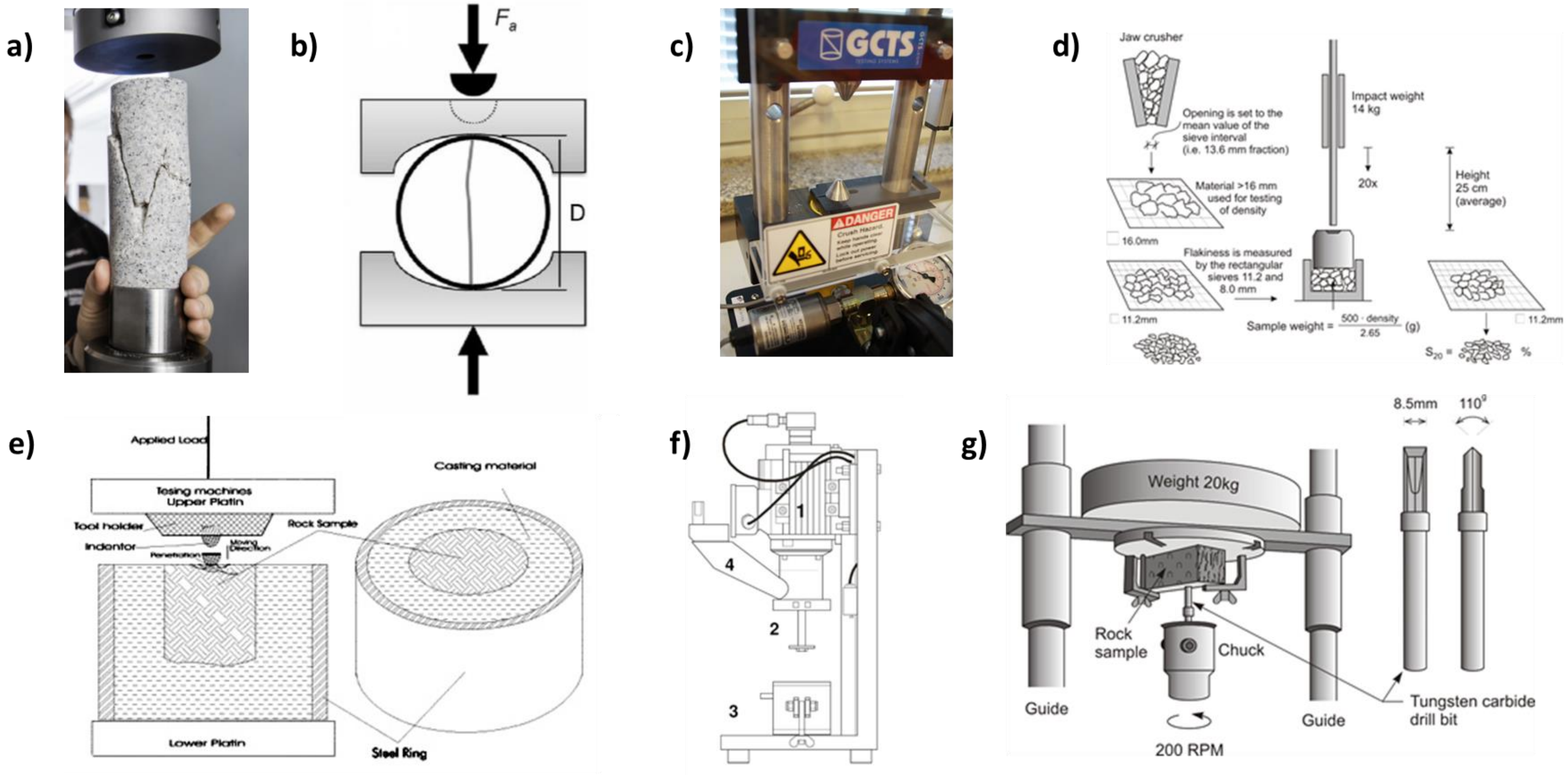
Laboratory test methods: "Breakability"



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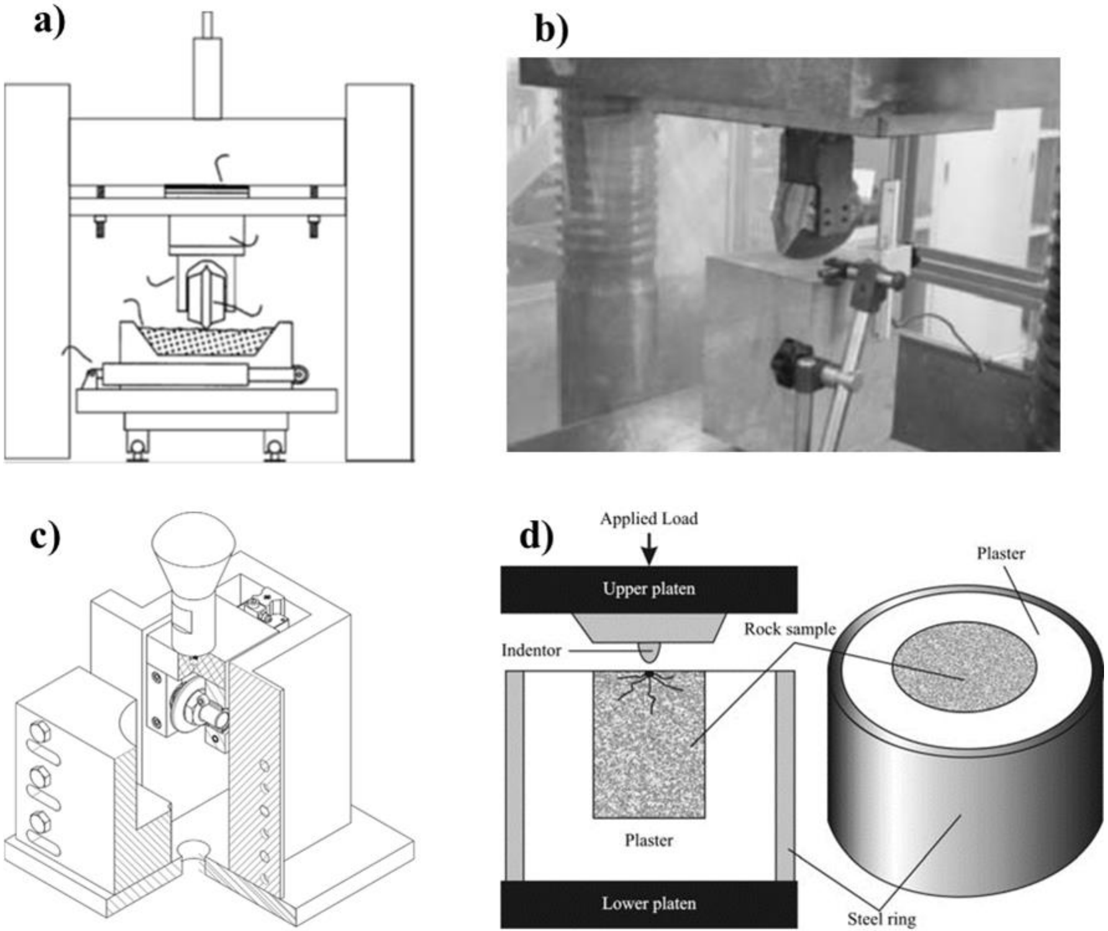
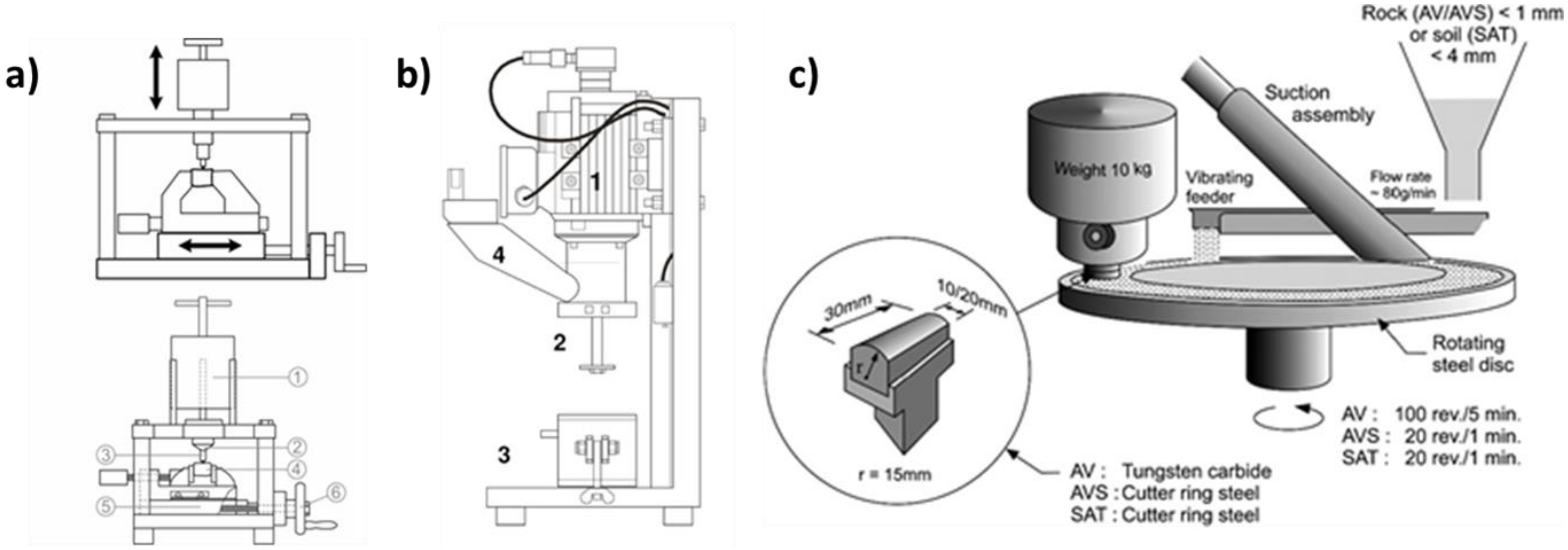


Laboratory test methods: "Abrasivity"



Rock abrasivity testing

Cerchar abrasivity test

LCPC test

Abrasion Value cutter Steel (AVS) test

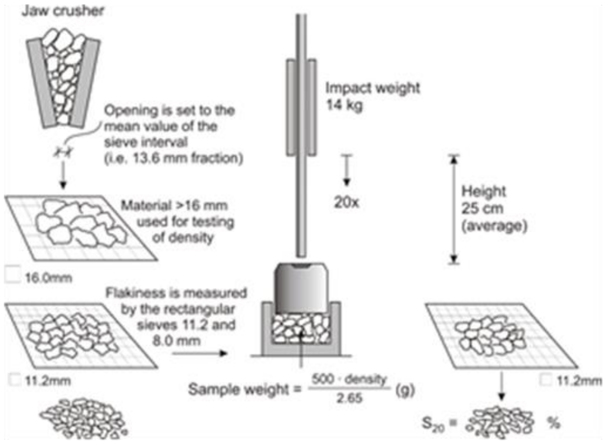
Drillability assessments for hard rock

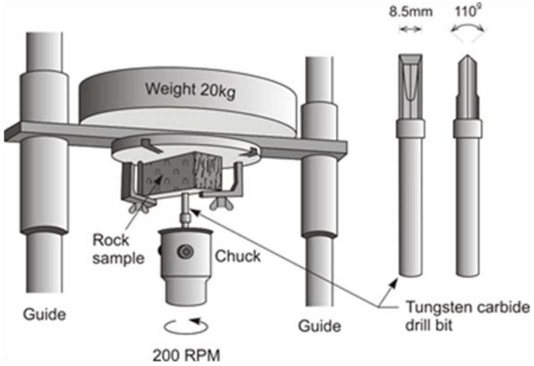
- Uniaxial Compressive Strength (UCS)
- Rock Toughness
- Drilling Rate Index (DRI)
- Cutter Life Index (CLI)
- Cerchar (CAI)

Laboratory test methods: "Breakability"

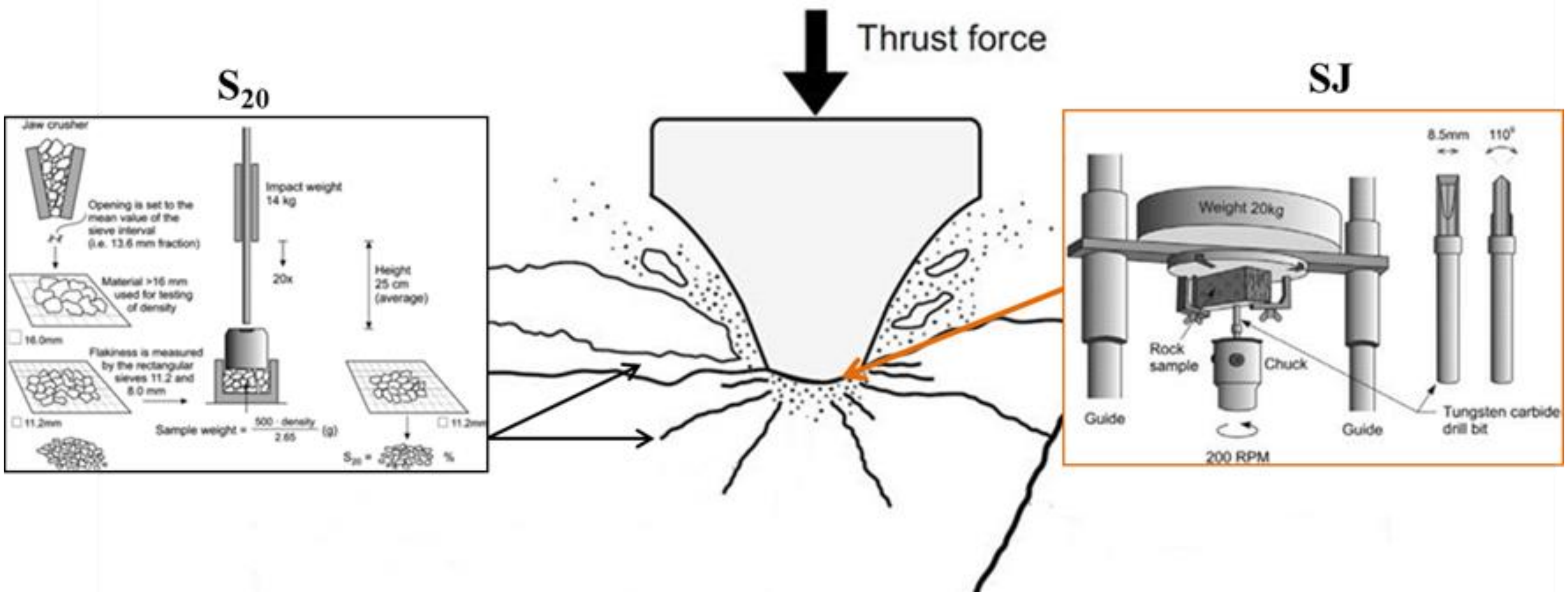
Drillability assessments for hard rock

- ➢ **Drilling Rate Index (DRI)**
- ➢ Cutter Life Index (CLI)



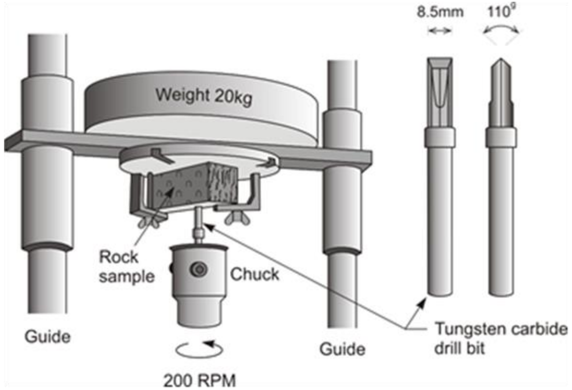


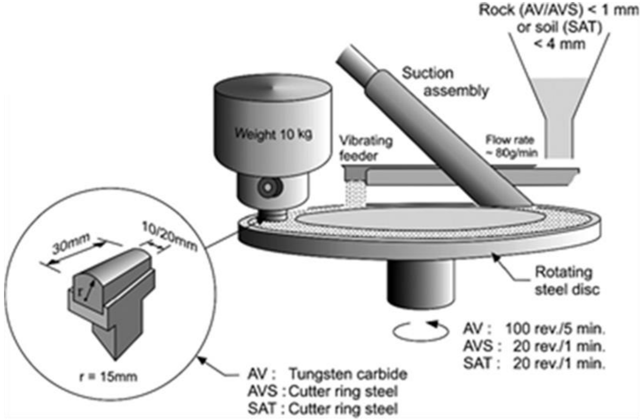
Drillability assessments for hard rock



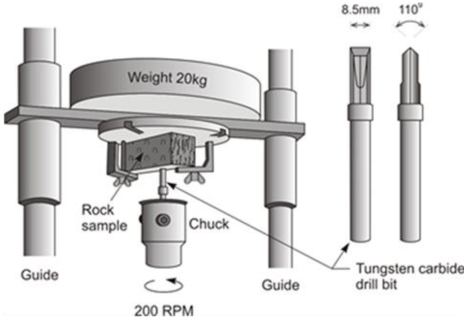
Drillability assessments for hard rock

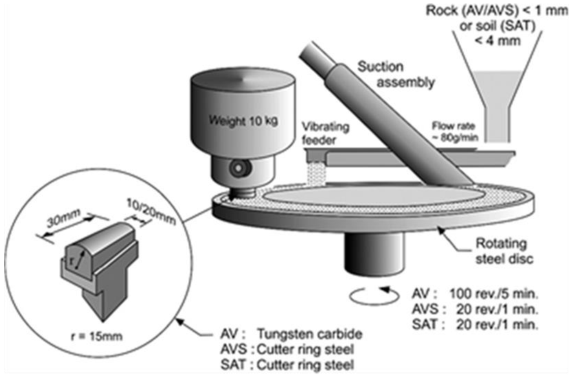
- Drilling Rate Index (DRI)
- Cutter Life Index (CLI)

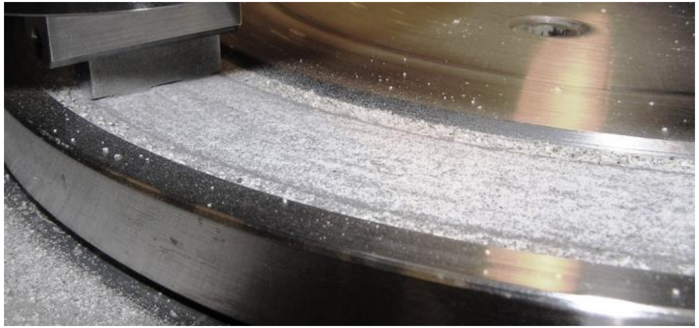




Laboratory test methods "cutter wear"







Rock Mass Assessments

- There is no single parameter that can fully represent the properties of jointed rock masses

Rock mass classification	Author	Year
Rock Quality Designation (RQD)	D.U. Deere	1964
Rock Mass Rating (RMR)	Z.T. Bieniawki	1973
Rock Tunnelling Quality Index (Q)	N. Barton, R. Lien and J. Lunde	1974
Degree of fracturing (k_s factor)	NTNU (NTH)	1981
Rock Mass Index (RMi)	A. Palmström	1995
Geological Strength Index (GSI)	E. Hoek and E.T. Brown	1997

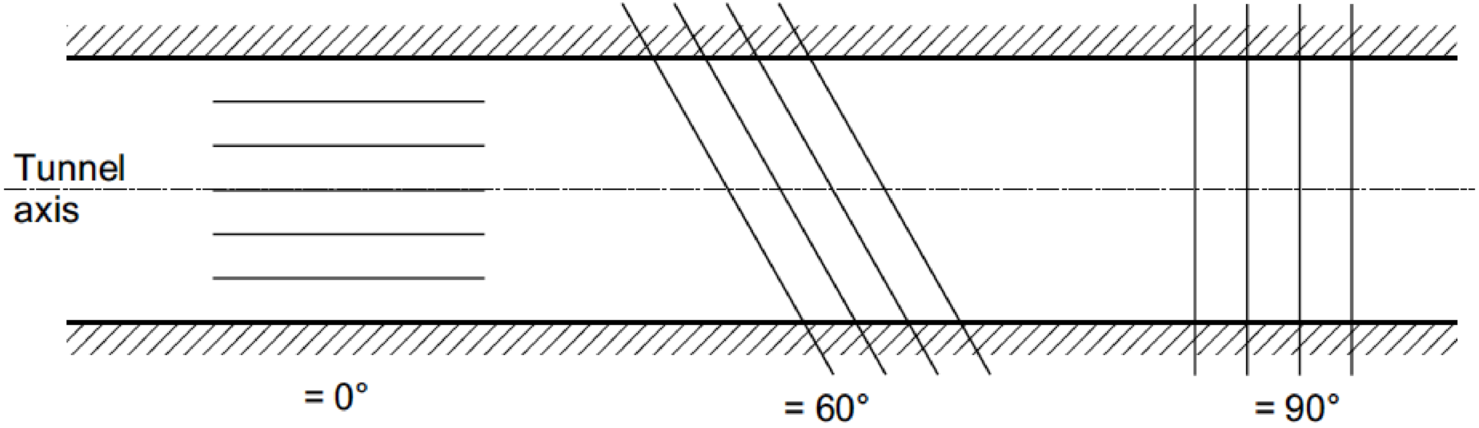
Rock Mass Assessments

- In hard rock tunnel boring:
  - Discontinuities or planes of weakness in a rock mass contribute considerably to net penetration rate and cutter wear
  - Degree of fracturing
  - Orientation regarding to the tunnel alignment
  - Joint characteristics (filling, persistence…)
  - In/situ stress
  - …

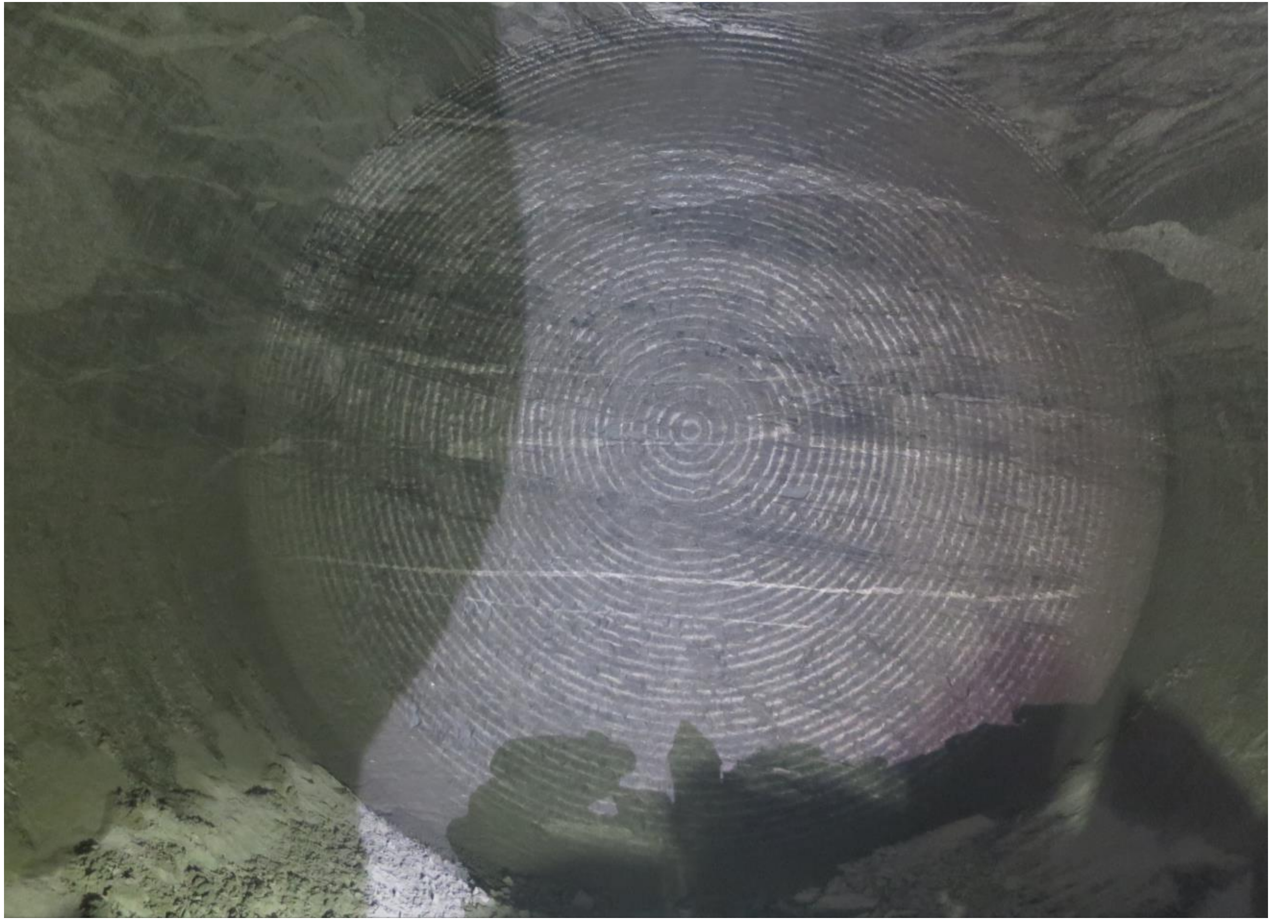
Rock Mass Assessments

Fracture Class (Sf)	Average spacing between fractures a_f (cm)	Range class (cm)	Degree of fracturing
0	∞	480 – ∞	Non-fractured
1	320	240 – 480	Extremely low
2	160	120 – 240	Very low
3	80	60 – 120	Low
4	40	30 – 60	Medium
5	20	15 – 30	High
6	10	7.5 – 15	Very high
7	5	4 – 7.5	Extremely high

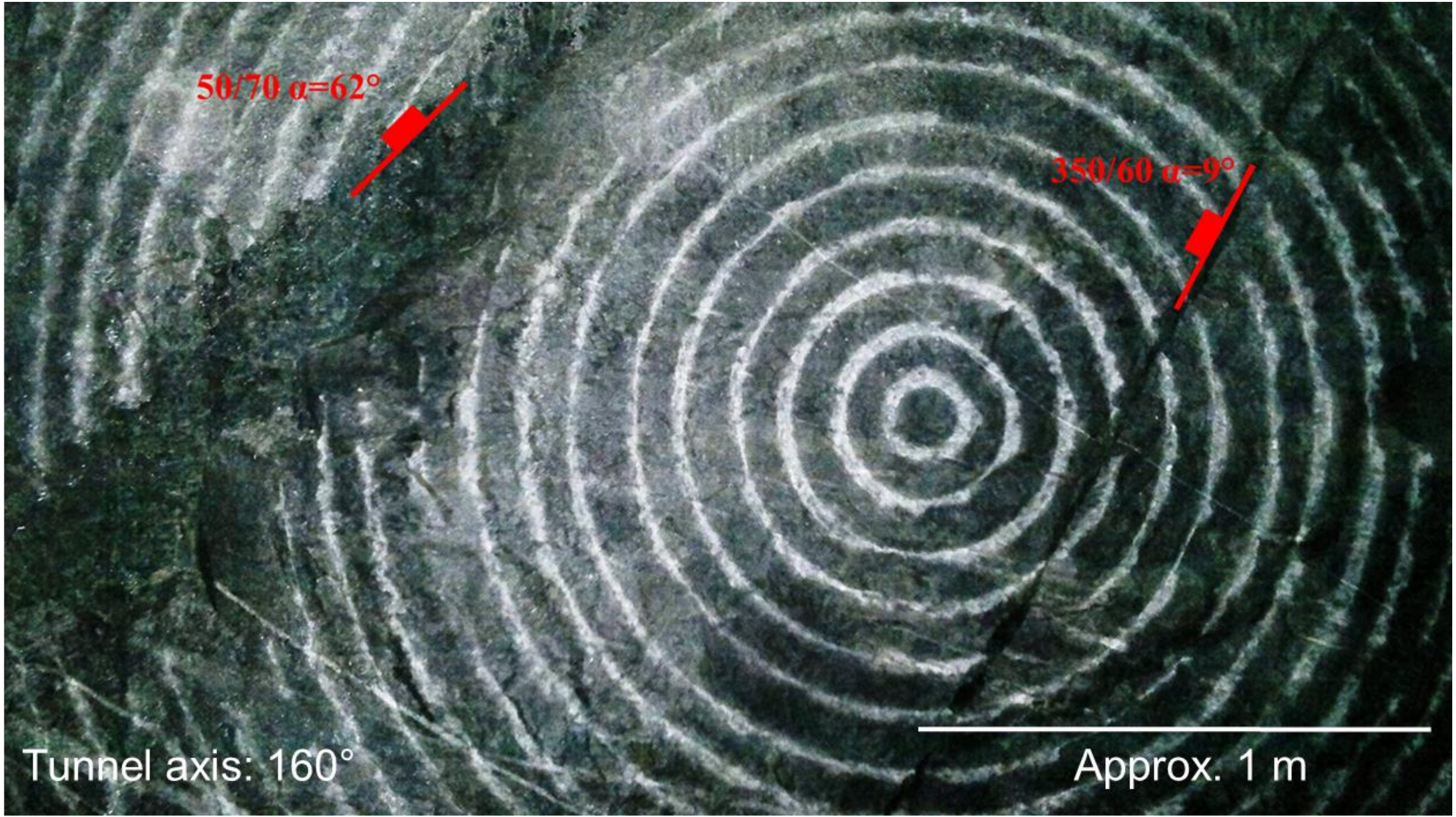
Rock Mass Assessments



Rock Mass Assessments



Rock Mass Assessments



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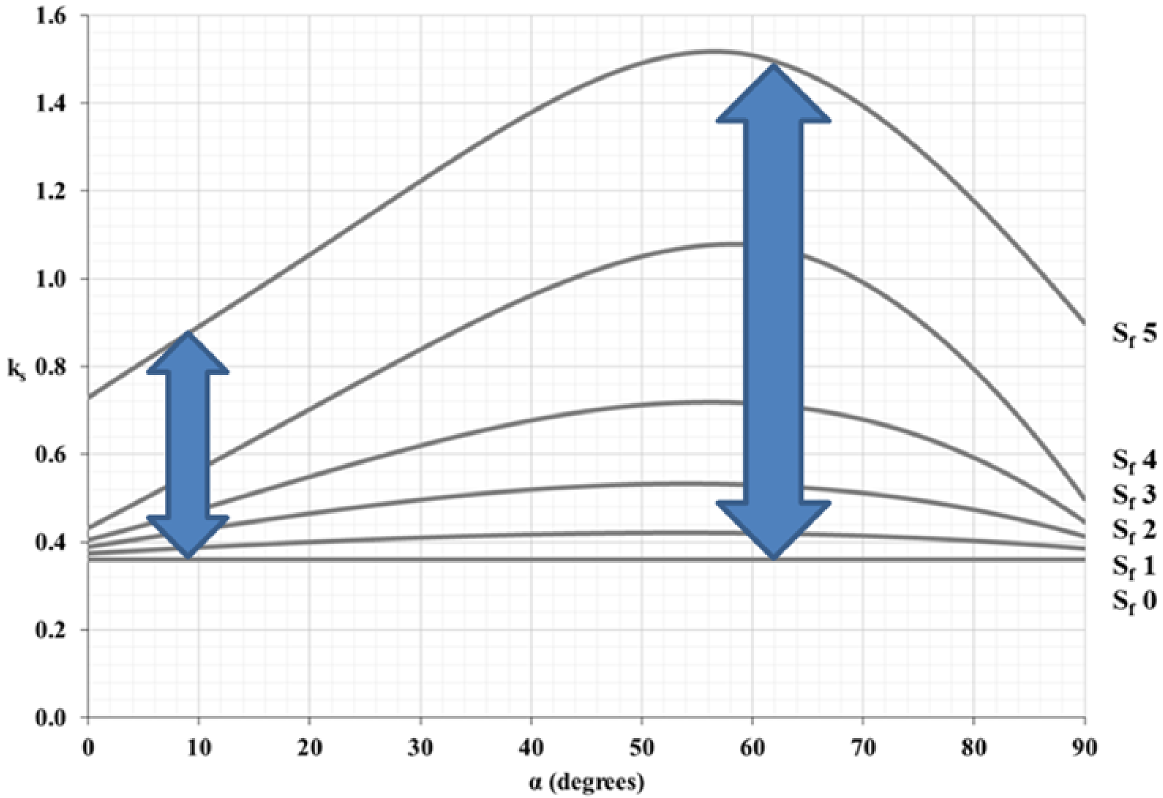

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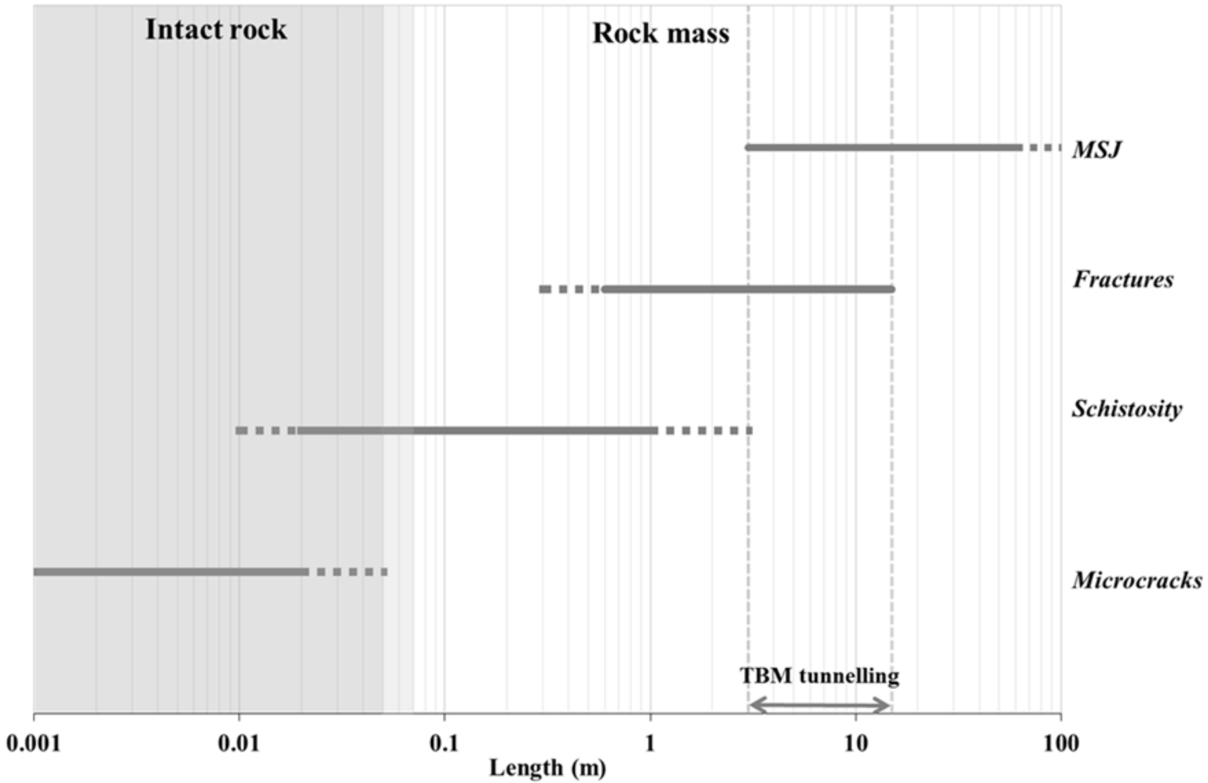

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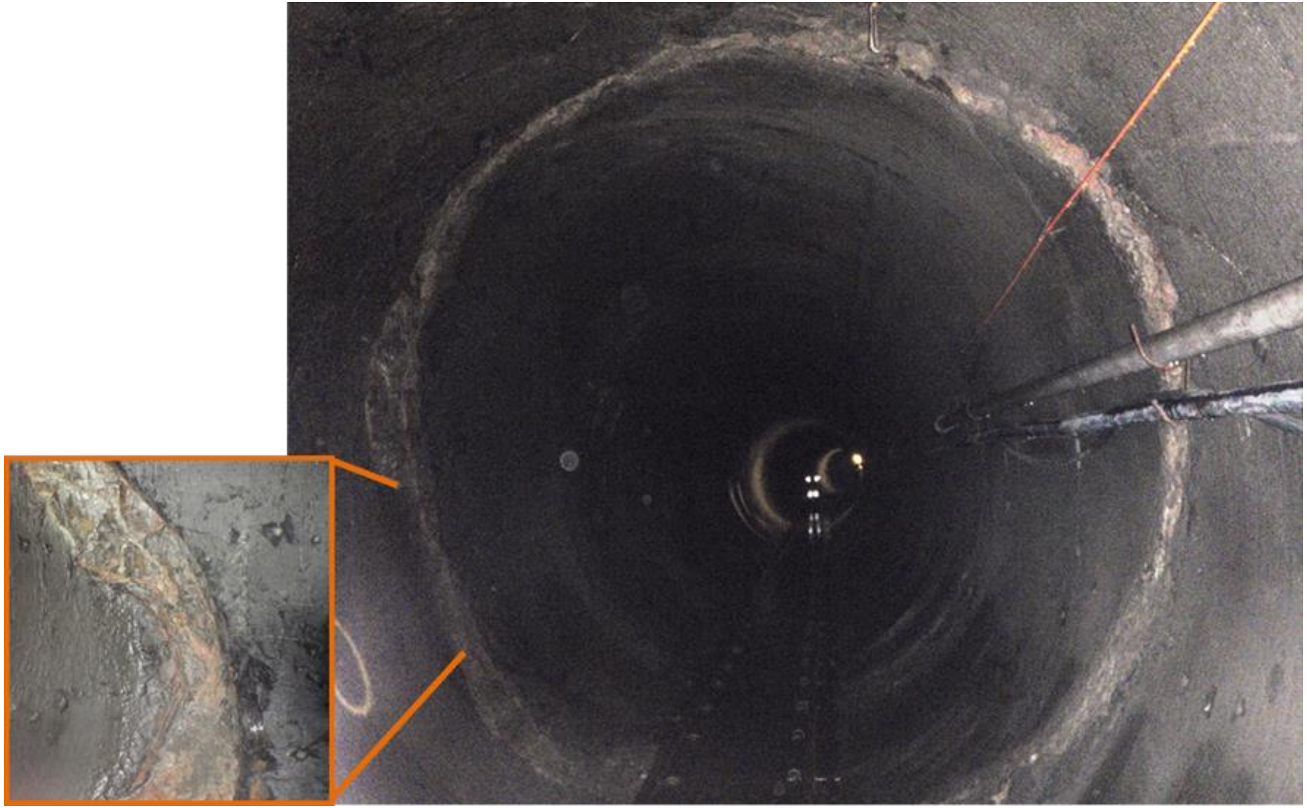

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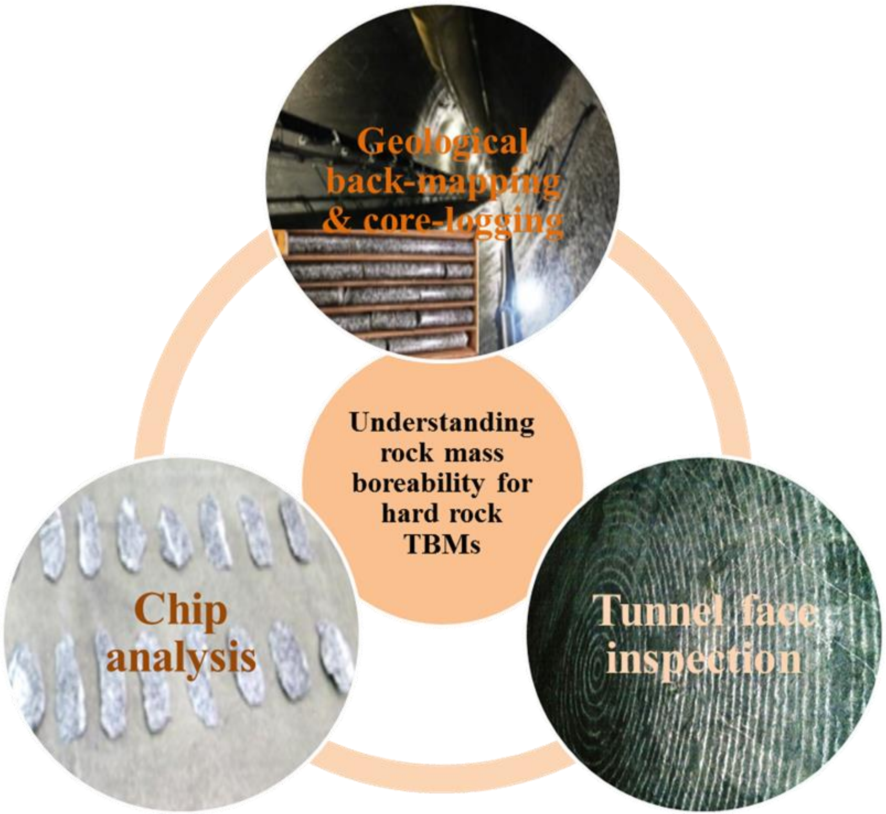

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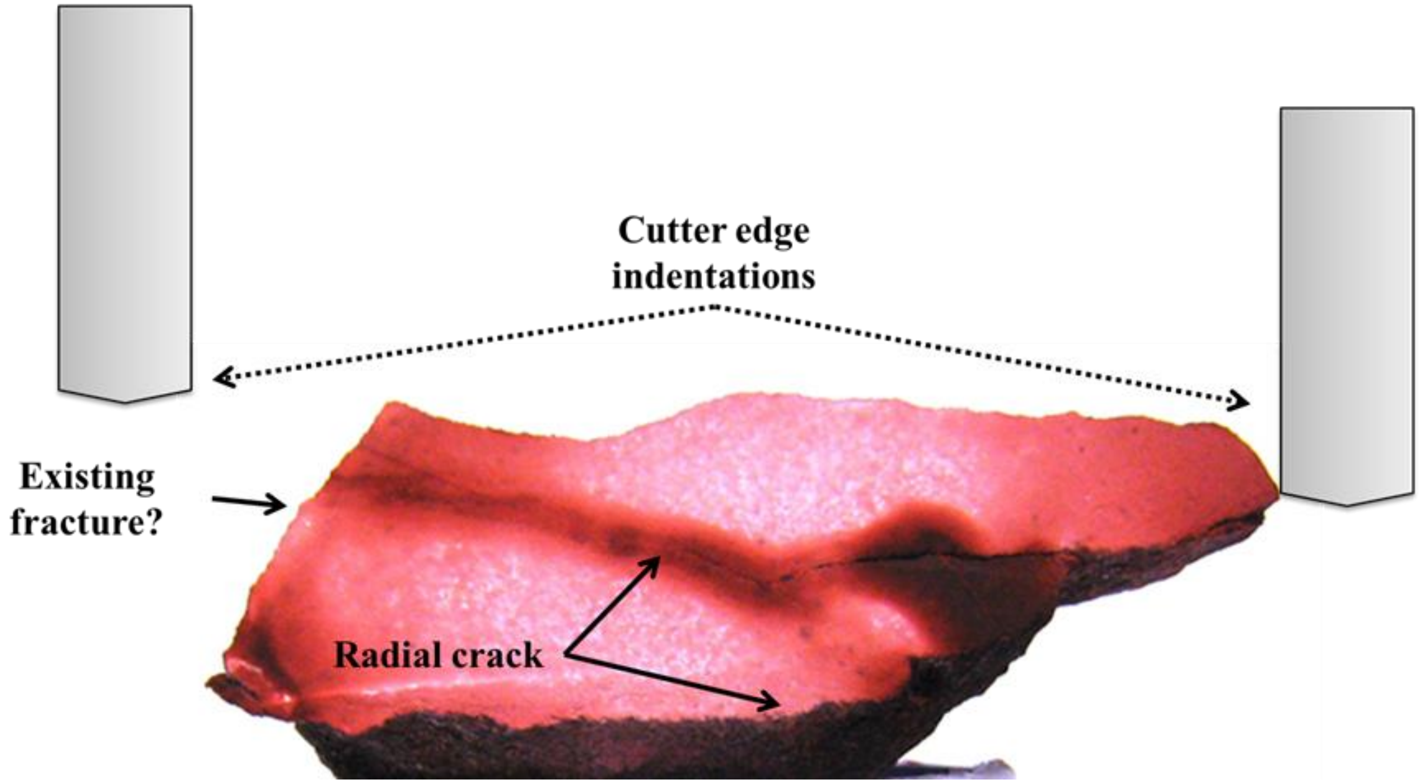

Conclusive remarks

- ‘Rock mass boreability’ is a comprehensive parameter:
  - Intact rock properties
  - Rock mass parameters
- Rock mass fracturing is found to be the geological factor that exerts the greatest influence on net penetration rate
- More effort should be emphasized on understanding the rock breaking process and tool wear tribological system


Takk!
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Rock mass influence