

Rock Mass Classification Series –

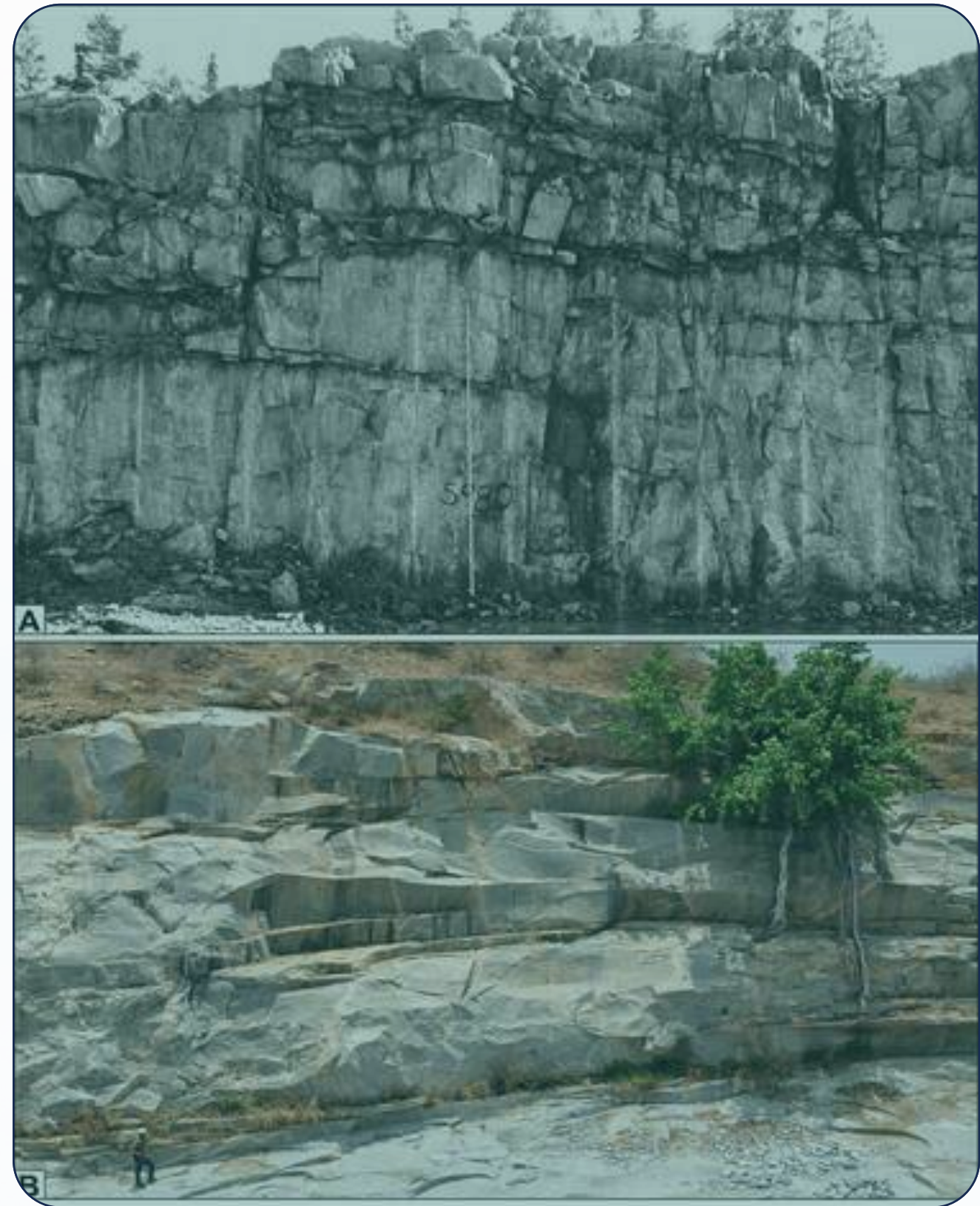
Rock Mass Rating (RMR)



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Rock Mass Rating (RMR)

➤ **Bieniawski (1976)** - for use in tunnels in hard and soft rocks

➤ **Scheme considers 6 factors:** **Range**

➤ Factor A1: **UCS** 0 to 15

➤ Factor A2: **RQD** 3 to 20

➤ Factor A3: **Spacing of Discontinuities** 5 to 20

➤ Factor A4: **Condition of Discontinuities** 0 to 30

➤ Factor A5: **Groundwater Conditions** 0 to 15

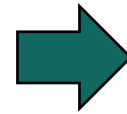
➤ Factor B: **Adjustment for Discontinuities** -50 to 0

$$RMR = \sum_{i=1}^5 A_i + B$$

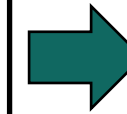


Rock Mass Rating (RMR)

Uniaxial Compressive Strength (MPa)	Point Load Strength Index (MPa)	Factor A1
> 250	> 10	15
100 - 250	4 - 10	12
50 - 100	2 - 4	7
25 - 50	1 - 2	4
5 - 25	n/a	2
1 - 5	n/a	1

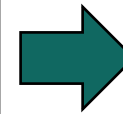


Rock Quality Designation	RQD (%)	Factor A2
Very good rock	90 - 100	20
Good rock	75 - 90	17
Fair rock	50 - 75	13
Poor rock	25 - 50	8
Very poor rock	0 - 25	3

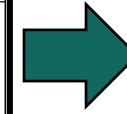


Minimum Average Discontinuity Spacing (cm)	Factor A3
> 200	20
60 - 200	15
20 - 60	10
6 - 20	8
<6	5

Description of Discontinuity Surfaces (Roughness, Persistence, Separation, Wall Contact)	Factor A4
Very rough surfaces: Not continuous (non-persistent): No separation (full wall contact): Unweathered joints	30
Slightly rough surfaces: Moderately persistent: Separation < 1 mm: Slightly weathered joints	25
Slightly rough surfaces: Moderately persistent: Separation < 1 mm: Highly weathered joints	20
Slickensided or gouge < 5 mm OR Separation = 1 - 5 mm: Continuous (highly persistent)	10
Soft gouge (or clay) > 5 mm thick OR Separation > 5 mm: Continuous (highly persistent)	0



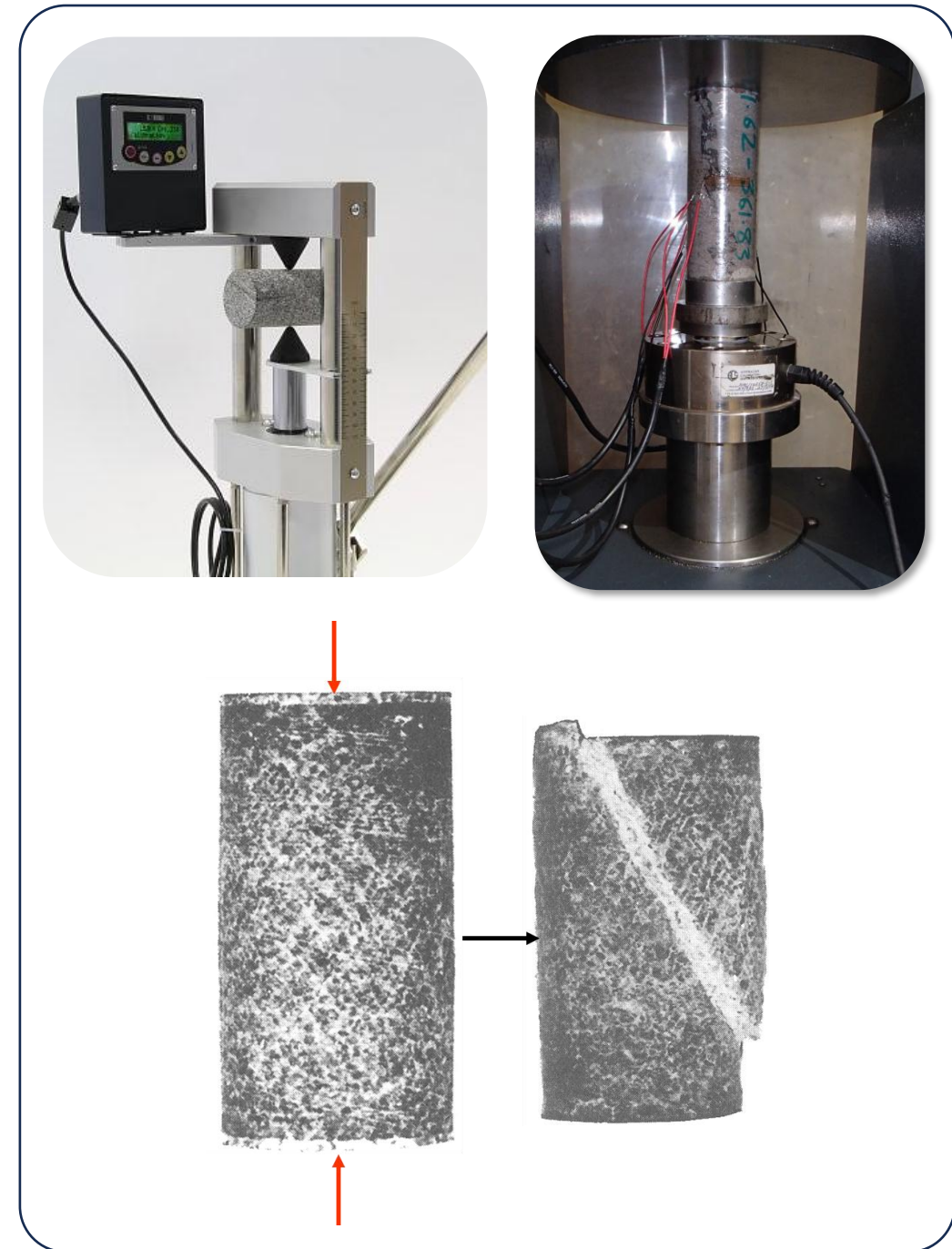
Inflow in litres per 10 m tunnel length	(Joint water pressure) / (Major Principal Stress)	General Conditions	Factor A5
None	0	Dry	15
< 10	< 0.1	Damp	10
10 - 25	0.1 - 0.2	Wet	7
25 - 125	0.2 - 0.5	Dripping	4
> 125	> 0.5	Flowing	0



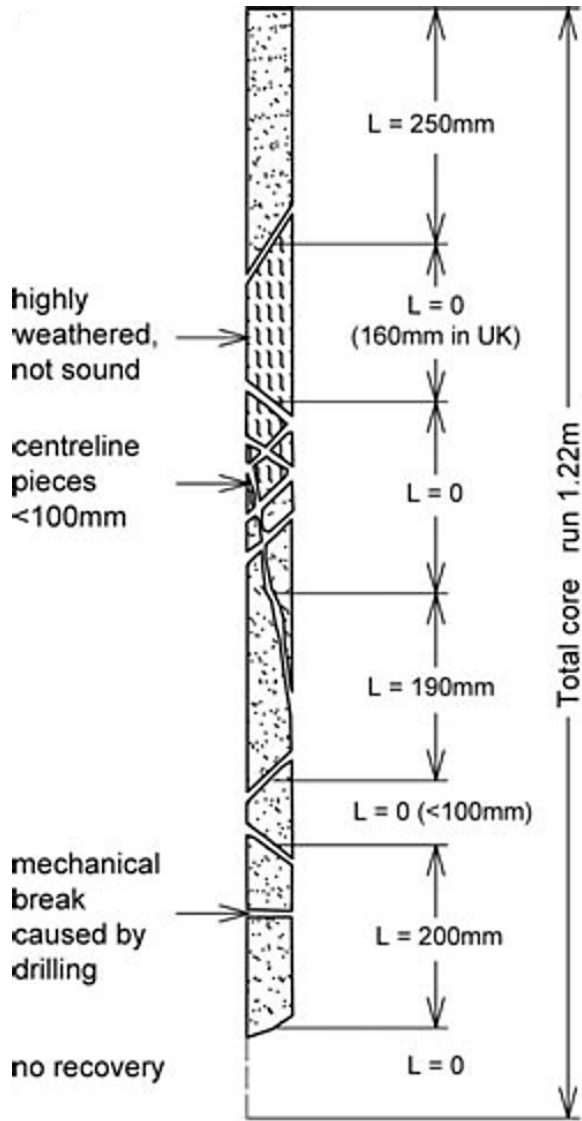
Orientation of critical (most detrimental) joint set with respect to tunnel or underground mine excavation	Factor B
Very Favourable	0
Favourable	-2
Fair	-5
Unfavourable	-10
Very Unfavourable	-12

Factor A1 - UCS

Uniaxial Compressive Strength (MPa)	Point Load Strength Index (MPa)	Factor A1
> 250	> 10	15
100 - 250	4 - 10	12
50 - 100	2 - 4	7
25 - 50	1 - 2	4
5 - 25	n/a	2
1 - 5	n/a	1



Factor A2 - RQD



$$RQD = \frac{250 + 190 + 200}{1220}$$

RQD = 52% (following Deere's)

In BS:5930 the criterion 'hard and sound' is omitted for the definition of RQD. Any 'rock' (i.e. with UCS > 0.6 MPa) is counted.

For the example on the left, the result is :

$$RQD = \frac{250 + 160 + 190 + 200}{1220}$$

i.e. RQD = 66% compared to 52% calculated by Deere.

If all the rock core in the example was very weak, RQD (UK & Europe) would still be 66% but by Deere should be 0%.

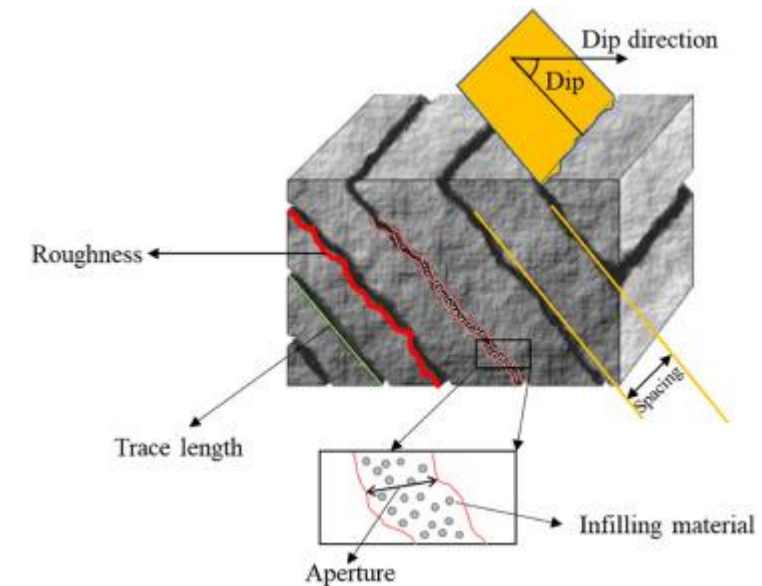
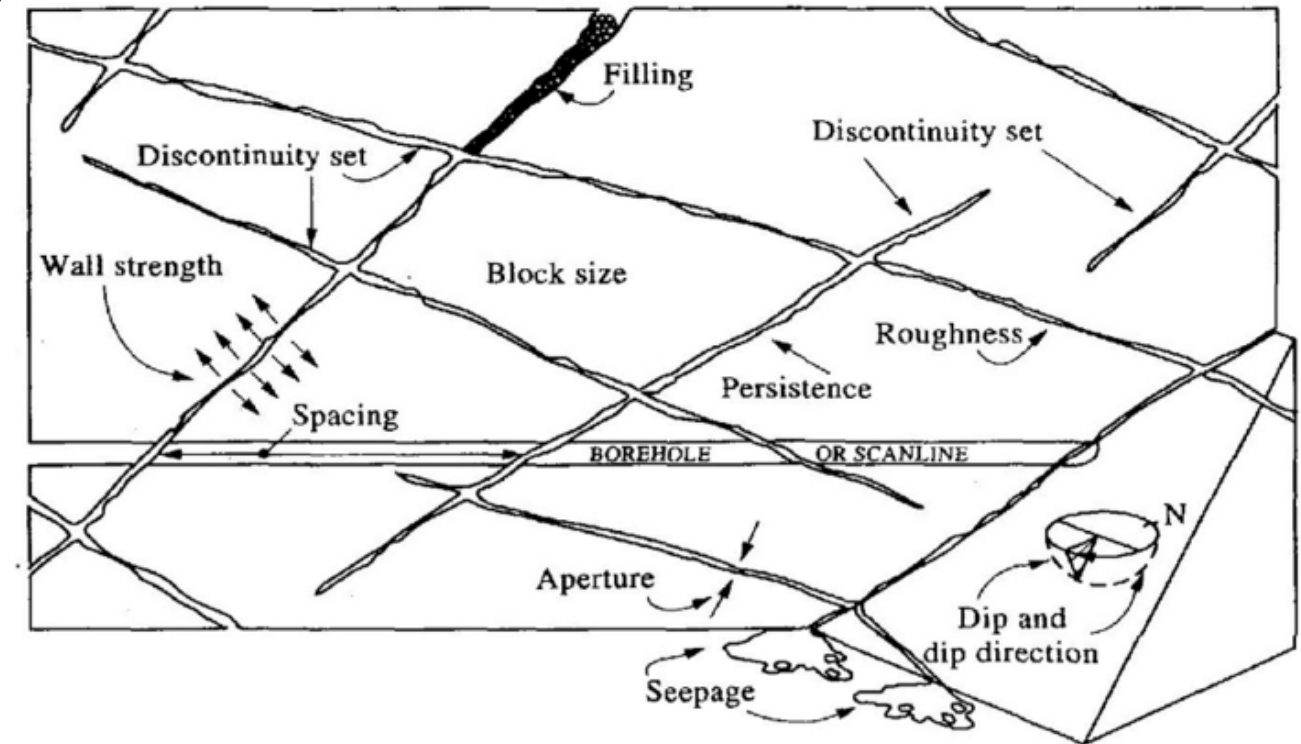


Bieniawski, 1973, 1976, 1989

Rock Quality Designation	RQD (%)	Factor A2
Very good rock	90 - 100	20
Good rock	75 - 90	17
Fair rock	50 - 75	13
Poor rock	25 - 50	8
Very poor rock	0 - 25	3

Factor A3 – Discontinuity Spacing

Minimum Average Discontinuity Spacing (cm)	Factor A3
> 200	20
60 - 200	15
20 - 60	10
6 - 20	8
<6	5



Factor A4 – Discontinuity Conditions



Description of Discontinuity Surfaces (Roughness, Persistence, Separation, Wall Contact)	Factor A4
Very rough surfaces: Not continuous (non-persistent): No separation (full wall contact): Unweathered joints	30
Slightly rough surfaces: Moderately persistent: Separation < 1 mm: Slightly weathered joints	25
Slightly rough surfaces: Moderately persistent: Separation < 1 mm: Highly weathered joints	20
Slickensided or gouge < 5 mm OR Separation = 1 - 5 mm: Continuous (highly persistent)	10
Soft gouge (or clay) > 5 mm thick OR Separation > 5 mm: Continuous (highly persistent)	0

Factor A5 – Groundwater Conditions

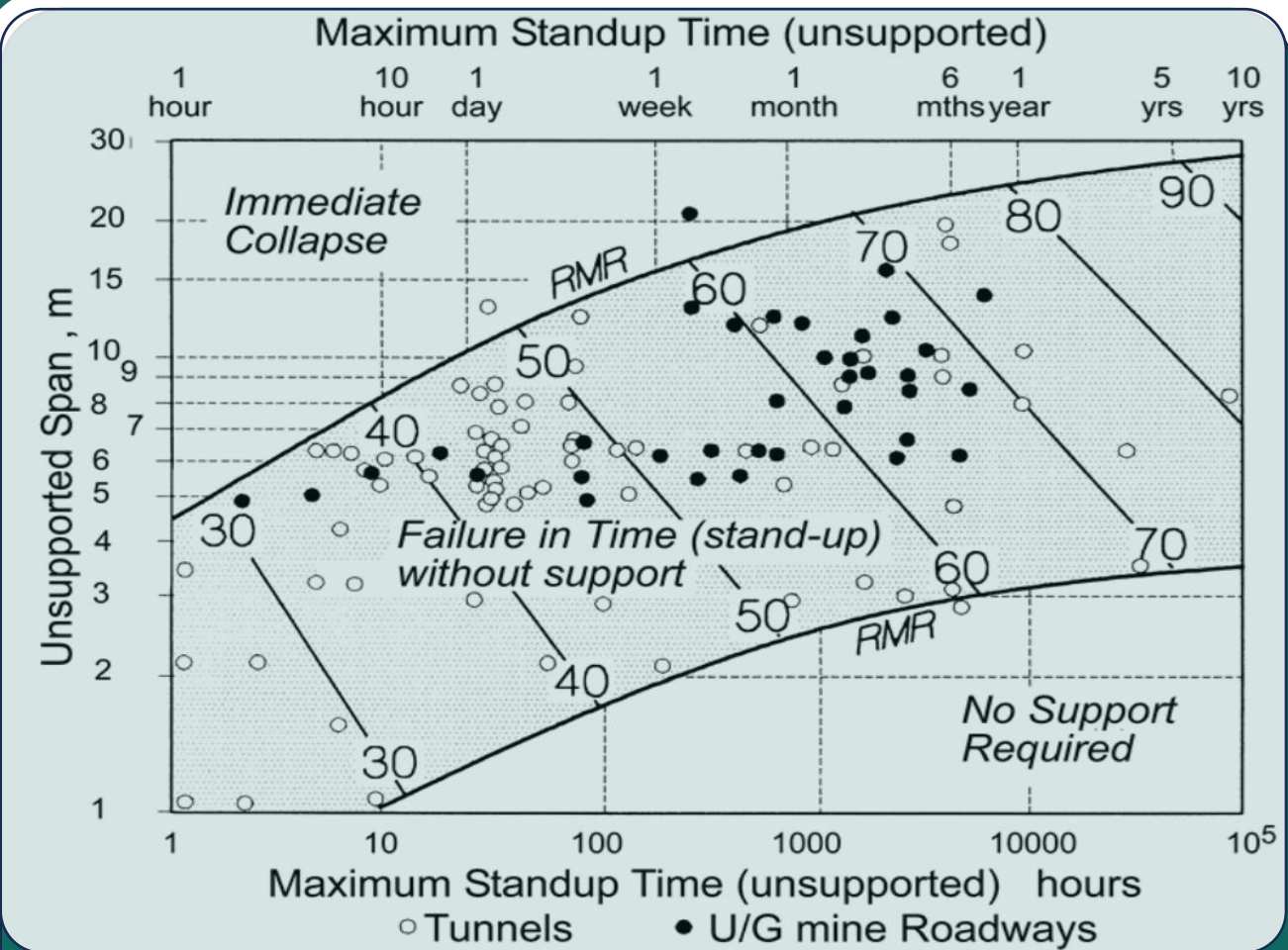
Inflow in litres per 10 m tunnel length	(Joint water pressure) / (Major Principal Stress)	General Conditions	Factor A5
None	0	Dry	15
< 10	< 0.1	Damp	10
10 - 25	0.1 - 0.2	Wet	7
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> 125	> 0.5	Flowing	0



(a)

(b)

(c)



Rock Mass Rating (RMR)

Application

- Estimation of tunnel stand-up time.
- **Stand-up time:** duration of time within which an excavation will remain **serviceable** and after which significant instability and caving occurs
- Guidelines apply to a **10m span horseshoe shaped tunnel**, in a rock mass subjected to **$\sigma_v < 25 \text{ MPa}$** .

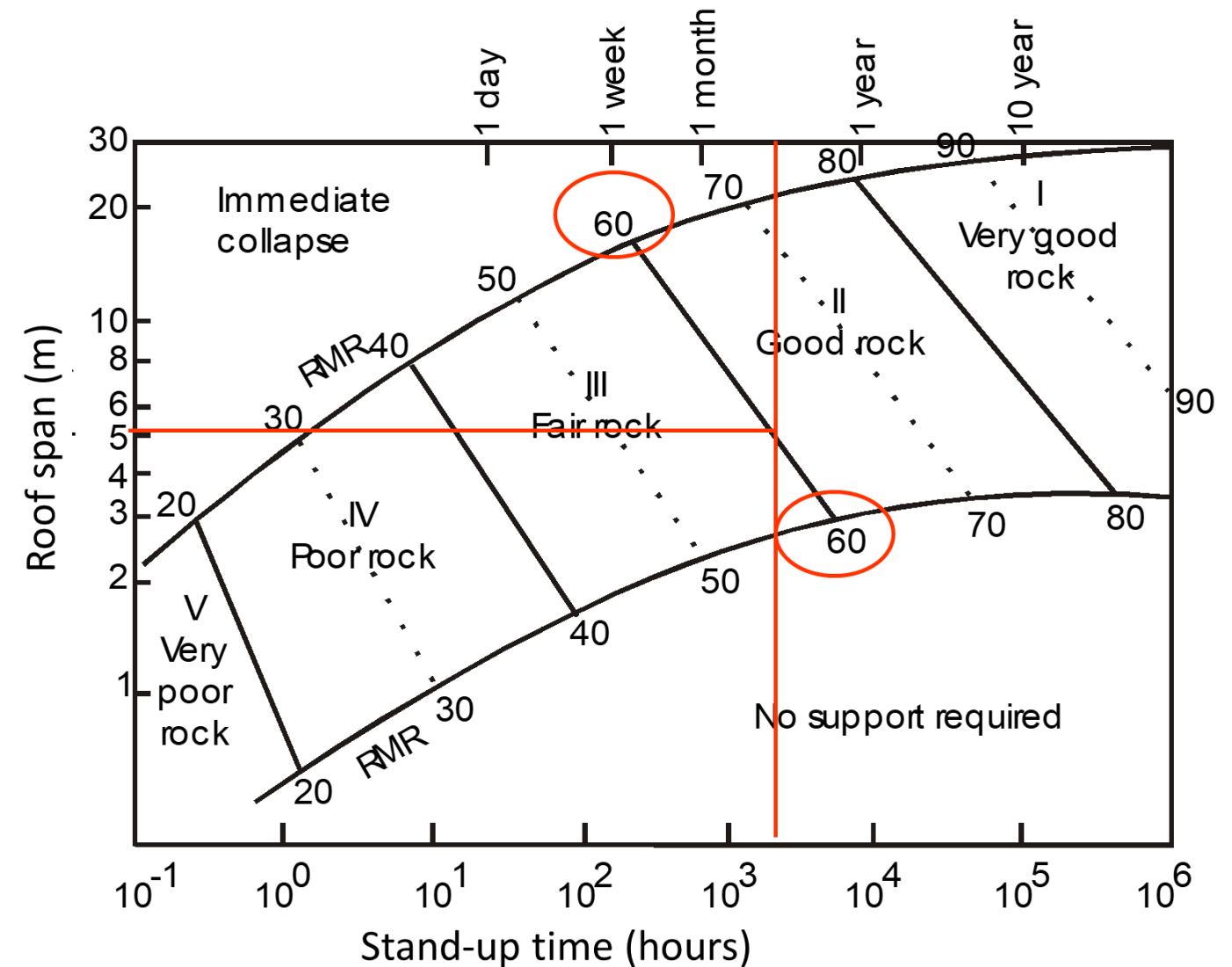
Rock Mass Class	Description	RMR
I	Very Good Rock	81 to 100
II	Good Rock	61 to 80
III	Fair Rock	41 to 60
IV	Poor Rock	21 to 40
V	Very Poor rock	< 20

After Bieniawski, reproduced in Goodman (1980)

Rock Mass Rating (RMR) - Application

Example of RMR and stand-up time for a tunnel with an unsupported span of **5m**, driven at a dip of **60°** with intact rock and joint properties as under:

Parameter	Value or description	Rating
A1. UCS	150 MPa	12
A2. RQD	70 %	13
A3. Joint spacing	0.5m	10
A4. Condition of joints	slightly rough surfaces, separation < 1mm, hard joint wall rock	25
A5. Ground water	water under moderate pressure	00
B. Joint orientation	very favourable	00
	TOTAL RMR	60



Ans: 2.5 months

Rock Mass Rating (RMR) - Application

Support guidelines for 10m Tunnel

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock RMR: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock RMR: 61-80	Full face , 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock RMR: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock RMR: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V – Very poor rock RMR: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

After Bieniawski, 1979)

Rock Mass Rating (RMR) - Application

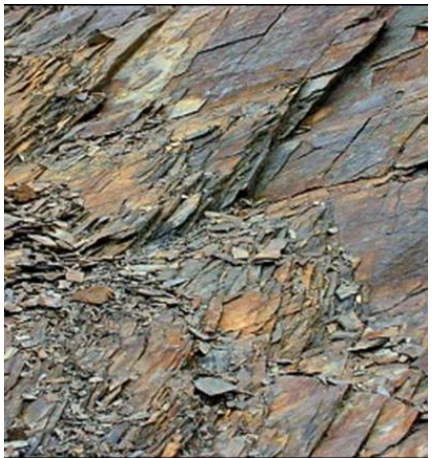


CAUTION
Things may not be as they seem



UCS	RQD	Spacing	Persistence	Separation	Roughness	Infilling	Weathering	
Weak	Excellent	Wide	High	Open	Smooth	Clay <5mm	Moderate	RMR
2MPa	80%	0.6-2m	10m	5mm				
1	16	16	1	0	1	2	3	40

UCS	RQD	Spacing	Persistence	Separation	Roughness	Infilling	Weathering	
Strong	Very Poor	Close	Medium	Mod Open	Slightly Rough	None	Slight	RMR
100MPa	10%	60 -200mm	3-10m	0.1-1.0mm				
10	4	6	2	4	3	6	5	40



Source: Andrew Davis, BTS Course 2011

Rock Mass Rating (RMR) - Limitations

- **Subjective judgments** – Many ratings (discontinuities, groundwater, orientation) depend on personal judgment.
- **Ignores complex structures** – Considers only one joint set; not suitable for highly anisotropic rock masses.
- **No stress effects** – In-situ stresses and their influence on behavior are not included.
- **Oversimplified groundwater** – Does not capture complex hydrogeological conditions.
- **Empirical & case-specific** – Developed mainly for tunnels in hard rock; less reliable for slopes, weak/soft rocks, or foundations

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