108.01

工程地質

Engineering Geology

第五週

不連續面(弱面)II

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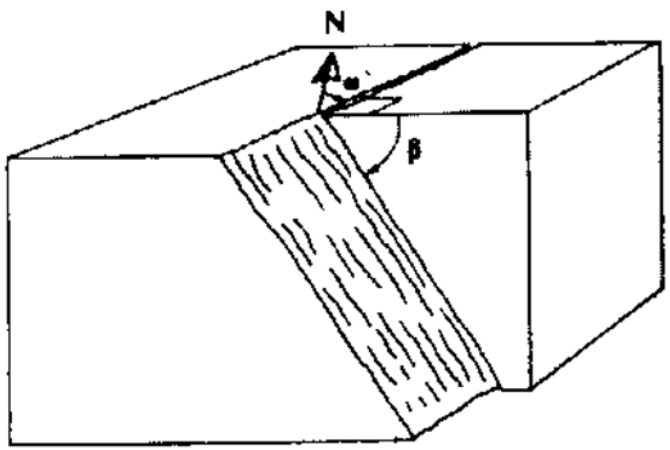
大綱Content

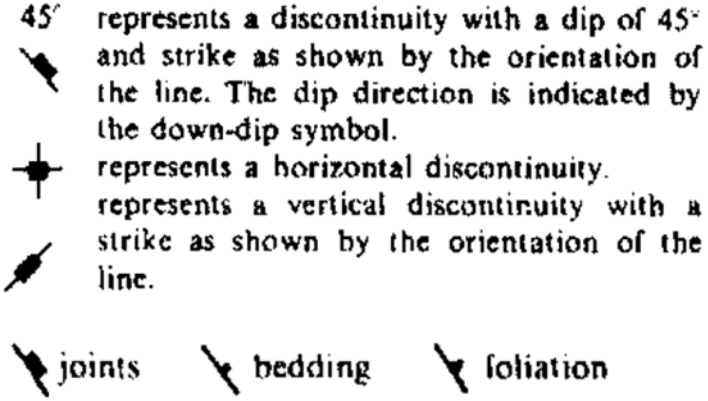
- 不連續面如何調查/描述/評估？
  1. 位態(位置、方位) Orientation：立體投影法
  2. 間距 Spacing
  3. 持續性 Persistence
  4. 粗糙度 Roughness
  5. 內壁材料強度 Strength
  6. 內寬
  7. 軟弱夾心
  8. 滲水情形
  9. 組數
  10. 弱面密度與岩體幾何形狀

不連續面如何調查/描述/評估？

1.位態Orientation



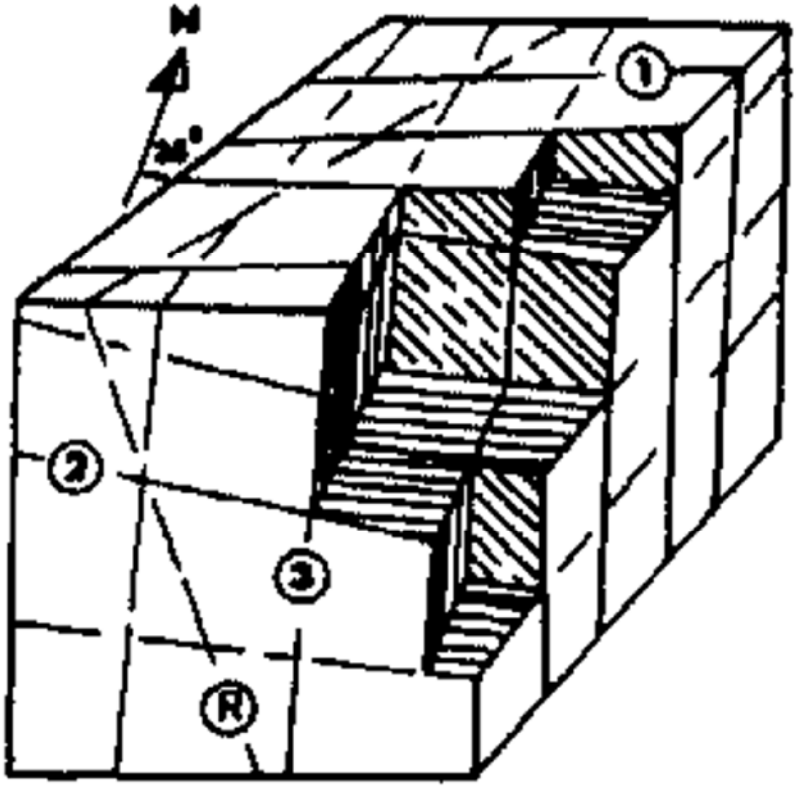
- 位態的表示方法
  1) 走向傾角符號



- 不連續面的空間姿態，包含走向及傾向/傾角
- 以地質羅盤量測
- 在關鍵地區挑選露頭較佳的地段設立調查站
- 隨機地測量不連續面之位態，不能主觀地挑選某一個面，而且不能只挑選明顯的一組，必須找各種不同方向的露頭面進行測量
- 每個調查站取得至少50個數據才有意義
- 拍照並放入報告內

1.位態Orientation

- 位態的表示方法
  2) 方塊圖Block diagram

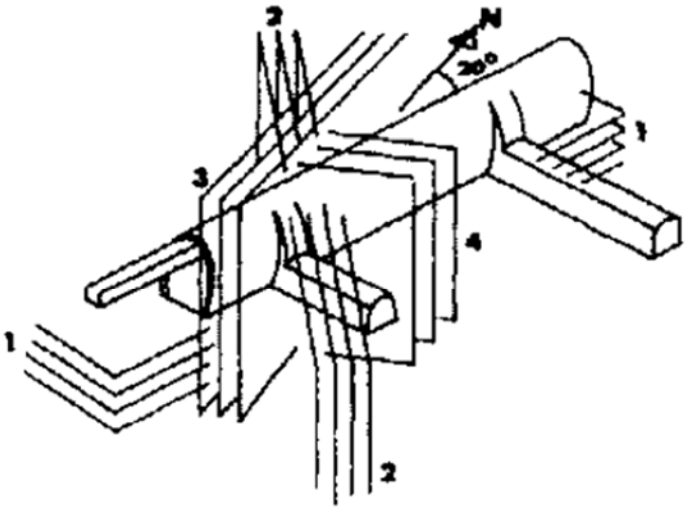


1. 200°/ 68°
2. 130°/ 15°
3. 285°/ 85°

1.位態Orientation

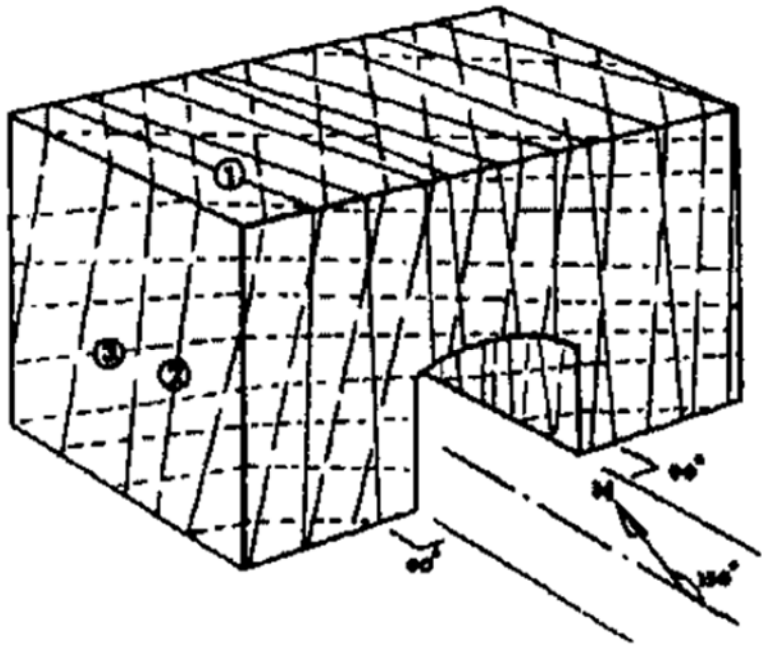
- 位態的表示方法
  - 2) 方塊圖Block diagram

(a)



1. 200°/10°
2. 230°/85°
3. 095°/90°
4. 180°/84°

(b)



1. 055°/85°
2. 285°/70°
3. 030°/32°

1.位態Orientation

- 位態的表示方法
  3) 節理玫瑰圖 Joint rosettes
  4) 球形投影 Spherical projection

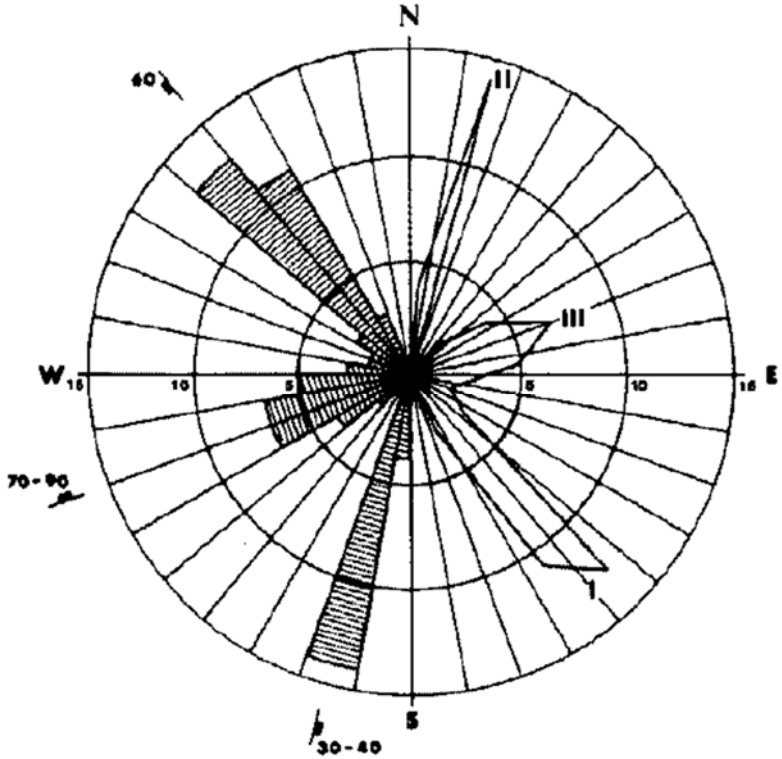


Fig. 3. Two methods of representing orientation data on a joint rosette

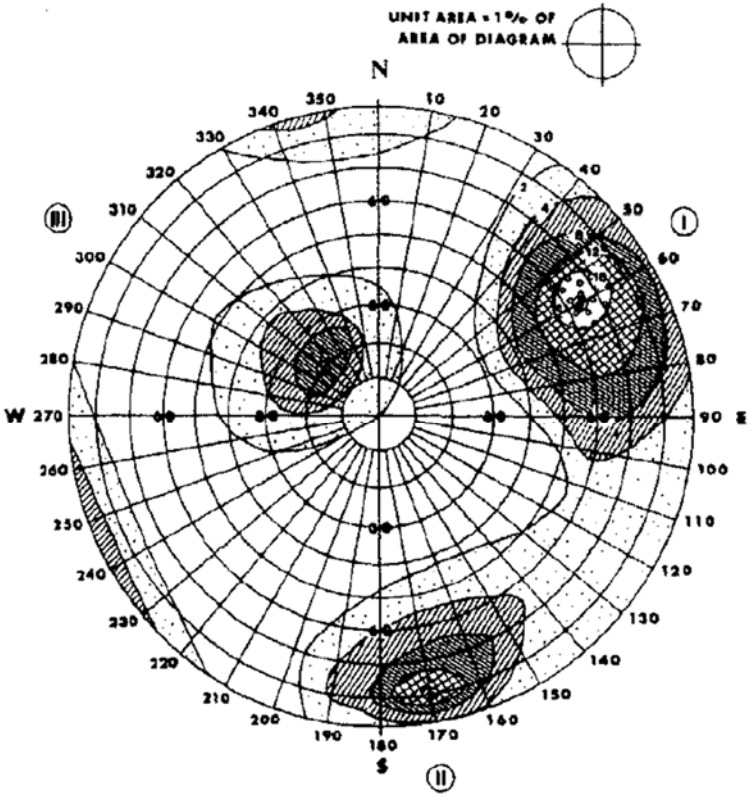


Fig. 5. Schmidt contour diagram representing the orientation of three sets of joints plotted on a polar equal-area net. The main sets I and II are approximately normal to each other, and the minor set III is nearly horizontal.

2.間距 Spacing

- 沿著所選擇的某一個測線方向上(一般是垂直於某一組不連續面)相鄰不連續面間的距離。
- 不連續面間距反映岩體的完整程度及岩塊的大小

測線(方向不同則間距不同

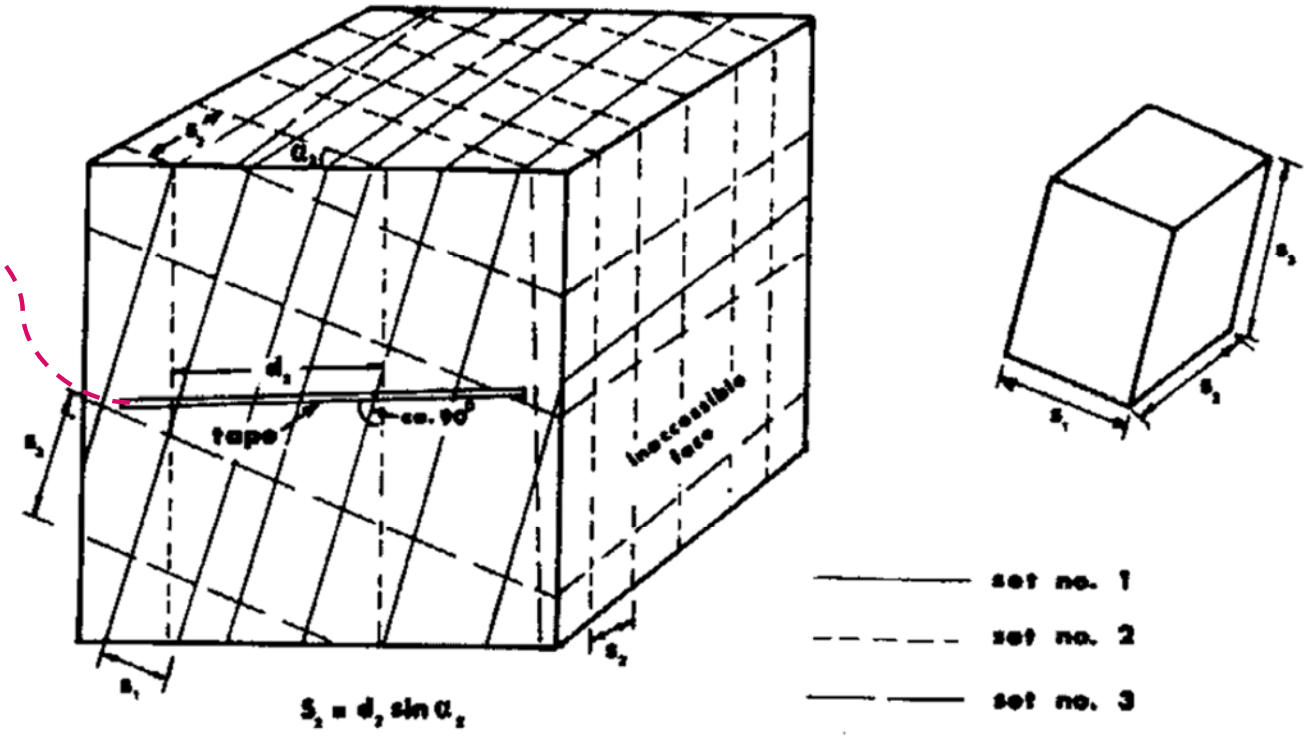


Fig. 10. Measurement of joint spacing from observation of a rock exposure.

2.(真實)間距 (true) spacing

- 量測(真實)間距時應儘使測線垂直不連續面
- 測線(取樣)長度應大於10倍間距，且不小於3 m
- 量測間距的誤差需在間距長5%內
- 測線與不連續面最小角度α，間距斜長量測值d，則真實間距 $S = d_m * \sin\alpha$，其中d_m為最常見距離(S modal)

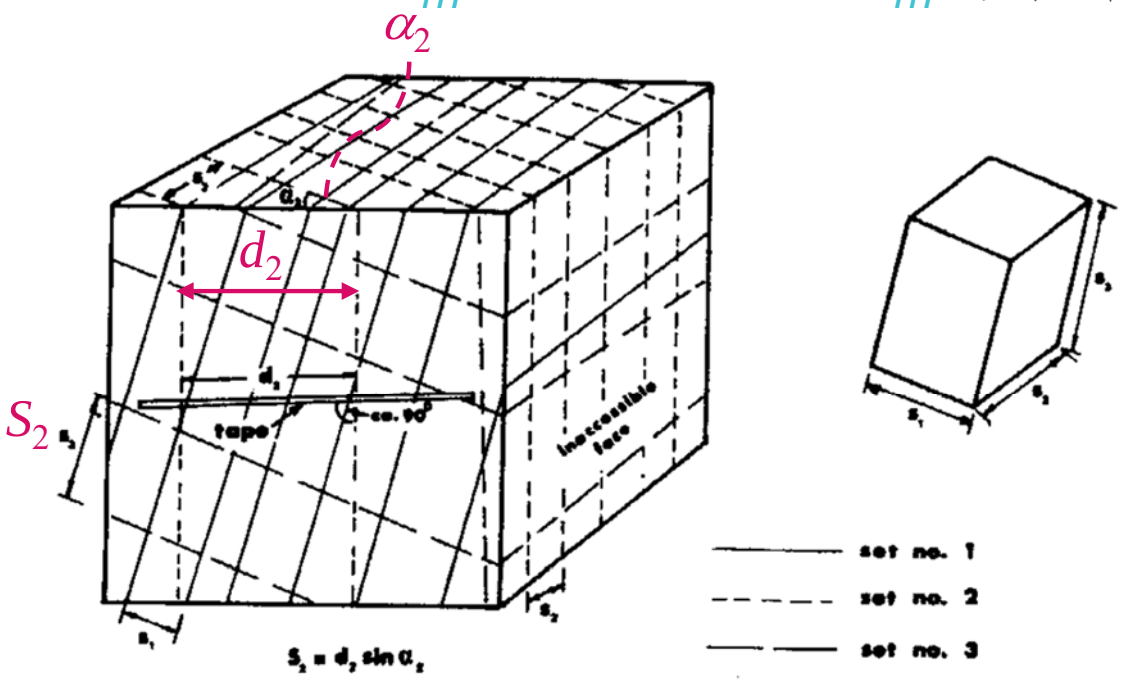


Fig. 10. Measurement of joint spacing from observation of a rock exposure.

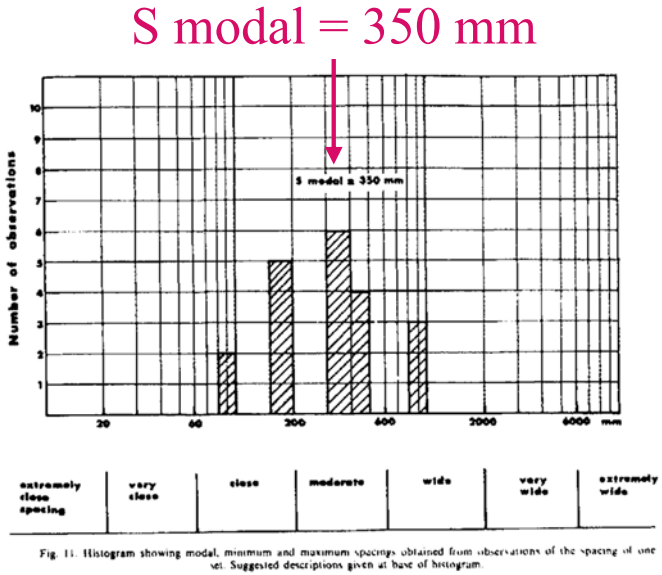


Fig. 11. Histogram showing modal, minimum and maximum spacings obtained from observations of the spacing of one set. Suggested descriptions given at base of histogram.


不連續面(節理)組數？
間距？

不連續面(節理)組數？
間距？

2.間距 Spacing

- 間距(s)的表示方法
  1) 最小間距，型態間距modal spacing，最大間距

Description	Spacing
Extremely close spacing	< 20 mm
Very close spacing	20–60 mm
Close spacing	60–200 mm
Moderate spacing	200–600 mm
Wide spacing	600–2000 mm
Very wide spacing	2000–6000 mm
Extremely wide spacing	> 6000 mm

2.間距 Spacing

2) 直方圖histogram

Description	Spacing
Extremely close spacing	< 20 mm
Very close spacing	20–60 mm
Close spacing	60–200 mm
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Extremely wide spacing	> 6000 mm

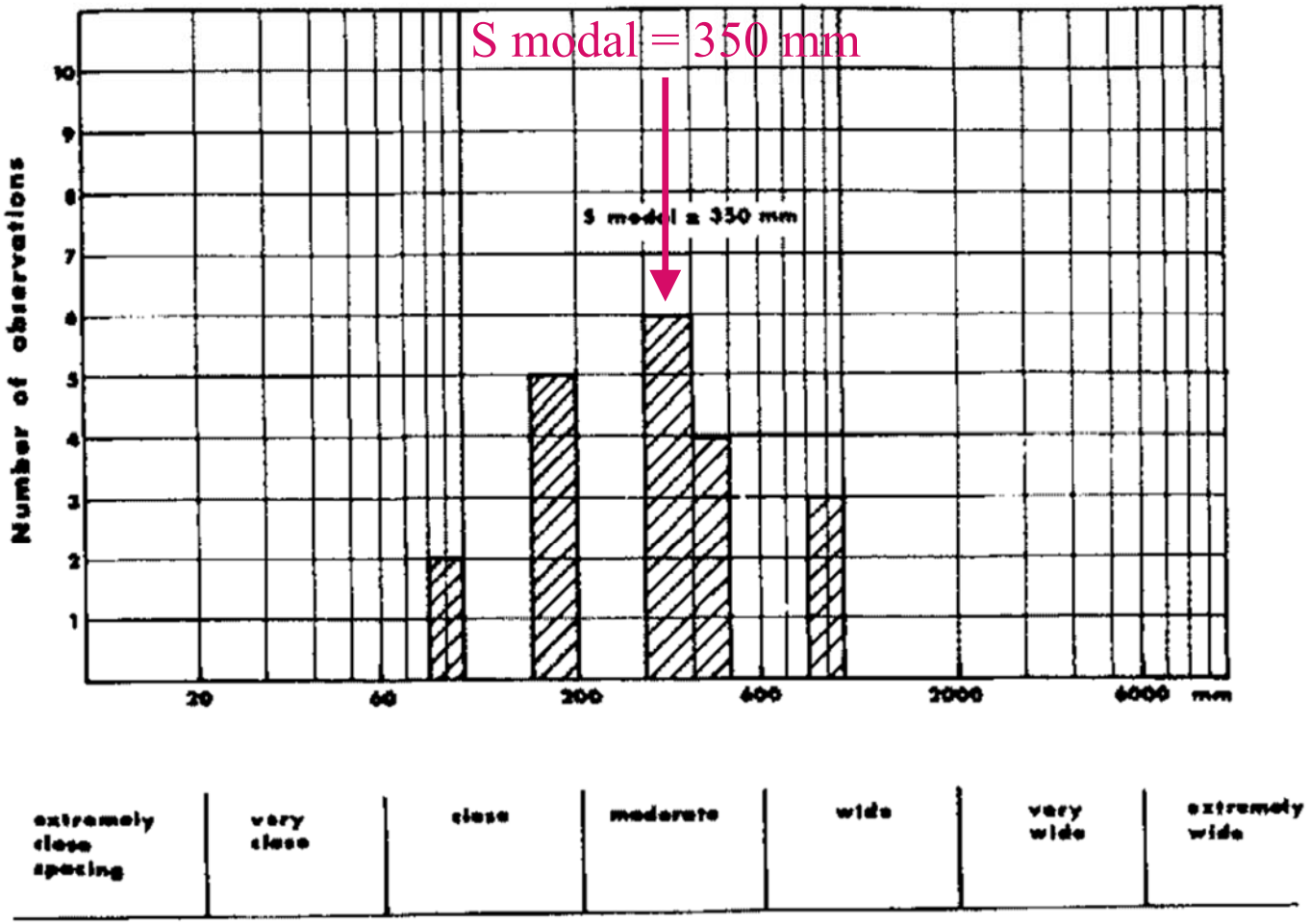


Fig. 11. Histogram showing modal, minimum and maximum spacings obtained from observations of the spacing of one set. Suggested descriptions given at base of histogram.

2.間距 Spacing

- 注意：
  - 使用地質羅盤及測量捲尺
  - 可在露頭上釘釘子及拉尼龍線輔助
- 節理密度/節理頻率
  - J_d=1/s, 其中J_d = 節理密度(條/m), s = 間距(m)

測線(方向不同則間距(斜距)不同

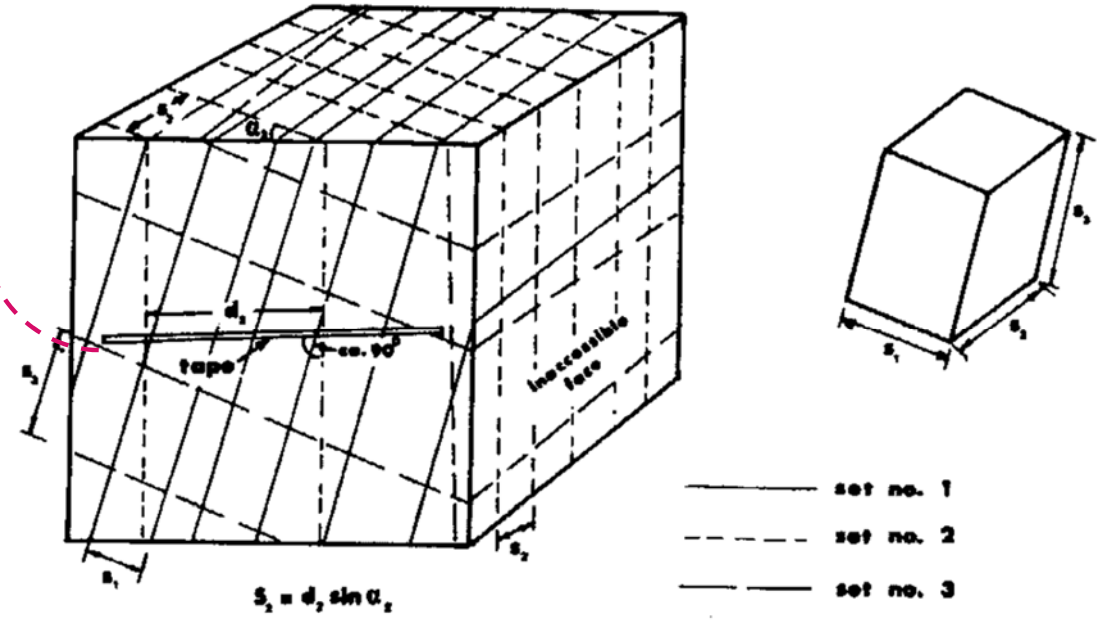


Fig. 10. Measurement of joint spacing from observation of a rock exposure.

3.持續性/延續性 Persistence

- 不連續面的延展範圍及其長短
- 如果不連續面的條數相同，則端點總數越多者表示不連續面的延續性越差
- 測線至少要10 m

Very low persistence	< 1 m
Low persistence	1–3 m
Medium persistence	3–10 m
High persistence	10–20 m
Very high persistence	> 20 m

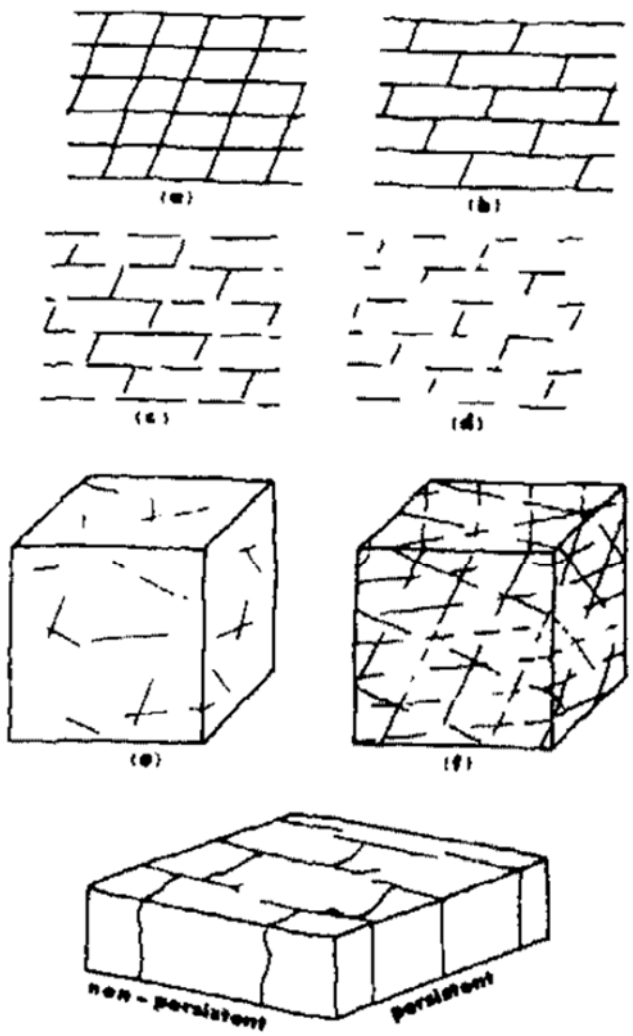
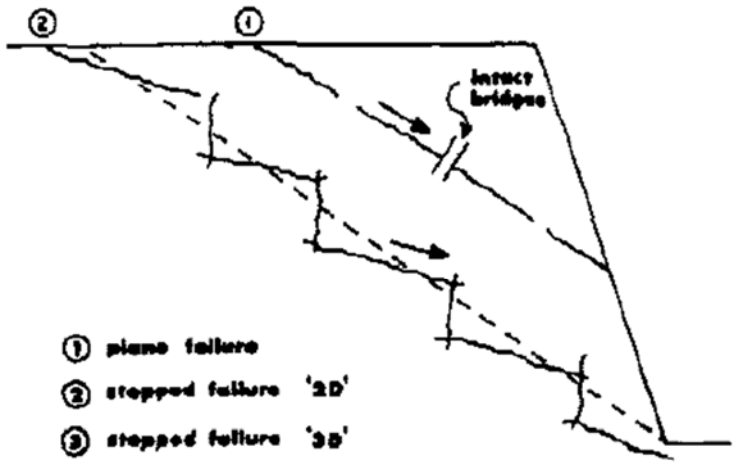


Fig. 12 Simple sketches and block diagrams help to indicate the relative *persistence* of the various sets of discontinuities. Examples adapted from [1] and [2].

3.持續性/延續性 Persistence

- 終止方式
  - (r): visibly terminate in rock in the exposure (終止於岩石)
  - (d): terminate against other discontinuities (終止於破裂面)
  - (x): Extend outside the exposure (終點無法測量)
- 延續性的影響



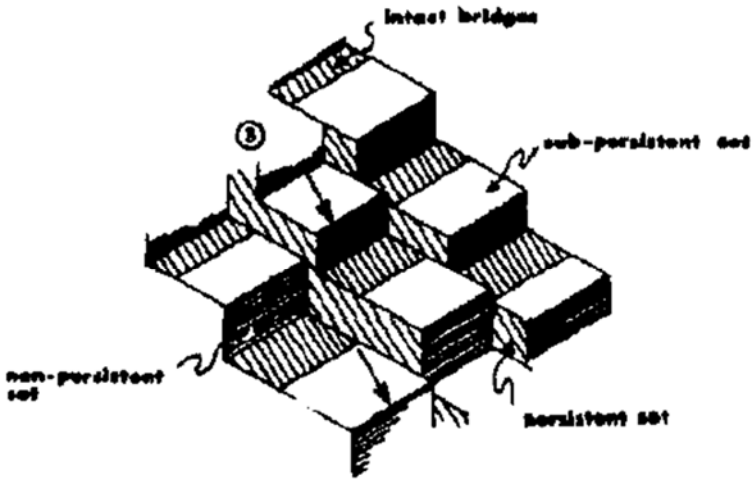


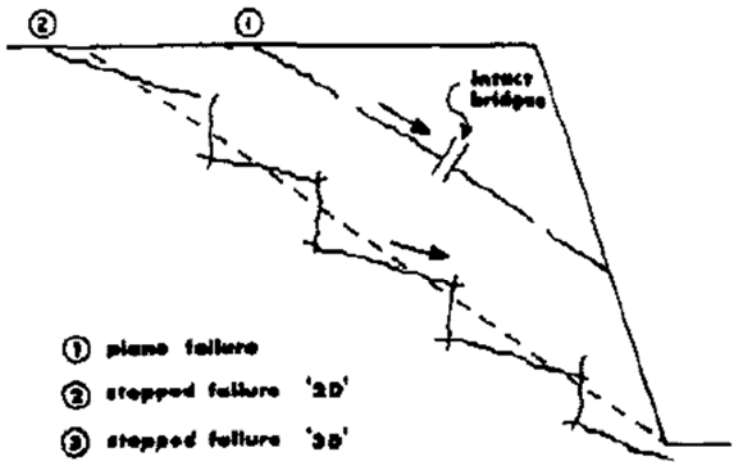
Fig. 13. Idealized examples of potential failure planes showing the importance of "intact bridges" and "down-stepping". Examples adapted from [4] and [7].


作業2
測線1


測線2

3.持續性/延續性 Persistence

- 延續性的影響
  - Persistent set
  - Non-persistent set
  - Sub-persistent set
  - Intact bridges
  - Down-stepping



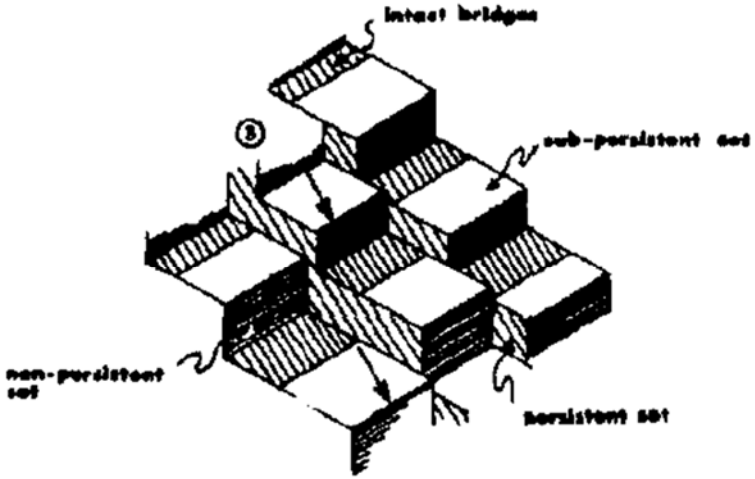


Fig. 13. Idealized examples of potential failure planes showing the importance of "intact bridges" and "down-stepping". Examples adapted from [4] and [7].

3.持續性/延續性 Persistence

- 延續性的表示方法
  - 方塊圖
  - 照片
  - 計算比例

$$T_r = \frac{(\Sigma r) \times 100}{2(\text{no. of discontinuities observed})}\ \%$$

  - (r): visibly terminate in rock in the exposure (終止於岩石)
  - (d): terminate against other discontinuities (終止於破裂面)
  - (x): Extend outside the exposure (終點無法測量)

4.粗糙度 Roughness

- 粗糙度是控制不連續面剪力強度的重要指標
- 粗糙度的重要性隨不連續面內寬(aperture)、充填物厚度(filing thickness)及剪位移累積量增加而減少
- 通常透過不連續面起伏(waviness)程度來量化粗糙度
  - 右圖*i*角
- 不同尺度試驗得到不同尺度的不連續面粗糙度

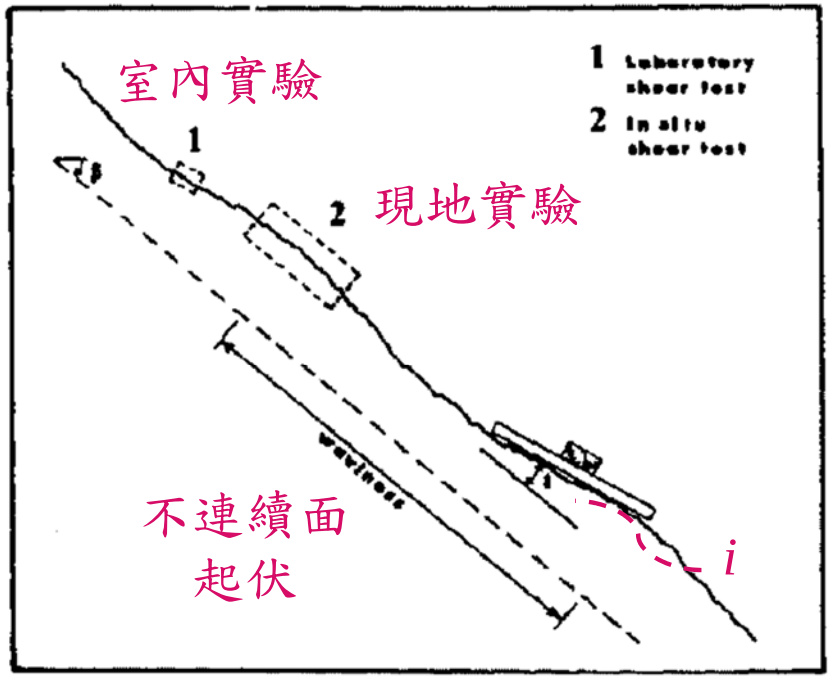
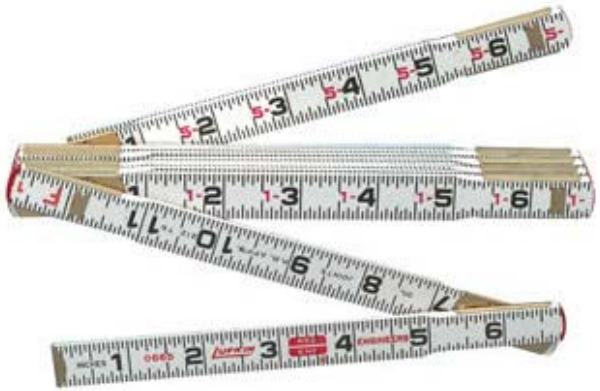
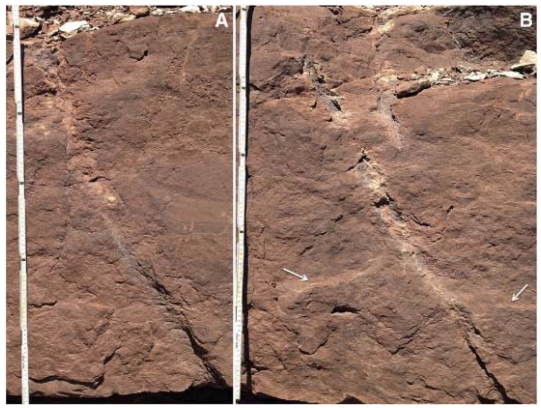


Fig. 14. Different scales of discontinuity roughness are sampled by different scales of tests. Waviness can be characterised by the angle (i).

4.粗糙度 Roughness

- 量測方法：folding ruler





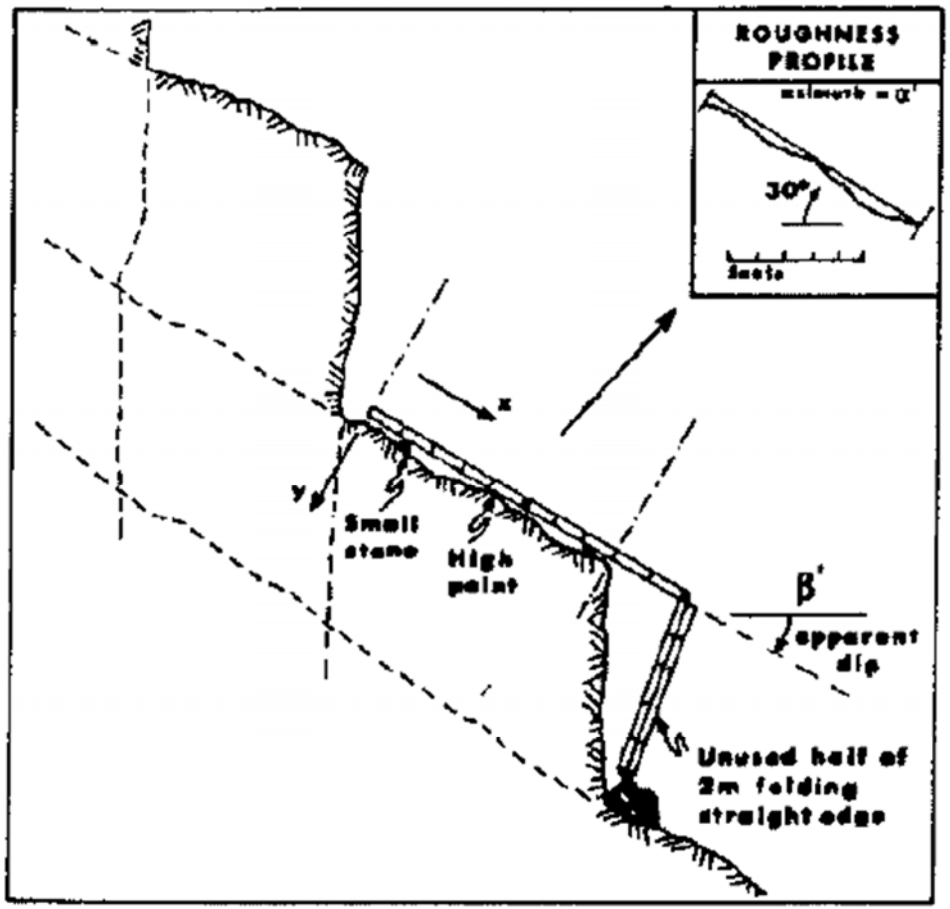
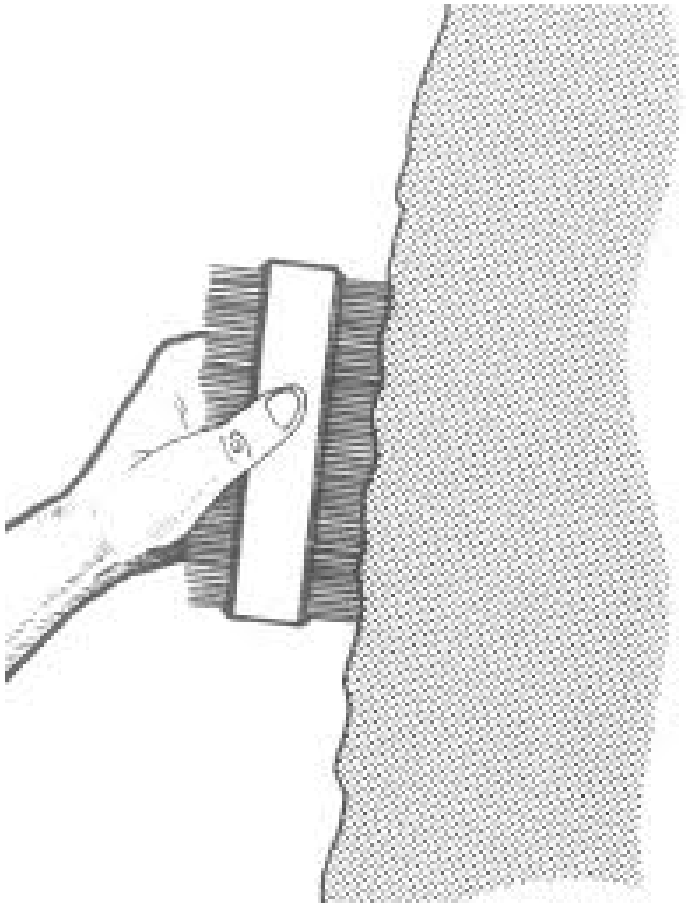


Fig. 15. A method of recording discontinuity roughness in two dimensions, along the estimated direction of potential sliding.

4.粗糙度 Roughness

- 量測方法：linear profiling (粗糙尺)



4.粗糙度 Roughness

- 量測方法：circular disc + 地質羅盤
  - 將圓盤貼在露頭上
  - 以地質羅盤量測位態
  - 以直徑5, 10, 20, 40 cm之圓盤量粗糙角*i*

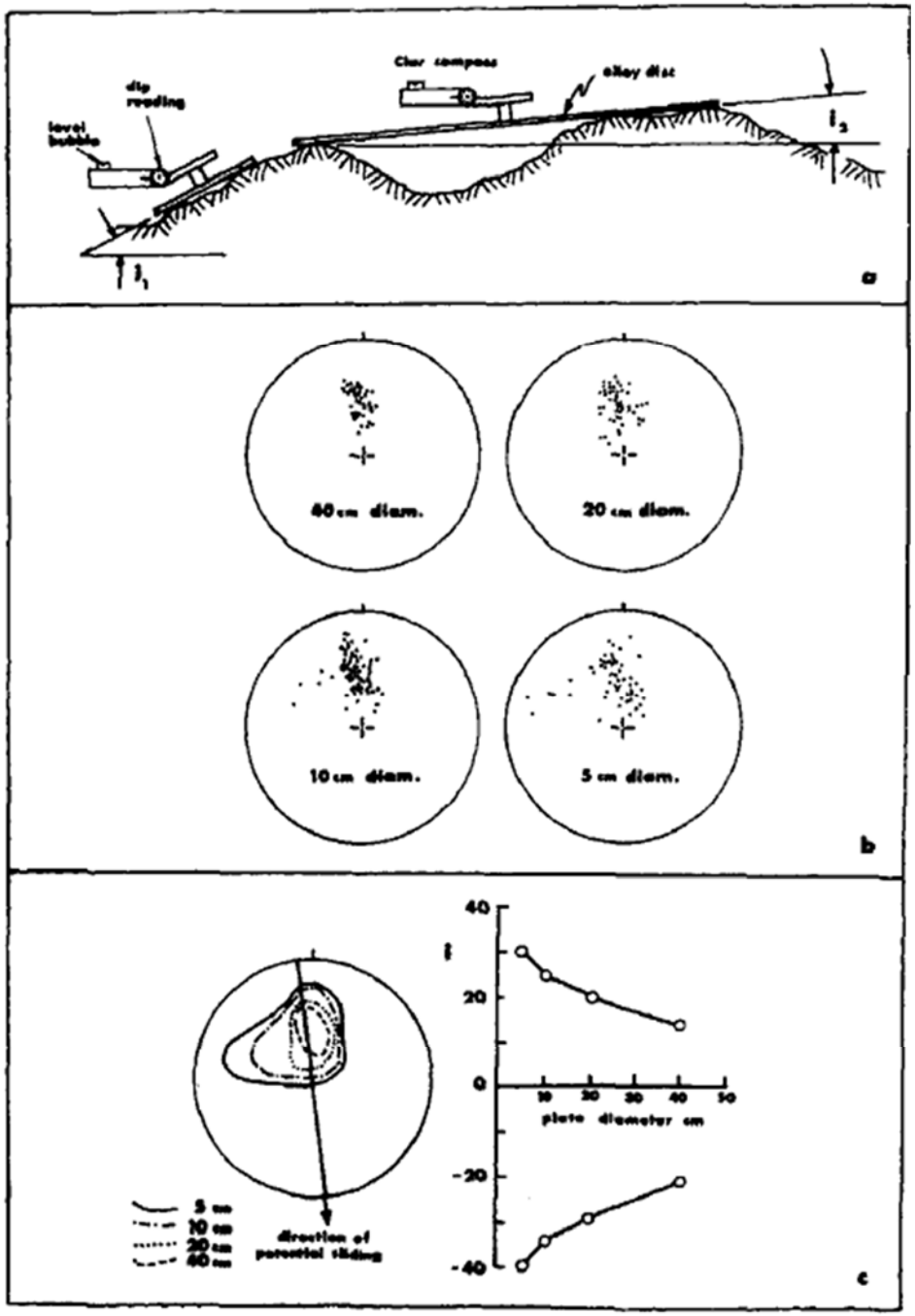


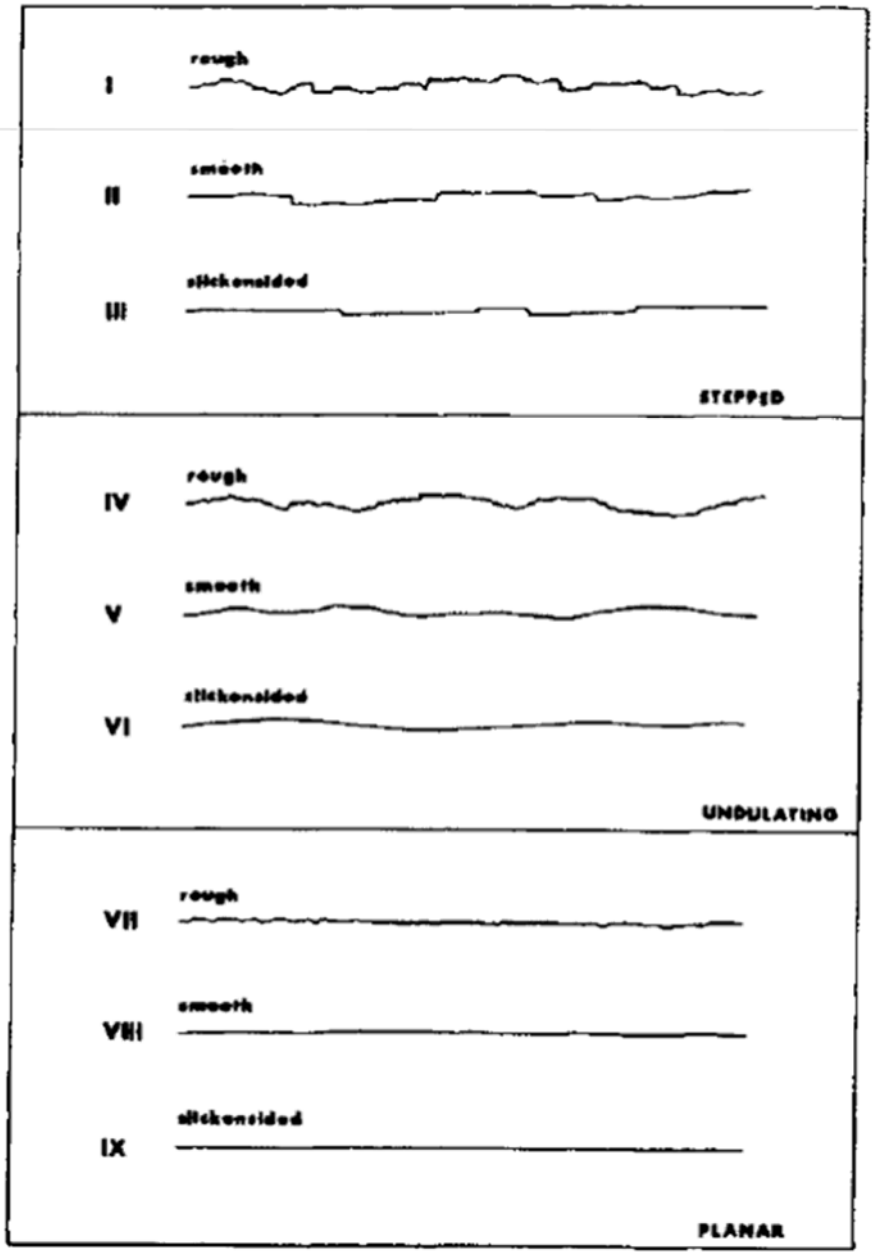
Fig. 16. A method of recording discontinuity roughness in three dimensions, for cases where the potential direction of sliding is not yet known. Circular discs of different dimensions (e.g. 5, 10, 20 and 40 cm) are fixed in turn to a Clar compass and clinometer. The dip direction and dip readings are plotted as poles on equal-area nets. Adapted from [1] and [2].

4.粗糙度 Roughness

- 粗糙度的表示方式

Small scale (several centimetres)
Intermediate scale (several metres)

I	Rough (or irregular), stepped
II	Smooth, stepped
III	Slickensided, stepped
IV	Rough (or irregular), undulating
V	Smooth, undulating
VI	Slickensided, undulating
VII	Rough (or irregular), planar
VIII	Smooth, planar
IX	Slickensided, planar

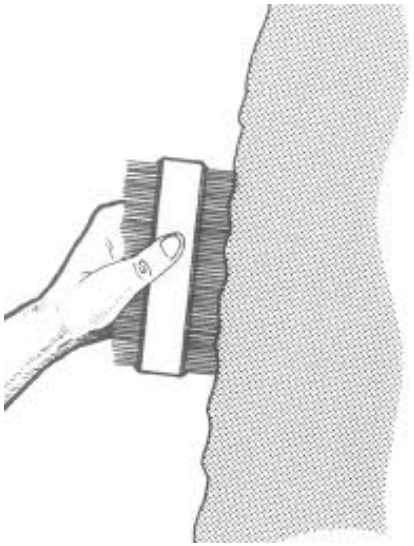


- 剪力強度相對關係

I > II > III
IV > V > VI
VII > VIII > IX
I > IV > VII
II > V > VIII
III > IX and VI > IX

4.粗糙度 Roughness

- 粗糙度的表示方式：
  - Joint roughness coefficient (JRC)節理粗糙度細數
  - 比對標準剖面



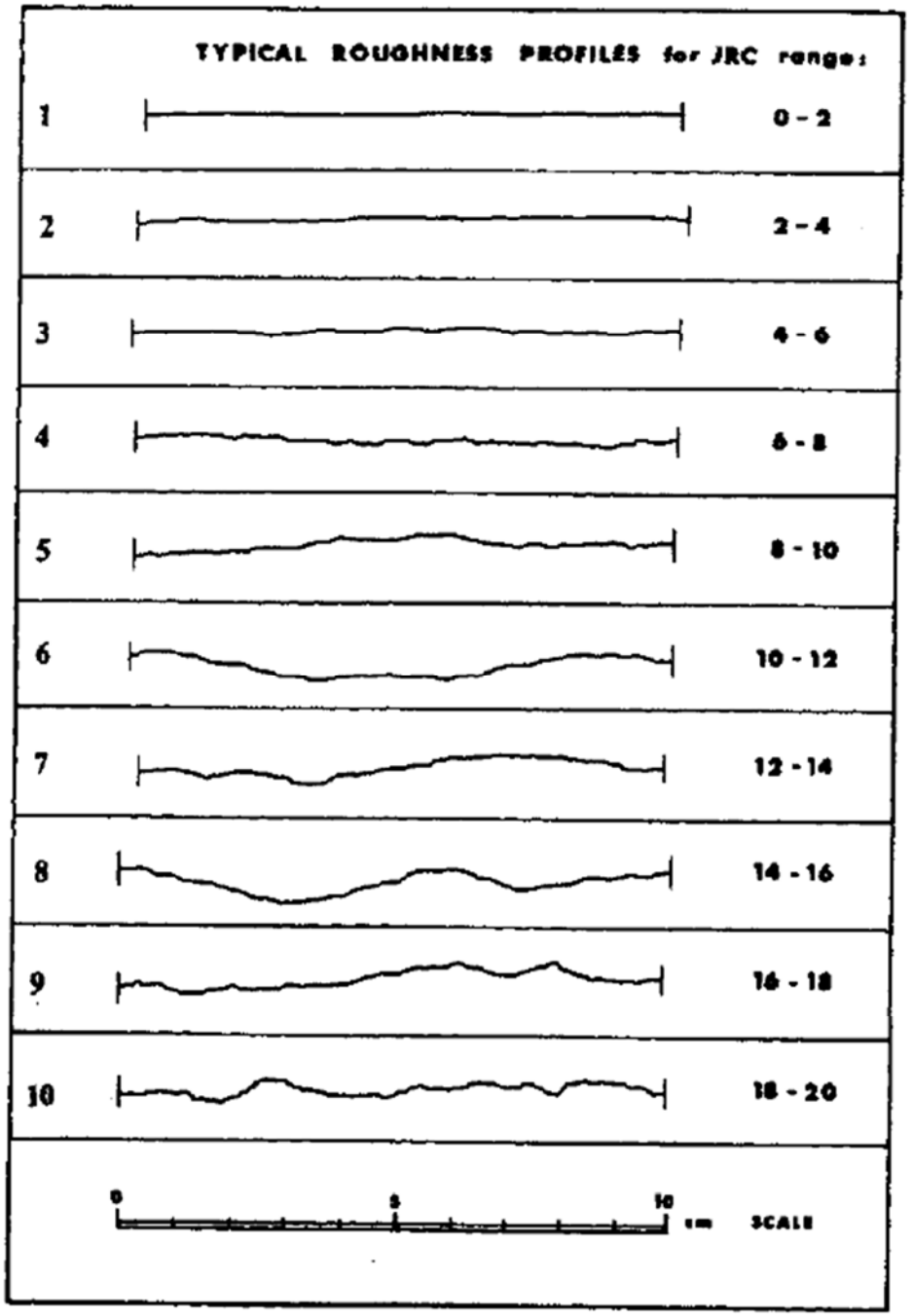


Fig. 19. Roughness profiles and corresponding range of JRC values associated with each one [6].

4.粗糙度 Roughness

- 剪力強度

$$\tau = \sigma'_n \tan(\phi + i)$$

τ = shear strength (peak or residual)
ϕ = friction angle (peak or residual)
σ'_n = effective normal stress
i = waviness (if present)

  - JRC: 以粗糙尺描繪後，比對右圖標準剖面判定
  - JCS: 完整岩石單軸壓縮強度

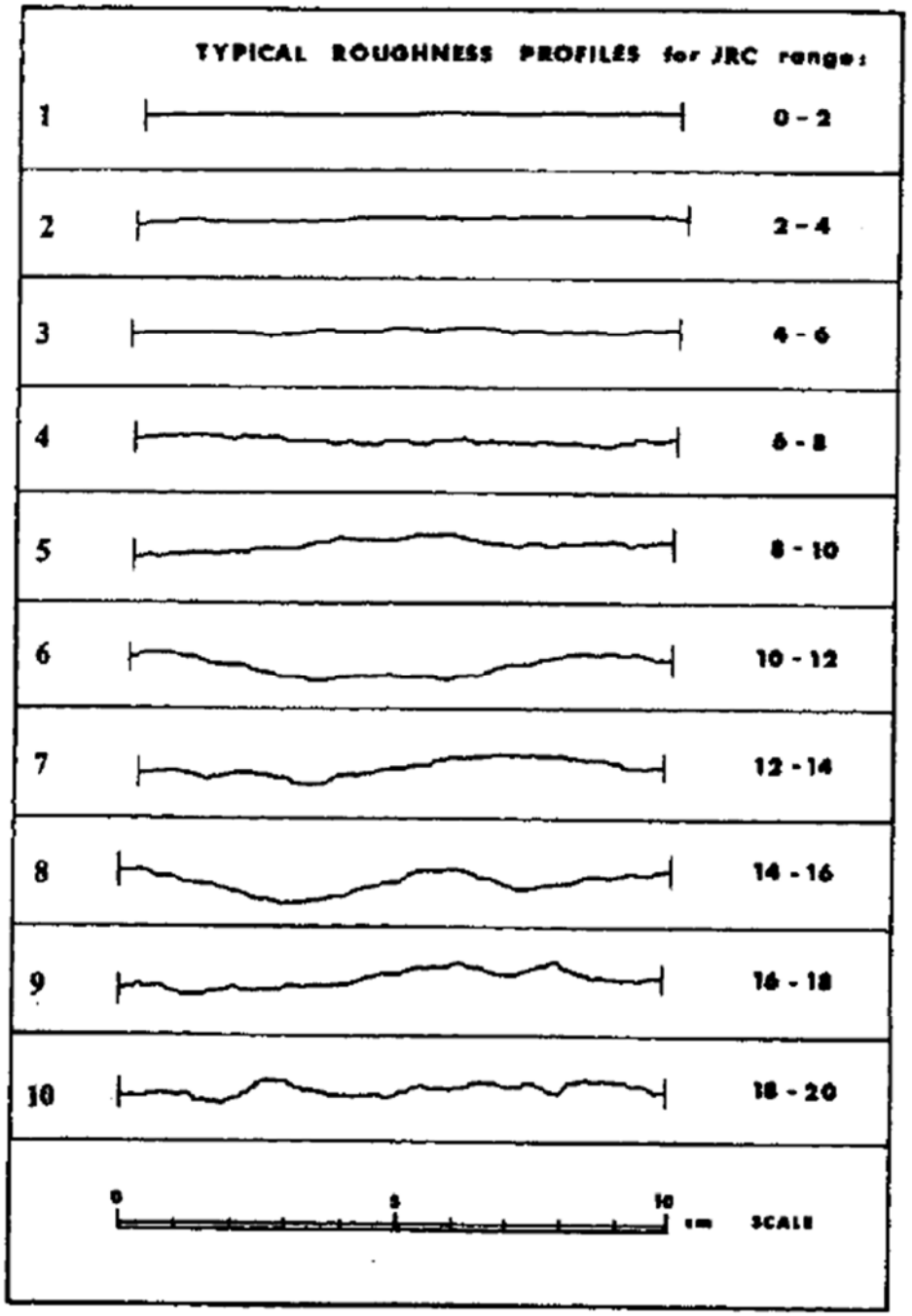


Fig. 19. Roughness profiles and corresponding range of JRC values associated with each one [6].

4.粗糙度 Roughness

- 應用

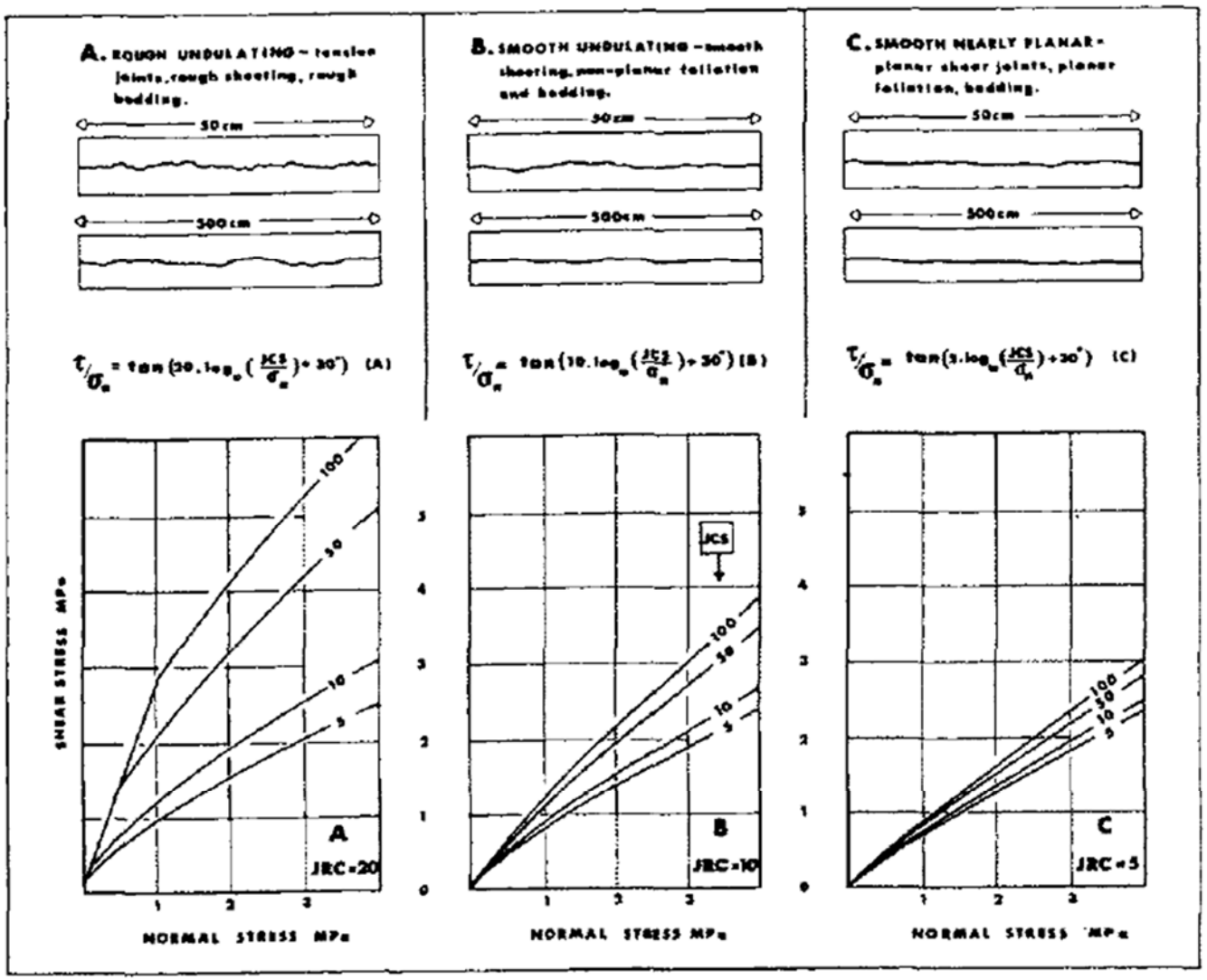


Fig. 18 A method of estimating peak shear strength from roughness profiles. Each curve is numbered with the appropriate JCS value (units of MPa). The roughness profiles are intended as an approximate guide to the appropriate JRC values 20, 10 and 5. Completely smooth planar joints have JRC = 0. [7]

5.內壁材料強度 Strength

- 主要決定於岩性及風化程度
  - 岩體風化程度

Term	Description	Grade
Fresh	No visible sign of rock material weathering: perhaps slight discolouration on major discontinuity surfaces	I
Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as corestones.	III
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	IV
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	V
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destoyed. There is a large change in volume, but the soil has not been significantly transported.	VI

5.內壁材料強度 Strength

- 岩石材料風化程度

Term	Description
Fresh	No visible sign of weathering of the rock material.
Discoloured	The colour of the original fresh rock material is changed. The degree of change from the original colour should be indicated. If the colour change is confined to particular mineral constituents this should be mentioned.
Decomposed	The rock is weathered to the condition of a soil in which the original material fabric is still intact, but some or all of the mineral grains are decomposed.
Disintegrated	The rock is weathered to the condition of a soil in which the original fabric is still intact. The rock is friable, but the mineral grains are not decomposed.

- 設備
  - 地質錘
  - 筆型小刀
  - 施密特錘

5.內壁材料強度 Strength

- S1-S6適用凝聚性土壤，如黏土、粉土質黏土，以及粉土與黏土的混合物
- R0-R6適用岩石
- 用拇指壓、地質錘敲、小刀刮

Grade	Description	Field identification	Approx. range of uniaxial compressive strength (MPa)
S1	Very soft clay	Easily penetrated several inches by fist	< 0.025
S2	Soft clay	Easily penetrated several inches by thumb	0.025–0.05
S3	Firm clay	Can be penetrated several inches by thumb with moderate effort	0.05–0.10
S4	Stiff clay	Readily indented by thumb but penetrated only with great effort	0.10–0.25
S5	Very stiff clay	Readily indented by thumbnail	0.25–0.50
S6	Hard clay	Indented with difficulty by thumbnail	> 0.50
R0	Extremely weak rock	Indented by thumbnail	0.25–1.0
R1	Very weak rock	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	1.0–5.0
R2	Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	5.0–25
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	25–50
R4	Strong rock	Specimen requires more than one blow of geological hammer to fracture it	50–100
R5	Very strong rock	Specimen requires many blows of geological hammer to fracture it	100–250
R6	Extremely strong rock	Specimen can only be chipped with geological hammer	> 250

Note. Grades S1 to S6 apply to cohesive soils for example clays, silty clays, and combinations of silts and clays with sand, generally slow draining. Discontinuity wall strength will generally be characterized by grades R0–R6 (rock) while S1–S6 (clay) will generally apply to filled discontinuities (see Filling).
Some rounding of strength values has been made when converting to S.I. units.

5.內壁材料強度 Strength

- 施密特錘Schmidt hammer
  - 向下、向上、斜向強度不一樣

Rebound r	Downwards x = −90	x = −45
10	0	−0.8
20	0	−0.9
30	0	−0.8
40	0	−0.7
50	0	−0.6
60	0	−0.4

Rebound r	Upwards x = +90	x = +45	Horizontal x = 0
10			−3.2
20	−8.8	−6.9	−3.4
30	−7.8	−6.2	−3.1
40	−6.6	−5.3	−2.7
50	−5.3	−4.3	−2.2
60	−4.0	−3.3	−1.7

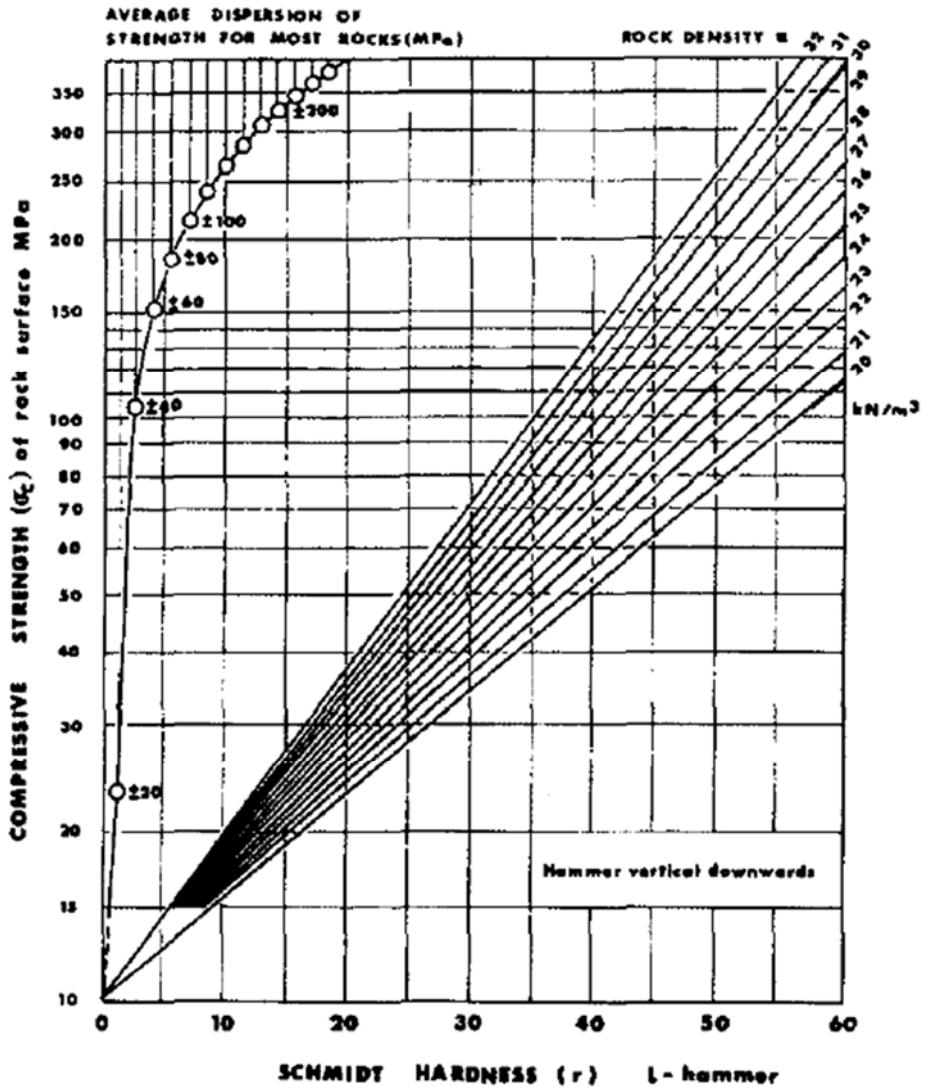


Fig. 20 Correlation chart for Schmidt (L) hammer, relating rock density, compressive strength and rebound number, after Miller [1].

史密特錘
(Schmidt hammer)

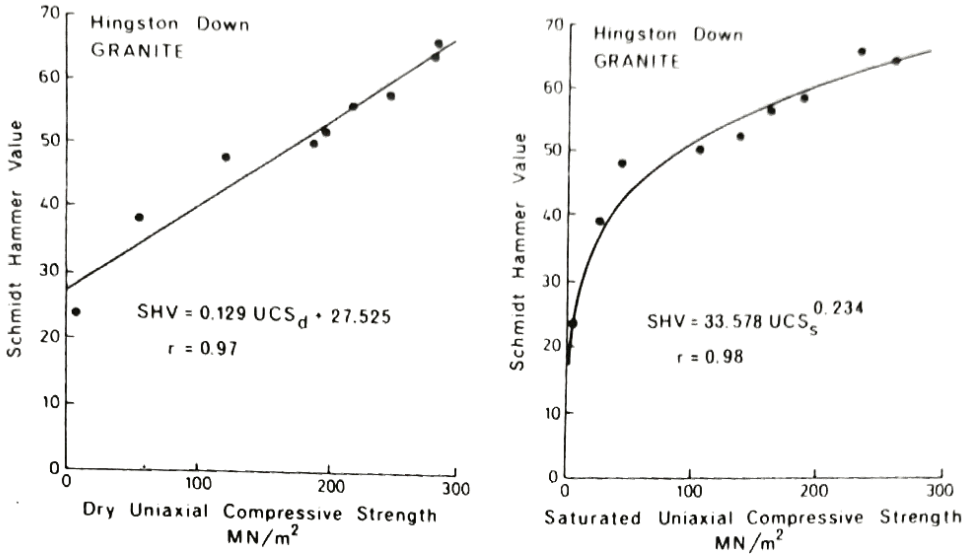


圖7.19 岩石在乾燥（左）與飽水（右）時，其施密特錘讀數（R 值）與單軸抗壓強度的關係 (Irfan and Dearman, 1978)

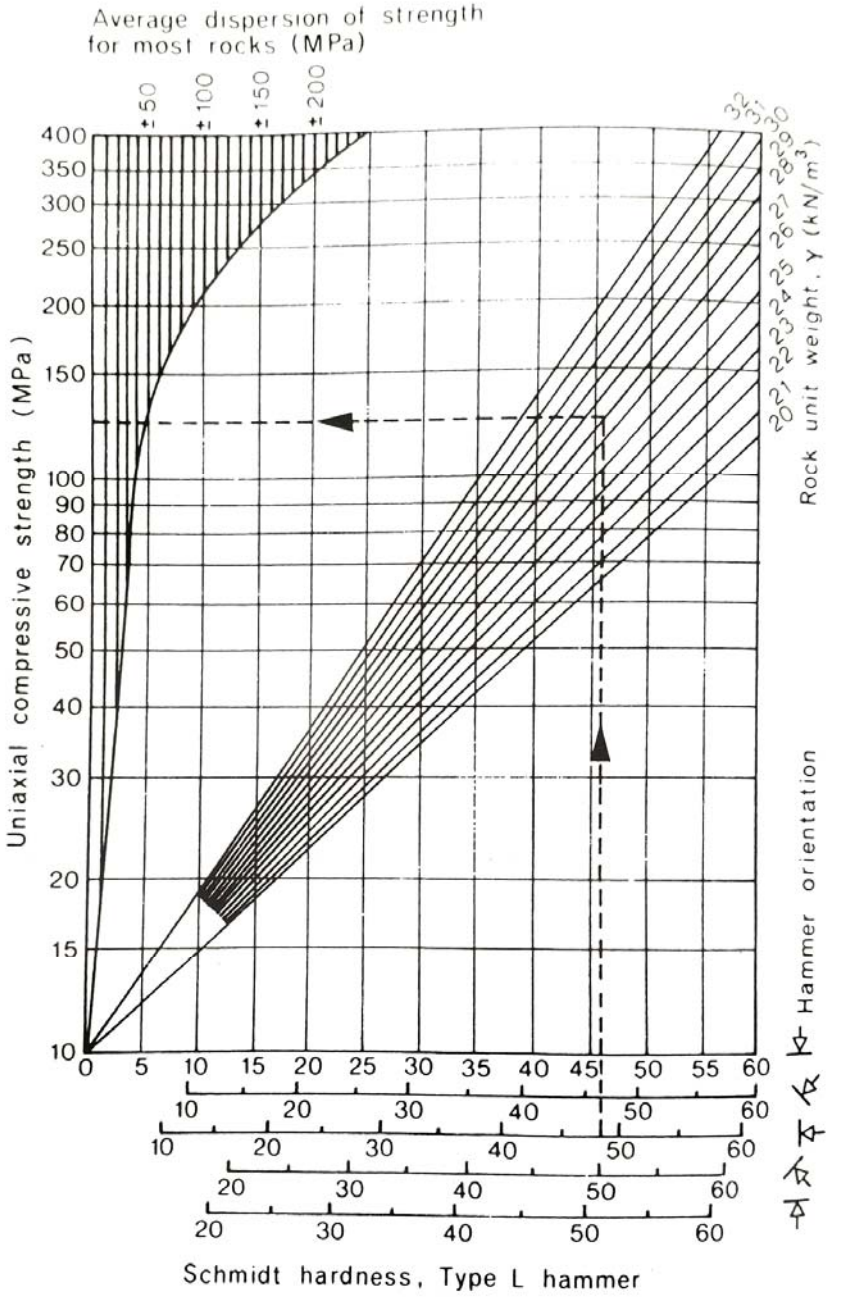
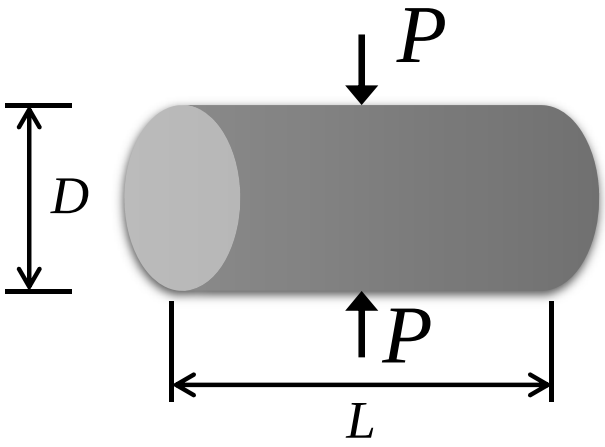


圖7.20 施密特錘讀數（R 值）與單軸抗壓強度的關係
(Hoek and Bray, 1977)

點荷重試驗



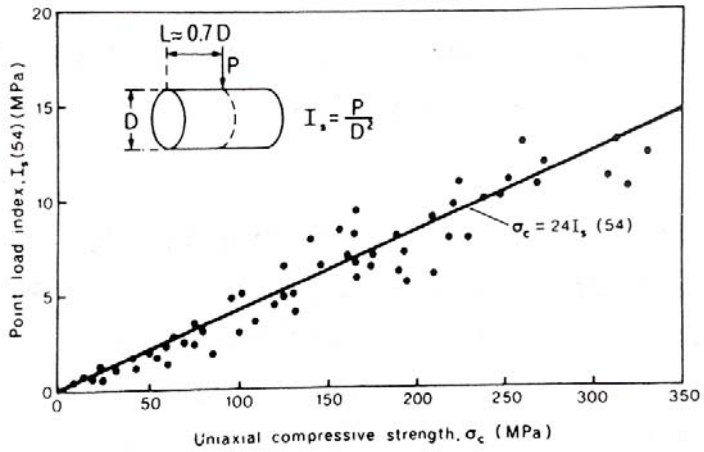


圖 7.17 點載重指數與單軸抗壓強度的關係 (Broch and Franklin, 1972)

$$I_s = \frac{P}{D^2} \qquad L \geq 1.4D$$

When D=50 mm, $q_u = 24 I_{s(50)}$

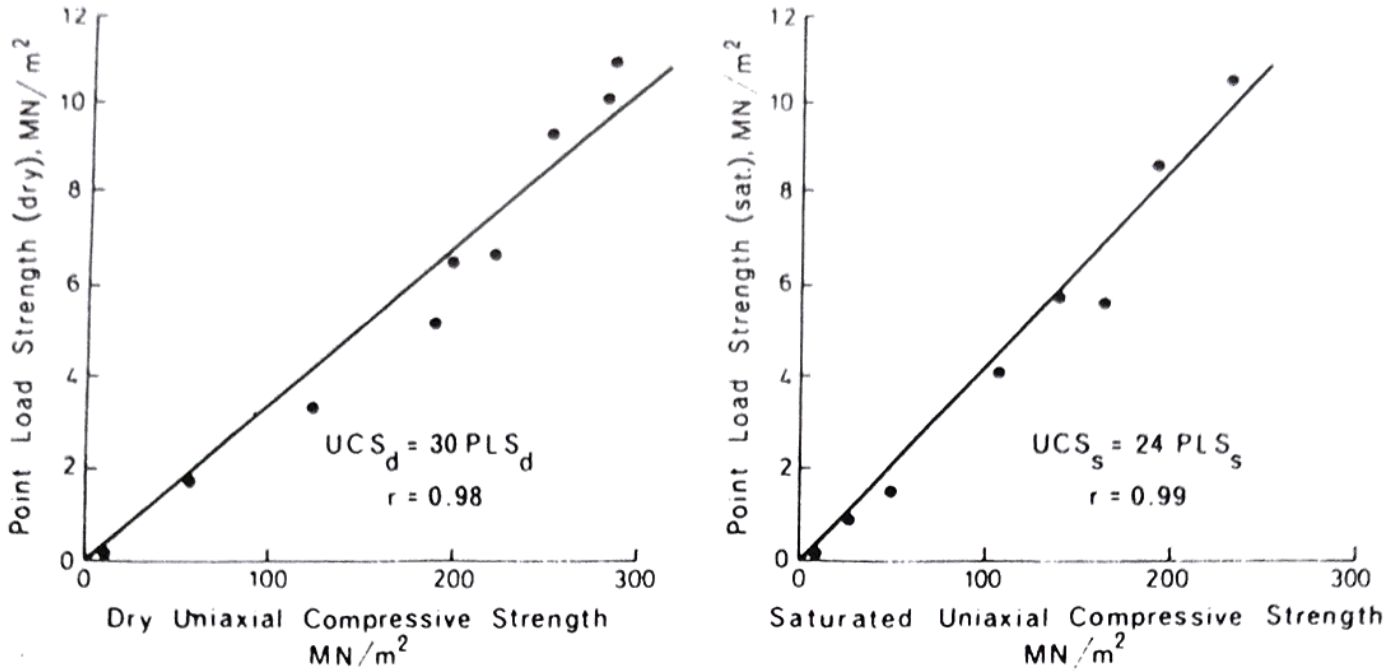


圖 7.18 樣品在乾燥（左）與飽水（右）時其點載重指數與單軸抗壓強度的關係（Irfan and Dearman, 1978）

Point-Load Test

(Reference: ISRM(1985), "Suggested Method for Determining Point-Load Strength," Int. J. R. M. vol.22, no.2, pp.51-60)

(1) Point-Load Index(strength)

$$I_{s(50)} = I_s \times F$$

where

$I_{s(50)}$ = size-corrected point-load strength (index)

$I_s = P / D_e^{\,2}$: uncorrected point-load strength

$F = \left(D_e / 50\right)^{0.45}$ (unit:mm) : size correction factor

P : point load

$D_e^{\,2} = D^2$ for diametral test

$4A/\pi$ for axial, block and lump tests

and

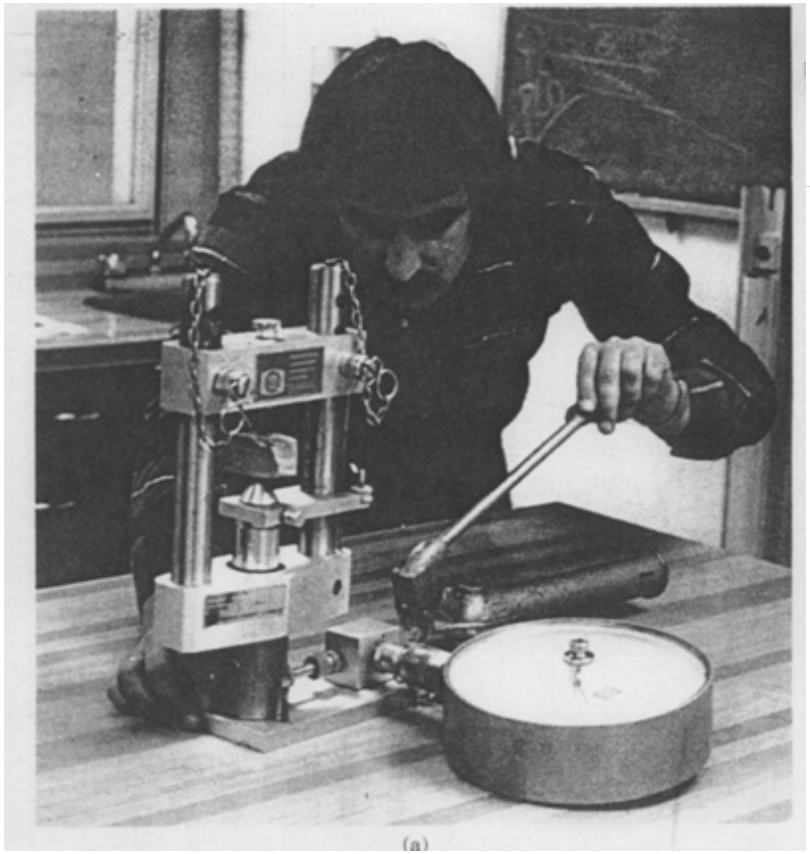
A = WD = minimum cross sectional area of a plane through the platen contact points

(2) (i) uniaxial compressive strength,

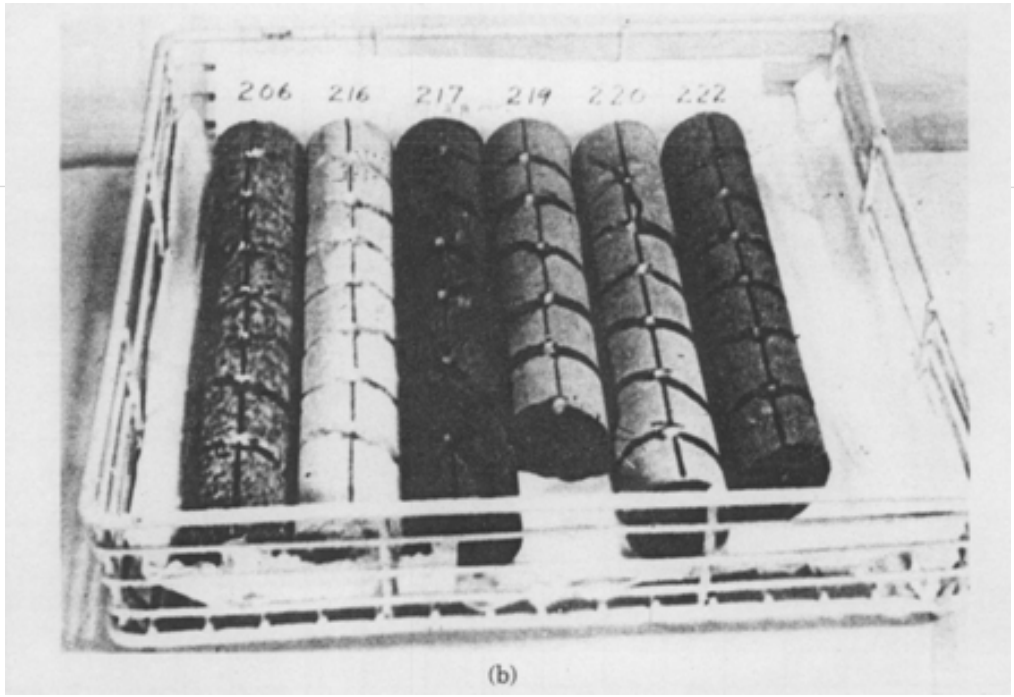
$$\sigma_c = (20 \sim 25) I_{s(50)}$$

(ii) uniaxial tensile strength,

$$\sigma_t = 1.25 I_{s(50)}$$



(a)



(b)

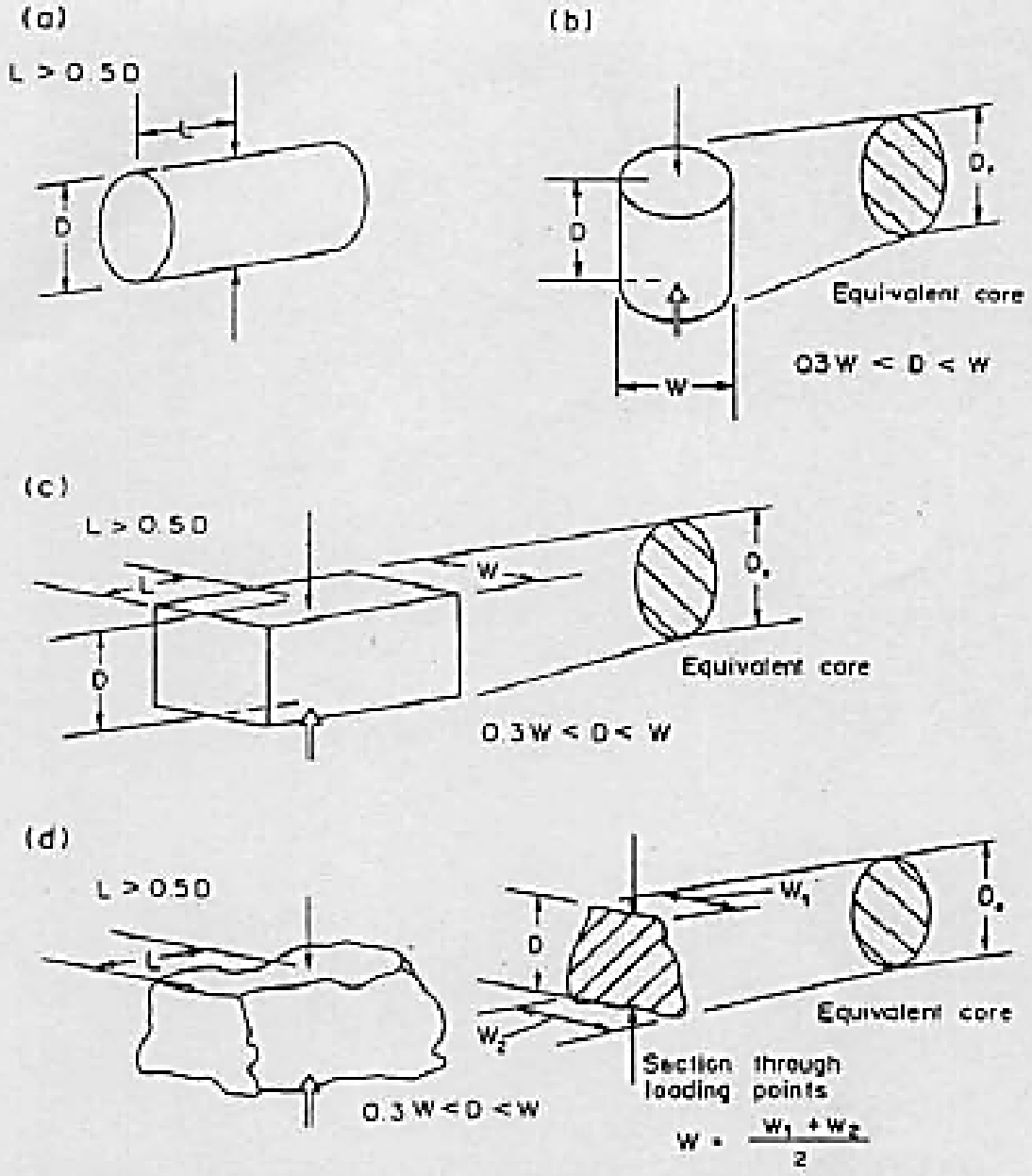


Fig. Specimen shape requirements for (a) the diametral test, (b) the axial test, (c) the block test, and (d) the irregular lump test.

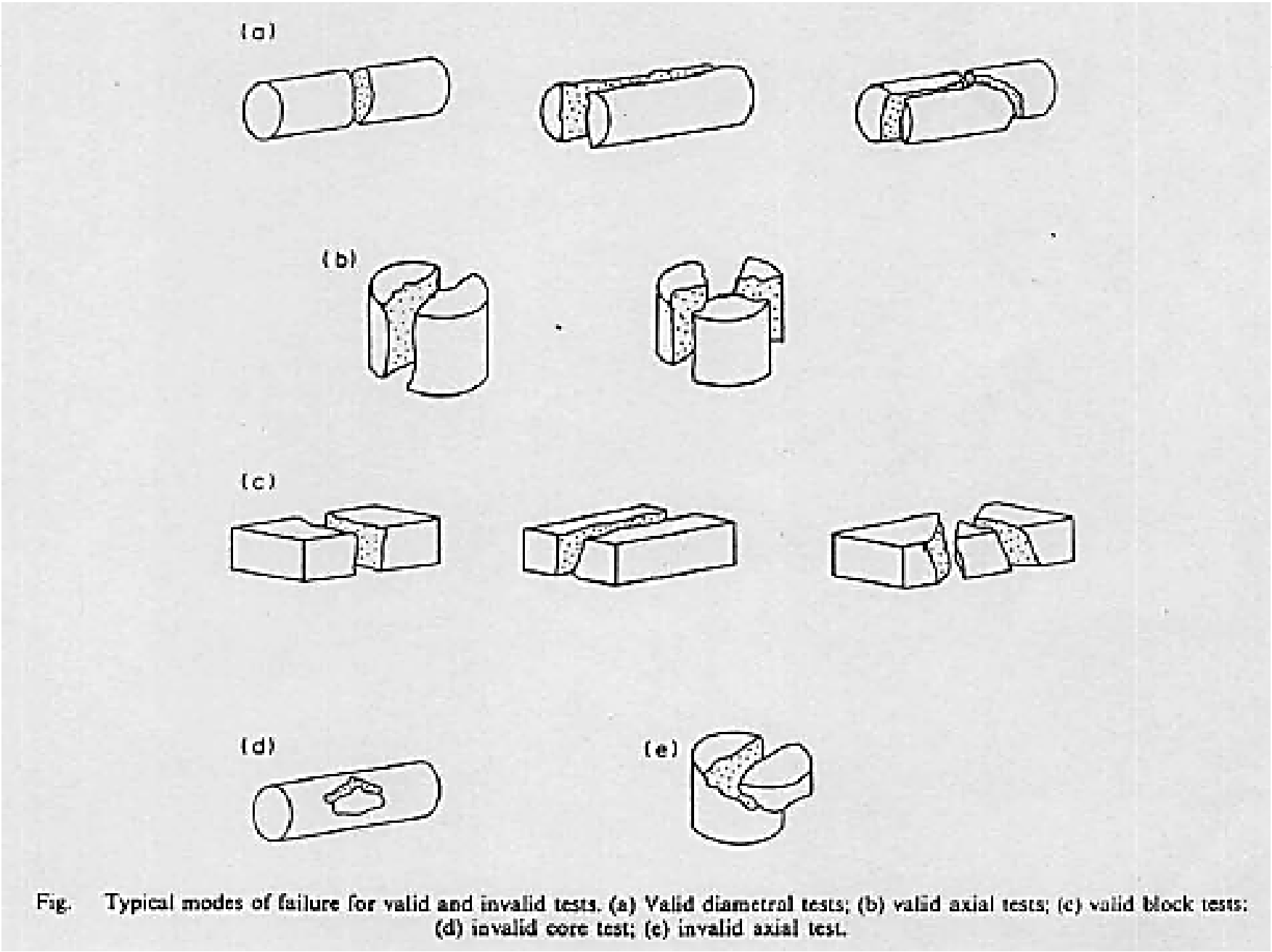


Fig. Typical modes of failure for valid and invalid tests. (a) Valid diametral tests; (b) valid axial tests; (c) valid block tests; (d) invalid core test; (e) invalid axial test.

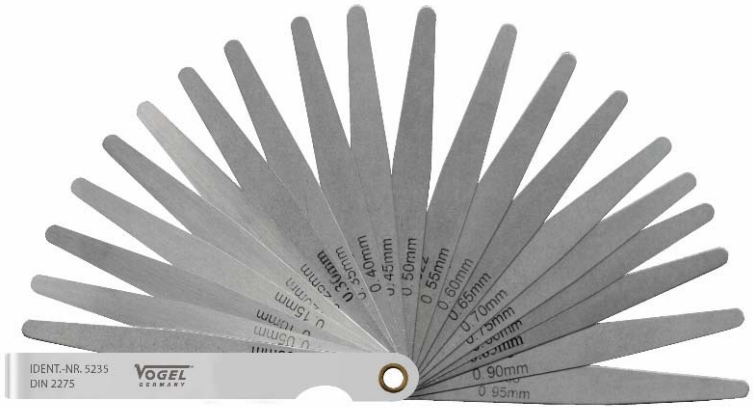
利用點荷重與施密特錘決定岩體強度(種類)

表 7.2 根據點載重指數與施密特錘讀數之簡略岩體分類法

岩質	點載重指數 (Mpa)	施密特錘讀數 (R)	單軸抗壓強度 (MPa)	特 性
極軟土			<0.04	用手易模塑，易留下腳印
軟土			0.04～0.08	可用力模塑，只留下模糊的腳印
密實土			0.08～0.15	用手難模塑，指甲可刮，鏟子難鏟
硬土			0.15～0.60	無法用手模塑，需用十字鎬才能挖掘
極硬土	0.02～0.04		0.60～1.0	堅硬，無法手掘，需用空壓鑿挖掘
極弱岩	0.04～1.0	10～35	1.0～25	用地質鎚尖頭敲擊可碎，小刀可刮
弱岩	1.0～1.5	35～40	25～50	用地質鎚尖頭敲擊可見深痕，小刀難刮
中強岩	1.5～4.0	40～50	50～100	用地質鎚尖頭敲擊只見淺痕，小刀不能刮
強岩	4.0～10.0	50～60	100～200	用地質鎚尖頭敲擊樣品一次可破裂
極強岩	>10	>60	>200	用地質鎚尖頭敲擊樣品多次才能破裂

6.內寬 Aperture

- 內寬是不連續面相鄰兩壁間的垂直距離
- 內寬的空間可能充滿空氣、水或其他填充物質
- 測線至少3 m，噴白漆後用 Feeler gauge (厚薄規；測隙規)量測，必要時先以水清洗露頭



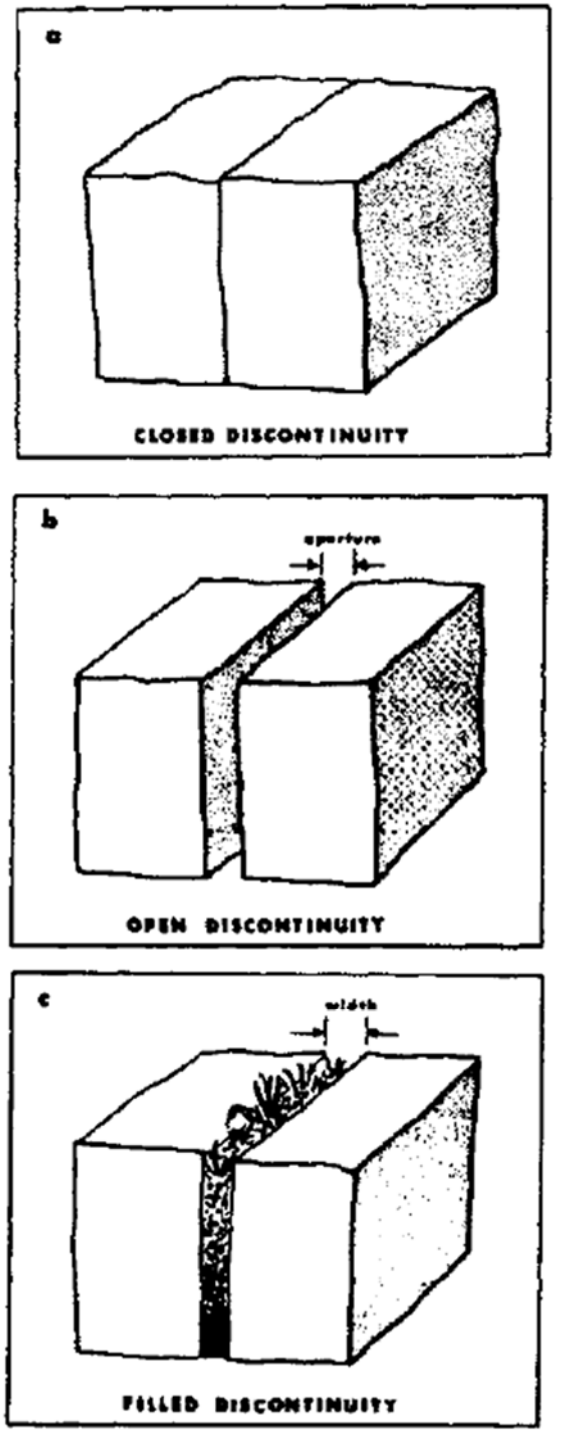
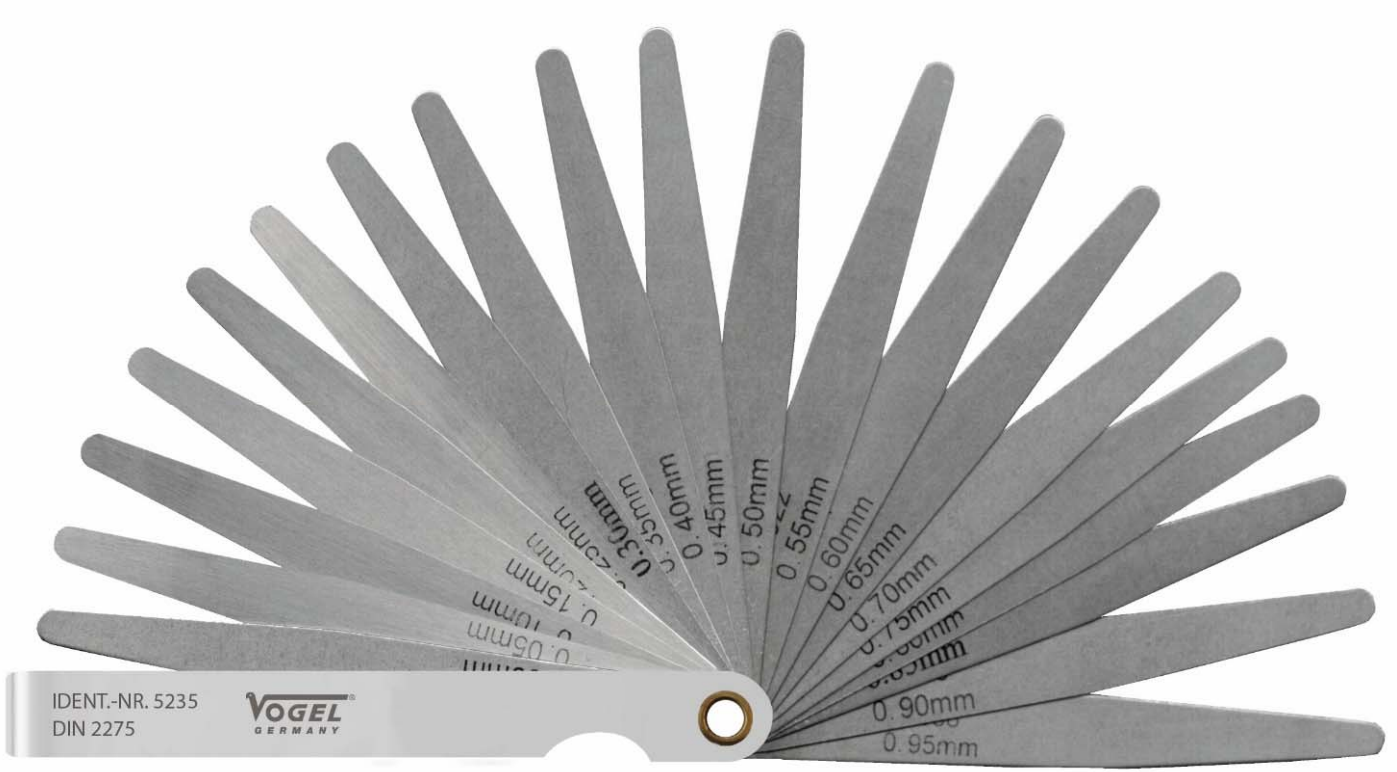


Fig. 21. Diagrams showing the suggested definitions of the *aperture* of open discontinuities and the *width* of filled discontinuities.

6.內寬 Aperture

- 噴白漆可凸顯最小內寬間隙位置，光線要充足
- 小內寬用feeler gauge，內寬大於mm直接用尺量即可



6.內寬 Aperture

- 每組不連續面紀錄最常見(modal)內寬
- 某一條裂隙內寬特別大時(比最常見內寬大)，應仔細記錄
- 極大內寬(10-100 cm)和洞穴狀內寬(>1 m)應附照片

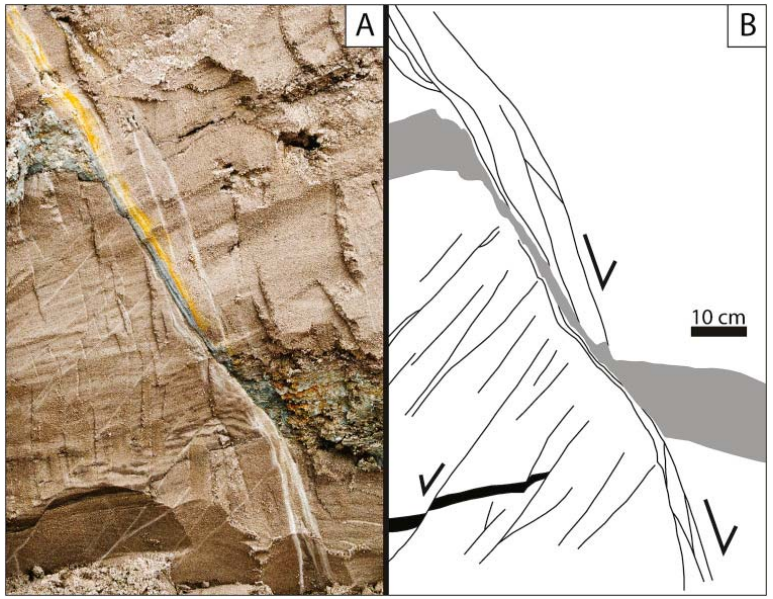
Aperture	Description		
<0.1 mm	Very tight		
0.1–0.25 mm	Tight	"Closed" features	緊密
0.25–0.5 mm	Partly open		
0.5–2.5 mm	Open		
2.5–10 mm	Moderately wide	"Gapped" features	開口
>10 mm	Wide		
1–10 cm	Very wide		
10–100 cm	Extremely wide	"Open" features	張開
>1 m	Cavernous		

7.不連續面充填情況 Filling

- 填充在不連續面中，分隔不連續面兩壁的材料
  - 方解石、綠泥石
  - 黏土、粉土
  - 斷層泥
  - 碎屑

clay filling rock fissure

calcite filling



Fault gauge filling rock fissure

7.不連續面充填情況 Filling

- 由於填充物質種類多樣，有充填物的不連續面特性(剪力強度、變形性、滲透性)差異非常大
- 短期與長期行為應該分開考量
- 有填充物的不連續面物理行為取決於：

(i) Mineralogy of filling material
(ii) Grading or particle size
(iii) Over-consolidation ratio
(iv) Water content and permeability
(v) Previous shear displacement
(vi) Wall roughness
(vii) Width
(viii) Fracturing or crushing of wall rock

- 量測：測線至少3 m，充填物質取樣1-2 kg(有時應考慮取不擾動樣本)。可用地質錘或小刀取樣。

7.不連續面充填情況 Filling

1) 寬度：量測最大與最小寬度，和最常見寬度

- 充填較薄時，可量測岩壁粗糙起伏的平均振幅，並與平均充填厚度比較(如右圖)
  - 振幅大小可用於判定剪位移量
  - 振幅越大，剪位移可能越大

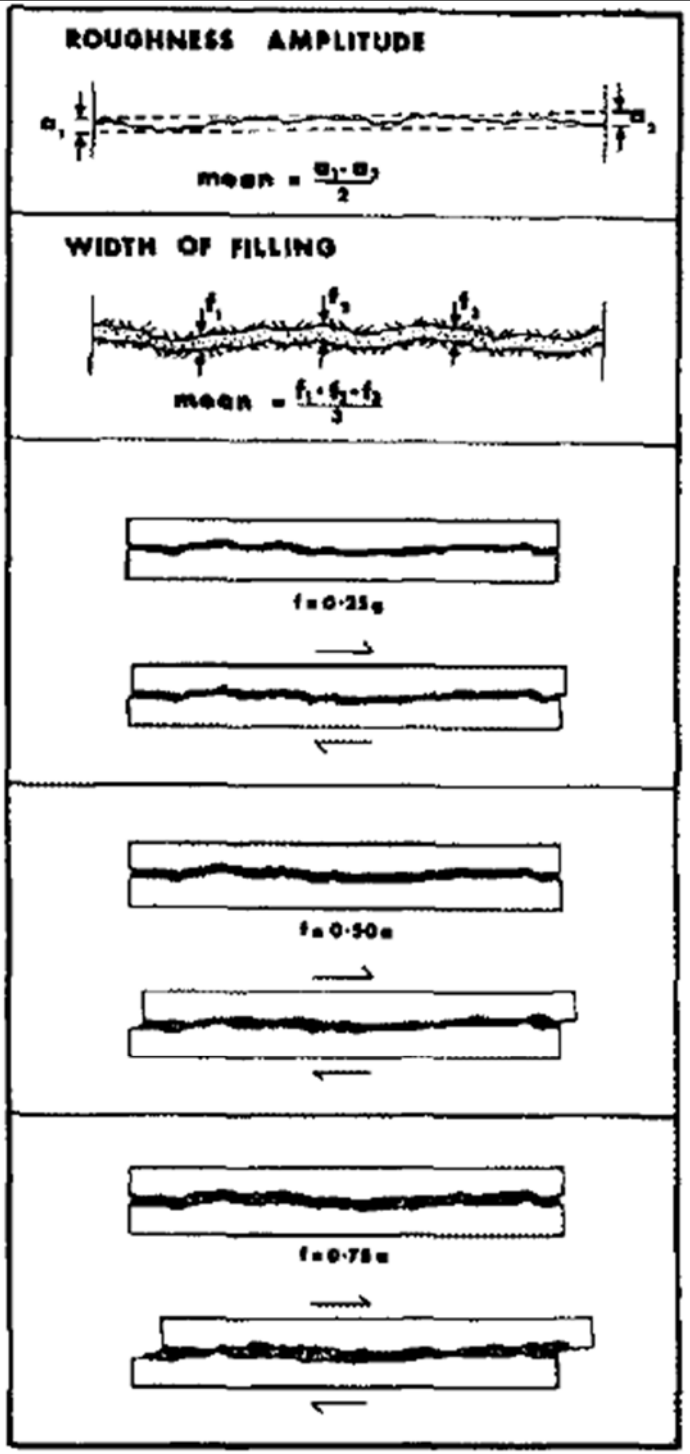


Fig. 22 In the case of simple filled discontinuities, the amplitude of the wall roughness and the thickness of the filling can help to indicate the amount of shear displacement required for rock contact (stiffening) to occur. (Zero volume change assumed during shear).

7.不連續面充填情況 Filling

2) 風化程度：是否保留原始組構

Decomposed:— The rock is weathered to the condition of a soil in which the original material fabric is still intact, but some or all of the mineral grains are decomposed.

Disintegrated:— The rock is weathered to the condition of a soil, in which the original material fabric is still intact. The rock is friable, but the mineral grains are not decomposed.

3) 礦物：特別注意膨脹性黏土礦物的存在(蒙托土、伊利土、高嶺土)

4) 顆粒大小

boulders	200–600 mm	coarse sand	0.6–2 mm
cobbles	60–200 mm	medium sand	0.2–0.6 mm
coarse gravel	20–60 mm	fine sand	0.06–0.2 mm
medium gravel	6–20 mm	silt, clay	<0.06 mm
fine gravel	2–6 mm		

7.不連續面充填情況 Filling

5) 充填物強度

Grade	Description	Field identification	Approx. range of uniaxial compressive strength (MPa)
S1	Very soft clay	Easily penetrated several inches by fist	< 0.025
S2	Soft clay	Easily penetrated several inches by thumb	0.025–0.05
S3	Firm clay	Can be penetrated several inches by thumb with moderate effort	0.05–0.10
S4	Stiff clay	Readily indented by thumb but penetrated only with great effort	0.10–0.25
S5	Very stiff clay	Readily indented by thumbnail	0.25–0.50
S6	Hard clay	Indented with difficulty by thumbnail	>0.50
R0	Extremely weak rock	Indented by thumbnail	0.25–1.0
R1	Weak rock	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	1.0–5.0
R2	Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	5.0–25
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	25–50
R4	Strong rock	Specimen requires more than one blow of geological hammer to fracture it	50–100
R5	Very strong rock	Specimen requires many blows of geological hammer to fracture it	100–250
R6	Extremely strong rock	Specimen can only be chipped with geological hammer	>250

Note. Grades S1 to S6 apply to cohesive soils, for example, clays, silty clays and combinations of silts and clays with sand, generally slow draining. Some rounding of the strength values has been made when converting to S.I. units.

7.不連續面充填情況 Filling

6) 前次位移previous displacement

7) 含水量與滲透性

W1 The filling materials are heavily consolidated and dry, significant flow appears unlikely due to very low permeability.

W2 The filling materials are damp, but no free water is present.

W3 The filling materials are wet, occasional drops of water.

W4 The filling materials show signs of outwash, continuous flow of water (estimate litres/minute).

W5 The filling materials are washed out locally, considerable water flow along out-wash channels (estimate litres/minute and describe pressure i.e. low, medium, high).

W6 The filling materials are washed out completely, very high water pressures experienced, especially on first exposure (estimate litres/minute and describe pressure).

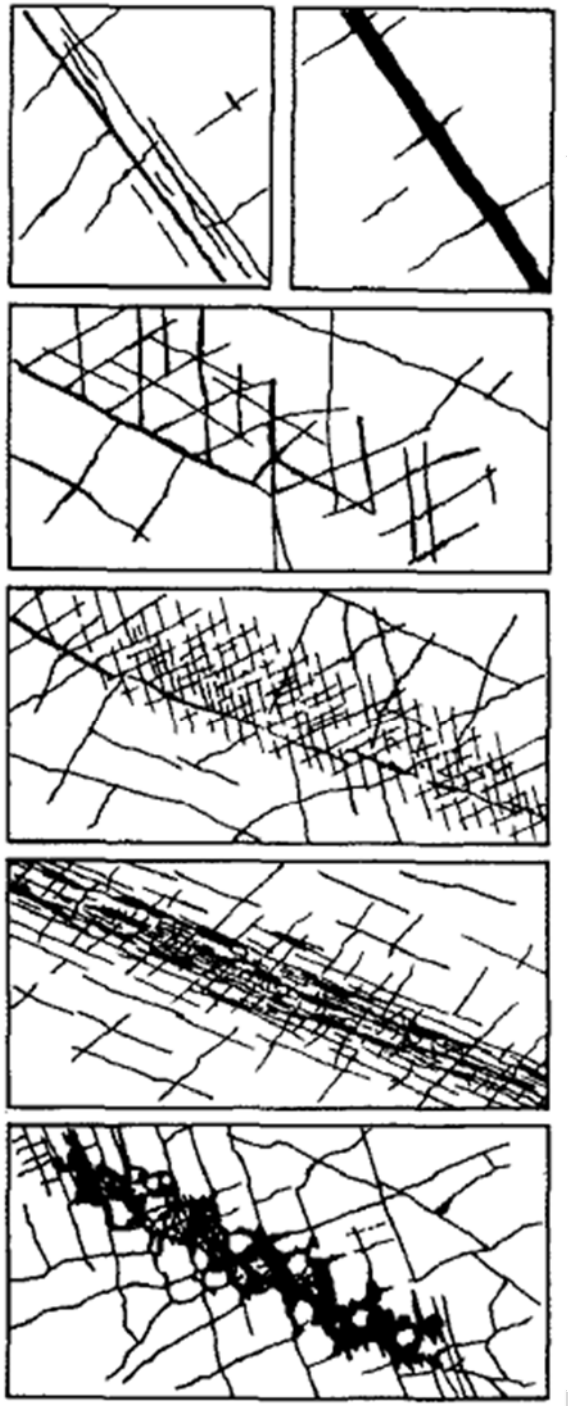


Fig. 23. Examples of field sketches of complex filled discontinuities [11]

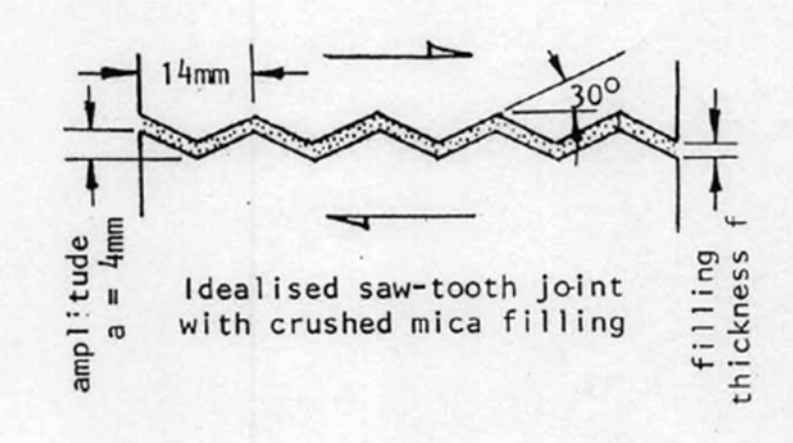
7.不連續面充填情況 Filling

- 結果表示方法

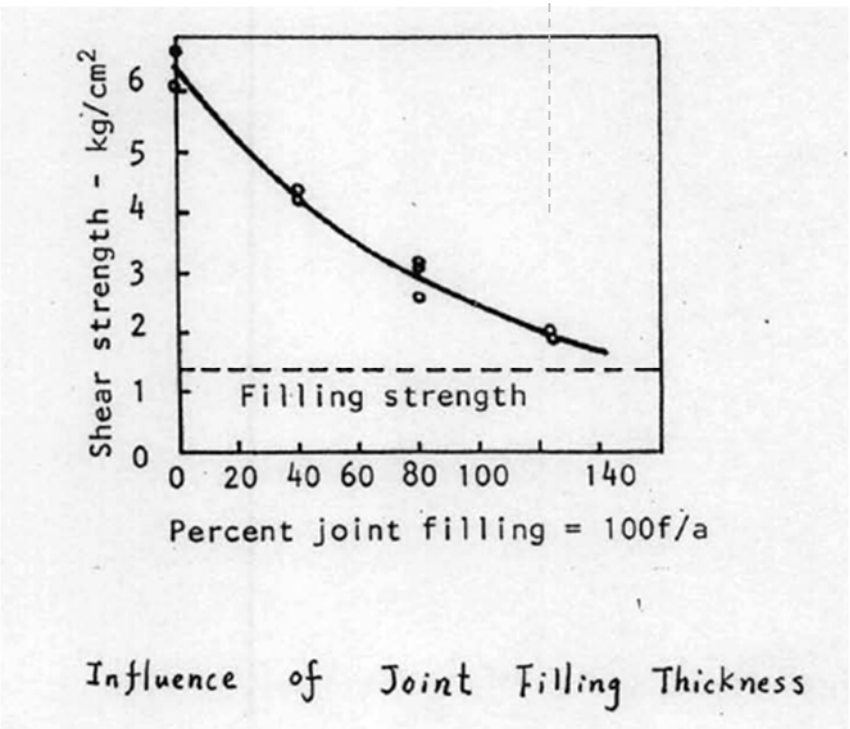
(*a*) Geometry:	width
	wall roughness
	field sketch
(*b*) Filling type:	mineralogy
	particle size
	weathering grade
	soil index parameters
	swelling potential
(*c*) Filling strength:	manual index (S1–S6)
	shear strength
	over-consolidation ratio
	displaced/undisplaced
(*d*) Seepage:	water content (rating as
	W1–W6) permeability
	quantitative data

7.不連續面充填情況 Filling

- 含夾泥弱面之剪力強度
  - 經風化後,水流經弱面時帶入之細粒料填充物
  - 當f為a之1.4倍時,強度由充填物控制



Idealised saw-tooth joint with crushed mica filling



Influence of Joint Filling Thickness

8.滲水(流)情形 Seepage

- 不連續面是地下水在岩體中流動的重要通道

8.滲水(流)情形 Seepage

- 不連續面滲透性因有無充填物而異

Unfilled discontinuities

Seepage rating	Description
I	The discontinuity is very tight and dry water flow along it does not appear possible.
II	The discontinuity is dry with no evidence of water flow.
III	The discontinuity is dry but shows evidence of water flow, i.e. rust staining, etc.
IV	The discontinuity is damp but no free water is present.
V	The discontinuity shows seepage, occasional drops of water, but no continuous flow.
VI	The discontinuity shows a continuous flow of water. (Estimate l/min and describe pressure i.e. low, medium, high).

Filled discontinuities

Seepage rating	Description
I	The filling materials are heavily consolidated and dry, significant flow appears unlikely due to very low permeability.
II	The filling materials are damp, but no free water is present.
III	The filling materials are wet, occasional drops of water.
IV	The filling materials show signs of outwash, continuous flow of water (estimate l/min).
V	The filling materials are washed out locally, considerable water flow along out-wash channels (estimate l/min and describe pressure i.e. low, medium, high).
VI	The filling materials are washed out completely, very high water pressures experienced, especially on first exposure (estimate l/min and describe pressure).

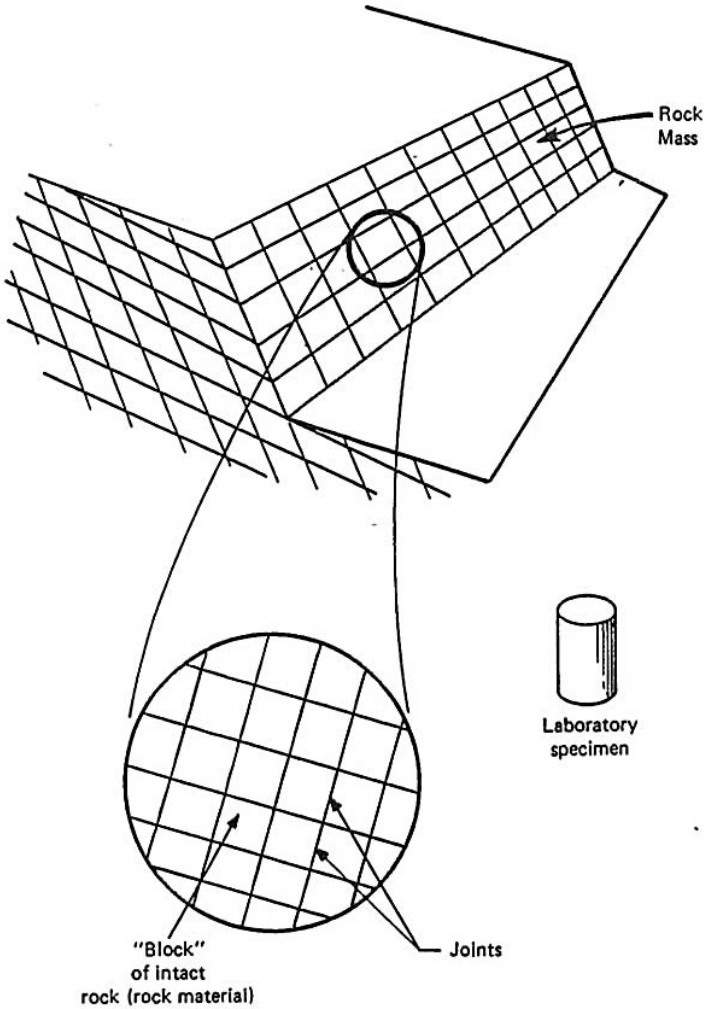
8.滲水(流)情形 Seepage

- 岩體滲透性之分類

Rock mass (e.g. tunnel wall)

Seepage rating	Description
I	Dry walls and roof, no detectable seepage.
II	Minor seepage, specify dripping discontinuities.
III	Medium inflow, specify discontinuities with continuous flow (estimate l/min/10 m. length of excavation).
IV	Major inflow, specify discontinuities with strong flows (estimate l/min/10 m. length of excavation).
V	Exceptionally high inflow, specify source of exceptional flows (estimate l/min/10 m. length of excavation).

回顧：岩體的定義



Definitions of *rock mass* and *rock material*.

岩體
(rock mass)

=

完整岩石
(intact rock)

+

不連續面
(discontinuity)

9.不連續面組數 Number of Sets

- 同一個位態的不連續面如果成群出現稱為一組(set)
- 量測：地質羅盤與相機
- 調查結果呈現

I	massive, occasional random joints
II	one joint set
III	one joint set plus random
IV	two joint sets
V	two joint sets plus random
VI	three joint sets
VII	three joint sets plus random
VIII	four or more joint sets
IX	crushed rock, earth-like

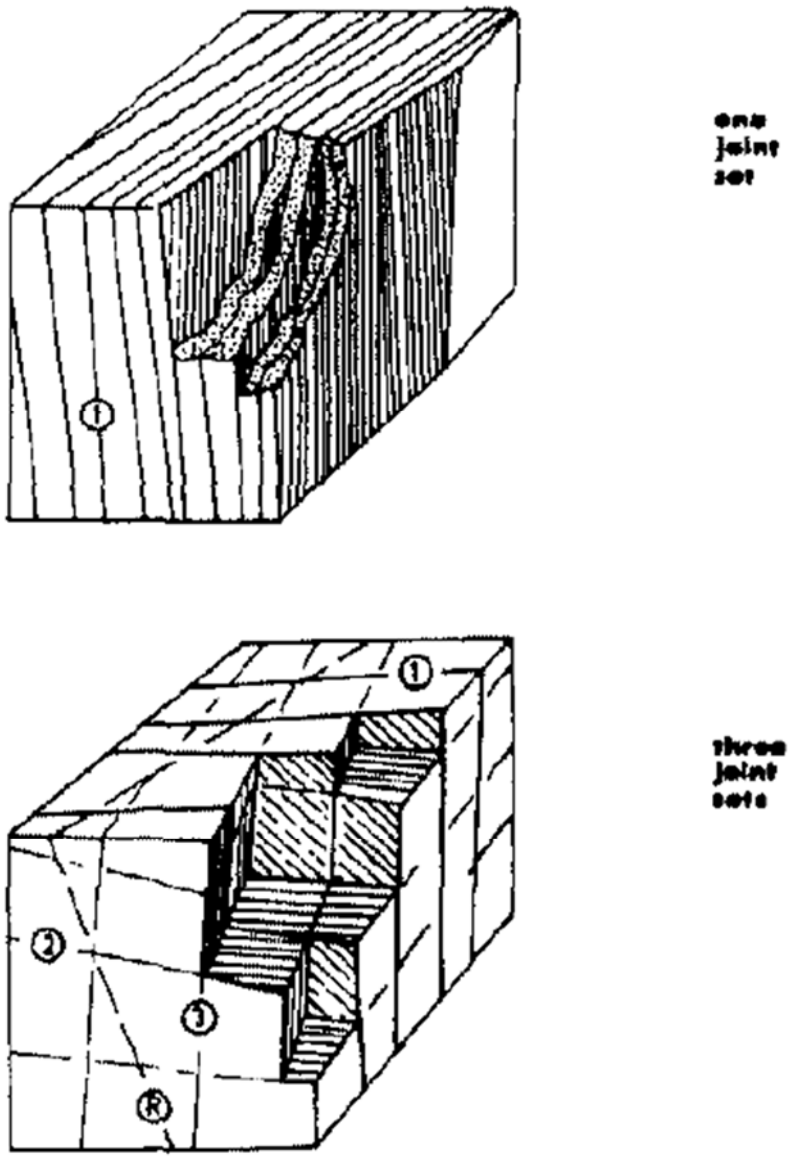


Fig. 24. Examples that demonstrate the effect of the number of joint sets on the mechanical behaviour and appearance of a rock mass.

10.岩塊尺寸(大小) Block size

- 不連續面的組數及間距決定了岩塊的形狀與大小
- 單位體積之弱面數(Volumetric Count of Weak Planes), J_r (或稱 J_V)

$$J_r = \frac{N_1}{L_1} + \frac{N_2}{L_2} + \cdots + \frac{N_n}{L_n}, \; N_i\text{為第}i\text{組弱面, 在長度}L_i\text{中之條數}$$

The following descriptive terms give an impression of the corresponding block size:

Description	J_r (joints/m^3)
Very large blocks	< 1 0
Large blocks	1–3
Medium-sized blocks	3–10
Small blocks	10–30
Very small blocks	> 30

Values of J_r > 60 would represent crushed rock, typical of a clay-free crushed zone.

- 每組不連續面的數量需沿垂直該不連續面的方向計數
- 建議取樣5或10 m

J_r = 6/10 + 24/10 + 5/5 + 1/10

J_r = 0.6 + 2.4 + 1.0 + 0.1 = 4.1/m^3 (medium-size blocks)

10.岩塊尺寸(大小) Block size

- 岩體按岩塊尺寸之分類

(i) *massive* = few joints or very wide spacing

(ii) *blocky* = approximately equidimensional

(iii) *tabular* = one dimension considerably smaller than the other two

(iv) *columnar* = one dimension considerably larger than the other two

(v) *irregular* = wide variations of block size and shape

(vi) *crushed* = heavily jointed to "sugar cube"

10.岩塊尺寸(大小) Block size

- 沉積岩中，通常出現兩組同時垂直層面的節理，使岩塊呈方形或稜柱塊狀，可用岩塊規模指數(Block size index),I_B

$$I_B = \frac{S_1 + S_2 + S_3}{n}, \; S_1 \text{為第1組之弱面間距}$$

- 岩石品質指標(Rock Quality Designation), RQD
  - 每m岩心中, 長度超過10cm部分者之總長度對全部岩心長 (1m)之百分比

$$RQD = 115 - 3.3J_r, \; RQD \leq 100$$

10.岩塊尺寸(大小) Block size

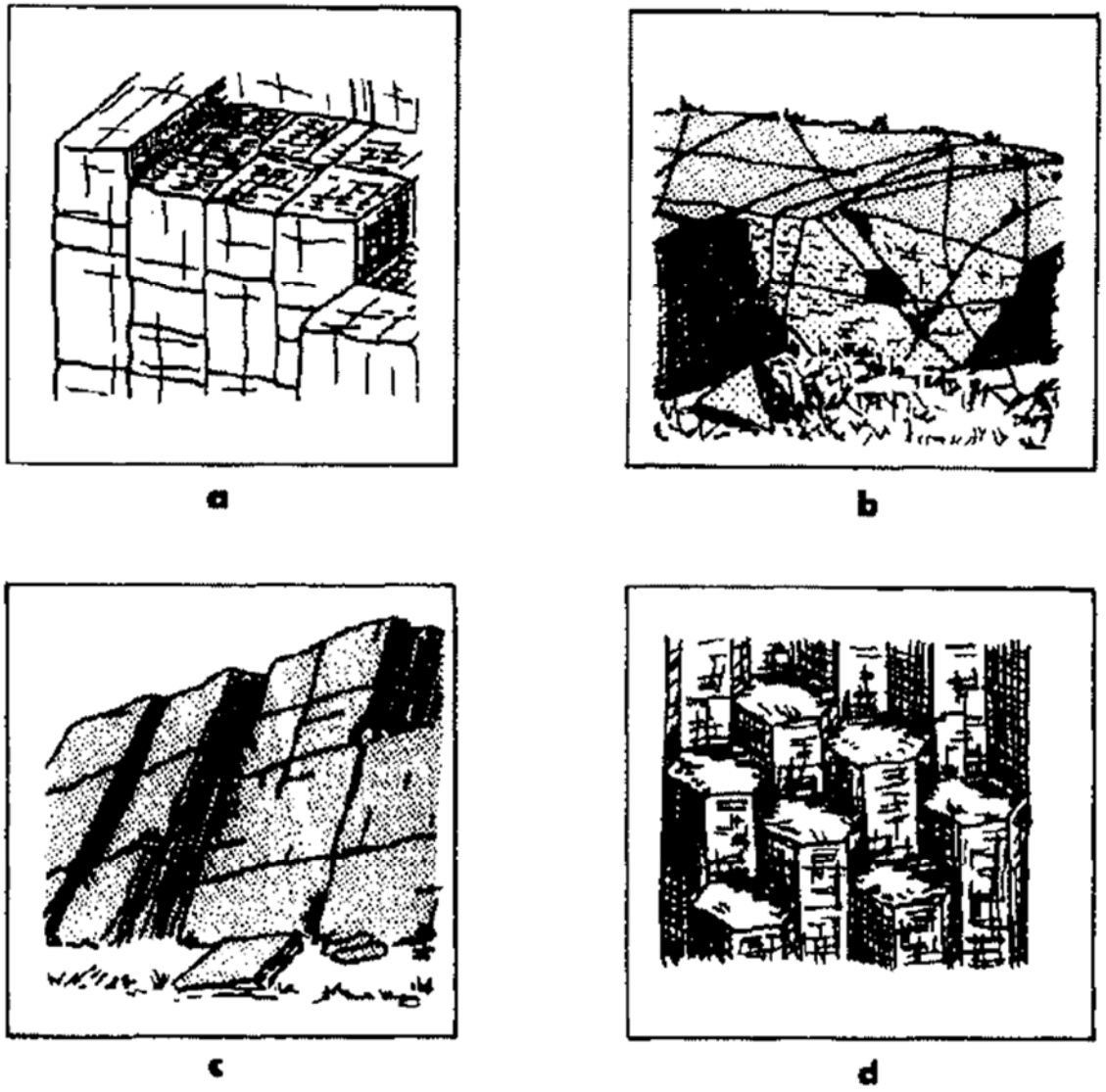


Fig. 25. Sketches of rock masses illustrating (a) *blocky*, (b) *irregular*, (c) *tabular* and (d) *columnar* block shapes.