



109.01

Engineering Geology  
工程地質

Ch7(補充) 岩石邊坡運動學分析

授課教師：邱雅筑

2020/11/23

# 大綱

1. 邊坡的破壞模式
2. 岩石邊坡運動學分析
  - 2.1 平面破壞
  - 2.2 楔型破壞
  - 2.3 傾覆破壞
3. 運動學分析之應用

# 邊坡的破壞模式

- Varnes(1978)

表 1 Varnes 山崩分類方法

運動型態		材料種類		
		岩石	工程土壤	
			岩屑	土
墜落	岩石墜落	岩屑墜落	土墜落	
傾覆	岩石傾覆	岩屑傾覆	土傾覆	
滑動	圓弧形	岩石滑動	岩屑滑動	土塊滑動
	平面型			
側滑	岩石側滑	岩屑側滑	土側滑	
流動	岩石流動 (深層潛移)	岩屑流動 (土壤潛移)	土流動	
複合型運動	綜合兩種或兩種以上之運動方式			

楊樹榮等(2011)，譯自Varnes(1978)

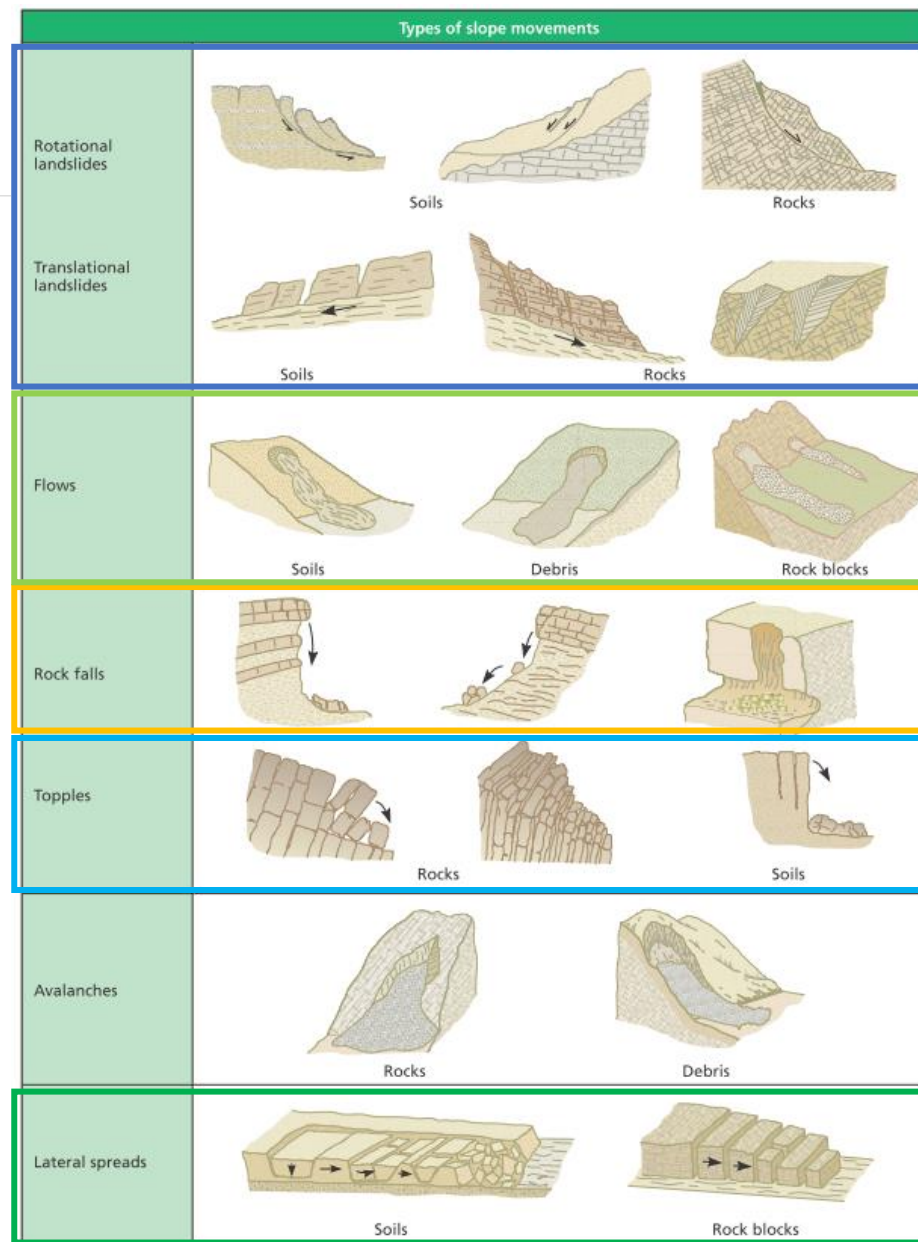


Figure 13.2 General classification of slope movements.

Gonzalez de Vallejo (2011)

# 邊坡的破壞模式

- Cruden and Varnes (1996): 綜合學者建議與 IAEG之UNESCO Working Party 的名詞定義
- 拿掉複合型運動，改以明確描述包含哪幾種運動型態

表1 Varnes 山崩分類方法

運動型態	材料種類		
	岩石	工程土壤	
		岩屑	土
墜落	岩石墜落	岩屑墜落	土墜落
傾覆	岩石傾覆	岩屑傾覆	土傾覆
滑動	圓弧形	岩石滑動	岩屑滑動
	平面型		
側滑	岩石側滑	岩屑側滑	土側滑
流動	岩石流動	岩屑流動	土流動
	(深層潛移)		
<del>複合型運動</del>	<del>綜合兩種或兩種以上之運動方式</del>		

楊樹榮等(2011)，譯自Varnes(1978)

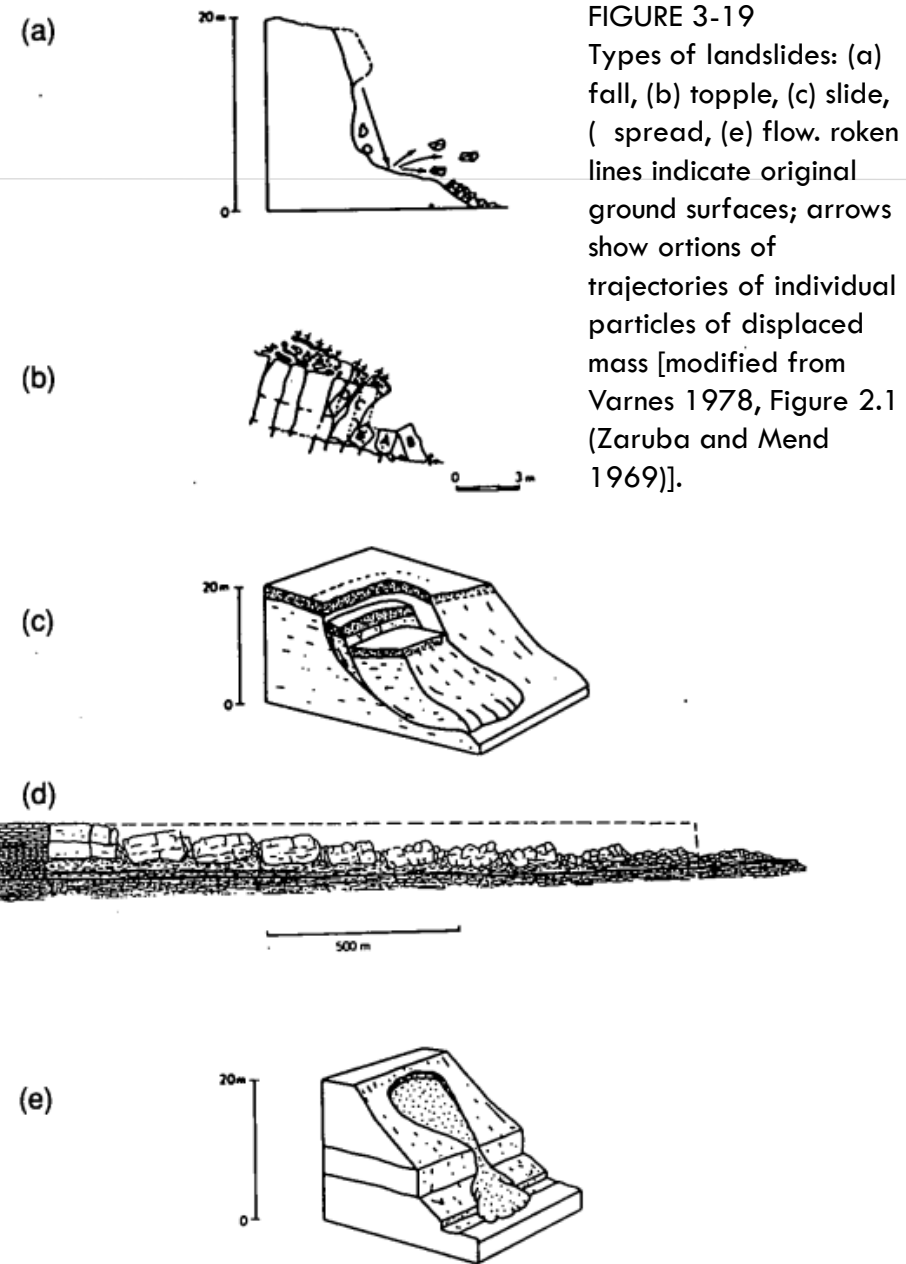


FIGURE 3-19  
Types of landslides: (a) fall, (b) topple, (c) slide, (d) spread, (e) flow. Broken lines indicate original ground surfaces; arrows show portions of trajectories of individual particles of displaced mass [modified from Varnes 1978, Figure 2.1 (Zaruba and Mendel 1969)].

# 邊坡的破壞模式 Hungr et al.(2014)

- The Varnes classification of landslide types, an update

**Table 5** Summary of the proposed new version of the Varnes classification system. The words in italics are placeholders (use only one)

Type of movement	Rock	Soil
Fall	1. <i>Rock/ice</i> fall <sup>a</sup>	2. <i>Boulder/debris/silt</i> fall <sup>a</sup>
Topple	3. <i>Rock block</i> topple <sup>a</sup>	5. <i>Gravel/sand/silt</i> topple <sup>a</sup>
	4. <i>Rock flexural</i> topple	
Slide	6. <i>Rock rotational</i> slide	11. <i>Clay/silt</i> rotational slide
	7. <i>Rock planar</i> slide <sup>a</sup>	12. <i>Clay/silt</i> planar slide
	8. <i>Rock wedge</i> slide <sup>a</sup>	13. <i>Gravel/sand/debris</i> slide <sup>a</sup>
	9. <i>Rock compound</i> slide	14. <i>Clay/silt</i> compound slide
Spread	15. <i>Rock slope</i> spread	16. <i>Sand/silt</i> liquefaction spread <sup>a</sup>
		17. <i>Sensitive clay</i> spread <sup>a</sup>
Flow	18. <i>Rock/ice</i> avalanche <sup>a</sup>	19. <i>Sand/silt/debris</i> dry flow
		20. <i>Sand/silt/debris</i> flowslide <sup>a</sup>
		21. <i>Sensitive clay</i> flowslide <sup>a</sup>
		22. <i>Debris</i> flow <sup>a</sup>
		23. <i>Mud</i> flow <sup>a</sup>
		24. <i>Debris</i> flood
		25. <i>Debris</i> avalanche <sup>a</sup>
Slope deformation	28. <i>Mountain slope</i> deformation	30. <i>Soil slope</i> deformation
	29. <i>Rock slope</i> deformation	31. <i>Soil</i> creep
		32. <i>Solifluction</i>

增加  
邊坡變形

For formal definitions of the landslide types, see text of the paper.

<sup>a</sup> Movement types that usually reach extremely rapid velocities as defined by Cruden and Varnes (1996). The other landslide types are most often (but not always) extremely slow to very rapid

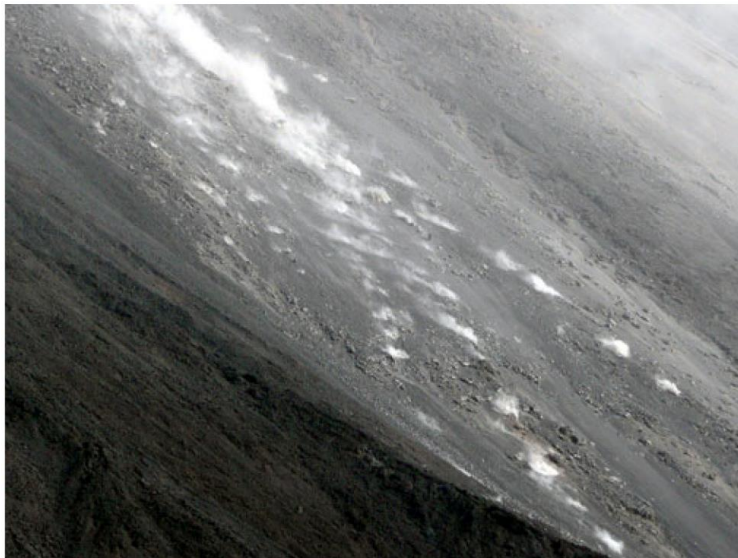
# 墜落Fall

Hungr et al.(2014)

**Table 5** Summary of the proposed new version of the Varnes classification system. The words in *italics* are placeholders (use only one)

Type of movement	Rock	Soil
Fall	1. <i>Rock/ice fall</i> <sup>a</sup>	2. <i>Boulder/debris/silt fall</i> <sup>a</sup>

- **Rock/ice fall:** Detachment, fall, rolling, and bouncing of **rock** or **ice fragments**.



**Fig. 2** Rock fall: rock fragments bouncing and rolling over the surface of a talus cone on Mt. Stromboli, Italy (Photo by O. Hungr)



圖1 落石主要發生在陡坡，材料為岩石，由至少兩組以上節理切割岩盤，造成岩石以自由落體、彈跳或是滾動的運動方式向下坡運動，並在坡腳形成崖錐堆積，且多發生在砂頁岩差異侵蝕之區域，變質岩區域亦常見到落石。多以混凝土噴漿或是掛網植生等方式穩定坡面。  
楊樹榮等(2011)

# 墜落(落石) Fall

Hungr et al.(2014)

<https://www.facebook.com/udnplus/videos/281680402881422/>



花蓮6.1震撼全台

TVBS新聞台 HD

台八線

TVBS  
NEWS

地震瞬間中橫落石如雨 駕駛狂閃尖叫





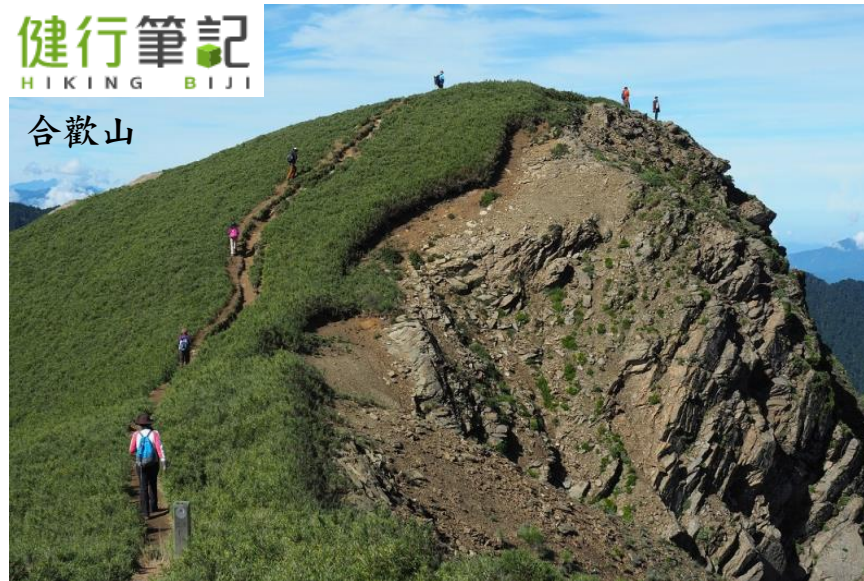
# 傾覆Topple

Hungr et al.(2014)

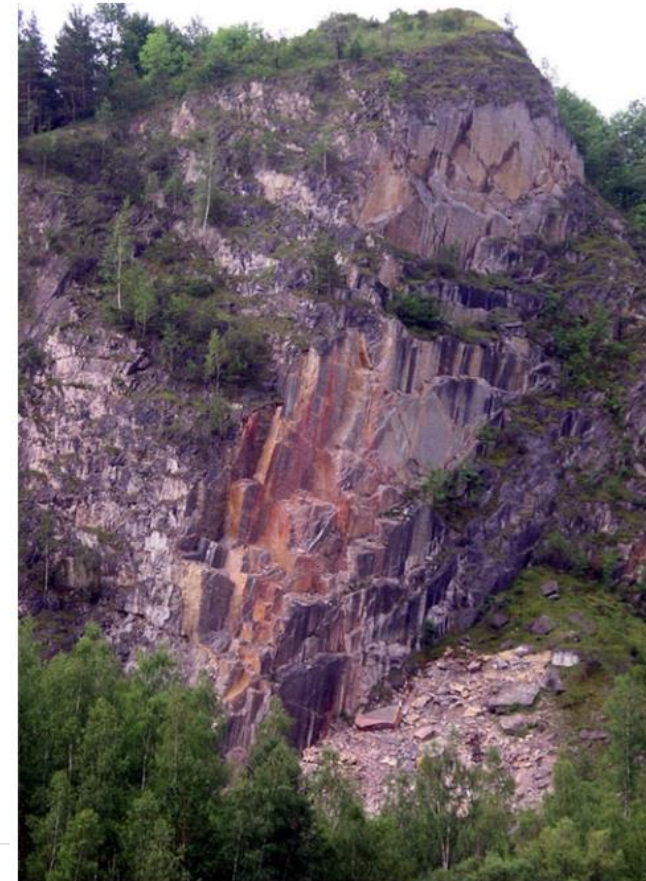
**Table 5** Summary of the proposed new version of the Varnes classification system. The words in *italics* are placeholders (use only one)

Type of movement	Rock	Soil
Topple	3. Rock block topple <sup>a</sup>	5. <i>Gravel/sand/silt</i> topple <sup>a</sup>
	4. Rock flexural topple	

- **Rock block topple:** Forward rotation and overturning of **rock columns** or **plates** (one or many), separated by steeply dipping joints.



<https://hiking.biji.co/index.php?q=news&act=info&id=7538>



**Fig. 4** Block topple in limestone, Czech Republic (Photo by O. Hungr)

# 滑動Slide

Hungr et al.(2014)

**Table 5** Summary of the proposed new version of the Varnes classification system. The words in *italics* are placeholders (use only one)

Type of movement	Rock	Soil
Slide	6. Rock rotational slide	11. <i>Clay/silt</i> rotational slide
	7. Rock planar slide <sup>a</sup>	12. <i>Clay/silt</i> planar slide
	8. Rock wedge slide <sup>a</sup>	13. <i>Gravel/sand/debris</i> slide <sup>a</sup>
	9. Rock compound slide	14. <i>Clay/silt</i> compound slide
	10. Rock irregular slide <sup>a</sup>	

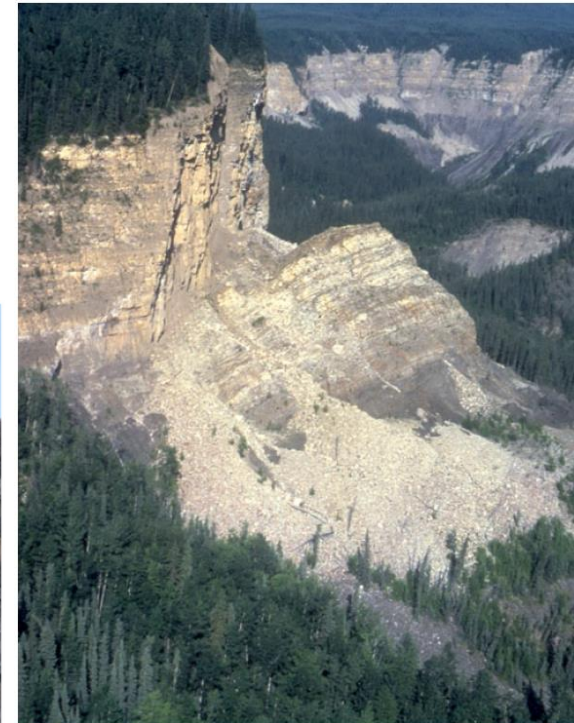
- Rock rotational slide (“rock slump”): Sliding of **a mass of weak rock** on a cylindrical or other rotational rupture surface which is not structurally controlled.



**Fig. 11** A translational slide in tectonized Tertiary clay shale, Murazzano, Langhe district, northern Italy (Courtesy of Servizio Geologico della Regione Piemonte and C. Scavia, Turin Polytechnic)



**Fig. 8** Scars of wedge failures in limestone, Canmore, Alberta, Canada. The cliff is approximately 50 m high (Photo by O. Hungr)



**Fig. 6** A rotational slide involving Cretaceous shale, overlain by sandstone. Liard Plateau, Canada (Photo by O. Hungr)



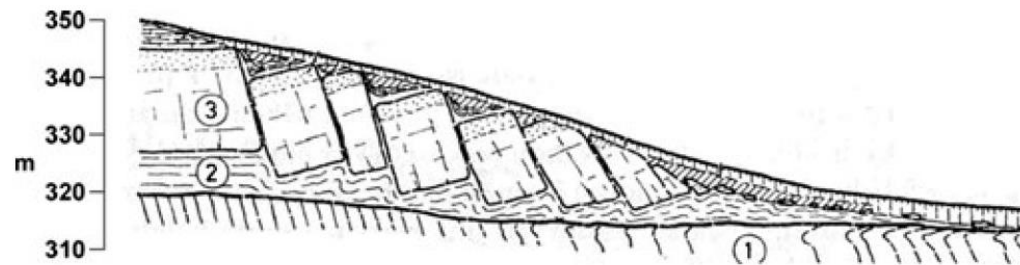
# 側滑 Spread

Hungr et al.(2014)

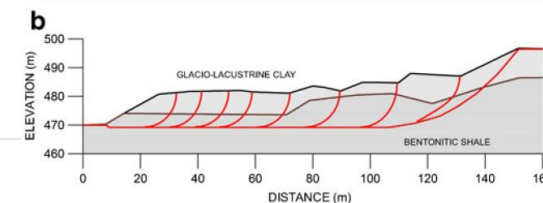
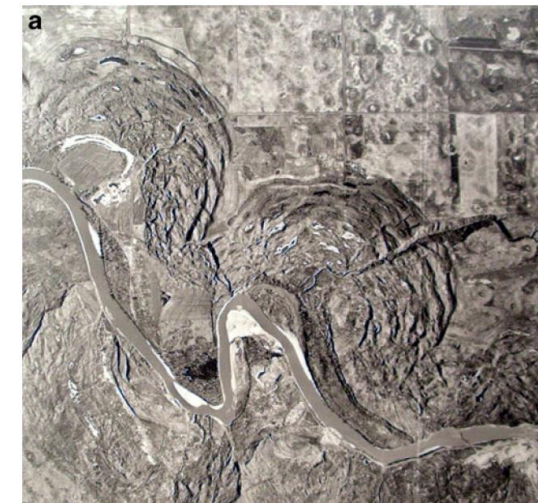
**Table 5** Summary of the proposed new version of the Varnes classification system. The words in italics are placeholders (use only one)

Type of movement	Rock	Soil
Spread	15. Rock slope spread	16. <i>Sand/silt</i> liquefaction spread <sup>a</sup>
		17. Sensitive clay spread <sup>a</sup>

- **Rock slope spread:** Near-horizontal stretching (elongation) of **a mass of coherent blocks of rock** as a result of intensive deformation of an underlying weak material, or by multiple retrogressive sliding controlled by a weak basal surface.



**Fig. 14** Slow spreading of blocks of sandstone blocks due to the deep deformation of a weak shale substrate, Prague, Czech Republic: 1, Phyllite; 2, deformed shale, and 3, sandstone. (Zaruba and Mencl 1969)



# 側滑Spread

Hungr et al.(2014)





**Table 5** Summary of the proposed new version of the Varnes classification system. The words in *italics* are placeholders (use only one)

Type of movement	Rock	Soil
Flow	18. <i>Rock/ice</i> avalanche <sup>a</sup>	19. <i>Sand/silt/debris</i> dry flow
		20. <i>Sand/silt/debris</i> flowslide <sup>a</sup>
		21. Sensitive clay flowslide <sup>a</sup>
		22. Debris flow <sup>a</sup>
		23. Mud flow <sup>a</sup>
		24. Debris flood
		25. Debris avalanche <sup>a</sup>
		26. Earthflow
		27. Peat flow

- **Rock/ice avalanche:** Extremely rapid, massive, flow-like motion of **fragmented rock** from a large rock slide or rock fall.



**Fig. 19** "Frank Slide" rock avalanche of 1903, southern Alberta, Canada. The horizontal length of the avalanche path is 3 km, volume 36 million m<sup>3</sup>. (Photo by O. Hungr)



**Fig. 21** The 1999 rock avalanche deposited on a glacier surface, Mt. Munday, British Columbia, Canada (Delaney and Evans 2013). (Topography and ortho-photo courtesy of MacElhanney, Ltd., Vancouver and image courtesy S.G. Evans, University of Waterloo)



**Fig. 22** Dry sand flow on the lee slope of a sand dune, Namib Desert (Courtesy of G.D. Plage)

# 邊坡變形 Slope deformation

Hungr et al.(2014)

**Table 5** Summary of the proposed new version of the Varnes classification system. The words in *italics* are placeholders (use only one)

Type of movement	Rock	Soil
Slope deformation	28. Mountain slope deformation	30. Soil slope deformation
	29. Rock slope deformation	31. Soil creep
		32. Solifluction

- **Mountain slope deformation:** *Large-scale gravitational deformation of steep, high mountain slopes*, manifested by scarps, benches, cracks, trenches and bulges, but lacking a fully defined rupture surface.
- Extremely slow or unmeasurable movement rates.



**Fig. 35** Slope deformation features on Mission Ridge, Southern B.C., Canada. (Courtesy of C. Esposito, La Sapienza, University of Rome)



**Adrienna R**  
**Geotechnical**



# 台灣所用的山崩分類

運動種類 Type of Movement		物質種類 Type of Material		
		基岩 Bedrocks	工程土壤 Engineering Soils	工程土壤 Engineering Soils
			粗粒為主	細粒為主
墜落 Falls		岩石墜落 Rock Fall	岩屑墜落 Debris Fall	土墜落 Earth Fall
傾覆 Topples		岩石傾覆 Rock Topple	岩屑傾覆 Debris Topple	土傾覆 Earth Topple
滑動 Slides	轉動 Rotational	岩石崩移 Rock Slump	岩屑崩移 Debris Slump	土崩移 Earth Slump
	移動 Translational	岩體滑動 Rock Block Slide	岩屑塊滑動 Debris Block Slide	土塊滑動 Earth Block Slide
		岩石滑動 Rock Slide	岩屑塊滑動 Debris Slide	土滑動 Earth Slide
側滑 Lateral Spreads		岩石側滑 Rock Spread	岩屑側滑 Debris Spread	土側滑 Earth Spread
流動 Flows		岩石流動 Rock Flow	岩屑流動 Debris Flow	土流動 Earth Flow
複合運動 Complex		復合兩種或 以上之運動		

經濟部中央地質調查所(2008)  
表 2 中央地質調查所山崩分類方法

運動型態		材料種類	
		岩石	工程土壤
		岩屑	土
墜落		落石	岩屑崩滑
傾覆			
滑動	圓弧形	岩體滑動	
	平面型		
流動		土石流	

楊樹榮等(2011)

表 3 水土保持局山崩分類方法

運動型態		材料種類	
		岩石	工程土壤
		岩屑	土
墜落		山崩	
傾覆			
滑動	圓弧形	地滑	
	平面型		
流動		土石流	

楊樹榮等(2011)

# 你說的山崩地滑土石流跟我說的一樣嗎？

- <https://scitechvista.nat.gov.tw/c/sZ1R.htm>
- 費立沅 2016/09/01

中央地質調查所山崩土石流分類			水土保持局山崩土石流分類	
移動物質 移動型態 或作用型態	基岩	工程土壤		(分類參考水保法及其子法。 以防治災害為目的之分類，故 不考慮移動物質類別。)
		岩屑	土壤	
墜落 傾翻	落石	岩屑崩滑		崩塌(崩落、崩坍、崩壞)
滑動	平面型 楔型	岩體滑動		地滑(岩盤型、風化層型、崩積型)
	圓弧型			
流動		土石流		土石流潛勢溪流
風化侵蝕	向源侵蝕、河岸侵蝕、 (蝕溝、指溝)		沖蝕(表層沖蝕，侵蝕)	
表層緩移	潛移(邊坡表層之土壤或 岩層的緩慢移動)		潛移(單指土壤)	

經濟部中央地質調查所(2008)  
表 2 中央地質調查所山崩分類方法

運動型態	材料種類		
	岩石	工程土壤	
		岩屑	土
墜落 傾覆	落石	岩屑崩滑	
滑動	圓弧形	岩體滑動	
	平面型		
流動	土石流		

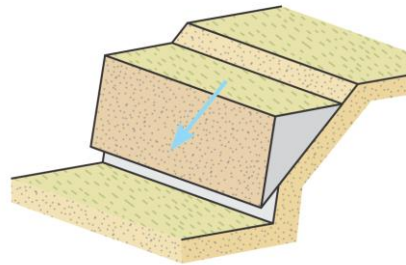
楊樹榮等(2011)

表 3 水土保持局山崩分類方法

運動型態	材料種類		
	岩石	工程土壤	
		岩屑	土
墜落 傾覆	山崩		
滑動	圓弧形	地滑	
	平面型		
流動	土石流		

楊樹榮等(2011)

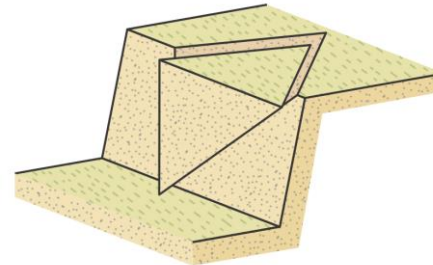
# 四種典型的岩石邊坡破壞型態



Plane failure



Figure 9.17 Plane failures along bedding planes on slope benches (slope height: 60 m).



Wedge failure

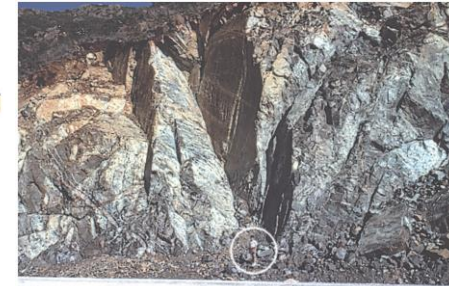
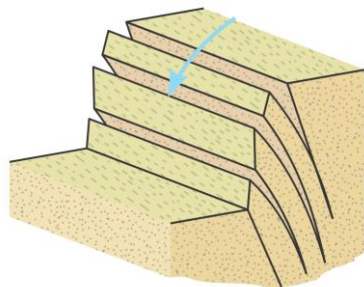


Figure 9.19 Planes of a wedge slide on a rocky slope in southern Spain.



Toppling of strata



Figure 9.22 Rock blocks on a slope where toppling has occurred.

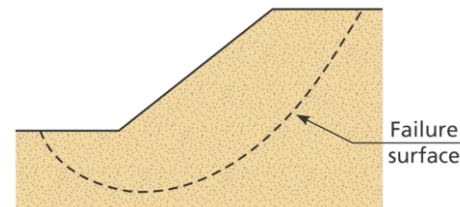


Figure 9.12 Curved failure in clays and shales in central Spain, showing the tension crack and vertical displacement of the slope head.

# 2 岩石邊坡運動學分析

平面破壞 楔型破壞 傾覆破壞

# 回顧：

## Equal-angle projection 等角投影

(Stereographic projection, Wulff projection)  
(Stereonet, stereographic net, Wulff net)

極投影  
(極圖)

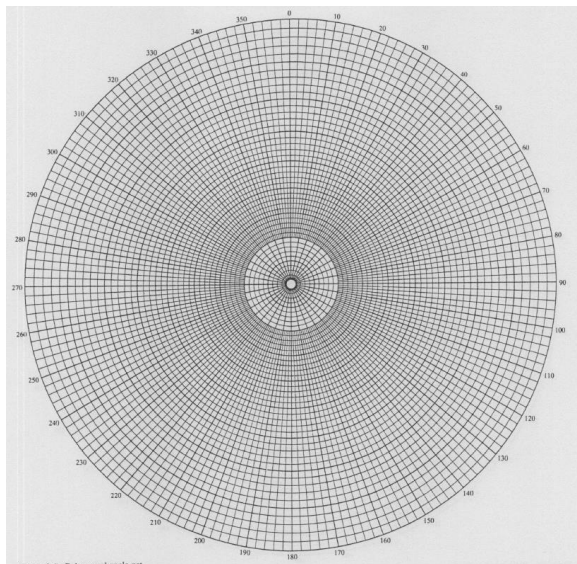


Figure 2.4 Polar equal-angle net.

赤道投影

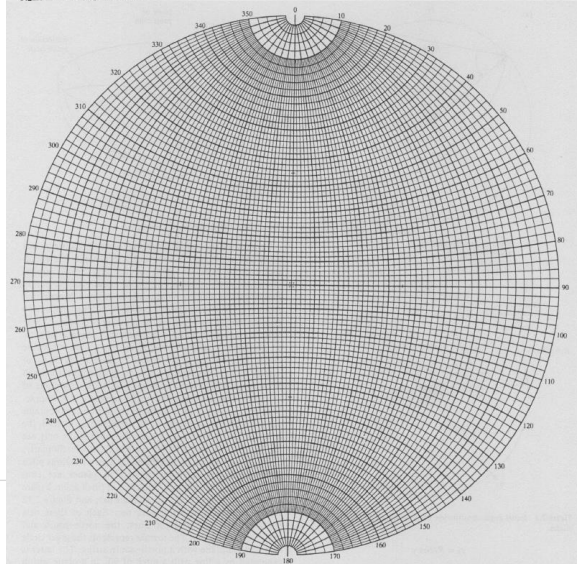


Figure 2.11 Equatorial equal-angle net.

## Equal-area projection 等面積投影

(Lambert projection, Schmidt projection)  
(Lambert net, Schmidt net)

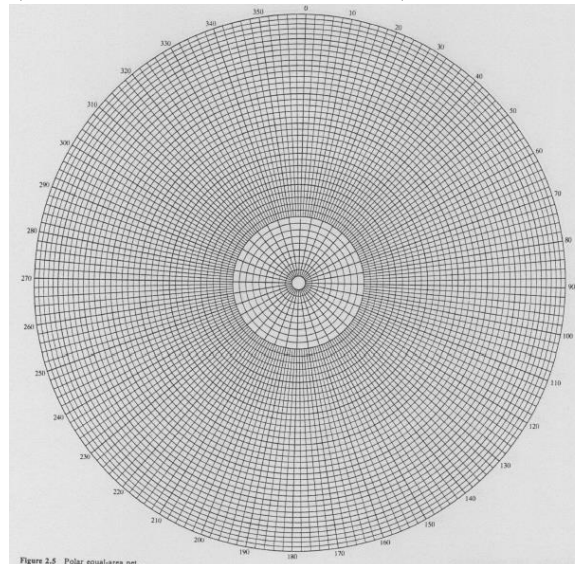


Figure 2.5 Polar equal-area net.

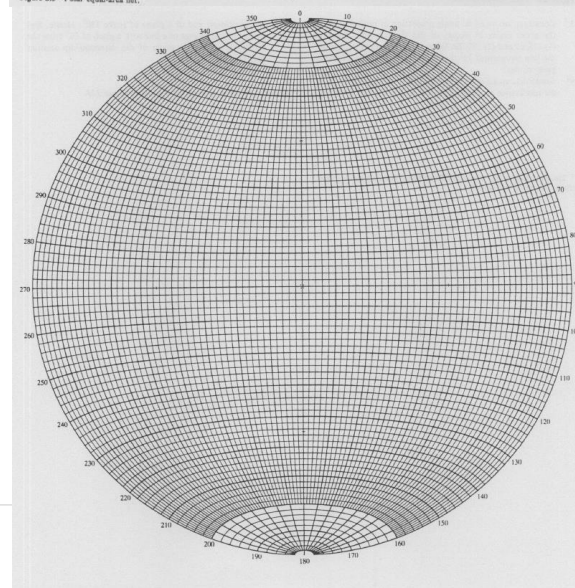
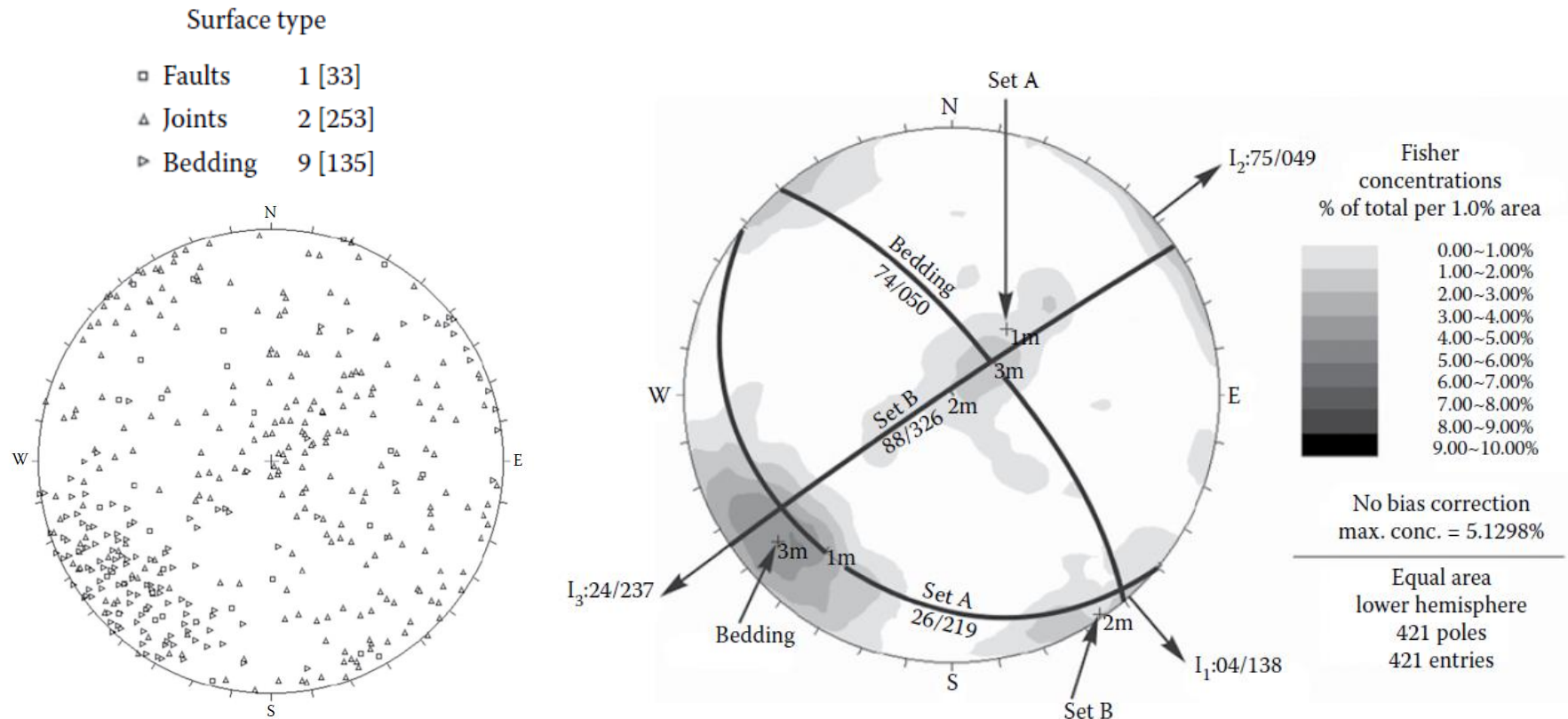


Figure 2.12 Equatorial equal-area net.

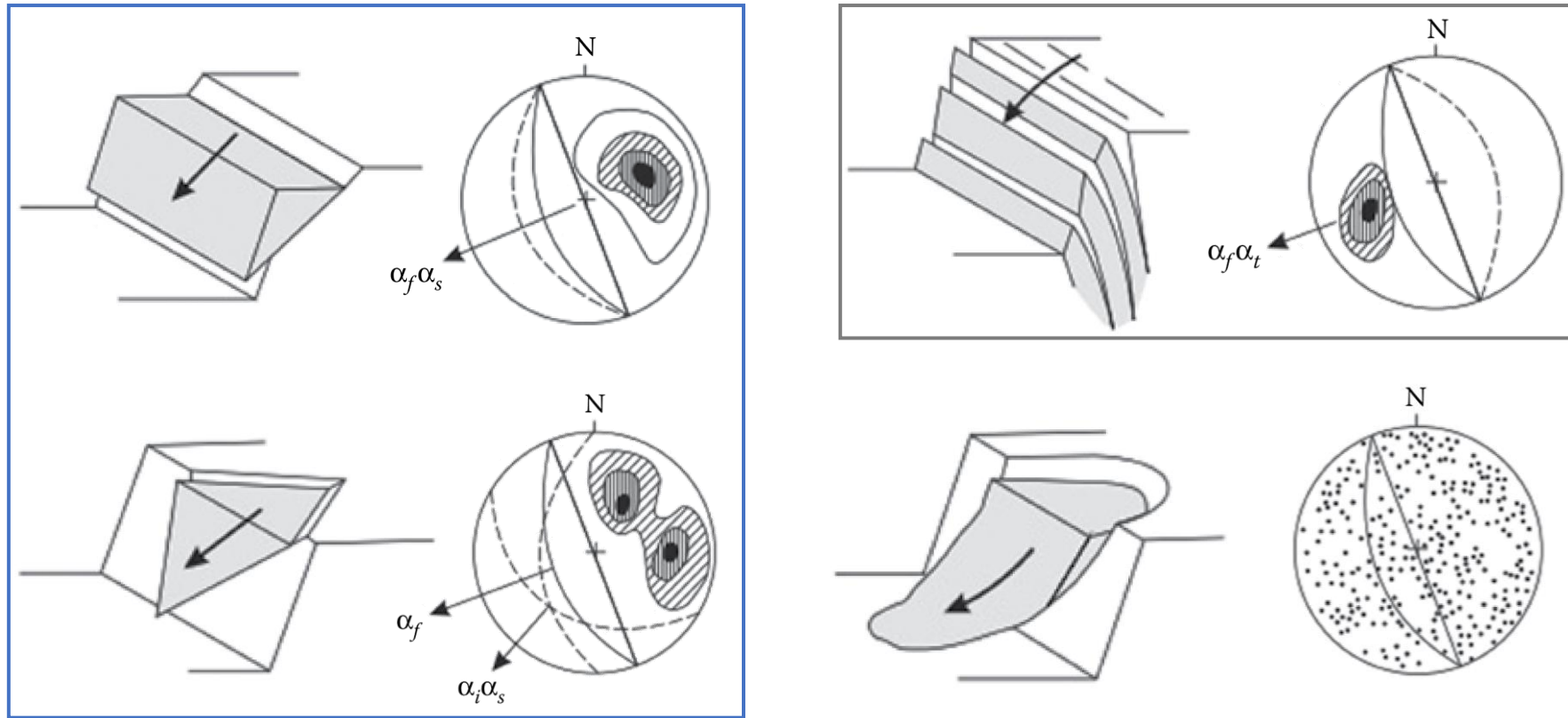
# 極點密度 Pole density

- 421個平面共分三種類型：Faults, Joints, Bedding
- 分別求出三種平面的平均位態



# 典型岩石邊坡塊體破壞模式

- 四種典型破壞模式可以利用立體投影法判斷



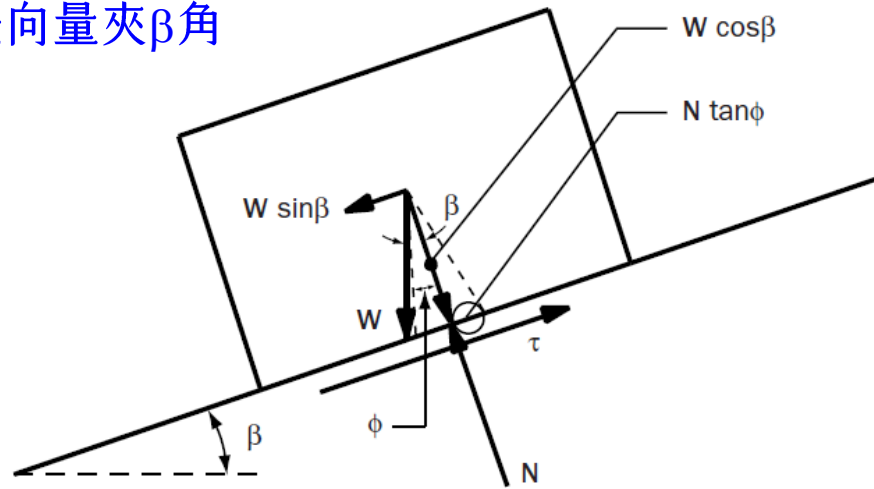
Legend:

- Pole concentrations
- Great circle representing face
- Great circle representing plane corresponding to centers of pole concentrations
- $\alpha_f$  Dip direction of face
- $\alpha_s$  Direction of sliding
- $\alpha_t$  Direction of toppling
- $\alpha_i$  Dip direction, line of intersection

Randomly oriented discontinuities

# 摩擦圓：空間中平面以極點判斷是否穩定

w向量與滑動面  
法向量夾β角



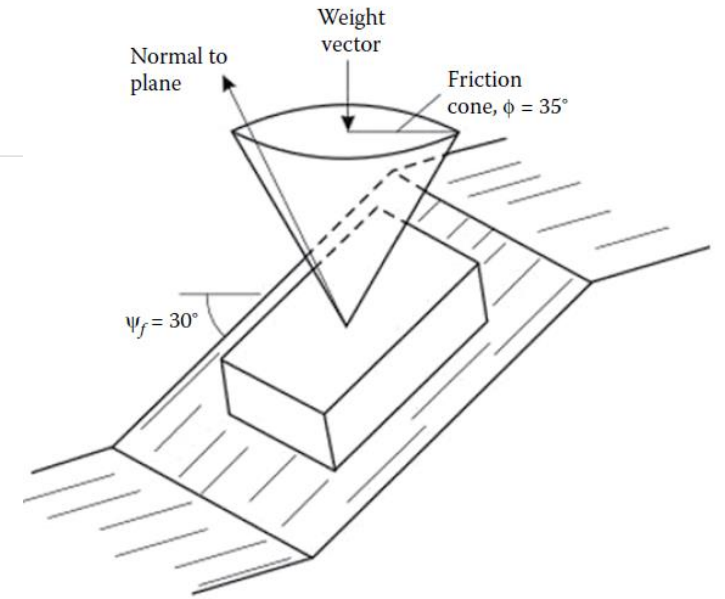
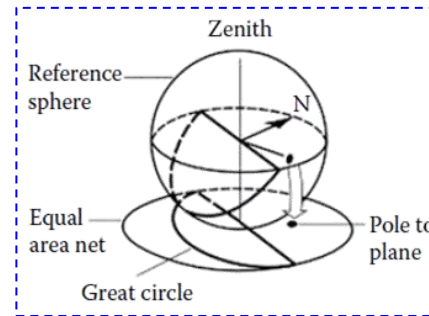
若邊坡坡角超過摩擦角，滑動發生。  
→ 塊體w向量落在摩擦圓之外時滑動

(塊體w與N重合時，坡面水平)

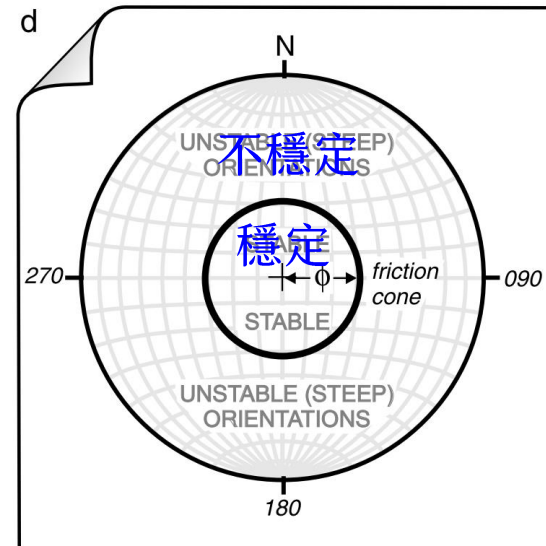
$$F.S. = \frac{\tan \phi}{\tan \beta}$$

β = 0 時為水平面  
β = φ 時發生滑動

極點越靠近圓周，  
平面越陡



任一平面極點在  
摩擦圓內穩定  
摩擦圓外不穩定

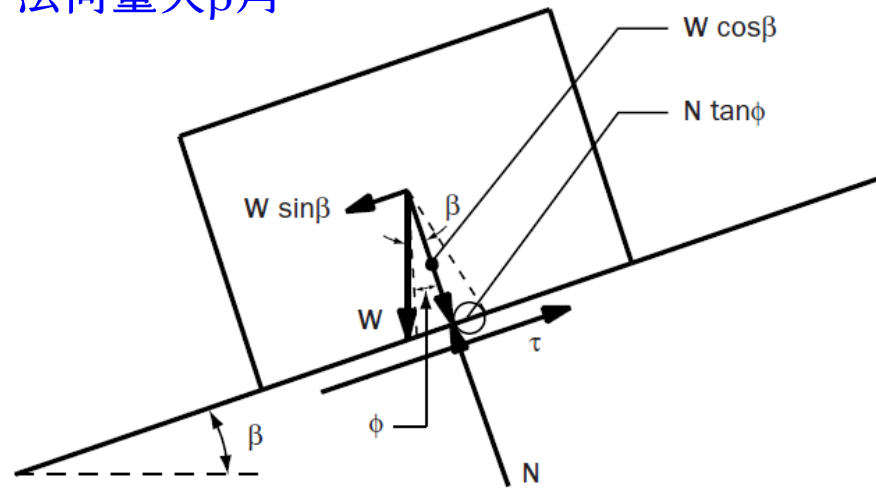


極點落在摩擦圓外：  
平面比摩擦角還陡  
極點落在摩擦圓內：  
平面比摩擦角還緩



# 摩擦圓：空間中的線是否穩定

w向量與滑動面  
法向量夾 $\beta$ 角



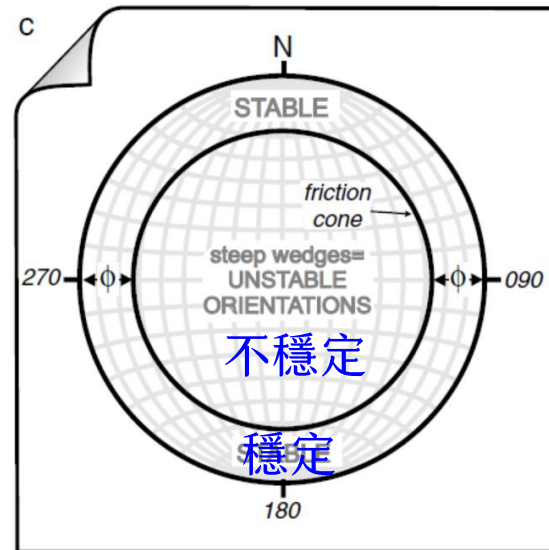
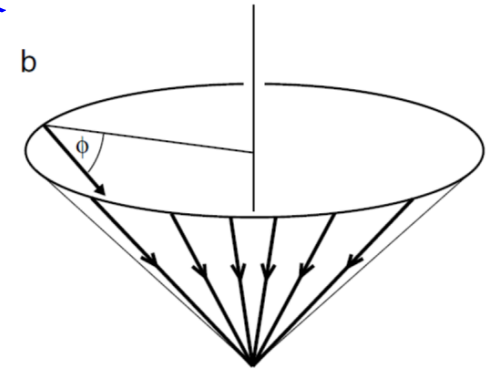
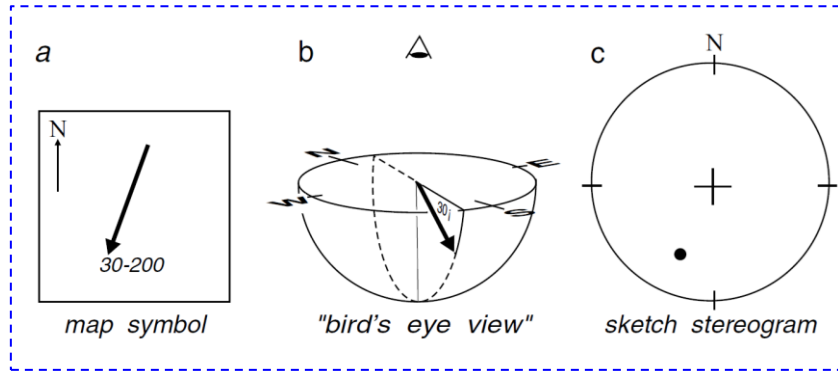
若邊坡坡角超過摩擦角，滑動發生。  
→塊體W向量落在摩擦圓之外時滑動

(塊體W與N重合時，坡面水平)

$$F.S. = \frac{\tan \phi}{\tan \beta}$$

$\beta = 0$  時為水平面  
 $\beta = \phi$  時發生滑動

代表空間中線的點越靠近圓周，該線越緩



空間中的線落在  
摩擦圓內不穩定  
摩擦圓外不穩定

點落在摩擦圓外：該  
線比摩擦角還緩  
極點落在摩擦圓內：  
平面比摩擦角還陡

# Markland test for plane shear

1. 弱面傾角/弱面交線傾沒角超過岩石面之摩擦角 $\phi$ 。
2. 弱面傾角/弱面交線傾沒角 $<$ 坡角 $\psi$ .

$$\psi > \beta > \phi$$

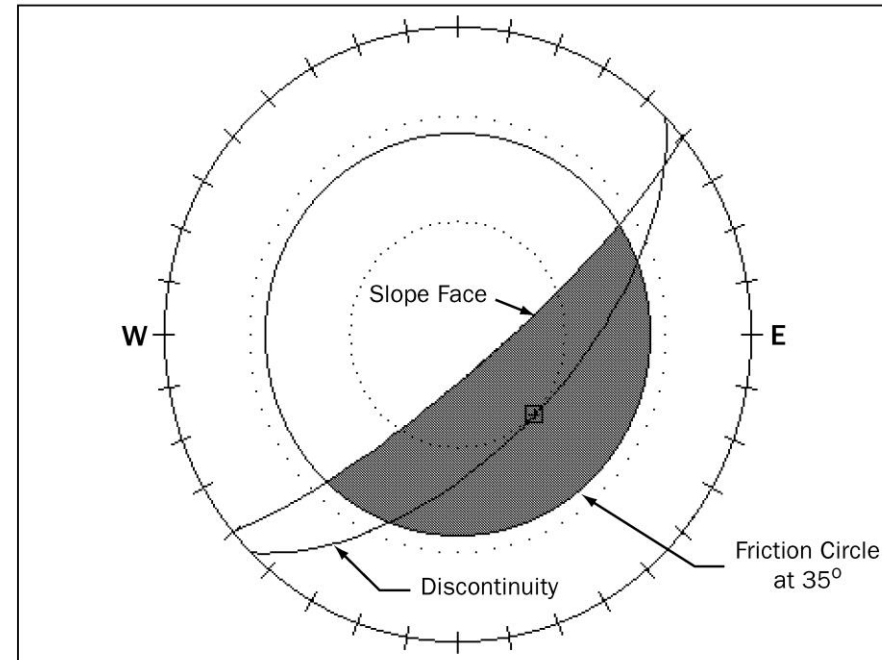
坡角 $>$ 滑動面傾角 $>$ 摩擦角

$\psi$  = dip of the slope face

$\beta$  = dip of the discontinuity or plunge of the line of intersection

$\phi$  = angle of friction for the rock surface

Markland (1972)



Markland Test Plot

Friction Angle = 35 degrees

Slope Dip Direction = 140 degrees, Dip = 80 degrees

平面破壞和楔型破壞皆適用  
平面破壞是楔型破壞的特例

# Assumptions of Markland test

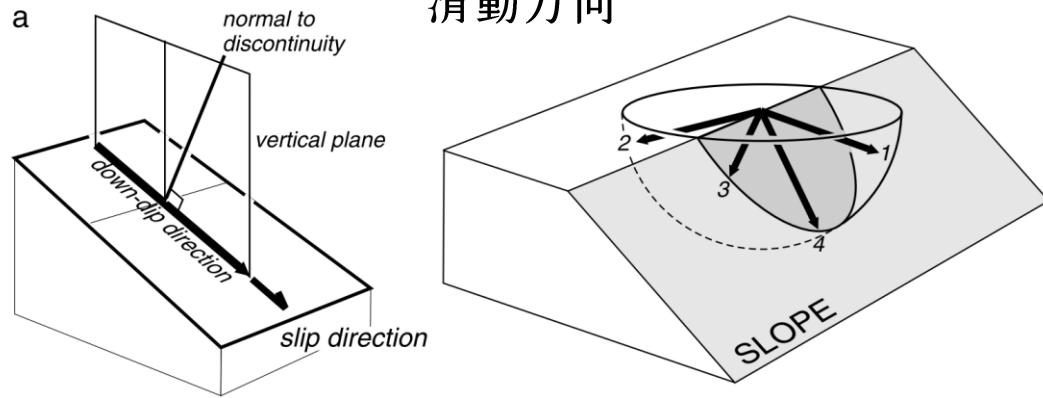
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前提假設：

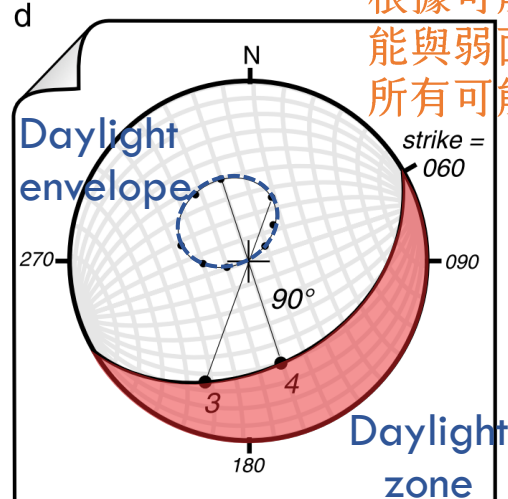
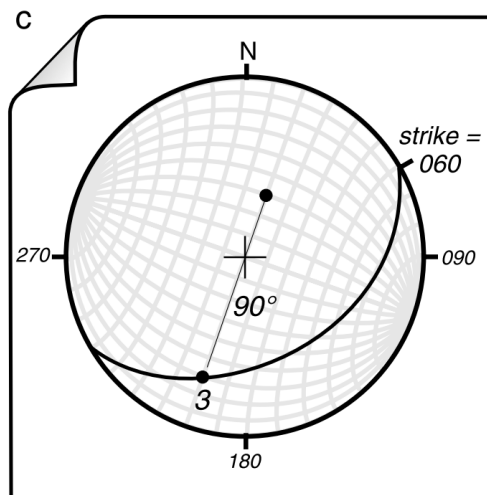
- 不考慮現實狀況，將所有弱面視為連續且完全延續。實際上只要有一小部分比例的弱面不完全延續，就可能提供足夠強度使滑動不至發生。
- 不考慮凝聚力，假設 $c=0$ ，忽略凝聚力的貢獻(偏保守)。此時安全係數  $F.S. = \tan\phi / \tan\beta$ .

# 坡趾見光包絡線 Daylight envelope

已知坡向，可畫出所有可能之滑動方向

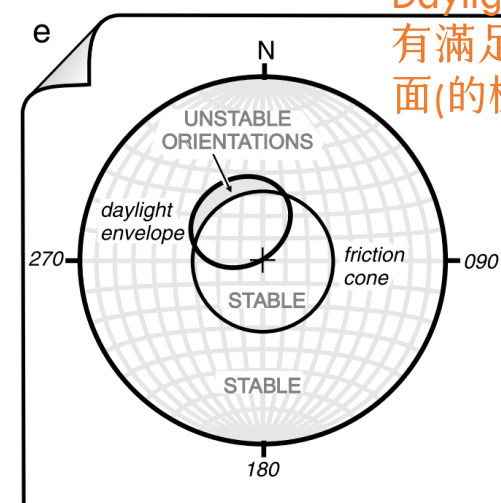


- 左圖內，線1, 3, 4都是可能的滑動軌跡
- 如圖a，滑動軌跡與弱面法向量都通過垂直面，而且相差90度
- 將所有可能滑動方位連接起來 → daylight envelop
- 見光包絡線落在摩擦圓之外的部分 → 會滑動的平面



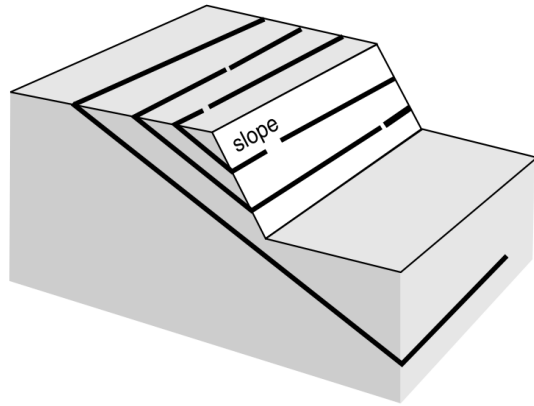
根據可能滑動方向(最可能與弱面傾向一致)畫出所有可能滑動面(之極點)

Daylight envelop內：所有滿足“見光”條件之平面(的極點)

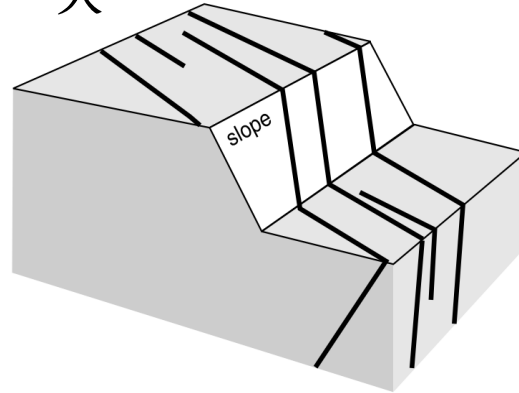


# 平面破壞 Plane failure

a 弱面在坡趾見光

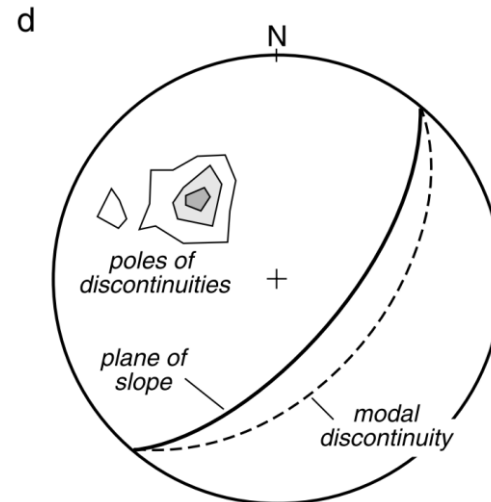
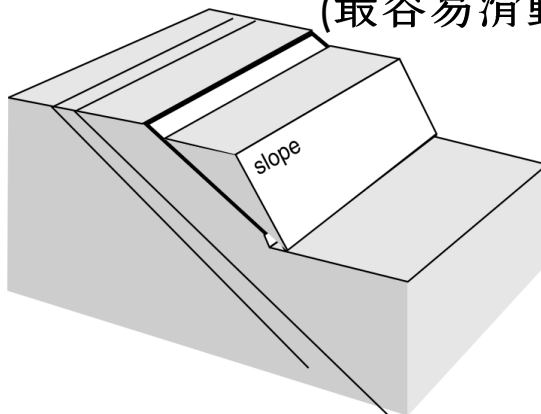


b 弱面對邊坡穩定影響不大



c Plane failure

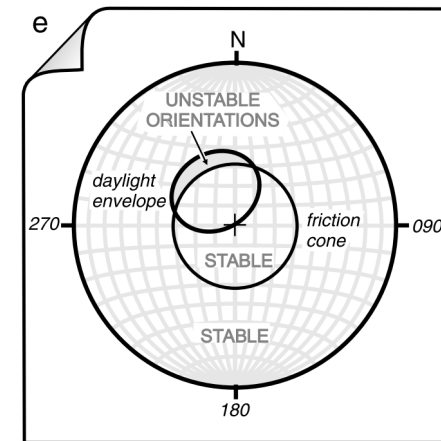
弱面平行坡面  
(最容易滑動)



- 統計現場弱面後，計算出代表位態。
- 根據Markland test檢核是否破壞。

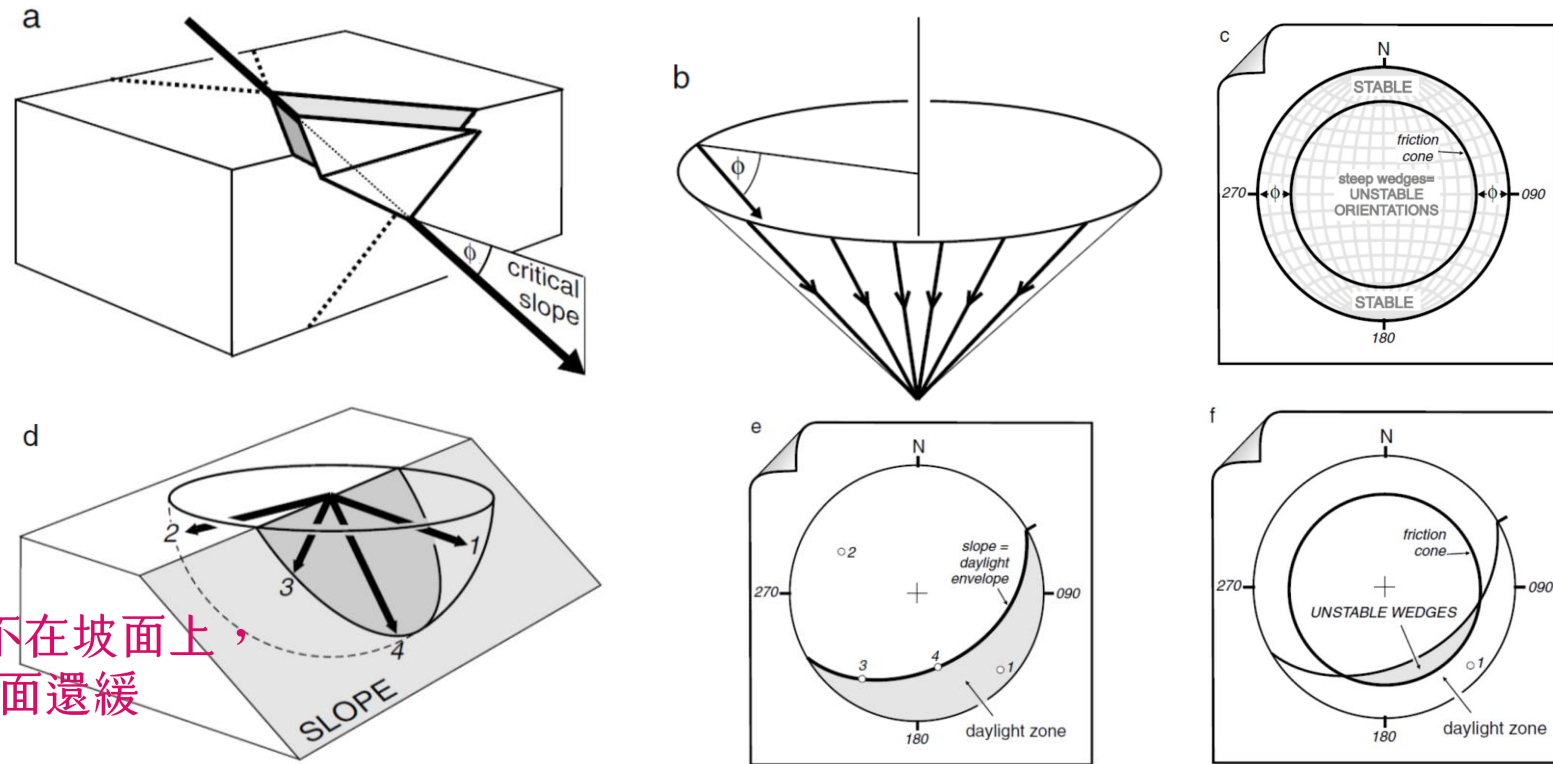
1. 坡趾是否見光(見光包絡線)

2.  $\psi > \beta > \phi$



1. 弱面的極點在見光包絡線以內
2. 弱面極點落在摩擦圓以外

# 楔型破壞Plane failure



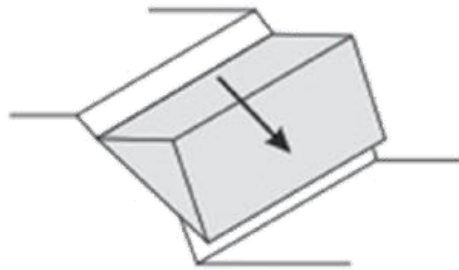
線1不在坡面上，  
比坡面還緩

- 統計現場弱面後，計算出平面1、平面2之代表位態，以及兩平面交線。
- 根據Markland test檢核是否破壞。
- 1. 坡趾是否見光(見光包絡線)
- 2.  $\psi > \beta > \phi$

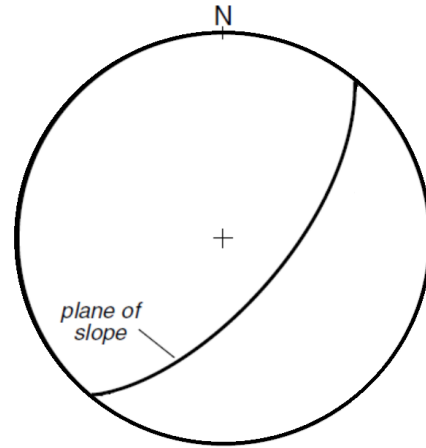
是否沿**平面1**滑動、是否沿**平面2**滑動、是否沿**交線**滑動

# 平面破壞

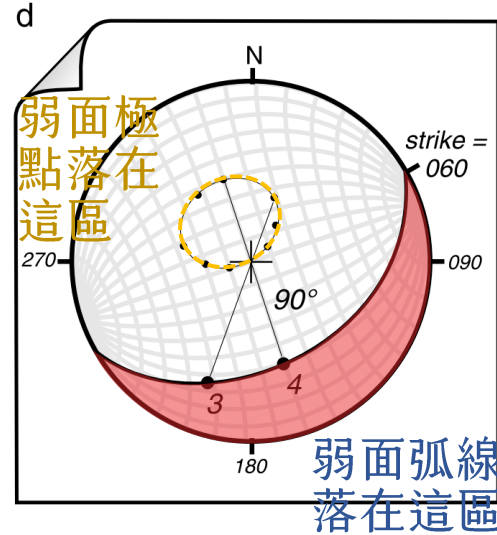
坡角 > 滑動面傾角 > 摩擦角



1. 畫出坡面

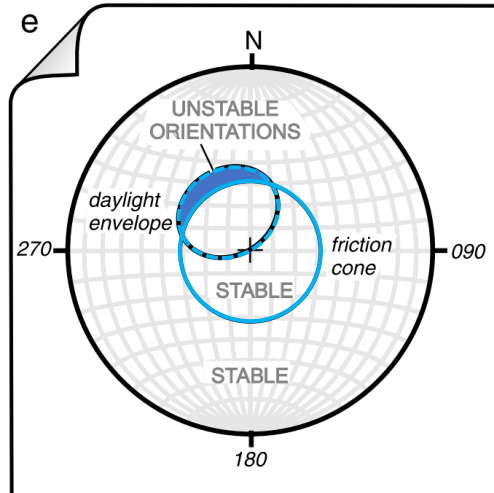


2. 坡角 > 弱面傾角



如有弱面(以弧線表示時)落在弱面極點範圍內，表示該弱面傾角 < 坡角

3. 坡角 > 弱面傾角 > 摩擦角

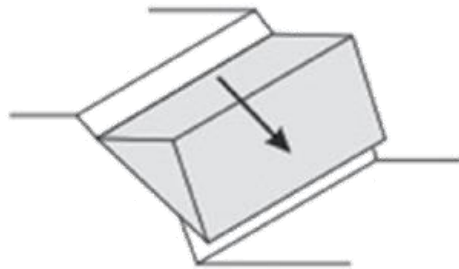


弱面極點在虛線橢圓範圍以內：弱面傾角 < 坡角

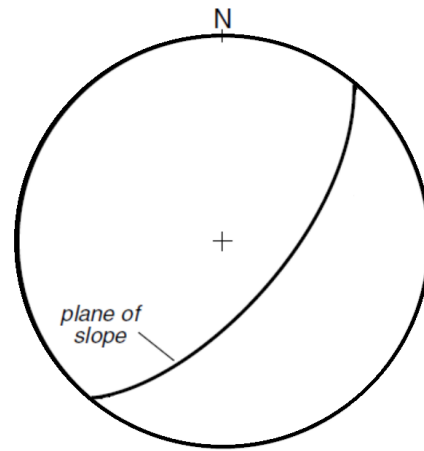
弱面極點在摩擦圓範圍以外：弱面傾角 > 摩擦角  
取兩者交集

# 順向坡平面破壞

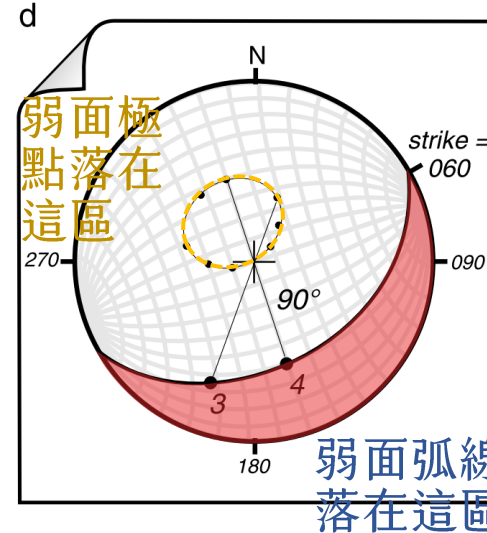
坡角 > 滑動面傾角 > 摩擦角



1. 畫出坡面



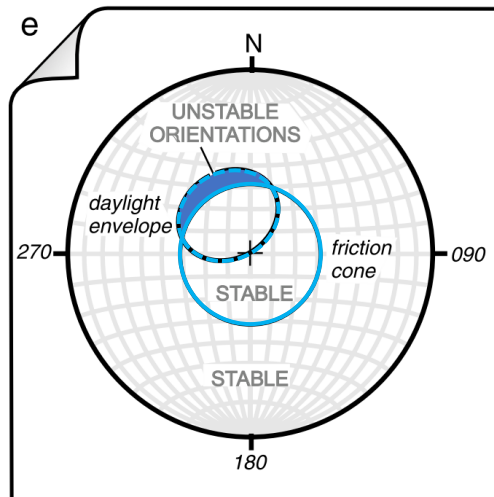
2. 坡角 > 弱面傾角



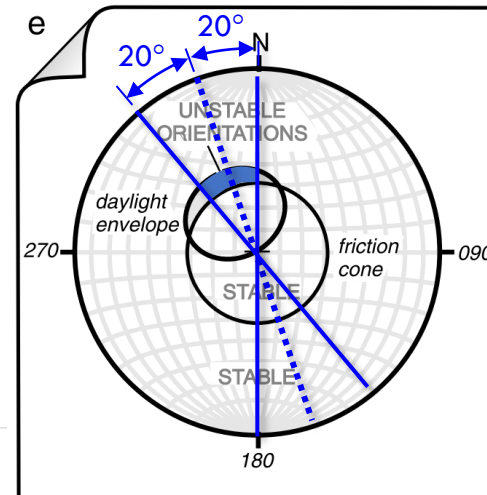
如有弱面(以弧線表示時)落在弱面極點範圍內，表示該弱面傾角 < 坡角

弱面極點在虛線橢圓範圍以內：弱面傾角 < 坡角  
 弱面極點在摩擦圓範圍以外：弱面傾角 > 摩擦角  
 取兩者交集

3. 坡角 > 弱面傾角 > 摩擦角



4. 坡向與弱面傾向夾角 < 20度

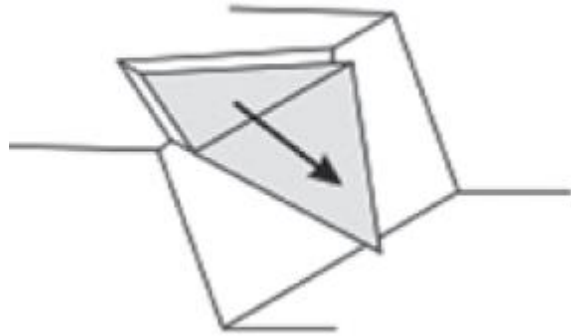


只留下與弱面夾角 < 20度的區域  
 弱面極點落在填色區內：會發生平面滑動

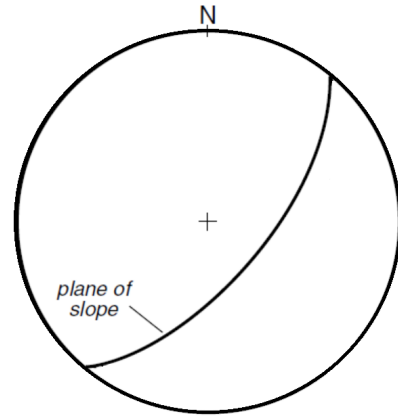


# 楔型破壞

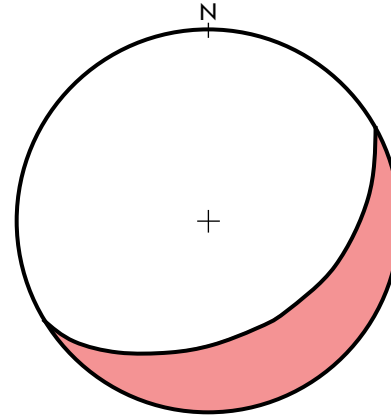
坡角 > 交線傾角 > 摩擦角



1. 畫出坡面



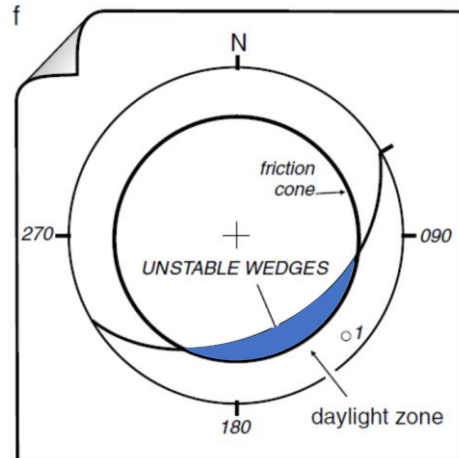
2. 坡角 > 兩面交線



如有兩面交線(以點表示)落在填色區, 表示該交線的傾角 < 坡角

3. 坡角 > 兩面交線傾角 > 摩擦角

弱面弧線/交線在虛線橢圓範圍以內: 弱面傾角 < 坡角  
 弱面交線在摩擦圓範圍以內: 交線傾角 > 摩擦角  
 取兩者交集



# 傾覆破壞

- 弱面傾角必須與坡面傾向之反向夾  $20^\circ$  以內，使弱面約略平行坡面(但是傾向反向)。
- 弱面坡度必須夠陡，才會發生滑動。

## 1. 塊體重心超出自身邊界

$$\psi_p < \phi_p \quad - \text{Stable}$$

$$\frac{\Delta x}{y} < \tan \psi_p \quad - \text{Topple}$$

## 2. 塊體間發生滑動

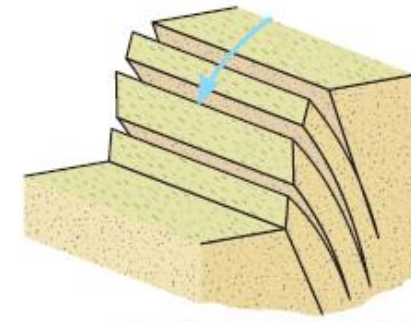
$$(180 - \psi_f - \psi_d) \geq (90 - \phi_d)$$

$$(90^\circ - \psi_f) + \phi_j < \psi_p$$

$\psi_f$  : dip angle of slope face

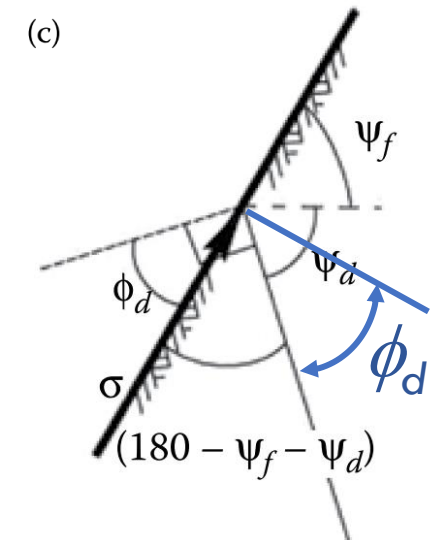
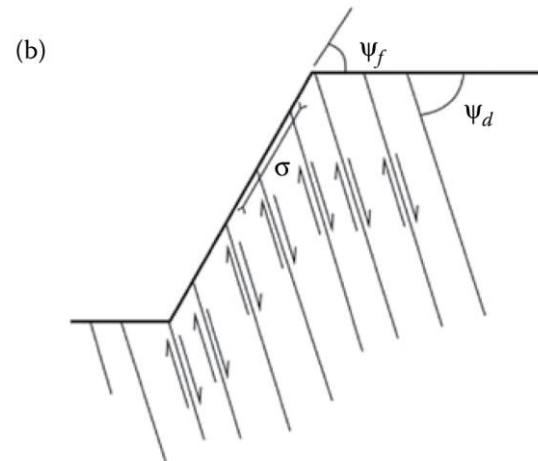
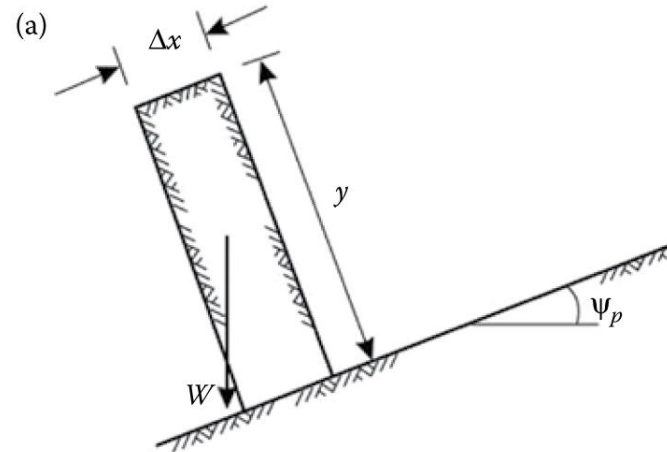
$\psi_p$  : dip angle of discontinuity

$\phi_d$  : the friction angle of the sides of the blocks



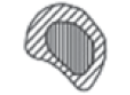


Toppling of strata

- 弱面較緩  $\rightarrow$  不會滑動
- 弱面較陡  $\rightarrow$  會滑動
- 弱面與坡面法向量夾  $\phi_d \rightarrow$  滑動



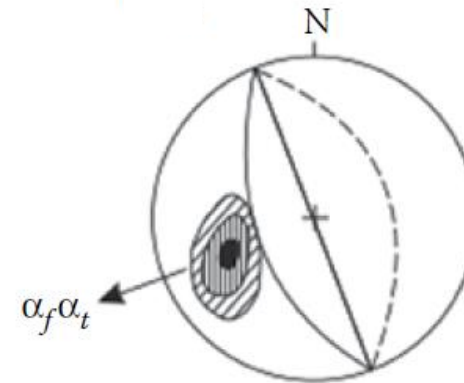
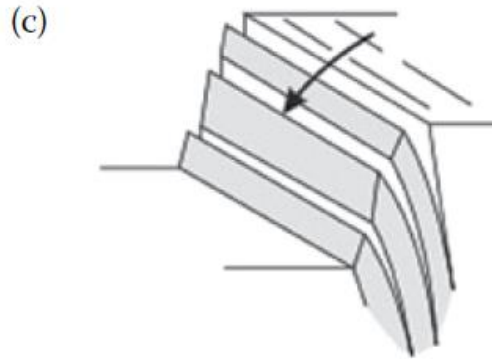
# 傾覆破壞 & 圓弧型破壞

Legend:

Pole concentrations		$\alpha_f$ Dip direction of face
Great circle representing face		$\alpha_s$ Direction of sliding
Great circle representing plane corresponding to centers of pole concentrations		$\alpha_t$ Direction of toppling
		$\alpha_i$ Dip direction, line of intersection

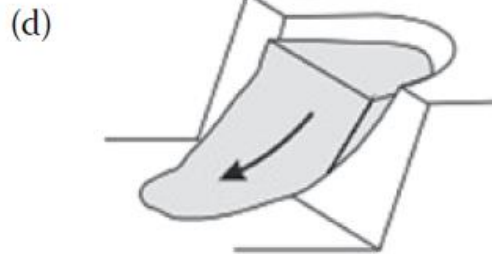
Toppling

(90-坡角)+摩擦角  
>滑動面傾角

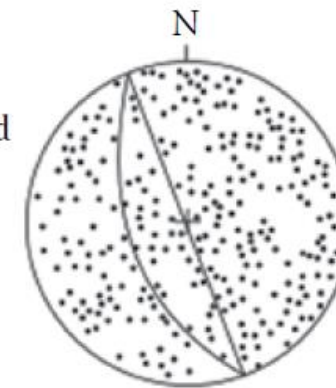


Circular failure

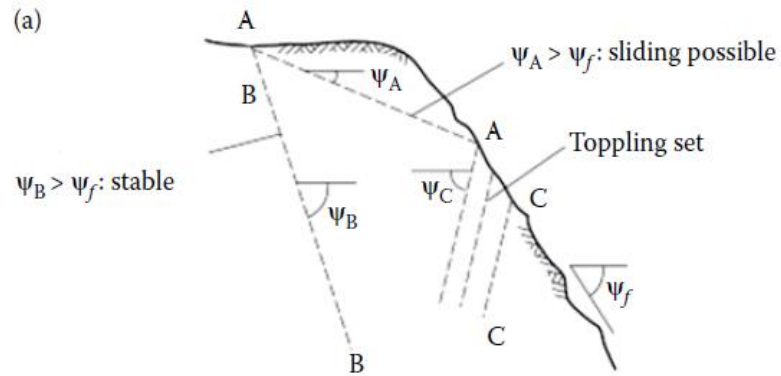
滑動面包含  
各種位態



Randomly oriented  
discontinuities



# Daylight envelop Toppling envelop

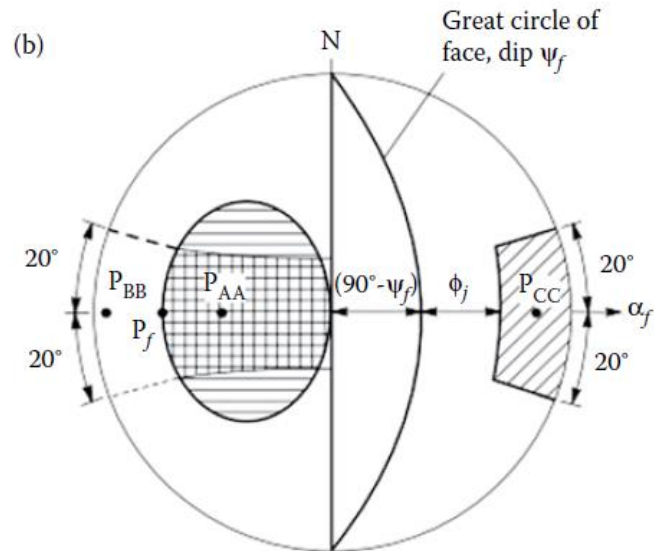


$\psi_f$  : dip angle of slope face

$\psi_A$  : dip angle of discontinuity A

$\psi_B$  : dip angle of discontinuity B

$\psi_C$  : dip angle of discontinuity C



	Daylight envelope for wedges	坡角 > 滑動面傾角 > 摩擦角
	Daylight envelope for planar failures	
	Toppling envelope	(90-坡角)+摩擦角 > 滑動面傾角

# 3 運動學分析之應用

- 調查基地範圍內所有弱面
- 統計得到每組弱面代表位態
- 評估各坡面位態之潛在破壞型態

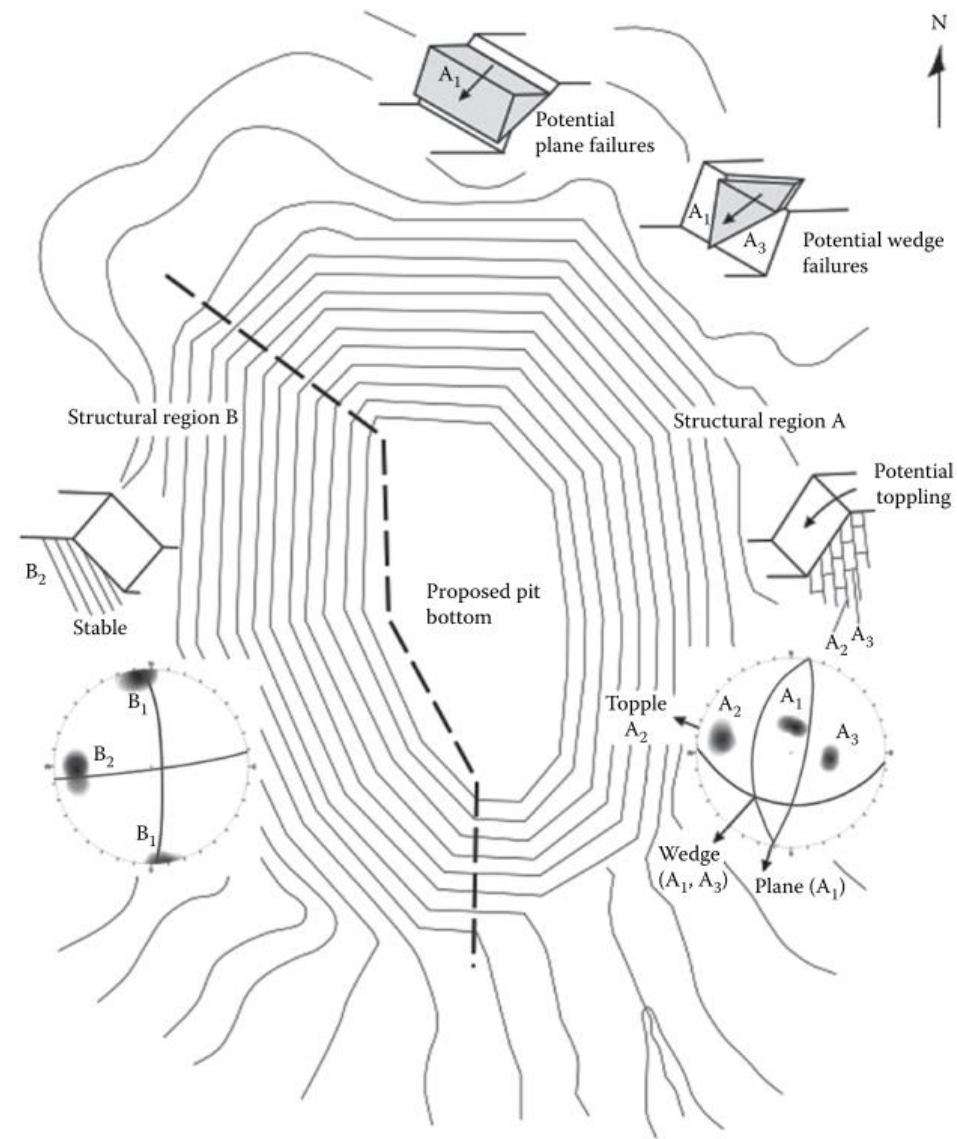
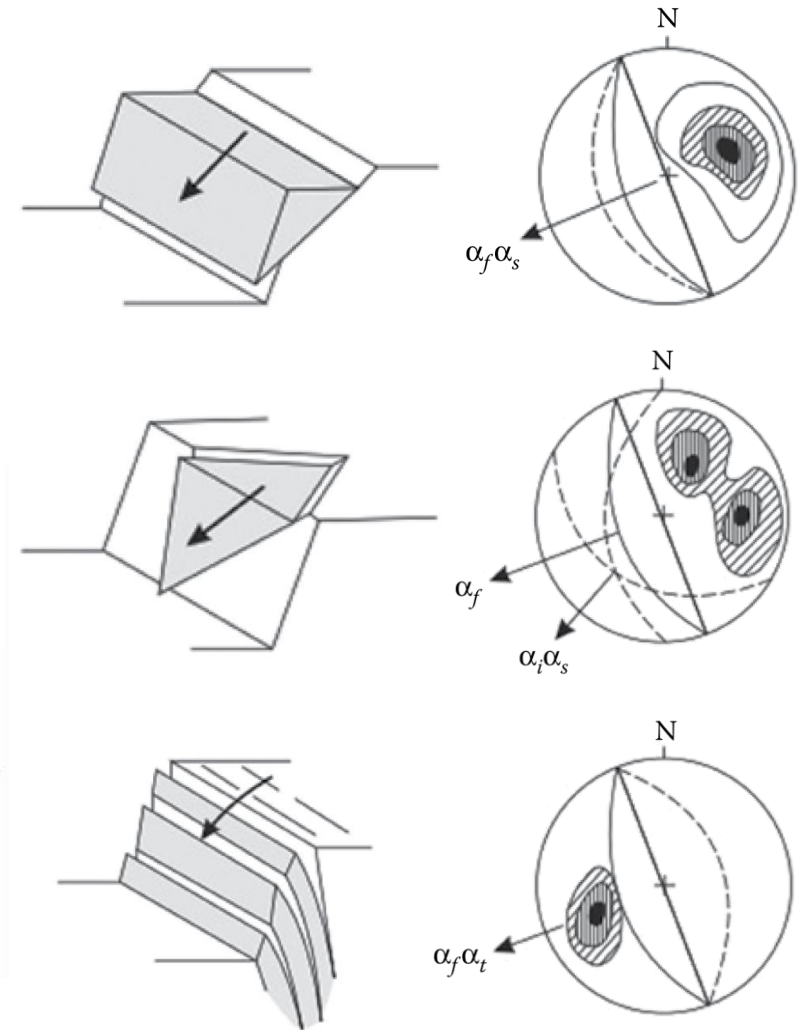
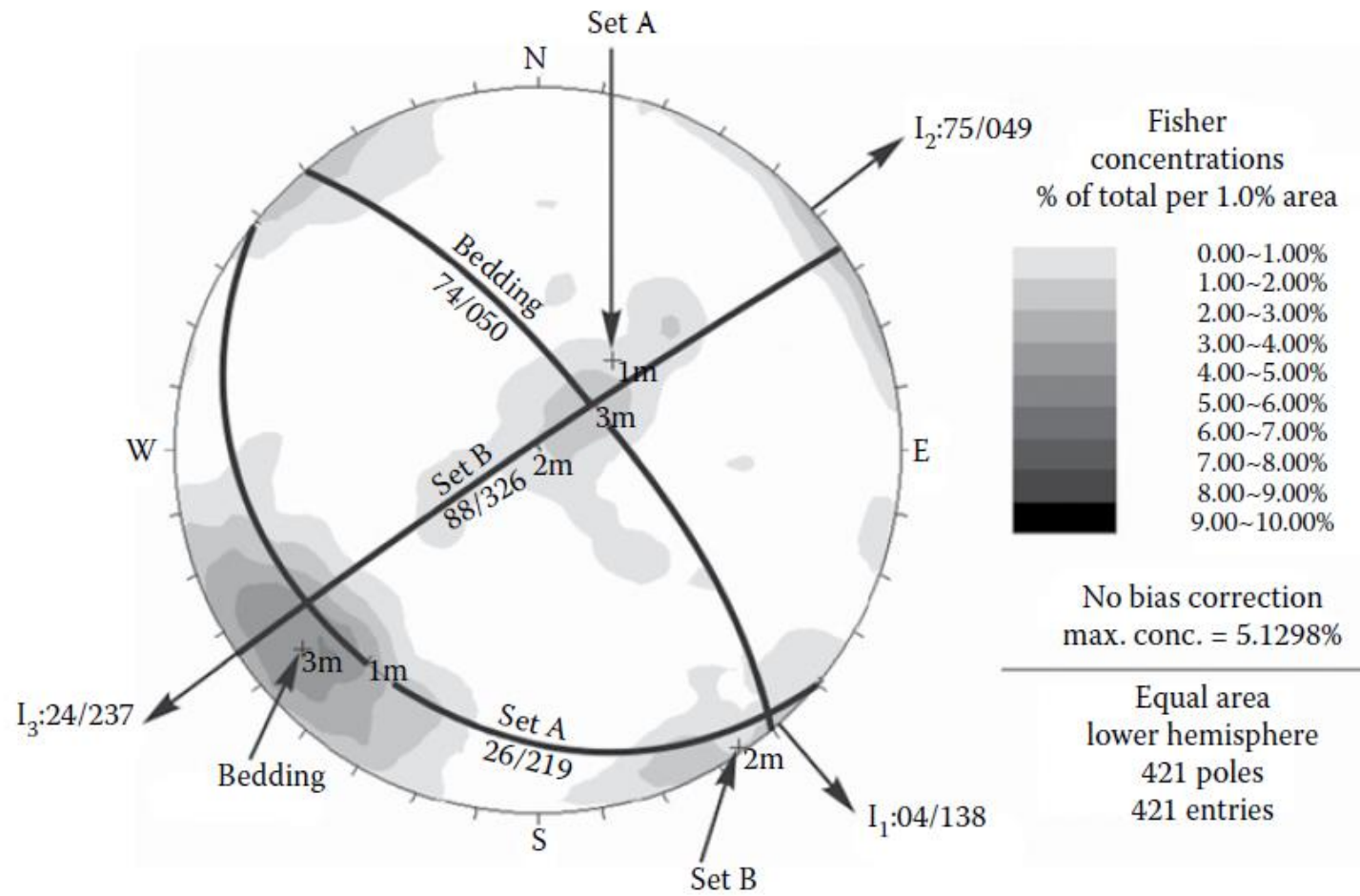


Figure 2.21 Presentation of structural geology on stereonet, and preliminary evaluation of slope stability of proposed quarry.

# 有幾種破壞模式？



# Rocscience - Dips



## Dips

Graphical & Statistical  
Analysis of Orientation Data

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