



# Fast report: preliminary analysis of coseismic landslides in the 2025 M6.4 Dapu earthquake

Yi-Yu Li, Chun-En Lin, and Chen-Yu Chen (2025)

2025/04/29

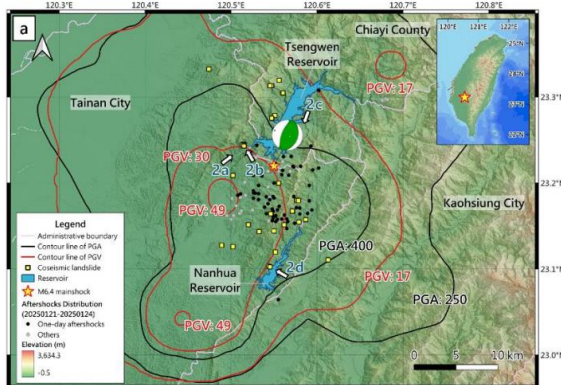
## 12 Fast Report: Preliminary Analysis of Coseismic Landslides in the 2025 M6.4 Dapu Earthquake

### 2025大埔地震同震山崩特性初步分析

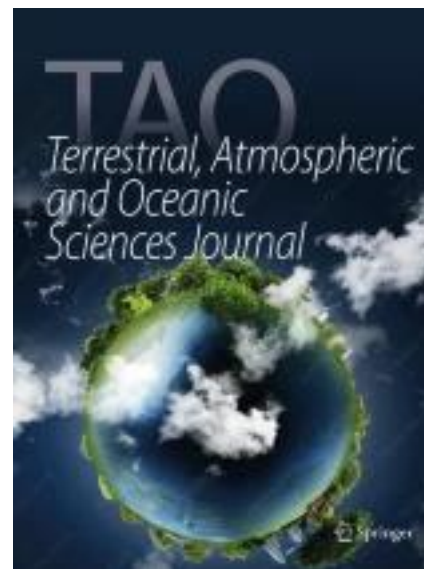
Yi-Yu Li (李易諭), Chun-En Lin (林駿恩), Chen-Yu Chen (陳振宇)

農業科技研究院、農村發展及水土保持署

在2025年大埔地震後，農村發展及水土保持署(農村水保署)利用Sentinel-2及PlanetScope衛星判釋出29處同震山崩，發現其中有三分之二的崩塌地位於震央南側，推測此分布可能反映南向的斷層破裂。這29處崩塌地具以下特性：(1)均位於PGA大於250 cm/s<sup>2</sup>、PGV大於17 cm/s的位置；(2)多發生於平均坡度30-50度的坡地，並集中在東南至西南坡向，另外本研究發現順向坡與歷史山崩的再活動也是引發大埔地震同震山崩的重要因素。雖然從衛星影像上判釋的山崩數量略少於其他類似規模地震所引起的山崩數量，但在野外調查時，可觀察到PGA大於400 cm/s<sup>2</sup>、PGV在30 cm/s左右的地點有許多小型的崩塌地與新鮮的崩崖。在這次大埔地震事件中，本研究提供山崩特性與促崩因子等資訊，指出震後詳細的山崩目錄圖繪與野外調查的重要性，可供主管機關針對受地震影響區域制訂減災策略，以因應即將到來的雨季。



(同震山崩分布與PGA、PGV之關係圖)



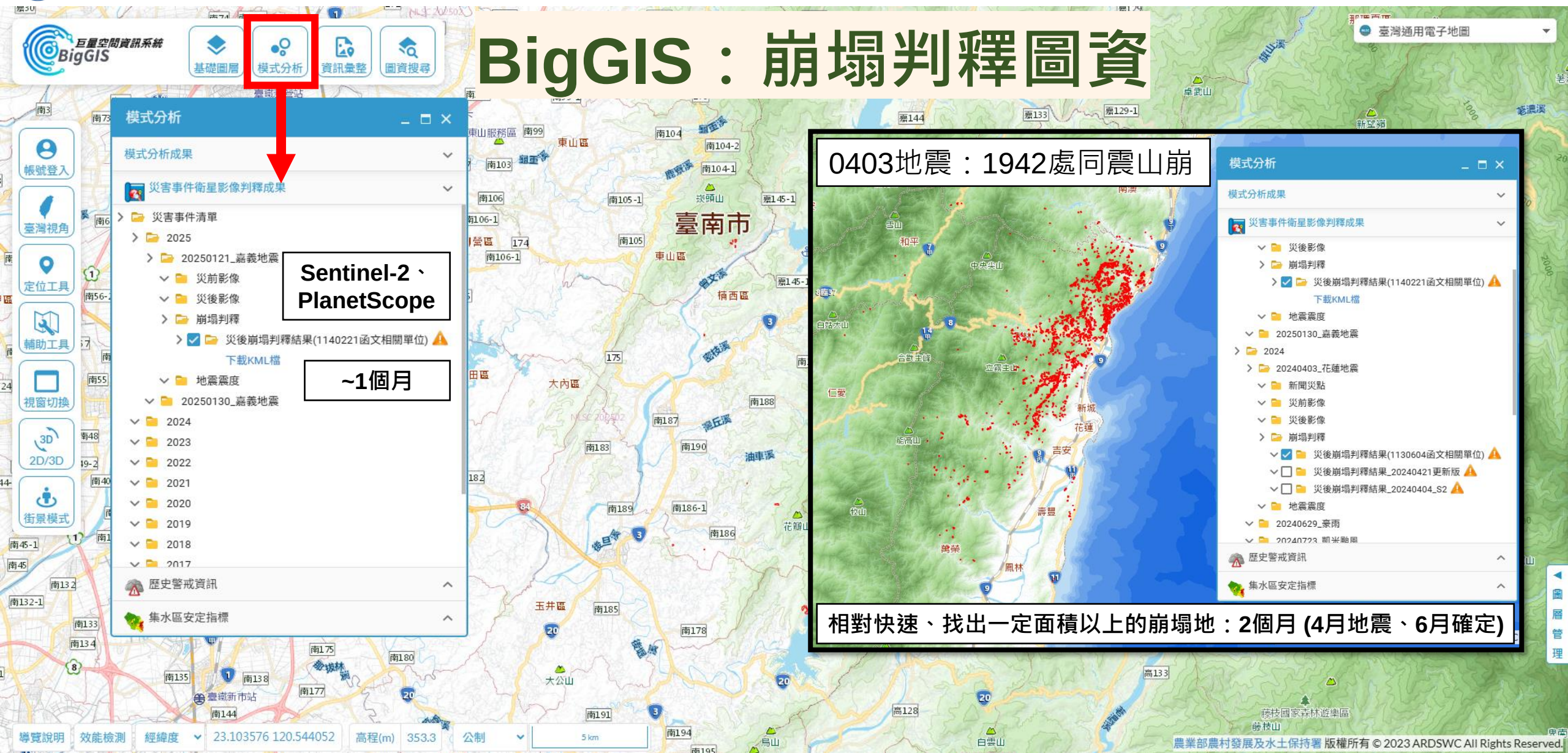
**TAO**  
Terrestrial, Atmospheric and Oceanic Sciences

**SPECIAL ISSUE**  
**Seismic and geologic hazards in southwestern Taiwan: Lessons learned from the 2025 M6.4 Dapu earthquake**  
*Open for submission*  
Feb. 1, 2025 - Feb. 1, 2026

| Fast Report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Regular Article                                                                                                                                                                                                                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>• short and time-sensitive manuscripts, in a concise format comprising only 2-3 figures, 1-2 tables, and less than 3000 words.</li><li>• should be submitted before March 1, 2025 or within 1 month of data collection</li><li>• The research must be scientifically sound and provide new information that goes beyond what is routinely provided by government agencies. Please add "Fast Report" at the beginning of the manuscript title.</li></ul> | <ul style="list-style-type: none"><li>• should follow the TAO submission guidelines at <a href="https://onlinelibrary.wiley.com/journal/10.1111/tao">https://onlinelibrary.wiley.com/journal/10.1111/tao</a></li><li>• should be submitted before Feb. 1, 2026</li></ul> |

**MORE DETAIL** →

We specifically encourage the **Fast Report** format for providing urgent information for policy-making, science strategizing, and fostering data sharing to facilitate subsequent comprehensive studies.

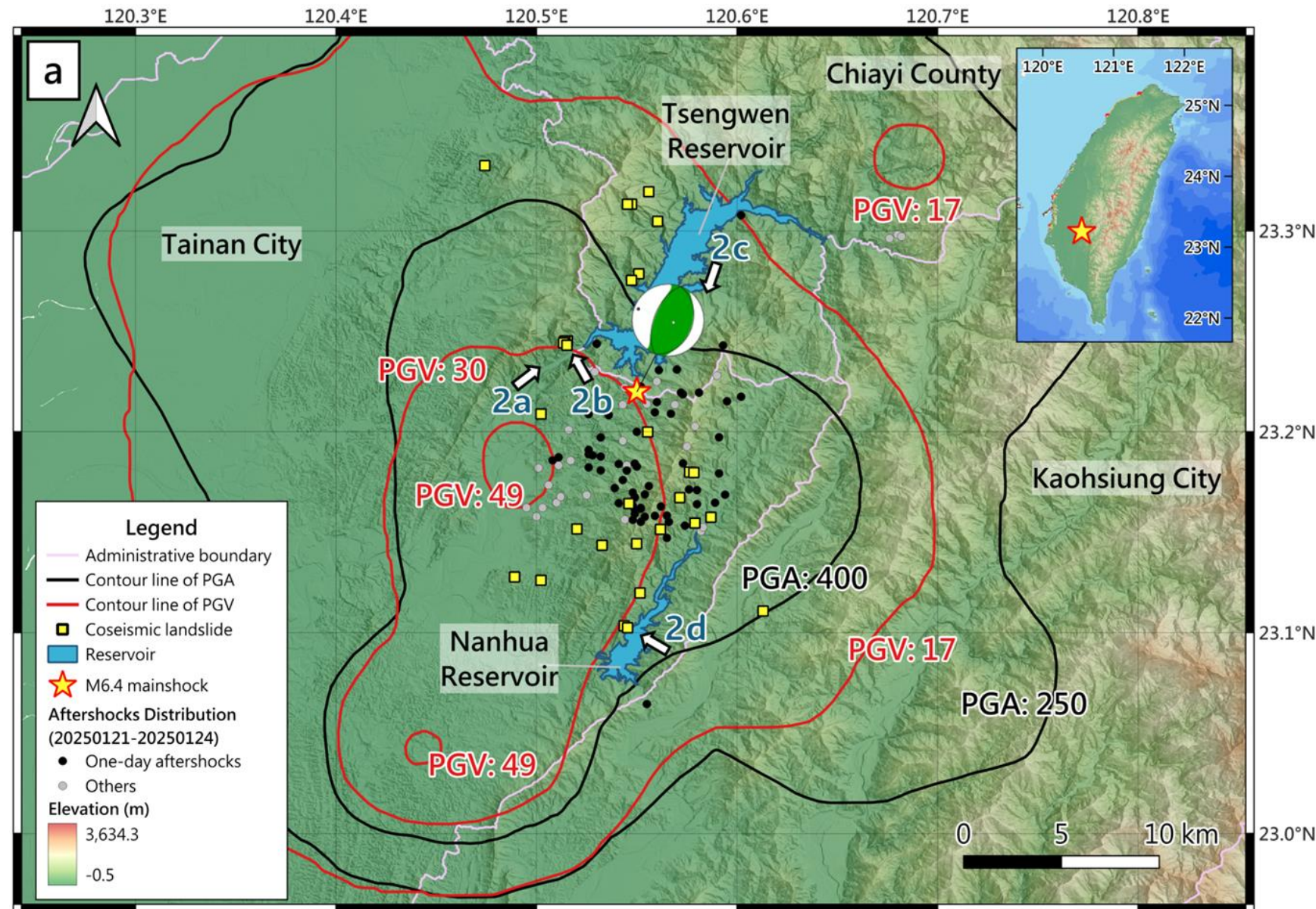


# 研究課題

## Fast Report: Preliminary Analysis of Coseismic Landslides in the 2025 M6.4 Dapu Earthquake

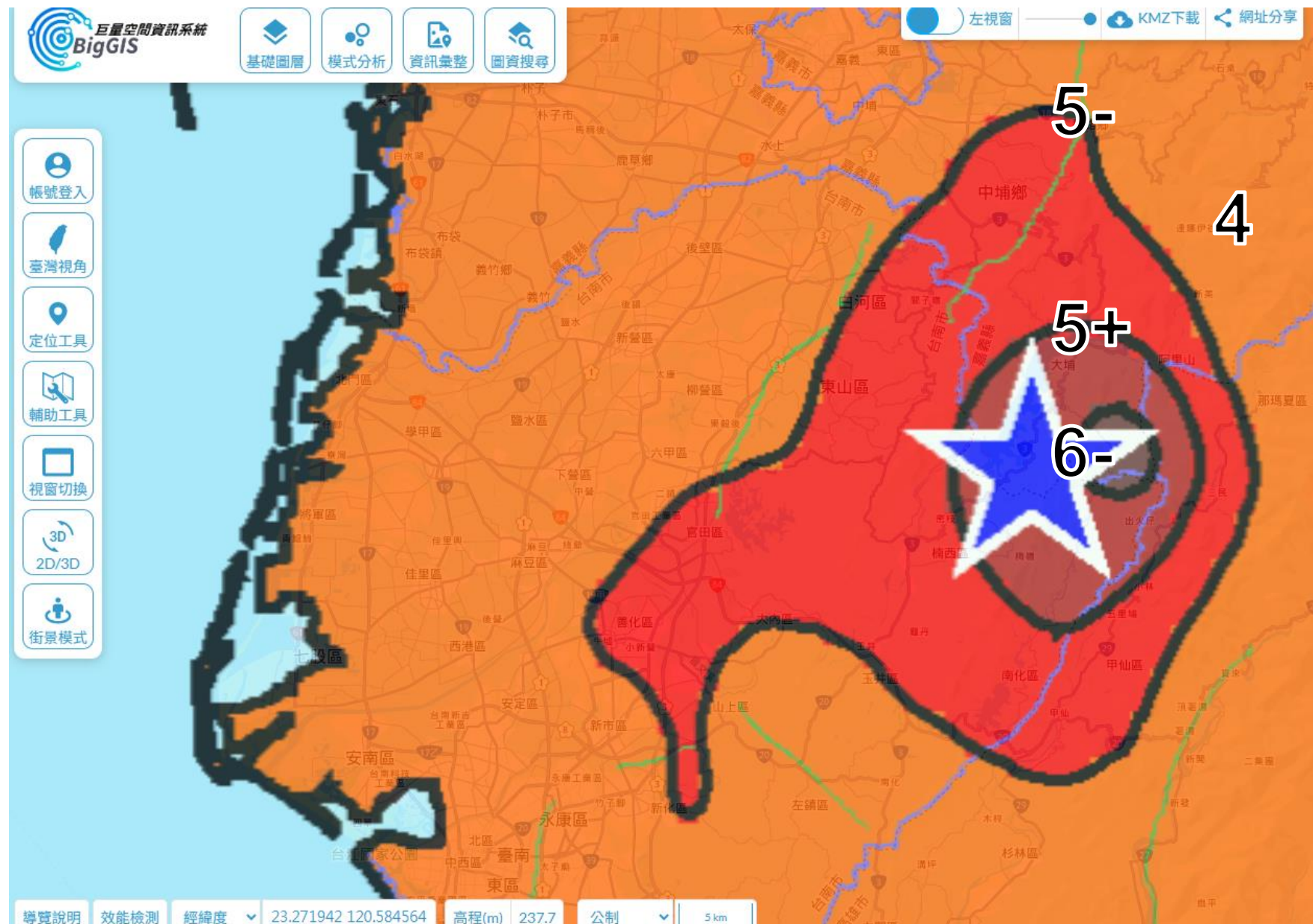


1. 崩塌地的空間分布特性
2. 什麼樣的條件下會容易發生同震山崩
3. 汛期時減災策略建議



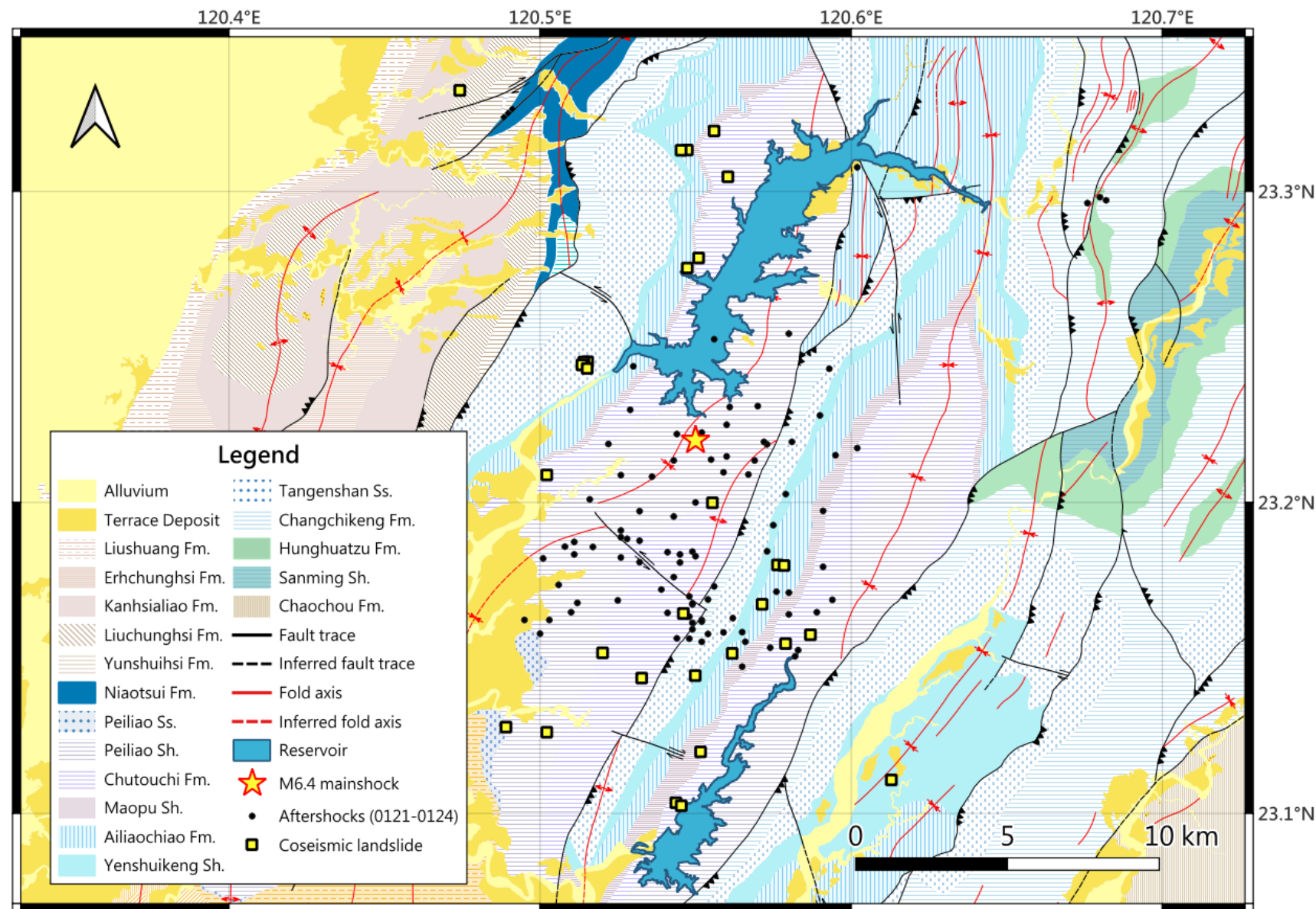
# 地震背景

- 地震深度：15.8公里  
(速報時深度為9.7公里)
- 芮氏規模 $M_L$ ：6.4
- 地震矩規模 $M_W$ ：6.0-6.1
- 發震斷層：逆斷層系統
- 最大震度：6弱 (6-)



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- 地質條件：
  - 沉積岩區
  - 斷層與褶皺
  - 順向坡富集

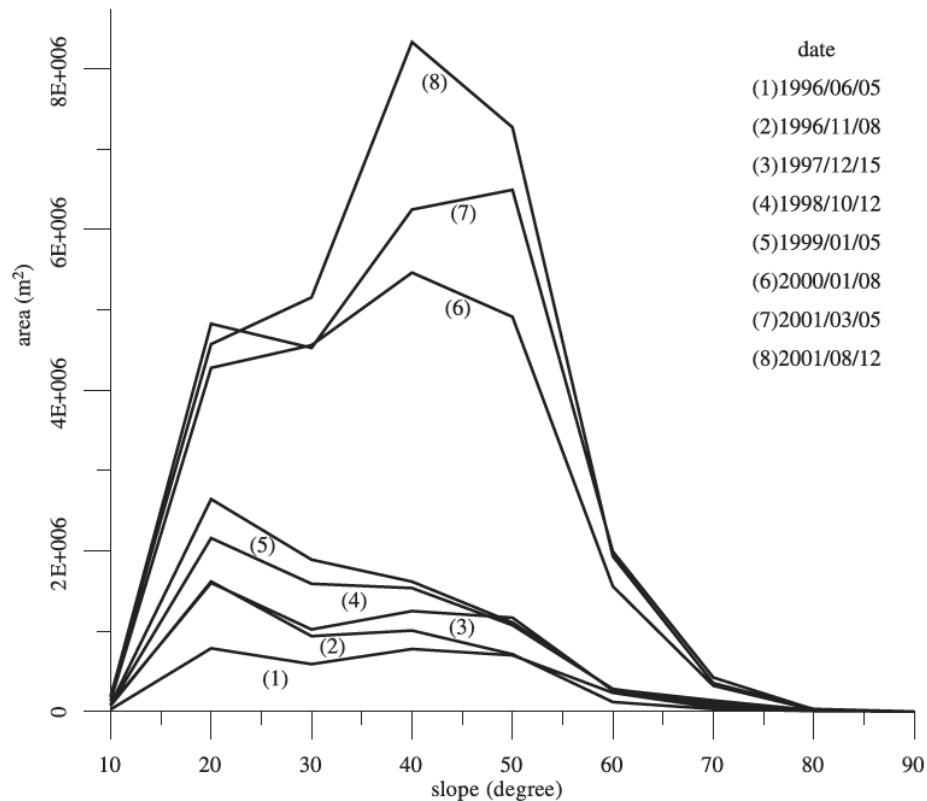


WMTS圖磚：<https://geomap.gsmma.gov.tw/mapguide/mapagent/mapagent.fcgi?>

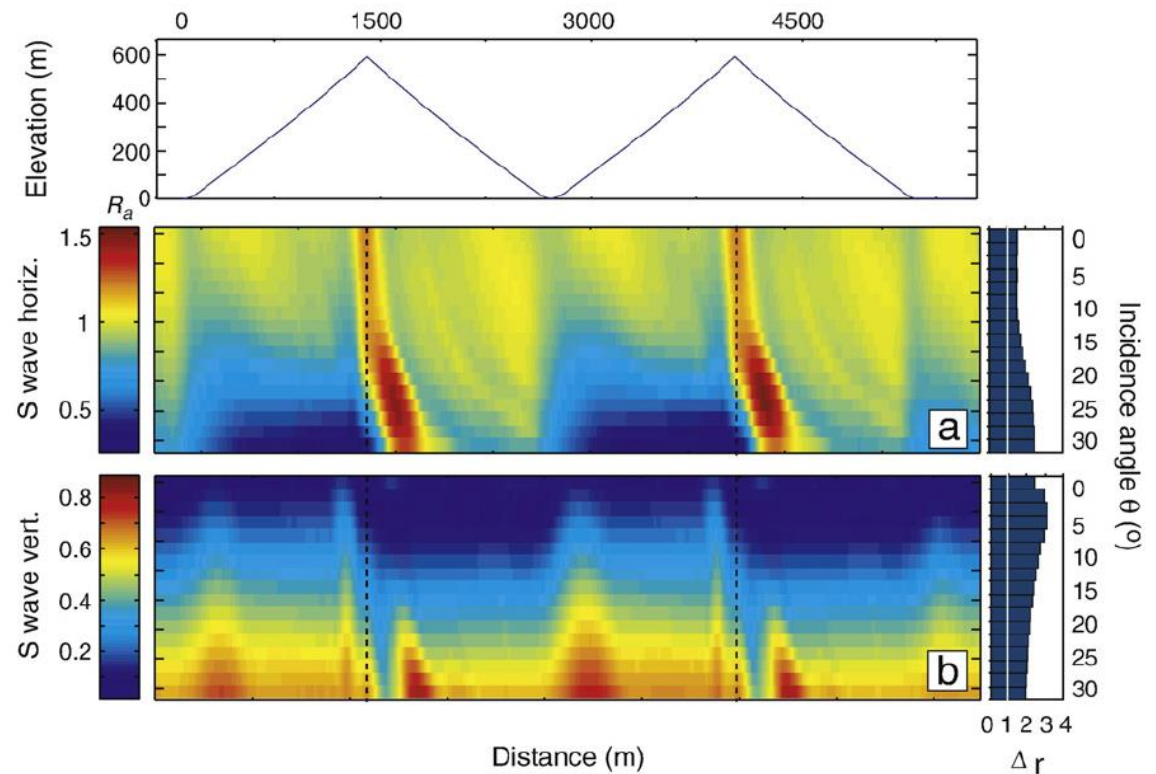
# 同震山崩 文獻回顧

# 同震山崩的特性 - 坡度

- 同震山崩通常發生在陡坡、山脊處，和降雨引致崩塌不同
  - Lin et al. (2004, 2006)：921地震崩塌多發生在坡度40-50度的位置
  - Meunier et al. (2008)：此現象與地形放大效應有關，山脊處的S波震幅有增強的現象



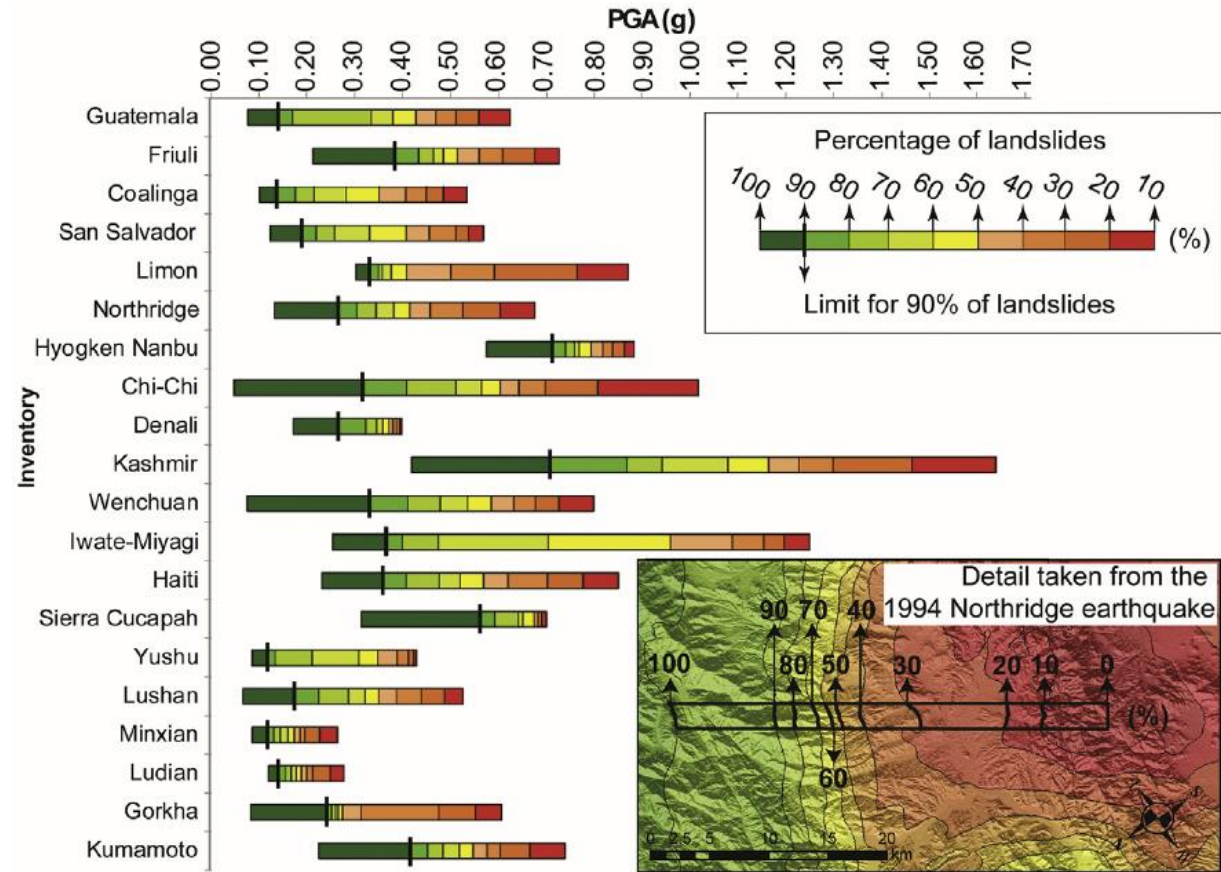
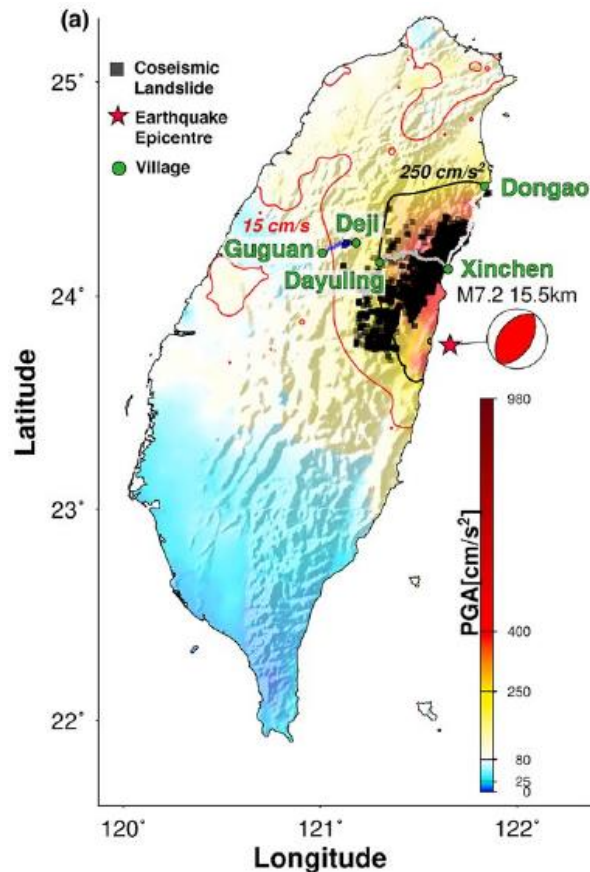
Lin et al. (2004)



Meunier et al. (2008)

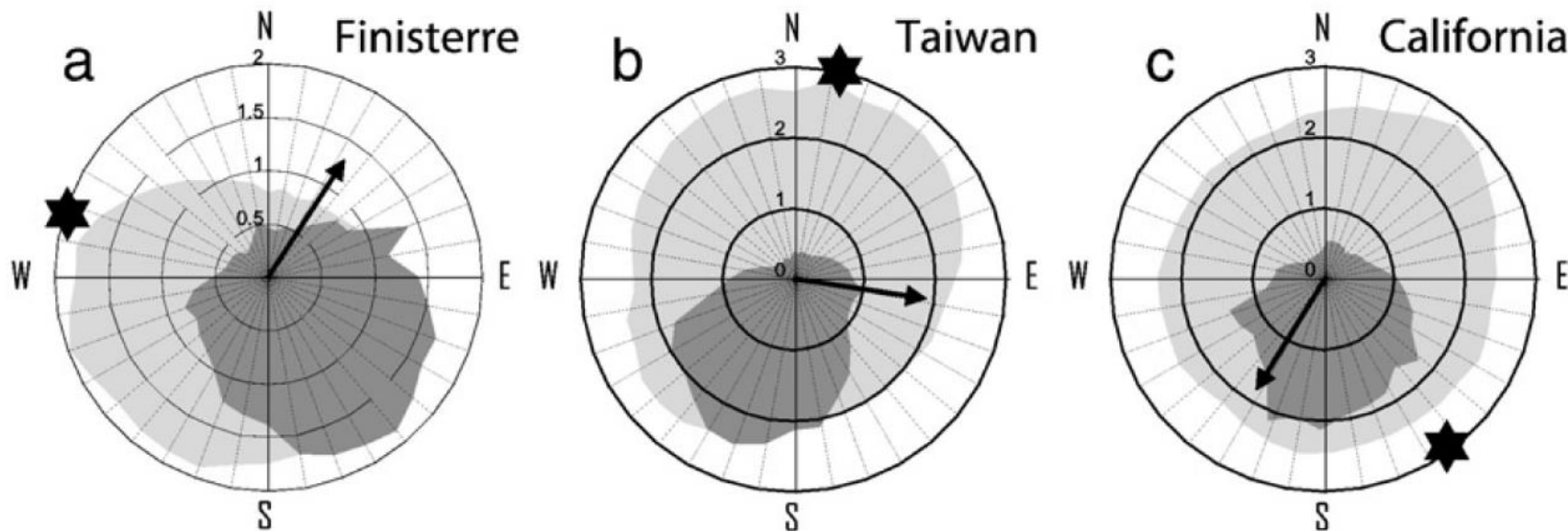
# 同震山崩的特性 - 地動程度

- 需要一定的地震規模、震度才能促發同震山崩 (約震度5弱)
- Chang et al. (2024) : PGA  $250 \text{ cm/s}^2$  (5強上界) 、PGV  $15 \text{ cm/s}$  (5弱下界) 是重要的界線
- Tanyaş and Lombardo (2019) : PGA在0.12以上(約5弱下界)可以解釋90%的同震山崩

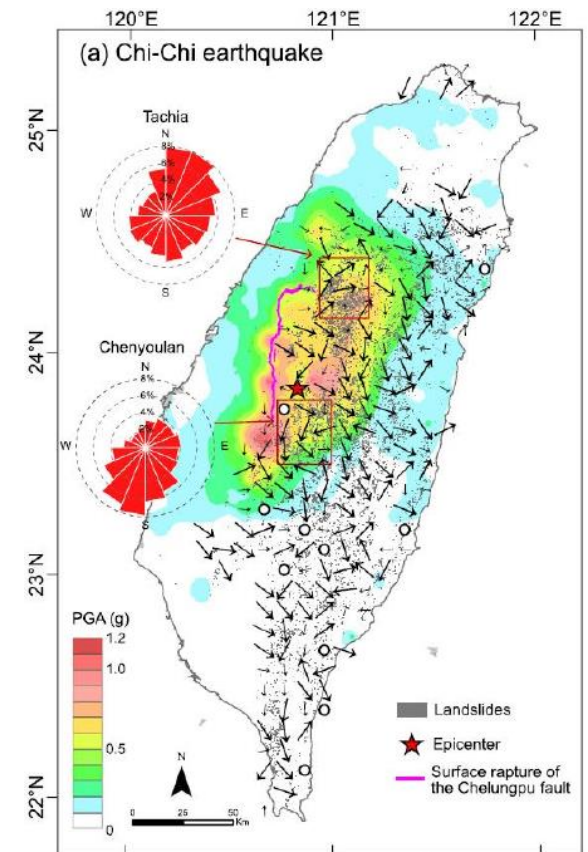


# 同震山崩的特性 - 坡向

- 在逆斷層誘發的崩塌事件中，崩塌通常發生在**背向震央**的邊坡
  - Meunier et al. (2008)：3起逆斷層事件的崩塌地坡向分析
  - Chen et al. (2019)：921地震崩塌分布的坡向在大甲溪和陳有蘭溪有明顯差異



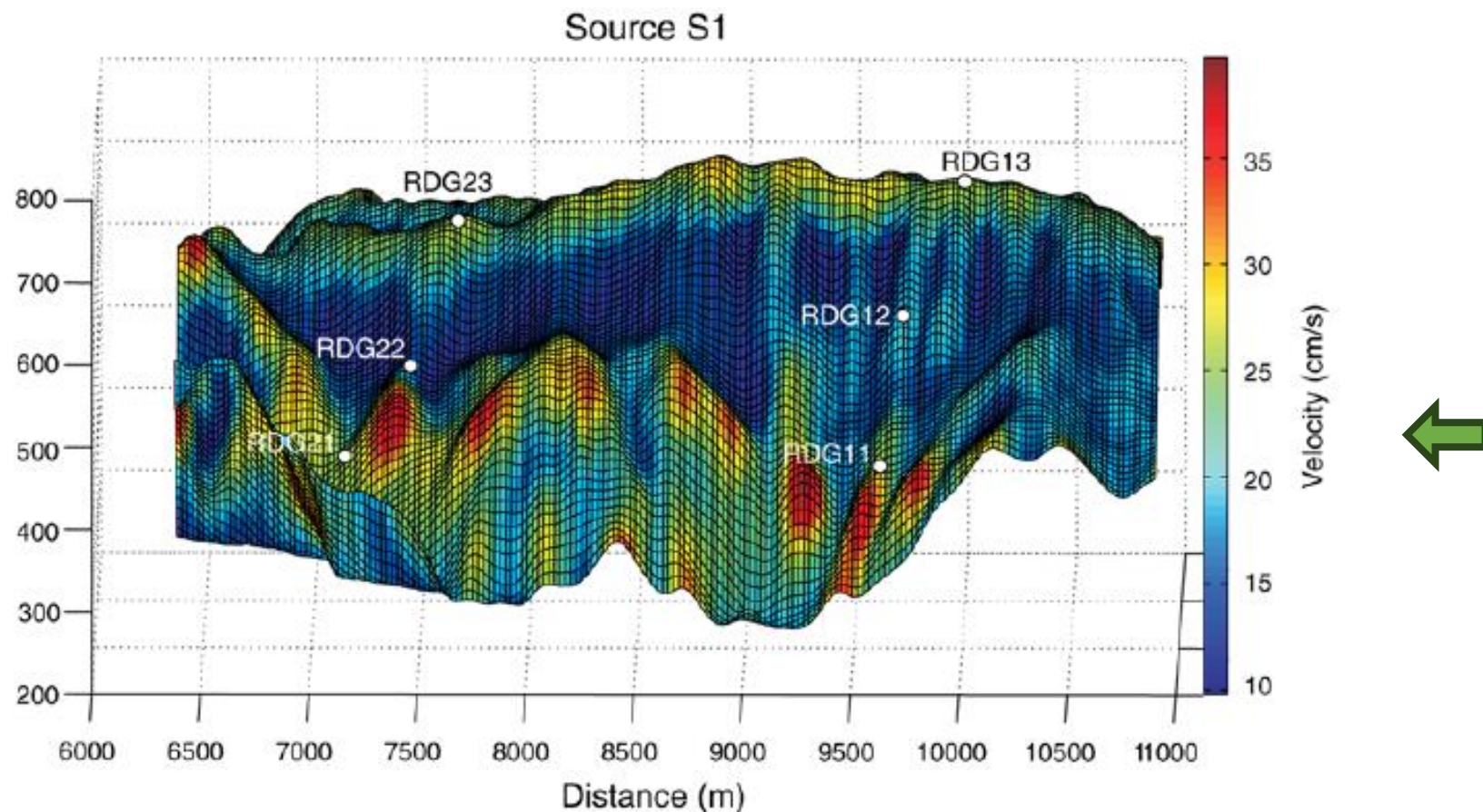
Meunier et al. (2008)



Chen et al. (2019)

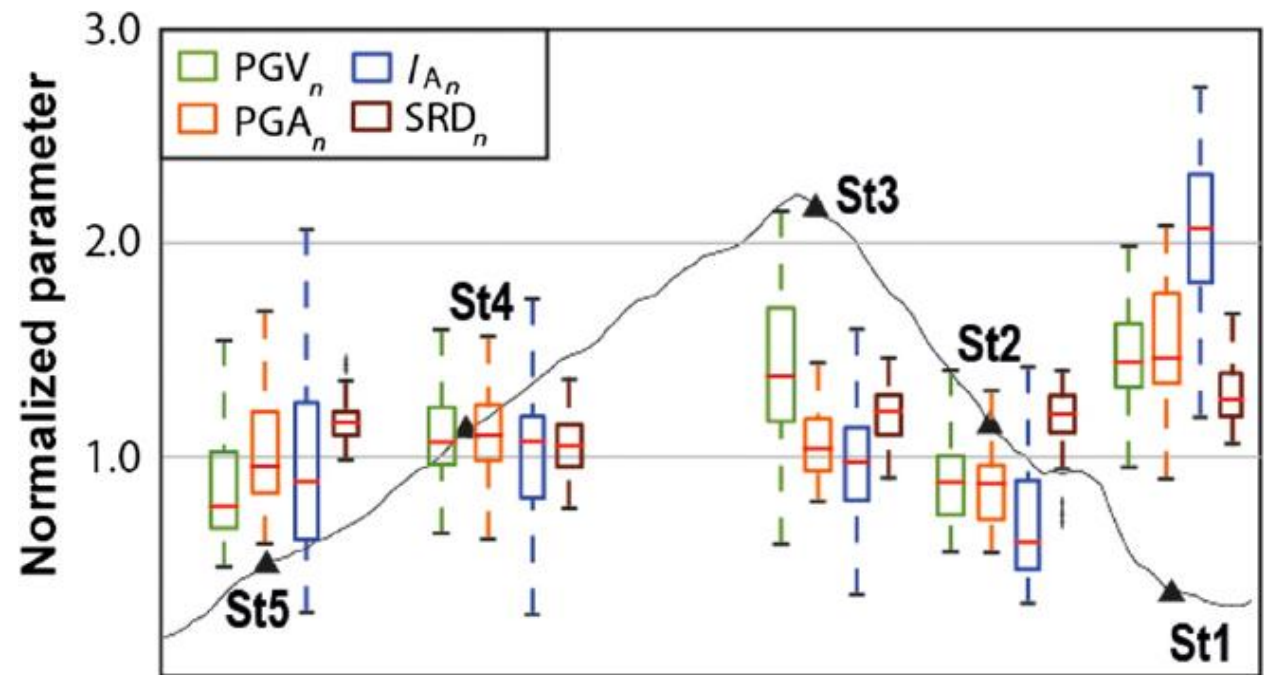
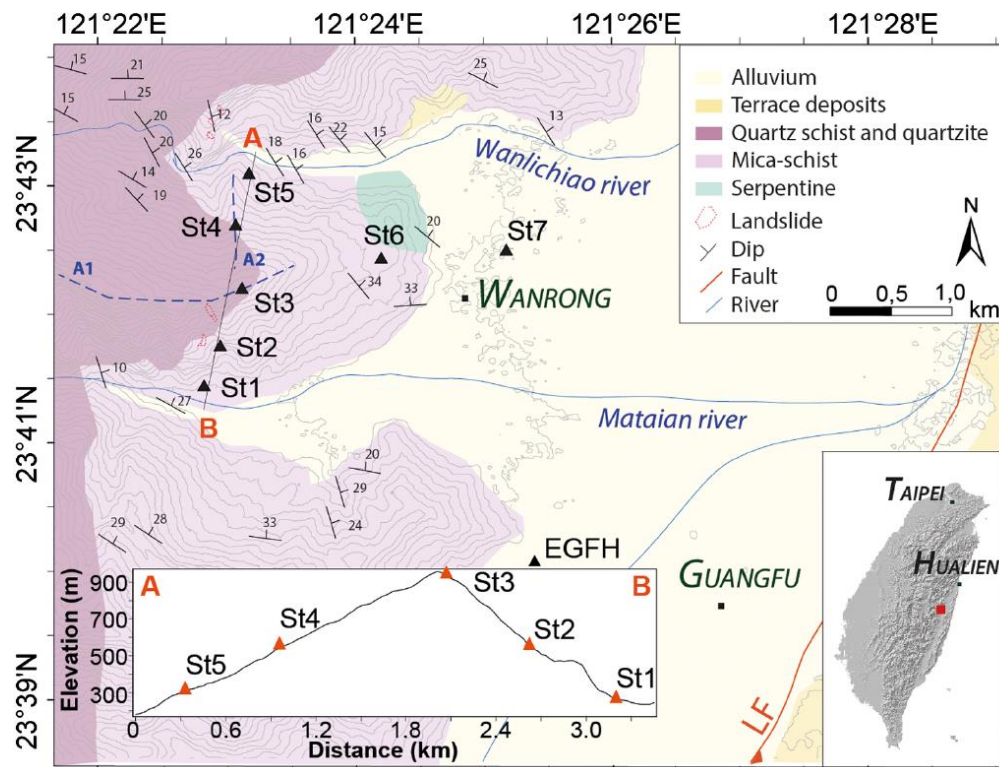
# 同震山崩的特性 - 坡向

- 地震波模擬資料顯示，邊坡放大震波的現象與地震波來向、山脊走向有關
- Hartzell et al. (2014)：放大現象與地震波的來向一致，不一定在背對震源方向



# 同震山崩的特性 - 地質條件

- 地質條件對於同震山崩也有一定程度的影響
  - Hailemikael et al. (2016)：指出地質材料(土層或岩盤)也需要納入考量 - 場址效應
  - Rault et al. (2024)：測站的訊號無明顯趨勢，應受控於地質條件(材料)
  - 順向坡(Guzzetti et al., 2008)、歷史山崩(Martino et al., 2022)同為重要因子

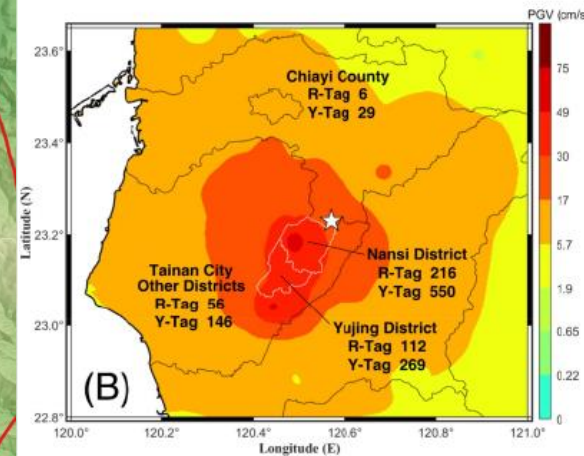
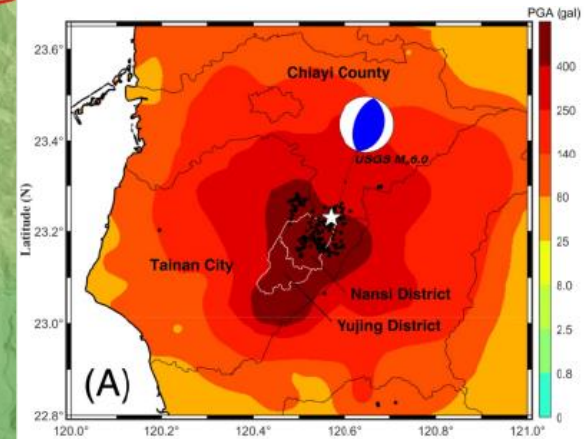
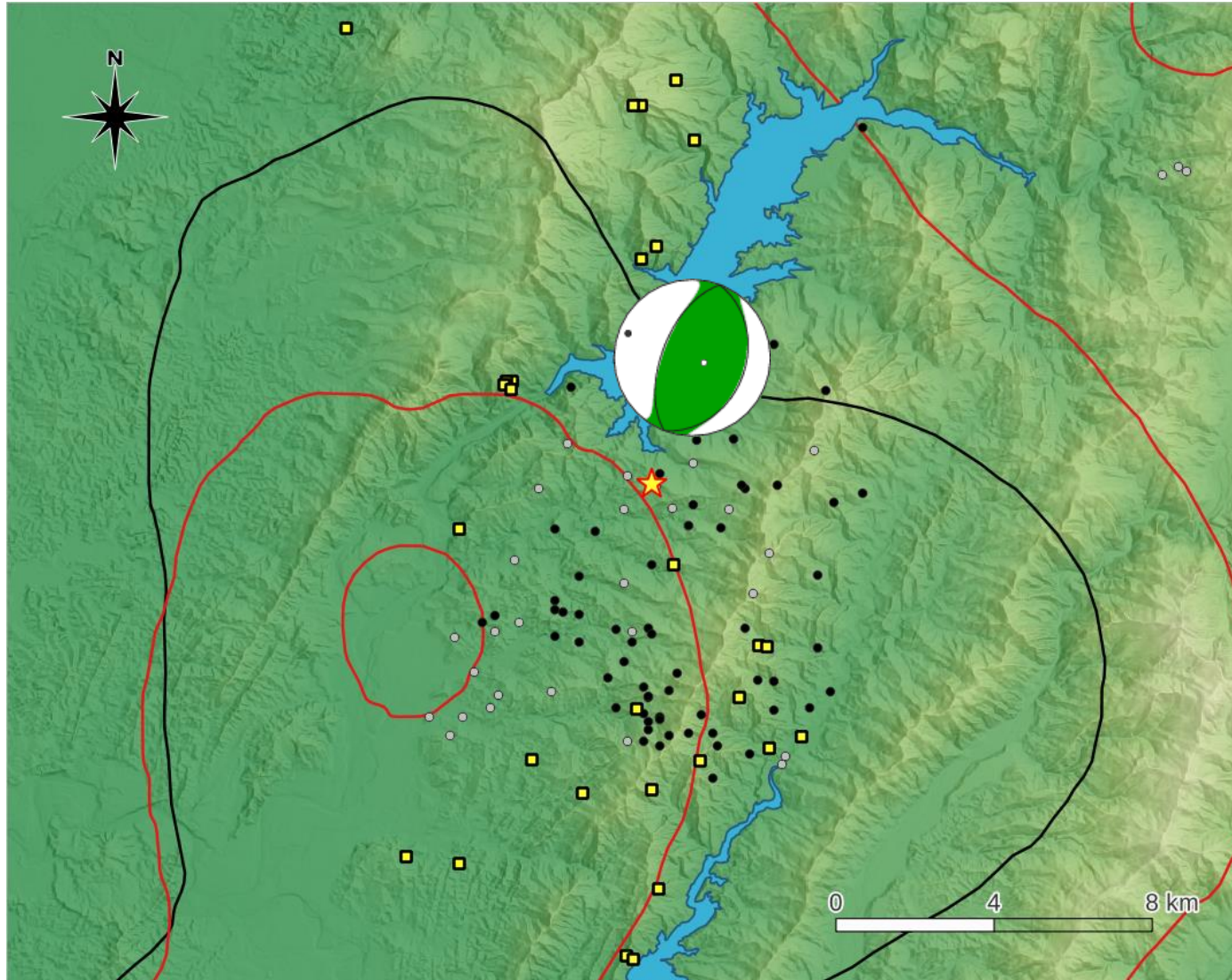


Rault et al. (2024)

# 研究方法&材料

# QGIS分析：基礎圖資與其空間分布

- [水保署崩塌圖資](#)
- [水利署水庫圖資](#)
- 內政部5mDEM
- PGA(黑)、PGV(紅)
  - Wu et al. (2025)
- [AutoBATS CMT](#)
- [氣象署地震資訊](#)
  - 星號(主震)
  - 1/21-1/24 UTC+8
  - 圓點(黑-1日內餘震)
  - 圓點(灰-其餘餘震)



Wu et al. (2025)

# QGIS分析：計算崩塌地坡度坡向

## 1. DEM資料處理：

- Raster tools > Fill NoData cells
- GDAL > Raster analysis > Fill nodata

## 2. 坡度計算：

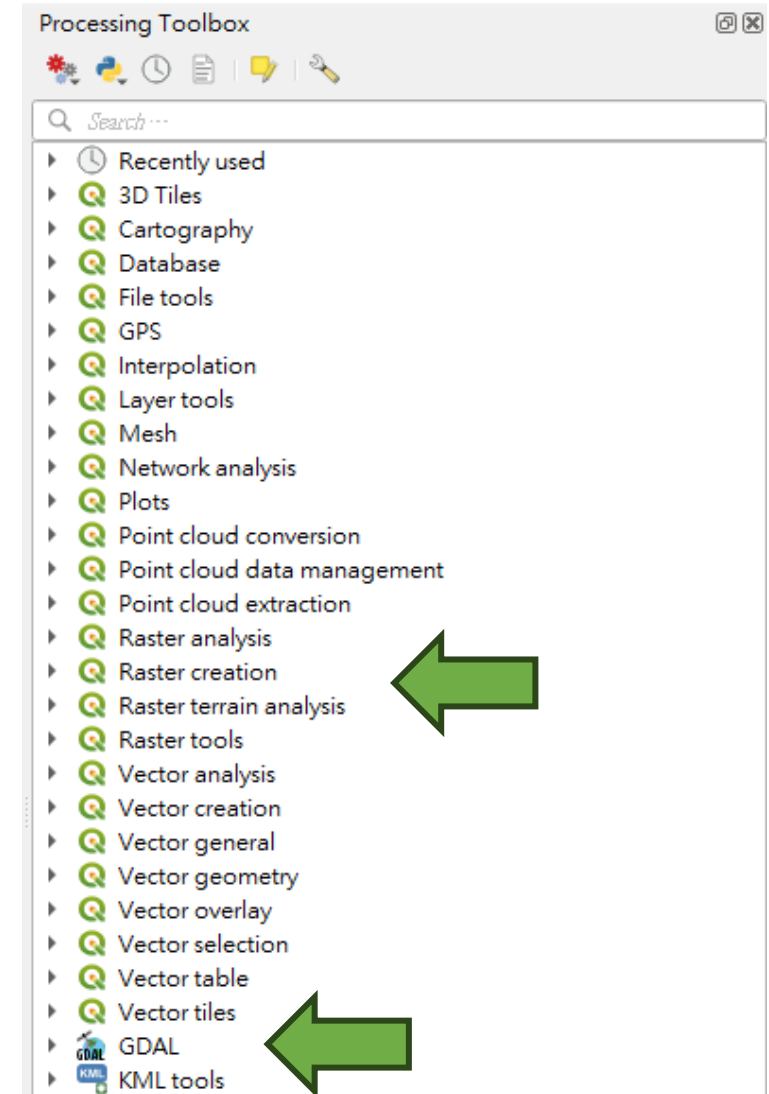
- Raster terrain analysis > Slope
- GDAL > Raster analysis > Slope

## 2. 坡向計算：

- Raster terrain analysis > Aspect
- GDAL > Raster analysis > Aspect

## 3. 崩塌地分析：Raster analysis > Zonal statistics

- 以崩塌地shp範圍計算raster值(坡度、坡向)

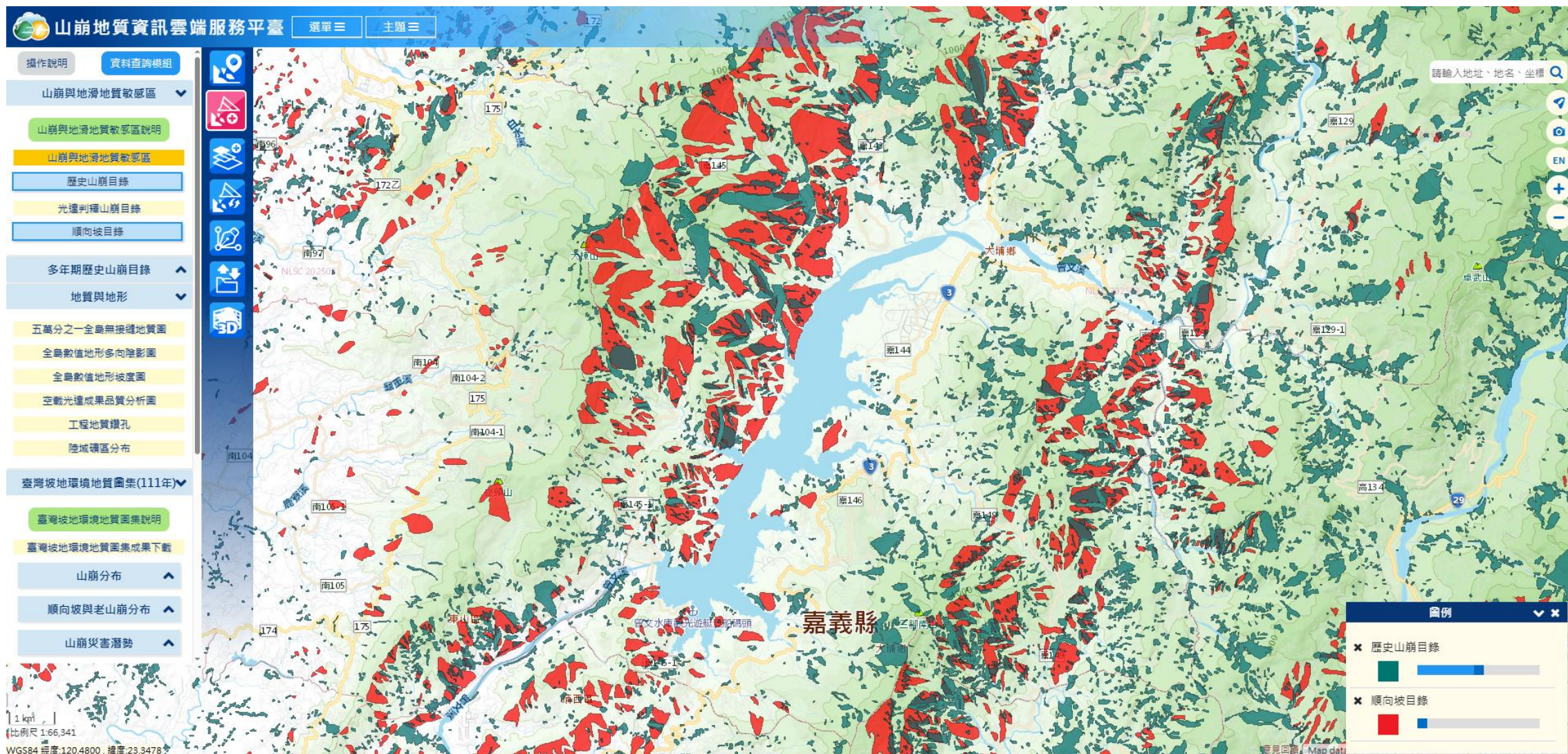




# 順向坡與歷史山崩圖資

地礦中心的山崩雲平台

<https://landslide.geologycloud.tw/map>



WMTS圖磚：<https://landslide.geologycloud.tw/jlwmts/jetlink/wmts>

# 現地調查 ( 20250319-20250320 )



中埔鄉, 台灣 2025/03/19

台3線沿途崩塌地調查 ( 照片：林駿恩 )

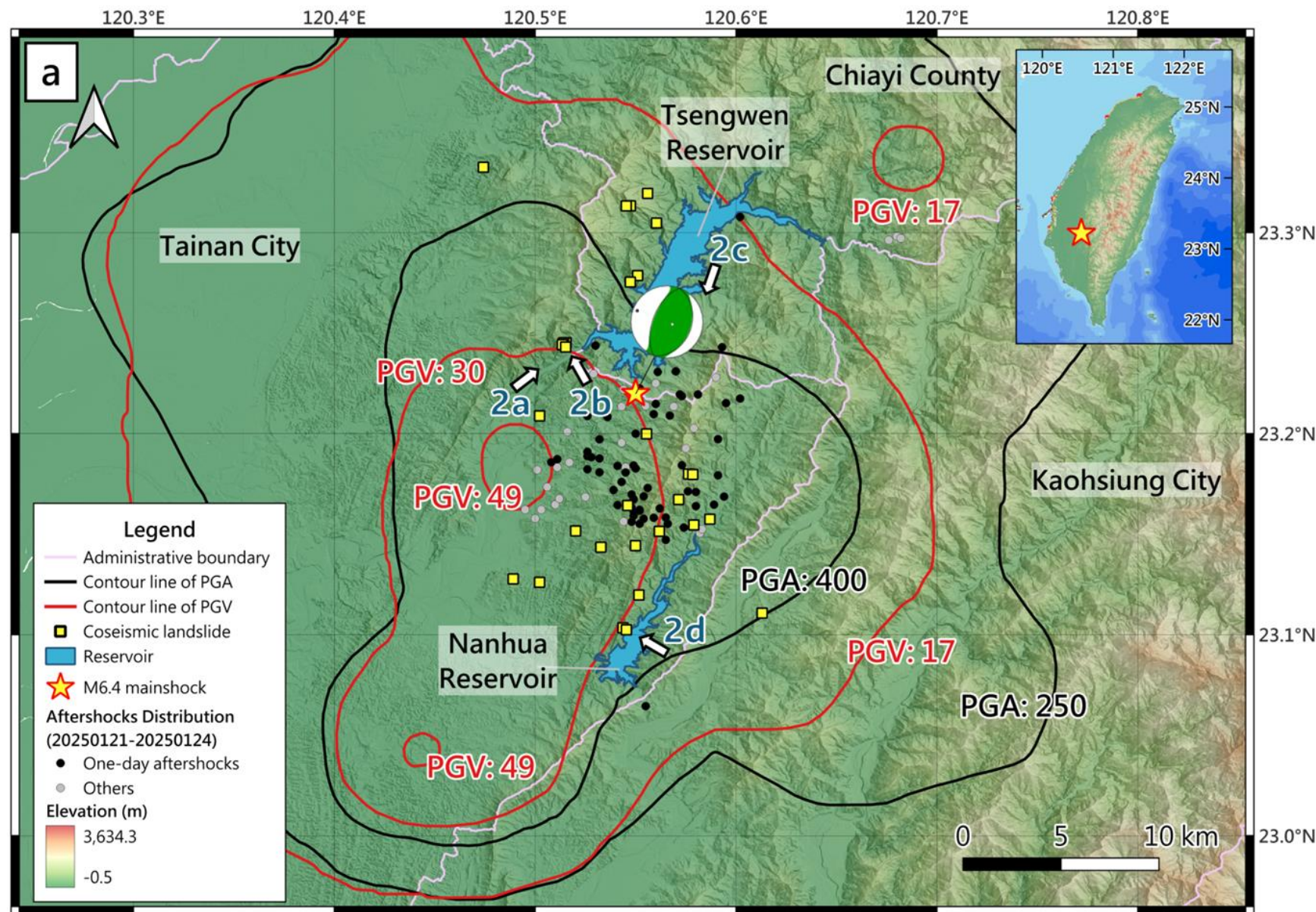


曾文水庫：西興觀景台向北拍攝

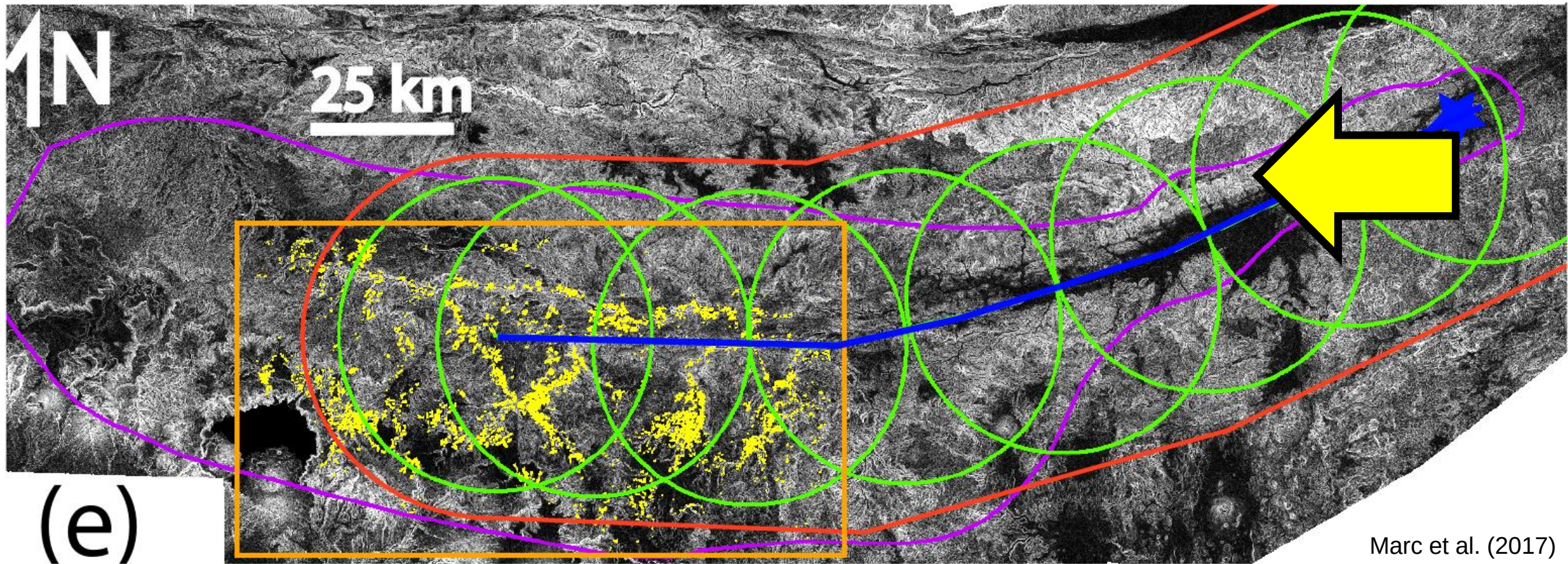
# 研究成果&討論

# 研究成果

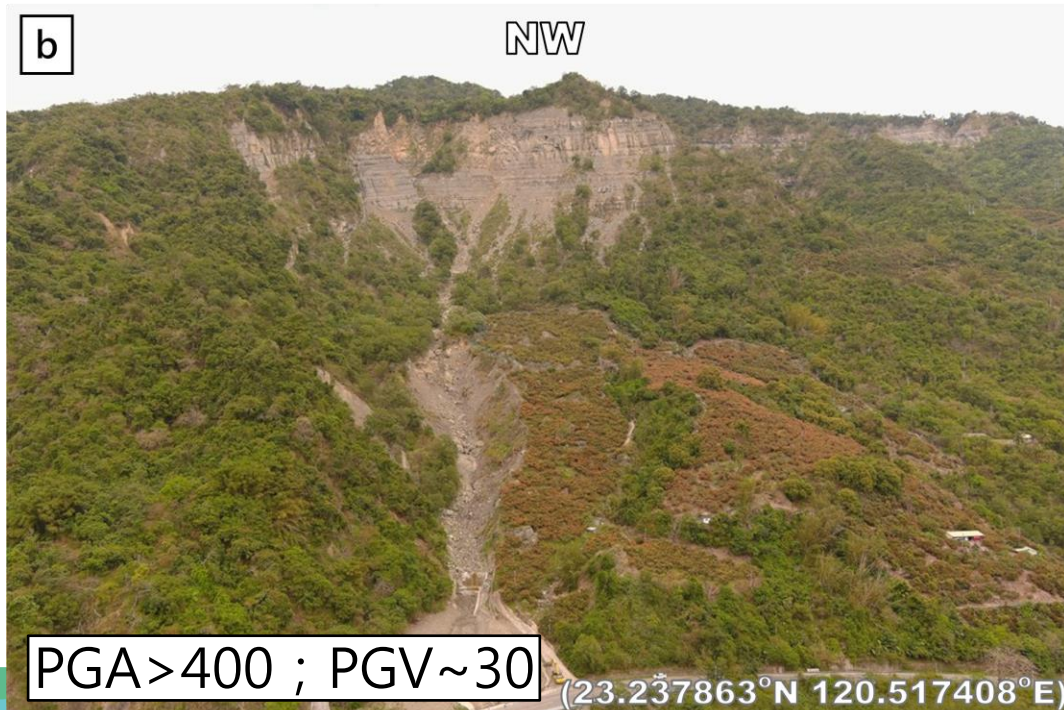
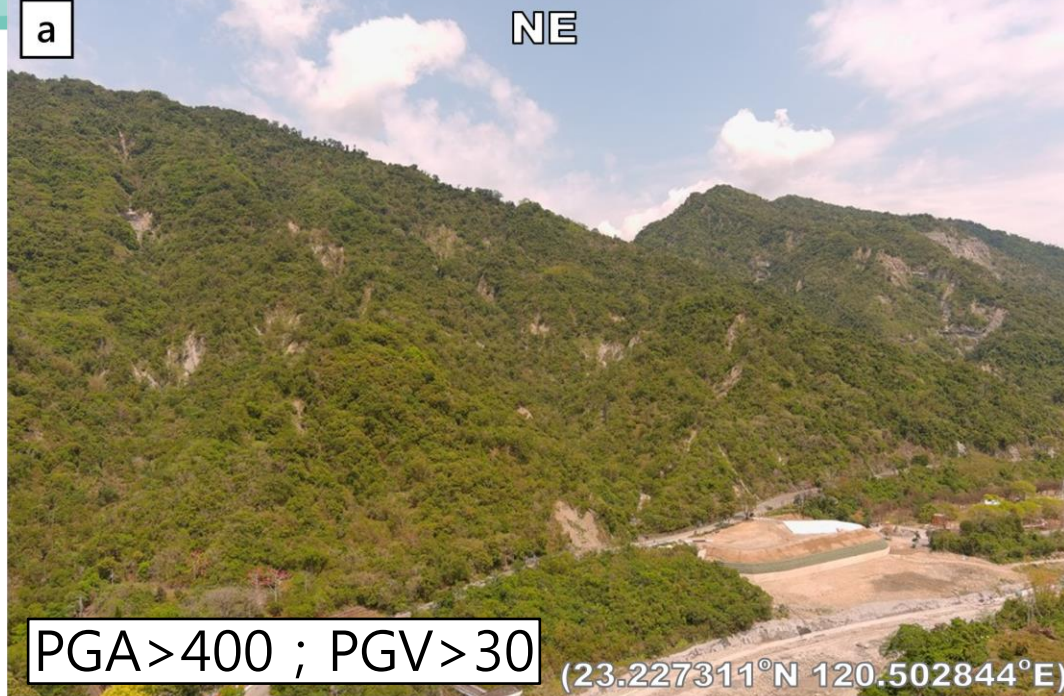
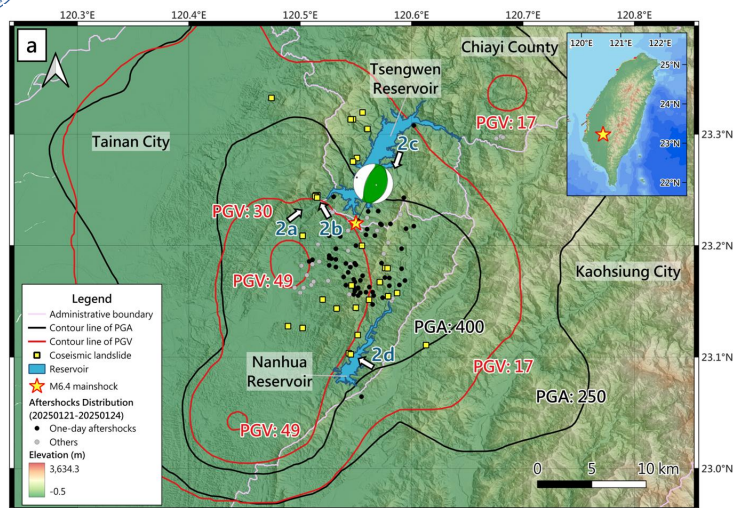
- 共29處衛星判釋新崩塌
- 三分之二的崩塌地發生在震央以南，可能反映地震破裂主要向南，導致南邊的地表變形較大，易產生崩塌（一日餘震主要也分布在南方） - Directivity Effects
- 崩塌地均在 PGV17、PGA250以內，且現地調查時，在此邊界內的沿途上可觀察到不少崩塌地。



# Directivity Effects



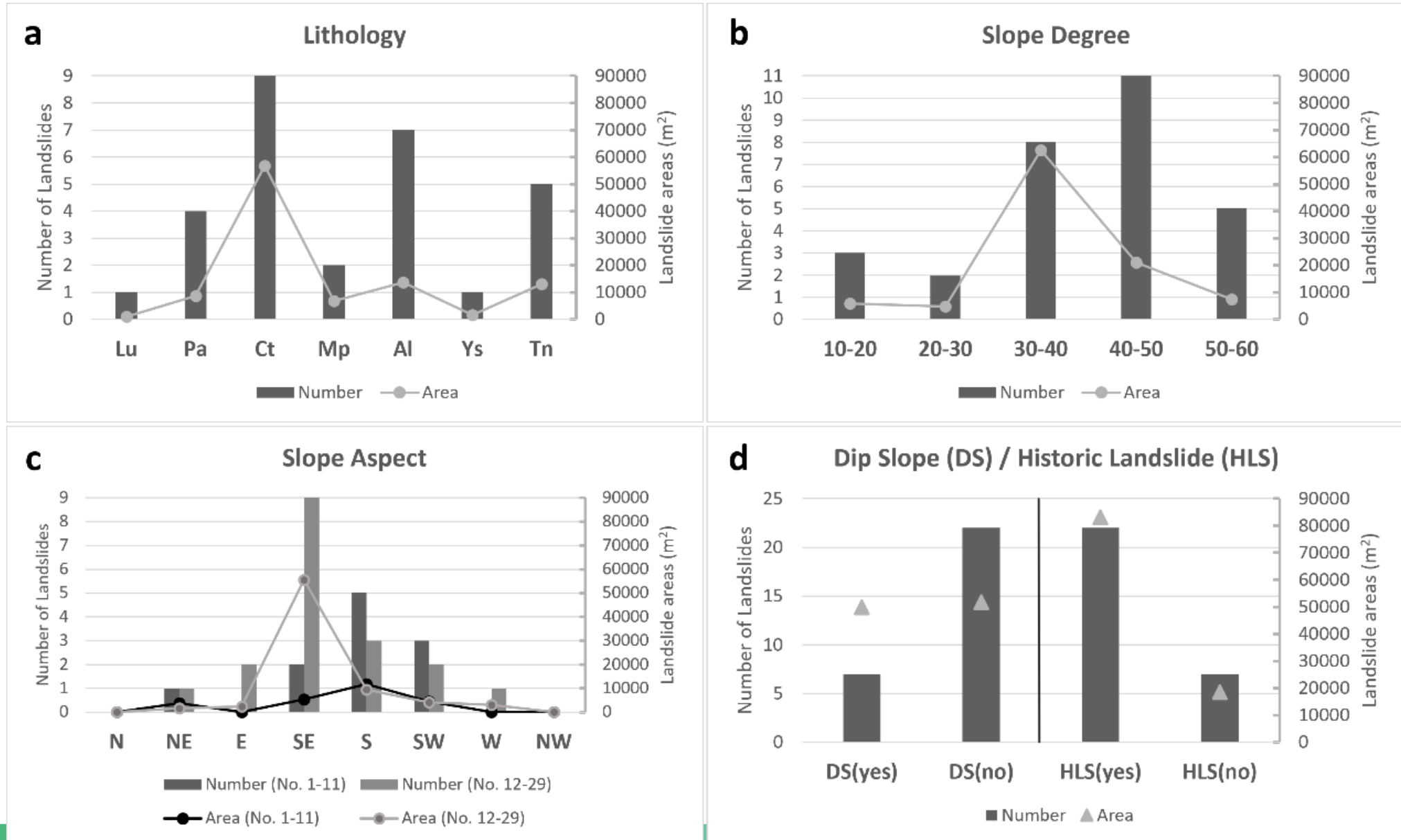
1976 瓜地馬拉地震



- 崩塌地均在  $PGV17$ 、 $PGA250$  以內，且現地調查時，在此邊界內的沿途上可觀察到不少崩塌地。
- $PGA \sim 400$  且  $PGV \sim 30$  的範圍內，有明顯的崩塌現象，但難從衛星影像判釋
- $PGA400$  左右但  $PGV$  不足  $30$  的區域，在調查時發現有零星小規模崩塌。



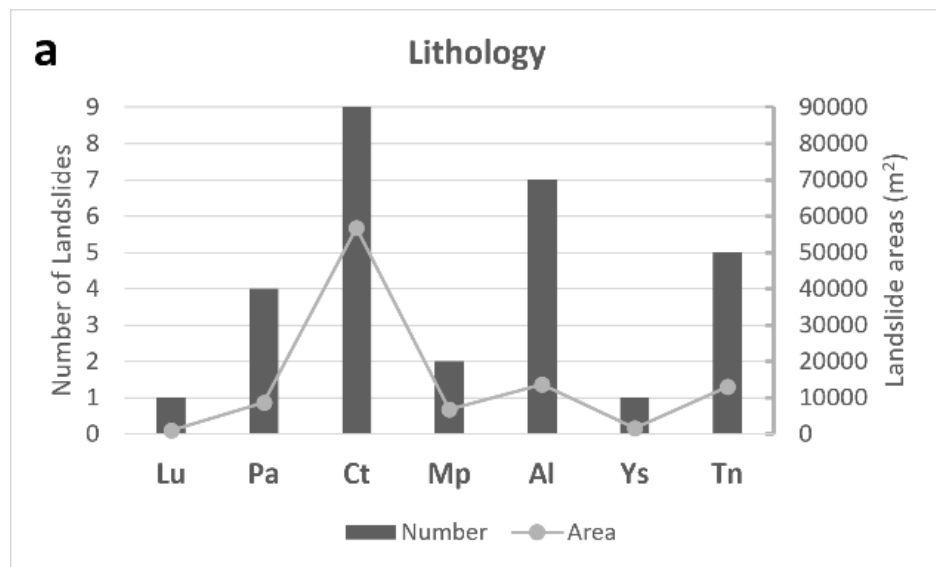
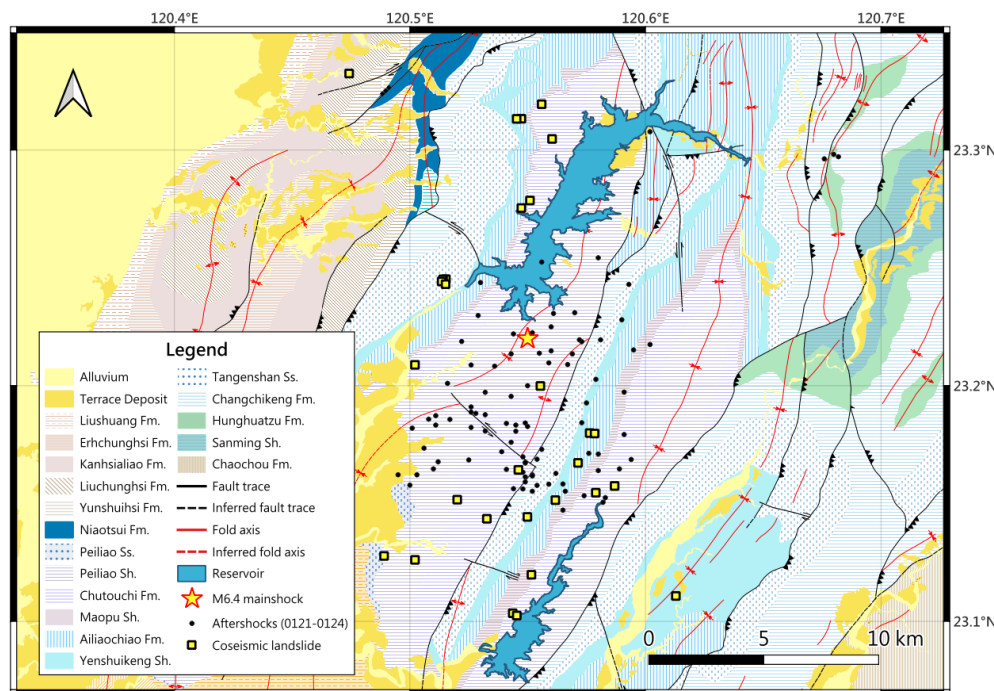
# 29處同震山崩的特性分析





# 岩性

• 無明顯趨勢



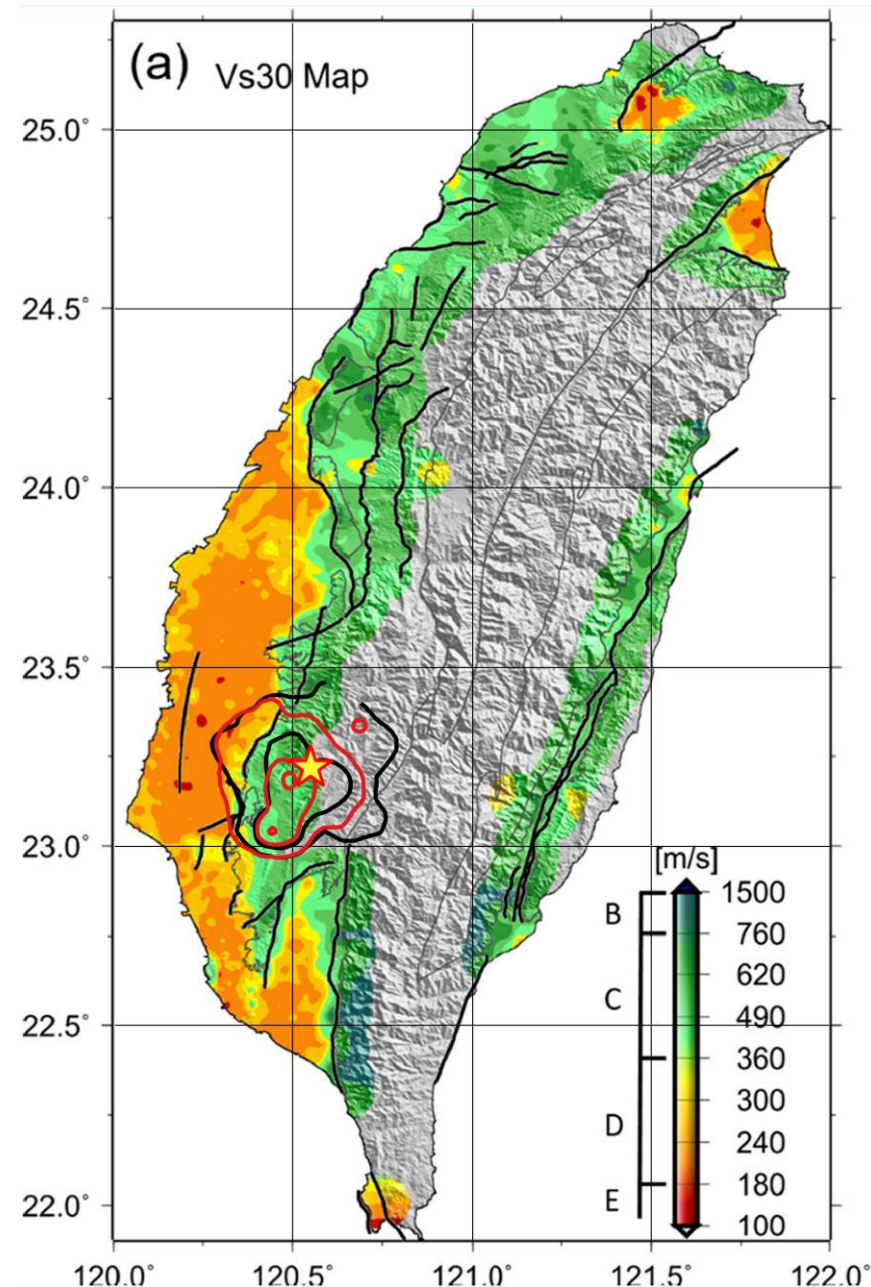
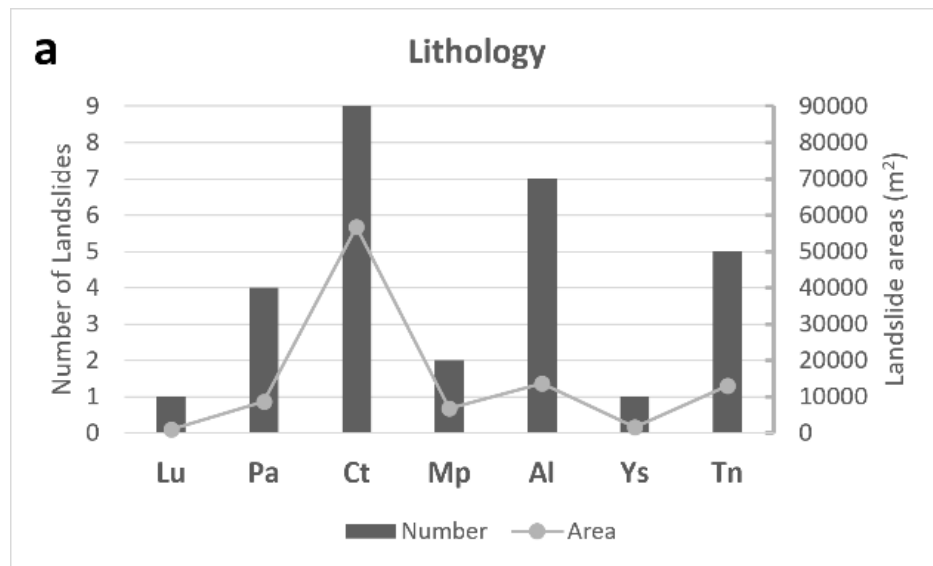
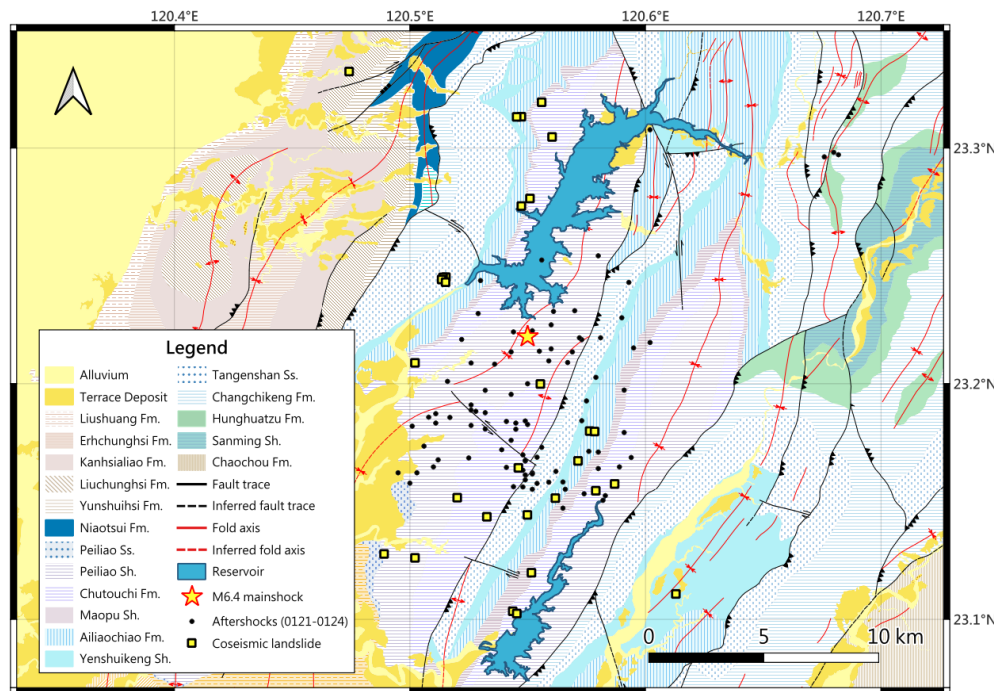
| 區分時代 |     | 鈣質超微化石<br>Martini (1971) | 浮游性有孔蟲<br>Blow (1969)           | 本圖幅<br>(2009)      |            | 台南地區<br>黃敦友(1978)<br>謝凱旋等(2003<br>, 2009修訂) | 台灣北部                                 |      |        |        |
|------|-----|--------------------------|---------------------------------|--------------------|------------|---------------------------------------------|--------------------------------------|------|--------|--------|
|      |     |                          |                                 | 觸口及崙後斷層以西          | 觸口及崙後斷層以東  |                                             | Huang.T.Y.(1978)<br>Huang.T.Y.(1984) |      |        |        |
| 第四紀  | 更新世 | 中期                       | c<br><br>b<br><br>a<br><br>NN19 | N22                | 二重溪層       |                                             | 頭崙山層                                 |      |        |        |
|      |     | 崙下寮層                     |                                 |                    |            |                                             |                                      |      |        |        |
|      |     | 六重溪層<br>Lu               |                                 |                    | 北寮頁岩<br>Pa |                                             |                                      | 玉井頁岩 |        |        |
|      |     | 鏡面砂岩<br>北寮頁岩             |                                 |                    | 卓蘭層        |                                             |                                      |      |        |        |
| 第三紀  | 上新世 | 晚期                       | NN18<br>NN16                    | N21                | 云水溪層       | 竹頭崎層<br>Ct                                  | 竹頭崎層                                 | 錦水頁岩 |        |        |
|      |     | 早期                       | NN15<br>NN13                    | N19                | 鳥嘴層        | 茅埔頁岩<br>Mp                                  | 茅埔頁岩                                 | 桂竹林層 | 魚藤坪砂岩段 |        |
|      |     |                          | NN12                            |                    | N18        | 中崙層                                         | 隘寮腳層<br>Al                           |      | 隘寮腳層   | 十六份頁岩段 |
|      |     |                          | NN11                            |                    | N17        | 鹽水坑頁岩<br>Ys                                 | 鹽水坑頁岩                                |      | 關刀山砂岩段 |        |
|      |     | 中新世                      | 中期                              | NN10<br>NN9<br>NN8 | N15        | 糖恩山砂岩<br>Tn                                 | 糖恩山砂岩                                | 南莊層  |        |        |
|      | 晚期  |                          | NN7<br>NN6                      | N14                |            | 長枝坑層                                        | 長枝坑層                                 |      |        |        |
|      |     |                          | NN12-N13                        |                    |            | 紅花子層                                        | 紅花子層                                 |      |        |        |
|      |     |                          |                                 |                    |            |                                             | 三民頁岩                                 |      | 三民頁岩   | 南港層    |



# 岩性

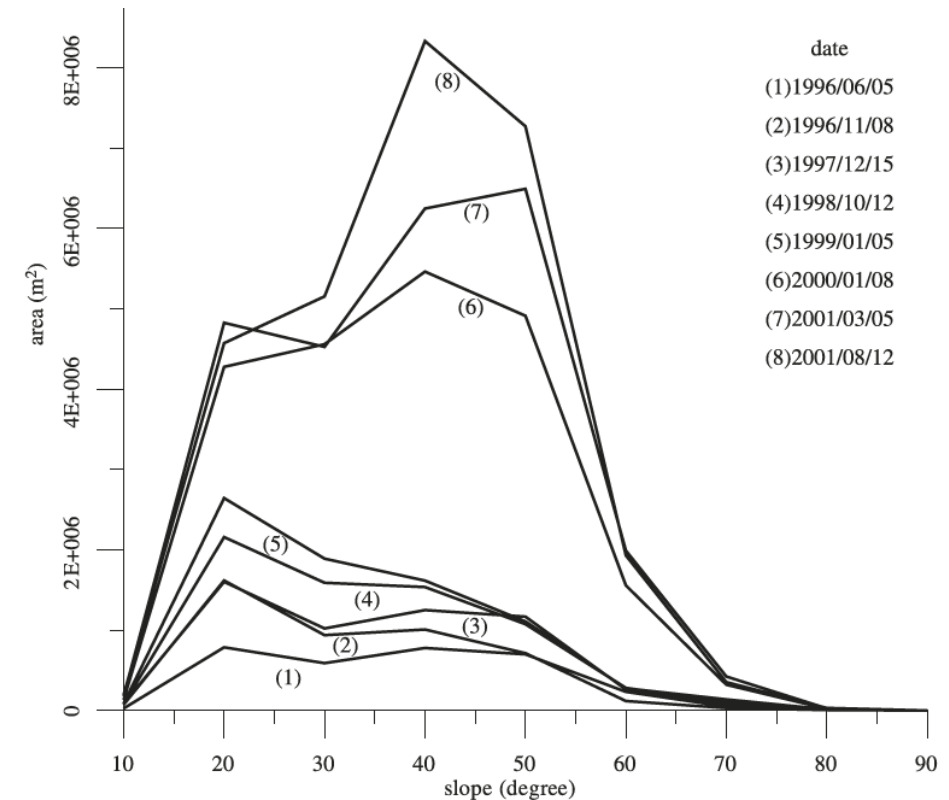
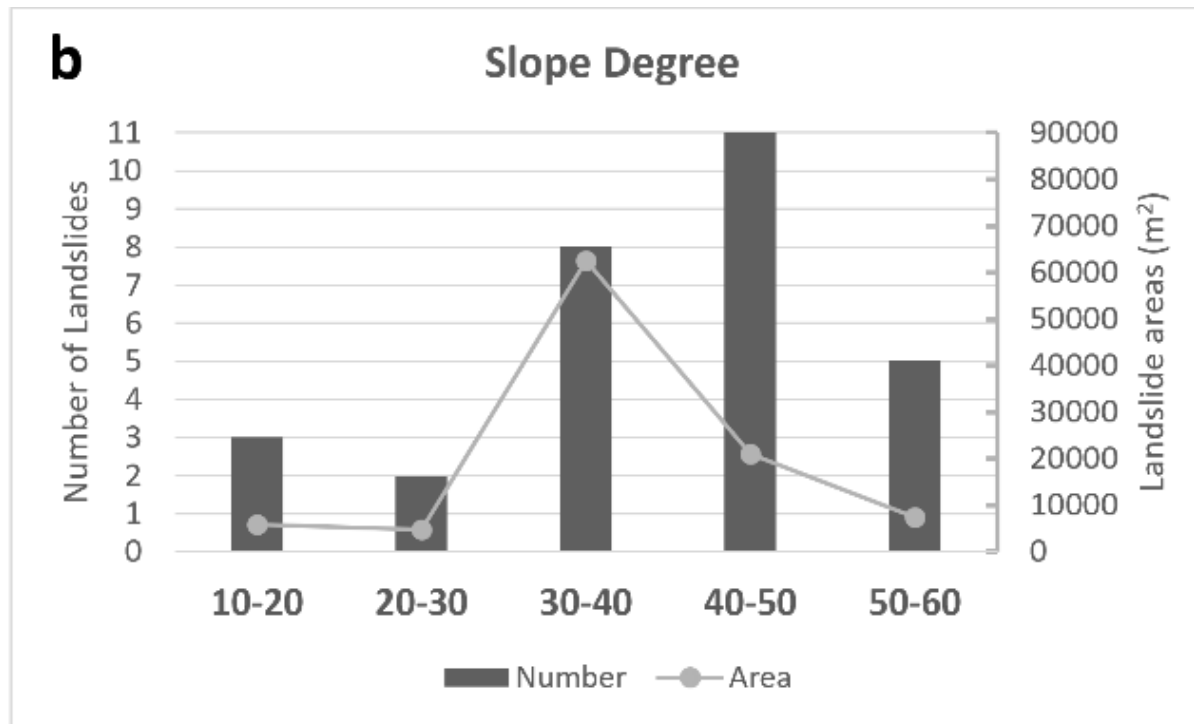
- 無明顯趨勢
- 岩體強度差異小
  - Rock Class C (NEHRP 美國國家地震災害防制計畫)

Very dense soil and soft rock



# 坡度

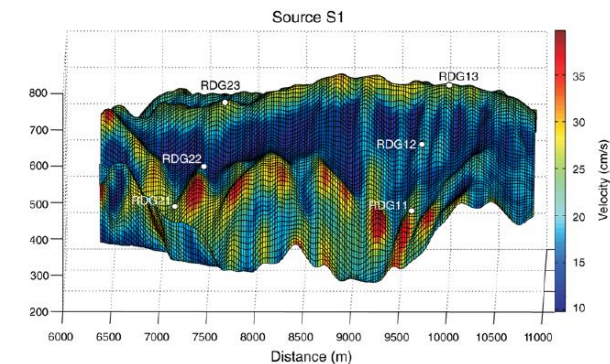
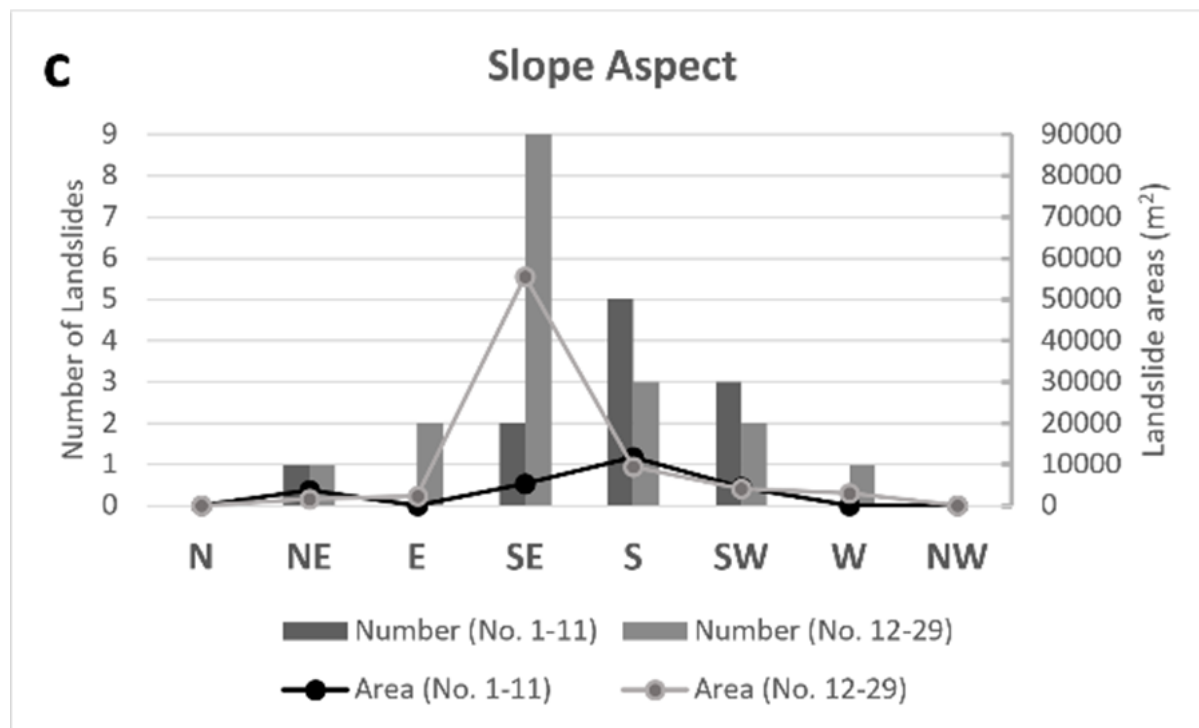
- 數量：40-50度最多；面積：30-40最大 > Topographic site effects



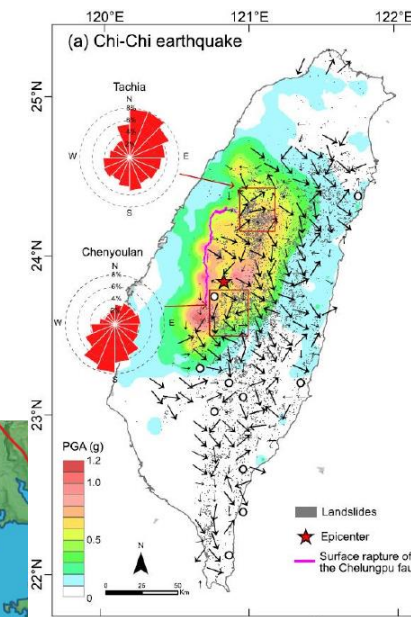
Lin et al. (2004)

# 坡向

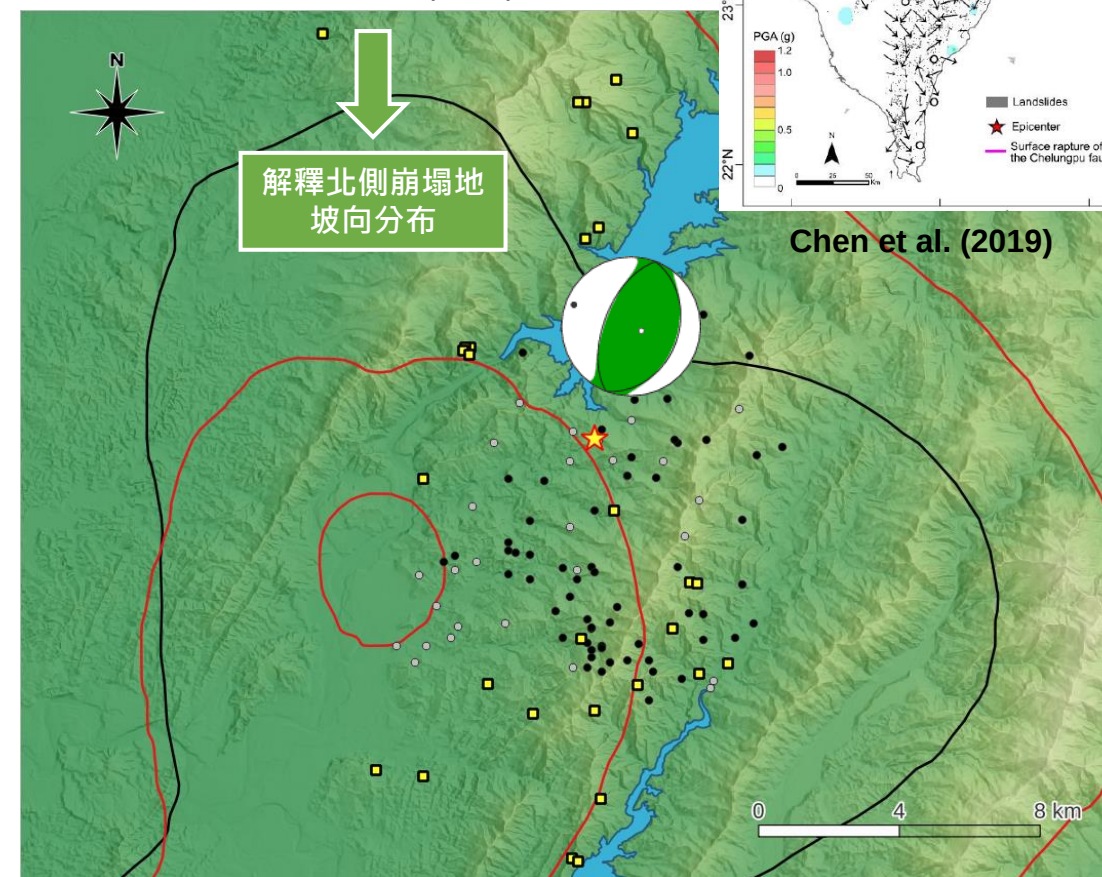
- 背向震源(央)方向的現象：僅研究區域南邊適用



Hartzell et al. (2014)

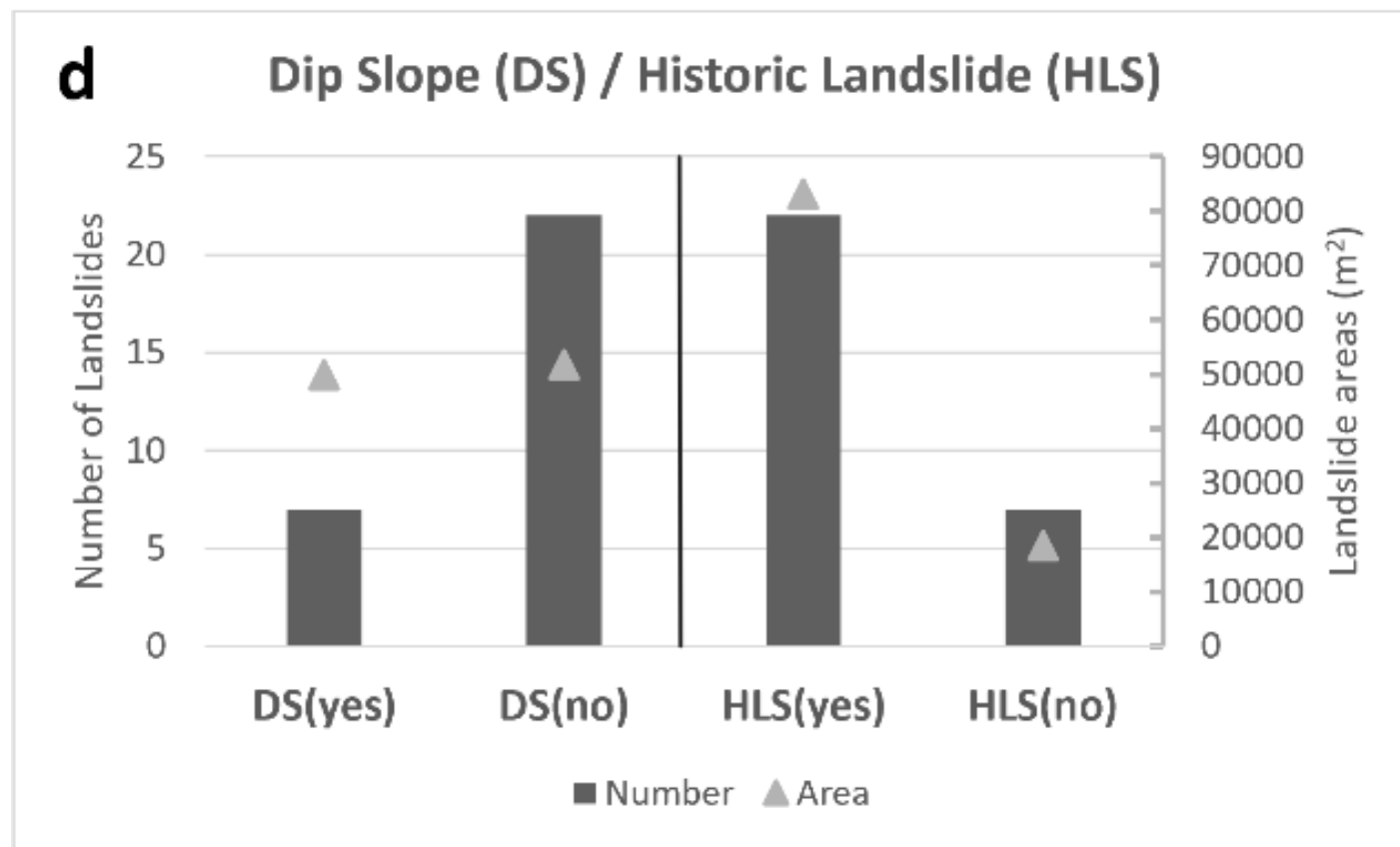
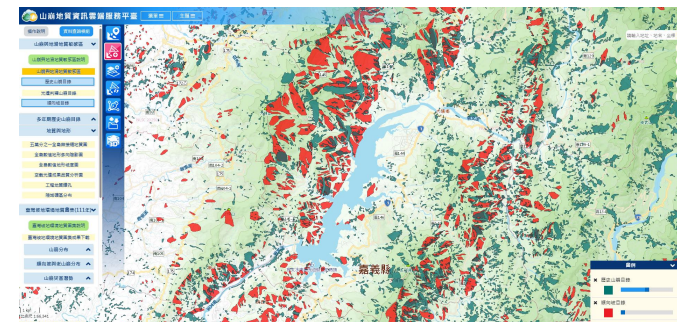


Chen et al. (2019)



# 順向坡(DS) / 歷史山崩(HLS)

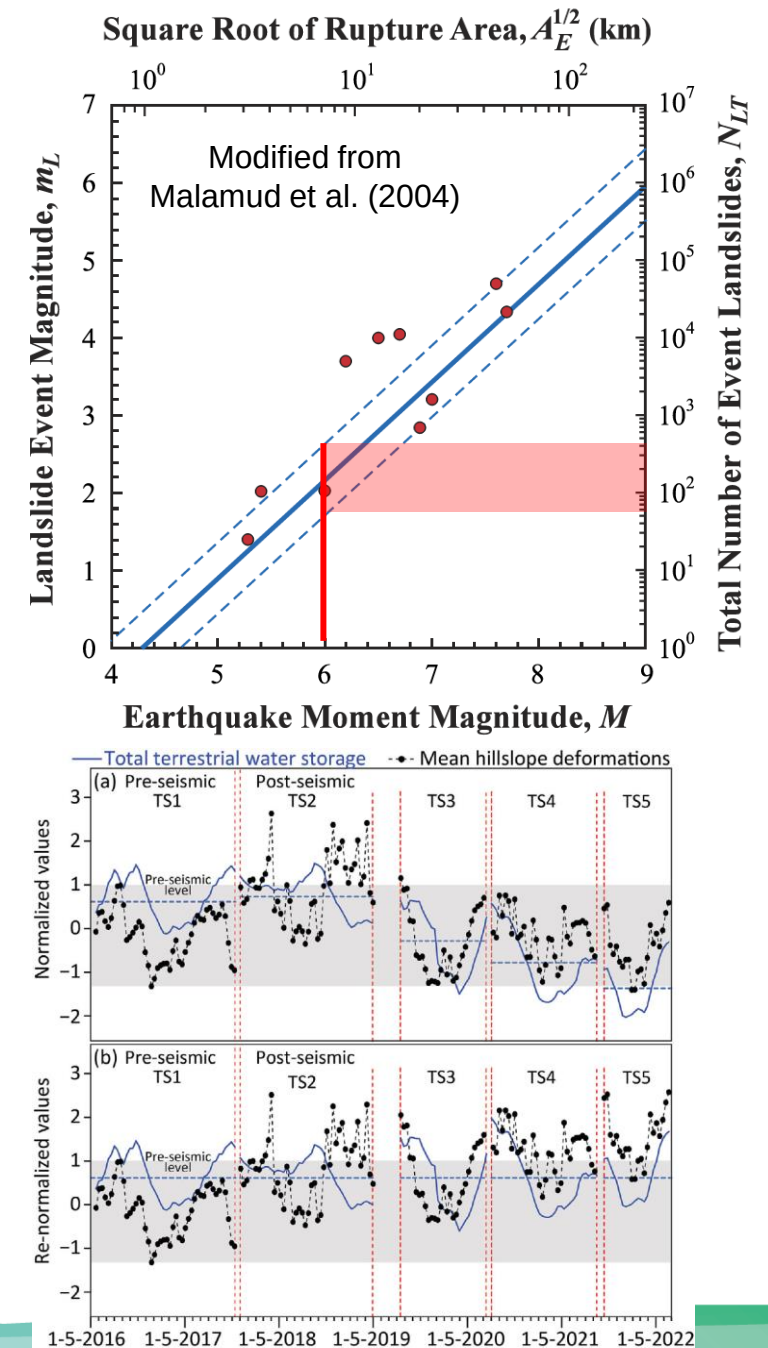
- 就本次事件，順向坡對於崩塌面積有顯著影響
- 歷史山崩可能是主導這個區域發生同震山崩的重要因素



# 討論：減災策略

- 衛星判釋僅 29 處相較前人研究略少 (e.g. Malamud et al., 2004)，但經過野外調查後，判斷應該是衛星影像解析度不足所致，實際上存在許多無法從影像上判釋的小崩塌地。
- Wang et al. (2025)：45處大埔地震同震山崩。
- 現地調查與精細的山崩圈繪，對於掌握災害熱區相當重要。
- 中大型地震的後續影響 (Earthquake Legacy Effects)，降低土石流與崩塌發生的門檻值。
- 須留意今年雨季時西南部台灣的災害狀況，並進一步探討規模6地震的影響與持續時間。

He et al. (2024)



# Summary

就2025年大埔地震的案例：

- PGA和PGV與同震山崩存在一定關係，目前以PGA 250  $\text{cm/s}^2$ 、PGV 15(或17)  $\text{cm/s}$  為界，可以大致框出可能受山崩影響的區域。
- **PGA 400  $\text{cm/s}^2$ 、PGV 30  $\text{cm/s}$** 可能導致較為嚴重的崩塌，需針對上述範圍做詳細調查。
- 坡向分析顯示地震波傳遞和山脊分布間複雜的交互關係，且順向坡、歷史山崩極可能也影響崩塌地的坡向，不同因子間的交互影響機制需要進一步的研究。

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## Data availability

Coseismic landslides inventory of the Dapu earthquake can be accessed through ARDSWC's BigGIS website at <https://gis.ardswc.gov.tw/map/>. The information of the Dapu earthquake and its aftershocks can be downloaded from CWA website at <https://scweb.cwa.gov.tw/zh-tw/earthquake/data>. The focal mechanism can be achieved from AutoBATS CMT Catalog website at <https://tecdc.earth.sinica.edu.tw/FM/AutoBATS/>. The 1:50,000 Geological Maps of Taiwan's river basins (2013), the Catalog of dip slopes and the Catalog of historic landslides from GSMMA can be accessed as WMS/WMTS layer using (1) <https://geomap.gsmma.gov.tw/mapguide/mapagent/mapagent.fcgi?>; (2) <https://landslide.geologycloud.tw/jlwmts/jetlink/wmts>.





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