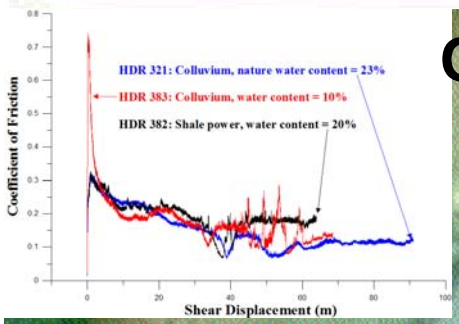
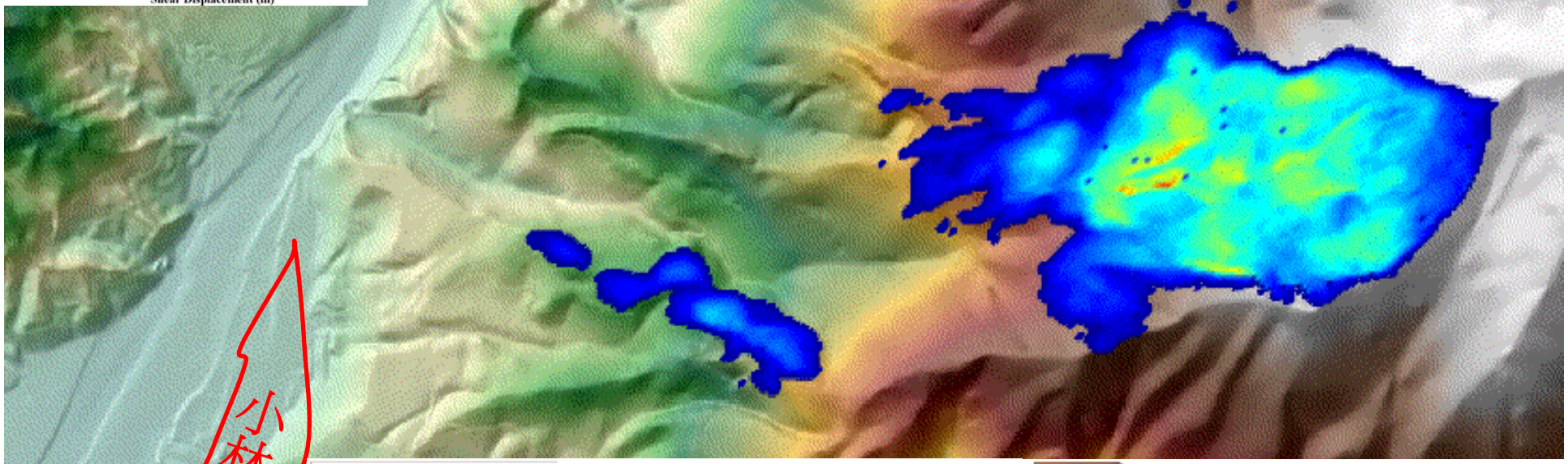
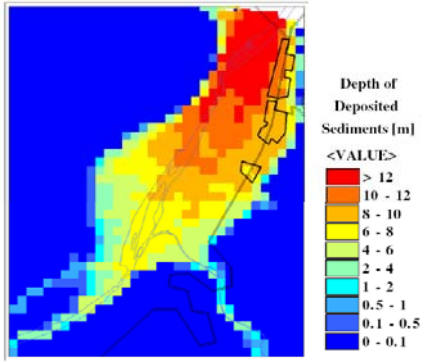
地電技術於邊坡失穩事件之監測研究

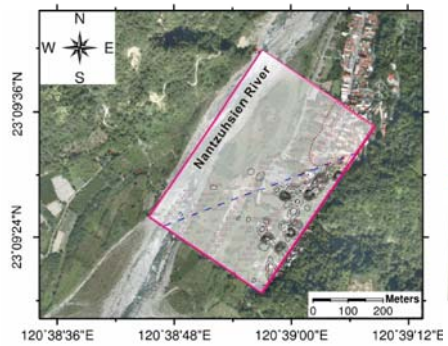
陳建志、王子賓
國立中央大學地球科學系

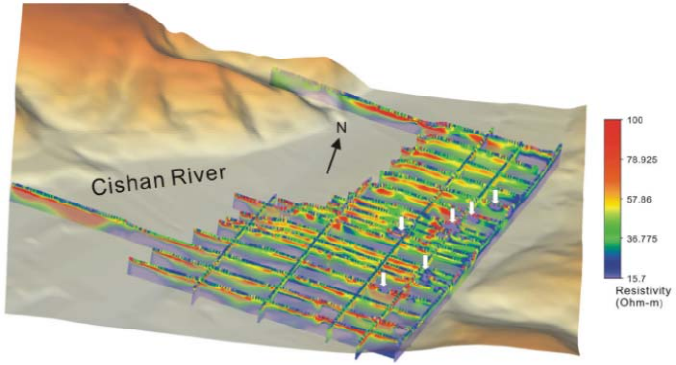
Coefficient of friction = 0.19





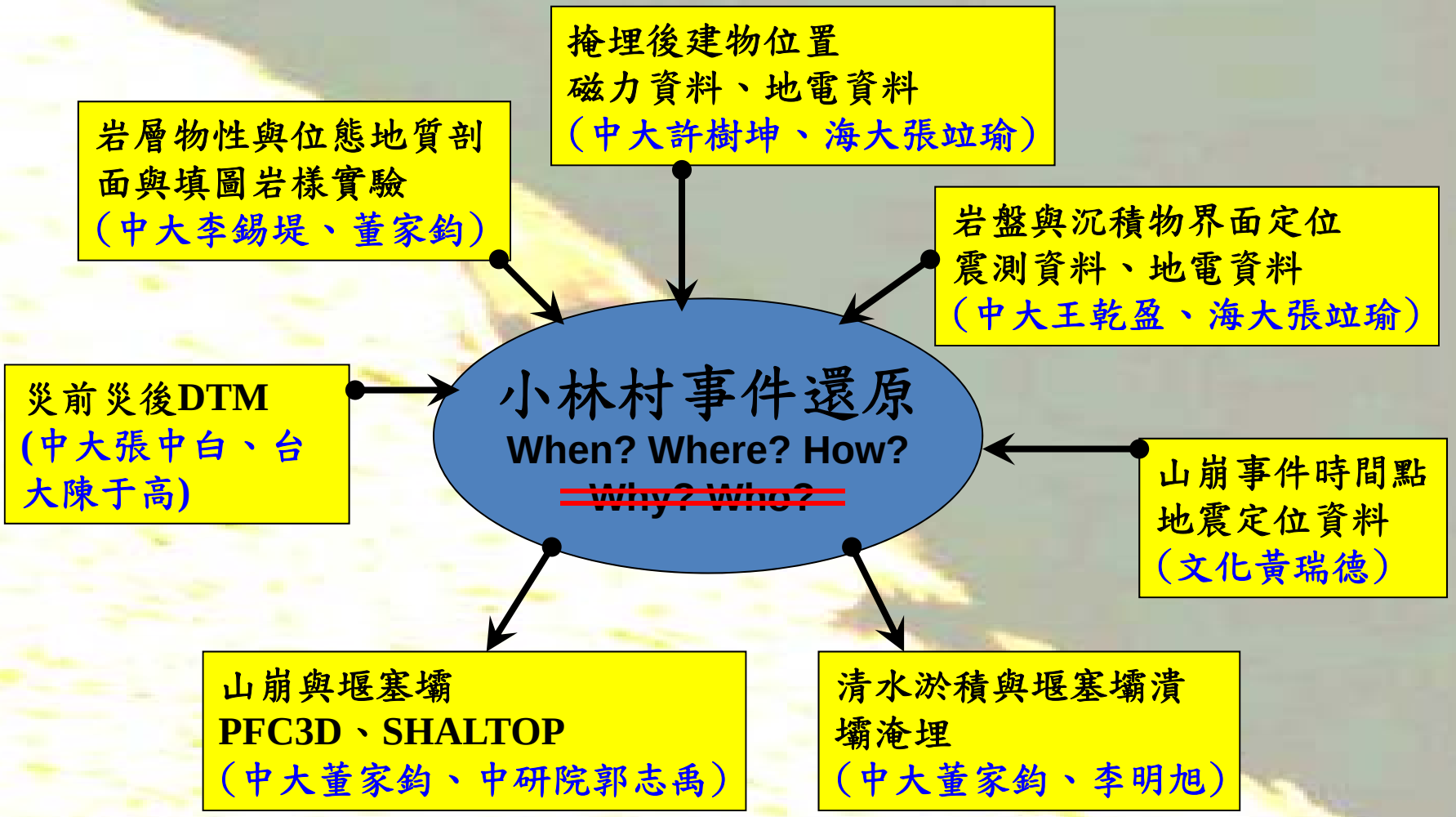






Doo et al. (2011, *Nat. Hazards Earth Syst. Sci.*, 11, 759-764), Dong et al. (2011, *Engineering Geology*, 123, 40-59), Li et al. (2011, *Engineering Geology*, 123, 60-71), Kuo et al. (2011, *JGR-Earth Surface*, 116, F04007, doi:10.1029/2010JF001921), Chang et al. (2012, *Geophys. J. Int.*, 188, 1012-1024)

崩、移、堆、潰


掩埋後建物位置
磁力資料、地電資料
（中大許樹坤、海大張竝瑜）
岩層物性與位態地質剖面與填圖岩樣實驗
（中大李錫堤、董家鈞）
岩盤與沉積物界面定位
震測資料、地電資料
（中大王乾盈、海大張竝瑜）
災前災後DTM
(中大張中白、台大陳于高)
小林村事件還原
When? Where? How?
~~Why? Who?~~
山崩事件時間點
地震定位資料
（文化黃瑞德）
山崩與堰塞壩
PFC3D、SHALTOP
（中大董家鈞、中研院郭志禹）
清水淤積與堰塞壩潰壩淹埋
（中大董家鈞、李明旭）

A Letters Journal Exploring the Frontiers of Physics

August 2011

EPL, 95 (2011) 49001
doi: 10.1209/0295-5075/95/49001

www.epljournal.org

Statistical physics of landslides: New paradigm

C.-c. Chen[1], L. Telesca[2(a)], C.-T. Lee[3] and Y.-S. Sun[1]

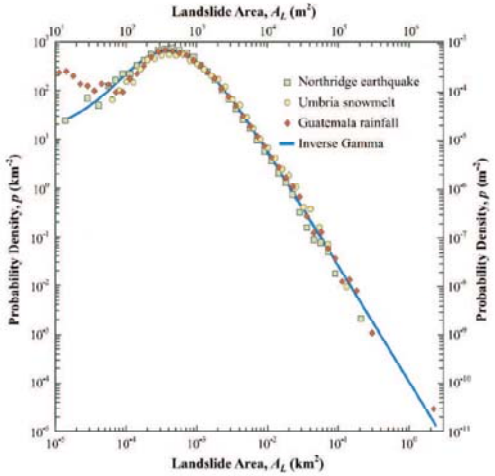
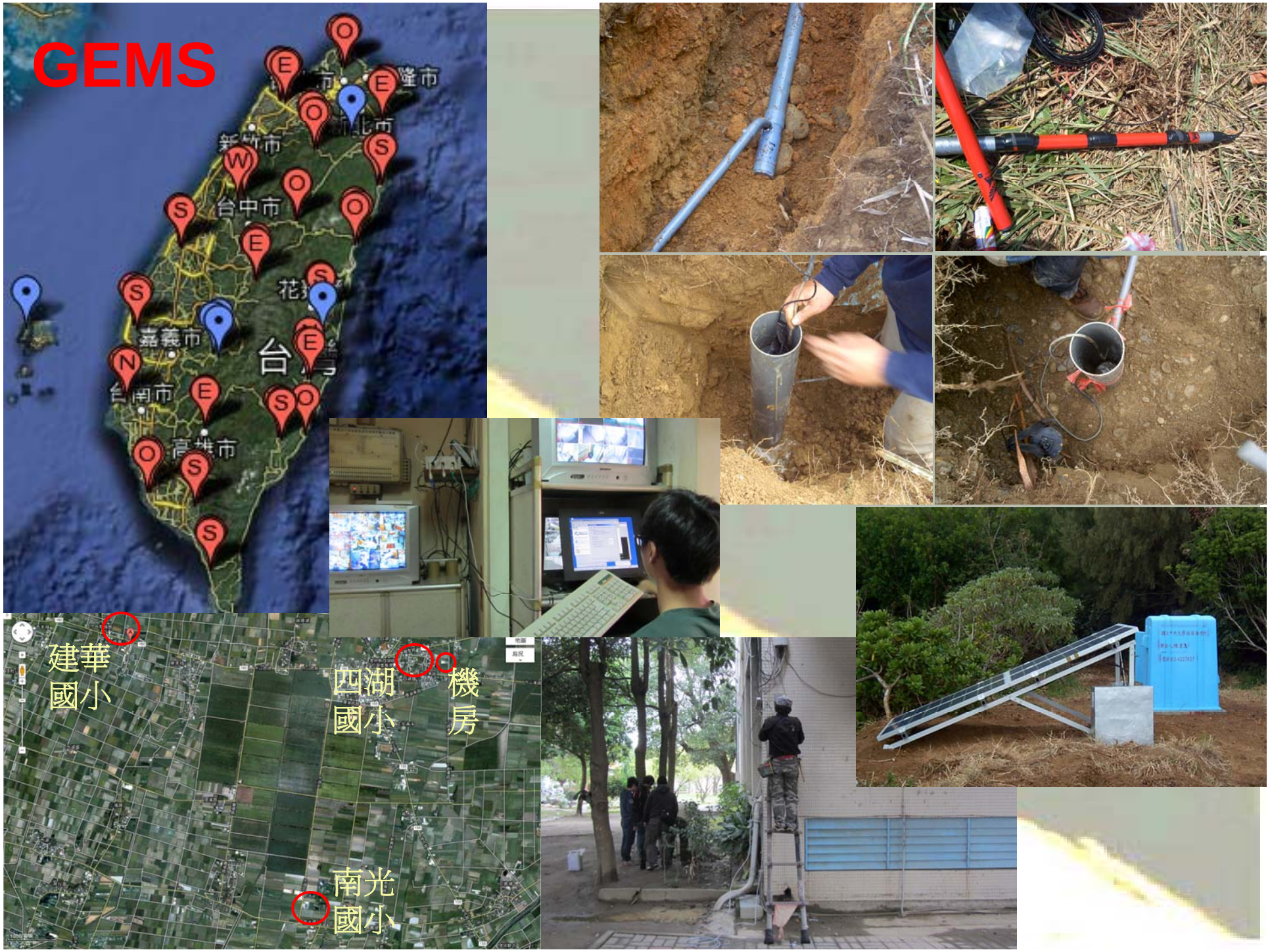
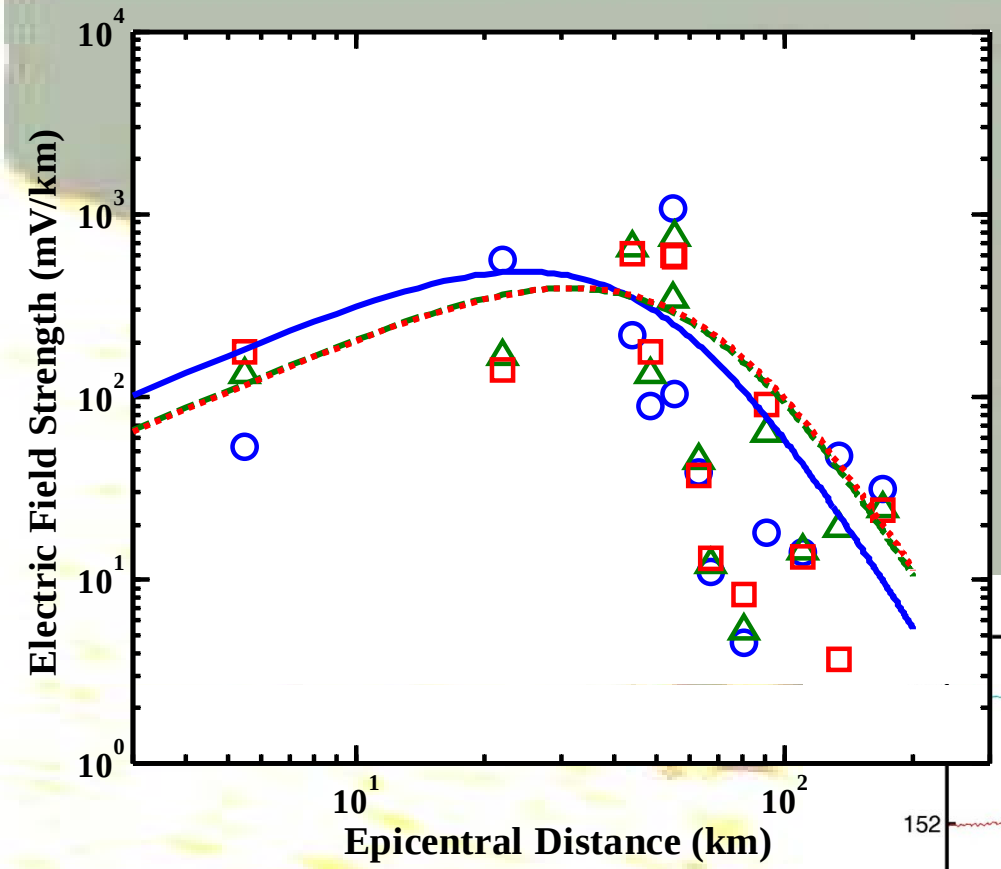
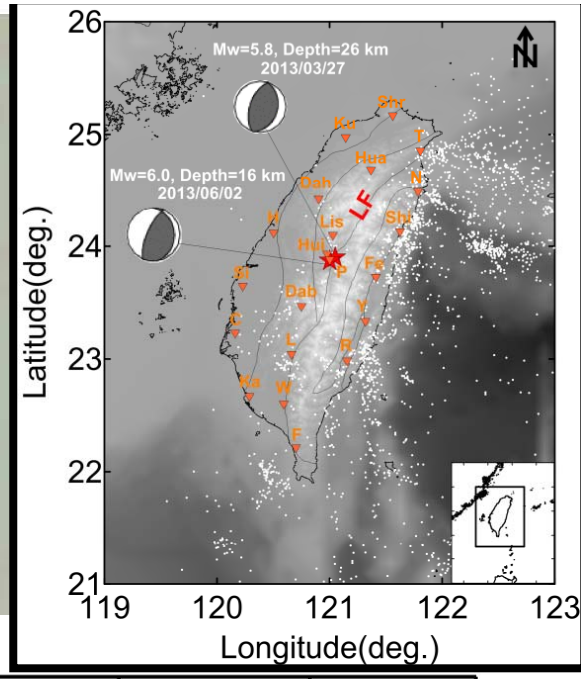
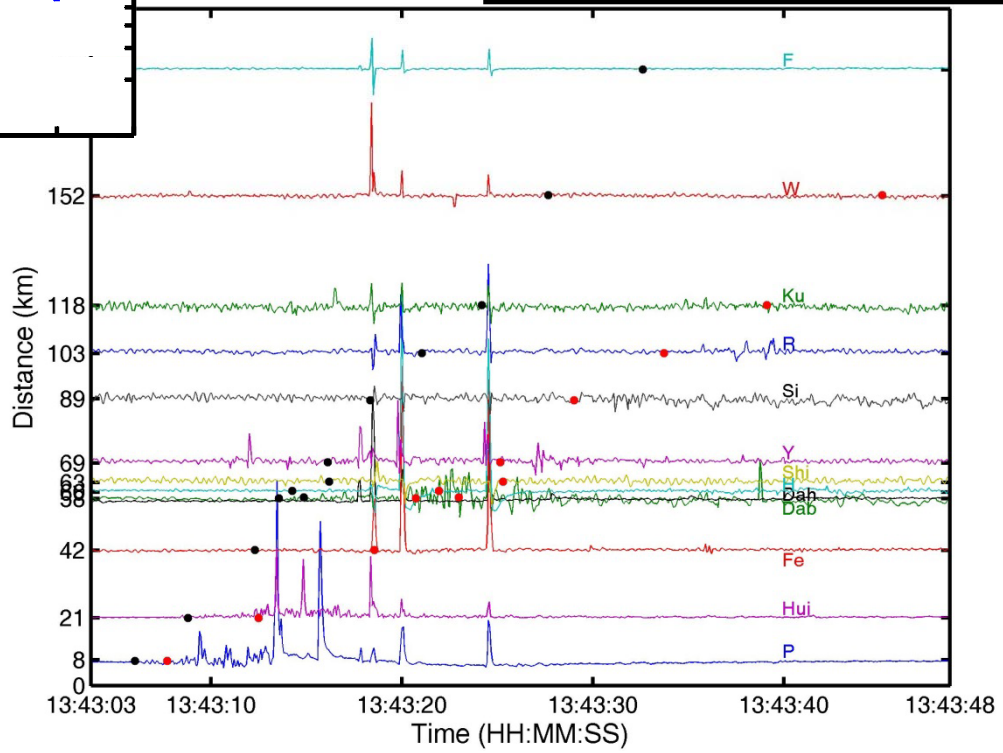


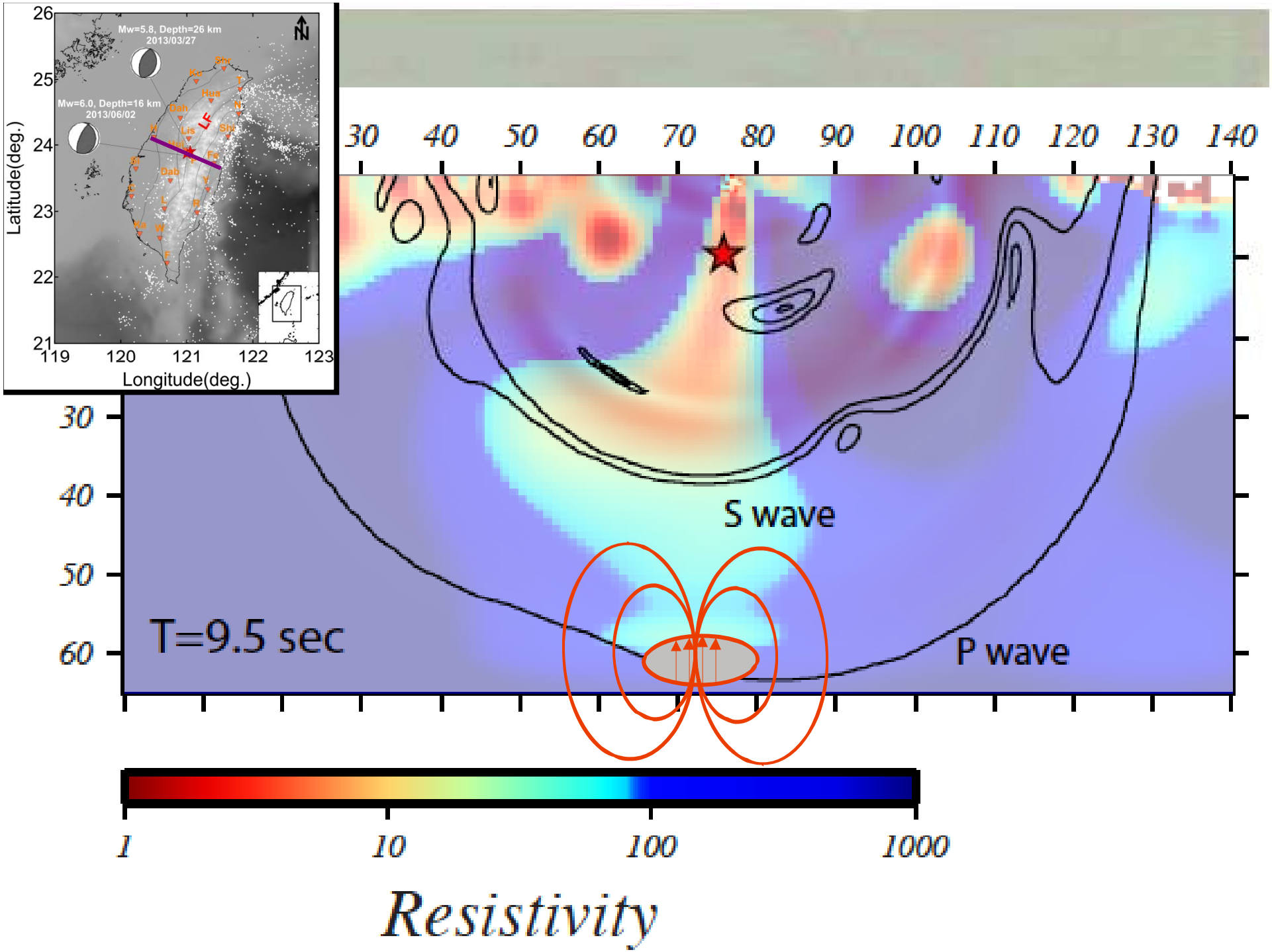
Fig. 1: (Colour on-line) Probability densities on landslide areas for three landslide datasets [2]: 11111 landslides (squares) triggered by the 1994 Northridge earthquake in California; 4233 landslides (circles) triggered by rapid snowmelt in the Umbria region of Italy in January 1997; 9594 landslides (diamonds) triggered by heavy rainfall from Hurricane Mitch in Guatemala in late October and early November 1998. The solid line is the best fit to the three datasets using the three-parameter inverse Gamma distribution suggested by Malamud *et al.* Note that the decreases at the small end in probability density functions of landslide areas are real, instead of causing by incomplete landslide data [2].


GEMS
台中市
嘉義市
台南市
建華
國小
四湖
國小
機
房
南光
國小


Electric Field Strength (mV/km)
Epicentral Distance (km)

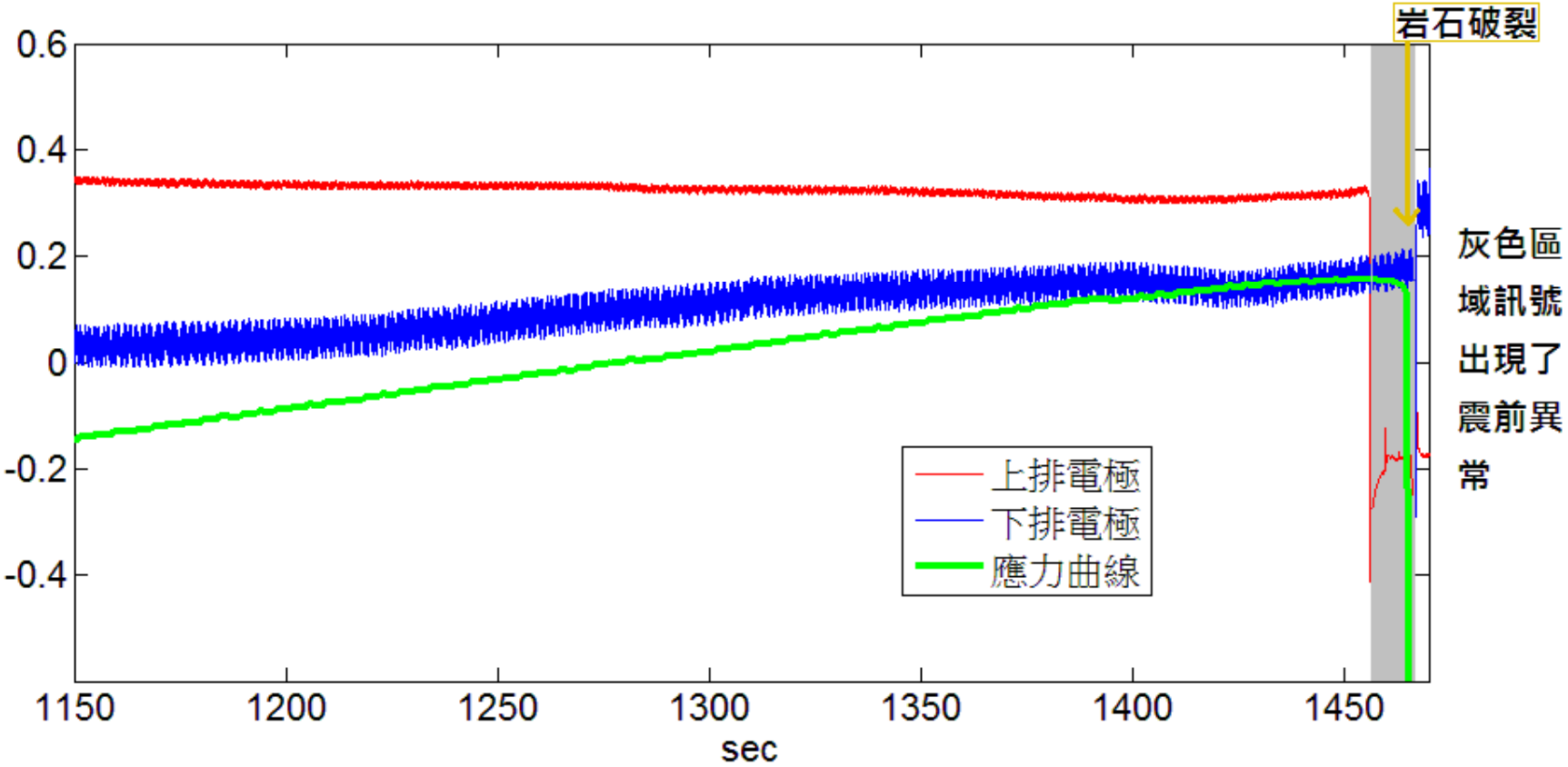

Mw=5.8, Depth=26 km
2013/03/27
Mw=6.0, Depth=16 km
2013/06/02
LF
Latitude(deg.)
Longitude(deg.)


Distance (km)
Time (HH:MM:SS)

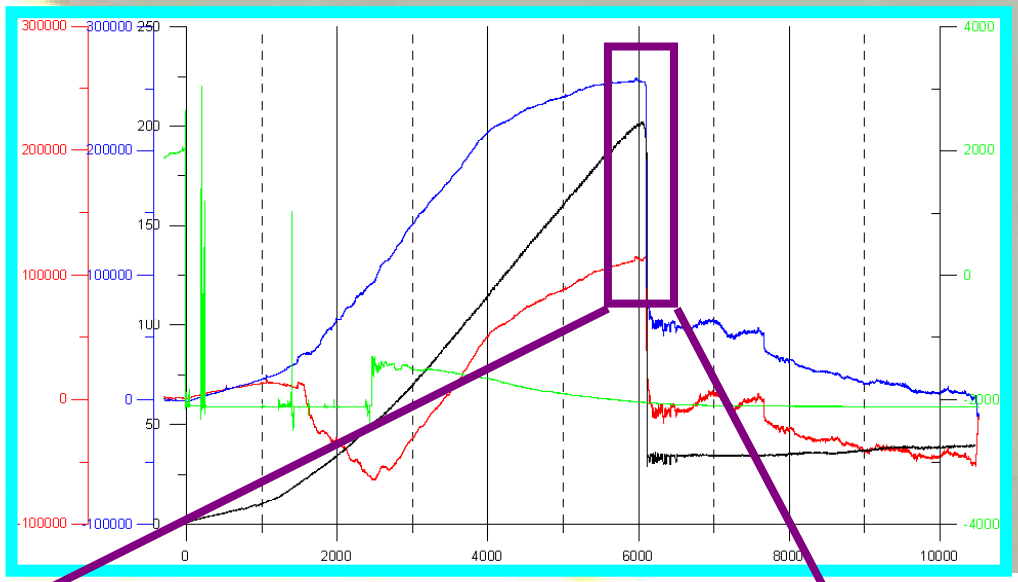

Mw=5.8, Depth=26 km
2013/03/27
Mw=6.0, Depth=16 km
2013/06/02
N
LF
Latitude(deg.)
Longitude(deg.)
26
25
24
23
22
21
119
120
121
122
123
30
40
50
60
70
80
90
100
110
120
130
140
S wave
P wave
T=9.5 sec
1
10
100
1000
Resistivity

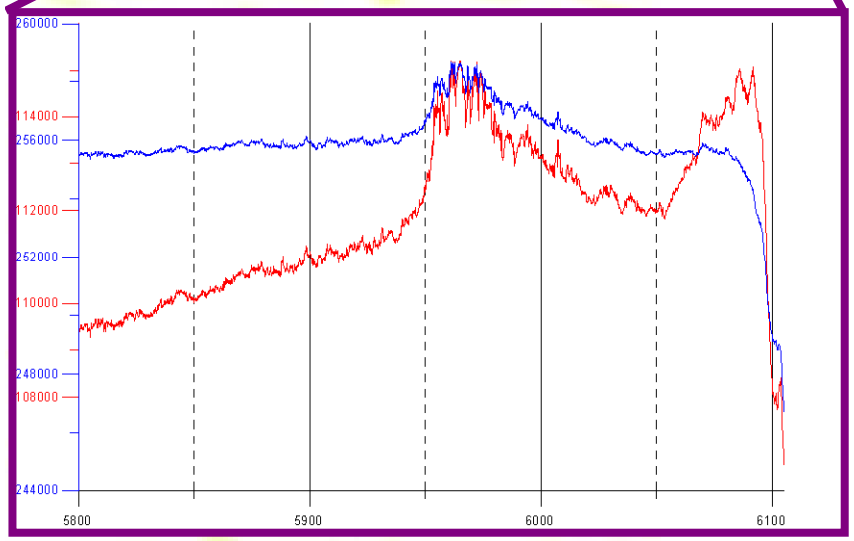
花崗岩單軸加壓實驗

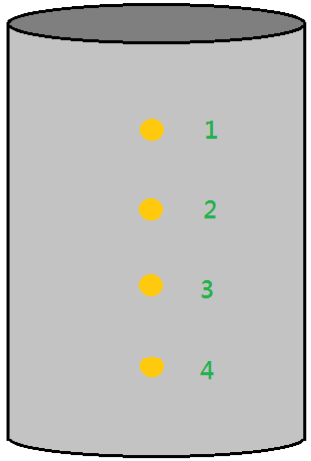
上排電極對
下排電極對

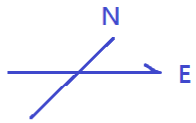

岩石破裂
0.6
0.4
0.2
0
-0.2
-0.4
1150
1200
1250
1300
1350
1400
1450
sec
上排電極
下排電極
應力曲線
灰色區域訊號出現了震前異常

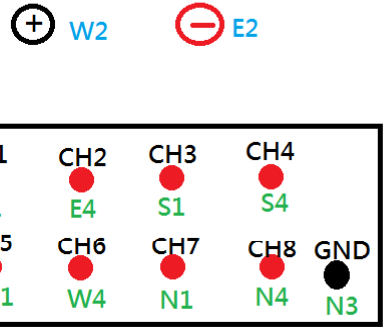
地震地電前兆
VS.
邊坡失穩事件前兆

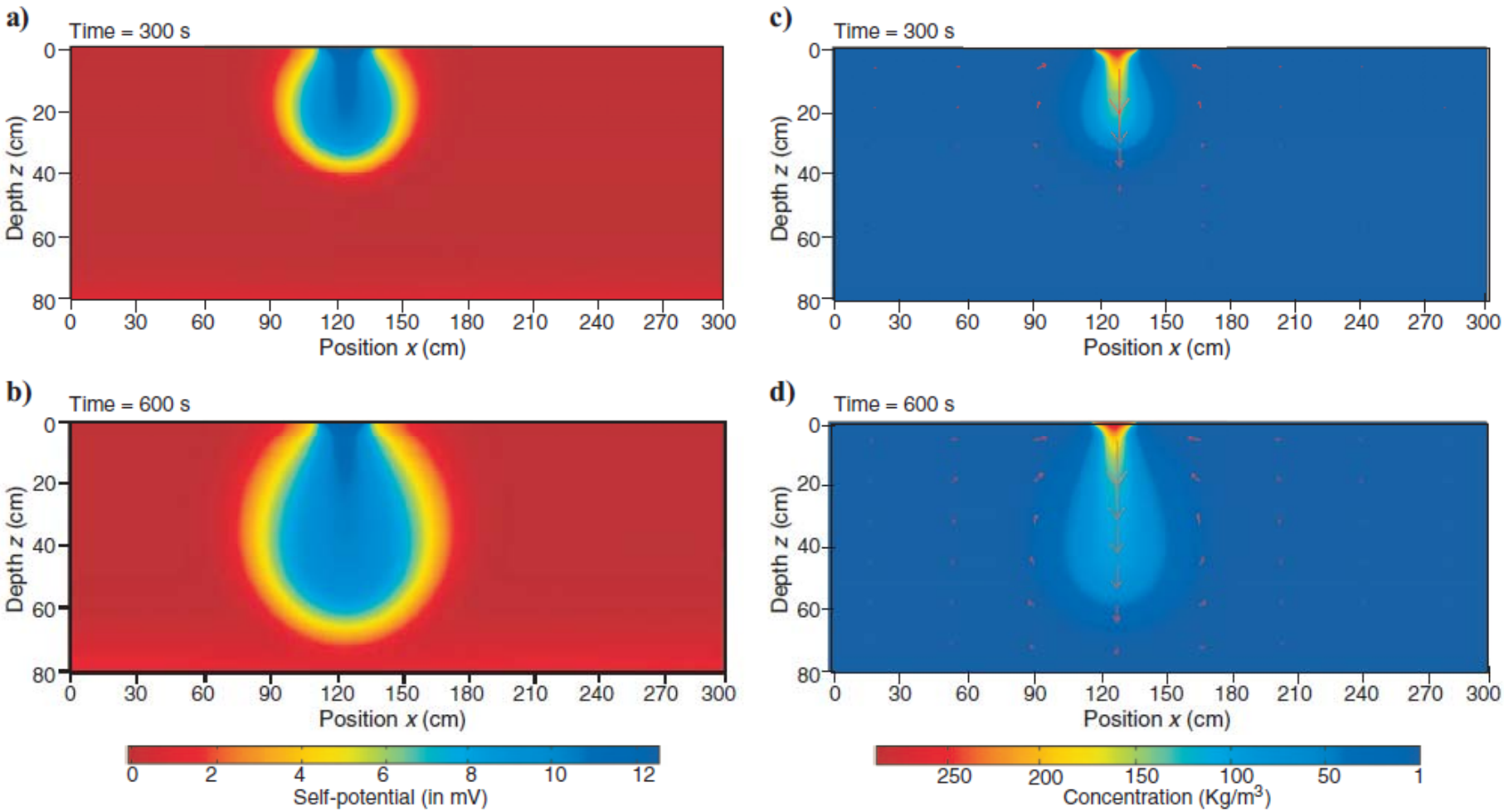






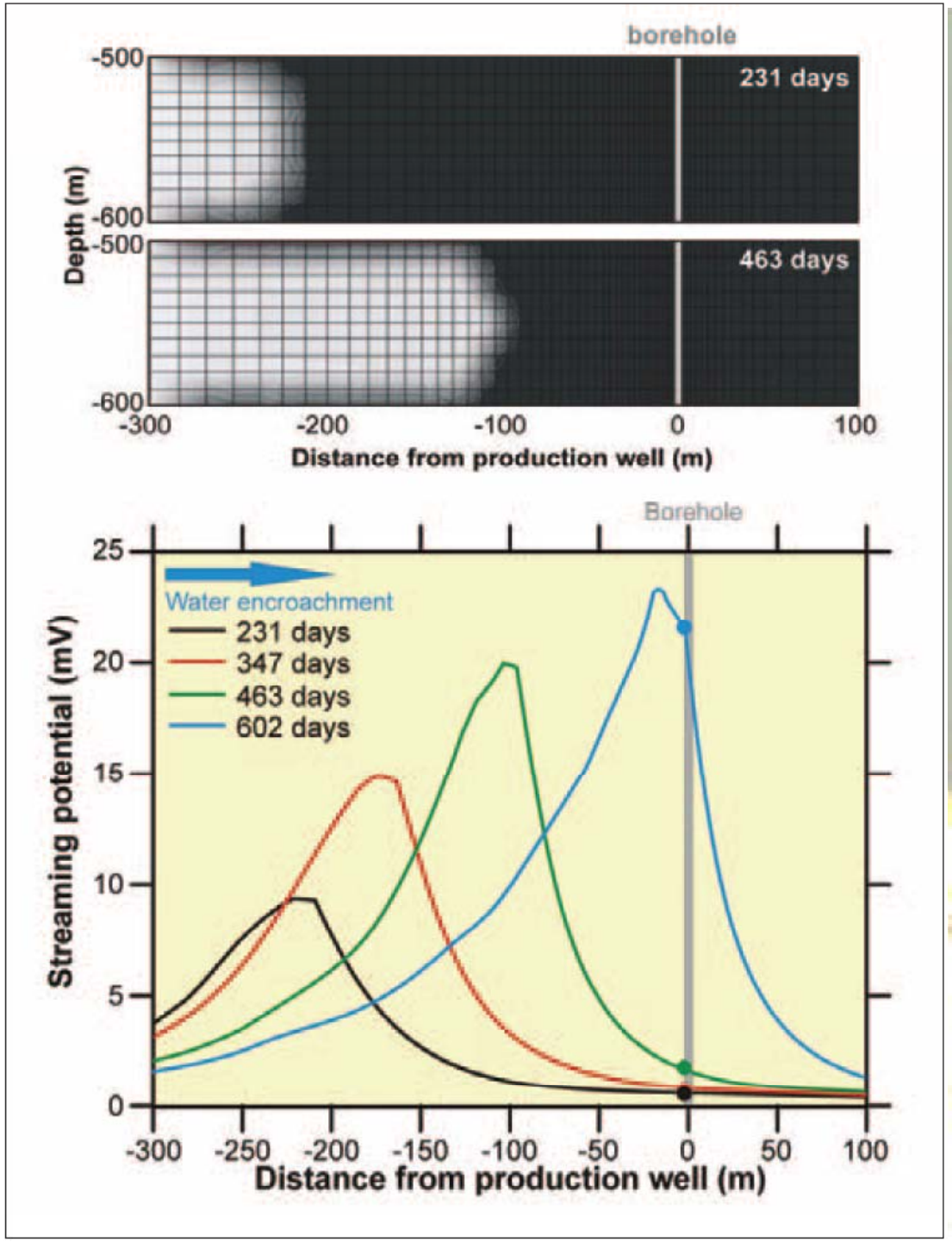






有限元素法模擬自上方向下入侵的滷水柱體(右圖)在300秒及600秒時引起的自然電位改變(左圖)。注意高自然電位(>10mV)與滷水柱體(>150Kg/m3)有良好的對應關係。

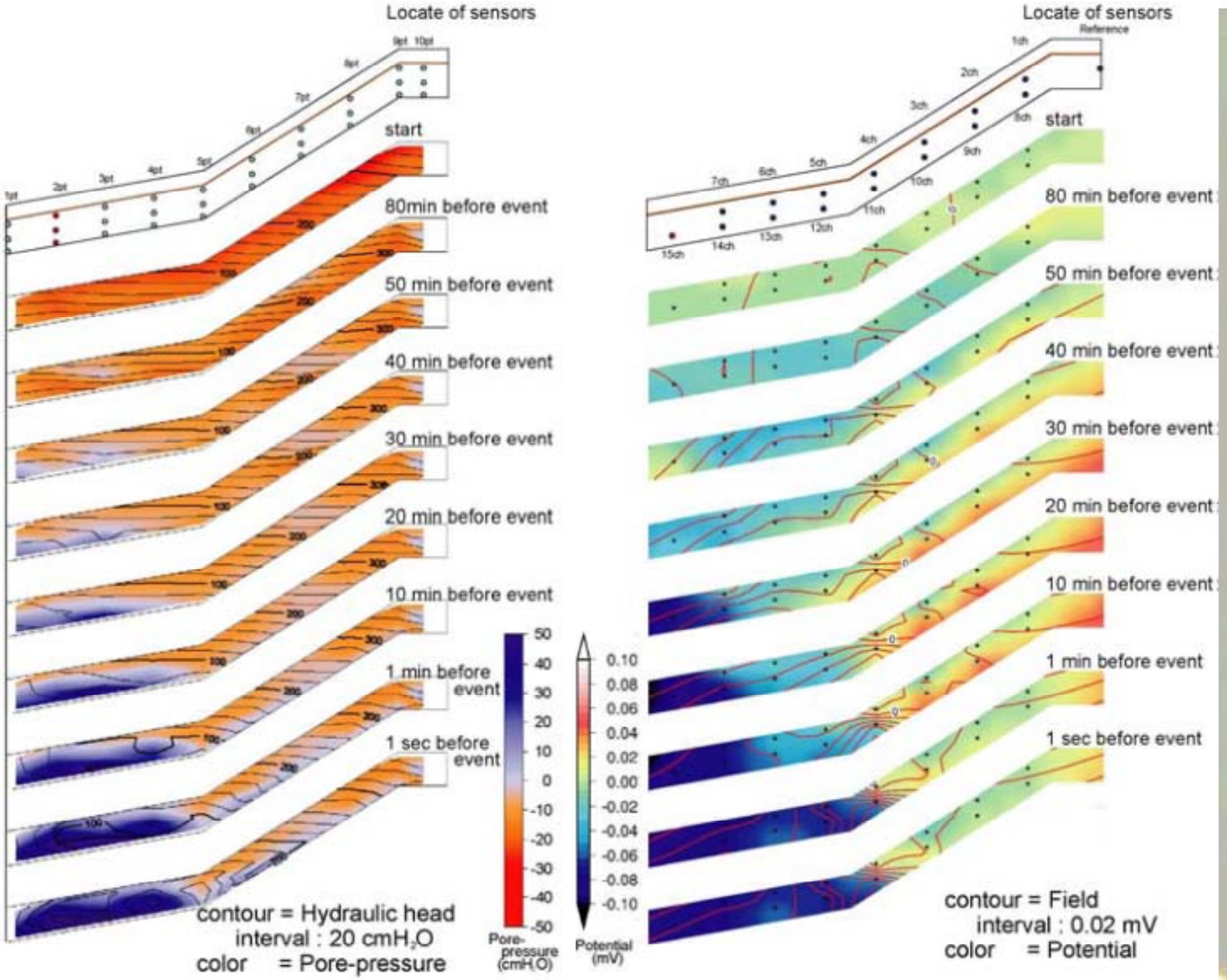
P. Martínez-Pagán[1,2], A. Jardani[3], A. Revil[2,4], and A. Haas[2]
GEOPHYSICS, VOL. 75, NO. 4 (JULY-AUGUST 2010); P. WA17–WA25, 9 FIGS.
10.1190/1.3475533



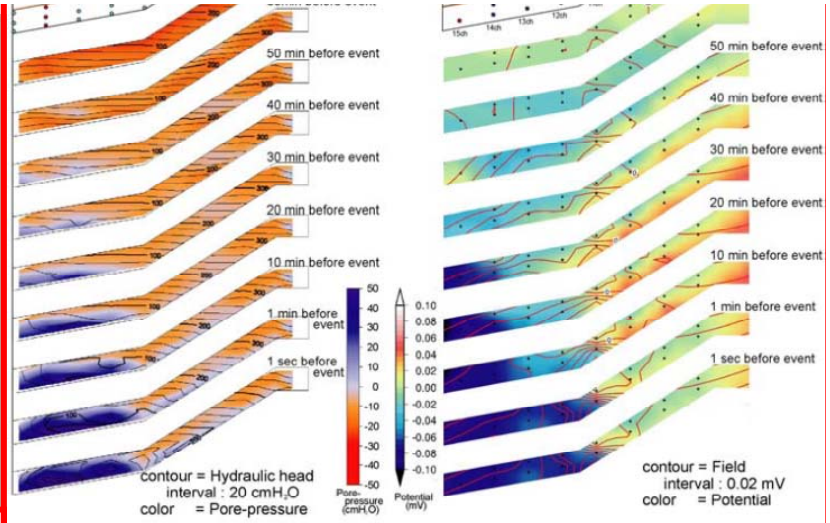
油工業以自然電位法監測油氣(上圖黑色部分)與灌注液(上圖白色部分)的界面移棲。隨著灌注液推擠油氣，地表自然電位(下圖)的峰值極好地對應兩種流體界面的位置。注意下圖的黑線與綠線峰值所在位置與上圖的油水界面對應良好。

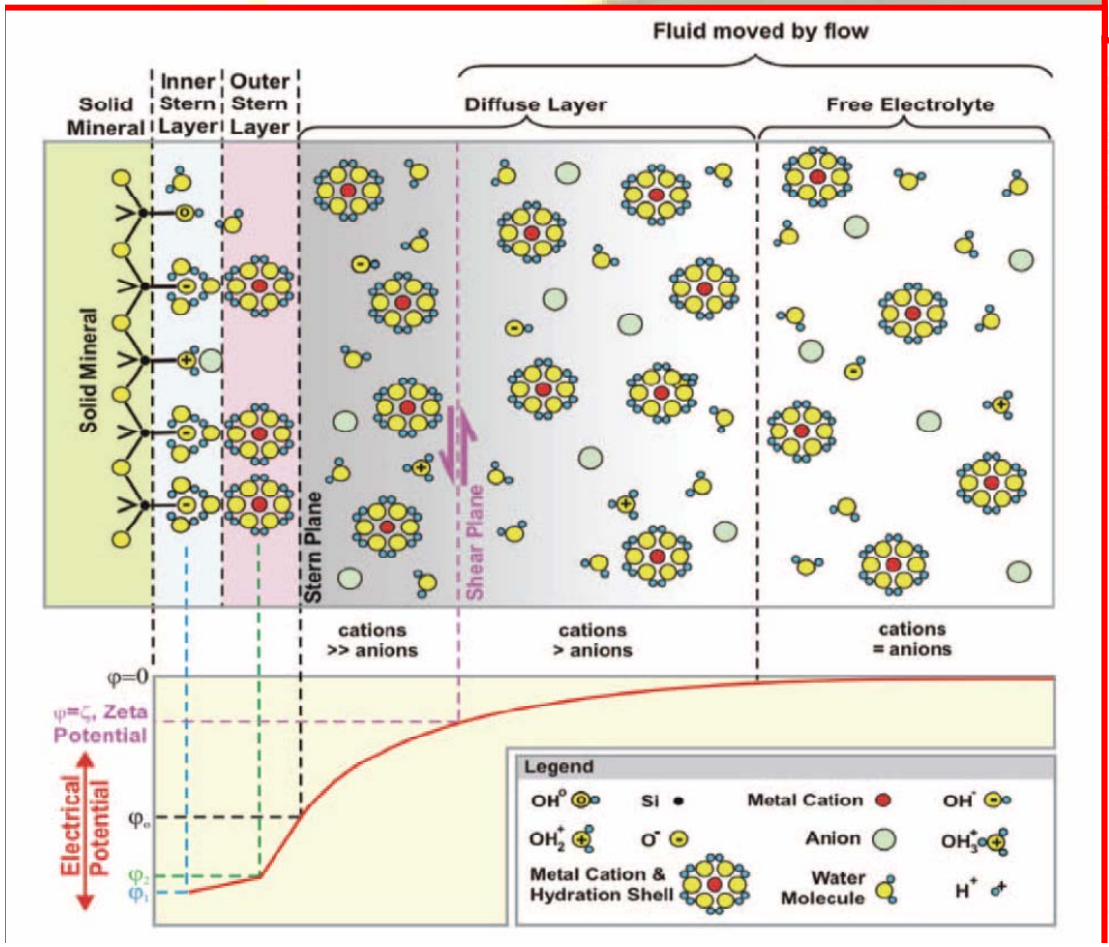
Borehole electrokinetics

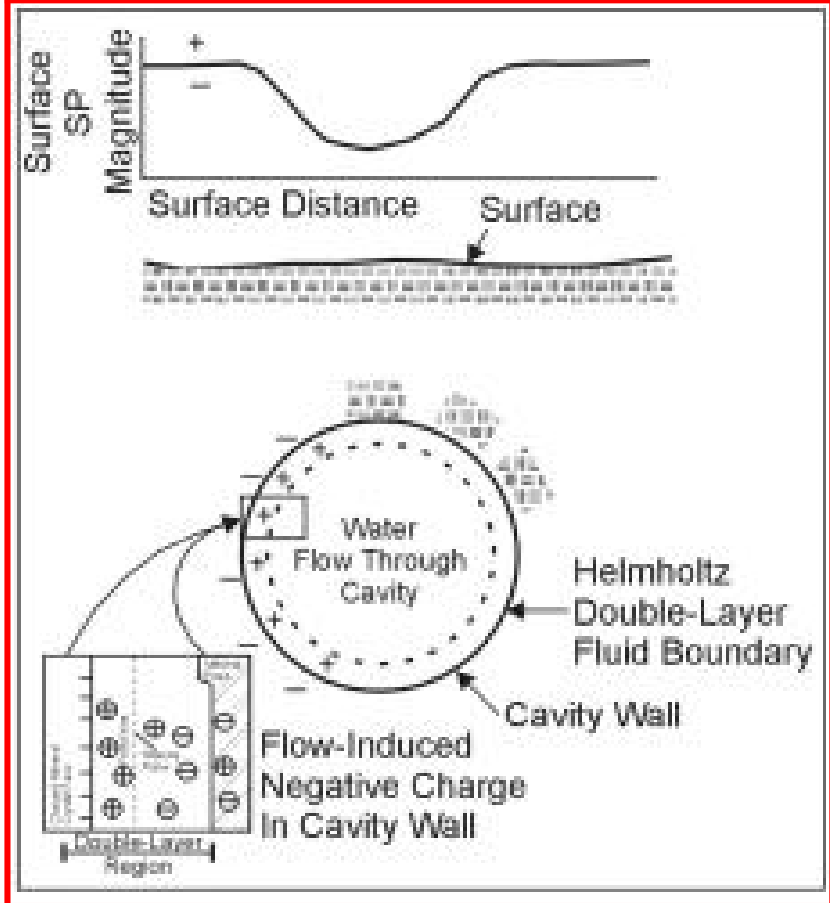
Paul W.J. Glover, Université Laval
Matthew D. Jackson, Imperial College London


Locate of sensors
start
80min before event
50 min before event
40 min before event
30 min before event
20 min before event
10 min before event
1 min before event
1 sec before event
contour = Hydraulic head
interval : 20 cmH2O
color = Pore-pressure
Pore-pressure (cmH2O)
Potential (mV)
Locate of sensors
Reference
start
80 min before event
50 min before event
40 min before event
30 min before event
20 min before event
10 min before event
1 min before event
1 sec before event
contour = Field
interval : 0.02 mV
color = Potential

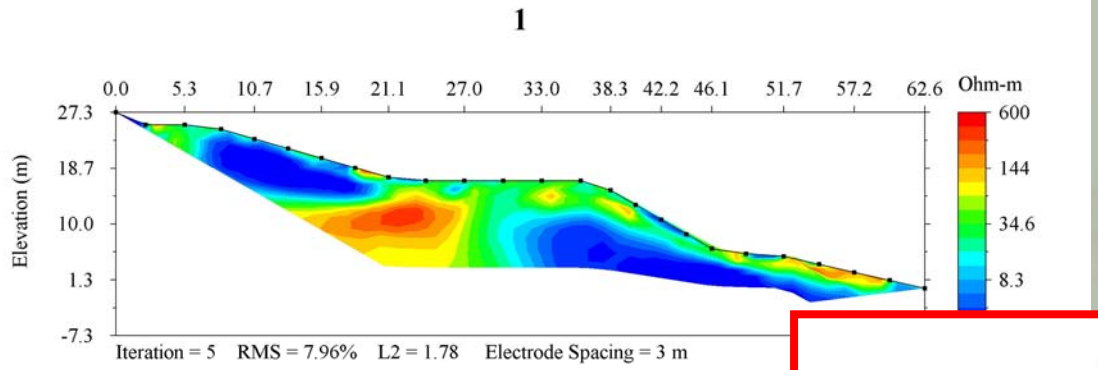
動電效應
Electrokinetics



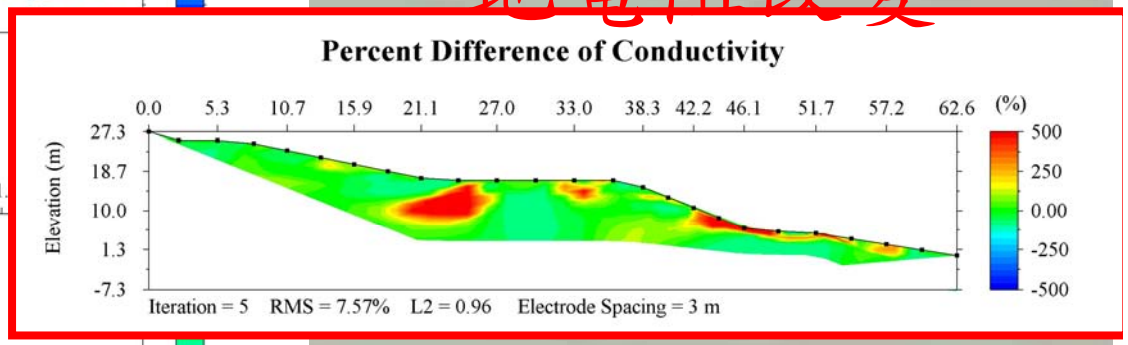


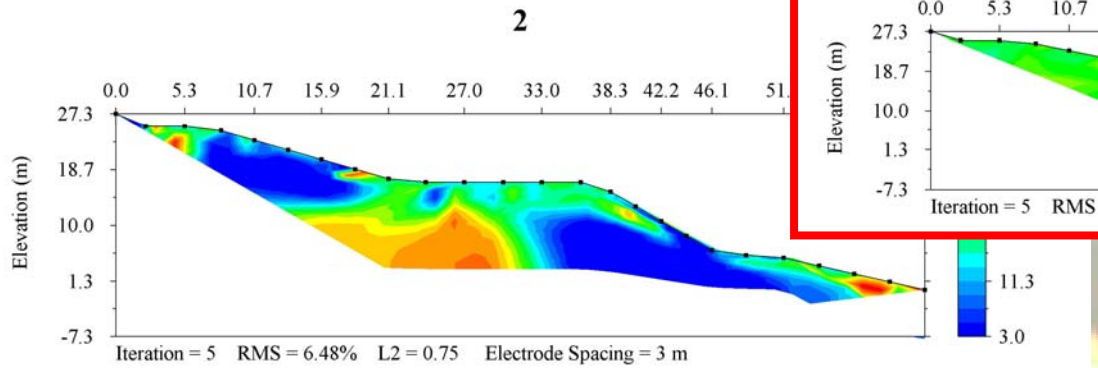


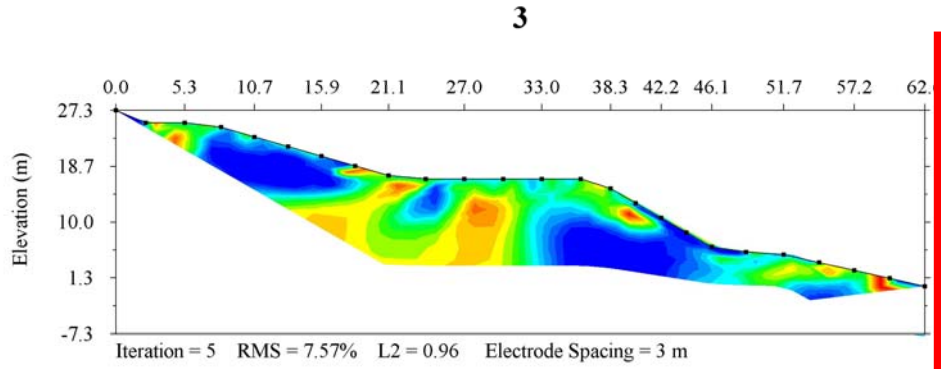
國道三號85公里南下邊坡地電阻監測



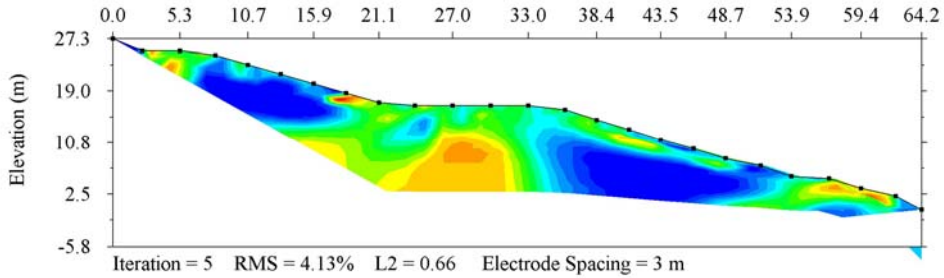
一次邊坡失穩前的地電阻改變







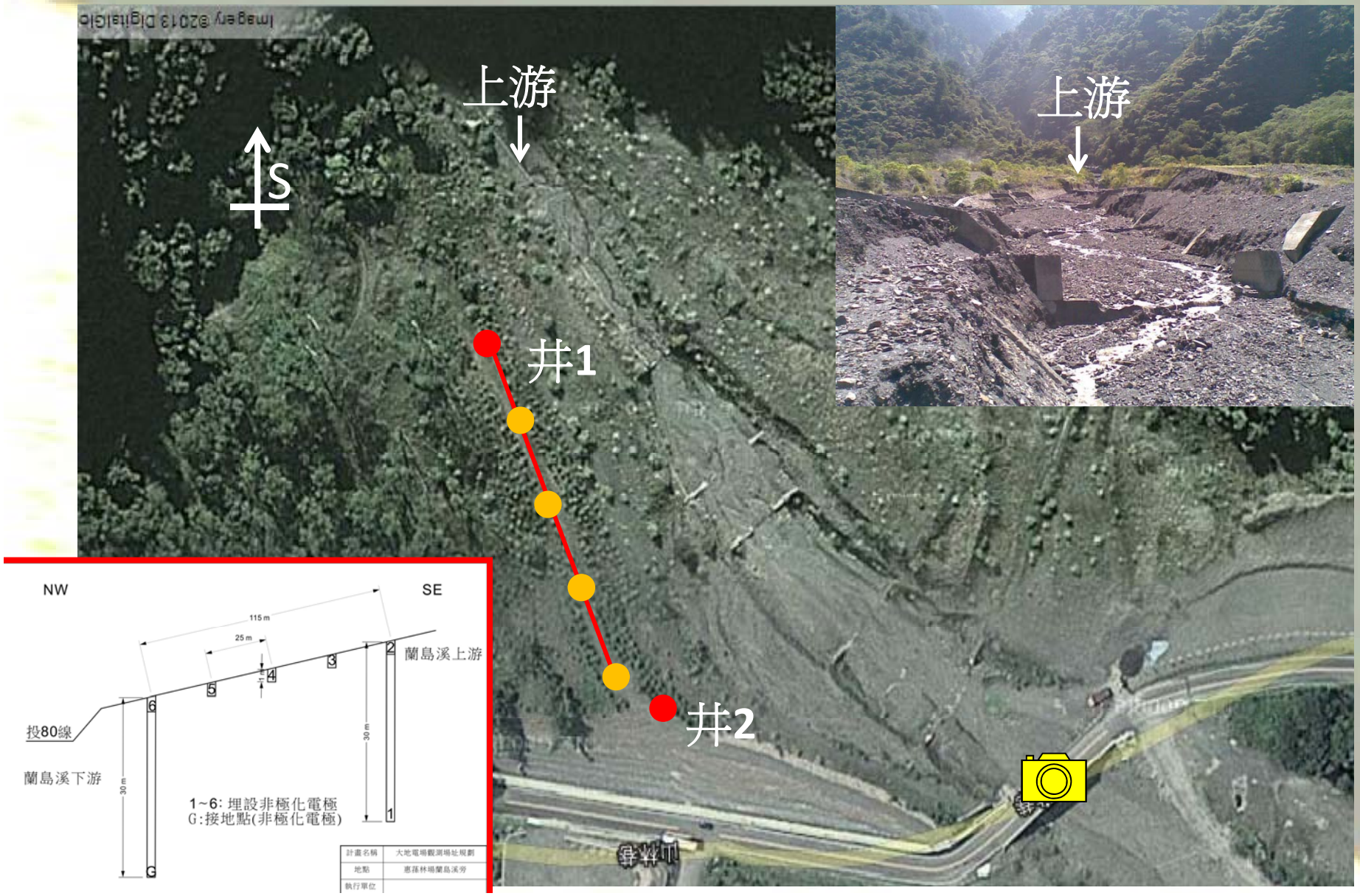
滑動後的現地重測



監測的時間尺度

- 舉 time-lapsed ERT 技術為例說明，此法在觀念上是指在相隔一段固定時間後，回到實測場址重複地進行地電阻掃描的工作。這其中有兩個面向值得深思。
- 其一從實際作業面上論，由於現有的商業化ERT儀器，不常**配備網路傳輸功能**，乃至於前述「相隔一段固定時間」常是在數週或月的尺度上進行，勞師動眾地攜帶ERT儀器設備回到現場重複施測，恐難有效地掌握地下地層即時的變化過程。所幸，近來已有部份儀器商注意到傳統地電阻儀器在這方面的限制，開始轉向開發可遠端控制的ERT系統。
- 再就理論上的觀測時間尺度而論，當面臨一特定邊坡監測案例時，常常在事前無法得知該邊坡失穩過程的時間尺度，因此就很難決定作業上重複返回施測場址的時間間隔。應該注意的是，一個邊坡失穩的時間尺度可能有很多因子控制。舉例來說，邊坡所在大範圍內的水文傳導係數影響了土層內流體的富集過程，也就進而影響了邊坡失穩的時間尺度。所以，很明顯地，**作業上「相隔一段固定時間」的設定，應該是依個案不同而異**。

惠蓀林場蘭島溪自然電位監測實驗場址



自行研發之多頻道數位紀錄器

A/D: 24 bit
Chs.: 8 (extendable)
Sync: GPS & NET

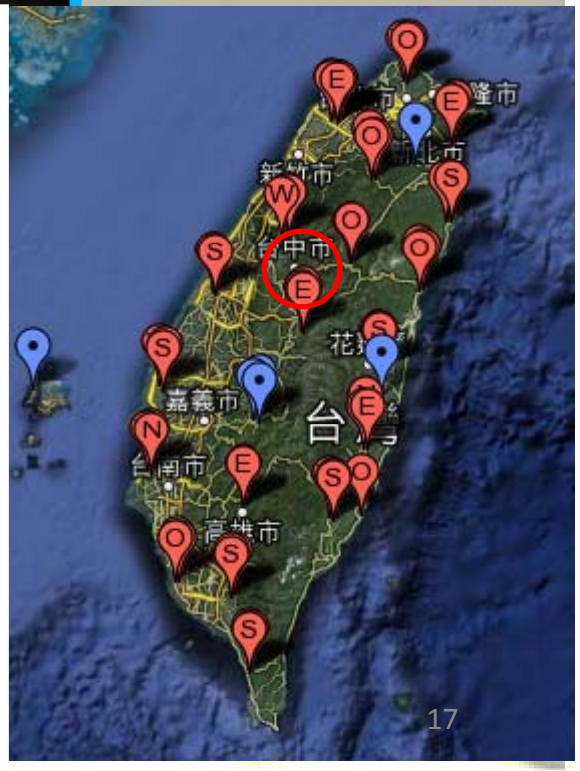
2012年11月8日/星期四 自由時報 生活新聞 A12

全球首創

土石流試驗站 調流量觀測潰決型態

全球首創第一個可調整流量的土石流觀測試驗站就在南投縣仁愛鄉惠蓀林場！

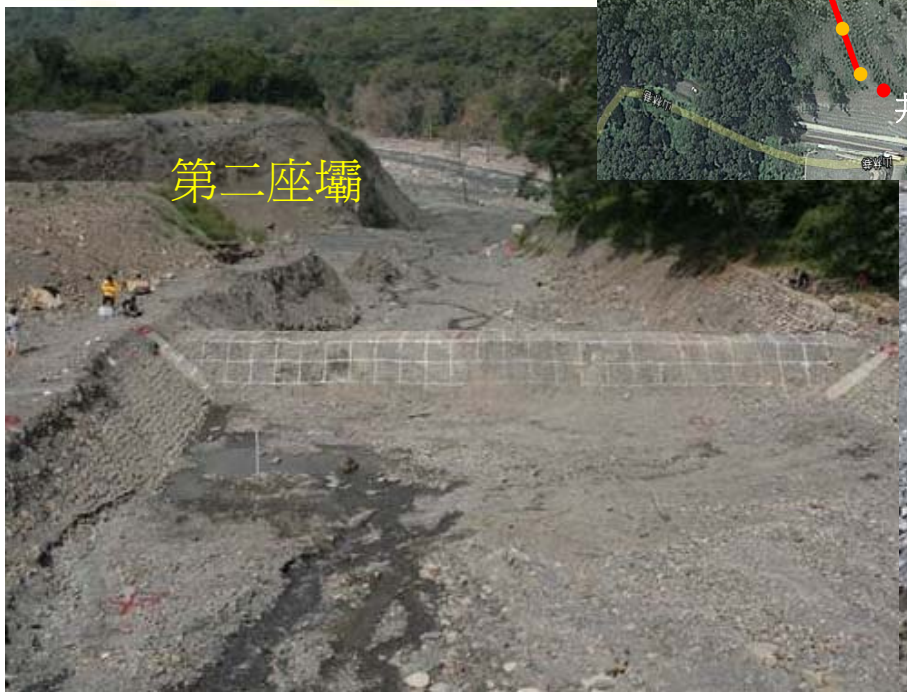
昨天中興大學農學院院長陳樹群率領研究團隊，以中型颱風的水量進行堰塞壩潰決實驗，不到10分鐘，壩體就開始滲水潰堤，最終倒塌；希望藉由調整水量，記錄不同的潰決型態，掌握各階段破壞機制，提供未來土石流、堰塞湖潰堤防災應變更精細的預警修正。



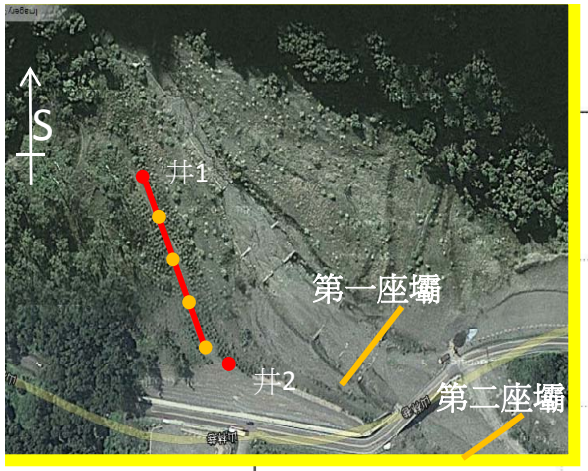
第一座壩

10/16
10:30 放水
10:57第一座壩潰決

S
井1
井2
第一座壩
第二座壩

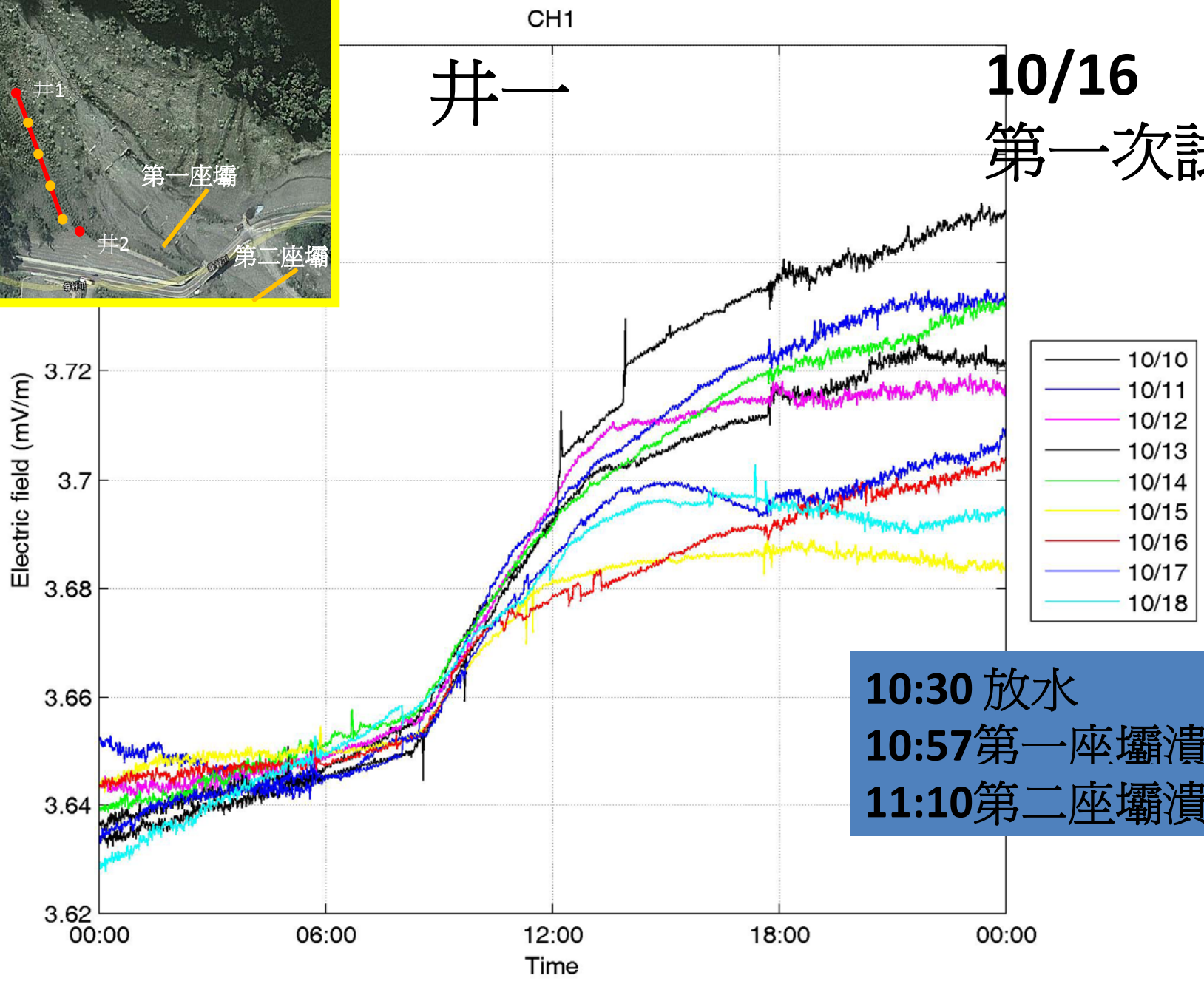

第二座壩

11:10第二座壩潰決

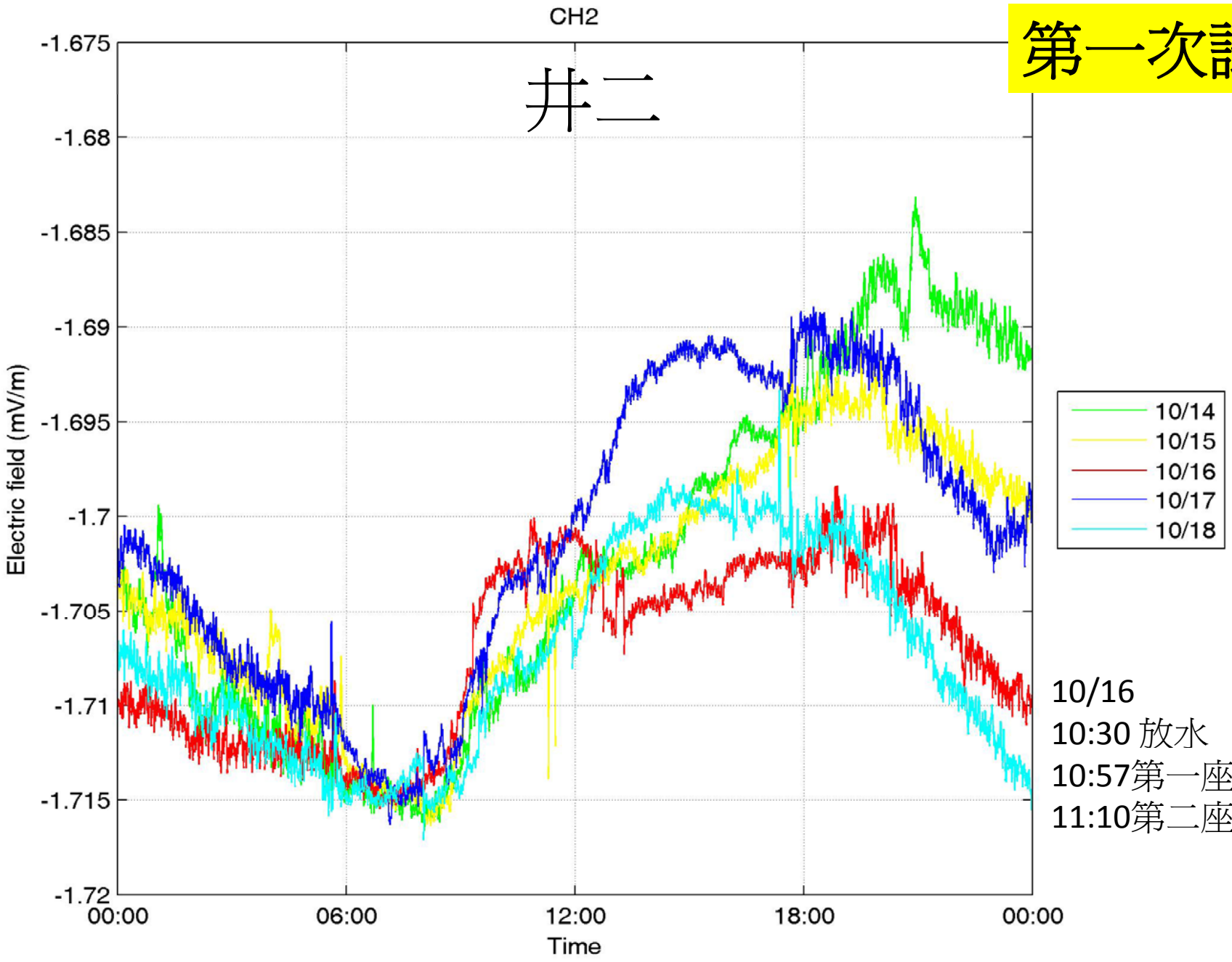


井一

10/16
第一次試驗

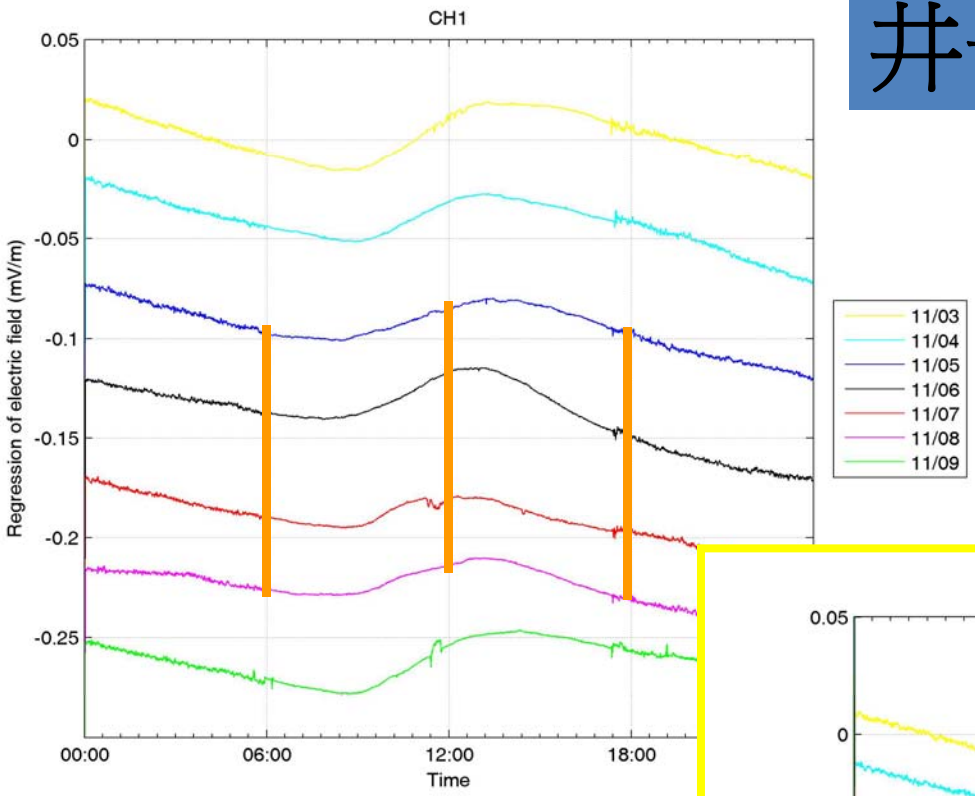


10:30 放水
10:57第一座壩潰決
11:10第二座壩潰決



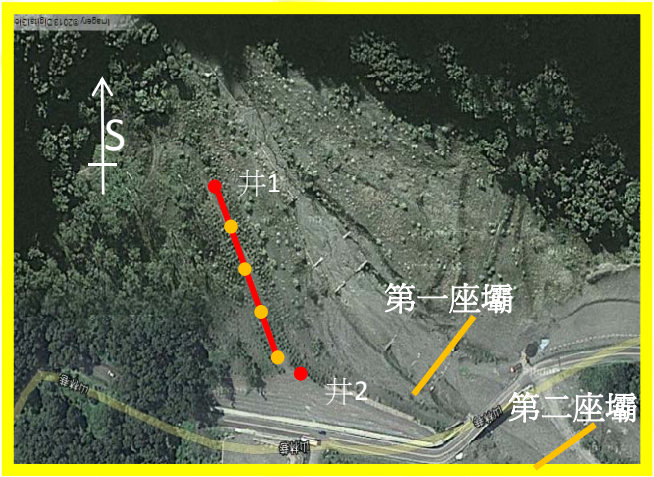
第一次試驗

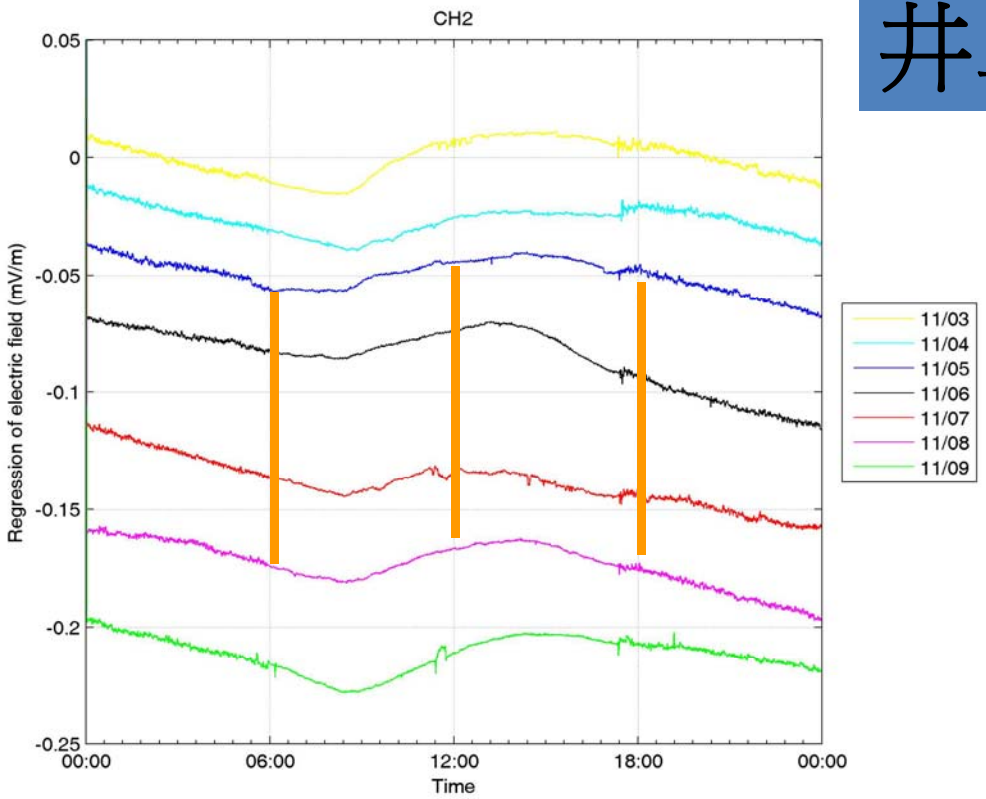
10/16
10:30 放水
10:57第一座壩潰決
11:10第二座壩潰決



井一

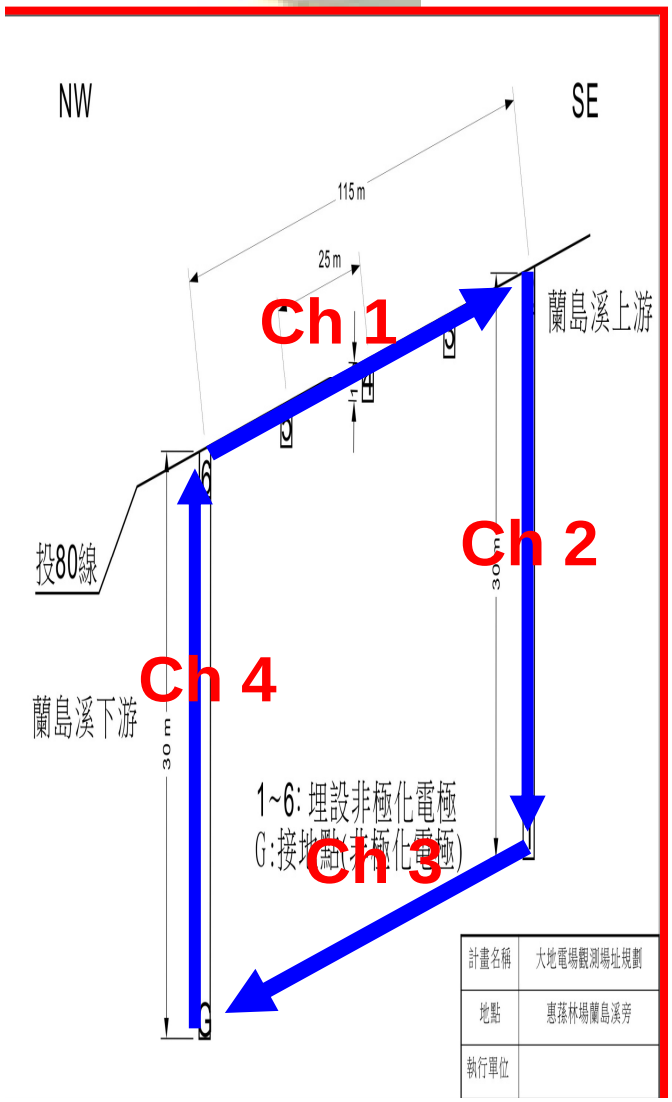
11/7
第二次試驗

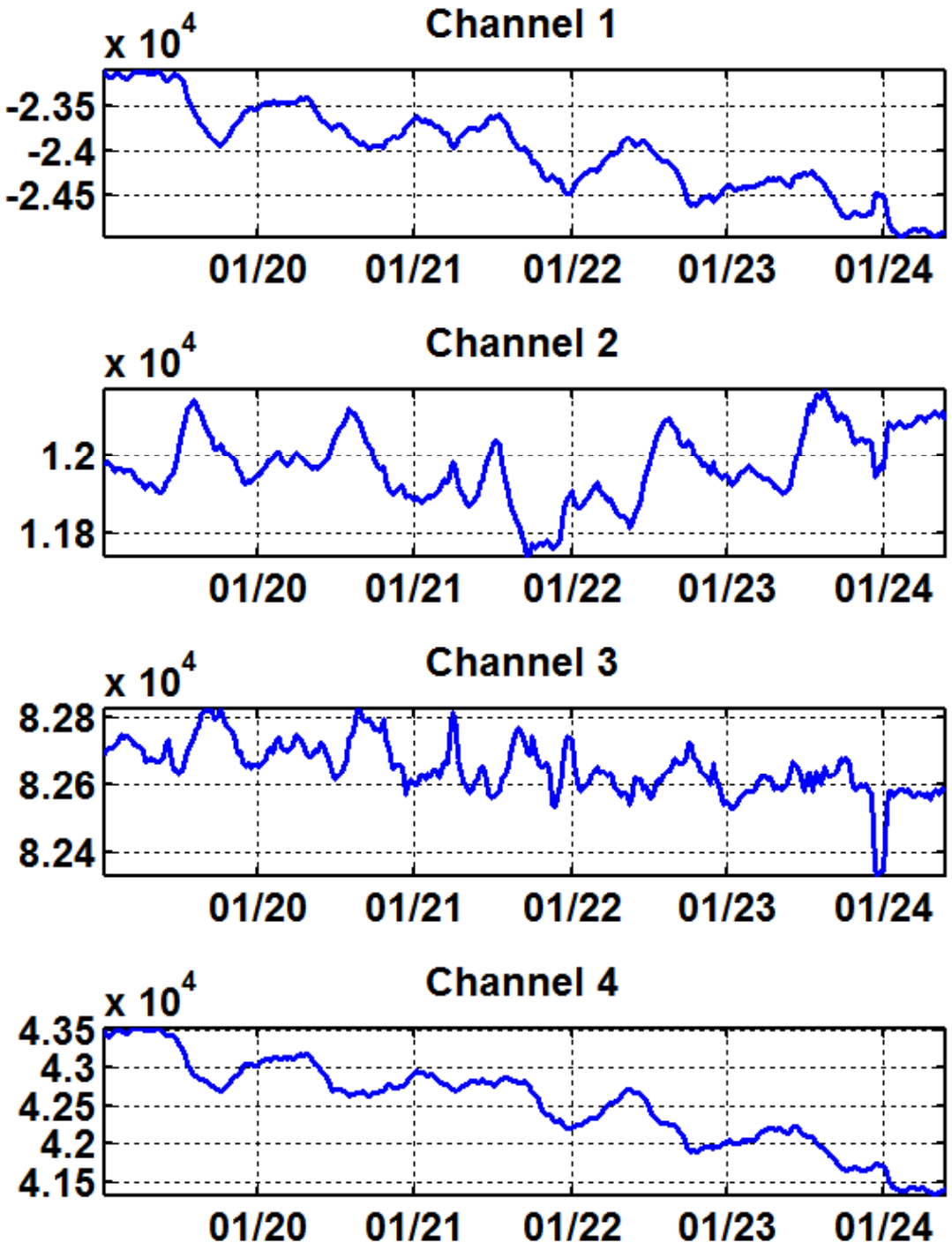




井二

惠蓀林場的即時監測


NW
SE
115 m
25 m
Ch 1
蘭島溪上游
投80線
Ch 2
30 m
Ch 4
蘭島溪下游
30 m
1~6: 埋設非極化電極
G:接地點(非極化電極)
Ch 3
計畫名稱
大地電場觀測場址規劃
地點
惠蓀林場蘭島溪旁
執行單位

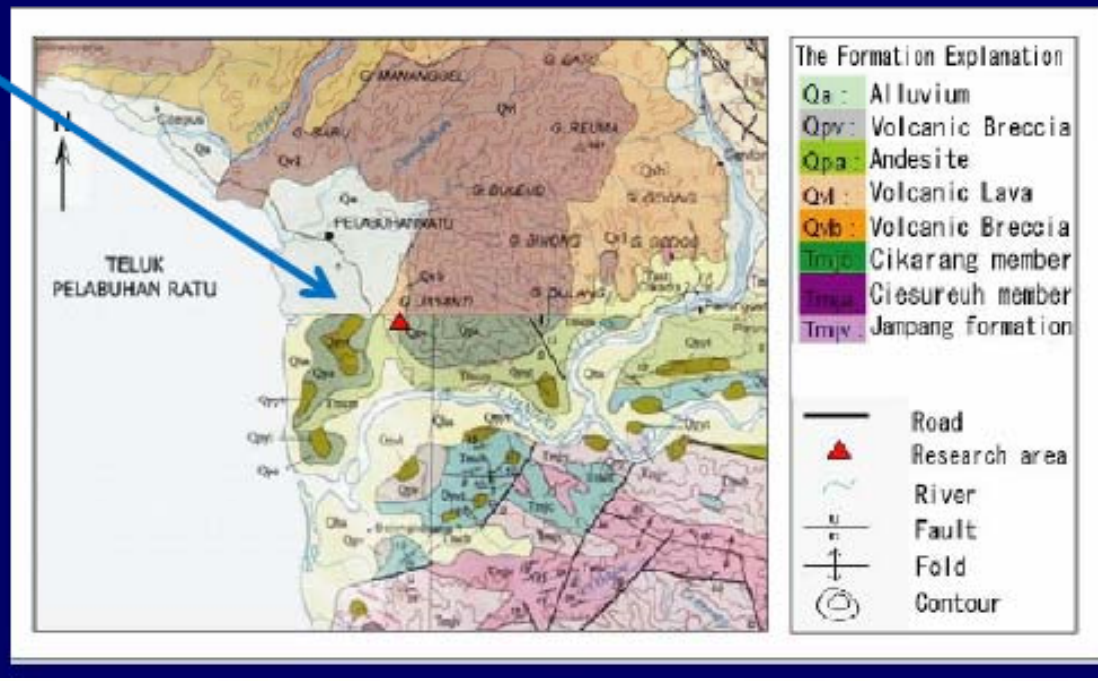

Channel 1
x 10^4
-2.35
-2.4
-2.45
01/20
01/21
01/22
01/23
01/24
Channel 2
x 10^4
1.2
1.18
01/20
01/21
01/22
01/23
01/24
Channel 3
x 10^4
8.28
8.26
8.24
01/20
01/21
01/22
01/23
01/24
Channel 4
x 10^4
4.35
4.3
4.25
4.2
4.15
01/20
01/21
01/22
01/23
01/24

結論

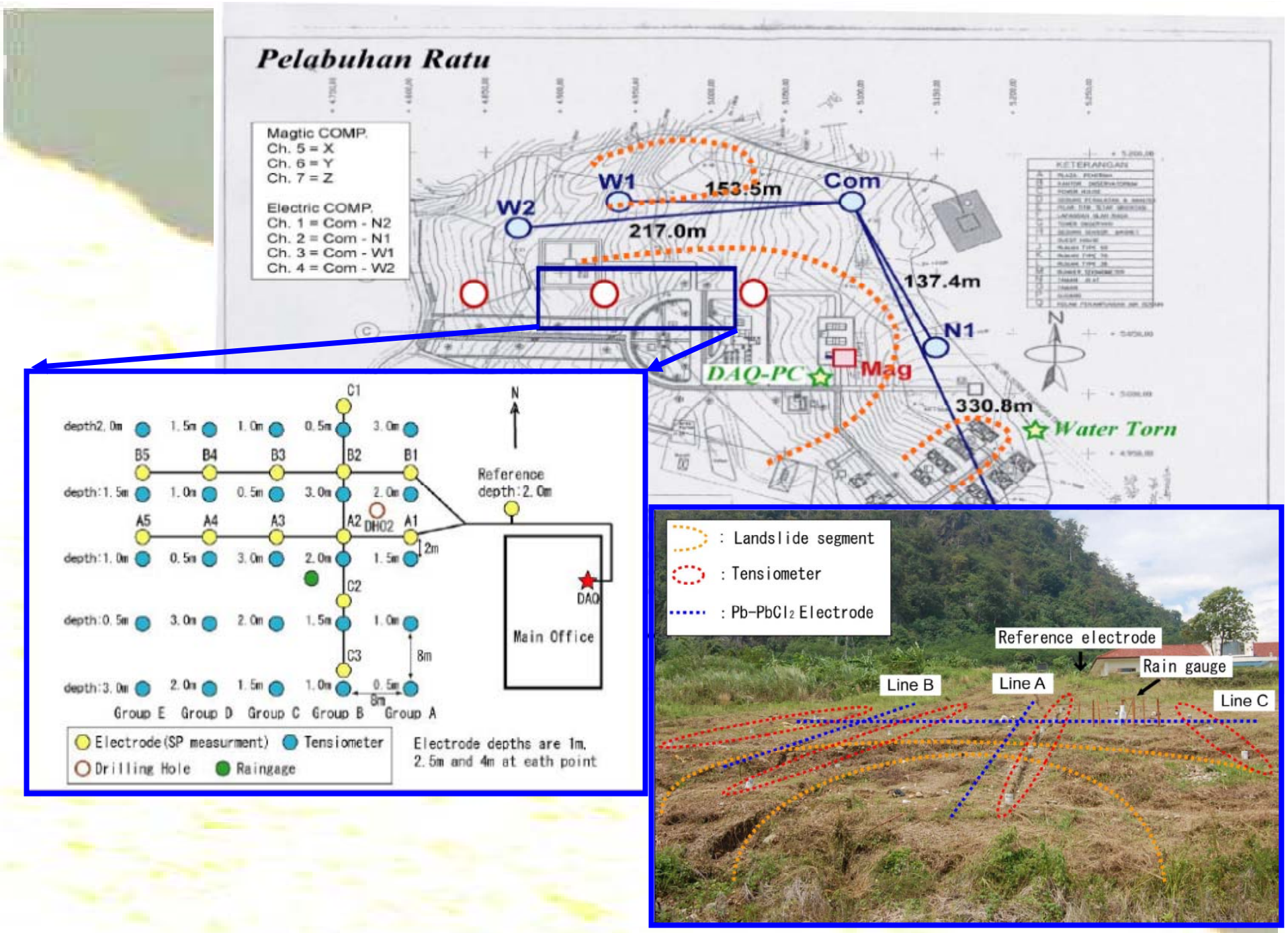
- 潰壩試驗放水的前一天，大地電場即開始呈現變化，試驗結束後大地電場則逐步恢復正常的背景變化。
- 兩次潰壩試驗前後，皆造成大地電場異常，推測可能因地下流體飽和度變化，導致大地電場異常現象。
- 即時監測大地電場變化，未來可能可以做爲土石流事先警訊之一，降低災害風險。

In-situ site

Pelabuhan Ratu,
West Jawa, Indoensia
(106.6° E 7° S)



- Geophysical station, BMKG, Indoensia
- Geology : silt
- Landslide is going on now


Pelabuhan Ratu
Magtic COMP.
Ch. 5 = X
Ch. 6 = Y
Ch. 7 = Z
Electric COMP.
Ch. 1 = Com - N2
Ch. 2 = Com - N1
Ch. 3 = Com - W1
Ch. 4 = Com - W2
W1
W2
Com
N1
153.5m
217.0m
137.4m
330.8m
DAQ-PC
Mag
Water Torn
N
C1
C2
C3
B1
B2
B3
B4
B5
A1
A2
A3
A4
A5
DH02
DAQ
Main Office
Reference depth:2.0m
depth2.0m
depth:1.5m
depth:1.0m
depth:0.5m
depth:3.0m
Group E
Group D
Group C
Group B
Group A
Electrode(SP measurment)
Tensiometer
Drilling Hole
Raingage
Electrode depths are 1m, 2.5m and 4m at eath point
: Landslide segment
: Tensiometer
: Pb-PbCl2 Electrode
Reference electrode
Rain gauge
Line A
Line B
Line C