Geophysics Case Studies: Slope Investigations

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Prof. Bob Whiteley

Senior Principal

Unexpected slope & embankment collapses can have catastrophic consequences

Case studies

- **Deep road cut- New England Hwy.**
- **Slopes adjacent to rivers - Thailand**
- **Buried boulder location – Malaysia**
- **Mapping lithologies & buried hazards with ERI**
- **Seismic Imaging of hazardous slopes LHD**
- **Shear zone mapping for new road tunnel - Malaysia**

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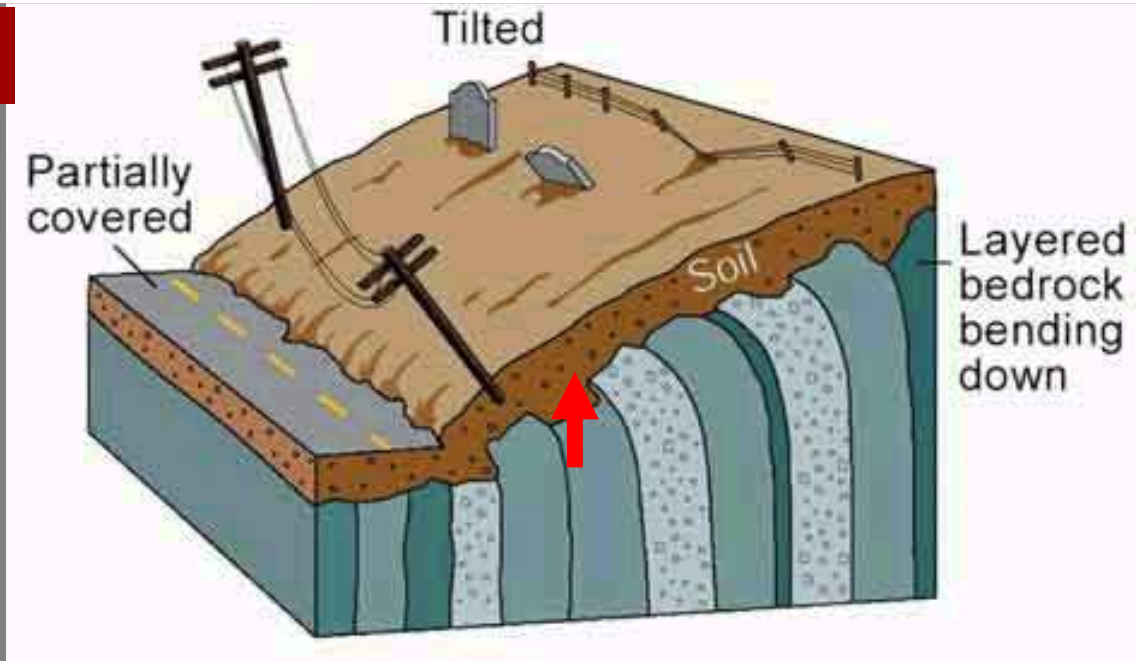
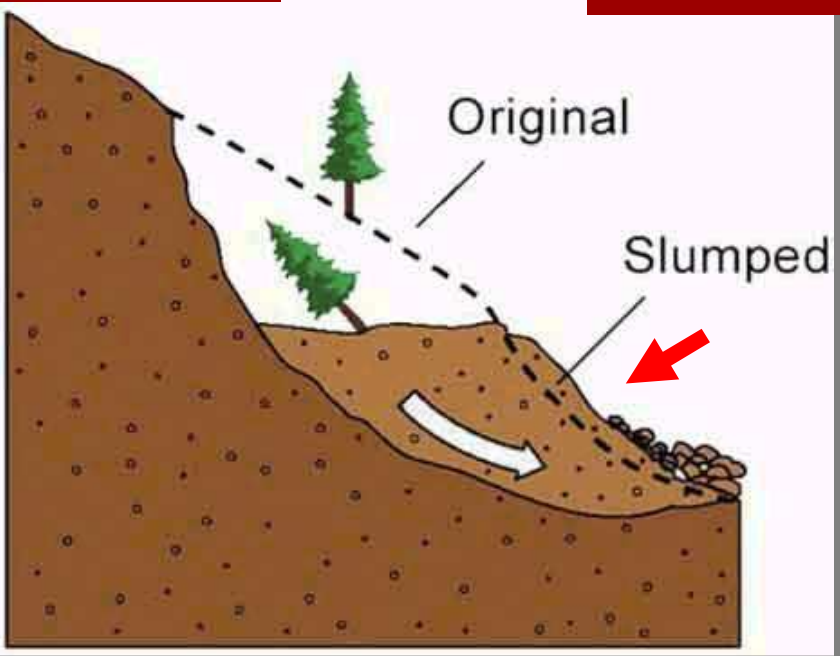
UNSTABLE MASSES

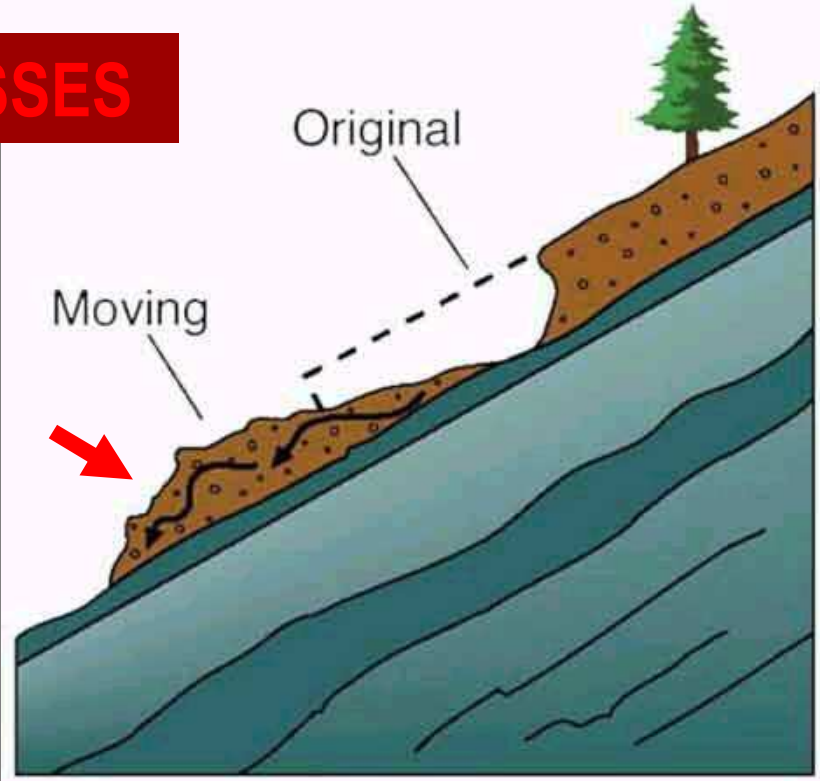
CREEP



FLOW

SLUMP





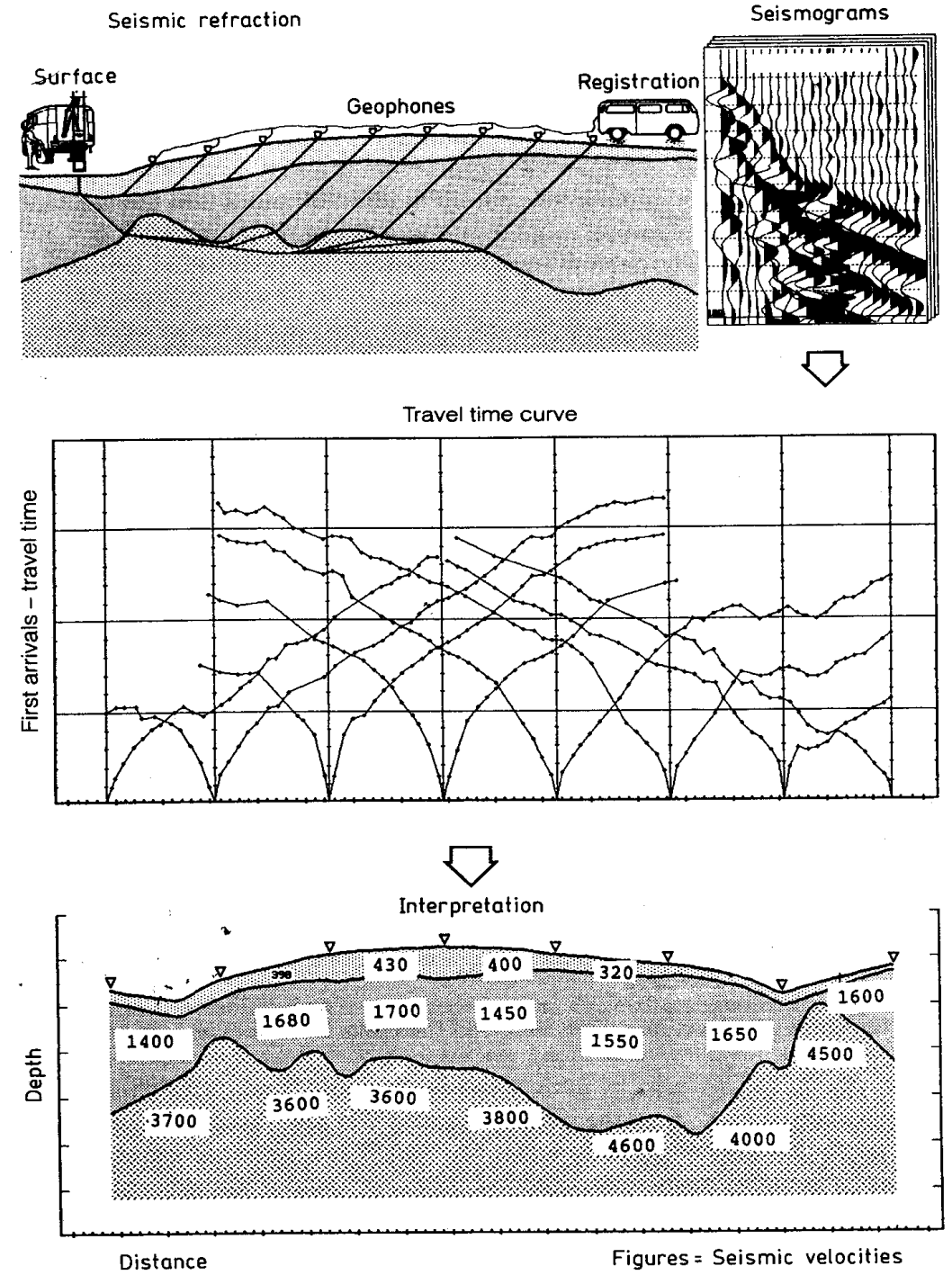
Key issues for geophysics

- Depth and lateral extent of unstable mass
- Location and shape of base
- Buried objects e.g. boulders
- Groundwater conditions
- Possible surrounding unstable material

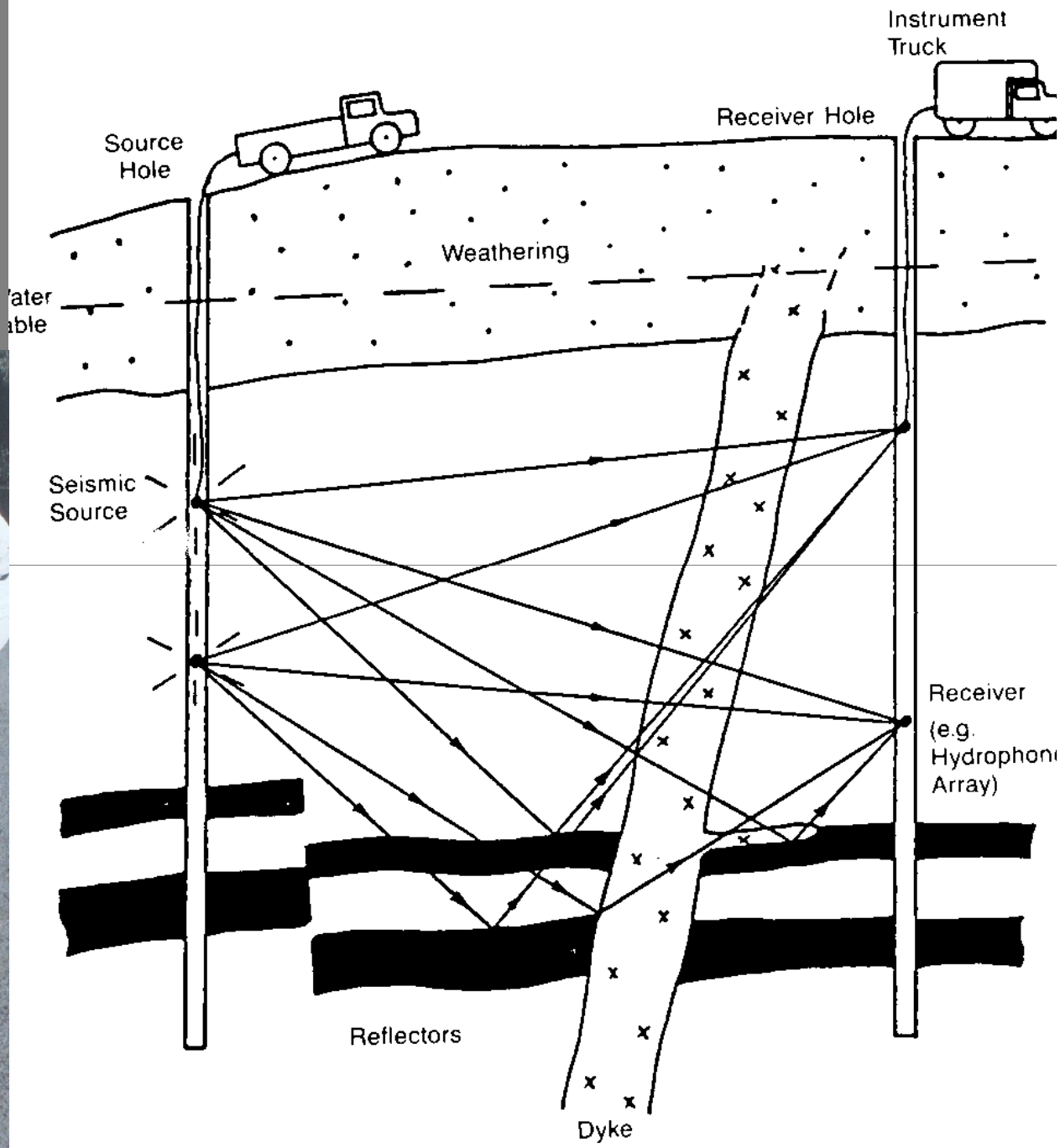
UNSTABLE MASS PARAMETER INCREASING	SEISMIC VELOCITY	ELECTRICAL RESISTIVITY
Depth	↑	↑
Weathering (clay content)	↓	↓
Discontinuity frequency	↓	↓
Strength	↑	↑
Residual Stress	↑	↑
Saturation	↑	↓
Groundwater salinity	↔	↓

↑ Increases ↓ Decreases ↔ No Change

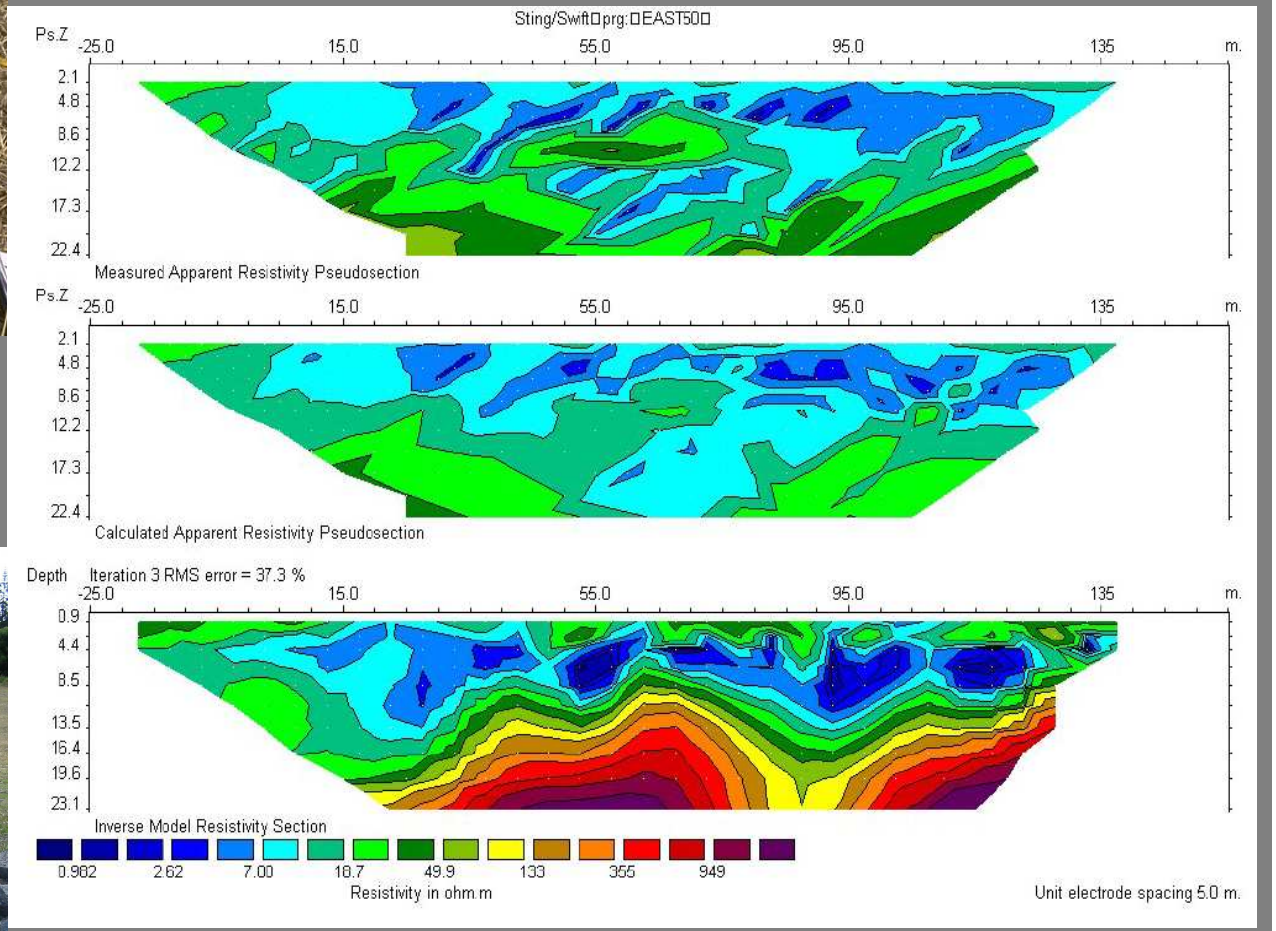
Seismic Refraction



Borehole Seismic

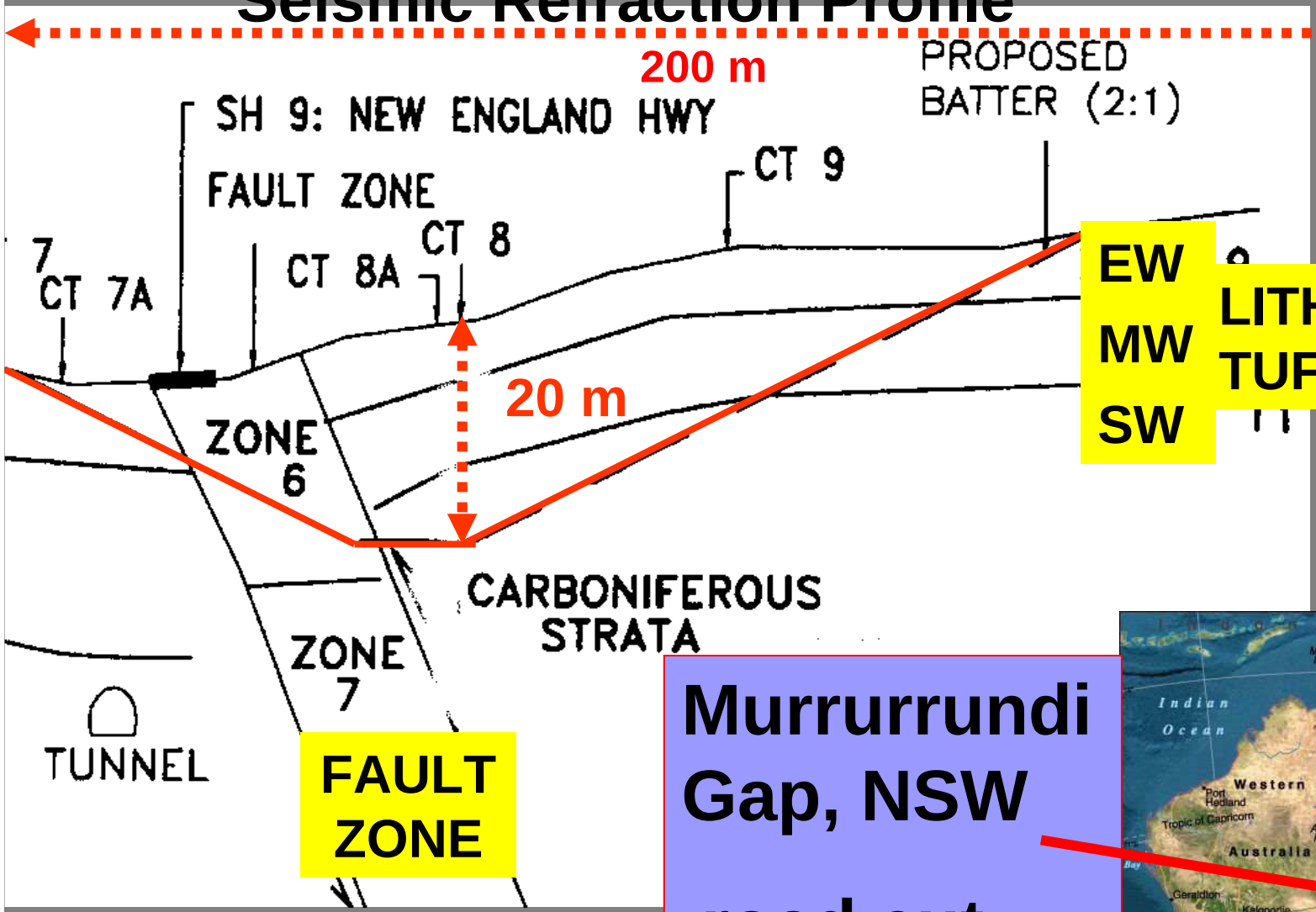


ELECTRICAL RESISTIVITY IMAGING



Coffey

Seismic Refraction Profile

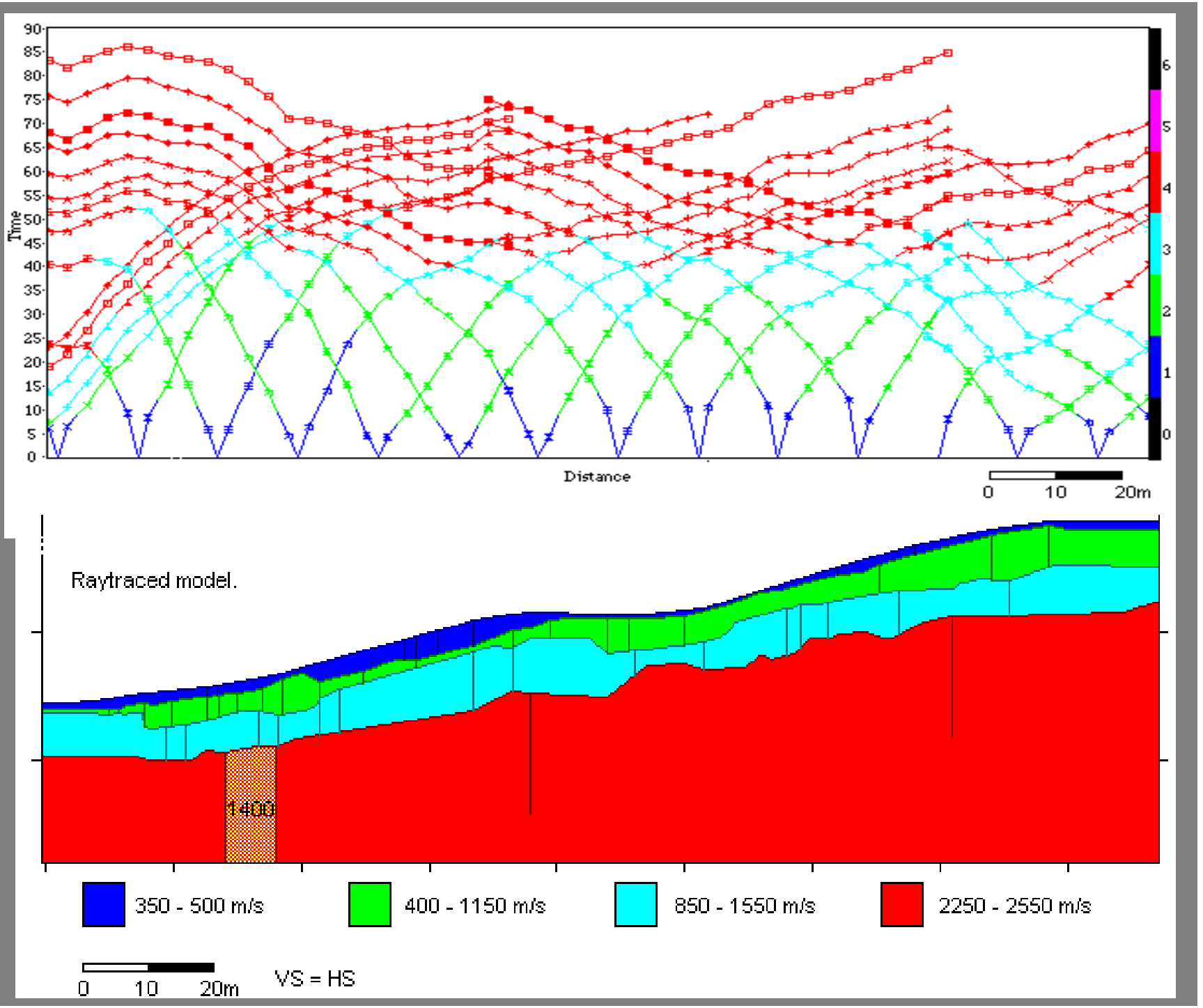


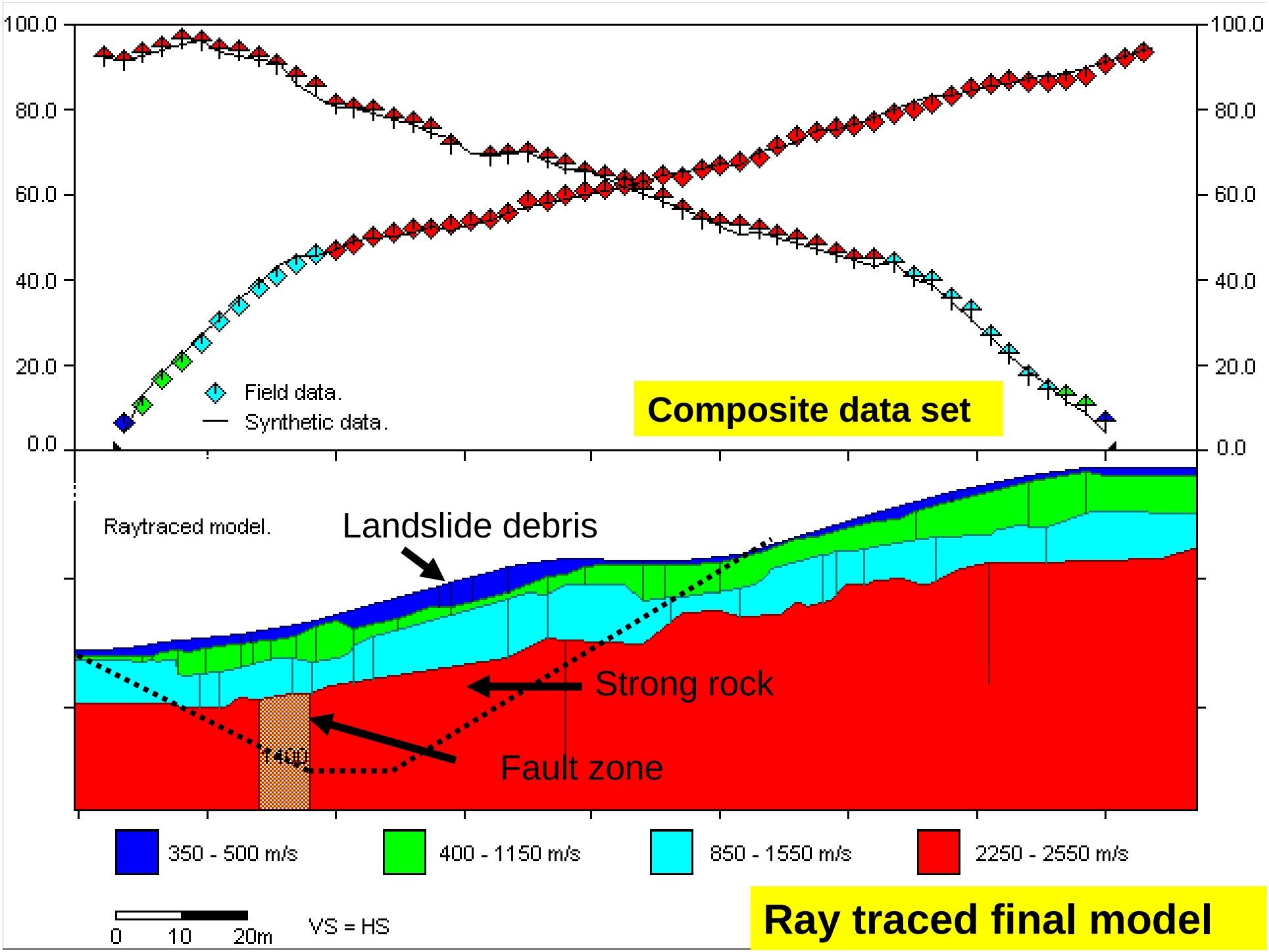
EW
MW
SW

LITHIC
TUFFS

Murrurrundi Gap, NSW

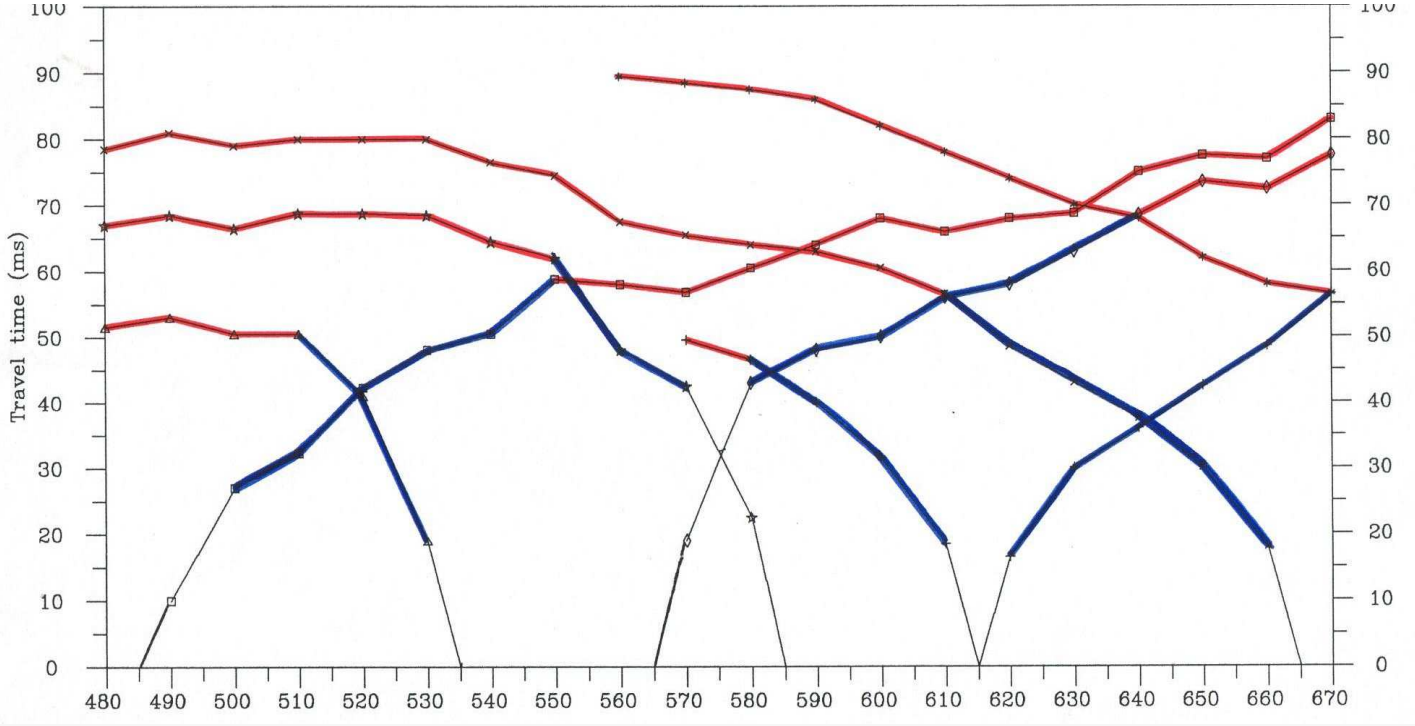
road cut


Time
Distance
0
10
20m
Raytraced model.
1400
350 - 500 m/s
400 - 1150 m/s
850 - 1550 m/s
2250 - 2550 m/s
0
10
20m
VS = HS

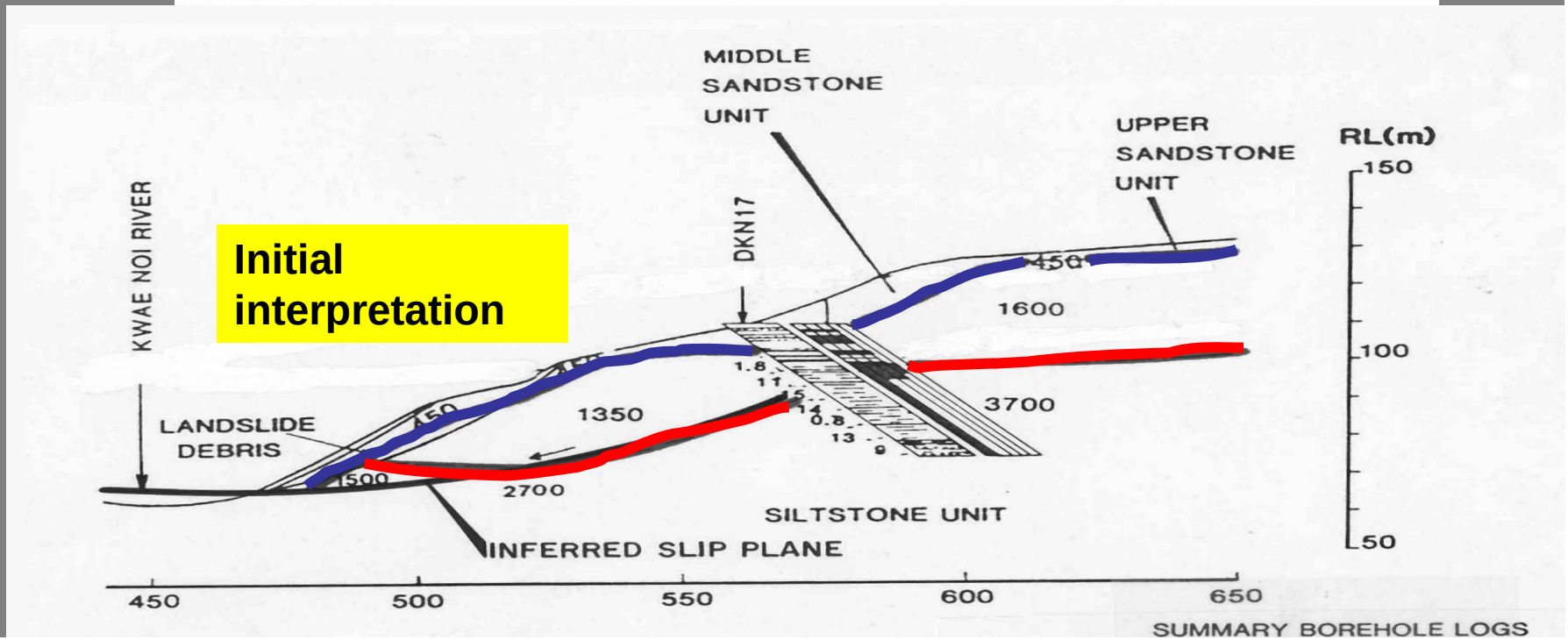

100.0
80.0
60.0
40.0
20.0
0.0
Field data.
Synthetic data.
Composite data set
Raytraced model.
Landslide debris
Strong rock
Fault zone
1400
350 - 500 m/s
400 - 1150 m/s
850 - 1550 m/s
2250 - 2550 m/s
0
10
20m
VS = HS
Ray traced final model

Project	Kwae Noi Dam Site Thailand
Nature of Instability	Slump failure right abutment
Task	Define unstable rock mass
Geophysical Technology	Seismic refraction

Seismic refraction data

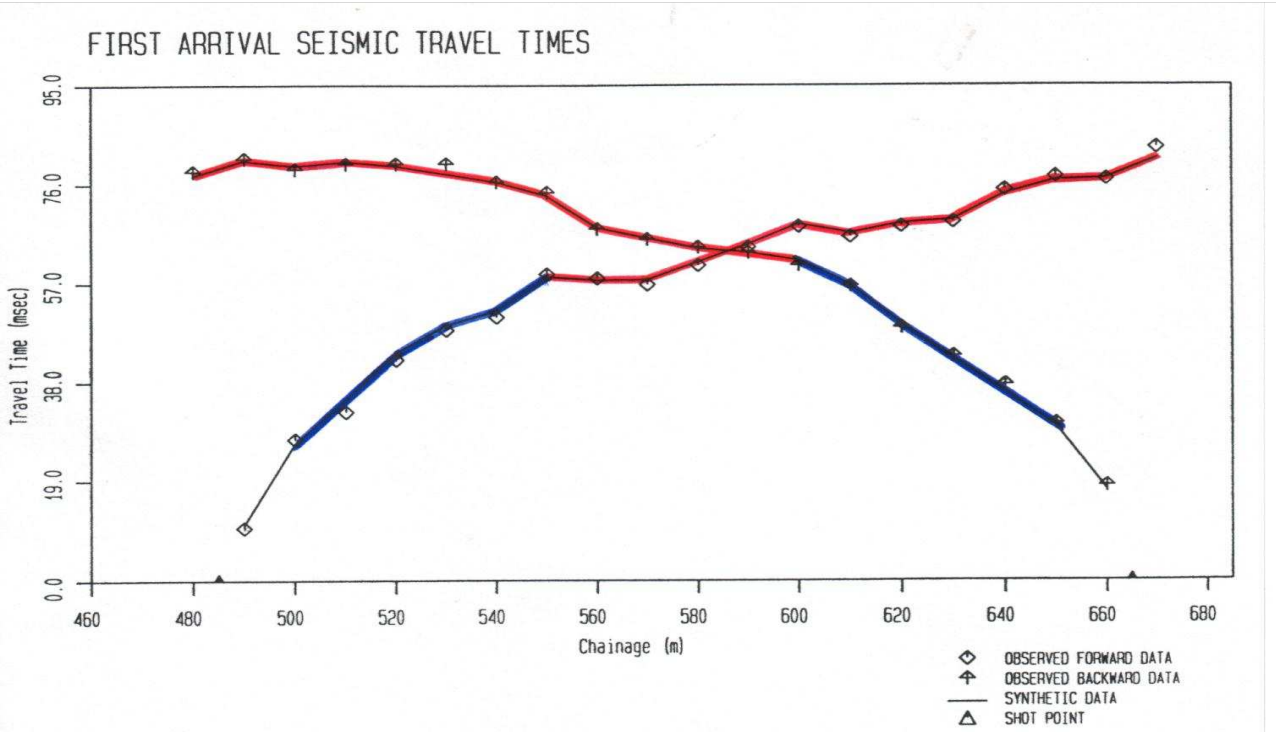


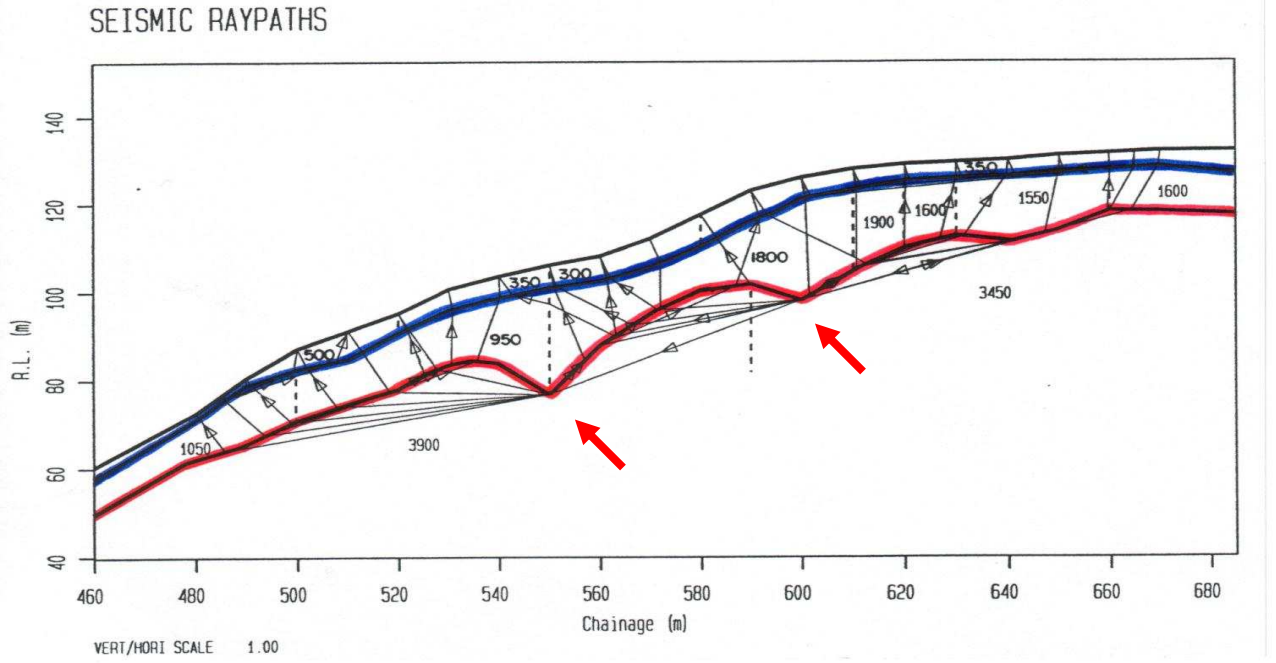
Initial interpretation



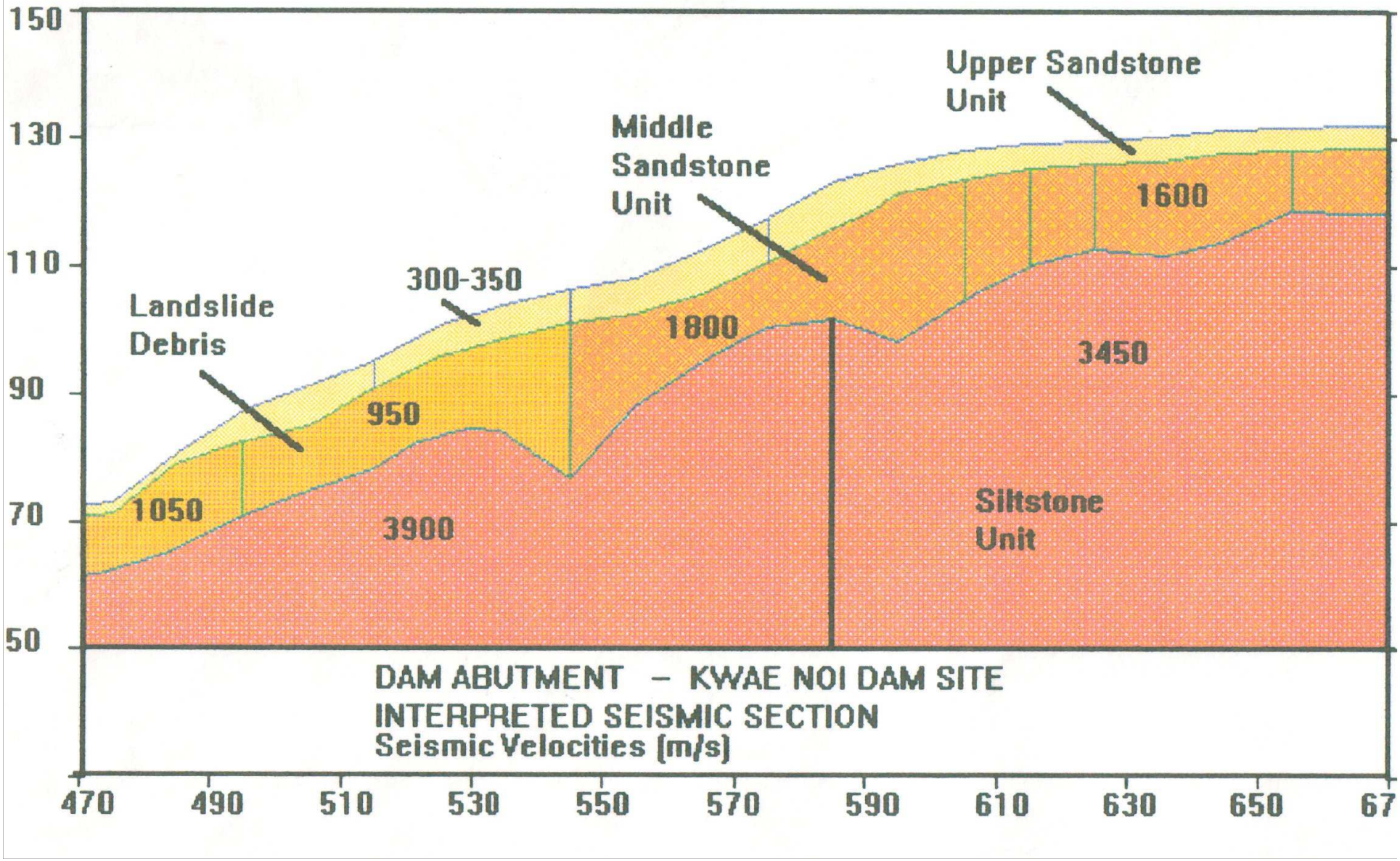
Re-interpretation

Visual Interactive Ray Tracing

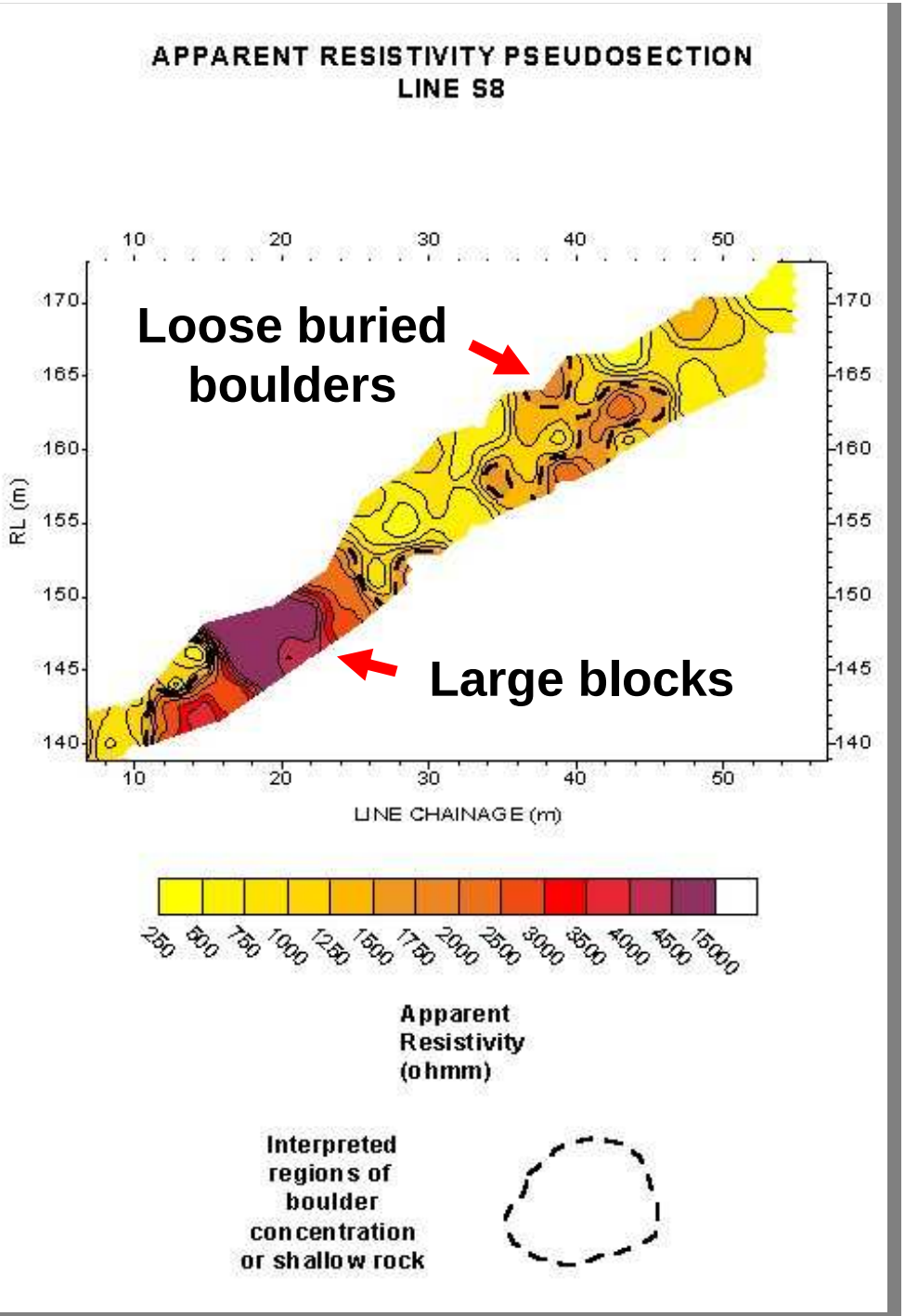


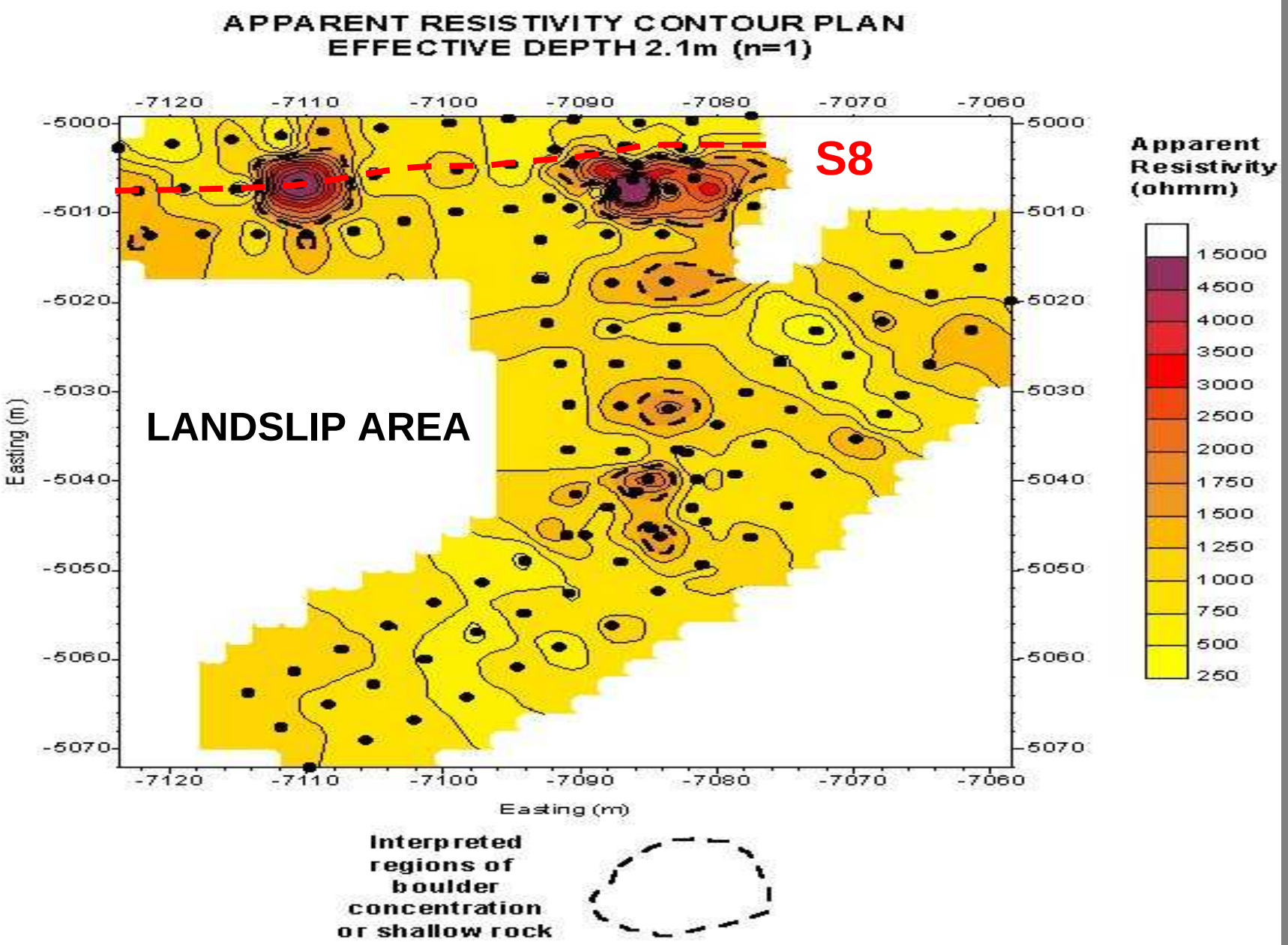


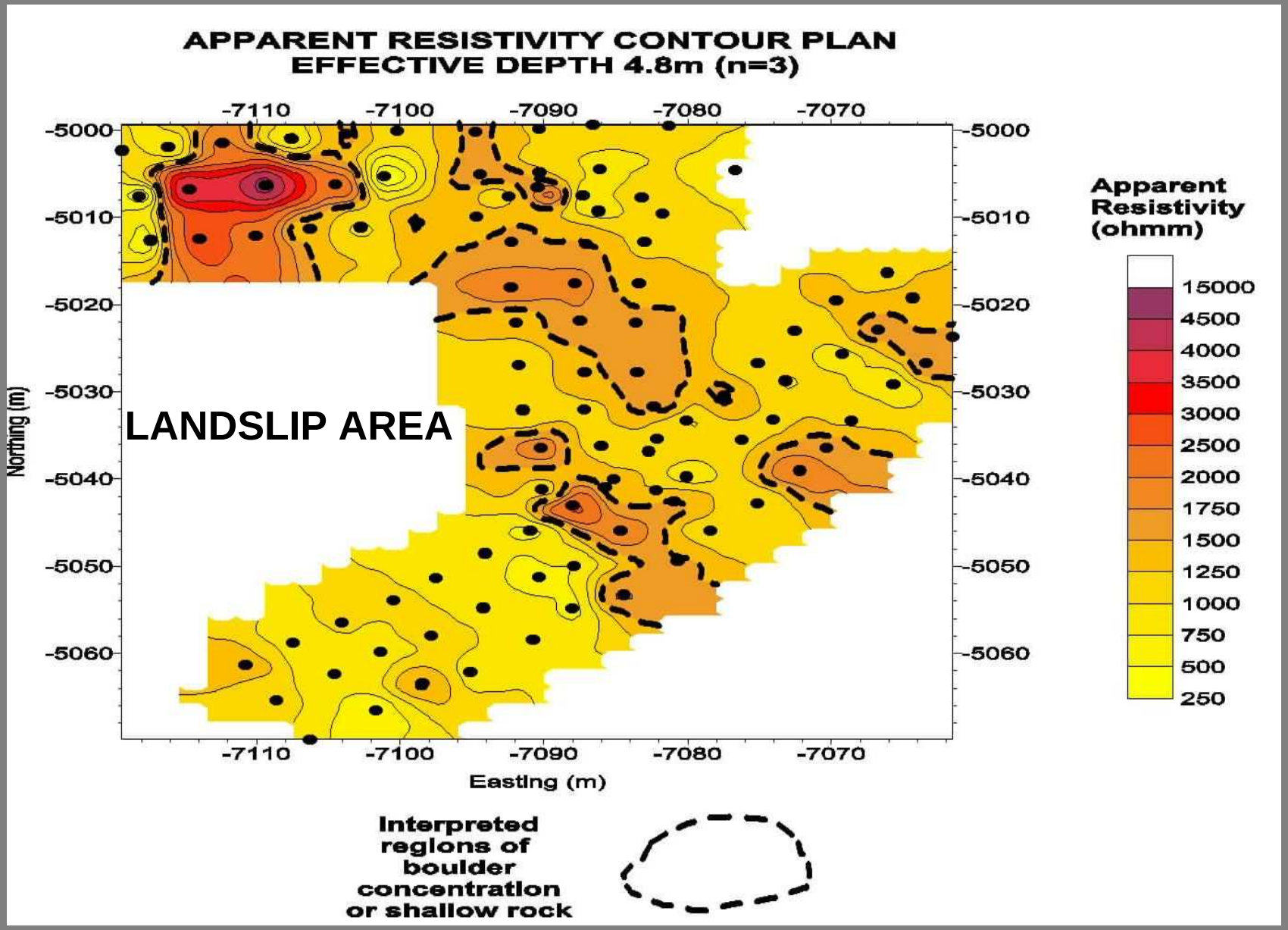
FINAL INTERPRETED SECTION

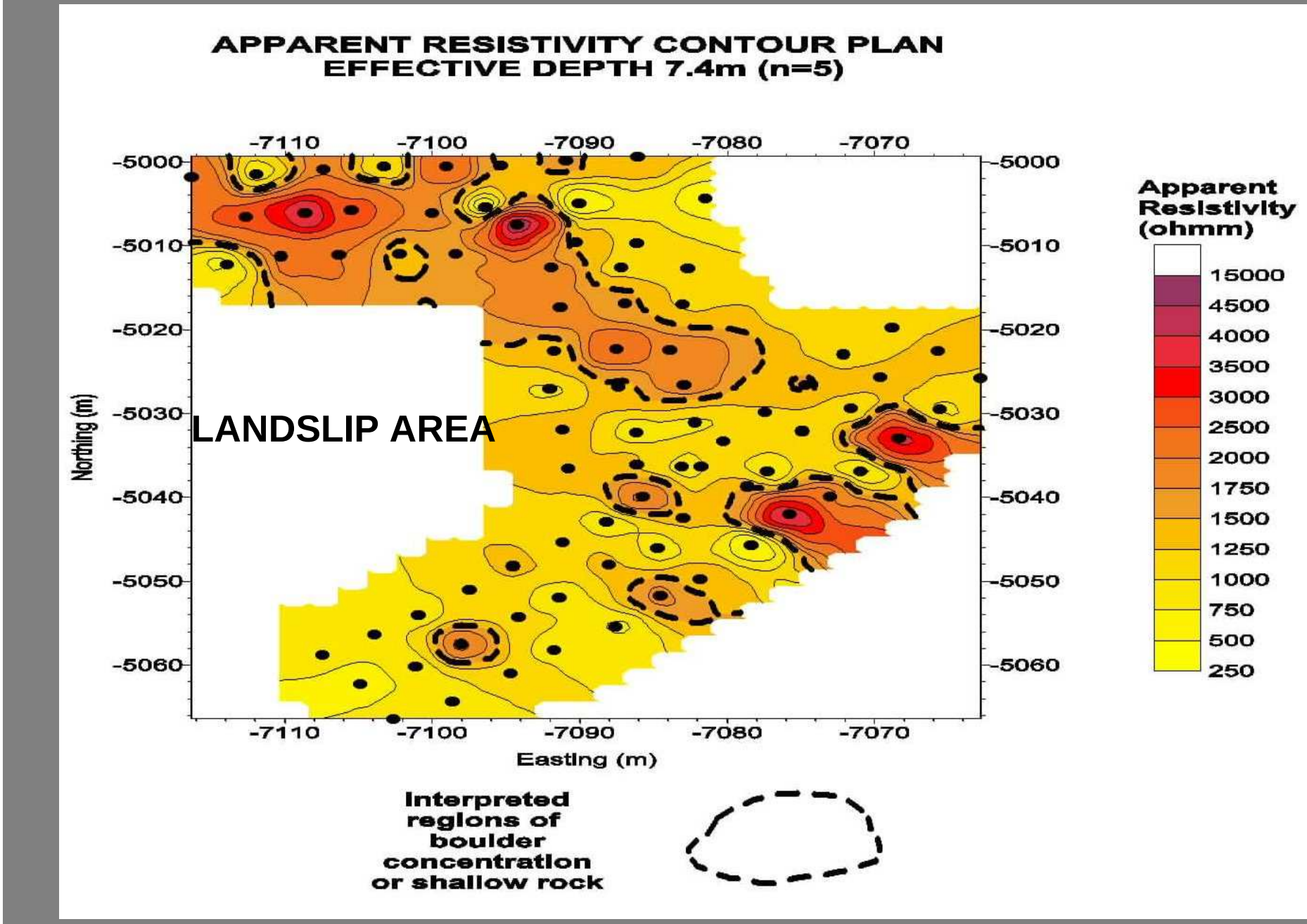


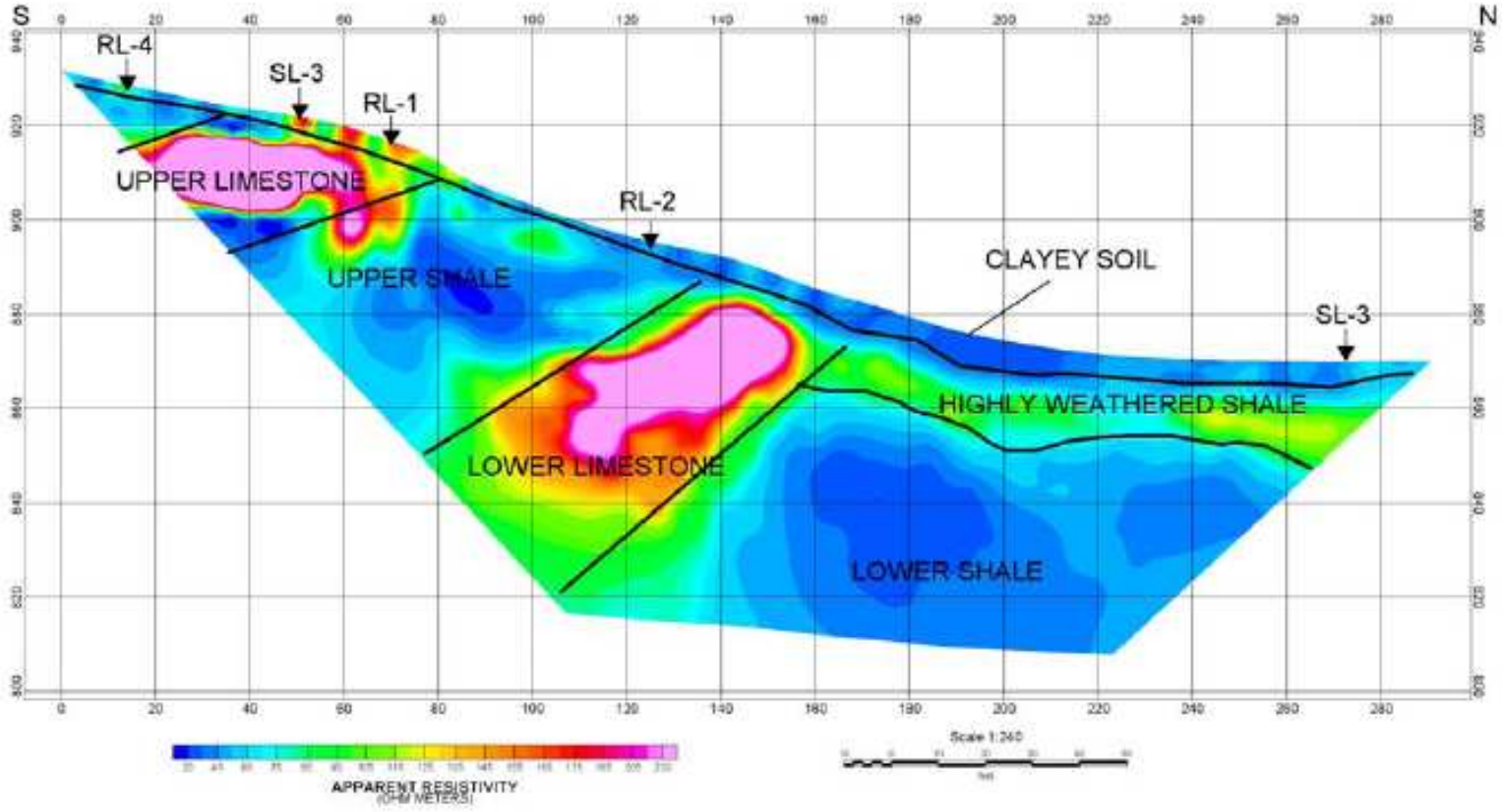
Project	**Road cutting Penang**
Nature of Instability	**Landslip in weathered granite**
Task	**Locate buried boulders**
Geophysical Technology	**Electrical resistivity**


APPARENT RESISTIVITY PSEUDOSECTION
LINE S8
Loose buried boulders
Large blocks
RL (m)
LINE CHAINAGE (m)
10
20
30
40
50
170
165
160
155
150
145
140
250
500
750
1000
1250
1500
1750
2000
2500
3000
3500
4000
4500
15000
Apparent Resistivity (ohmm)
Interpreted regions of boulder concentration or shallow rock


APPARENT RESISTIVITY CONTOUR PLAN
EFFECTIVE DEPTH 2.1m (n=1)
S8
LANDSLIP AREA
Apparent Resistivity (ohmm)
15000
4500
4000
3500
3000
2500
2000
1750
1500
1250
1000
750
500
250
-7120
-7110
-7100
-7090
-7080
-7070
-7060
-5000
-5010
-5020
-5030
-5040
-5050
-5060
-5070
Easting (m)
Northing (m)
Interpreted regions of boulder concentration or shallow rock

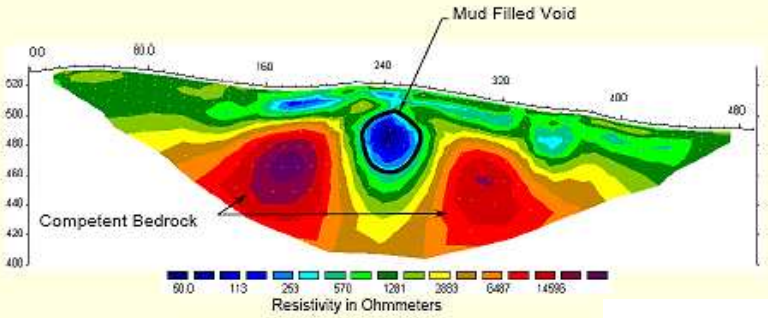

APPARENT RESISTIVITY CONTOUR PLAN
EFFECTIVE DEPTH 4.8m (n=3)
-7110
-7100
-7090
-7080
-7070
-5000
-5010
-5020
-5030
-5040
-5050
-5060
Northing (m)
Easting (m)
LANDSLIP AREA
Apparent Resistivity (ohmm)
15000
4500
4000
3500
3000
2500
2000
1750
1500
1250
1000
750
500
250
Interpreted regions of boulder concentration or shallow rock


APPARENT RESISTIVITY CONTOUR PLAN
EFFECTIVE DEPTH 7.4m (n=5)
-7110
-7100
-7090
-7080
-7070
-5000
-5010
-5020
-5030
-5040
-5050
-5060
Northing (m)
Easting (m)
LANDSLIP AREA
Apparent Resistivity (ohmm)
15000
4500
4000
3500
3000
2500
2000
1750
1500
1250
1000
750
500
250
Interpreted regions of boulder concentration or shallow rock



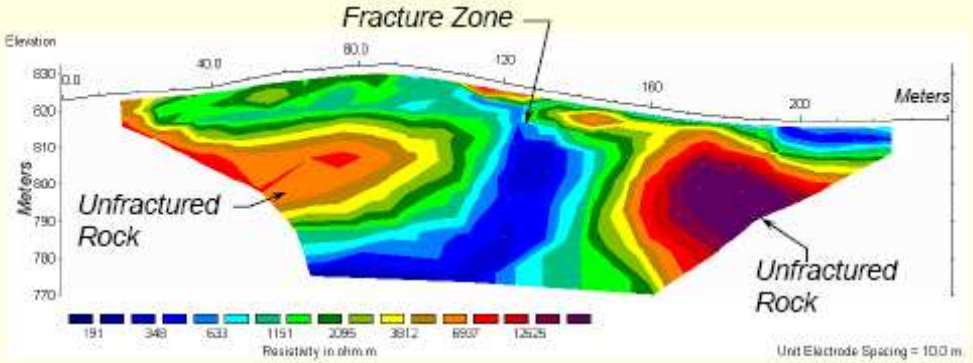
Lithological & soils mapping with Electrical Resistivity Imaging

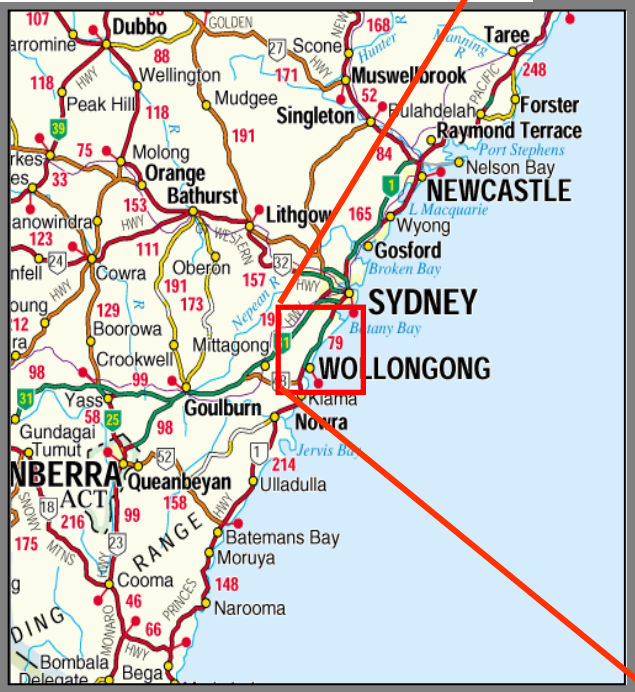
Karst Features/Voids



ERI in highly variable conditions

Fracture Zones





Site location

Some Historical - rock falls

1987-GD1

2001-GD3

2004-GD4

2004-GD2

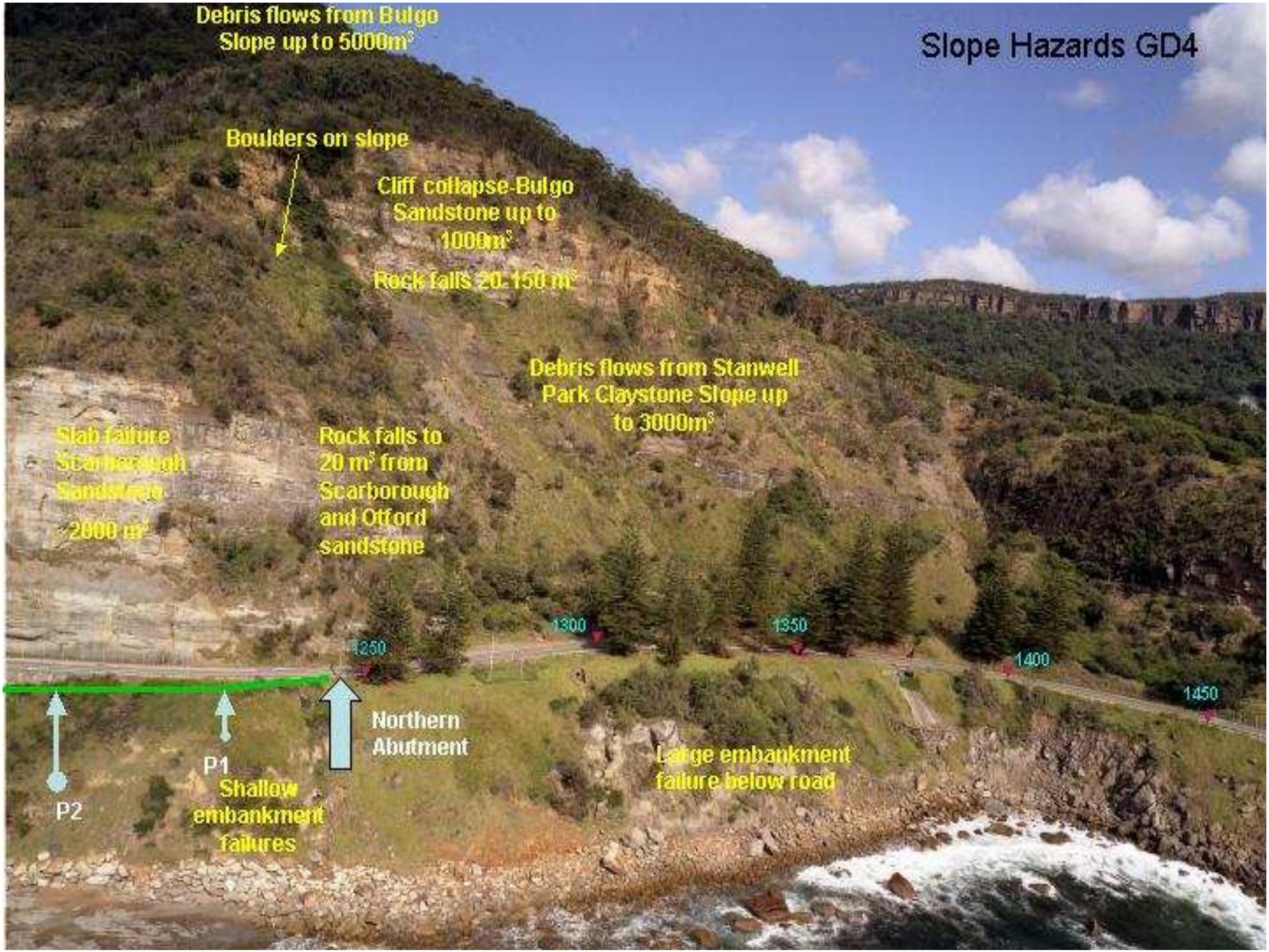
Some Historical - Debris Flows

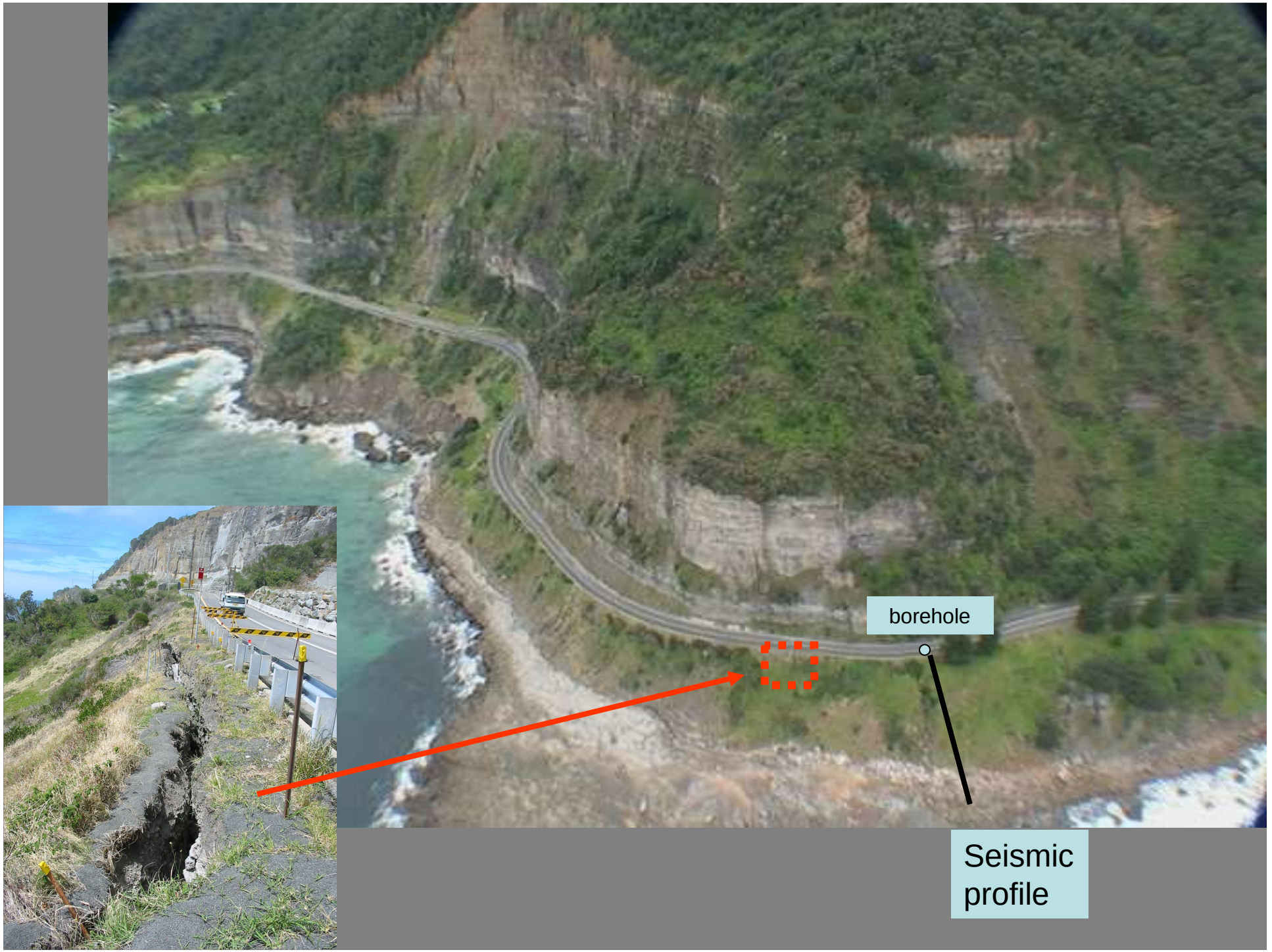
Circa 1880-GD3

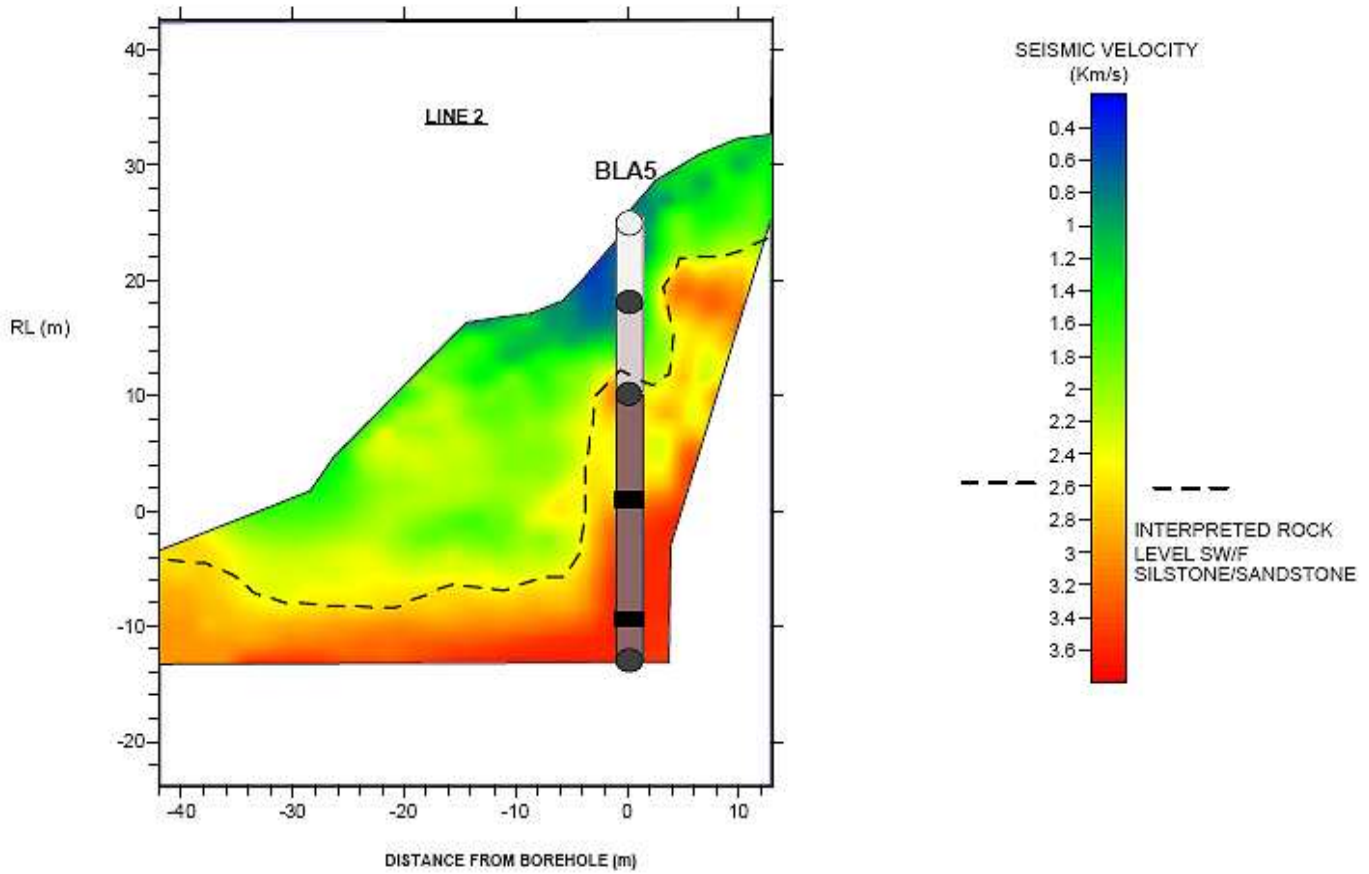
1950-GD1- looking south

1950-GD2

1988-GD1

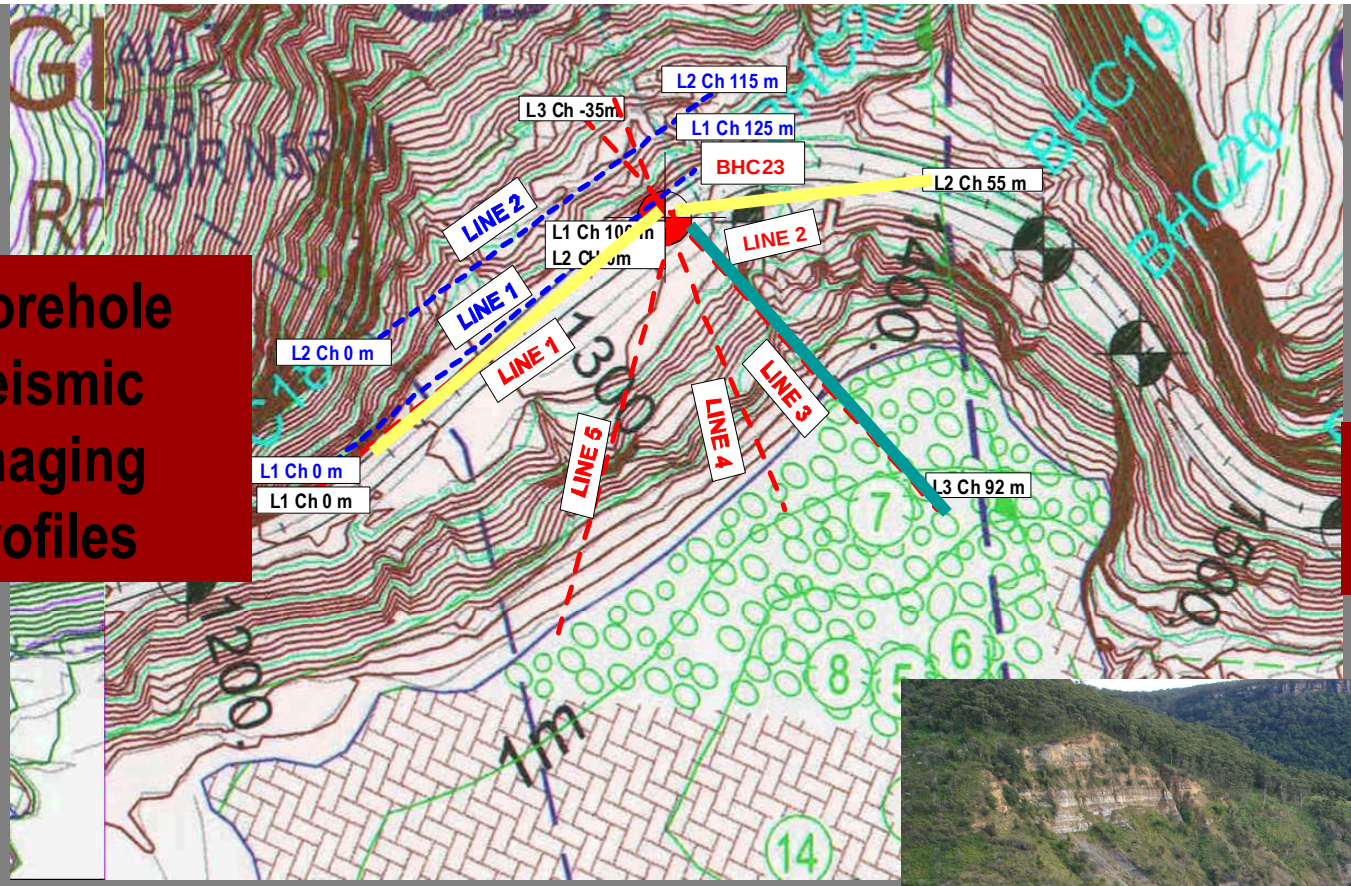

Slope Hazards GD4
Debris flows from Bulgo Slope up to 5000m³
Boulders on slope
Cliff collapse-Bulgo Sandstone up to 1000m³
Rock falls 20-150 m³
Debris flows from Stanwell Park Claystone Slope up to 3000m³
Slab failure Scarborough Sandstone ~2000 m³
Rock falls to 20 m³ from Scarborough and Otford sandstone
1250
1300
1350
1400
1450
Northern Abutment
P1
P2
Shallow embankment failures
Large embankment failure below road


borehole
Seismic profile



Seismic Layer	P-wave velocity (km/s)	Thickness range (m)	Simplified borehole log
1	0.4-0.7	1-12	Silty sand (fill & colluvium)
2	0.8-2.5	6-23	EW to HW sandstone, conglomerate, sandy clay, some boulders
3	2.6-3.7	-	SW to F siltstone/sandstone with coal seams

Borehole Seismic Imaging Profiles



LEGEND

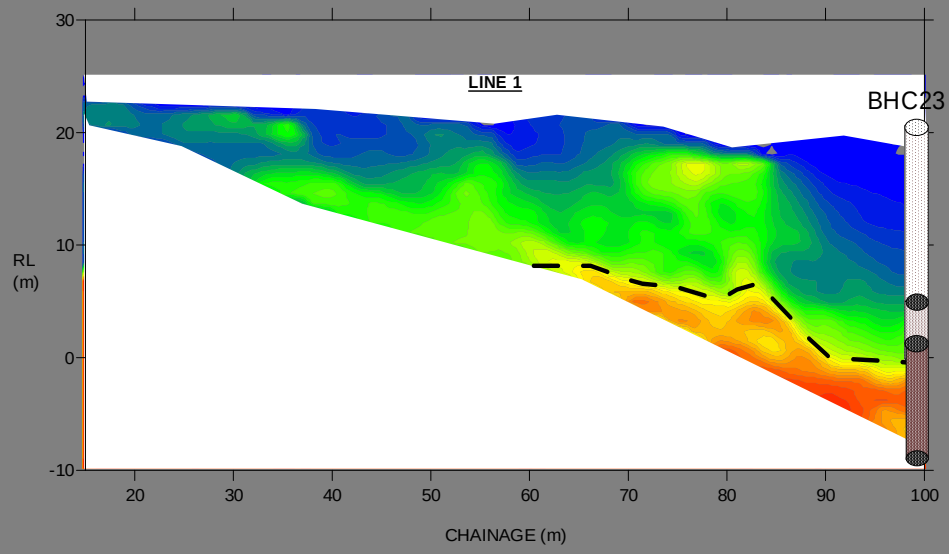
BOREHOLE BHC 23

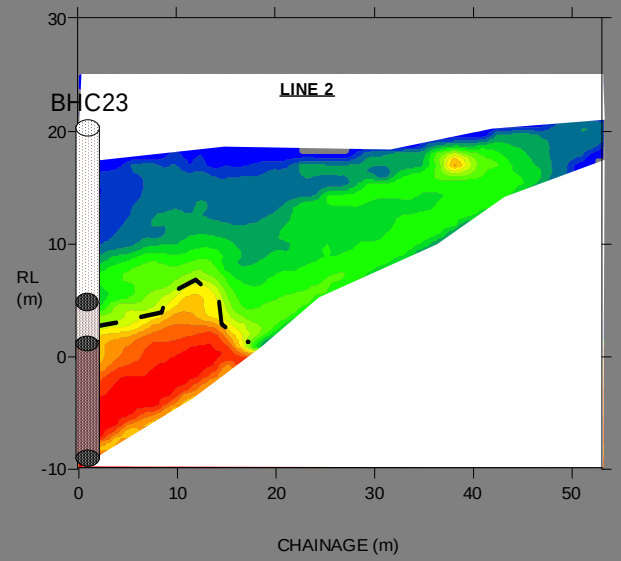
LINE 1 SEISMIC PROFILE

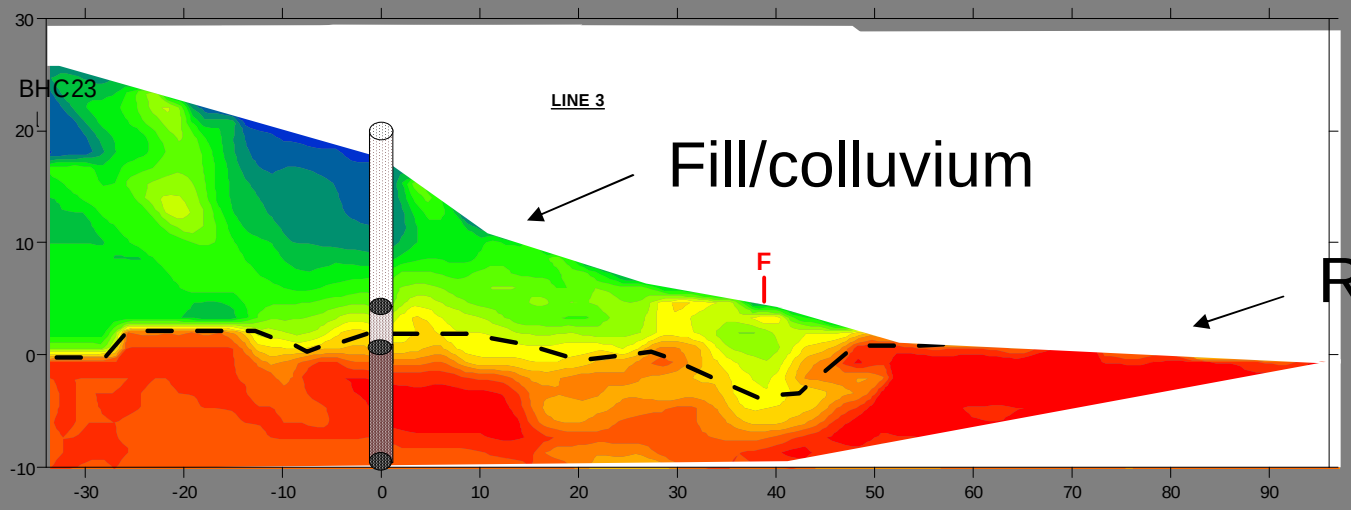
LINE 1 RESISTIVITYPROFILE

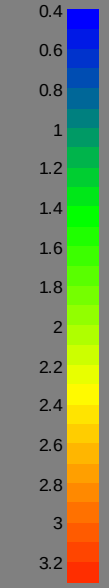
New Highway Construction

Elevated roadway under construction









LEGEND

- FILL/COLLUVIUM
- EW/HW SILTSONE/SANDSTONE
- SW/F SILTSTONE/SANDSTONE
- INTERPRETED ROCK LEVEL (SW/F SILTSTONE/SANDSTONE)
- F — POSSIBLE FAULT

Coffey Geosciences Pty Ltd	ABN 57 056 335 516 ACN 056 335 516 — Geotechnical | Resources | Environmental | Technical | Project Management
Drawn	CC
Approved	RJW
Date	6/01/04

LAWRENCE HARGRAVES DRIVE ALLIANCE
AREA GD4 NORTHERN AMPHITHEATRE
GEOPHYSICAL STUDY

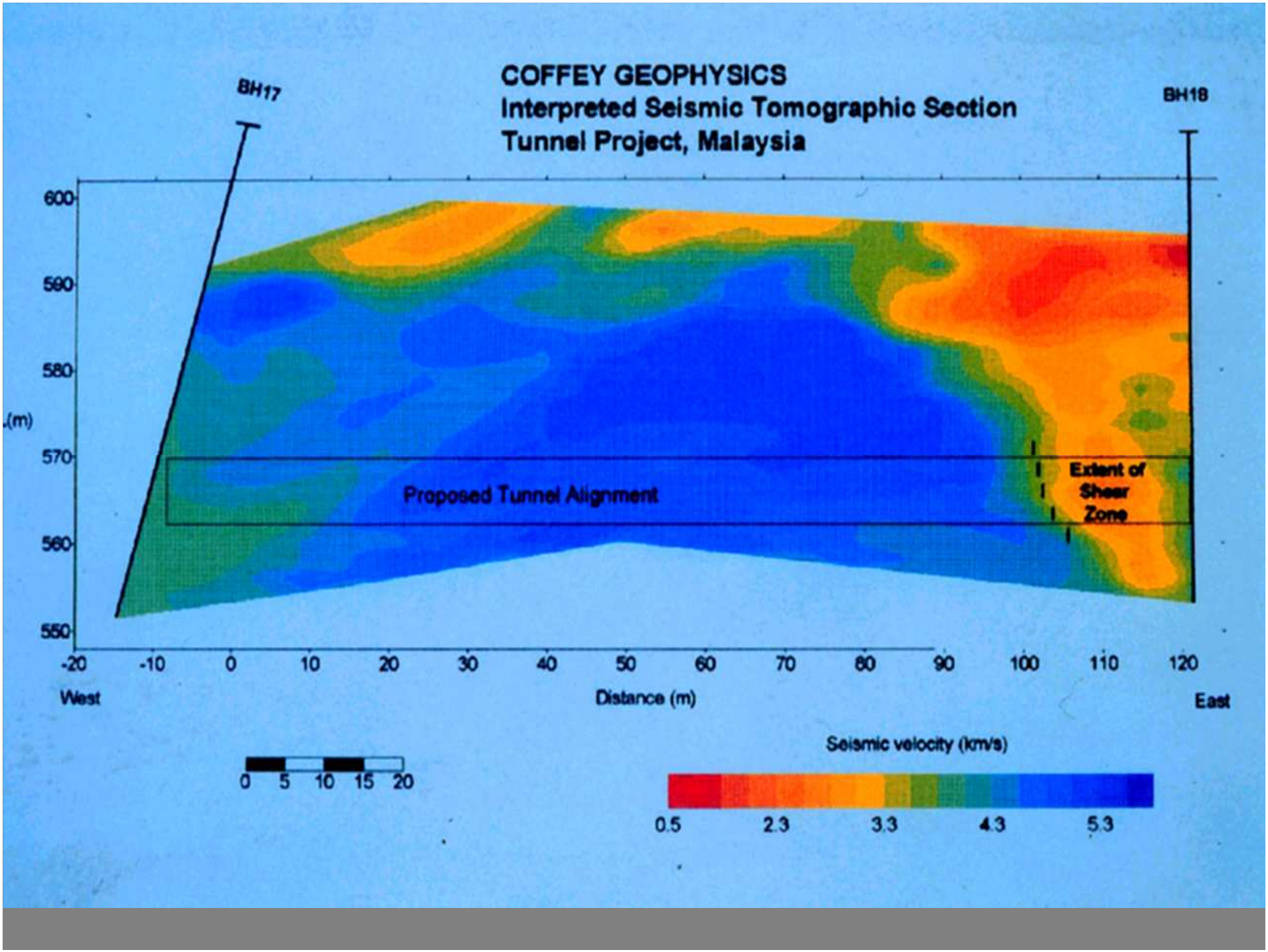
FIGURE 2

Lawrence Hargrave Drive

Genting Malaysia:The Old Karak Road Tunnel

New Karak Road Tunnel

- **790 m of 8.4 m high & 11.4 m wide tunnel, 20 shafts in granite at 20 to 70 m depth**
- **Geotechnical and seismic investigations 1994 from limited drilling sites**
- **Construction by roadheaders 1995 - 97**


COFFEY GEOPHYSICS
Interpreted Seismic Tomographic Section
Tunnel Project, Malaysia
BH17
BH18
600
590
580
(m)
570
560
550
Proposed Tunnel Alignment
Extent of Shear Zone
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
West
Distance (m)
East
0 5 10 15 20
Seismic velocity (km/s)
0.5
2.3
3.3
4.3
5.3

The shear zone exposed