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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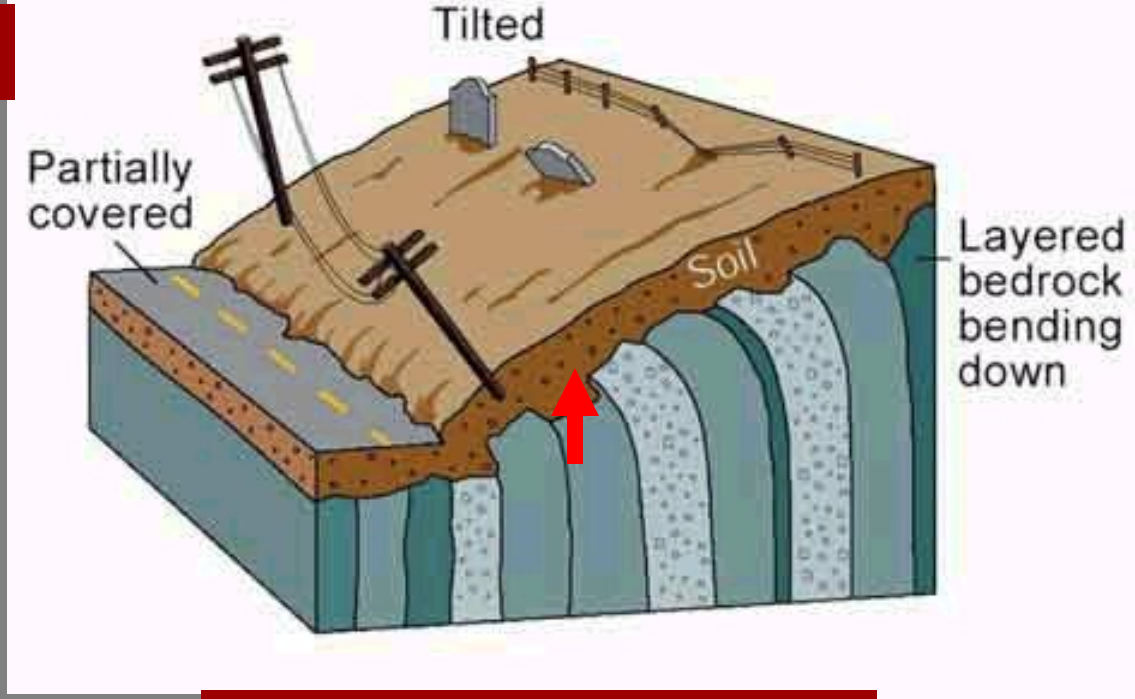
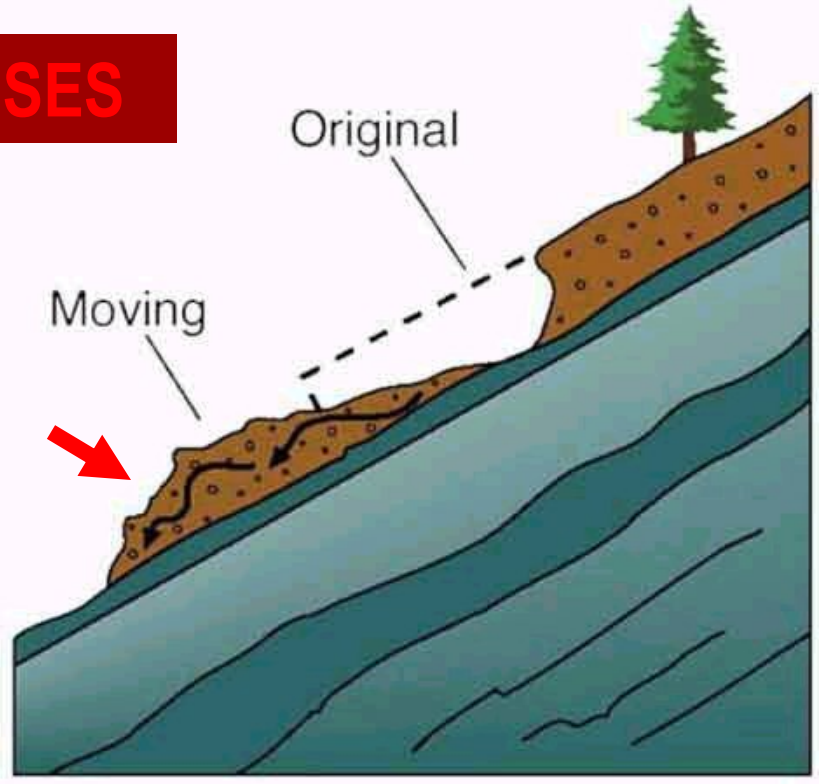
UNSTABLE MASSES

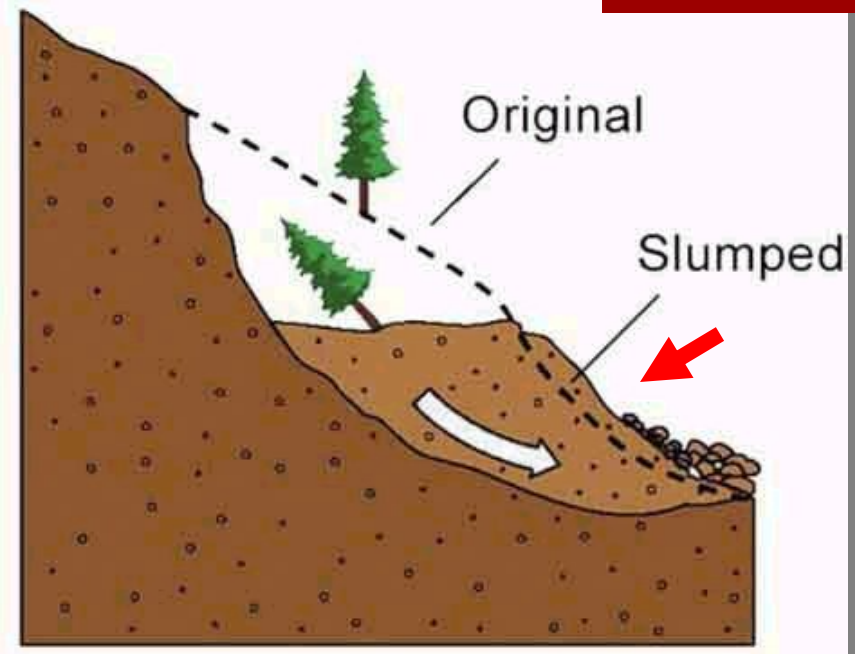
CREEP



FLOW



SLUMP



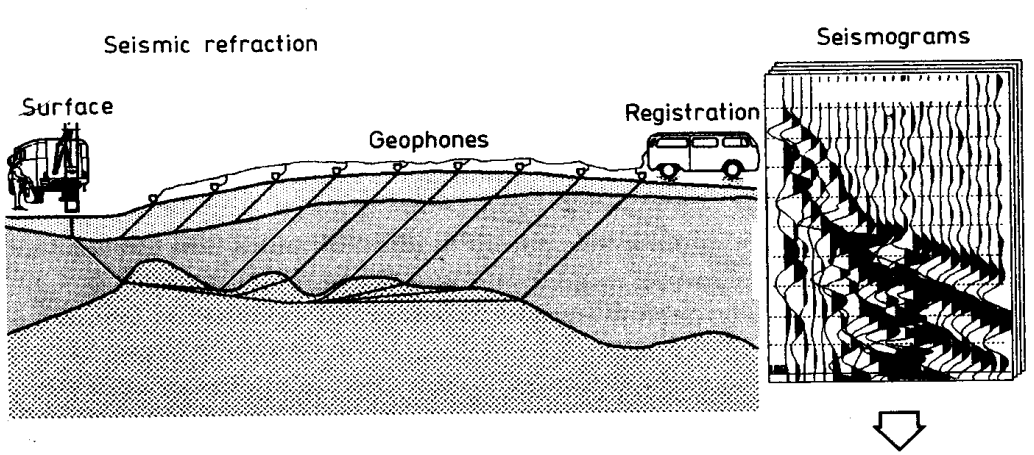
Key issues for geophysics

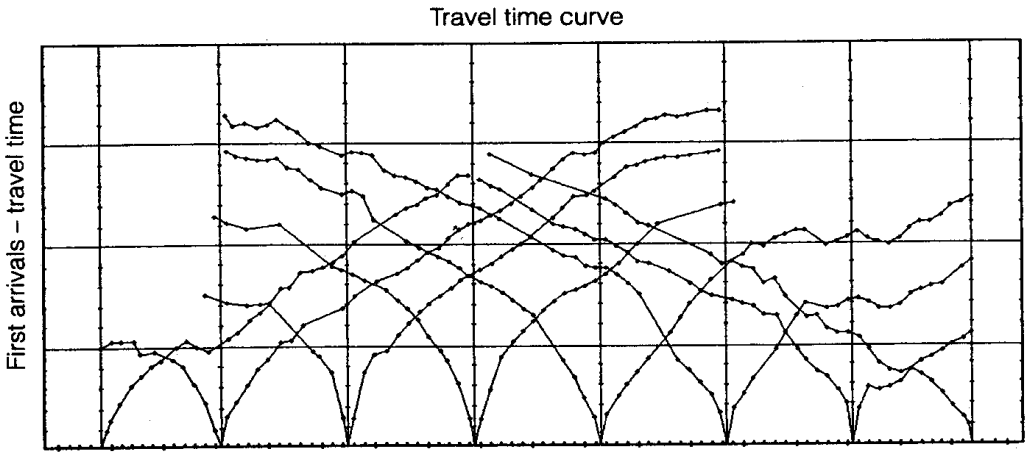
- Depth and lateral extent of unstable mass
- Location and shape of base
- Buried objects e.g. boulders
- Groundwater conditions
- Possible surrounding unstable material

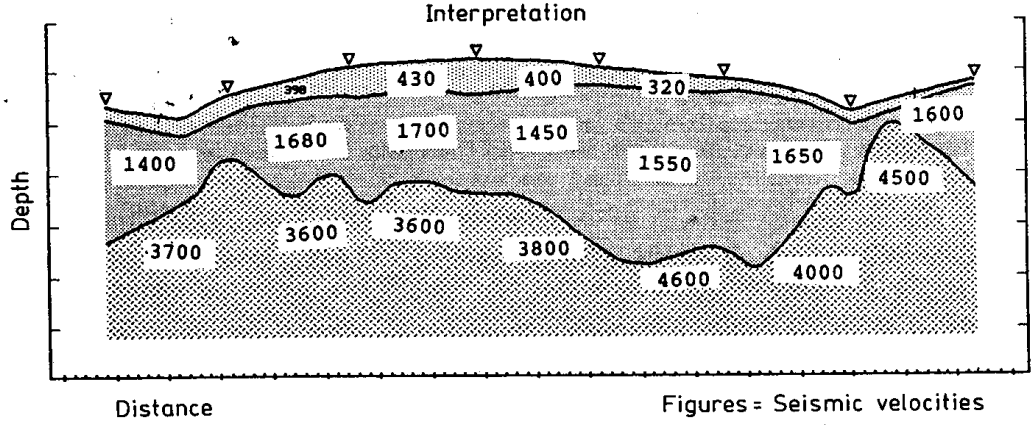
UNSTABLE MASS PARAMETER INCREASING	SEISMIC VELOCITY	ELECTRICAL RESISTIVITY
Depth	↑	↑
Weathering (clay content)	↓	↓
Discontinuity frequency	↓	↓
Strength	↑	↑
Residual Stress	↑	↑
Saturation	↑	↓
Groundwater salinity	↔	↓

↑ Increases ↓ Decreases ↔ No Change

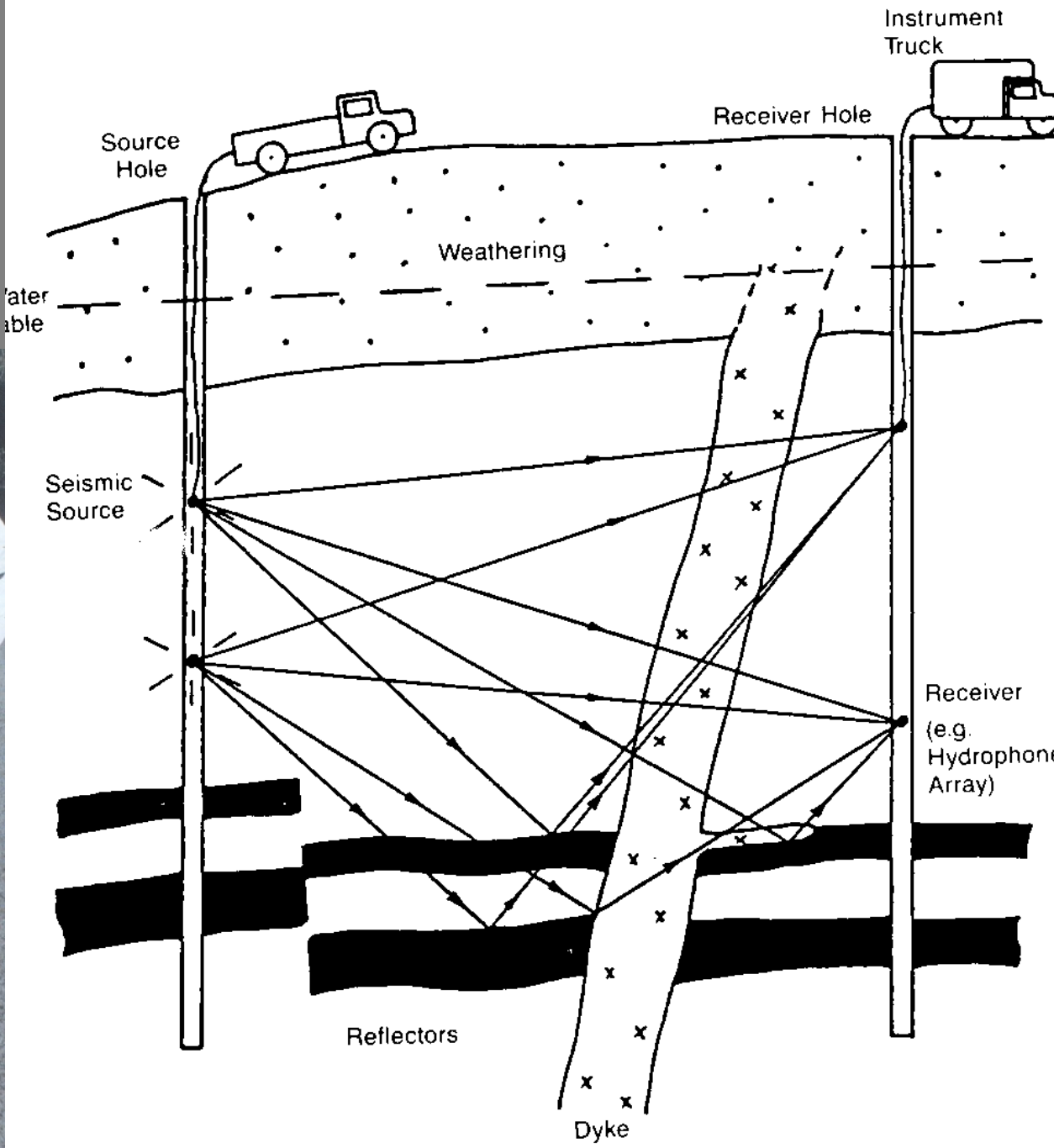
Seismic Refraction



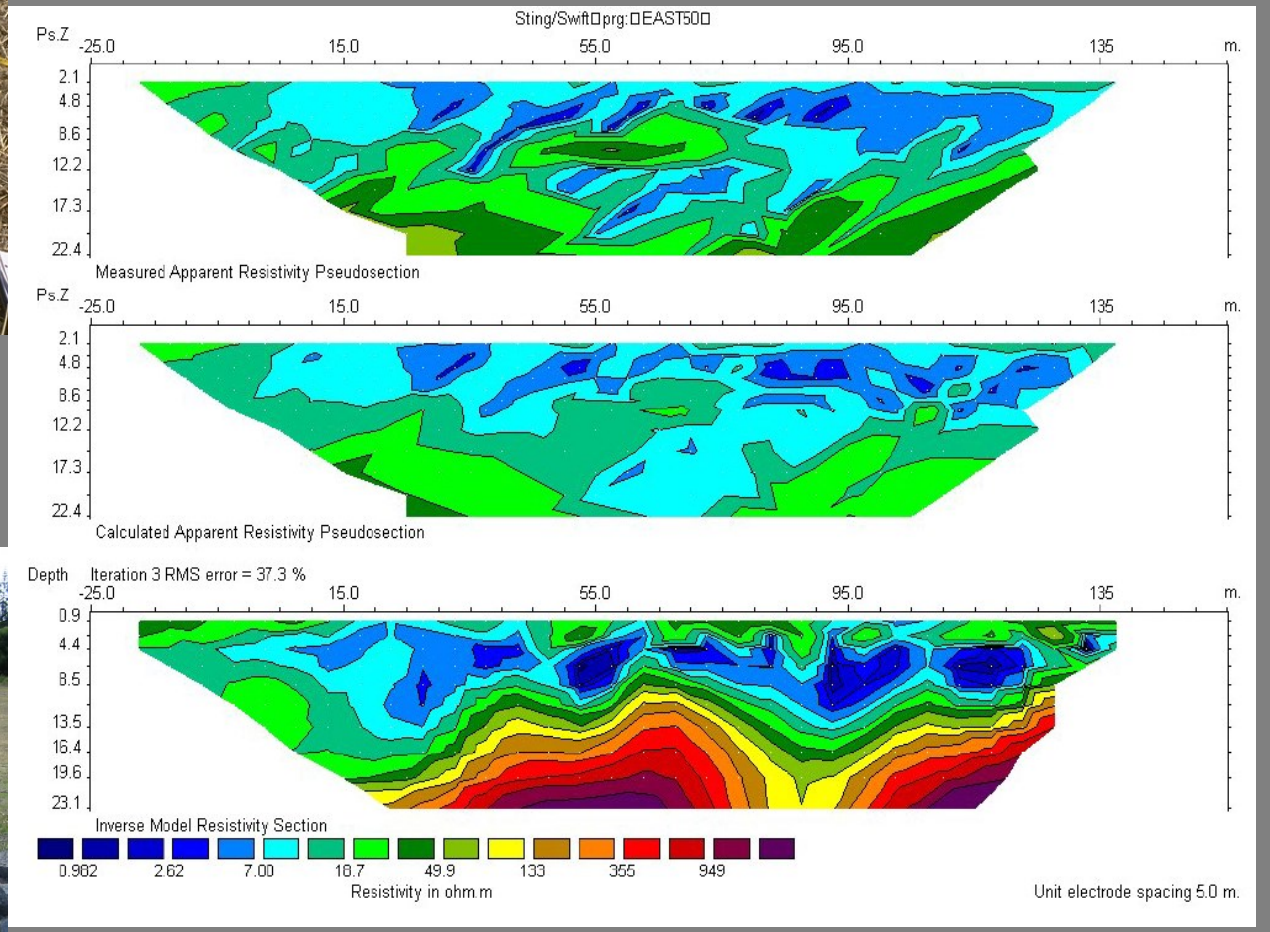




Borehole Seismic

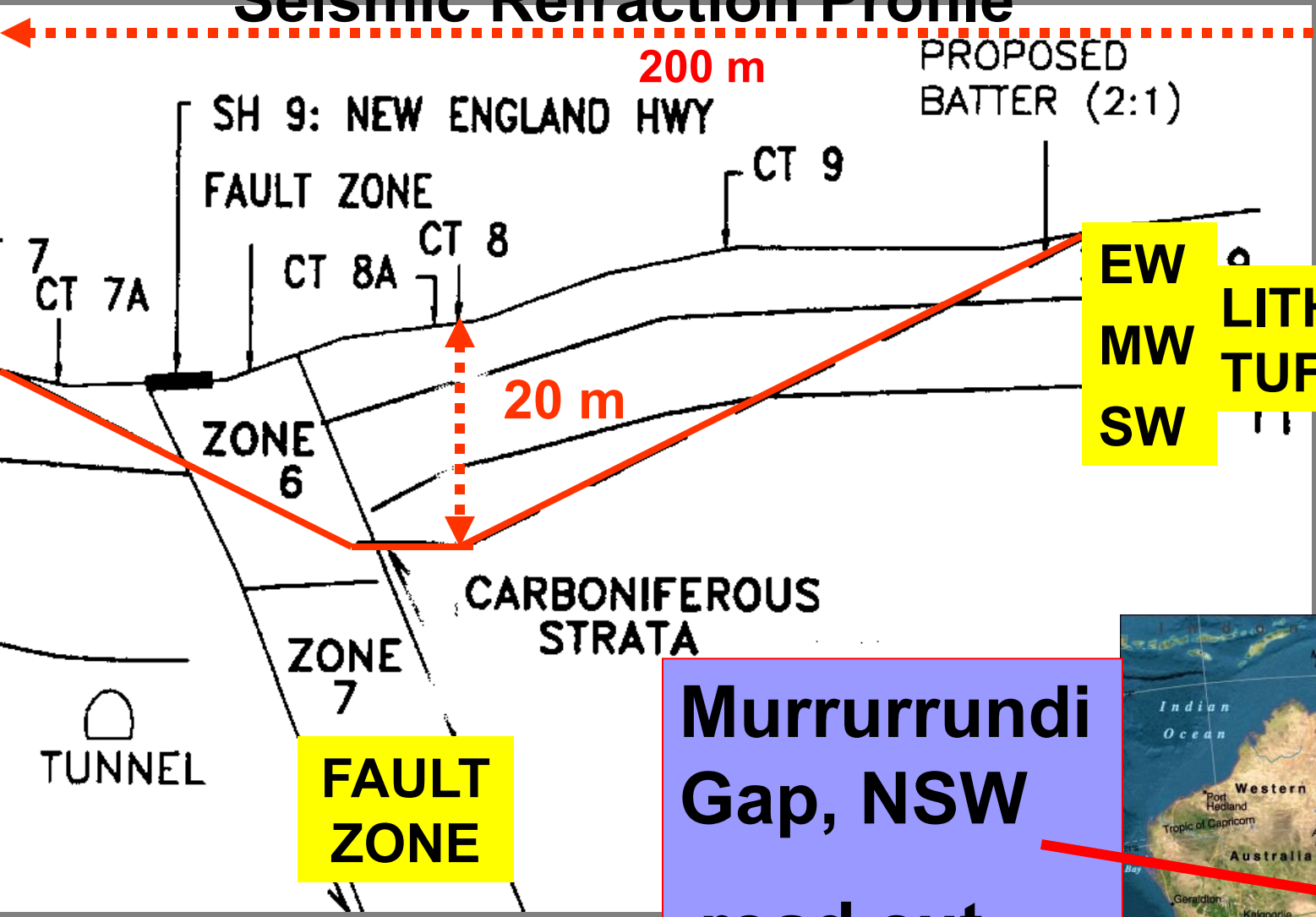


ELECTRICAL RESISTIVITY IMAGING



Coffey

Seismic Refraction Profile

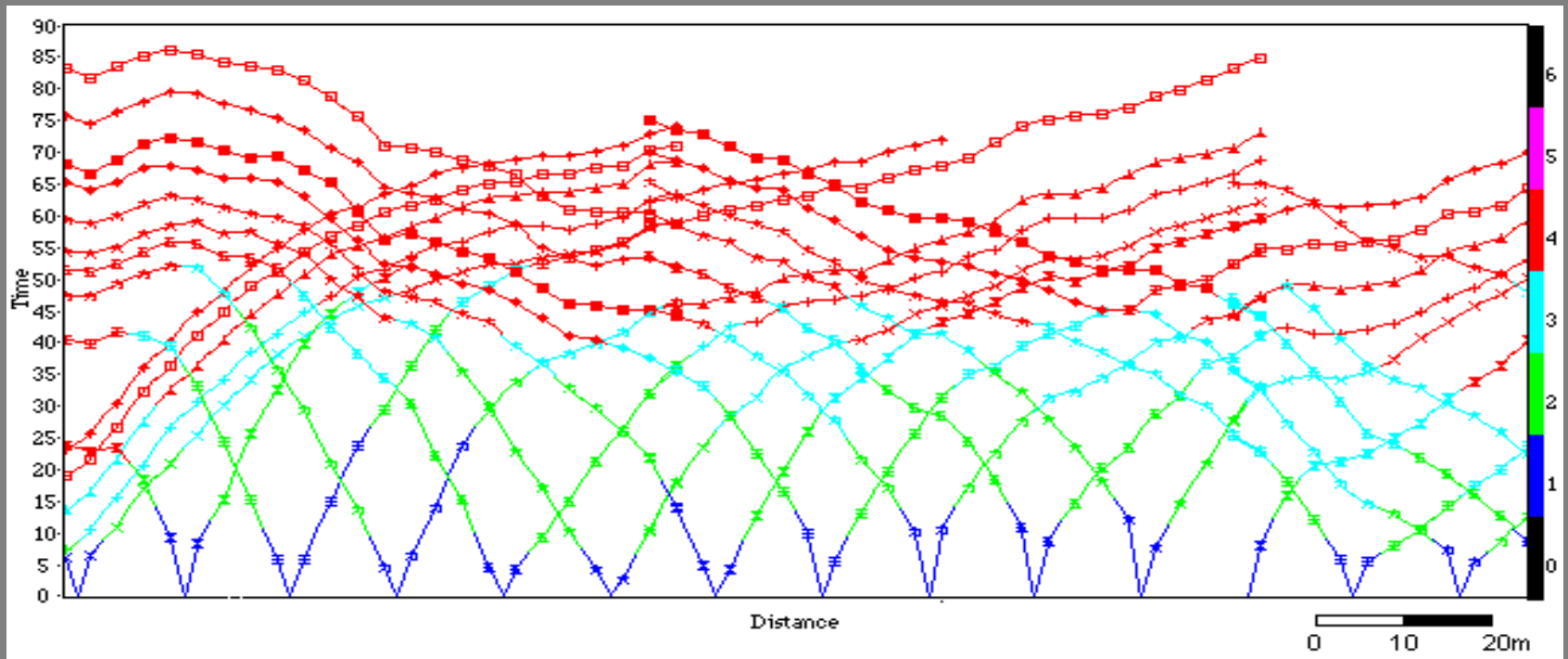


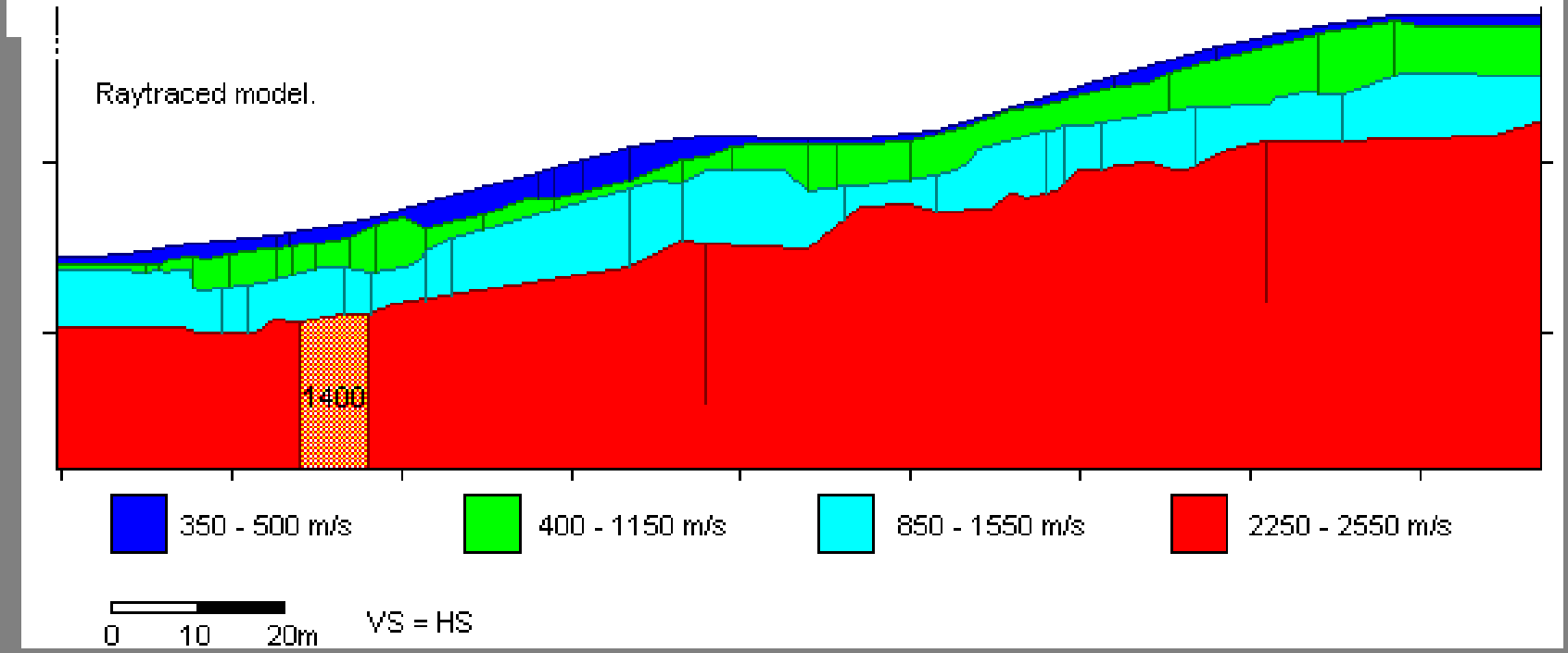
EW
MW
SW

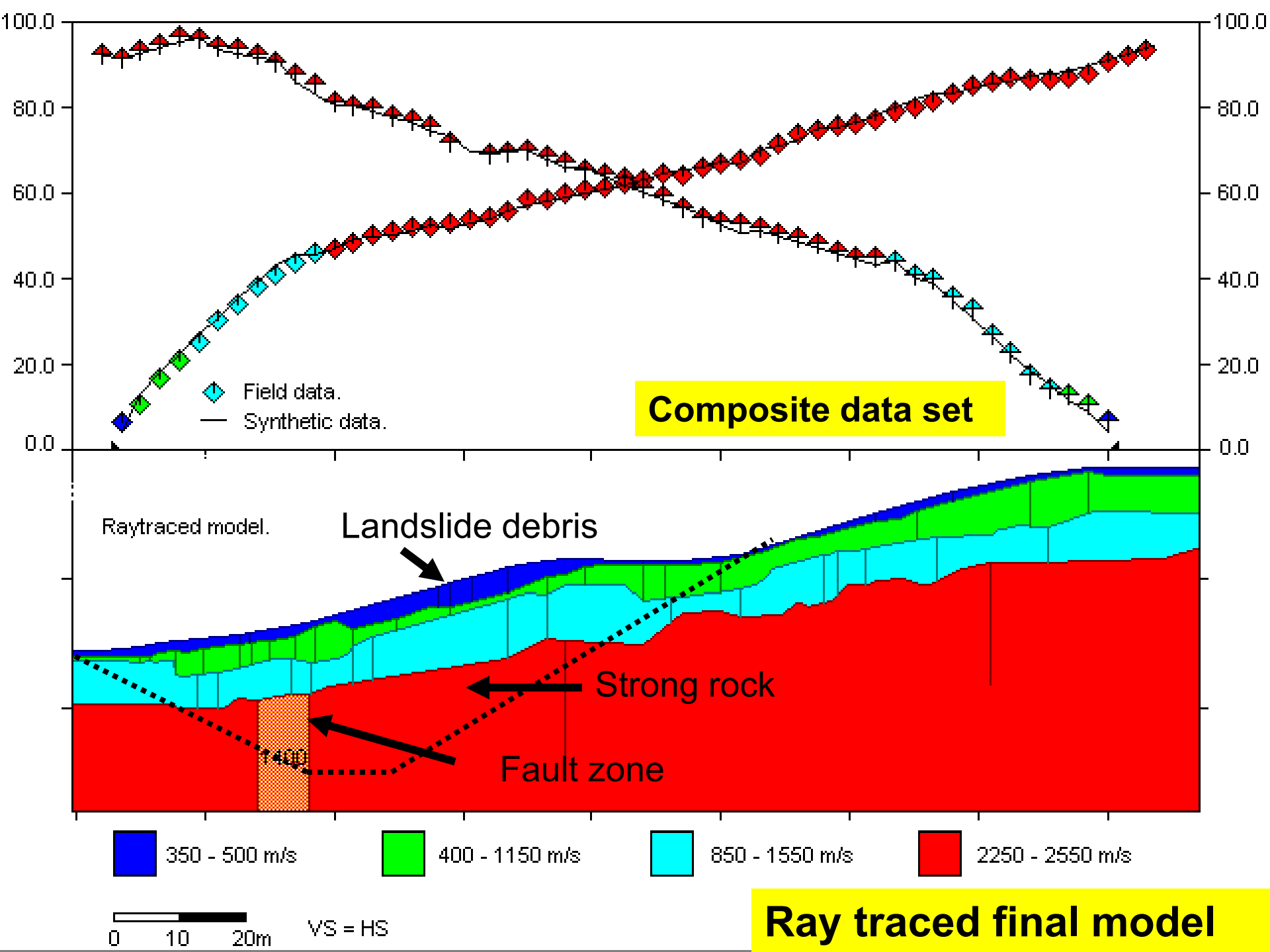
LITHIC
TUFFS

Murrurrundi Gap, NSW

road cut

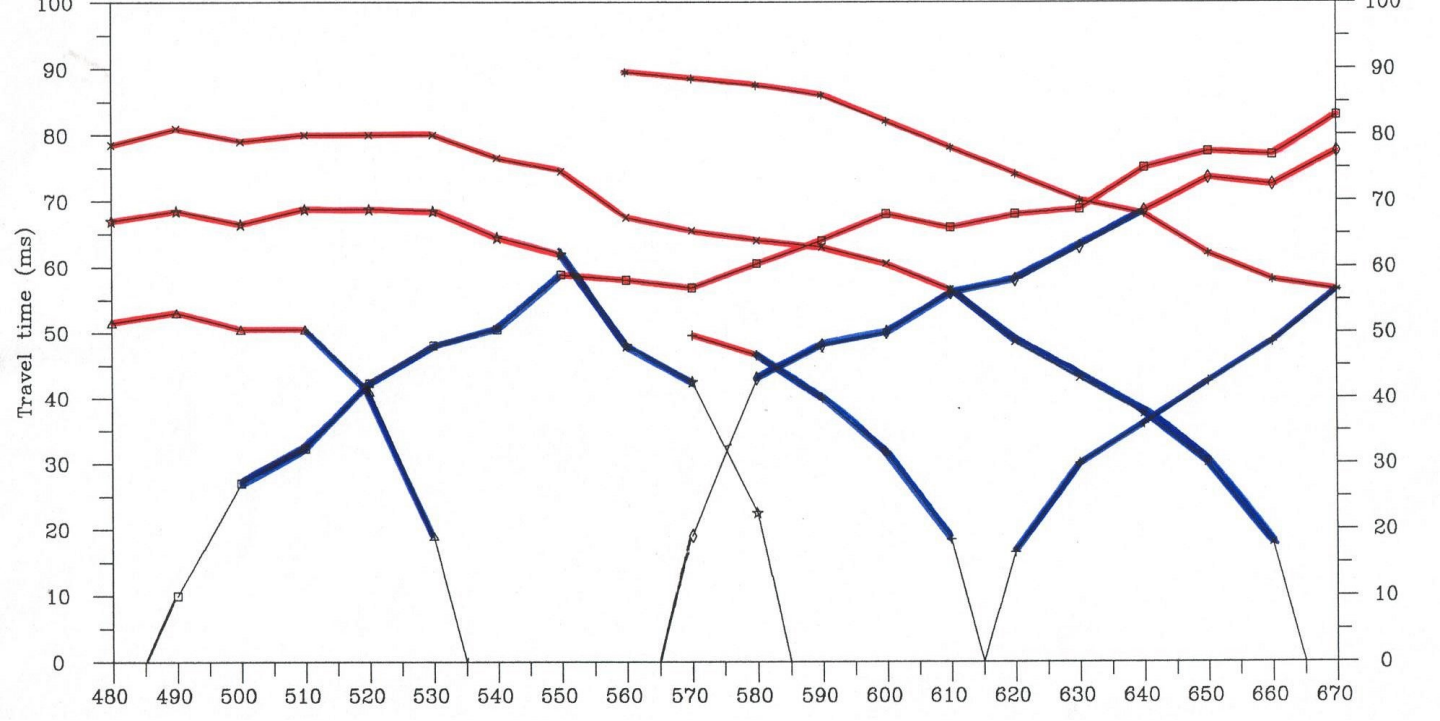

Time
Distance
0
10
20m
0
1
2
3
4
5
6


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

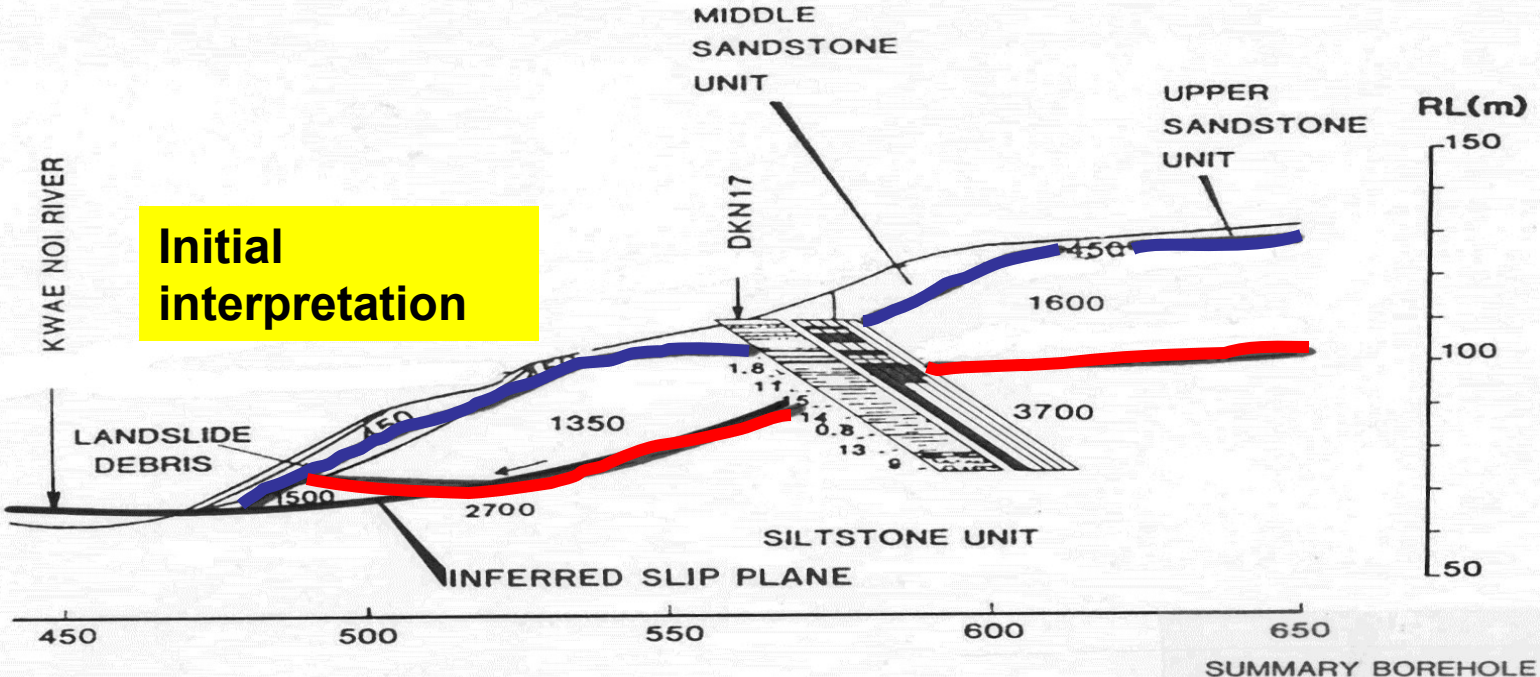

100.0
80.0
60.0
40.0
20.0
0.0
Field data.
Synthetic data.
Composite data set
Raytraced model.
Landslide debris
Strong rock
Fault zone
1400
350 - 500 m/s
400 - 1150 m/s
850 - 1550 m/s
2250 - 2550 m/s
0
10
20m
VS = HS
Ray traced final model

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



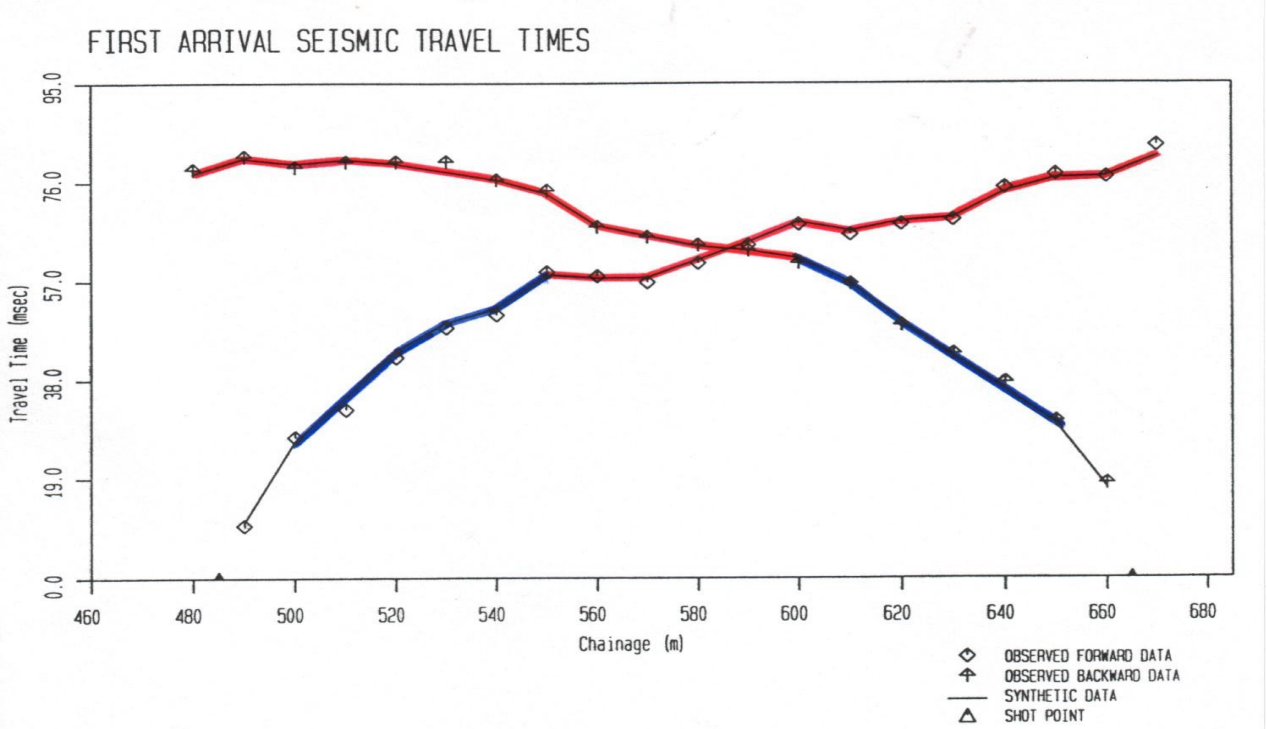
Initial interpretation

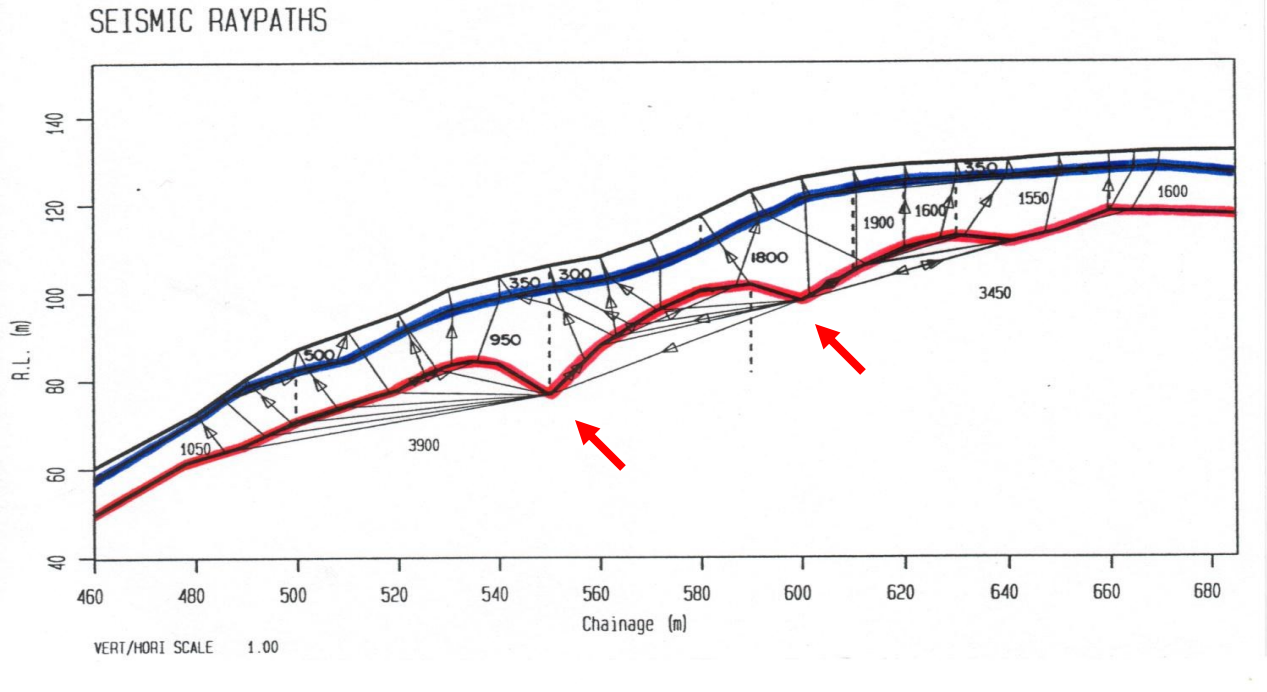


SUMMARY BOREHOLE LOGS

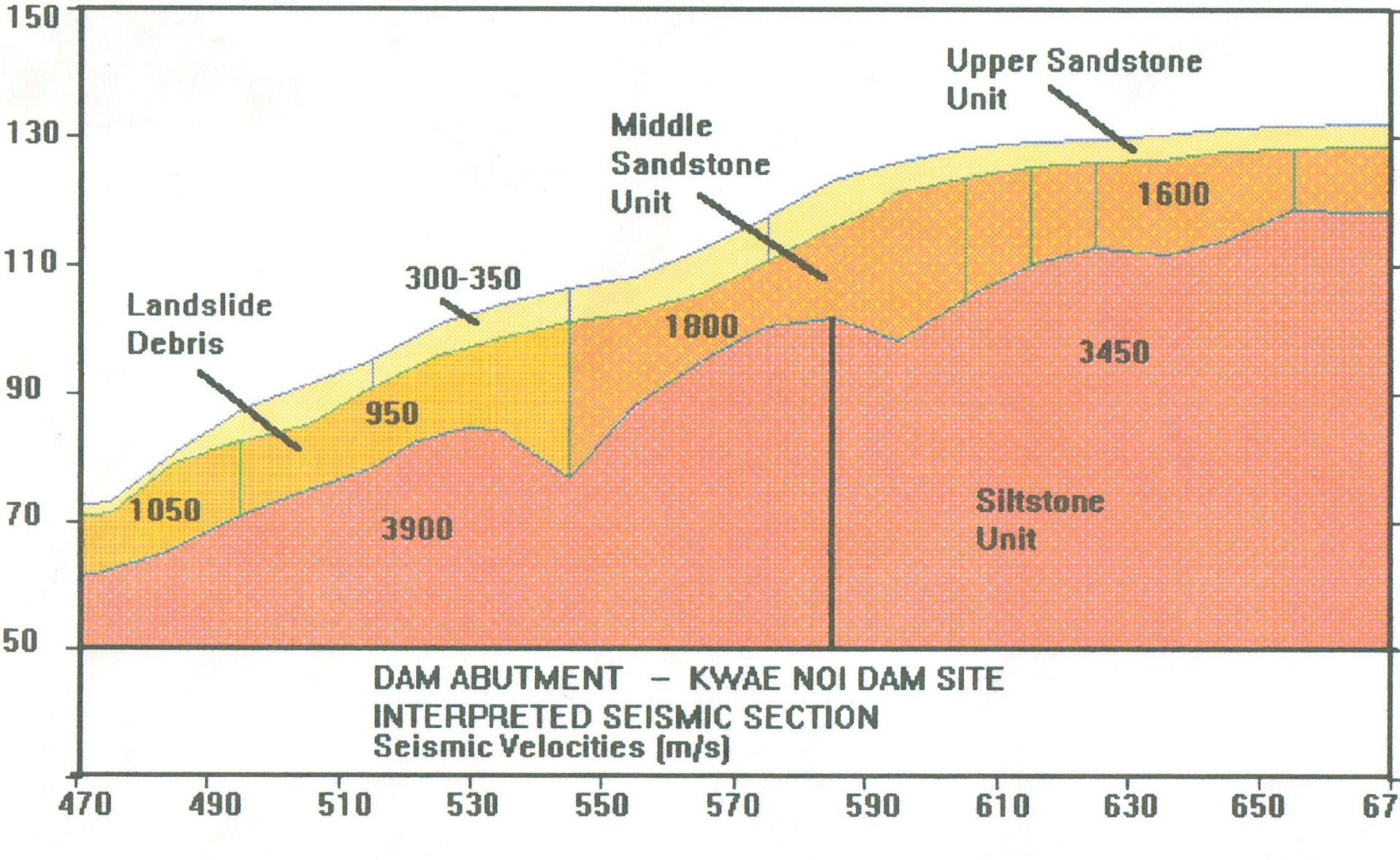
Re-interpretation

Visual Interactive Ray Tracing



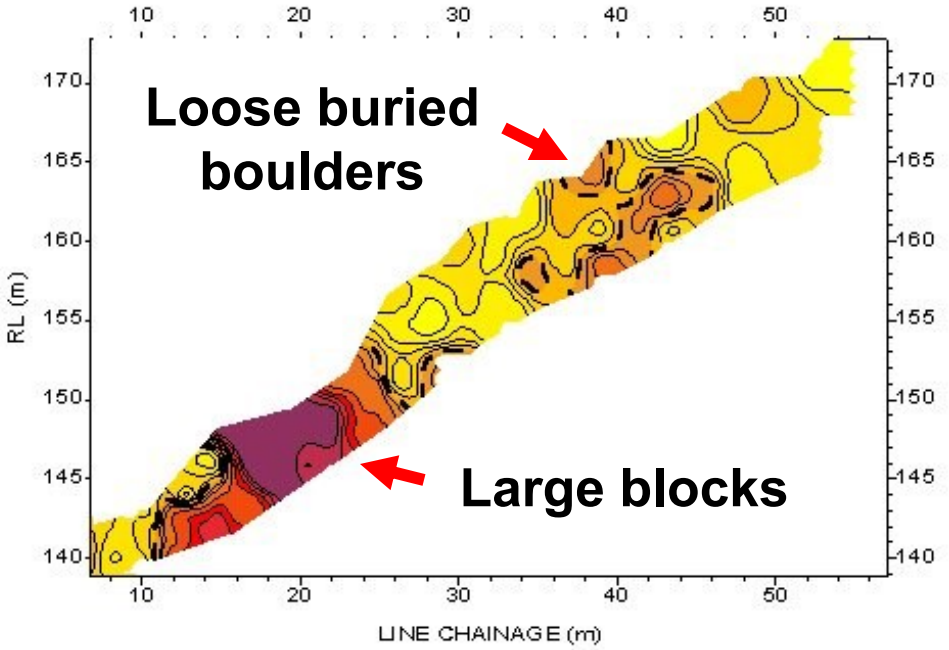


FINAL INTERPRETED SECTION

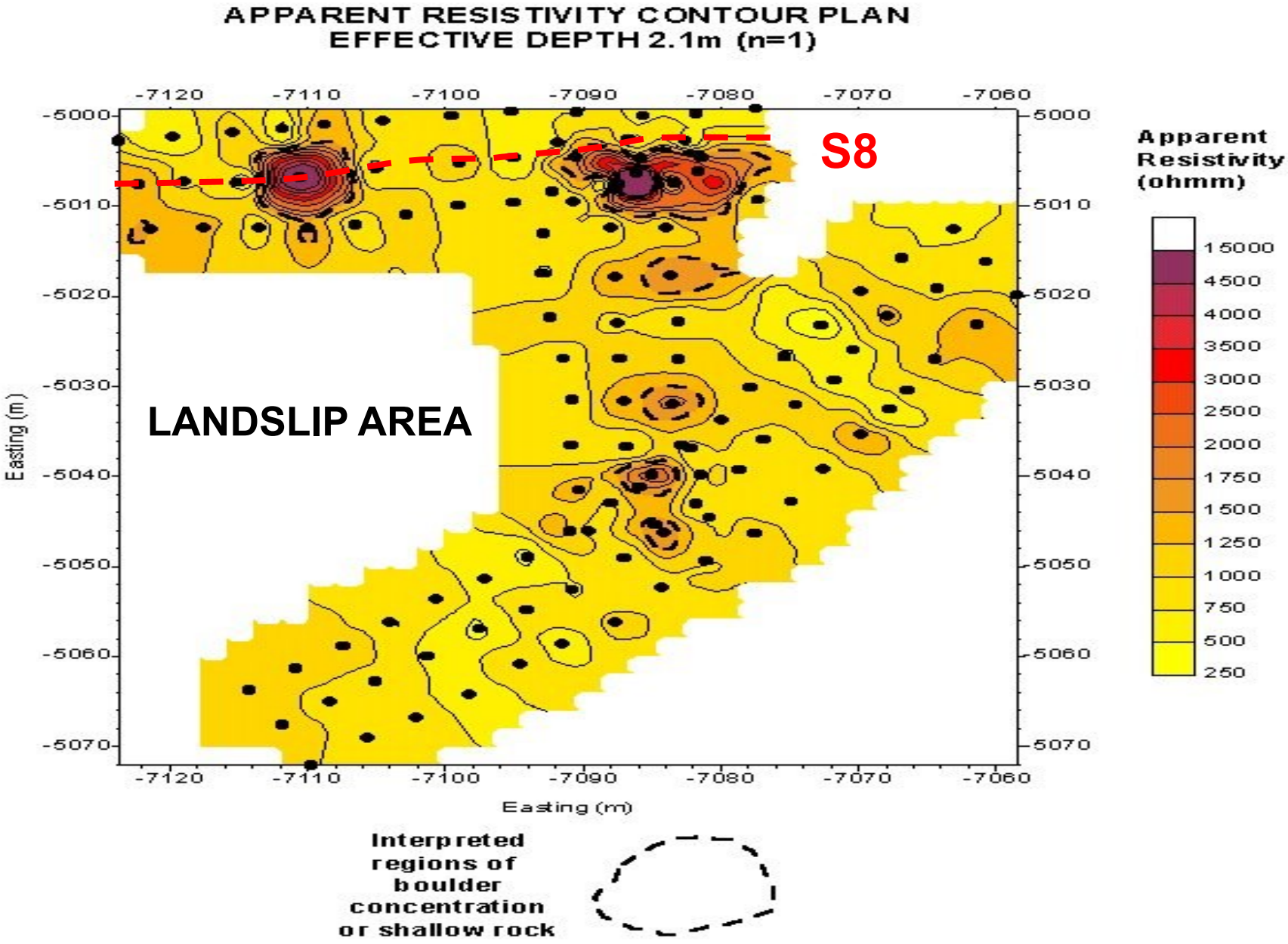


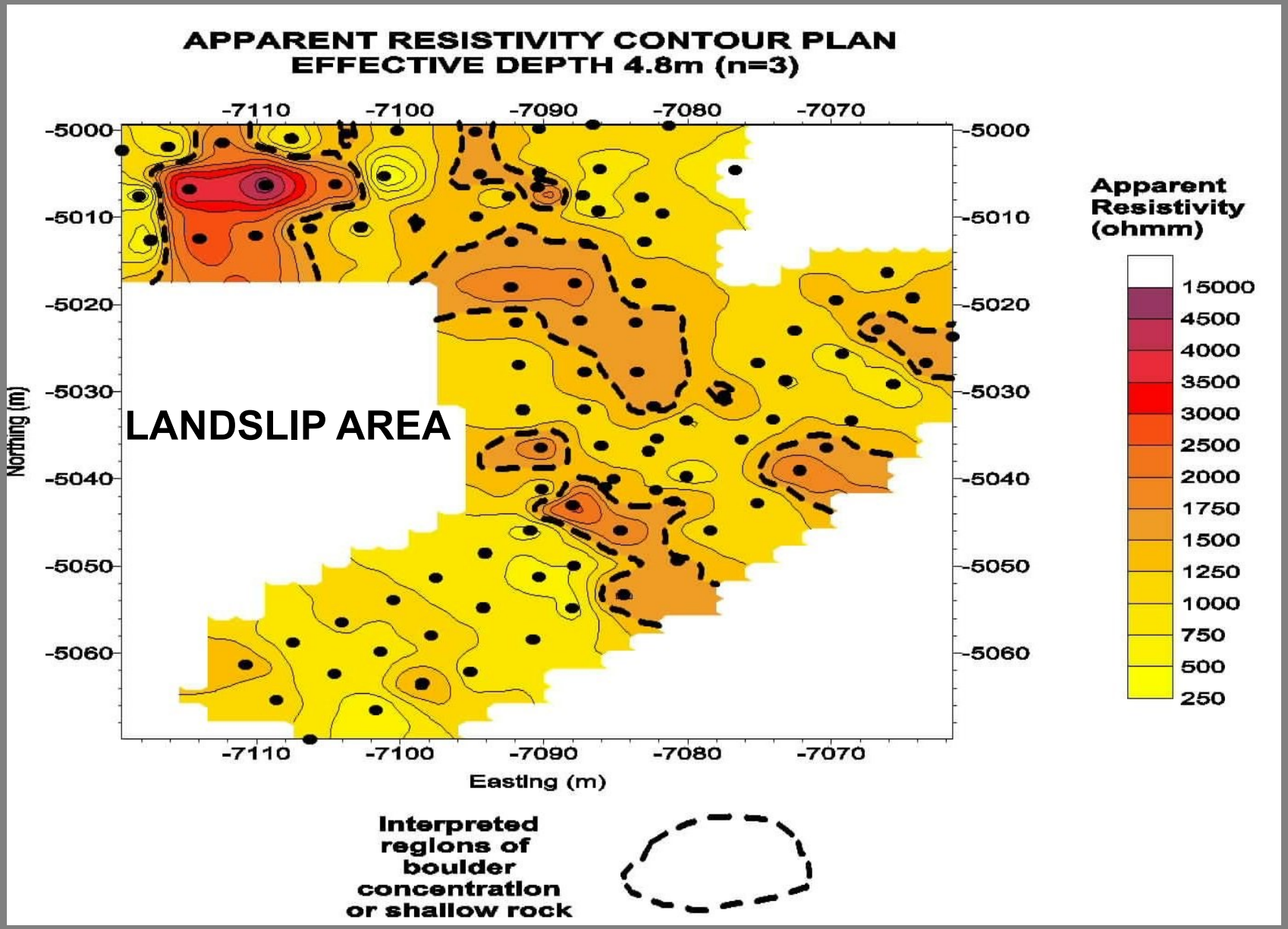
Project	**Road cutting Penang**
Nature of Instability	**Landslip in weathered granite**
Task	**Locate buried boulders**
Geophysical Technology	**Electrical resistivity**

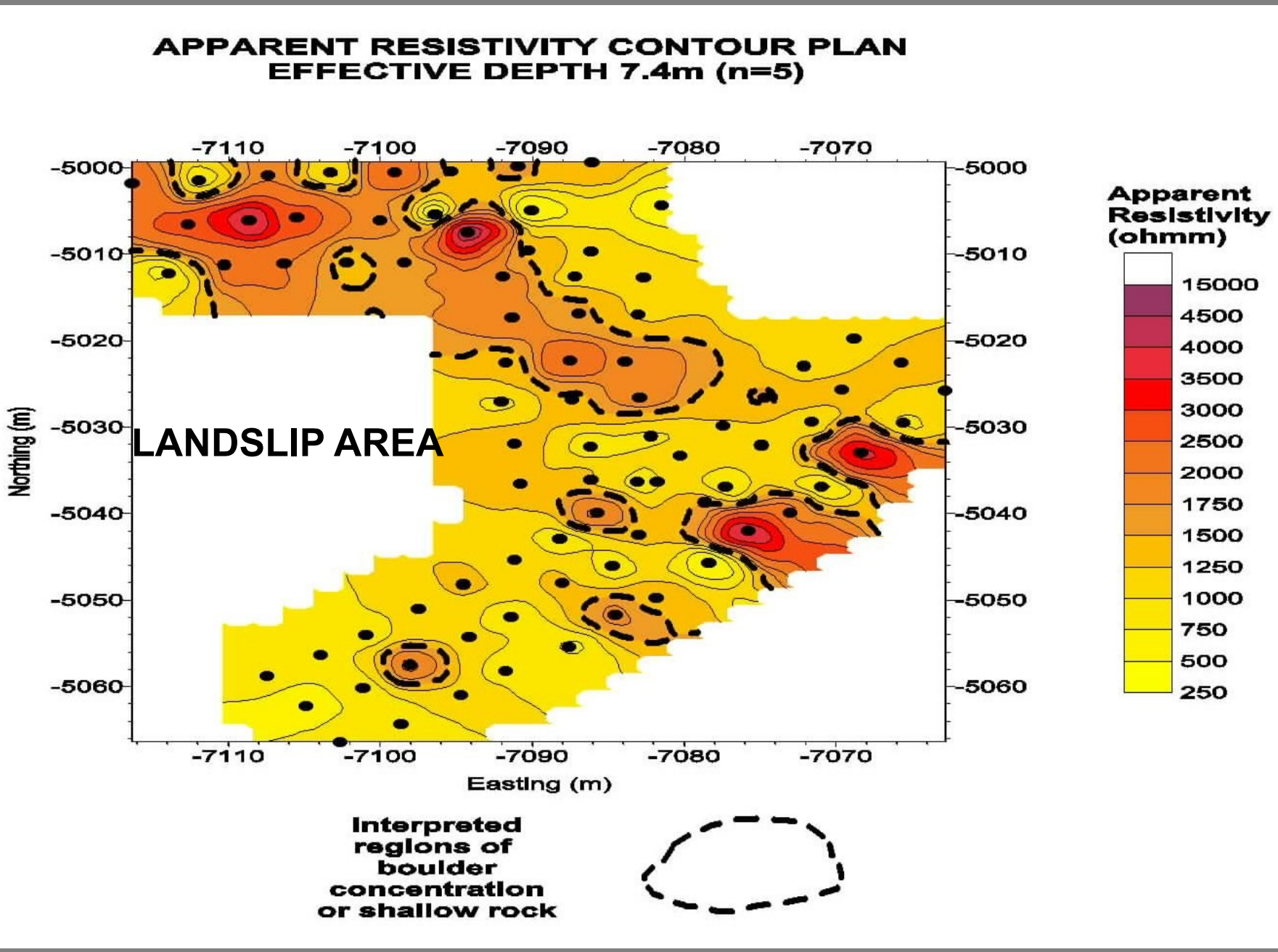
APPARENT RESISTIVITY PSEUDOSECTION
LINE S8

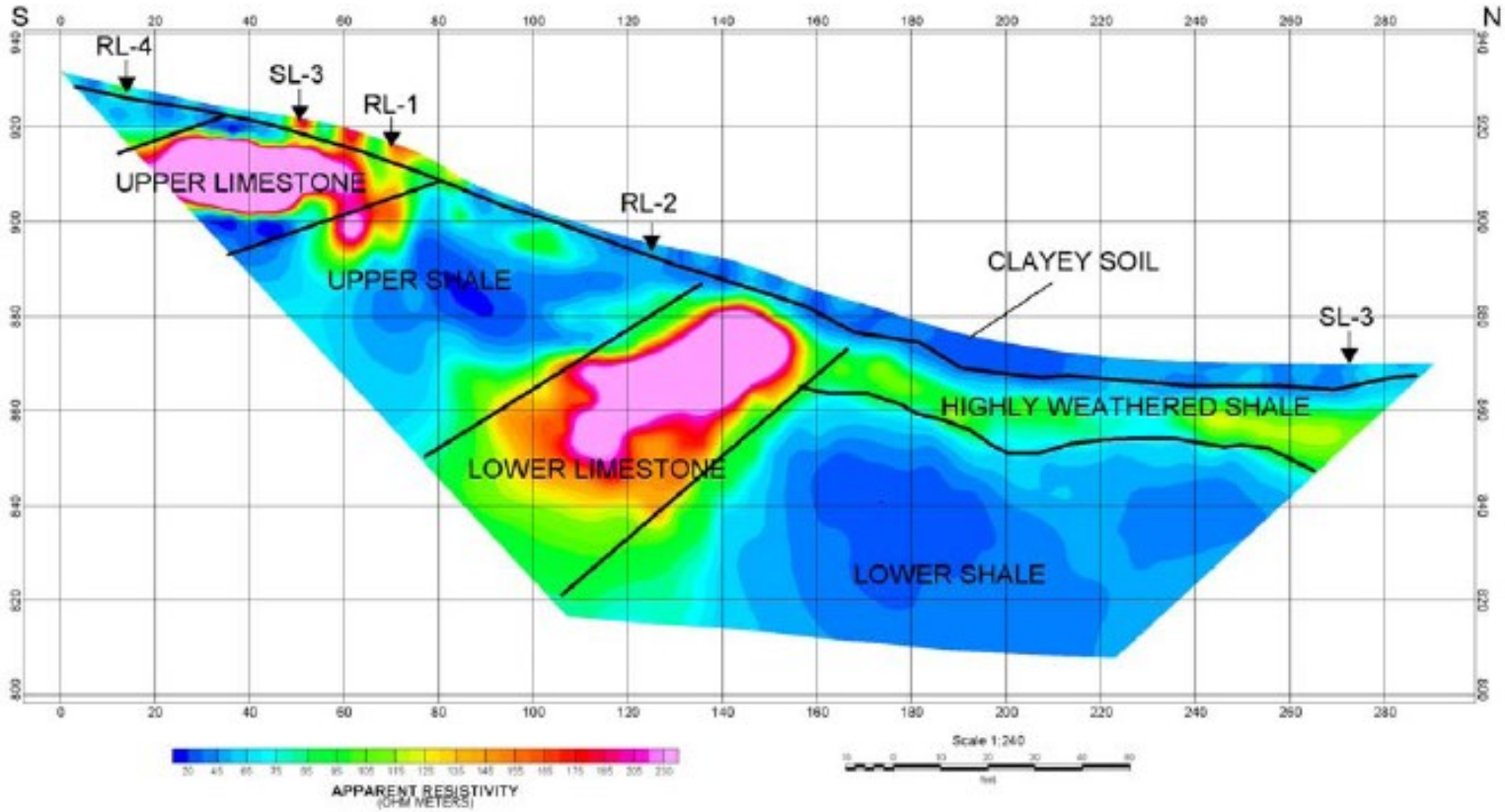


Interpreted regions of boulder concentration or shallow rock


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

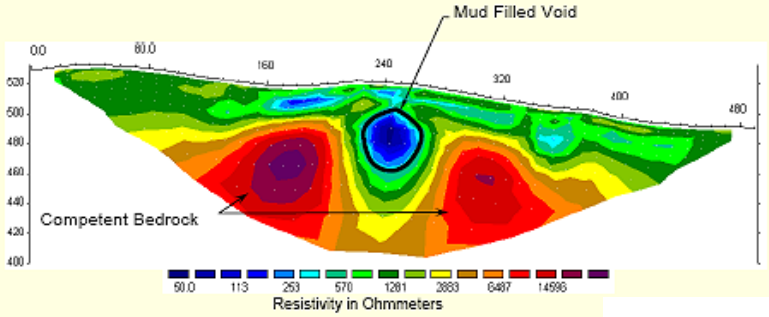

APPARENT RESISTIVITY CONTOUR PLAN
EFFECTIVE DEPTH 4.8m (n=3)
-7110
-7100
-7090
-7080
-7070
-5000
-5010
-5020
-5030
-5040
-5050
-5060
Northing (m)
Easting (m)
LANDSLIP AREA
Apparent Resistivity (ohmm)
15000
4500
4000
3500
3000
2500
2000
1750
1500
1250
1000
750
500
250
Interpreted regions of boulder concentration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



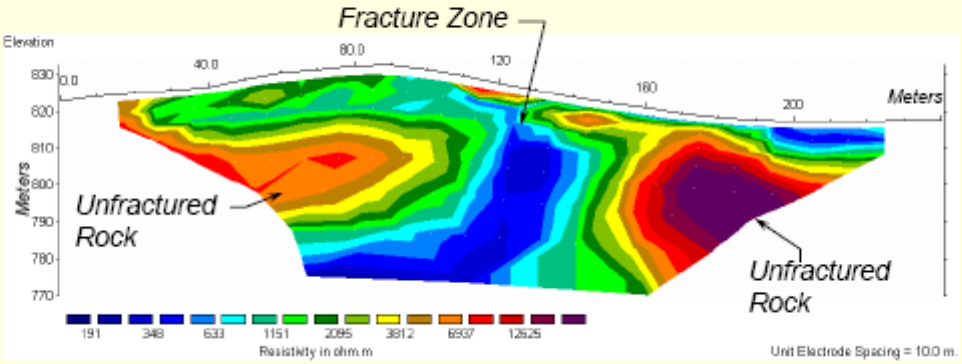
Lithological & soils mapping with Electrical Resistivity Imaging

Karst Features/Voids



ERI in highly variable conditions

Fracture Zones




Darwin
NT
QLD
WA
SA
Brisbane
Perth
NSW
Sydney
Adelaide
VIC
Canberra
Melbourne
TAS
Hobart


Dubbo
Taree
Scone
Wellington
Muswellbrook
Peak Hill
Mudgee
Singleton
Forster
Raymond Terrace
Molong
Orange
Bathurst
Nelson Bay
NEWCASTLE
Lithgow
Wyong
Gosford
Cowra
Oberon
SYDNEY
Boorowa
Mittagong
Crookwell
WOLLONGONG
Yass
Goulburn
Kiama
Nowra
Gundagai
Tumut
Queanbeyan
Ulladulla
ACT
Batemans Bay
Moruya
Cooma
Narooma
Bombala
Bega


CAMDEN
CAMPBELLTOWN
Kentlyn
Engadine
Heathcote
CARINGBAH
Heathcote NP
Maianbar
Bundeena
Waterfall
ROYAL NP
Wattamolla (Loc)
Douglas Pk
Appin
HELENSBURGH
Lilyvale
Otford
Darkes Forest
Stanwell Park
Coalcliff
Scarborough
Wombarra
Coledale
Austinmer
Thirroul
Bulli
Woonona
Corrimal
Towradgi
Balgownie
Fairy Meadow
Mt Ousley
Keiraville
Fig Tree
WOLLONGONG
UNANDERRA
Coniston
Lake Cataract
Punch Bowl Ck
Woronora Lake
Woronora R
Hacking R
Cataract R
Stokes Ck
O'Hares Ck
SRA
Darkes Forest Track
BULLI PASS
Site location

Some Historical - rock falls

1987-GD1

2001-GD3

2004-GD4

2004-GD2

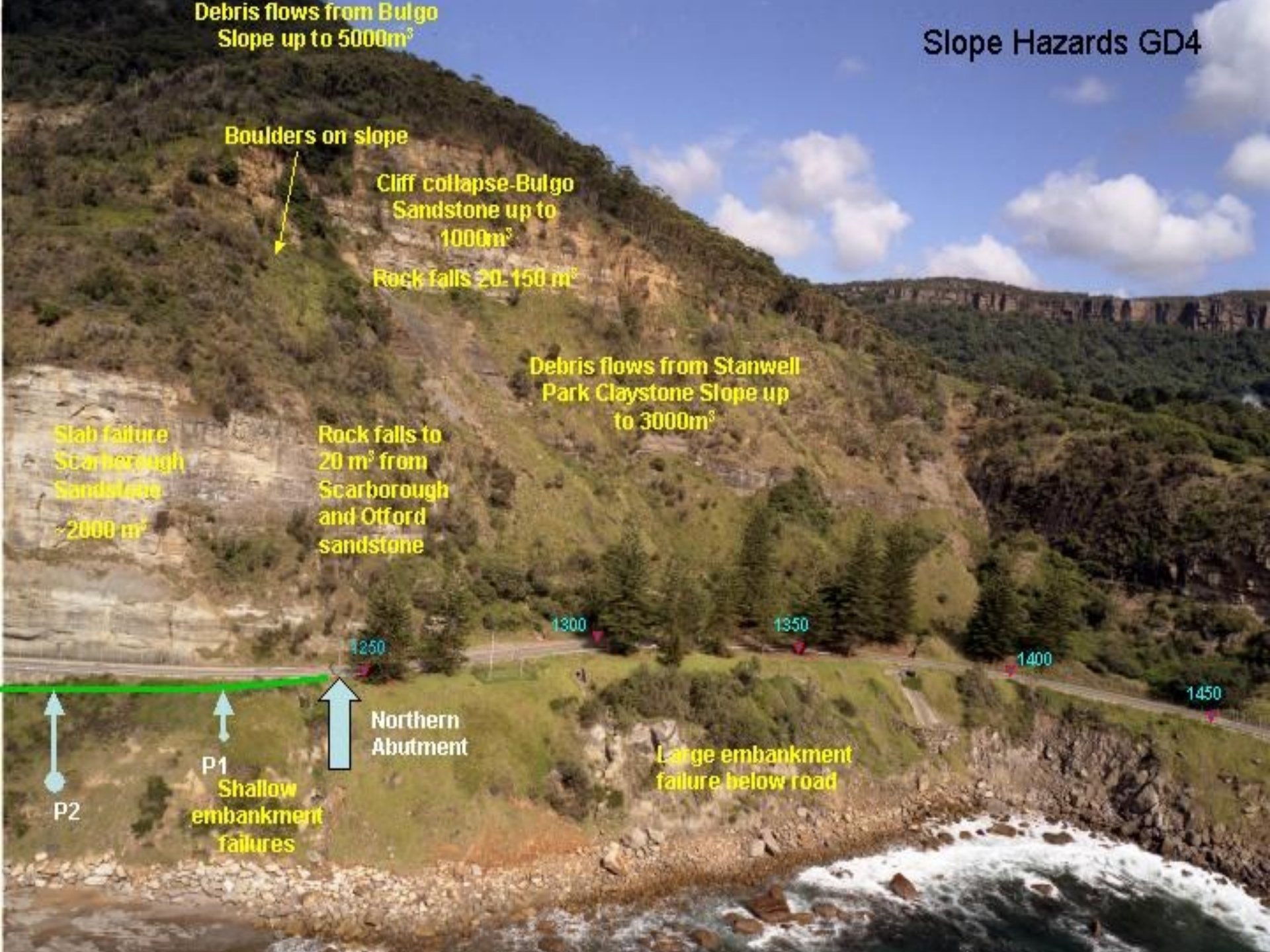
Some Historical - Debris Flows

Circa 1880-GD3

1950-GD1- looking south

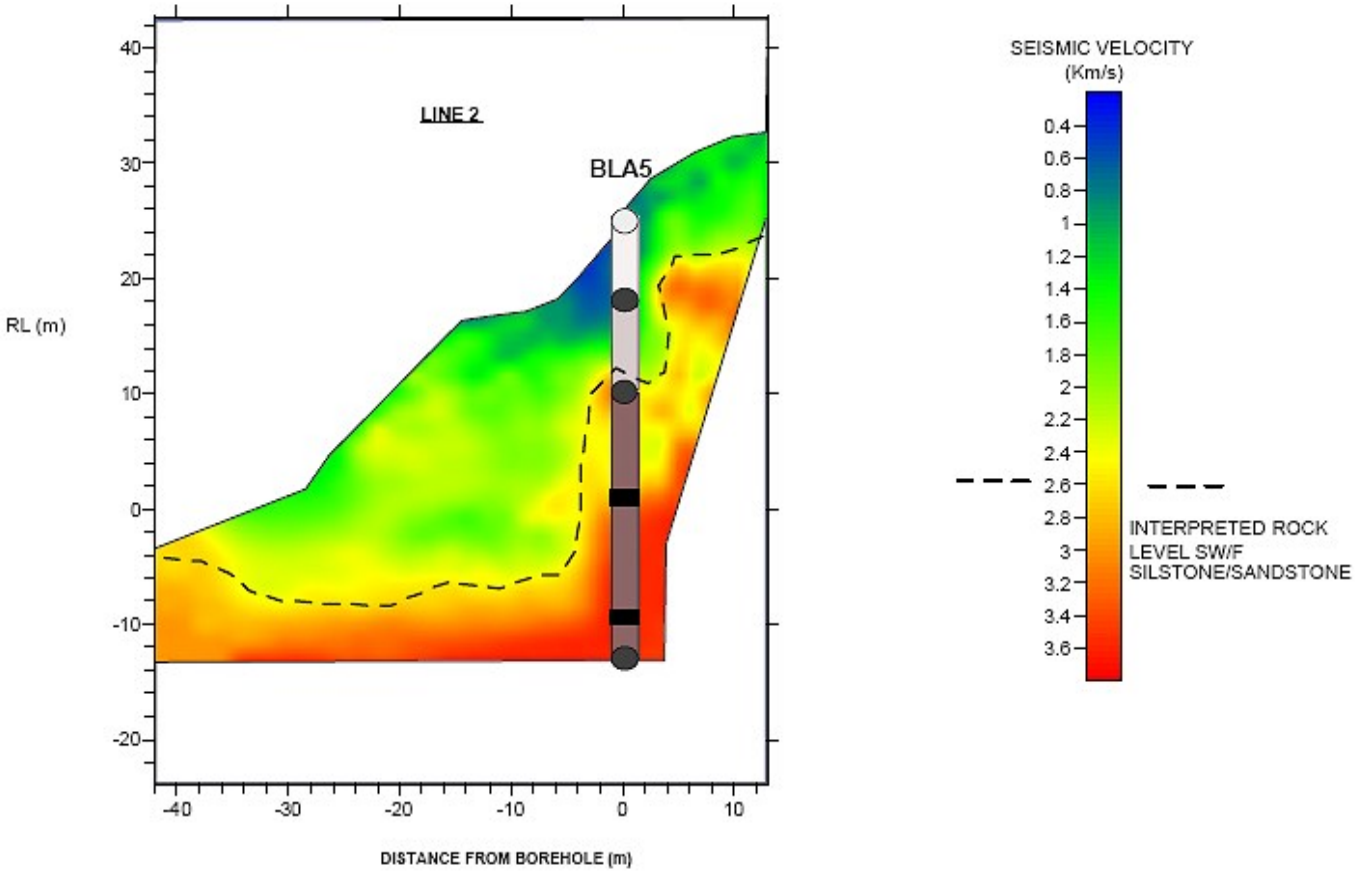
1950-GD2

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
1300
1350
1250
1400
1450
Northern Abutment
P1
P2
Shallow embankment failures
Large embankment failure below road

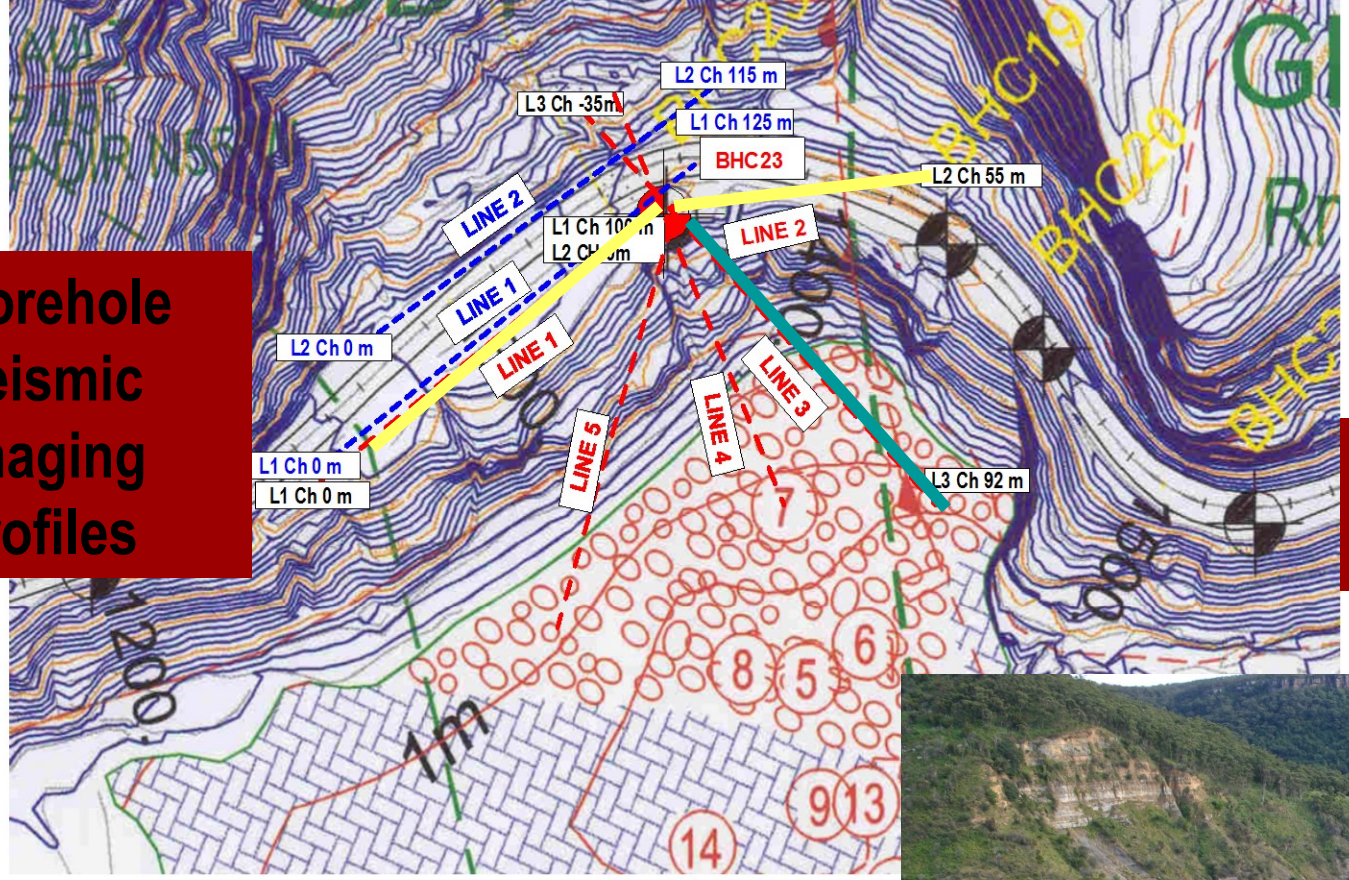
borehole

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

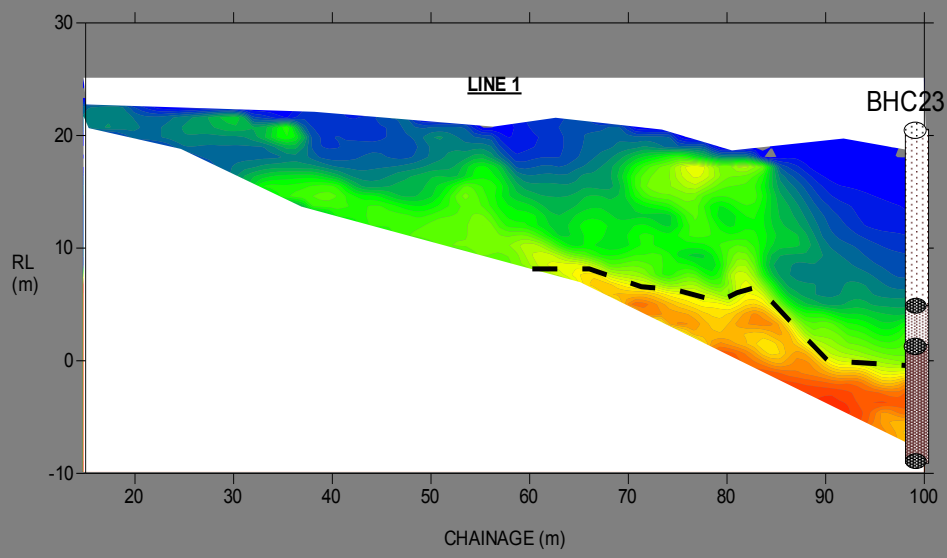


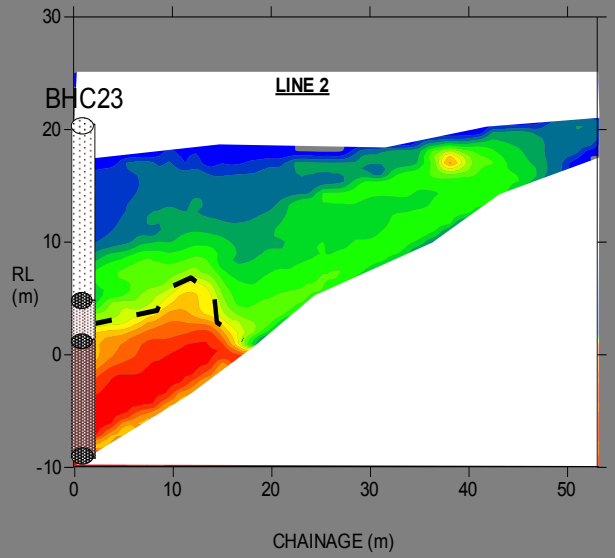
LEGEND

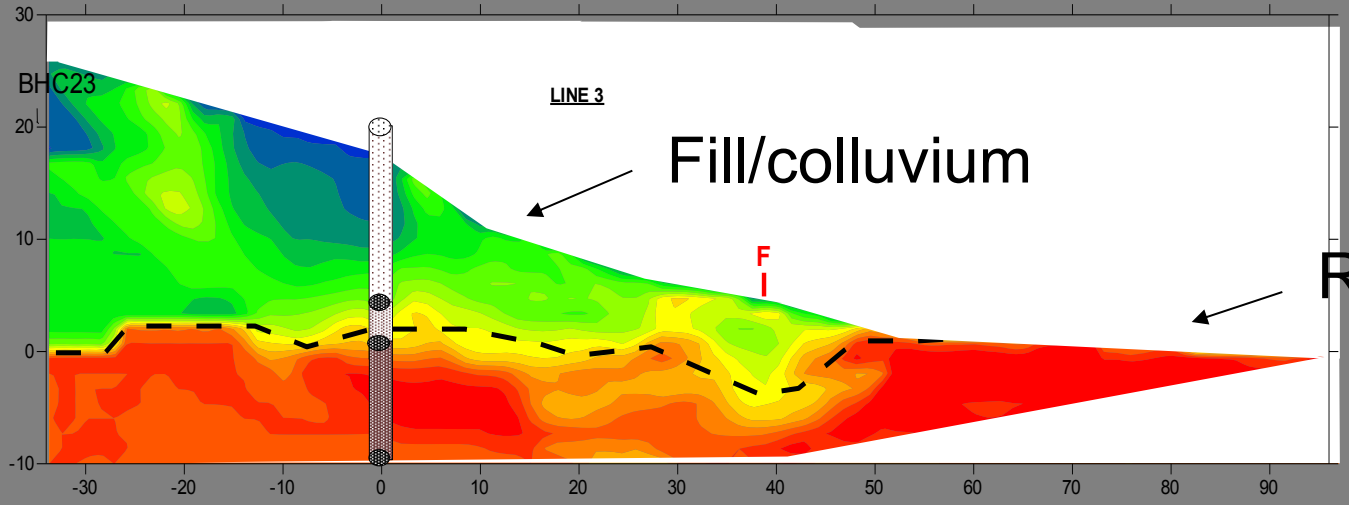
- BOREHOLE BHC 23
- LINE 1 SEISMIC PROFILE
- LINE 1 RESISTIVITY PROFILE

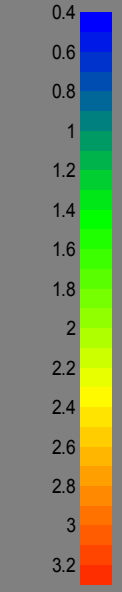
New Highway Construction

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
SEISMIC IMAGES

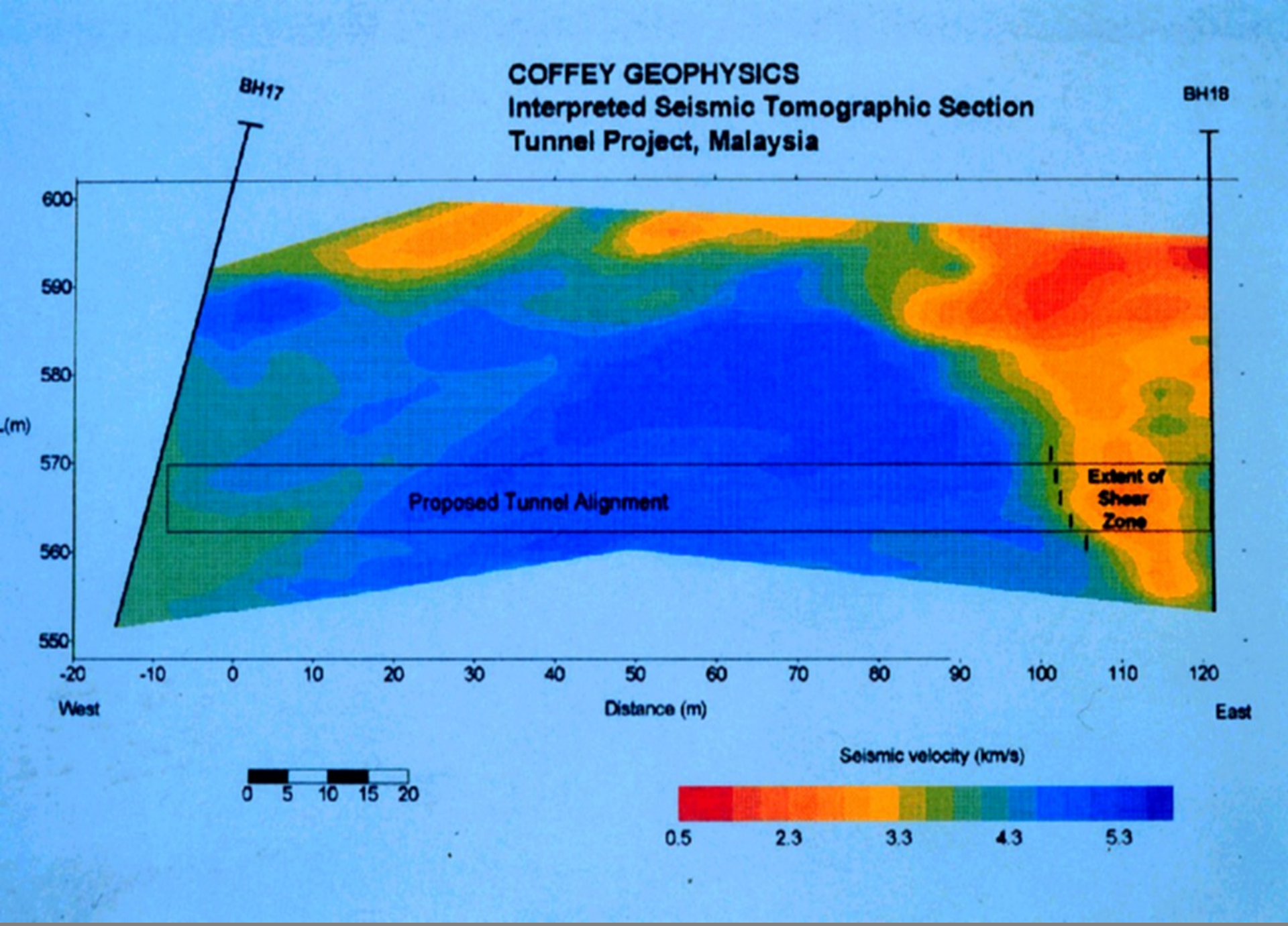
FIGURE 2

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
570
560
550
(m)
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