Site Investigations

for

Natural Terrain Hazard Assessments

Steve Parry (GEO)

Talk is divided into two parts

- use of geomorphology and API to develop hazard models
- Focused detailed GI to assess hazard models

- Site Investigation does not equal Ground Investigation
- For Natural Terrain a holistic approach is required i.e. all encompassing
- Given difficult access, dense vegetation, the size of site any SI needs to be focused and this is best achieved by the development of models
- To develop models you be able to “read” the landscape which requires skills and experience, these including an understanding of engineering geology, geomorphology and natural terrain hazards. However, there is limited experience of geomorphological mapping in Hong Kong and even less experience with respect to developing models of landscape evolution

Geomorphology

"is the study of the forms of the surface of the earth, their origin, the processes involved in their development, the properties of the materials of which they are made and predictions about their future form, behavior and status"

(D Brunsden, 5th Glossop Lecture, 2002)

"While engineering geological mapping is perhaps concerned with a snapshot in time regarding the properties of materials and their immediate or short term engineering implication, geomorphological mapping, in theory, takes in a greater sweep of time, combining the recent geological past with the present geomorphology and its foreseeable future. Deriving an engineering evaluation from an integration of these two approaches combines the short term static with the longer term dynamism of the landscape: an evaluation which is critical to the survival of engineering structures throughout and beyond their notional design life"

Hearn, (2002) Engineering geomorphology for road design in unstable mountainous areas: lessons learnt after 25 years in Nepal. QJEG Vol 35 p143-154

- Need to understand how the landscape evolved and what that can tell us about future hazards
- Key component is API – Interpretation
- Not observation which is what many reports contain often being simple site histories – this is of little use for NTHA.
- Key photographs are 1963/4 use both high and low level as these help put the site in context i.e. where it is within the landscape
- In addition colour photographs, particular early ones are beneficial for vegetation changes, rock outcrops etc.
- A site reconnaissance is also critical during the API helps you to confirm both your observations and interpretation

Common Problems:

- Geomorphological boundaries derived from API are not verified in the field
- Assessments are often restricted to site boundaries. Landforms do not evolve in isolation and in order to develop a model a sufficient large area has to be studied
- When geomorphological mapping is carried out it commonly shows only rudimentary morphological data
- Single mapping approaches are often used e.g. regolith mapping. However as all sites are to some degree unique, some approaches are more useful than others (see TGN 22)
- Studies do not focus on the hazard and risk

Brief introduction to geomorphological approaches

For more details refer to TGN 22

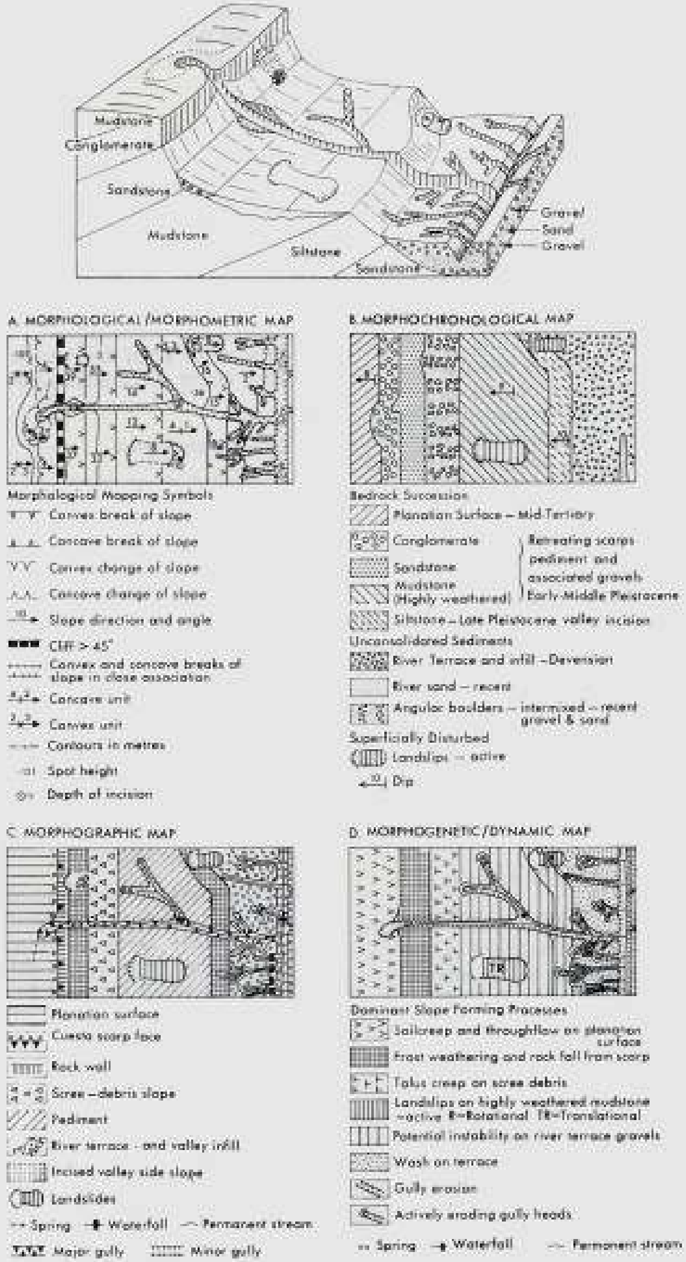
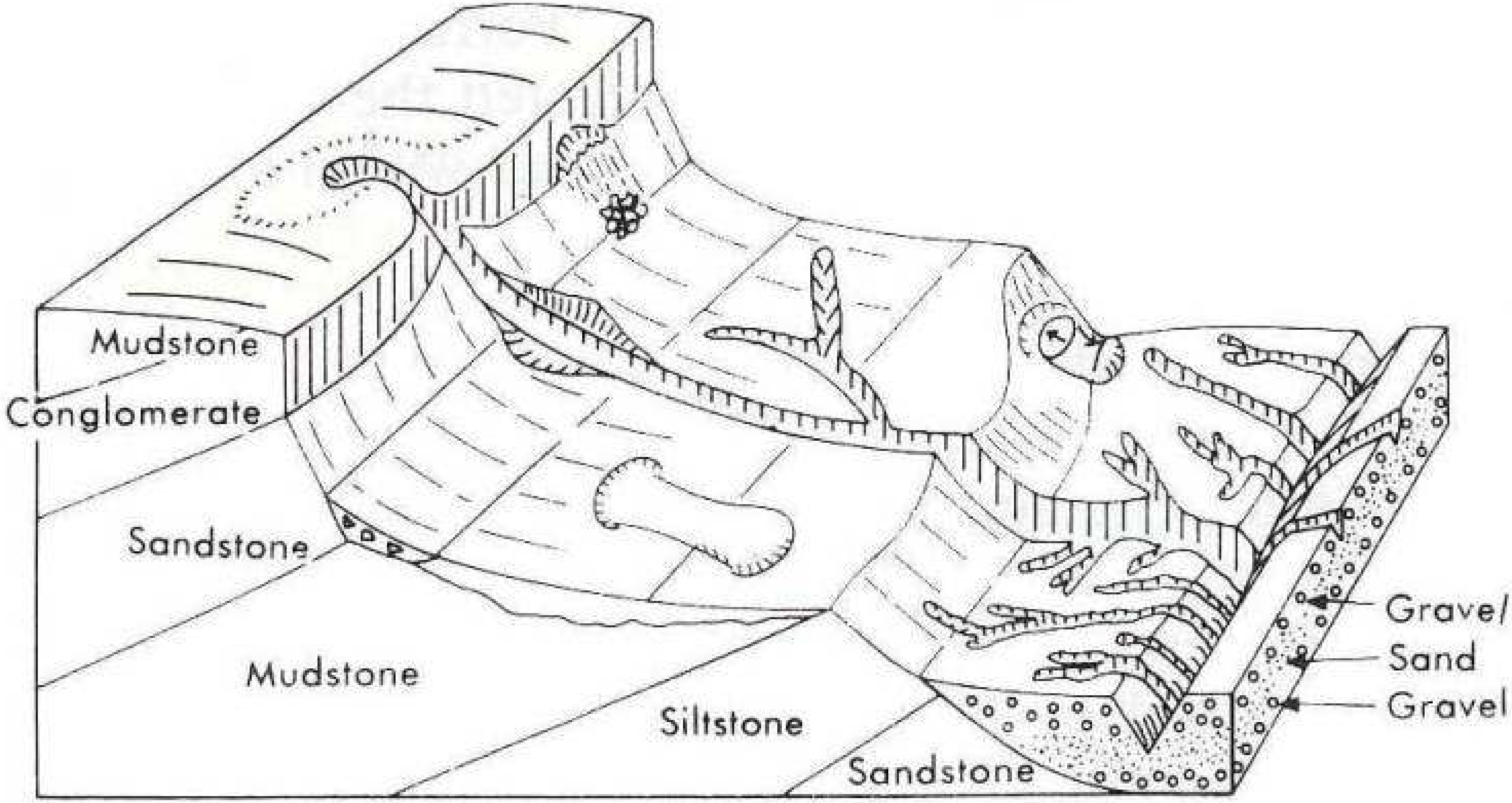
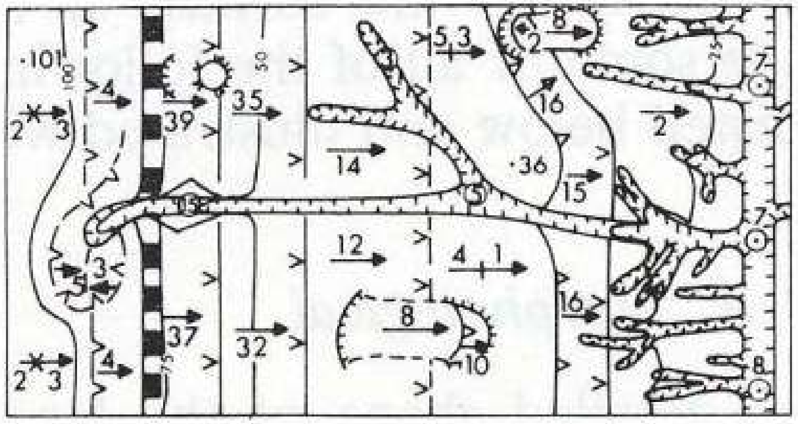


FIG. 2. Schematic diagrams illustrating the different principles of geomorphological map presentation for the same land surface. See paragraph 2.6.1, A–D.


Mudstone
Conglomerate
Sandstone
Mudstone
Siltstone
Sandstone
Gravel
Sand
Gravel

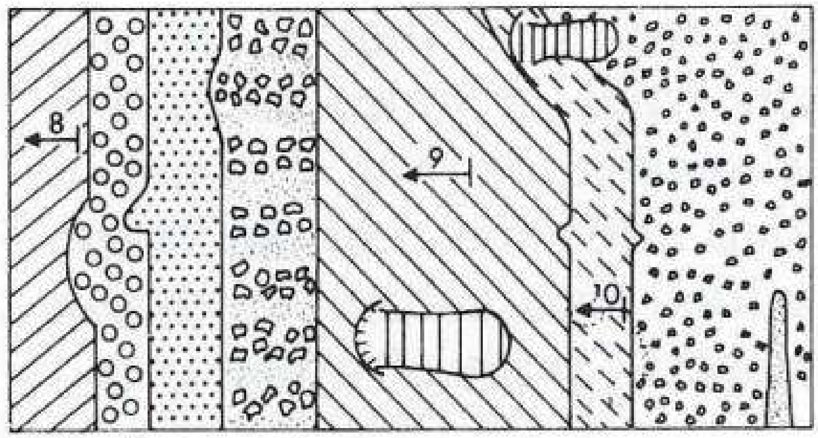
A. MORPHOLOGICAL/MORPHOMETRIC MAP



Morphological Mapping Symbols

- Convex break of slope
- Concave break of slope
- Convex change of slope
- Concave change of slope
- 10 Slope direction and angle
- Cliff > 45°
- Convex and concave breaks of slope in close association
- 4 2 Concave unit
- 2 3 Convex unit
- 75 Contours in metres
- ·121 Spot height
- 15 Depth of incision

B. MORPHOCHRONOLOGICAL MAP



Bedrock Succession

Planation Surface – Mid-Tertiary

Conglomerate

Sandstone

Mudstone (Highly weathered)

Retreating scarps pediment and associated gravels Early-Middle Pleistocene

Siltstone – Late Pleistocene valley incision

Unconsolidated Sediments

River Terrace and infill – Devensian

River sand – recent

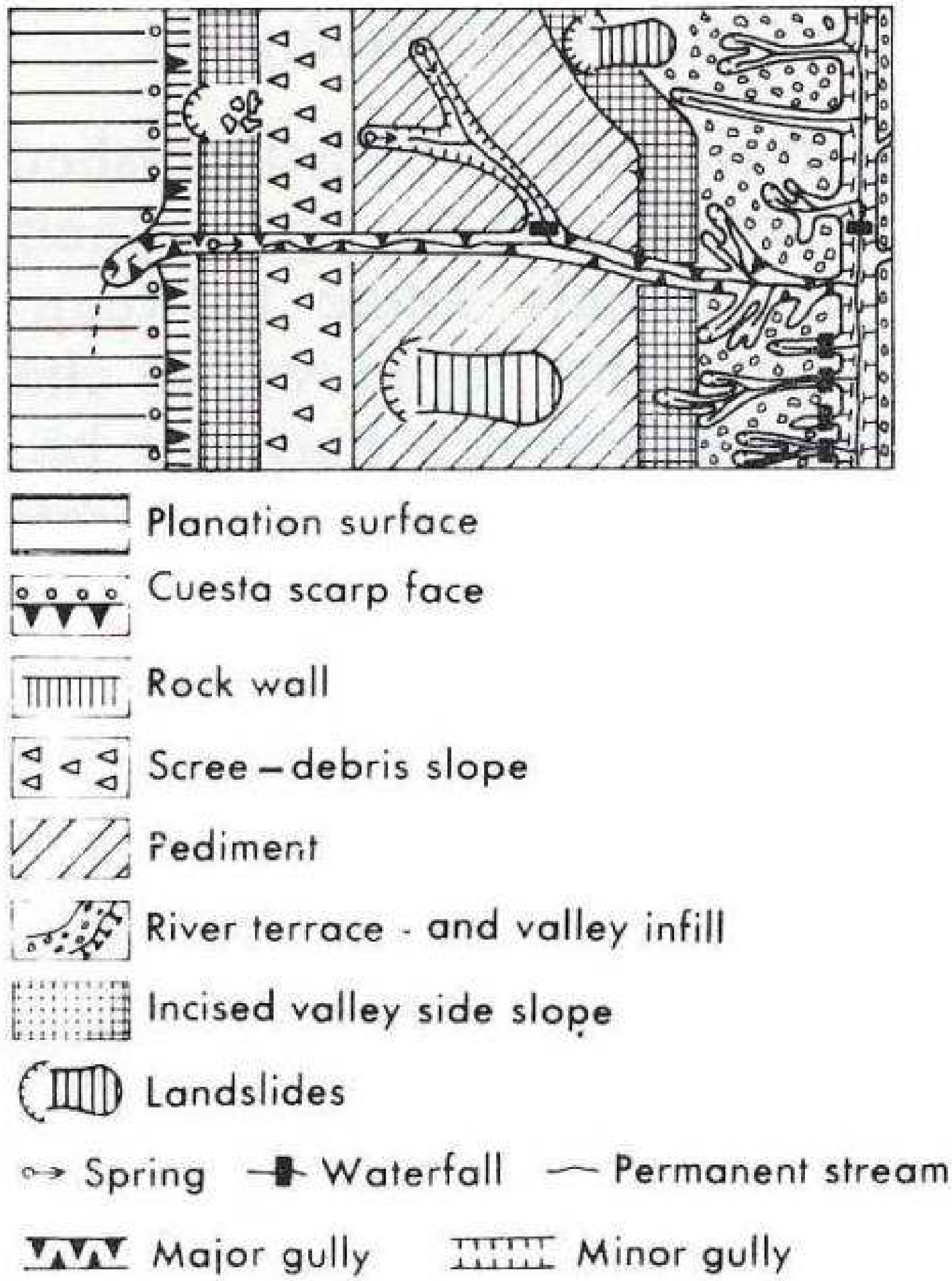
Angular boulders – intermixed – recent gravel & sand

Superficially Disturbed

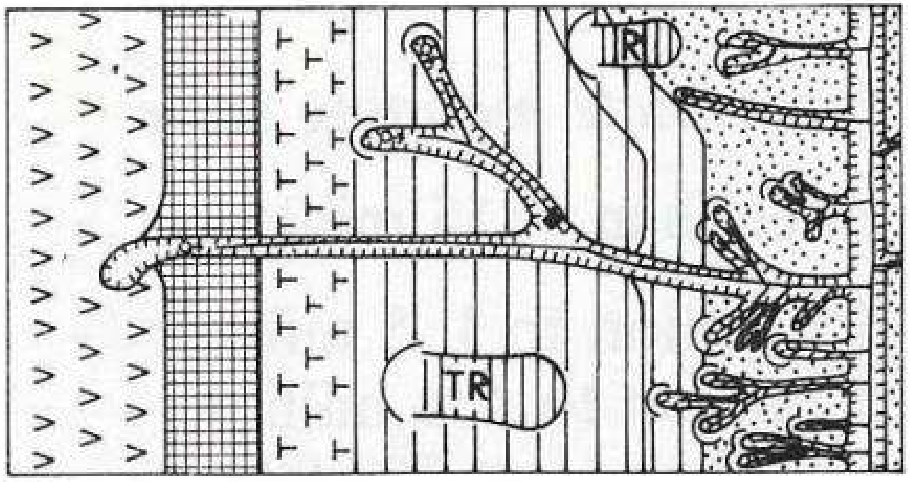
Landslips – active

10 Dip

C. MORPHOGRAPHIC MAP



D. MORPHOGENETIC/DYNAMIC MAP



Dominant Slope Forming Processes

- Soilcreep and throughflow on planation surface
- Frost weathering and rock fall from scarp
- Talus creep on scree debris
- Landslips on highly weathered mudstone –active R=Rotational TR=Translational
- Potential instability on river terrace gravels
- Wash on terrace
- Gully erosion
- Actively eroding gully heads

Spring — Waterfall — Permanent stream

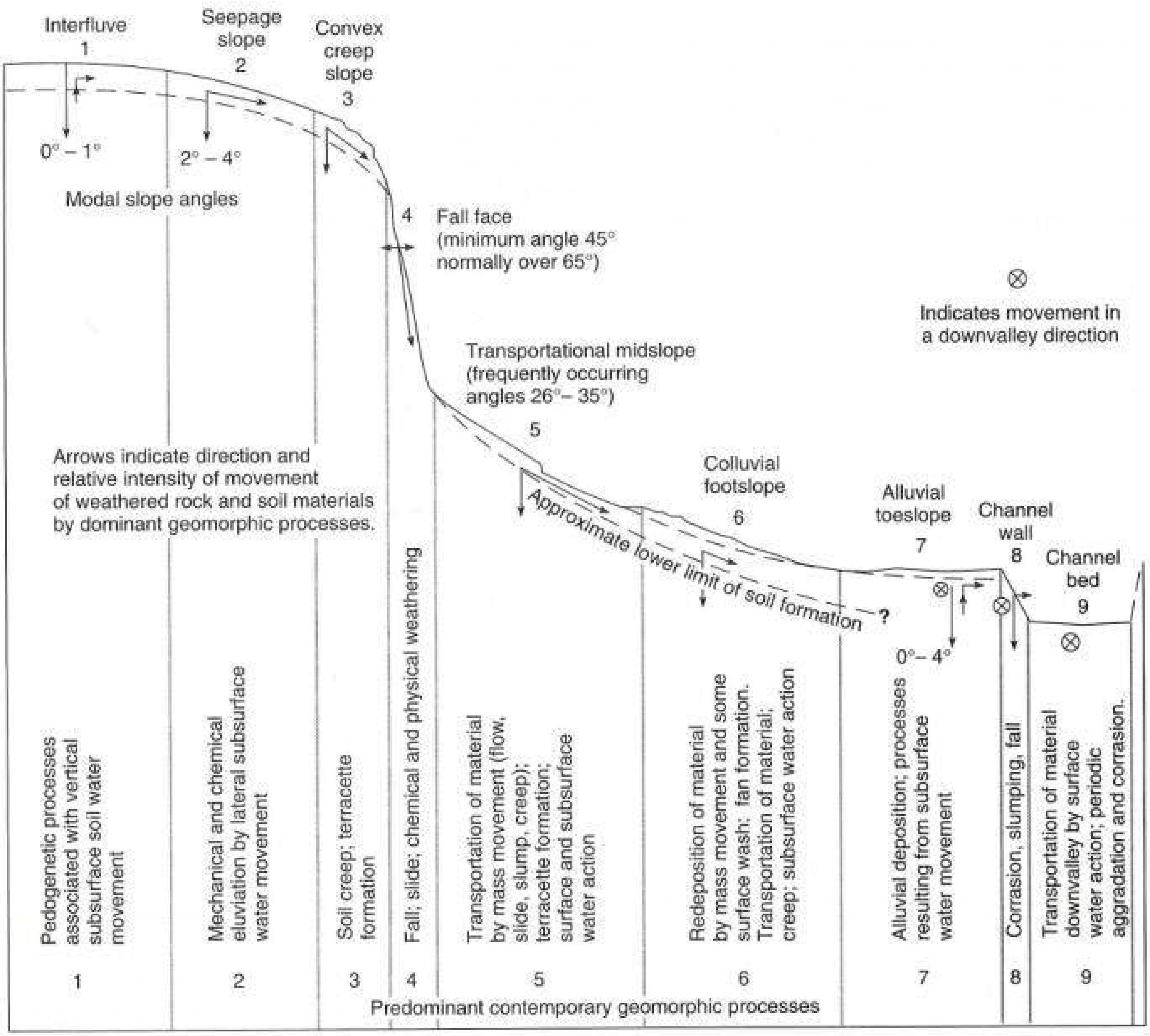
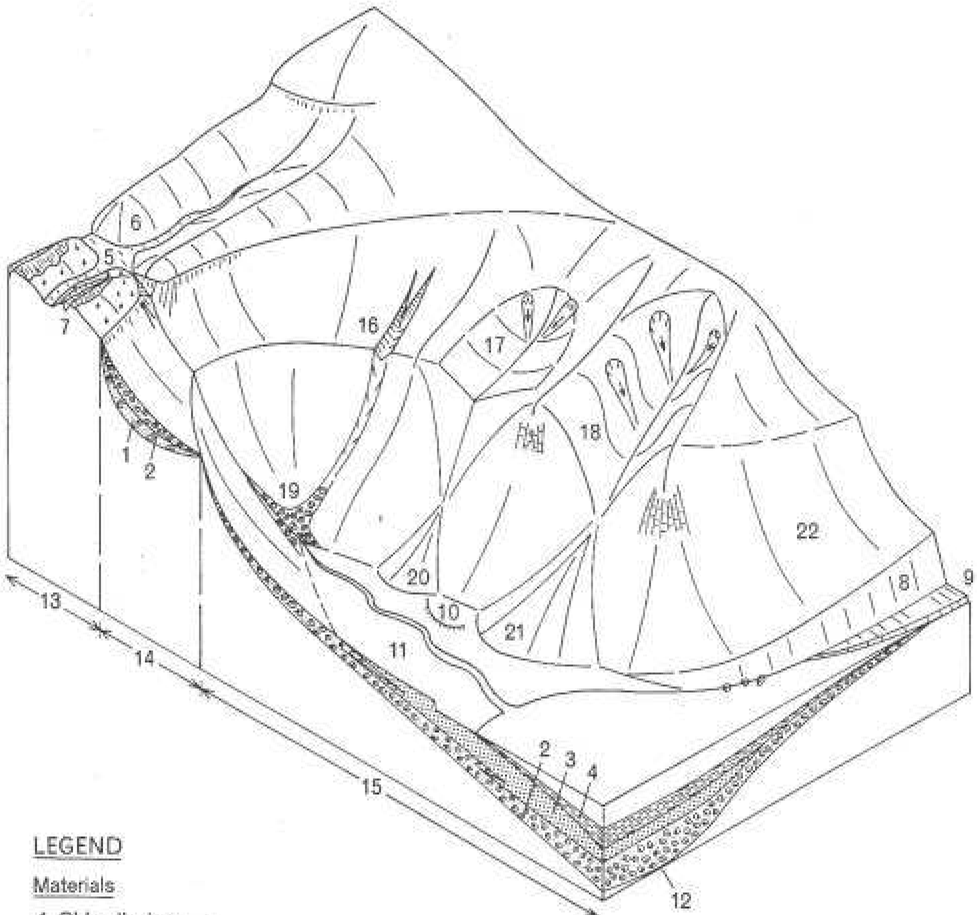


FIGURE 4.45

Diagrammatic representation of the hypothetical nine-unit landsurface model.

(Dalrymple 1968)



LEGEND

Materials

1 Old colluvium
2 Young colluvium
3 Alluvium
4 Marine deposits

Landforms

5 Upland valley
6 Deeply weathered hills
7 Ridge crest gully erosion
8 Coastal cliffs
9 Wave cut platform
10 Alluvial terrace
11 Floodplain
12 Submarine buried valley
13 Relict landforms on uplands
14 Older landforms
15 Younger landforms
16 Stream incising into superficial deposits
17 Initial incision has widened to a small valley, landslips active at margins
18 Deep, bowl-shaped valley between spurs, relict and recent instability on sides
19 Boulders in stream channel
20 Small colluvial fan
21 Large colluvial fan
22 Coastal slope (thin soils)

Hansen, 1984

Examples of developing geomorphological models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(Old reference)
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Serial No. 8063
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Date:06Feb.63
3700'
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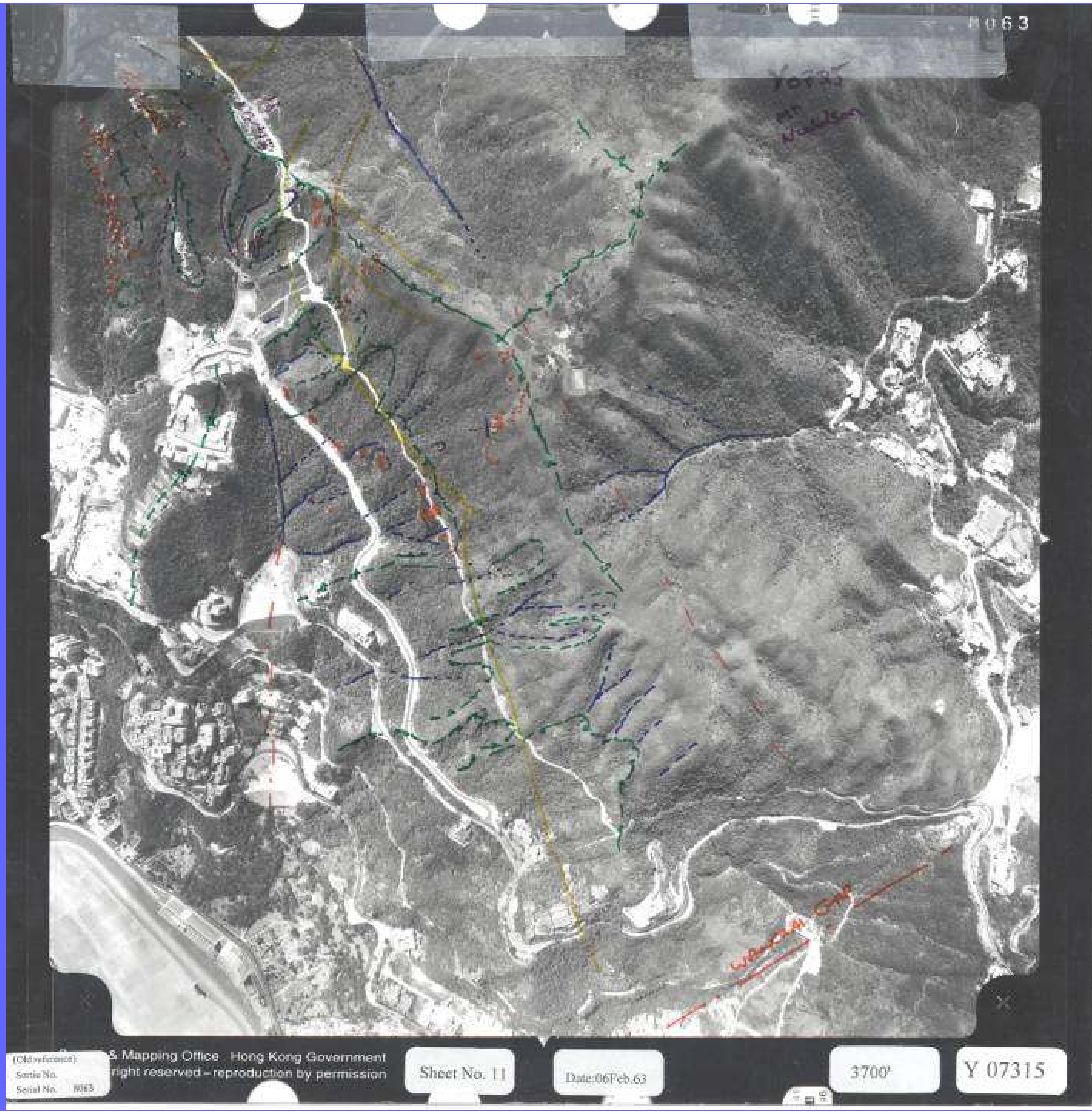
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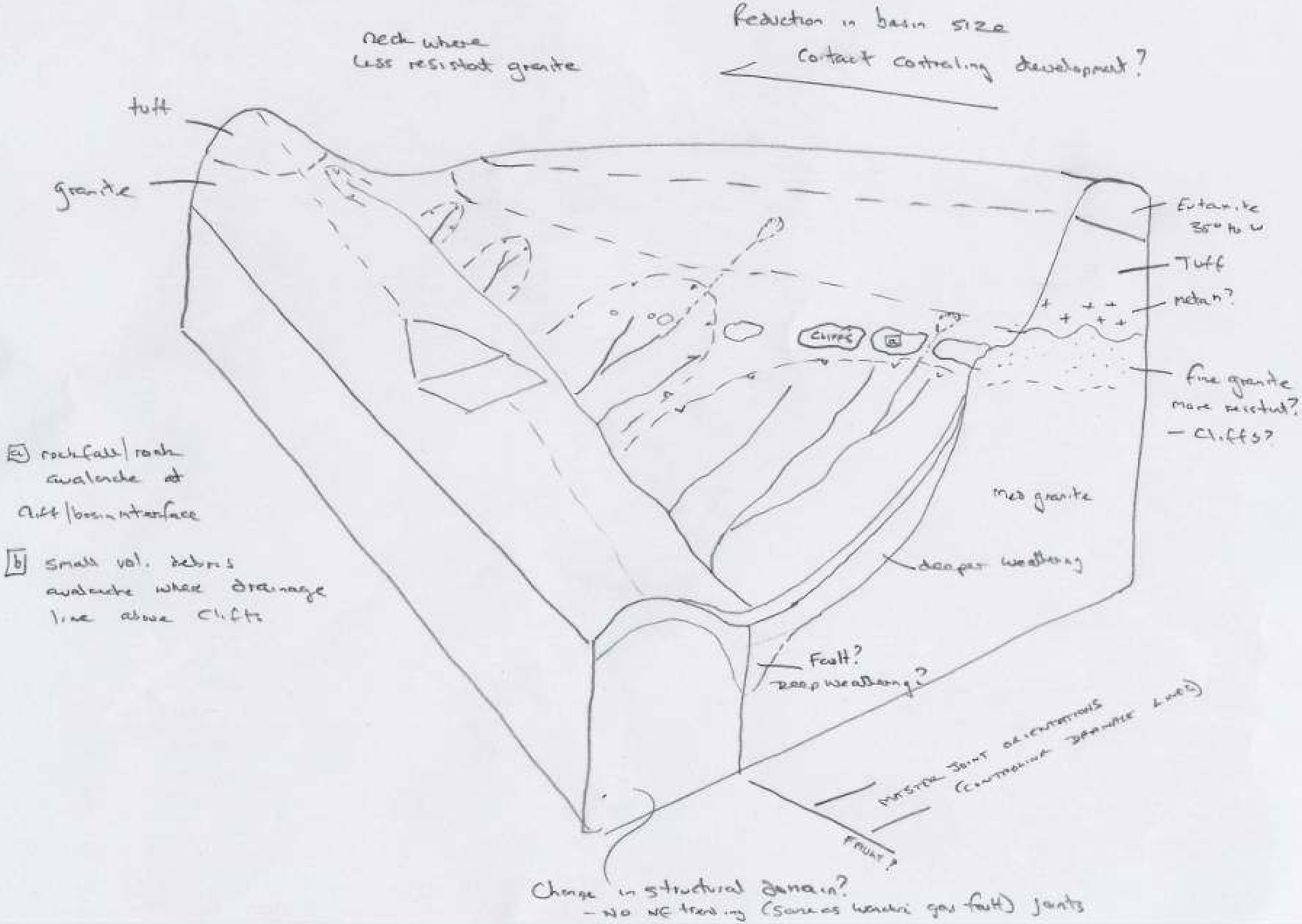
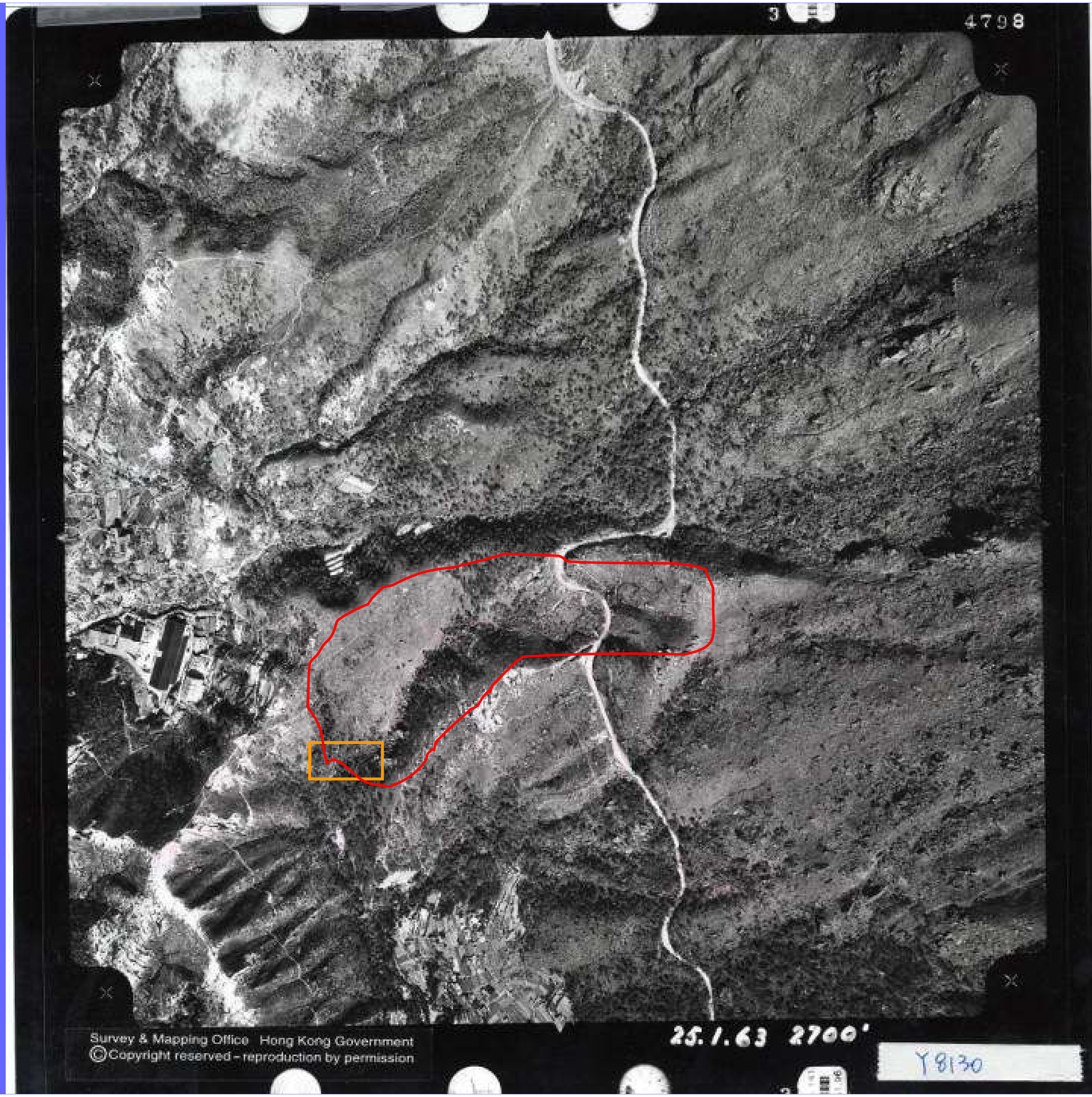


Reduction in basin size
Contact controlling development?
neck where
less resistant granite
tuff
granite
35° to W
Tuff
fine granite
more resistant?
— Cliffs?
Cliffs
med granite
deeper weathering
Fault?
deep weathering?
MASTER JOINT ORIENTATIONS
(CONTROLLING DRAINAGE LINES)
FAULT?
(a) rockfall/rock avalanche at cliff/basin interface
(b) small vol. debris avalanche where drainage line above cliffs
Change in structural domain?
— no NE trending (same as ... fault) joints



3
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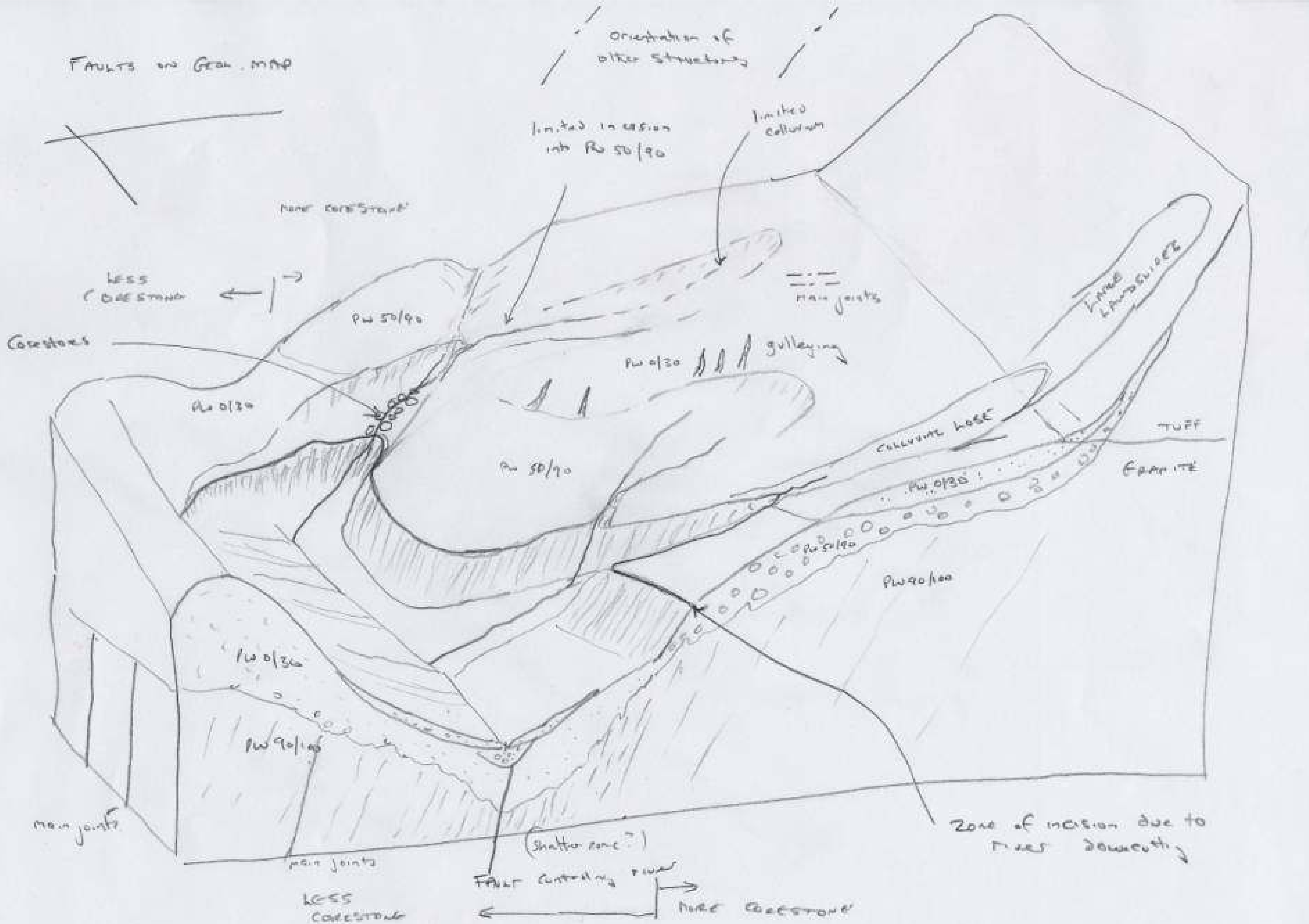
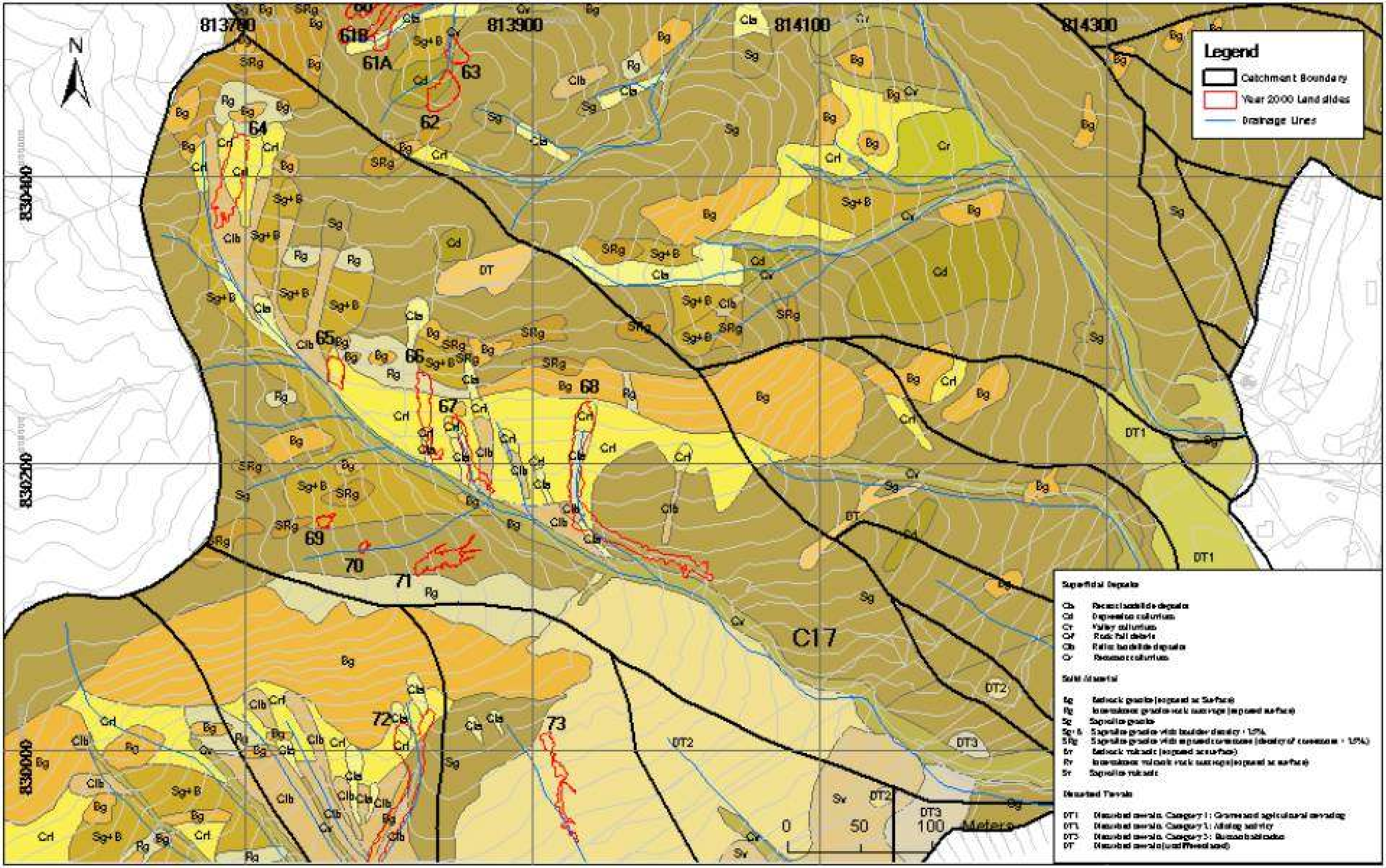
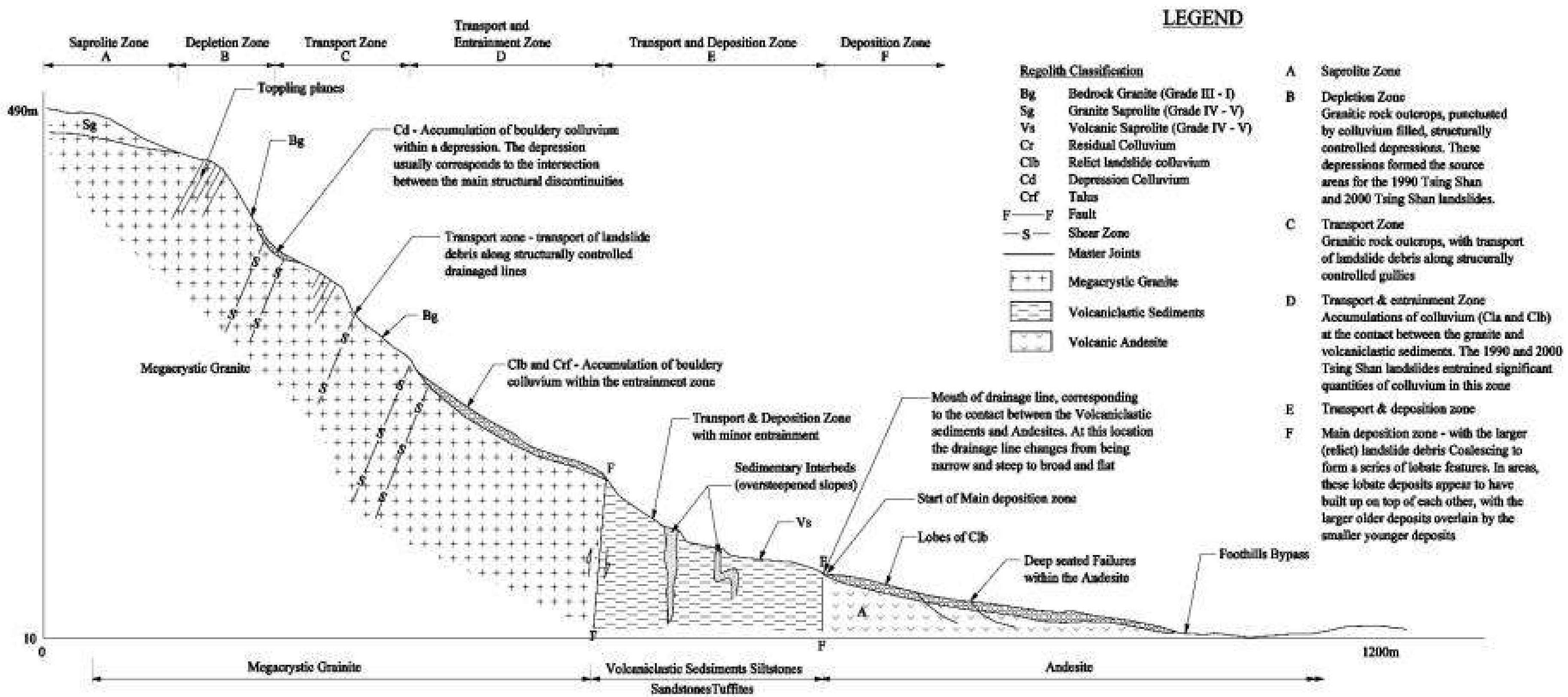

FAULTS ON GEOL. MAP
Orientation of other structures
limited incision into PW 50/90
limited colluvium
MORE CORESTONE
LESS CORESTONE
Main joints
Corestones
PW 50/90
PW 0/30
gulleying
LARGE LANDSLIDES
COLLUVIAL LOBE
TUFF
GRANITE
PW 0/30
PW 50/90
PW 90/100
PW 0/30
PW 90/100
Main joints
(Shatter zone?)
main joints
FAULT CONTROLLING RIVER
LESS CORESTONE
MORE CORESTONE
Zone of incision due to river downcutting


Legend
Catchment Boundary
Year 2000 Landslides
Drainage Lines
813700
813900
814100
814300
830400
830200
830000
N
C17
0
50
100
Meters



Development of Hazard Models

Fletcher et al., 2002

Type I Landslide (Shallow)

Location: At the boundary between the upper and lower assemblage, generally at the heads of drainage lines.

Description: Shallow translational slide (~0.5 m to 2 m deep) typically along the old colluvium/saprolite interface of the upper landform.

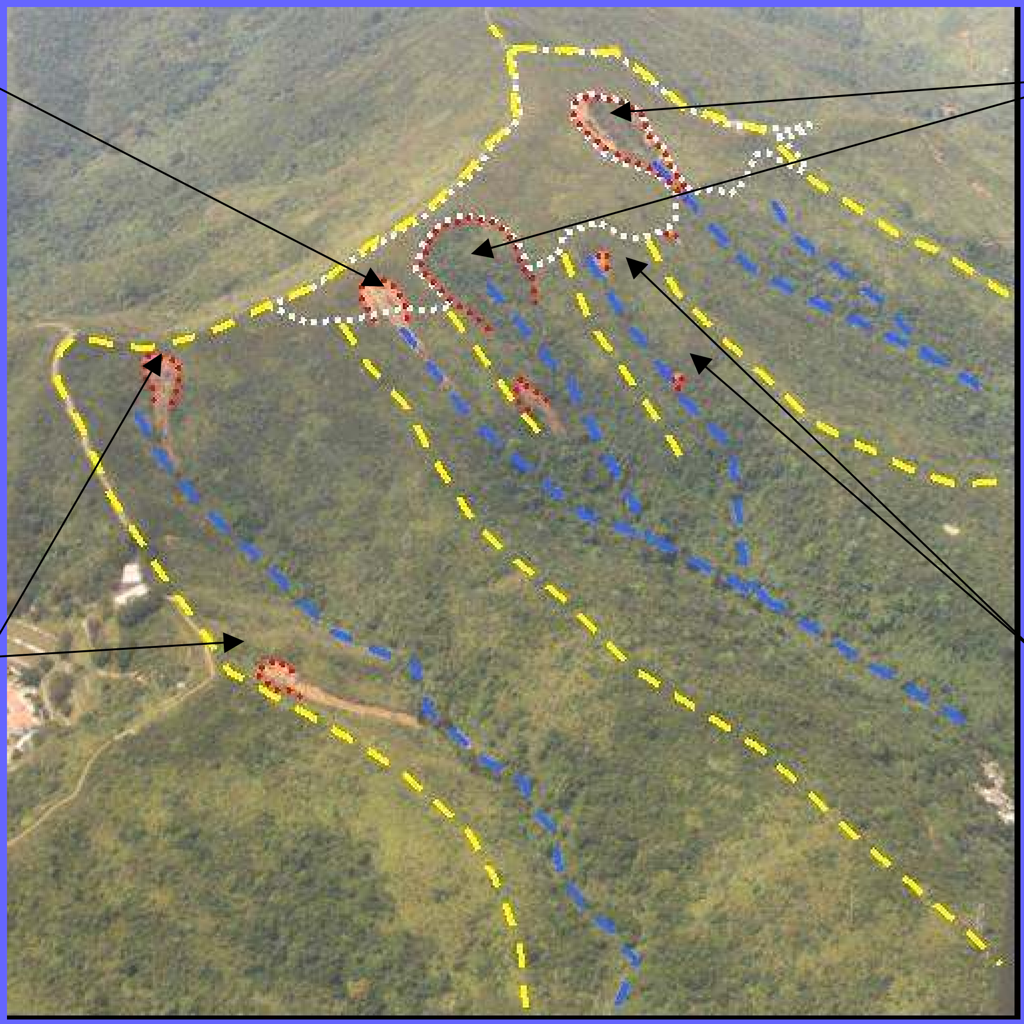
Typical Size: ~5 m to 25 m wide.

Type II Landslide

Location: At the head and flanks of incised valleys, generally located just below ridge lines within shallow hallows at the head of minor often poorly defined drainage lines. Typically located on the zero curvature line of a plan profile map.

Description: Shallow translational slide (~0.5 m to 2 m deep) generally along the colluvium/saprolite interface. Typically such landslides will occur episodically at the same location.

Typical Size: ~5 m to 15 m wide



Halcrow, 2003

Type I Landslide (Large Multiple)

Location: At the boundary between the upper and lower landform assemblage, generally directly above the head of incising drainage lines.

Description: Generally large scale
(~2 m to 10 m deep) within the deeply weathered saprolite forming the upper landform. Often retrogressive, resulting in multiple phases of landsliding.

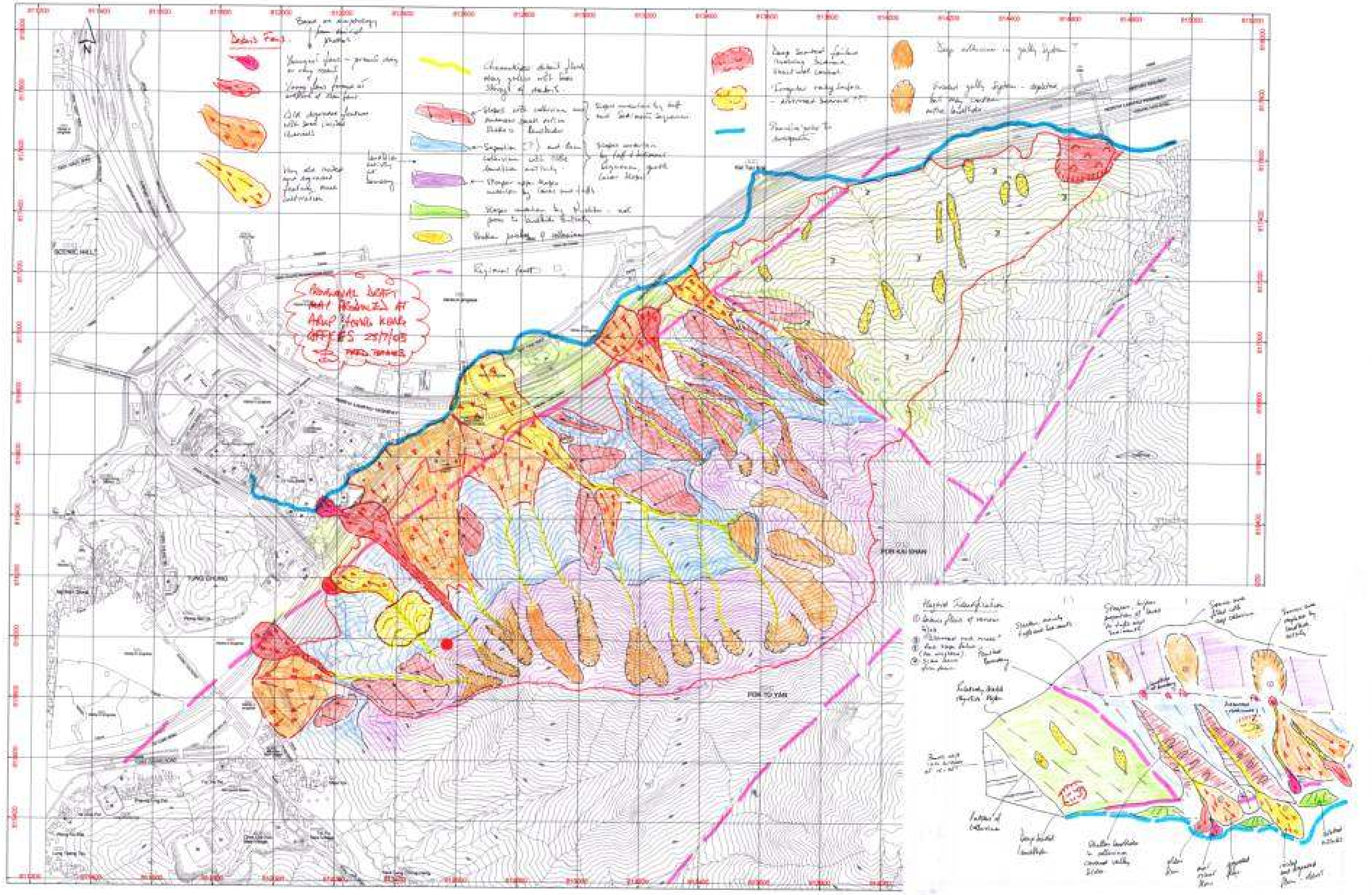
Typical Size: ~20 m to 80 m wide.

Edge of Drainage Line Landslide

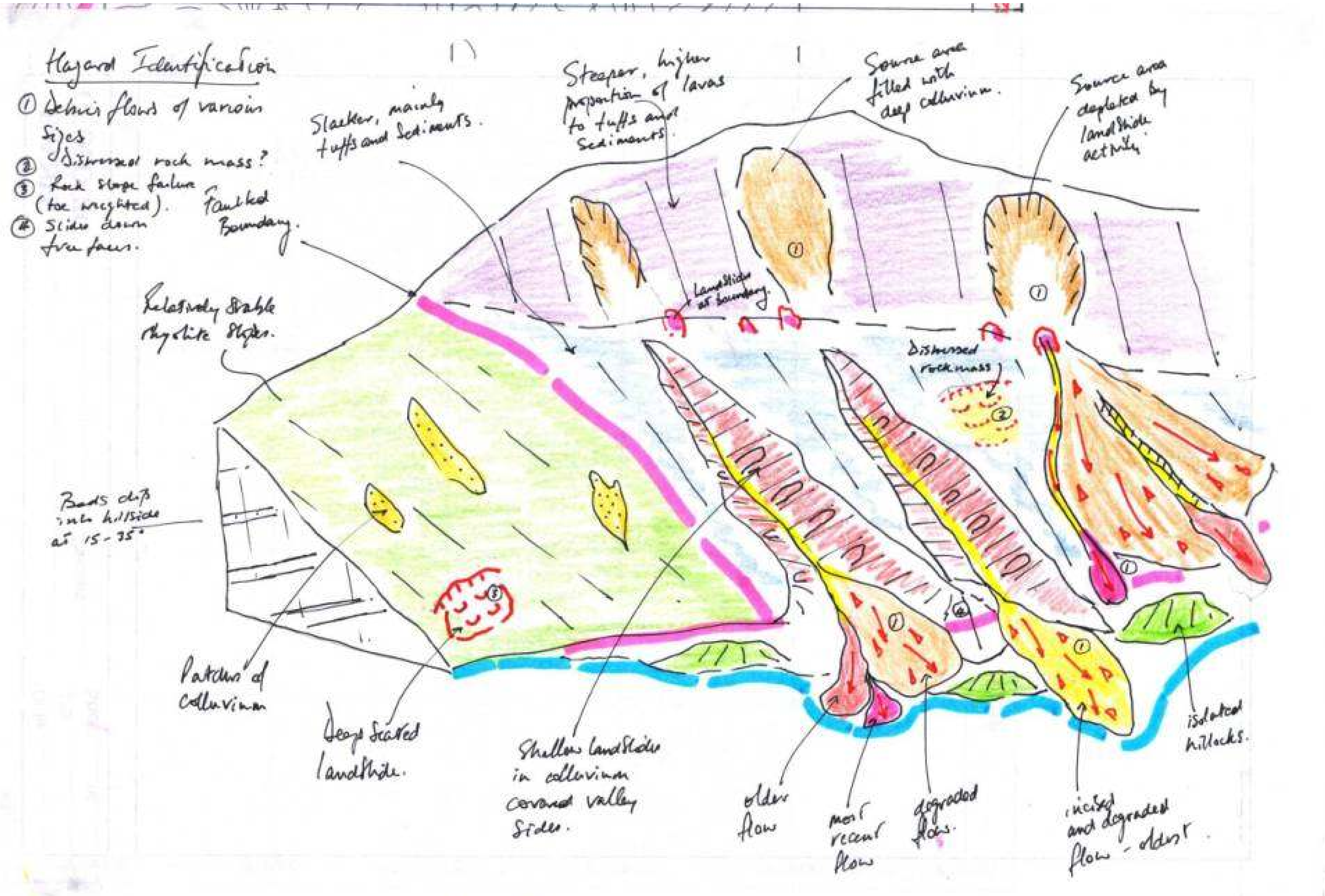
Location: Directly adjacent to eroding drainage lines, particularly at bends.

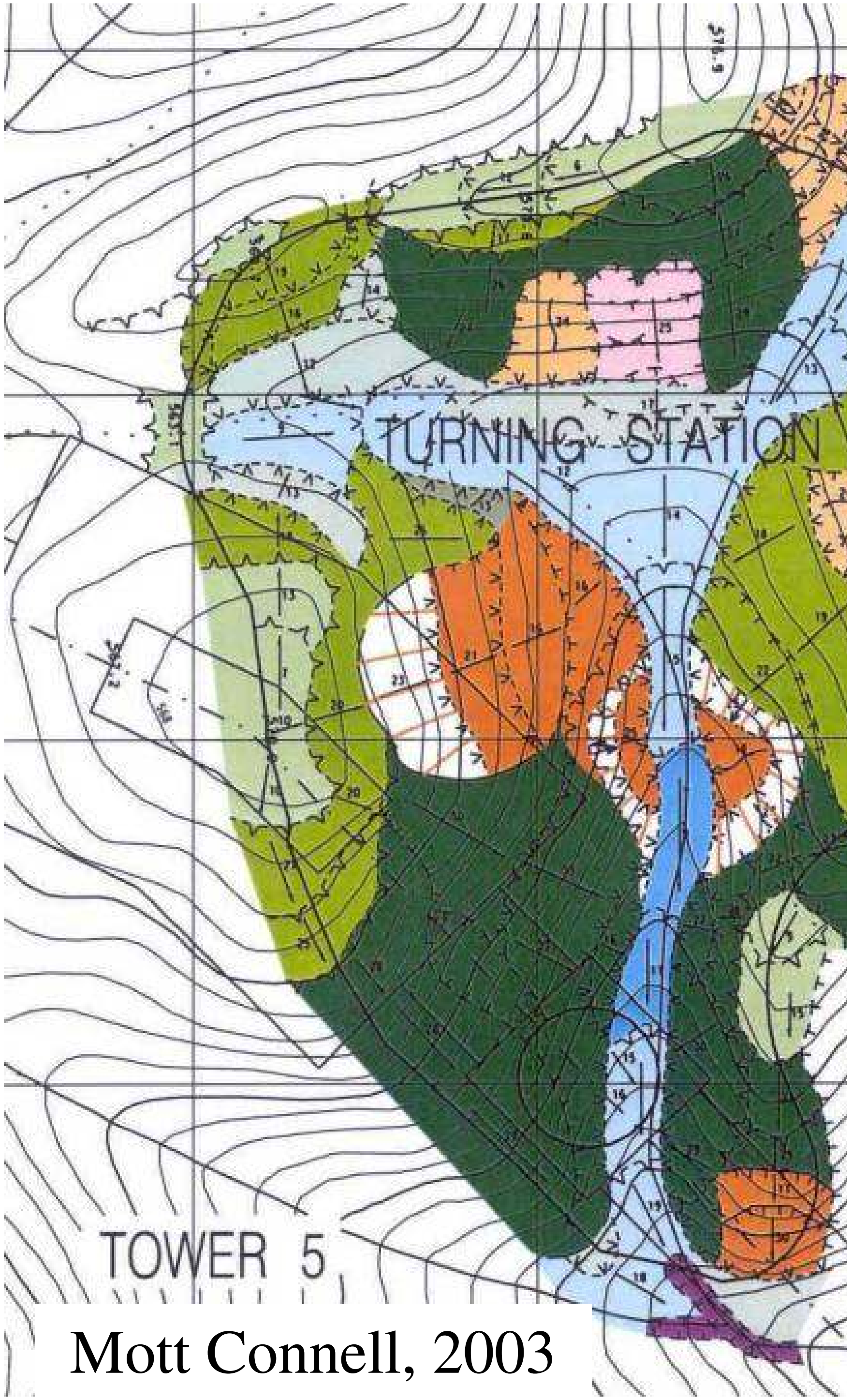
Description: Generally shallow rotational slumps (~0.5 m to 2 m deep) usually within colluvium deposits forming the flanks of the channel.

Typical Size: ~0.5 m to 5 m wide.



Arup, 2004


Hazard Identification
① Debris flows of various sizes
② Distressed rock mass?
③ Rock slope failure (toe weighted).
④ Slides down free faces.
Faulted Boundary.
Slacker, mainly tuffs and sediments.
Steeper, higher proportion of lavas to tuffs and sediments.
Source area filled with deep colluvium.
Source area depleted by landslide activity
Landslide at boundary.
Relatively stable rhyolite slopes.
Distressed rock mass
Beds dip into hillside at 15-35°
Patches of colluvium
Deep seated landslide.
Shallow landslide in colluvium covered valley sides.
older flow
most recent flow
degraded flows.
incised and degraded flow - oldest.
isolated hillocks.



Mott Connell, 2003

SLOPE FEATURES

RIDGES AND ISOLATED HILL TOPS. SUB-CONICAL HILLS WITH INTERCONNECTING RIDGES THAT ARE TYPICALLY NOT GREATER THAN 15m WIDE. SLOPE ANGLES CAN BE VARIABLE RANGING UP TO 9° TO 15°. CONSIDERED THAT BEDROCK IS RELATIVELY CLOSE TO THE GROUND SURFACE IE WITHIN 2m AND THAT SAPROLITIC SOILS DOMINATE THE NEAR SURFACE. SOME LOCAL SHEET EROSION IS IN EVIDENCE.

UPPER VALLEY SIDE SLOPES. TYPICALLY PRESENT DIRECTLY DOWNSLOPE OF THE RIDGES AND ISOLATED HILL TOPS. SLOPES ARE USUALLY 16° TO 26°. SURFACE IS USUALLY LIGHTLY VEGETATED WITH GRASS. BOULDERS TEND TO BE ABSENT. A STIFF SANDY SILT SOIL IS LOCALLY EXPOSED.

VALLEY SIDE SLOPES. TYPICALLLY PRESENT BETWEEN THE UPPER VALLEY SIDE SLOPES AND FOOTSLOPES OR CHANNELS BELOW. SLOPES ARE USUALLY 26° TO 33°, ALTHOUGH LOCALLY AS STEEP AS 35°. SOME BOULDERS UP TO 1m ARE EVIDENT PARTICULARLY ON THE NORTHERN SIDE OF THE CATCHMENT, THAT ARE POORLY EMBEDDED. CONSIDERED THAT COLLUVIAL DEPOSITS AND SAPROLITIC SOILS ARE RELATIVELY THIN (?m <1m). THESE SLOPES ARE CONSIDERED STABLE UNDER PRESENT CONDITIONS.

FOOTSLOPES. DEVELOPED BELOW A CONCAVE CHANGE OF SLOPE AT THE BASE OF THE OTHER SLOPE UNITS. SLOPES RECORDED AS 12° TO 17°.

CHANNEL FEATURES

GENTLE CHANNEL BOTTOMS. CONFINED CHANNELS THAT HAVE BASE WIDTHS UP TO 10m. SLOPE ANGLES WITHIN THE CHANNELS ARE NORMALLY 9° TO 11°. THERE IS LITTLE EVIDENCE FOR EPHEMERAL WATER FLOW AND ACTIVE EROSION. COLLUVIAL ACCUMULATIONS WITHIN THE CENTRAL PART OF THE CATCHMENT ARE CONSIDERED TO BE UP TO 2m THICK.

CHANNELS. GENERALLY CONFINED CHANNELS THAT HAVE BASE WIDTHS TYPICALLY UP TO 10m. SLOPE ANGLES WITHIN THE CHANNELS ARE NORMALLY 12° TO 19°. THERE IS SOME EVIDENCE FOR EPHEMERAL WATER FLOW PARTICULARLY LOWER DOWN THE CATCHMENT WHERE EPHEMERAL WATER SEEPAGES MIGHT OCCUR.

STEEP CHANNELS. CONFINED CHANNELS THAT HAVE BASE WIDTHS TYPICALLY <5m. SLOPE ANGLES WITHIN THE CHANNELS ARE NORMALLY >19°. THERE IS EXTENSIVE EVIDENCE FOR EPHEMERAL WATER FLOW AND ACTIVE EROSION. THE CHANNEL BED SHOWS RELATIVELY CLEAN COBBLE AND BOULDERS WITH LOCAL BEDROCK EXPOSURES. EROSION INTO THE CHANNEL SIDES OF UP TO 0.5m IS ALSO EVIDENT.

INSTABILITY FEATURES

DEGRADED DEEP TRANSLATIONAL LANDSLIDES. DEVELOPED DIRECTLY UPSLOPE OF THE CHANNELS AND GENTLE CHANNEL BOTTOMS. COMPRISE OF STEEPER BACKSCARPS TO 38° ABOVE SHALLOWER LANDSLIDE BODIES AT 16° TO 25°. DEPTH OF FAILURE UP TO 2m. WHERE THE TOE IS ABSENT IT IS CONSIDERED THAT THIS MATERIAL HAS BEEN ENTRAINED INTO THE GENTLE CHANNEL BOTTOMS DOWNSTREAM. THERE IS NO EVIDENCE OF RECENT REACTIVATION.

DEGRADED SHALLOW TRANSLATIONAL LANDSLIDES. DISCRETE LANDSLIDE FEATURES THAT ARE TYPICALLY UP TO 30m LONG AND 20m WIDE THAT MIGHT COALESCE INTO LARGER AREAS. FAILURE DEPTH IS NOT CONSIDERED TO BE GREATER THAN 1m. THE BODY OF THESE LANDSLIDES IS AT 20° - 32° AND APPEARS TO BE MARGINALLY STABLE UNDER PRESENT CONDITIONS. ASSOCIATED WITH PAST EROSION OF PREDOMINATELY SAPROLITIC SOILS.

ACTIVE SHEET EROSION AND SHALLOW TRANSLATIONAL LANDSLIDING. AN AREA 20m BY 20m AFFECTED BY ACTIVE SHALLOW SOIL REMOVAL BY A COMBINATION OF PROCESSES. FAILURE DEPTH IS NOT CONSIDERED TO BE GREATER THAN 1m. THE SLOPE IN THIS AREA IS 25°. ASSOCIATED WITH ONGOING EROSION OF PREDOMINATELY SAPROLITIC SOILS SUCH THAT BEDROCK EXPOSURES ARE PRESENT.

MORPHOLOGY

CONVEX BREAKS OF SLOPE

CONCAVE BREAKS OF SLOPE

CONVEX CHANGES OF SLOPE

CONCAVE CHANGES OF SLOPE

BREAKS OF SLOPE

CHANGES OF SLOPE

12 SLOPE DIRECTION WITH ANGLE IN DEGREES

27 UNDULATING SLOPE DIRECTION WITH ANGLE IN DEGREES

TOWER 5 CATCHMENT GEOMORPHOLOGICAL MODEL

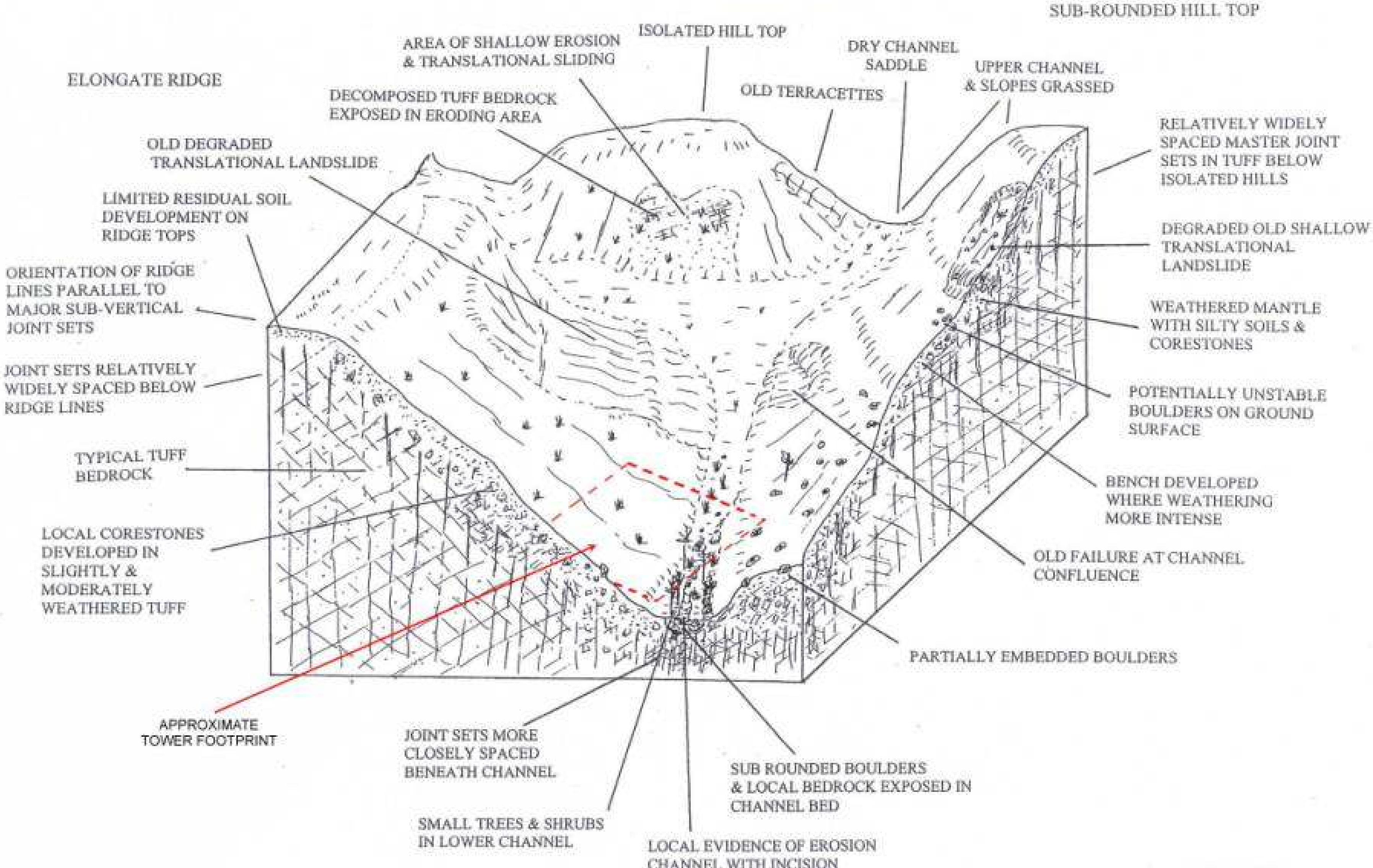


FIGURE 2

Advantages of a geomorphological approach

Assists in determining:

- the type of natural terrain hazards present
- the location of potential source areas
- the estimation of source volumes for hazard types
- the likely frequency of the hazard types
- the presence of entrainable material

Physical Investigations of Natural Terrain

Natural Terrain Hazard Study for Tsing Shan Foothill Area
Landslide Field Proforma

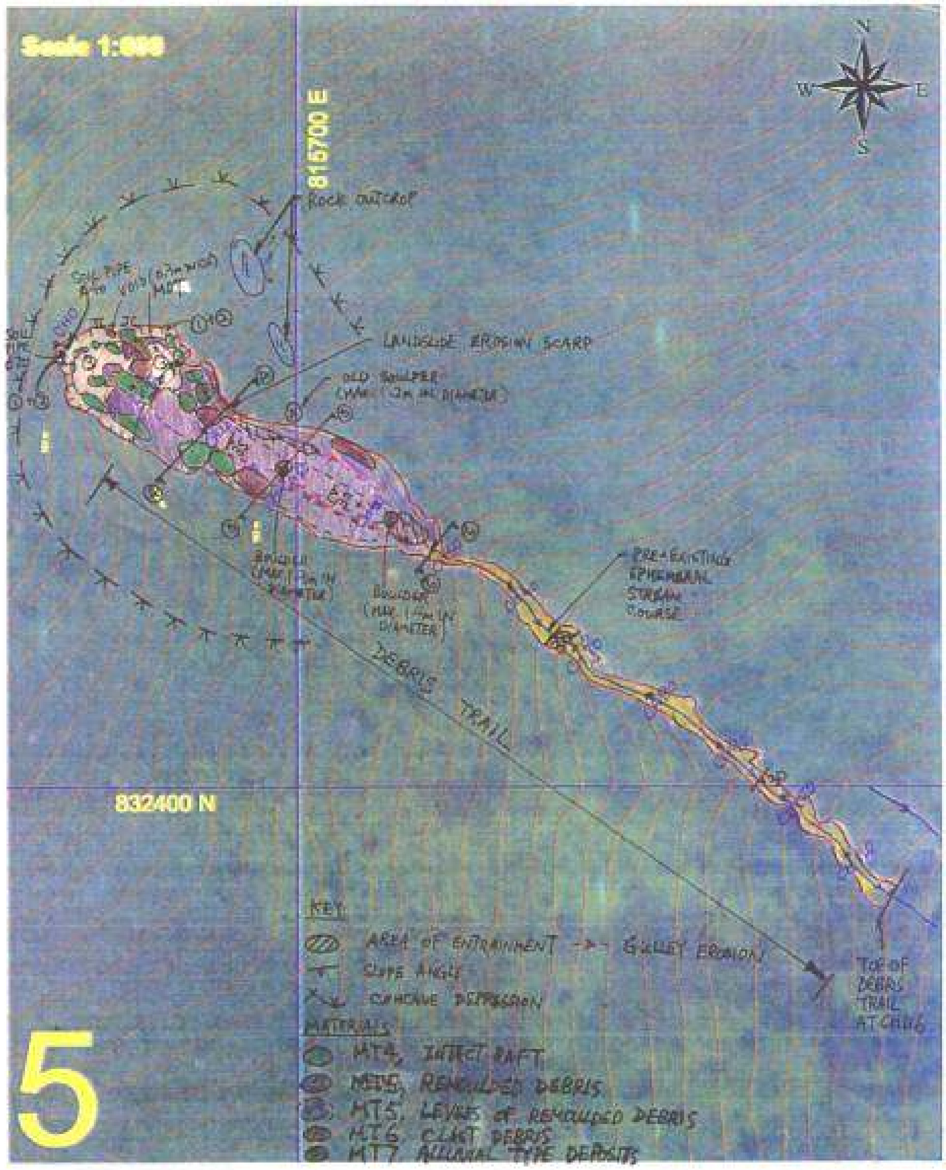


Figure 4a Sketch plan of debris trail

(Note: based on orthorectified photograph with material type average thicknesses and maximum clast diameter for each deposition area)

MFJV, 2004

Natural Terrain Hazard Study for Tsing Shan Foothill Area
Landslide Field Proforma

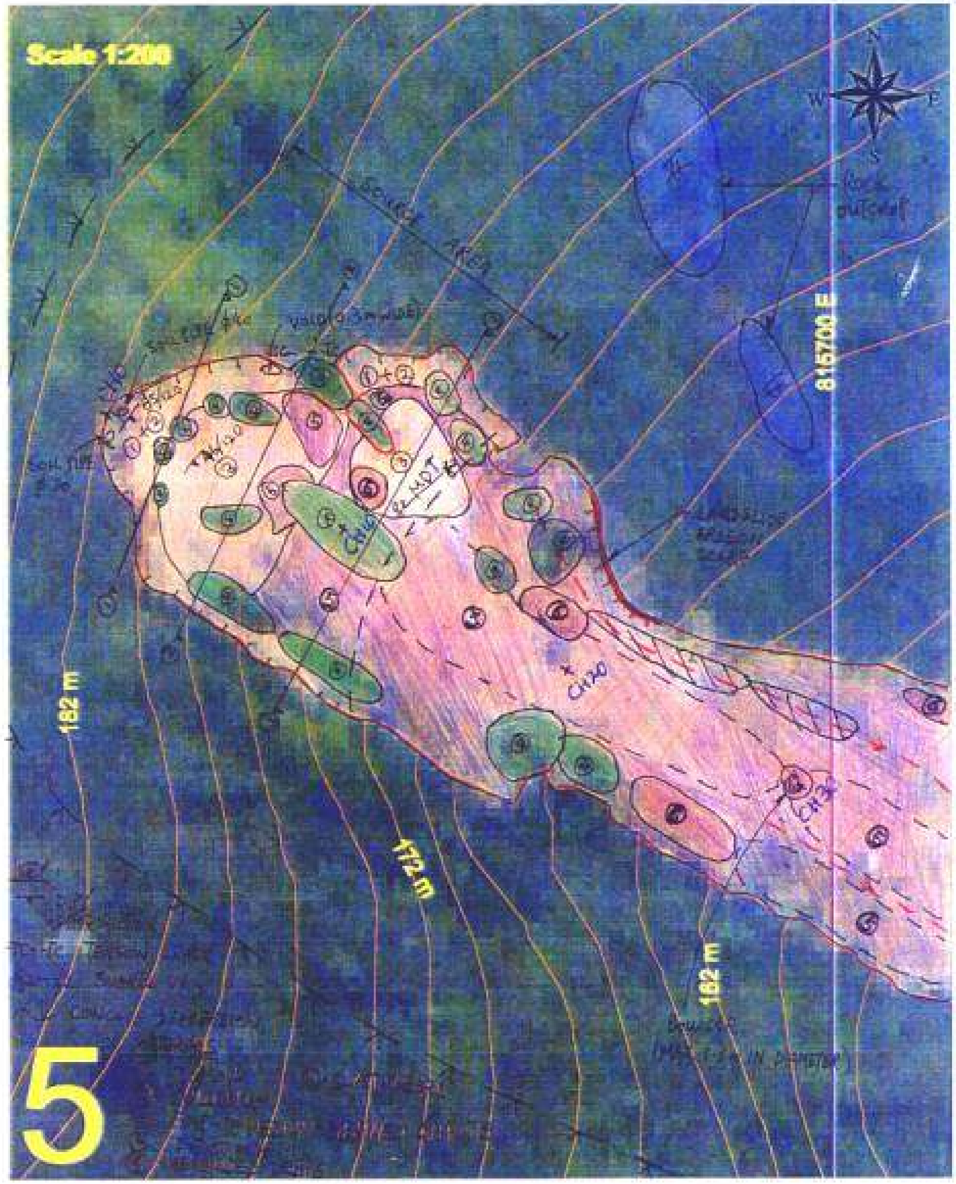
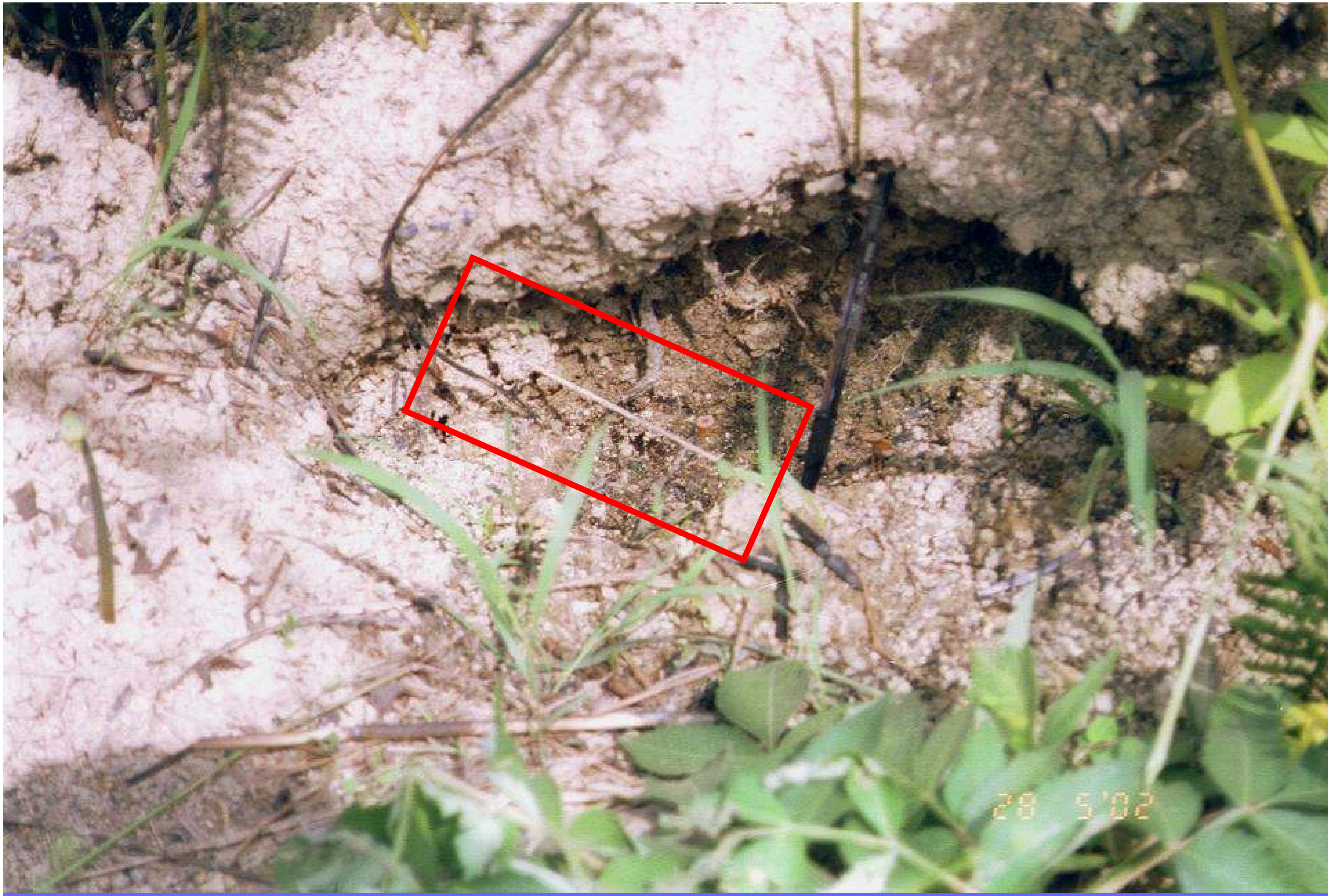


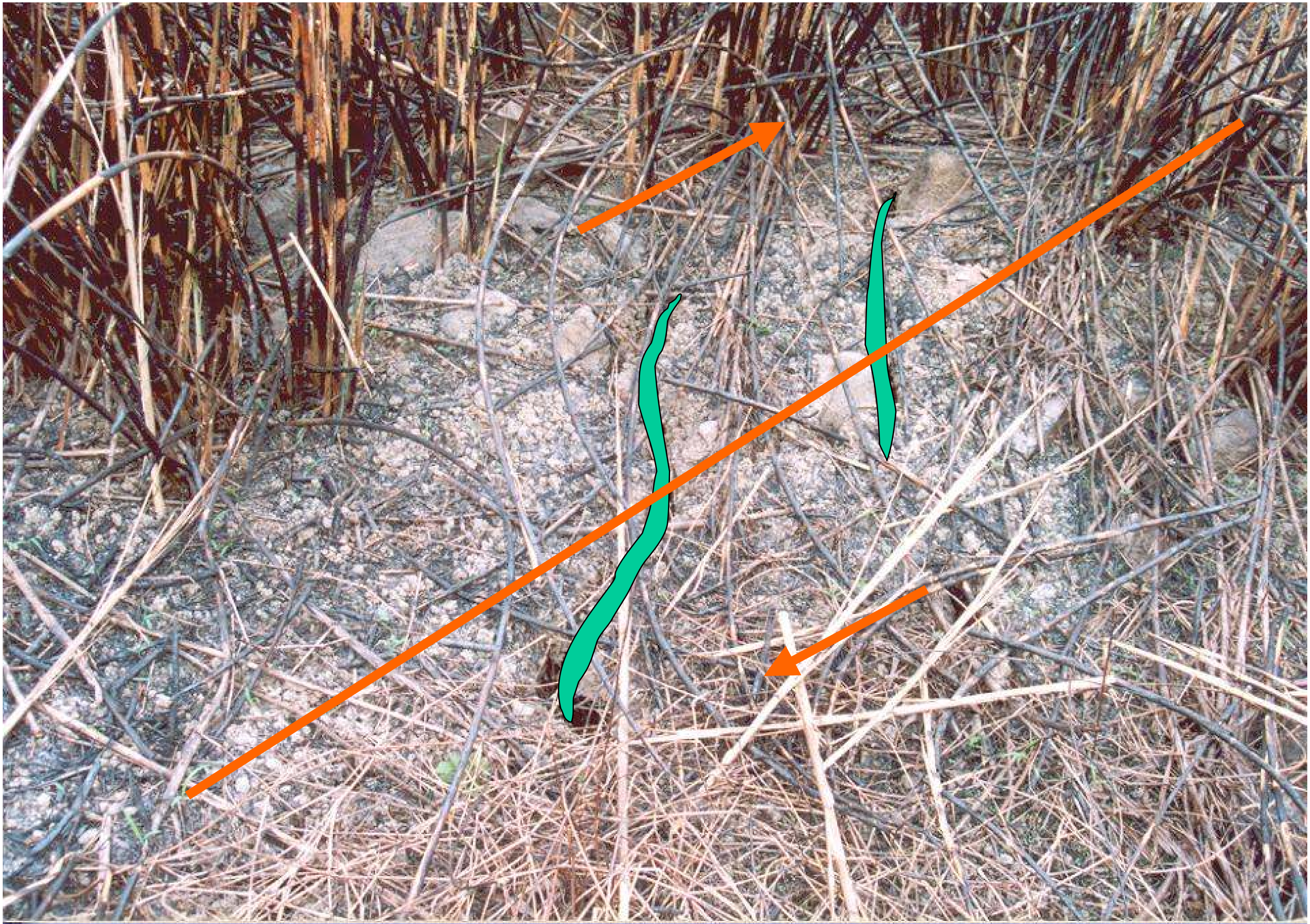
Figure 2 Sketch plan of landslide source

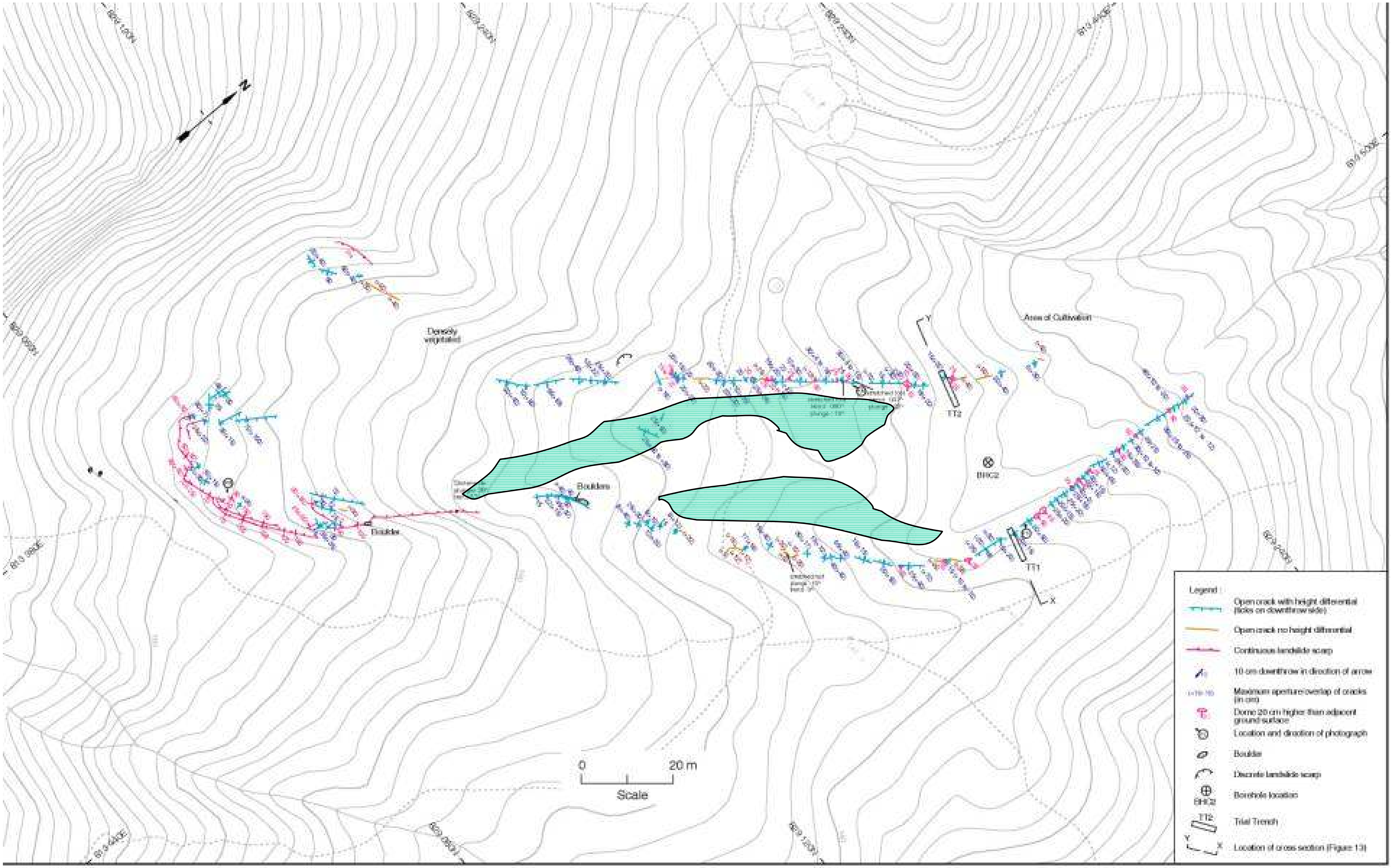
(Note: based on orthorectified photograph with average thicknesses of depletion on overlay)

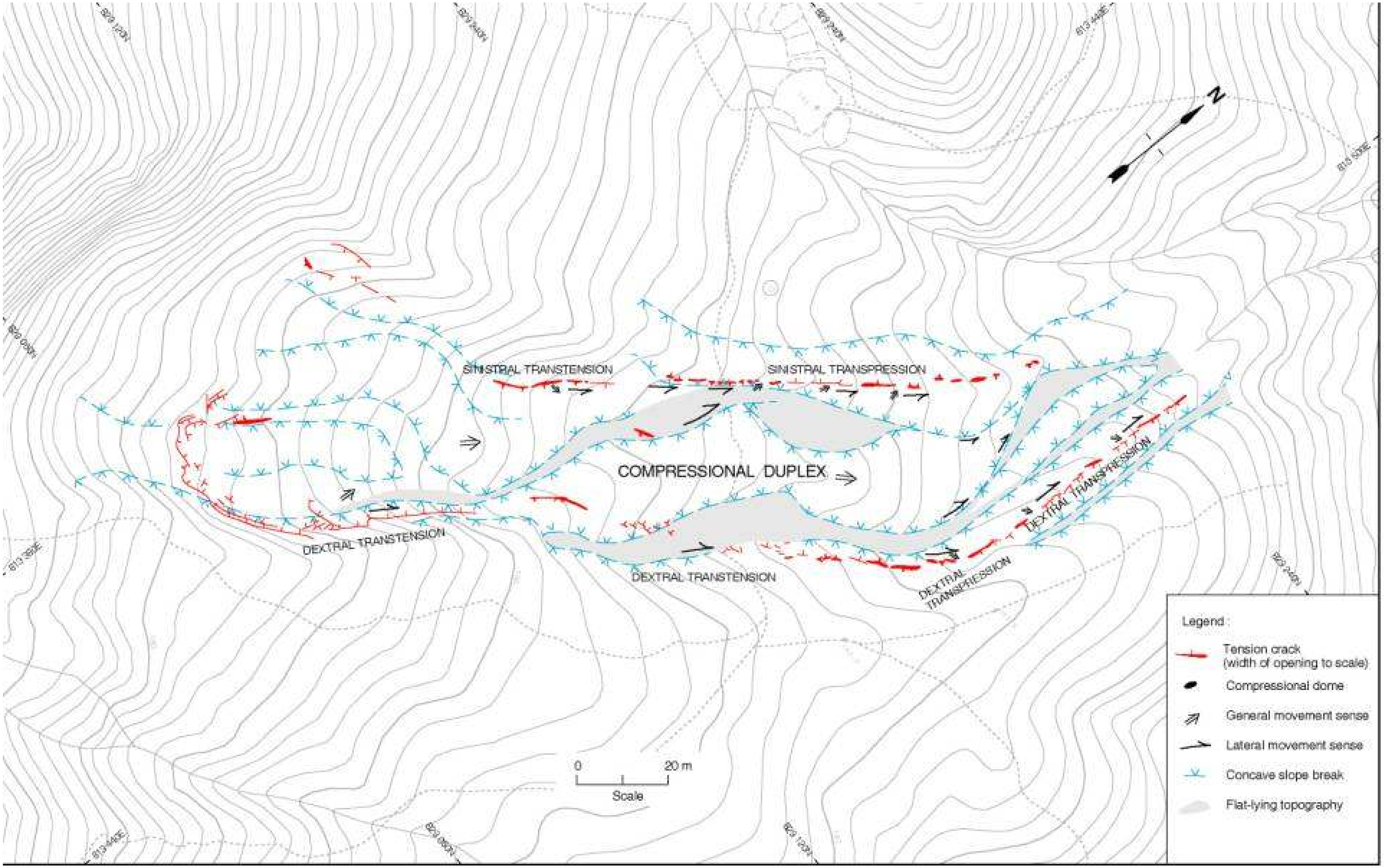
MFJV, 2004


Estwing


28 5'02




N
Densely vegetated
Area of Cultivation
Boulders
Boulder
BHC2
TT1
TT2
Y
X
0
20 m
Scale
Legend :
Open crack with height differential (ticks on downthrow side)
Open crack no height differential
Continuous landslide scarp
10 cm downthrow in direction of arrow
Maximum aperture/overlap of cracks (in cm)
Dome 20 cm higher than adjacent ground surface
Location and direction of photograph
Boulder
Discrete landslide scarp
Borehole location
BHC2
TT2
Trial Trench
Location of cross section (Figure 13)



Parry & Campbell, 2003

GEOTECHNICS & CONCRETE ENGG. (H.K.) LTD.
GROUND INVESTIGATION DEPARTMENT

HOLE NO. **BHC2**

SHEET 1 of 3

DRILLHOLE RECORD

CONTRACT NO. GE/2001/14

PROJECT	Agreement No. CE 72/2000, Landslide Investigation Consultancy for Landslides Reported within Kowloon and the New Territories Between April 2001 and the End of 2002, Landslide Age-dating for Landslide on Natural Hillside above Tsing Shan, Ground Investigation		
METHOD	Rotary Cored	Works Order No.	GE/2001/14.29
MACHINE & No.	DR114	DATE from	10/07/2002 to 19/07/2002
FLUSHING MEDIUM	Air-Foam	GROUND LEVEL	134.29 mPD
CO-ORDINATES	E 813498.76 N 829203.27	ORIENTATION	Vertical

Drilling Progress: 10/07/2002 – 10/07/2002 / 11/07/2002; Casing size: SX

Water level (m) & Time: 3.45m at 18:00; 2.60m at 08:00; 9.20m

Total core Recovery %: 85, 75, 85, 75, 100, 100, 100, 95, 90, 31, 95, 91, 100, 100, 100, 99

Tests: 21 bls, 17 bls, 28 bls, 24 bls

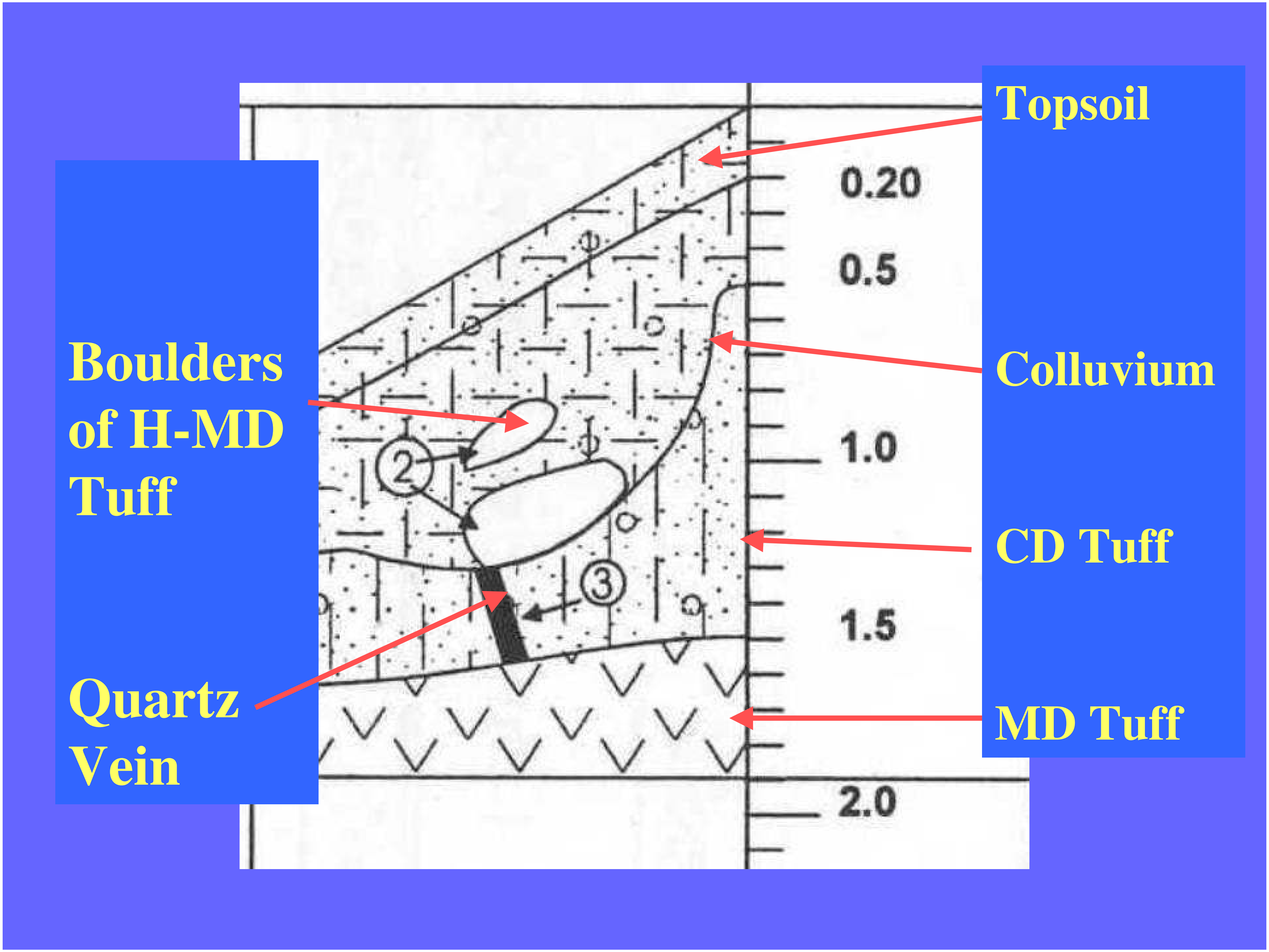
Samples: 1, 2, 3, 4, 5, 6, 7, 8; HC-MLC

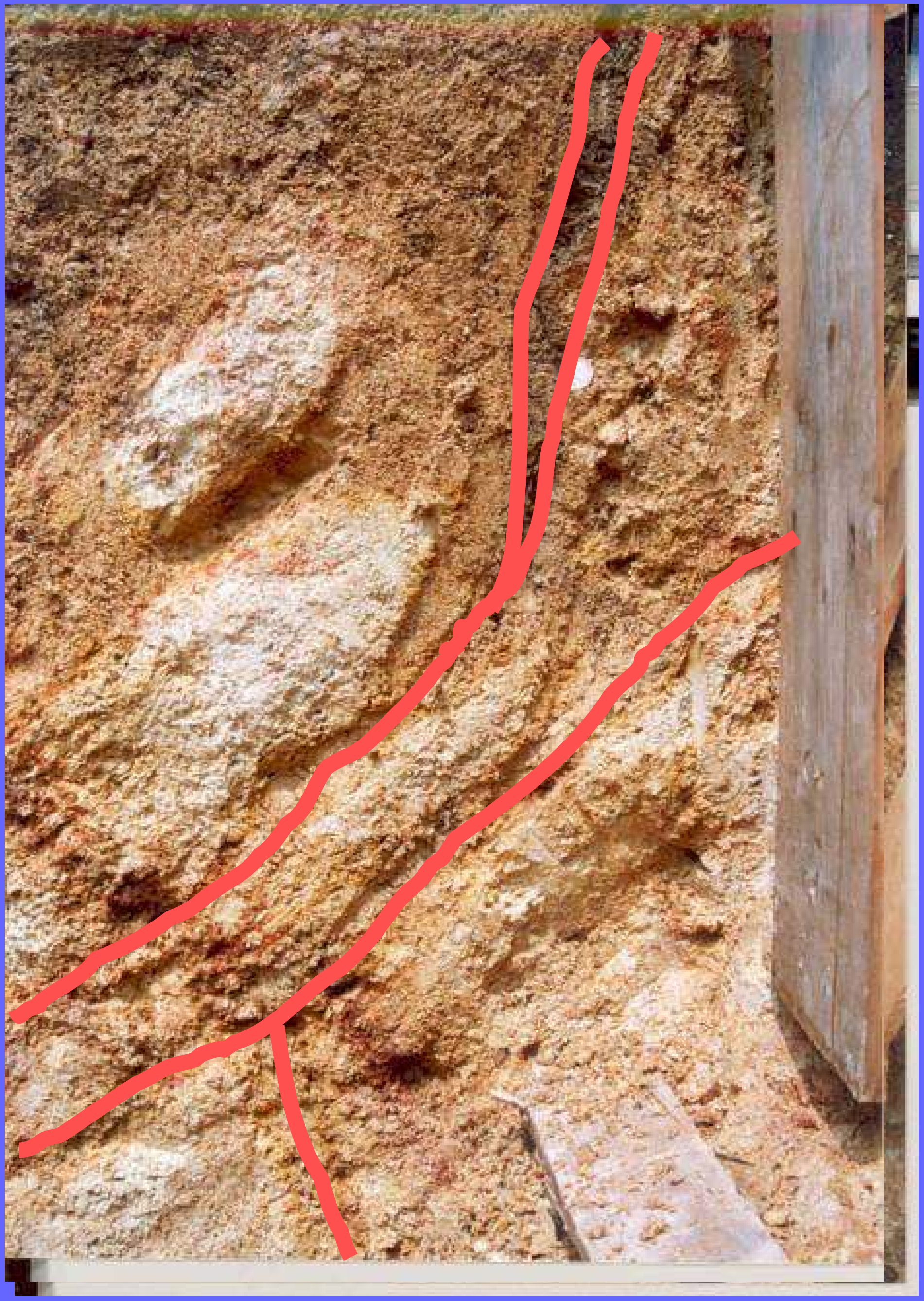
Reduced Level	Depth (m)	Grade	Description
134.29	0.00		
133.84	0.45		Firm, greyish brown(2.5YR 5/2), occasionally mottled reddish brown, sandy SILT with occasional angular to subangular fine to medium gravel sized quartz and granite fragments. (COLLUVIUM)
132.94	1.35		Greyish brown (2.5YR 5/2), slightly clayey, silty fine to coarse SAND with some angular to subangular fine to coarse gravel sized granite fragments. (COLLUVIUM)
132.49	1.80		Very stiff, greyish brown (2.5YR 5/2) mottled yellowish brown, slightly sandy SILT with occasional angular to subangular fine gravel sized rock fragments. (COLLUVIUM)
132.39	1.90		Light brownish grey (2.5YR 6/2), angular COBBLE sized granite fragment. (COLLUVIUM)
132.26	2.03		Greyish brown (2.5YR 5/2), silty sandy angular to subangular fine to coarse GRAVEL with occasional cobble sized granite fragments. (COLLUVIUM)
131.26	3.03		Firm, greyish brown (2.5YR 5/2) mottled yellowish brown, slightly sandy SILT with occasional angular to subangular fine to coarse gravel sized rock fragments. (COLLUVIUM) From 2.85m to 2.95m : With occasional rootlets.
131.03	3.26	V	Light pinkish brown (5YR 6/4), slightly clayey, silty sandy angular to subangular fine to coarse GRAVEL with occasional cobble sized granite fragments, occasionally fine to medium gravel sized quartz fragments. (COLLUVIUM)
130.89	3.40	V	Light pinkish brown (5YR 6/4), slightly clayey, silty fine to coarse SAND with occasional angular to subangular fine to coarse gravel sized granite fragments. (COLLUVIUM)
130.29	4.00	V	Greyish brown (2.5YR 5/2), slightly clayey, silty fine to coarse SAND with much angular to subangular fine to coarse gravel and occasional cobble sized granite fragments, occasionally quartz fragments. (COLLUVIUM) From 3.86m to 3.94m : Cobble sized granite fragment.
130.01	4.28		Light pinkish brown (5YR 6/4), slightly silty, sandy angular to subangular fine to coarse GRAVEL sized granite fragments. (COLLUVIUM) From 4.23m to 4.28m : Firm, yellowish brown, slightly clayey, sandy silt with occasional angular to subangular fine to coarse gravel sized rock fragments.
129.39	4.90		No core recovered, assumed to be interface between COLLUVIUM and completely decomposed ANDESITE.
127.95	6.34		Extremely weak, yellowish brown (10YR 5/8) spotted and mottled light brownish grey, completely decomposed, ANDESITE with relict iron and manganese oxide stained joints. (Very stiff, slightly sandy SILT) At 5.07m : White kaolin vein of maximum thickness 1mm dipping at 0° to 10°. From 6.16m to 6.26m : An 80° to 90° iron and

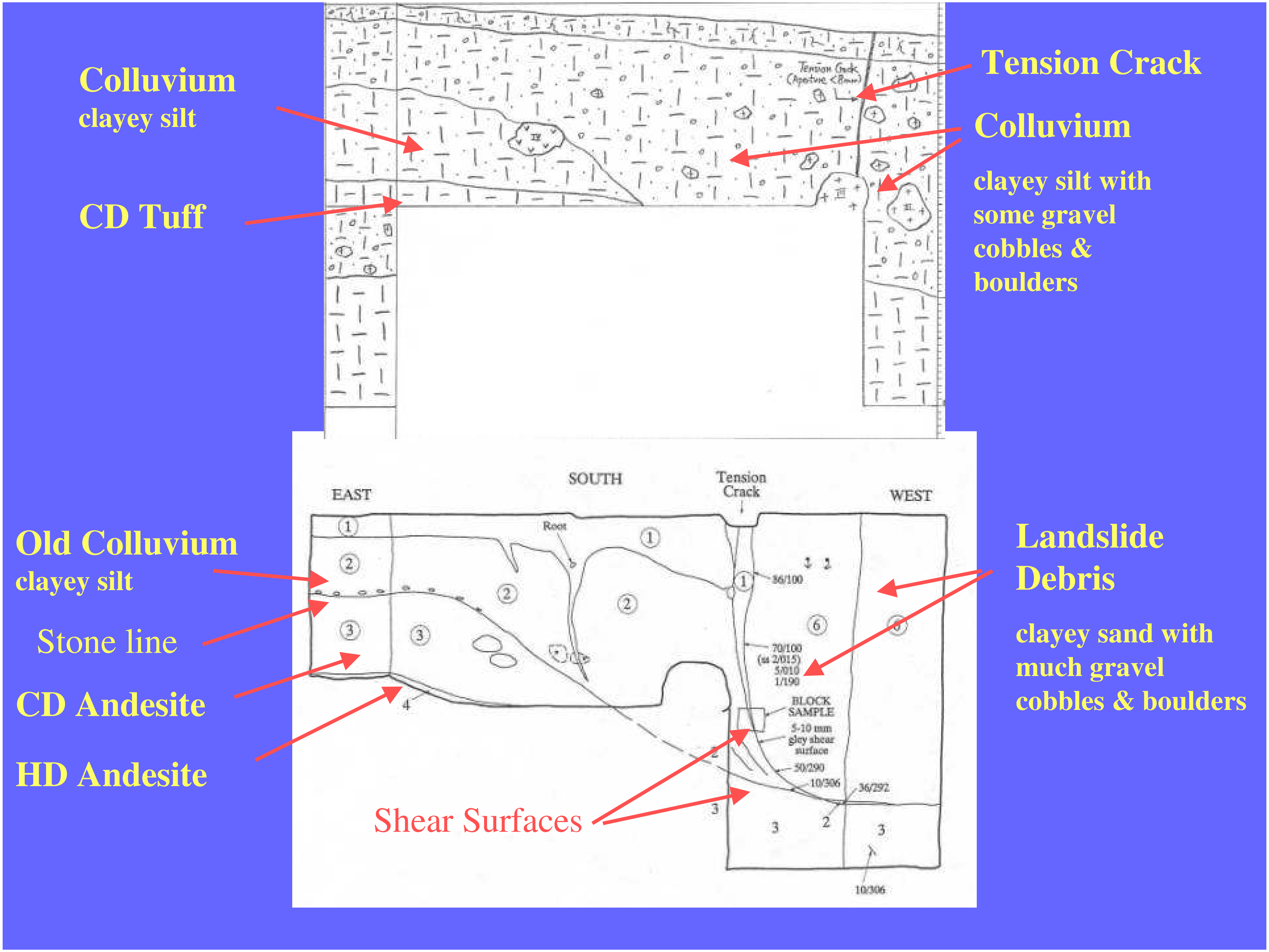
• SMALL DISTURBED SAMPLE	△ WATER SAMPLE
LARGE DISTURBED SAMPLE	PIEZOMETER TIP
SPT LINER SAMPLE	STANDPIPE
U76 UNDISTURBED SAMPLE	STANDARD PENETRATION TEST
U100 UNDISTURBED SAMPLE	PERMEABILITY TEST
MAZIER SAMPLE	IMPRESSION PACKER TEST
PISTON SAMPLE	V IN-SITU VANE SHEAR TEST
	PACKER TEST

LOGGED D.Y. Yip
DATE 22/07/2002
CHECKED James Lu
DATE 20/07/2002

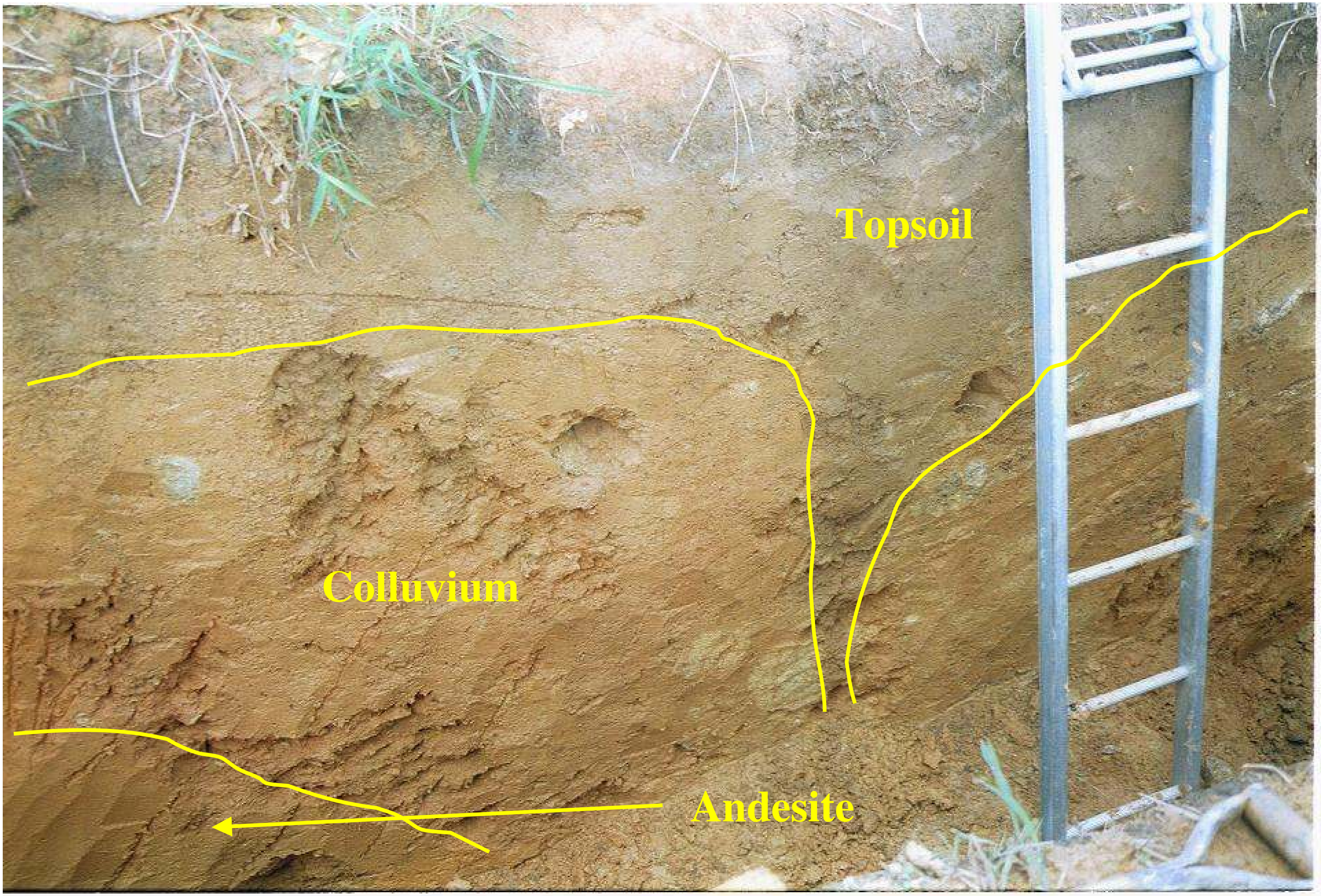
REMARKS
1. Inclinometer access tube was installed to depth 24.46m.


Topsoil
Colluvium
CD Tuff
MD Tuff
Boulders of H-MD Tuff
Quartz Vein
0.20
0.5
1.0
1.5
2.0
2
3





Colluvium
clayey silt
CD Tuff
Tension Crack
Colluvium
clayey silt with some gravel cobbles & boulders
EAST
SOUTH
Tension Crack
WEST
Root
86/100
70/100
5/010
1/190
BLOCK SAMPLE
5-10 mm gley shear surface
50/290
10/306
36/292
10/306
Old Colluvium
clayey silt
Stone line
CD Andesite
HD Andesite
Shear Surfaces
Landslide Debris
clayey sand with much gravel cobbles & boulders


Topsoil
Colluvium
Andesite

Thank You