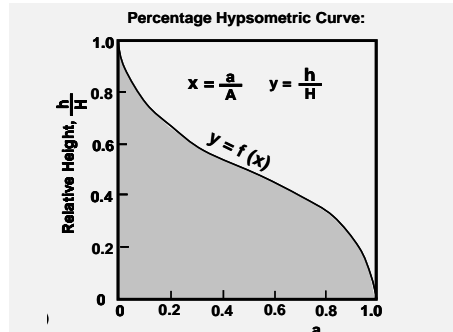


An Application of Quantitative Geomorphology on Regional Scale Landslide Hazard Assessment in Hong Kong



Angel K Y Ng
Geomorphologist
Ove Arup & Partners Hong Kong Limited



Introduction

Introduction

- What is the role of geomorphology in landslide hazard assessment?



Rotational slides at Stonebarrow, UK

What is Geomorphology?

‘Geomorphology is the interdisciplinary and systematic study of landforms and their landscapes as well as the earth surface processes that create and change them.’

<http://www.geomorph.org/main.html>



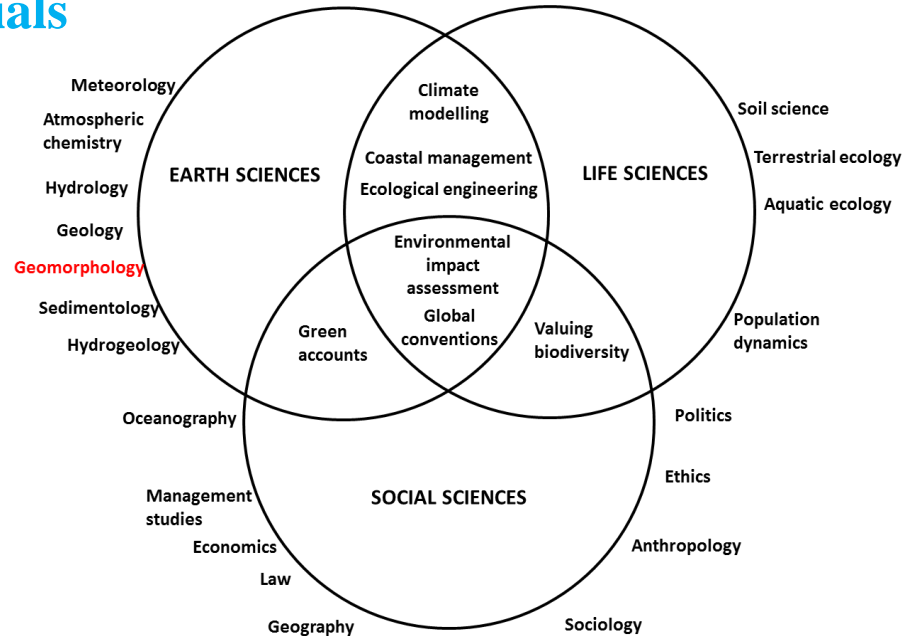
‘Geomorphology is the science concerned with understanding the form of the Earth's land surface and the processes by which it is shaped, both at the present day as well as in the past.’

<http://www.geomorphology.org.uk/>



What is Geomorphology?

- **Geomorphology is the scientific study of earth's surface through time, with a particular emphasis on the **landform**, its **formation processes**, and **materials****



Position of Geomorphology in science (after Gregory, 2000)

Or simply....

The Science of Scenery

HOW GEOMORPHOLOGY CAN HELP ASIA COPE WITH ITS ENVIRONMENTAL CHALLENGES.

Text and Photos: DAVID HIGGITT

Geomorphology can be regarded as the 'science of scenery.' It seeks to explain how landscapes develop over time, the operation of earth surface processes such as erosion, landsliding and river flows, and the interactions between these processes and the landscape.

Geomorphology seeks to understand landform dynamics and to predict changes through careful field observation, computer modelling and experimentation.

What geomorphology involves?

- History and epistemology of geomorphology
- Geomorphology and earth system science
- Planetary geomorphology
- Mega-geomorphology
- Tectonic geomorphology
- Volcanic geomorphology
- Magnitude and frequency in geomorphology
- Geomorphic processes and long term landscape evolution
- Rock control on geomorphic processes and landforms
- Quaternary geomorphology
- Hillslope processes and mass movements
- Fluvial geomorphology and river management
- Sediment budgets
- Coastal geomorphology and management
- Submarine geomorphology
- Aeolian systems and arid geomorphology
- Tropical geomorphology
- Cold region geomorphology
- Methods in Geomorphology
- Geomorphology and global environmental change

8th IAG International Conference on Geomorphology,
August 27th to 31st, 2013

Landslides as a major Geomorphic Hazard

- Landslides is a type of mass movement processes that involve downslope movement of slope materials under the force of gravity
- Result in lowering the landscape **and affect the society**



Landslide Mapping Course in Ethiopia

Landslide Hazard Assessment – a key topic in Applied Geomorphology

Landslides:
Causes,
Consequences and
Environment

Crozier, M.J.

Note: This is not the actual book cover

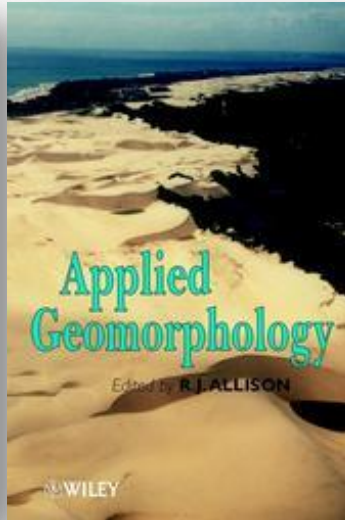
**GEOMORPHOLOGY
ENVIRONMENTAL
MANAGEMENT**

A NEW INTRODUCTION

**R.U. COOKE AND
J.C. DOORNKAMP**

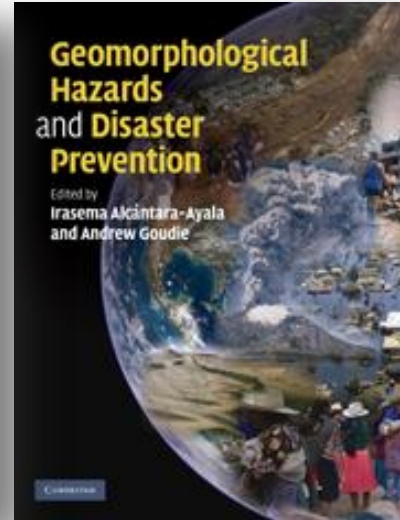
SECOND EDITION

FLASH
FLOOD
REA
WARNING



**Geomorphological
Hazards
and Disaster
Prevention**

Edited by
Irasema Alcántara-Ayala
and Andrew Goudie



**Engineering
Geomorphology**

Theory and Practice



P.G. Fookes, E.M. Lee and J.S. Griffiths

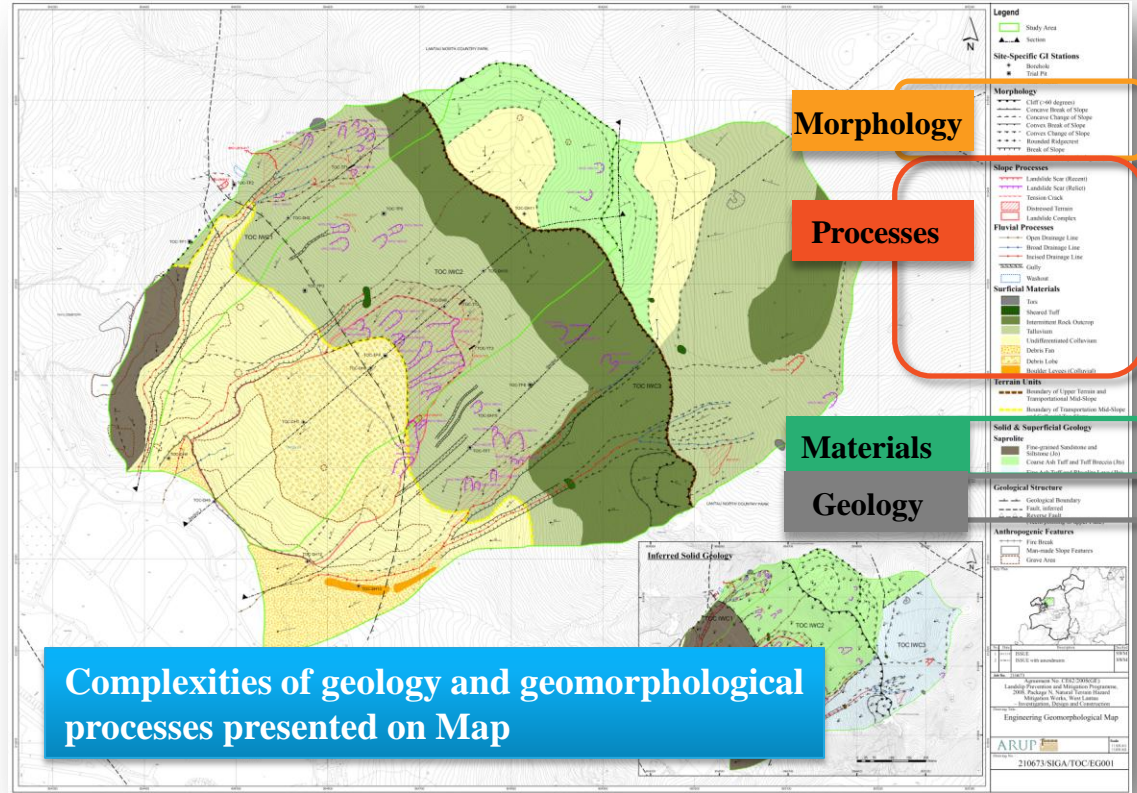
- Understanding the interactions between ‘form’, ‘processes’ and ‘materials’ helps explain how landslide behaves and mitigate its impact



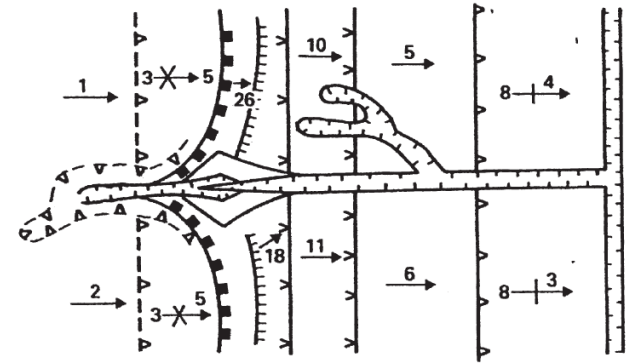
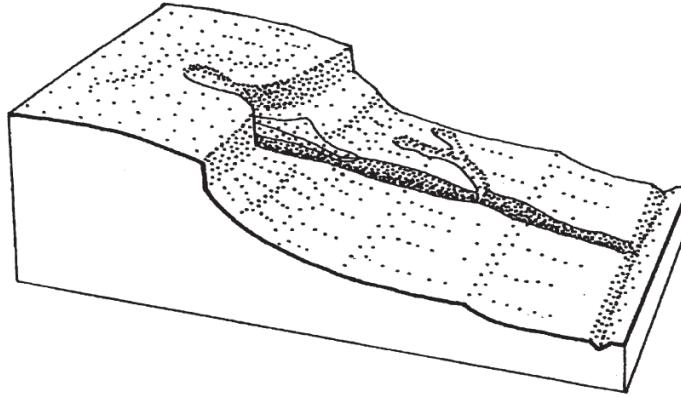
Application of Geomorphology on Landslide Assessment

Geomorphological Mapping

- Geomorphology mapping is used to record the **morphology, surface processes and materials**



Use of Morphological Mapping Symbols



Morphological mapping symbols

∇—∇ Angular convex
break of slope

∇—∇ Smoothly concave
change of slope

TTTTT * Breaks of slope

* Convex and concave too close together to allow
use of separate symbols

∇—∇ Angular concave
break of slope

—11→ Direction of slope
(angle in degrees)

TTTTT * Changes of slope

∇---∇ Smoothly convex
change of slope

■■■■ Cliffs (bedrock
40° or more)

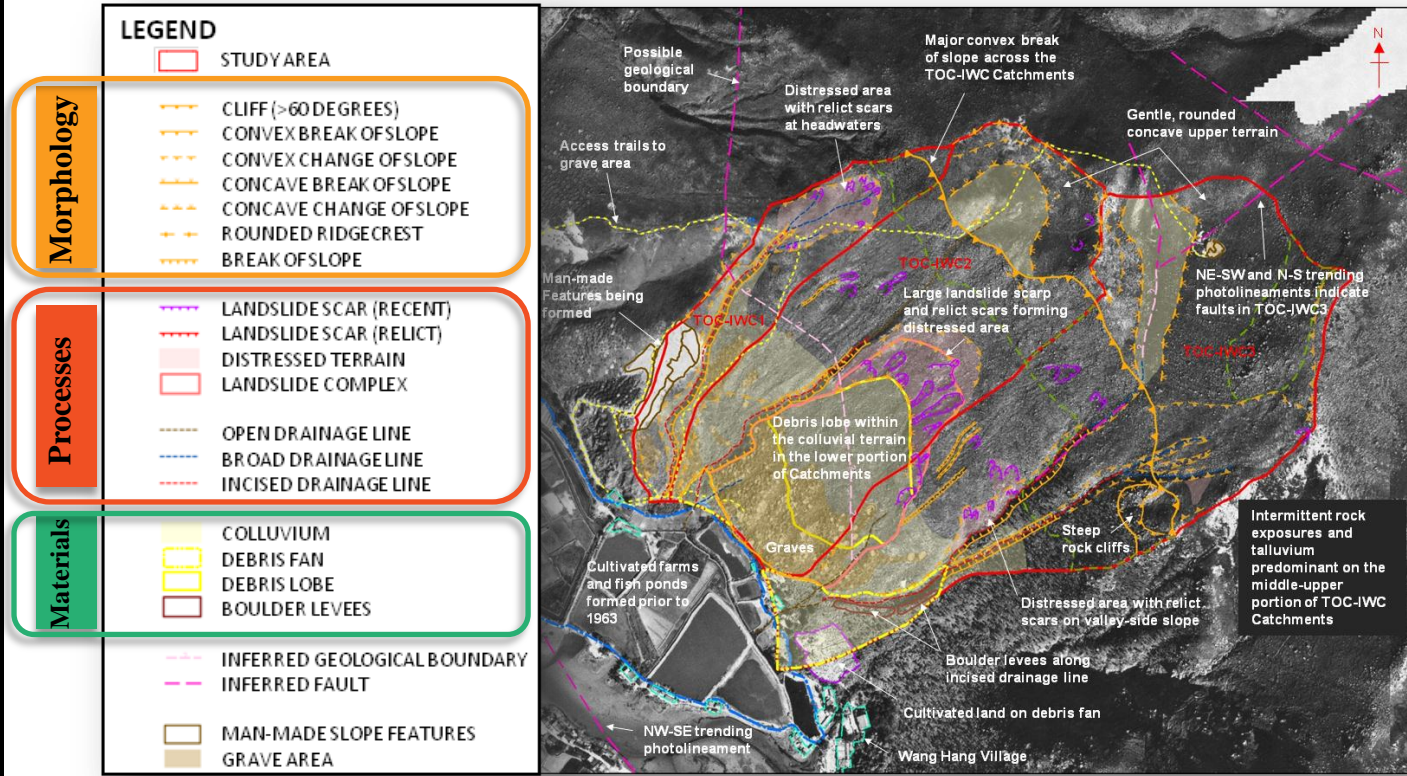
—X→ Convex slope unit

—+→ Concave slope unit

After Savigear (1965)

Reading the landscape...

Key Skills – Aerial Photo Interpretation



API for Landslide Hazard Assessment at Tai O

Reading the landscape.....

Key Skills – Field
Mapping



Field trip at the IAG Regional Conference, Ethiopia

Key Skills – Field Interpretation



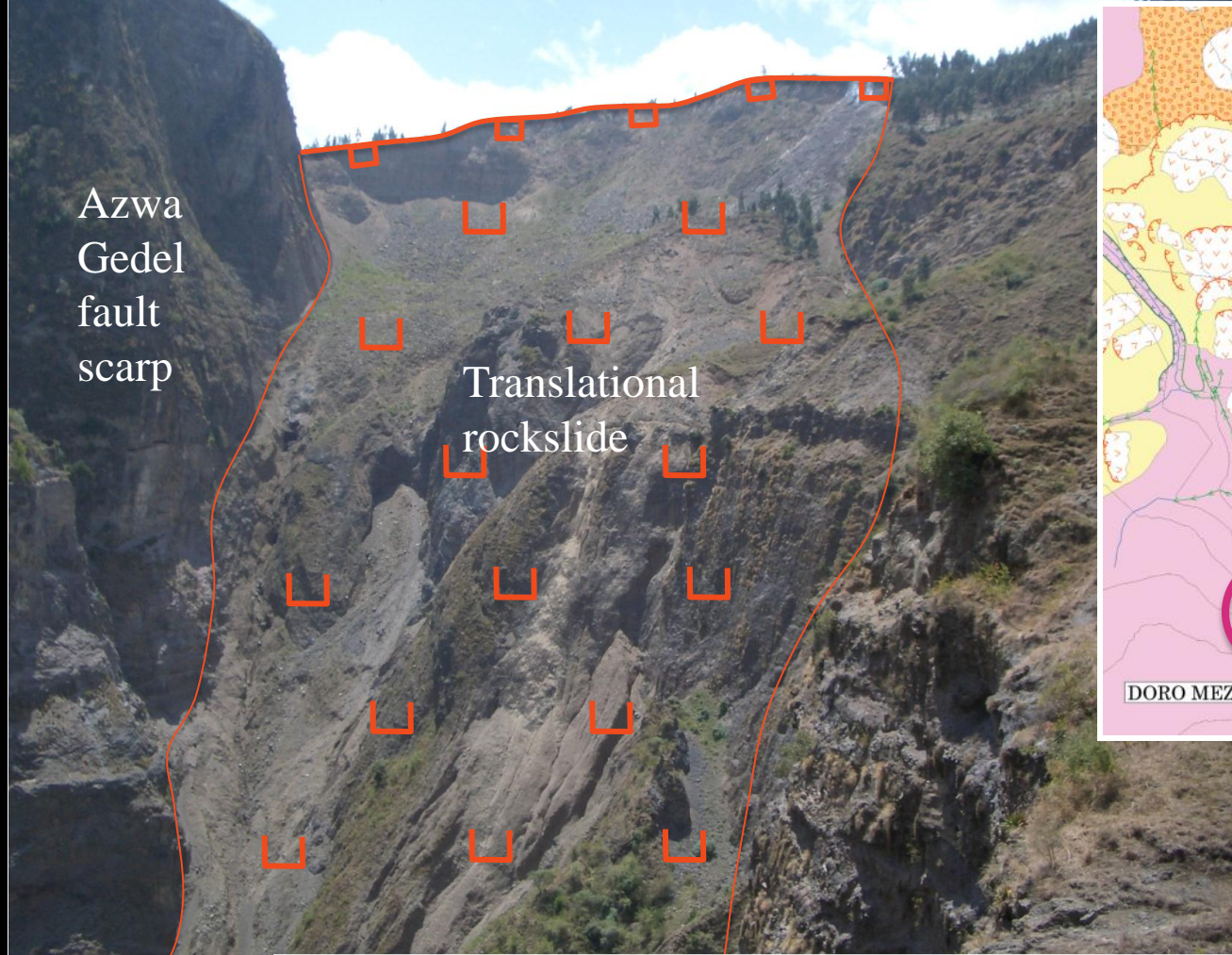
Translational rock slide, Dessie Basin. Ethiopia



LANDFORMS DUE TO GRAVITY AND RELATED DEPOSITS

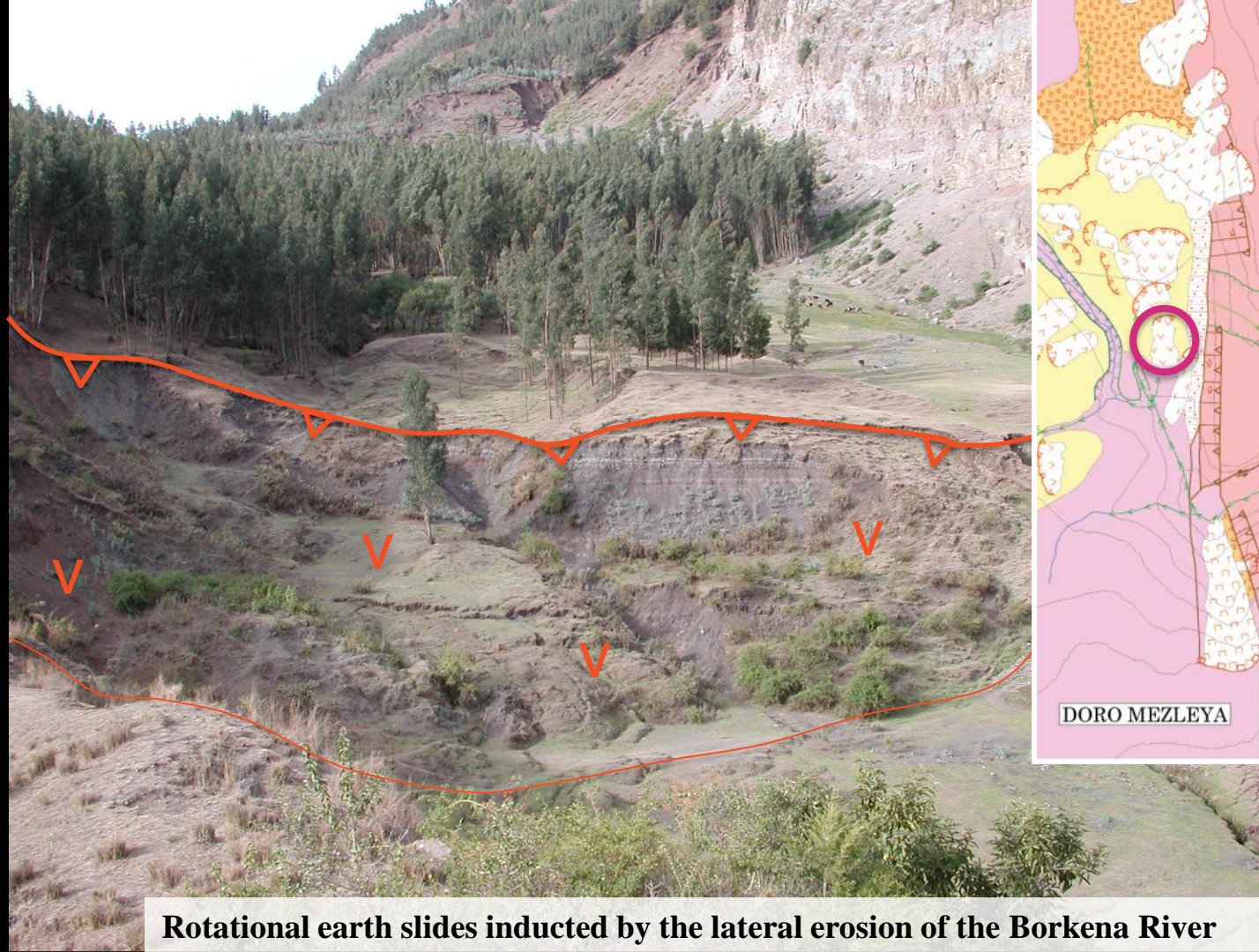
- Debris flow
- Fall landslide scarp
- Rotational landslide scarp
- Translational landslide scarp ←
- Fall/avalanche landslide body
- Rotational landslide body
- Translational landslide body ←

Key Skills – Field Interpretation



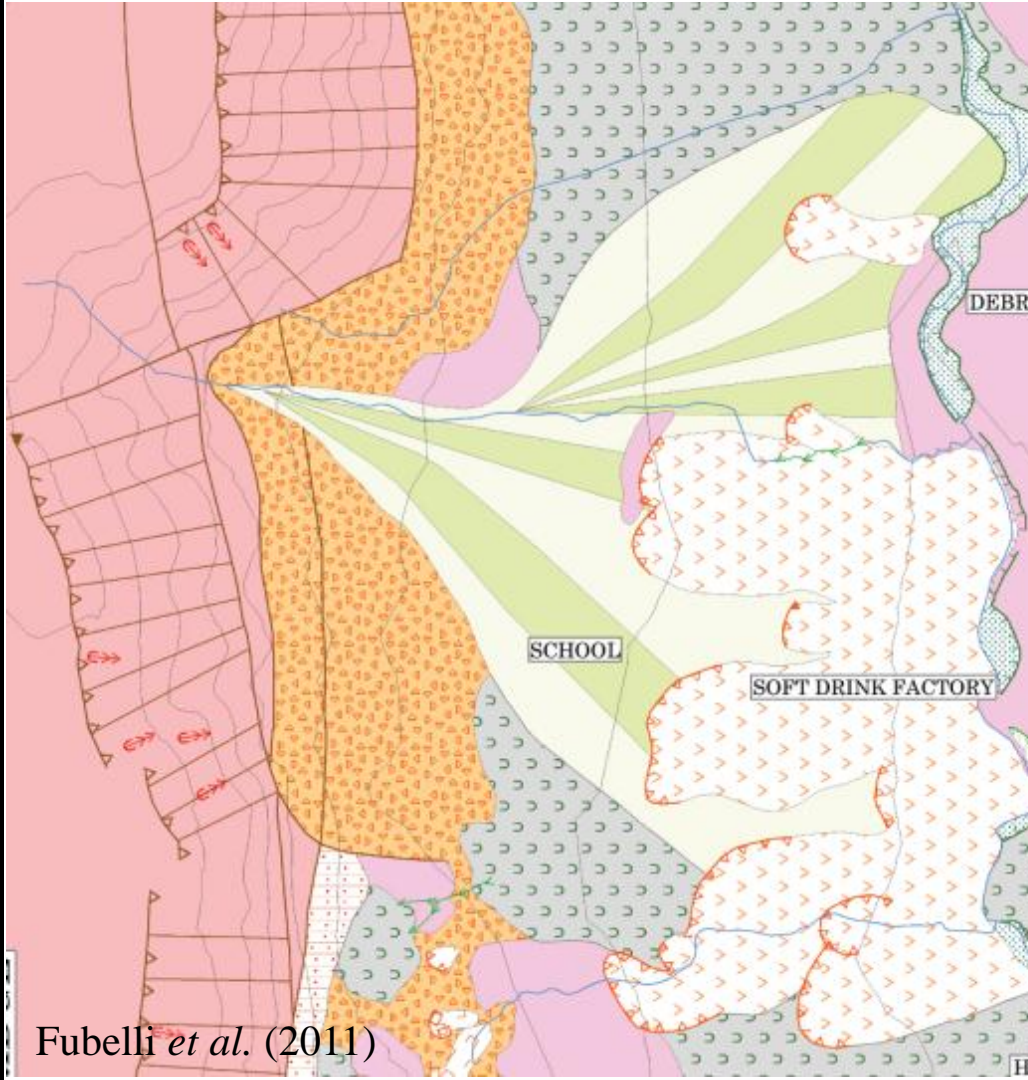
Translational rock slide on the south-eastern edge of the Dessie basin

Key Skills – Field Interpretation



Rotational earth slides induced by the lateral erosion of the Borkena River

What and where is the risk?



- How geomorphology was applied in landslide assessment in Hong Kong?



Landslides triggered by June 2008 rainstorm on Lantau Island

GEO Technical Guidance Note No. 22 (TGN 22)
Guidelines on Geomorphological Mapping for
Natural Terrain Hazard Studies

Issue No. : 1 Revision: - Date : 22.12.2004 Page : 1 of 8

Application of Geomorphological Mapping in HK

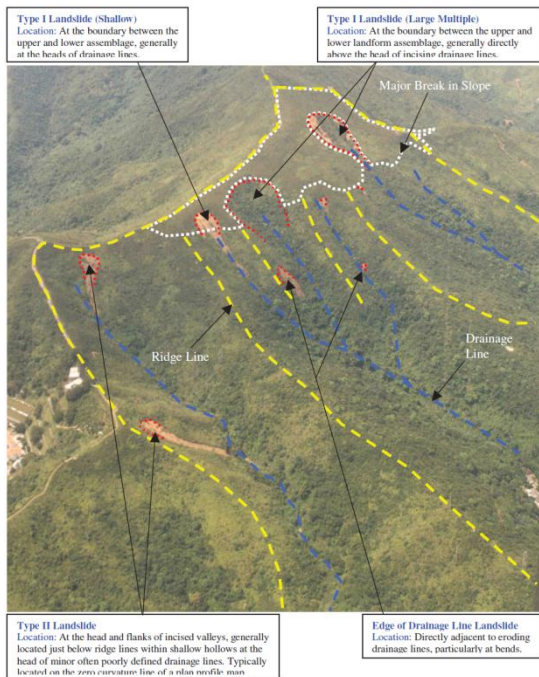
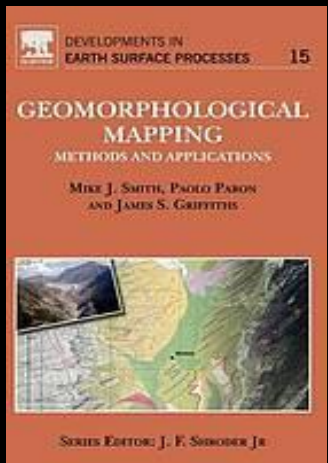


Figure 1 - Major Break in Slope Associated with Landsliding (Halcrow, 2003)

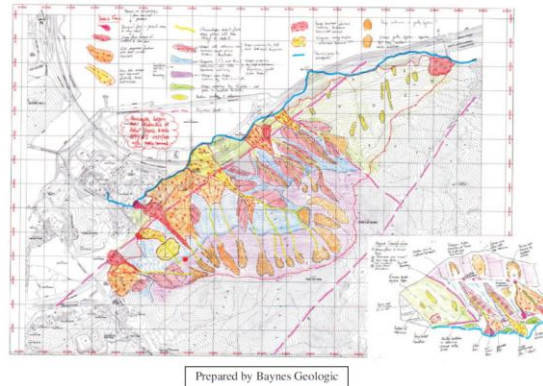


Figure 4 - Reconnaissance Morphogenetic Map for North Lantau (Ove Arup, 2004)

	Regolith Type Clf (Rock Fall Debris - Talus)
General description	Forms below rock slopes/escarpments either as a result of individual rock block failures or rock avalanches. The size of the rock blocks generally depends upon joint characteristics (e.g. spacing and orientation).
Topographic position	Most occur down-slope of rock outcrops. Commonly can form on planar (unconfined) slopes. Rock fall deposits can commonly be confined by topographic depressions e.g. gullies, ephemeral drainage lines.
Morphology	Concave break in slope usually occurs at the toe of the deposit. Can commonly be fan-shaped, becoming more linear on steeper slope angles. Can form a planar surface, which locally appears hummocky/irregular. Individual boulders commonly apparent. Occasionally incised/truncated by recent landslides or drainage lines.
Material Properties	Must be classic debris comprising angular boulders and cobbles with fine material either not present or present in minor amounts. The size of the blocks is dependent upon both joint spacing and the degree of comminution the blocks suffer in transport.
Vegetation	Can be bare on steep slopes, but commonly vegetated by both ferns and grasses if topographically confined.
Relative Age	Relatively recent (Category A).
Aerial Photograph Characteristics	
1963	Appears as a hummocky/irregular surface with boulders commonly apparent.
2000	Commonly vegetated with tall grasses; larger boulders can be apparent protruding above the vegetation.

Figure 2 - An Example of Regolith Mapping Guide (MFJV, 2002)

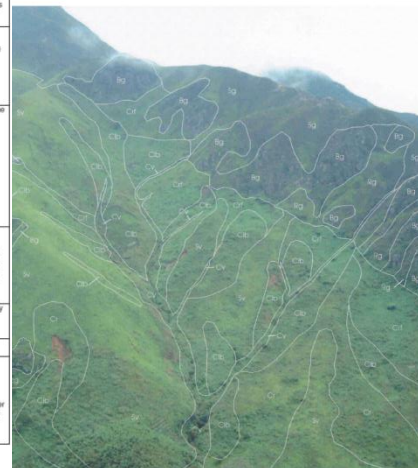
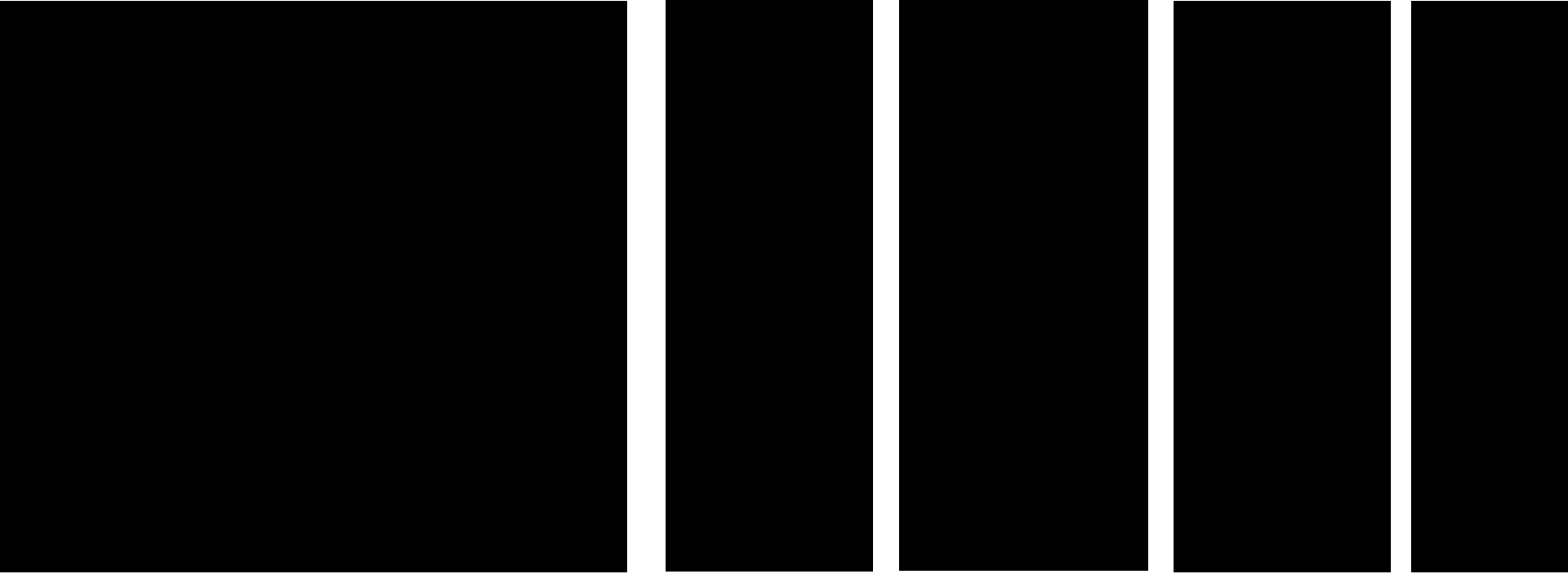


Figure 3 - Regolith Units Overlain on an Oblique Photograph (MFJV, 2002)

What is the gap?



Is it possible to apply **quantitative** geomorphology to assess landslides?





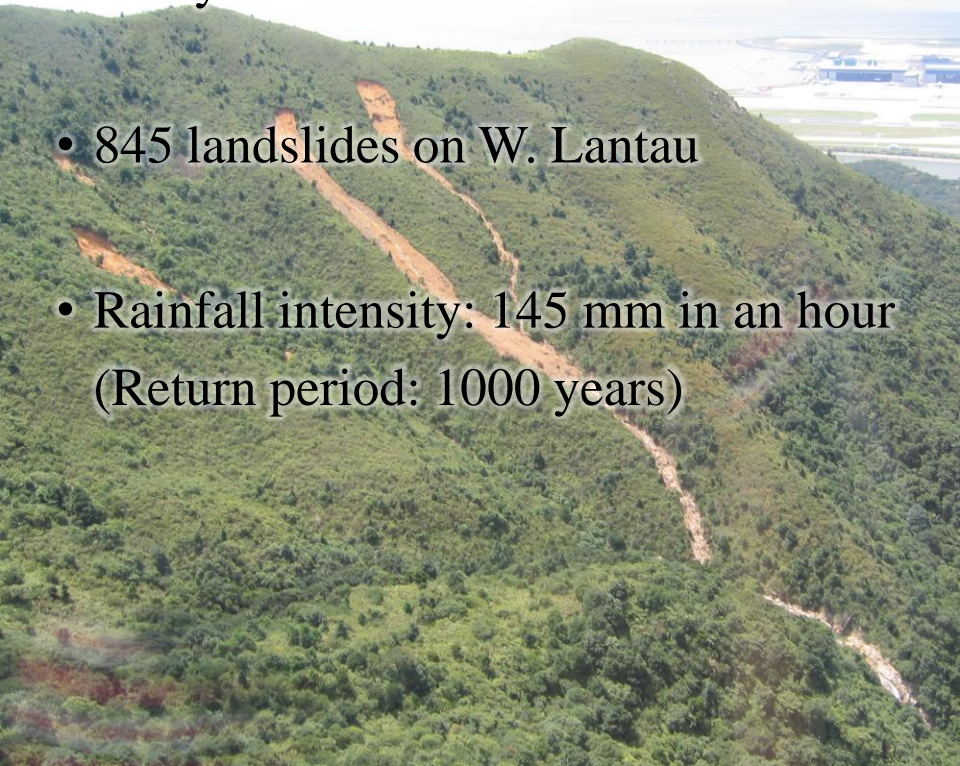
An Application of
Quantitative
Geomorphology

An opportunity comes up ...

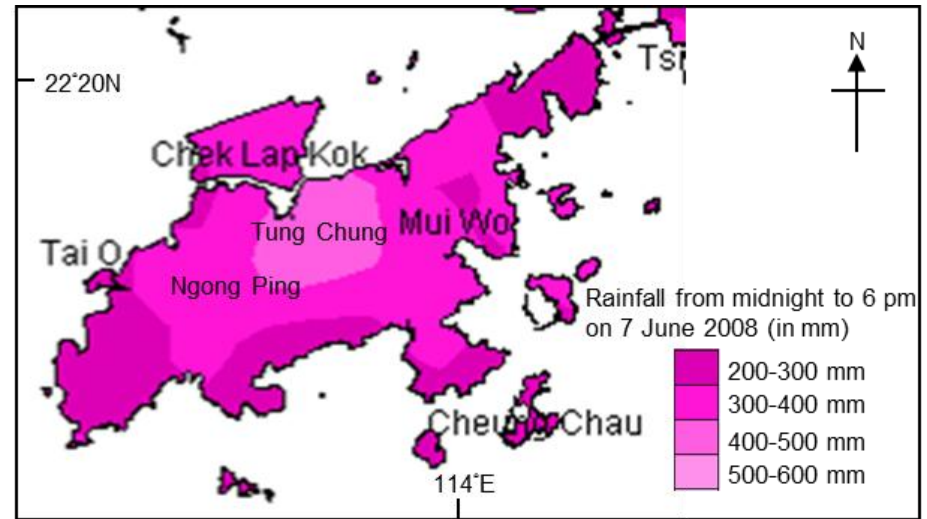


June 2008 landslides

- > 1,600 landslides were triggered by heavy rainstorm in June 2008



- 845 landslides on W. Lantau
- Rainfall intensity: 145 mm in an hour (Return period: 1000 years)



Source: Hong Kong Observatory



Shallow debris slides and flows

Aims of Study

- To quantify the relationship between the geomorphological parameters and landsliding process in a regional scale
- To explore the potential practical application of a quantitative approach to assess the spatial occurrence of landslides in Hong Kong

An Application of
Quantitative
Geomorphology



Study Area

- West Lantau Island
- 31 km² (refined catchments)

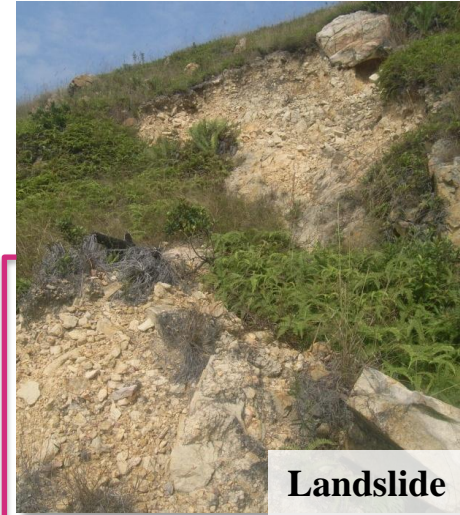
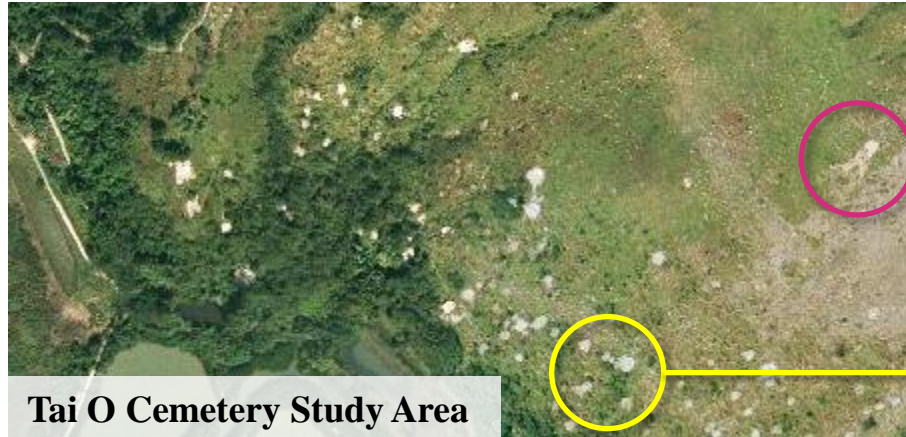
Geomorphology	Key Characteristics
Form	Steep terrain up to 750 mPD
Processes	Fluvial dissected hillslopes; mass movements
Materials	Weathered volcanic ash tuff; colluvium



Use of API & Field Verification

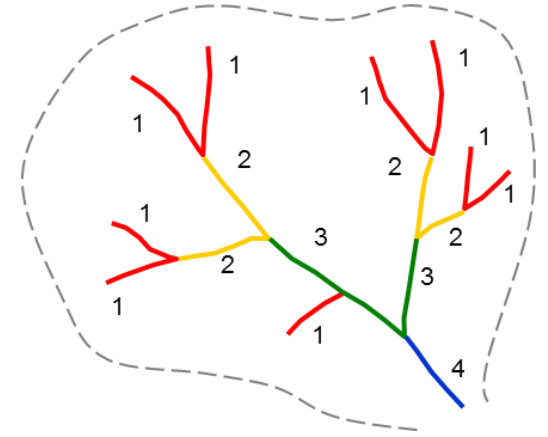
Methodology

- To confirm presence of streams and study area
- To identify / verify June 2008 landslide locations



Stream Ordering

- Strahler's ordering system can be adopted to classify natural streams and the associated catchment



Methodology –

Drainage line
delineation and
classification



Lower-order stream



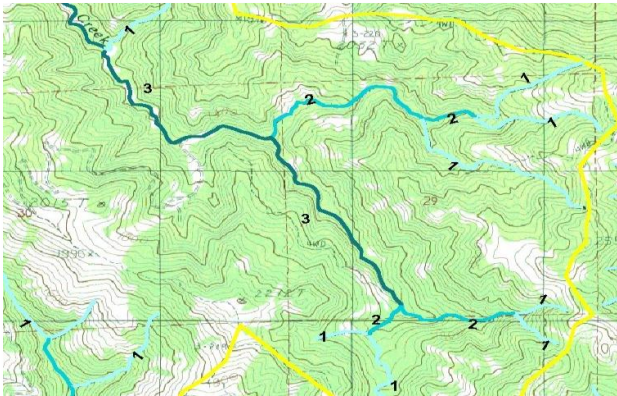
Higher-order stream

How to delineate a drainage line?

- 1:1,000 scale topographic maps
- API
- Field Verification



Increasing certainty



Methodology –

Measurement of
Parameters to
characterise
Drainage Basin
Morphometry

Linear Parameters

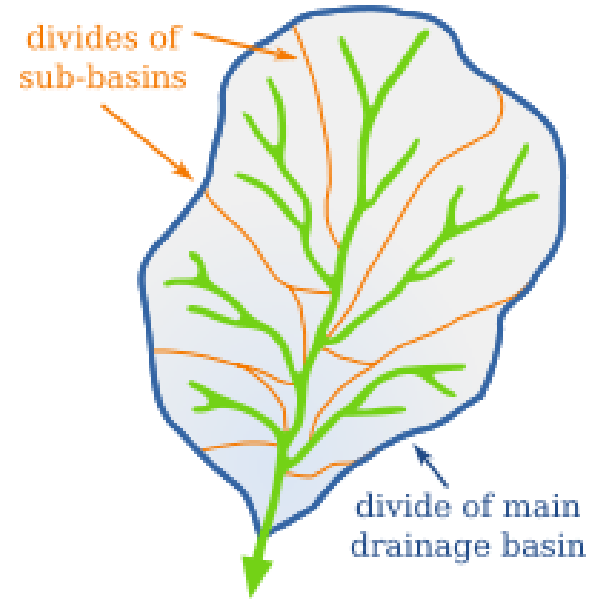
- Drainage order (No. / order)
- Drainage length (km)

Areal Parameters

- Drainage area (km^2)
- Drainage density (km/km^2)

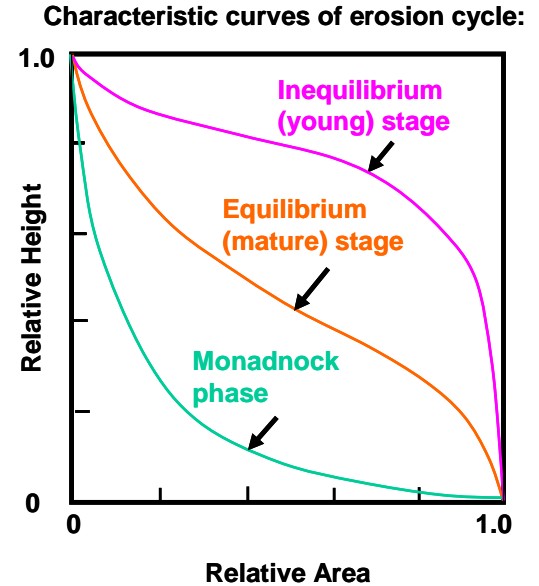
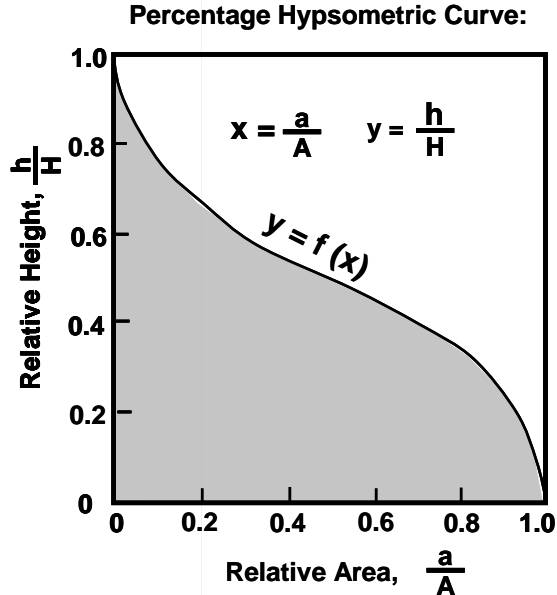
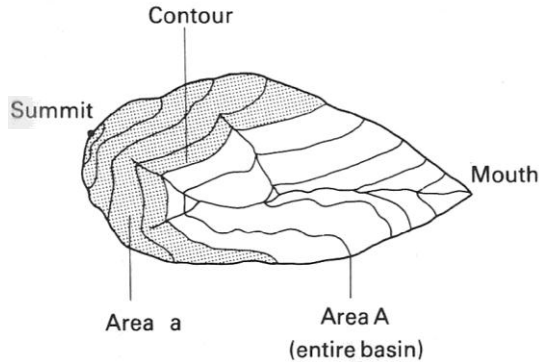
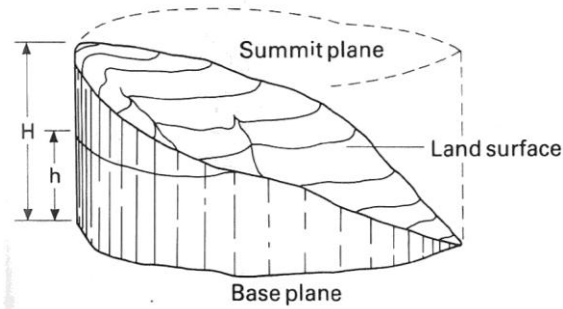
Relief Parameters

- Drainage gradient (ratio or degrees)
- Hypsometric Integral

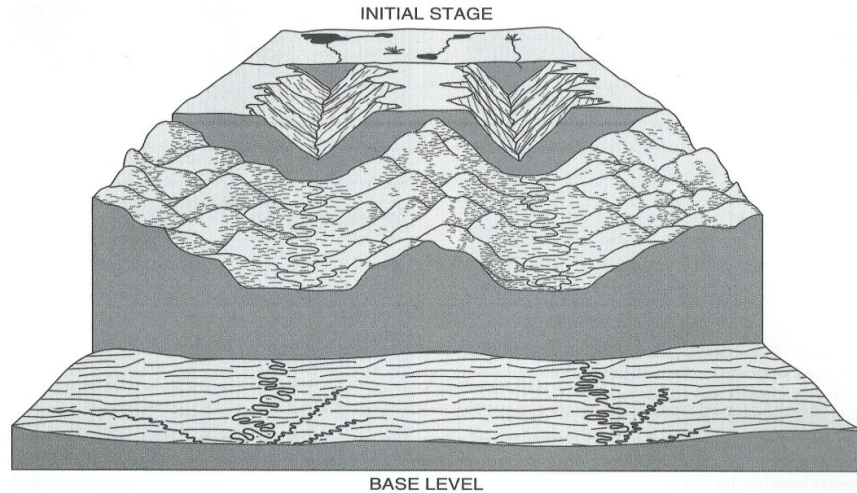


What is Hypsometric Integral?

- Calculation of area-altitude distribution of drainage basin



Fluvial Landform Evolution



Early stage

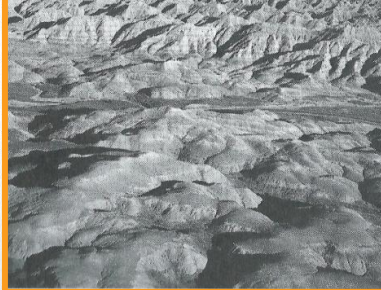
Mature stage

Old stage

**Headward erosion
Vertical incision**



Valley slopes



Gently sloping plain



Work in progress...

Study Area (refined)

GIS

Geomorphology references

Topographic maps

Field verification

API

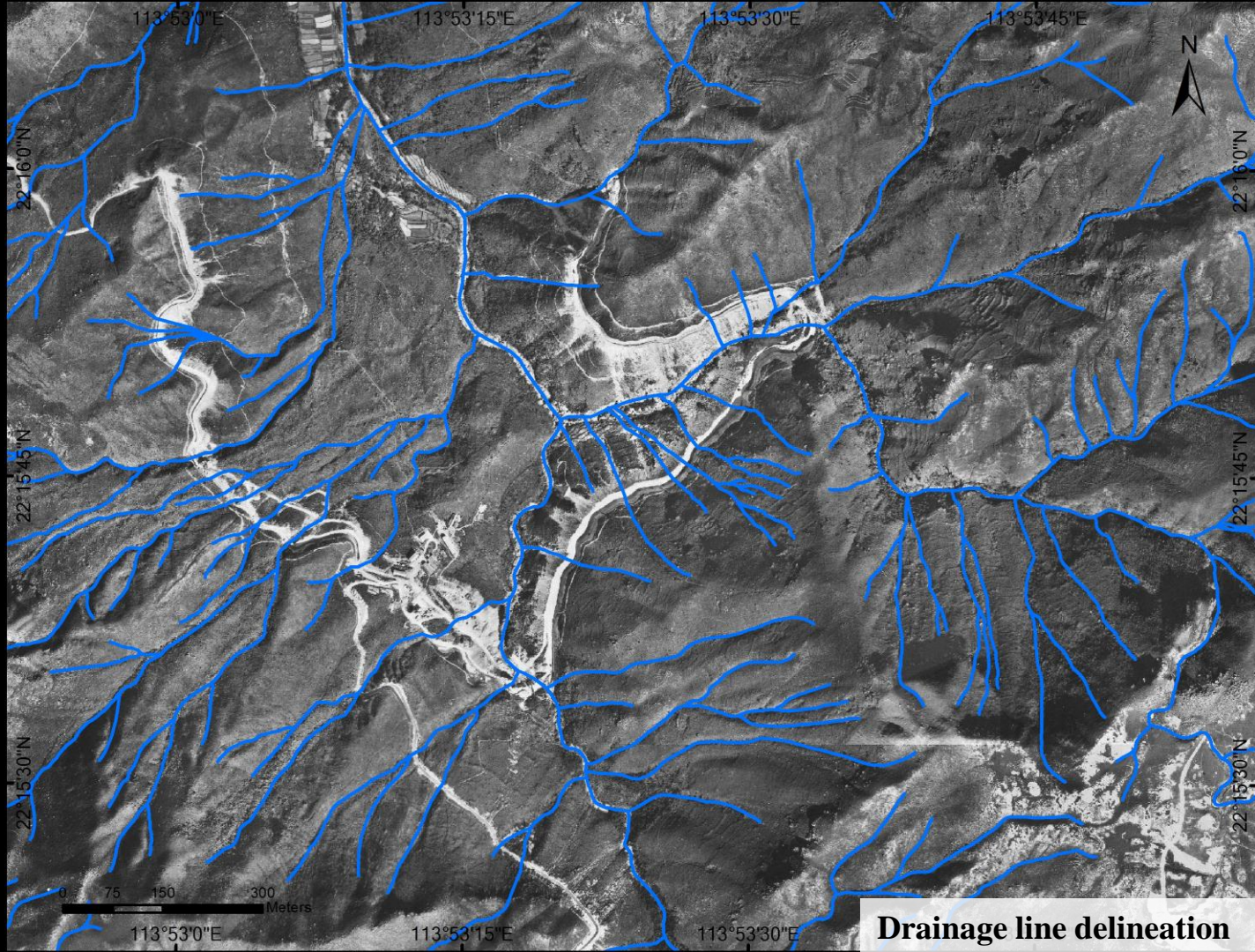


How it works?

API (1963)



API – Drainage line Identification

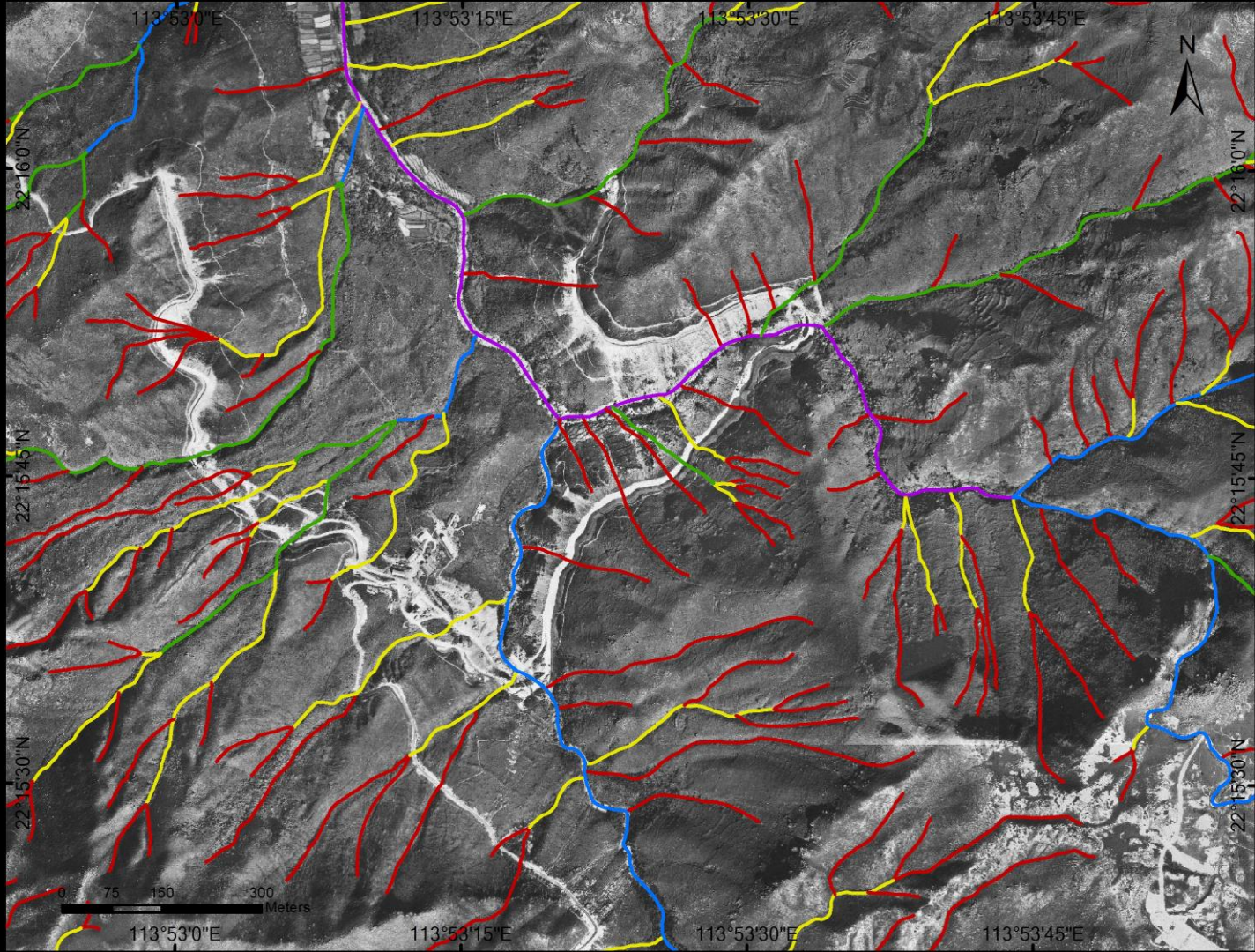


Drainage line classification using Strahler's Order

Legend

Drainage line classification

- 1st order
- 2nd order
- 3rd order
- 4th order
- 5th order
- 6th order

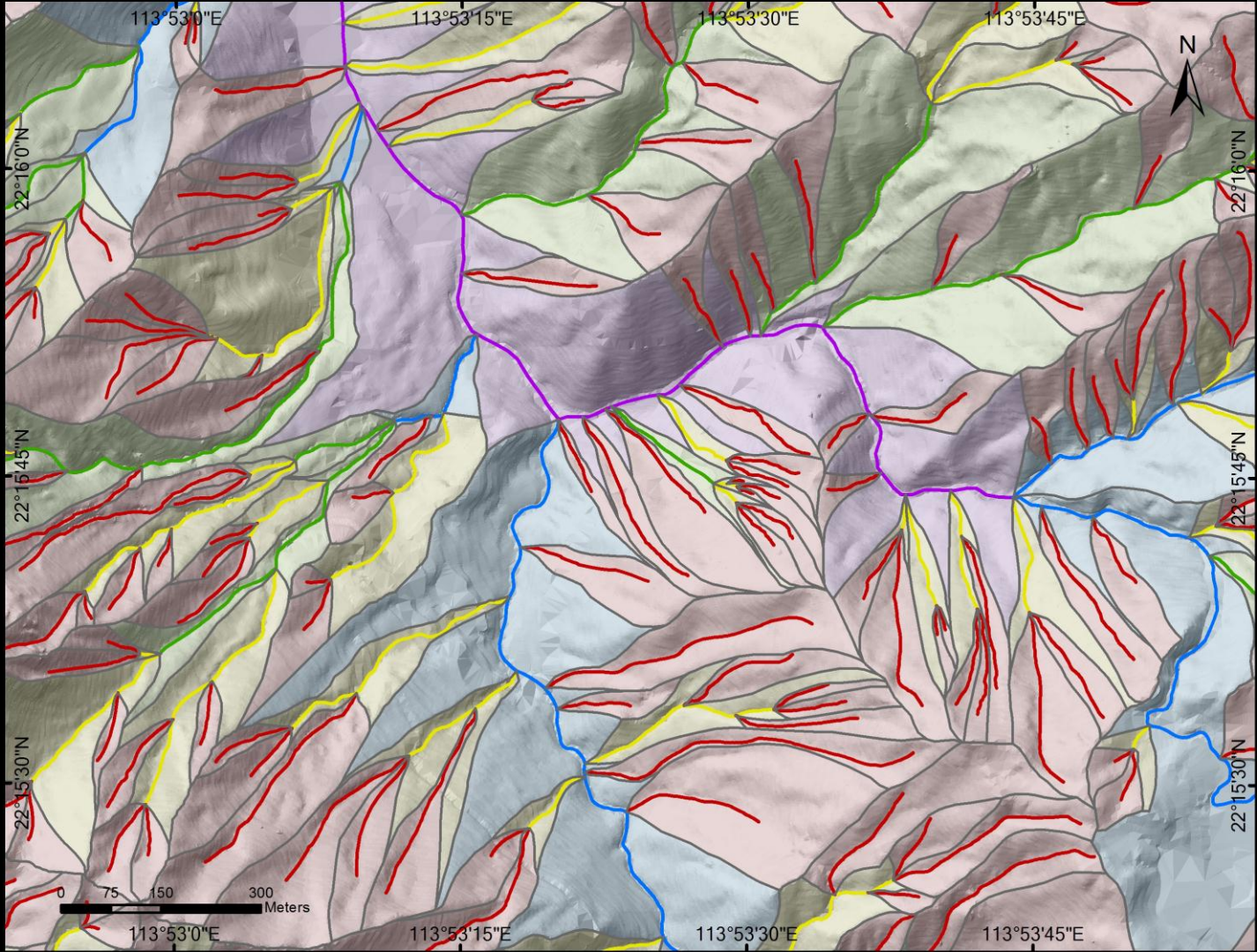


Drainage basin classification using Strahler's Order

Legend

Drainage basin classification

- 1st order
- 2nd order
- 3rd order
- 4th order
- 5th order
- 6th order



API
(before June 2008
rainstorm)

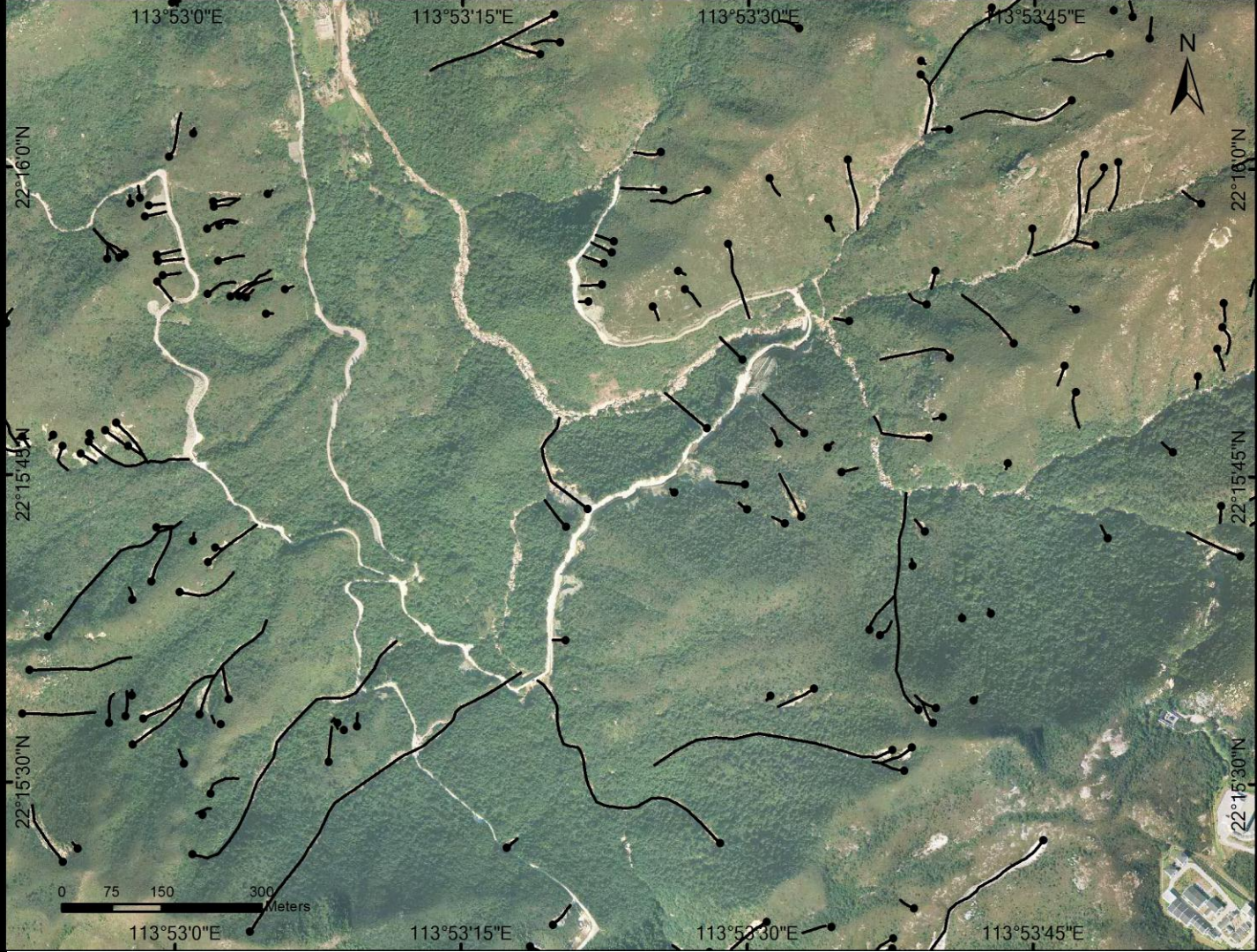


API
(after June 2008
rainstorm)



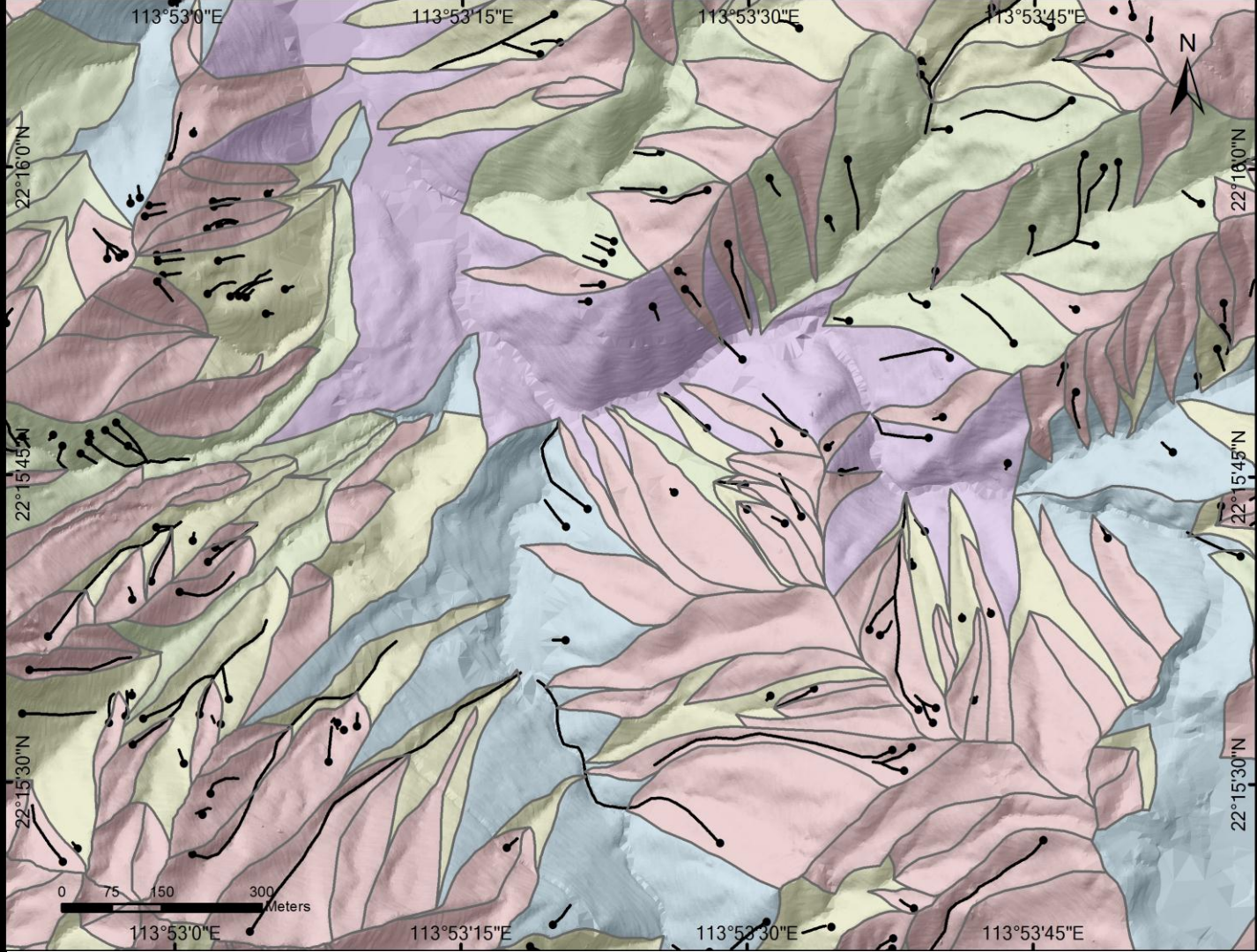
API

Identification of
landslides triggered
by the June 2008
rainstorm



GIS Analyses

Landslides &
Drainage basin
Morphometry





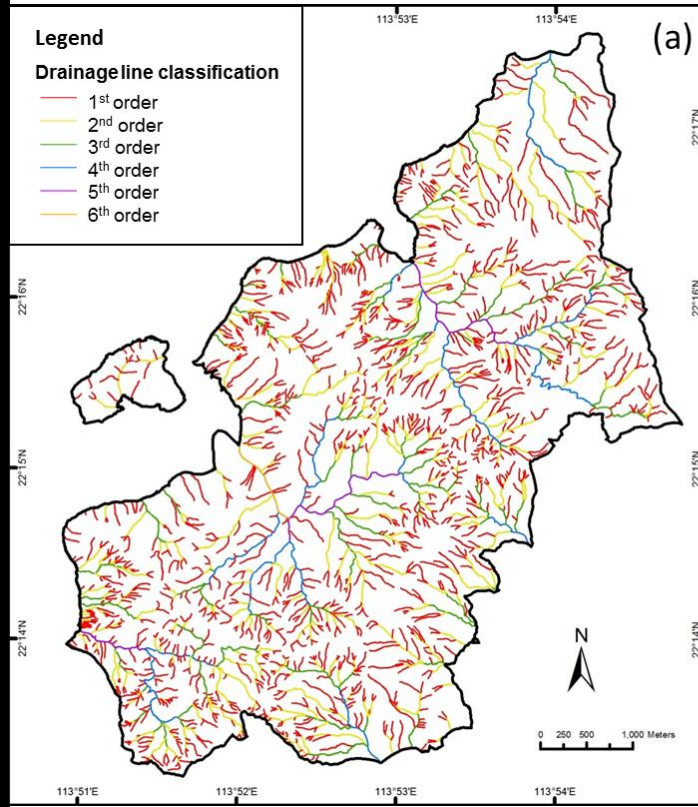
Results

Results

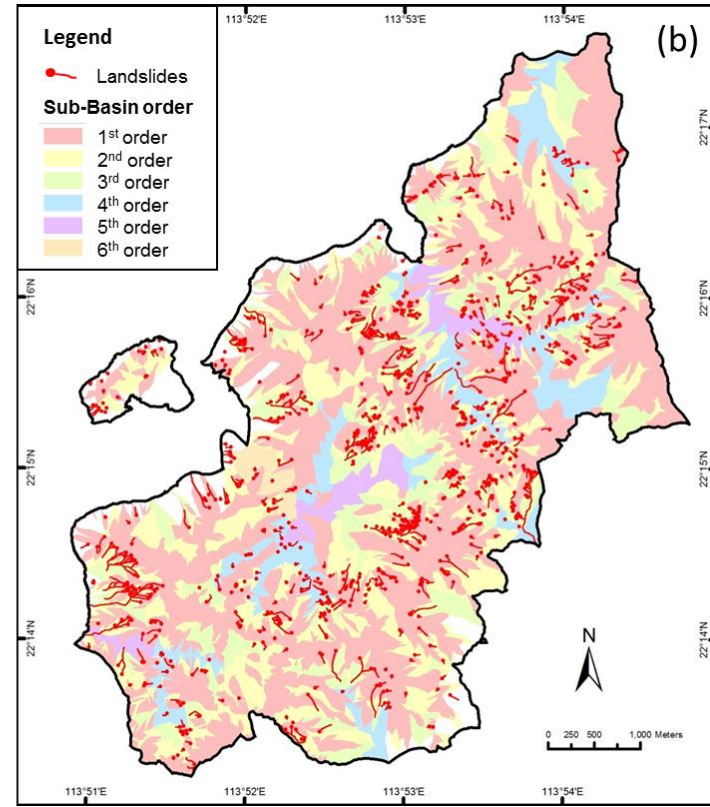
Which geomorphic location is most susceptible to landslides?



Key Findings – Spatial Distribution of the June 2008 Landslides in West Lantau

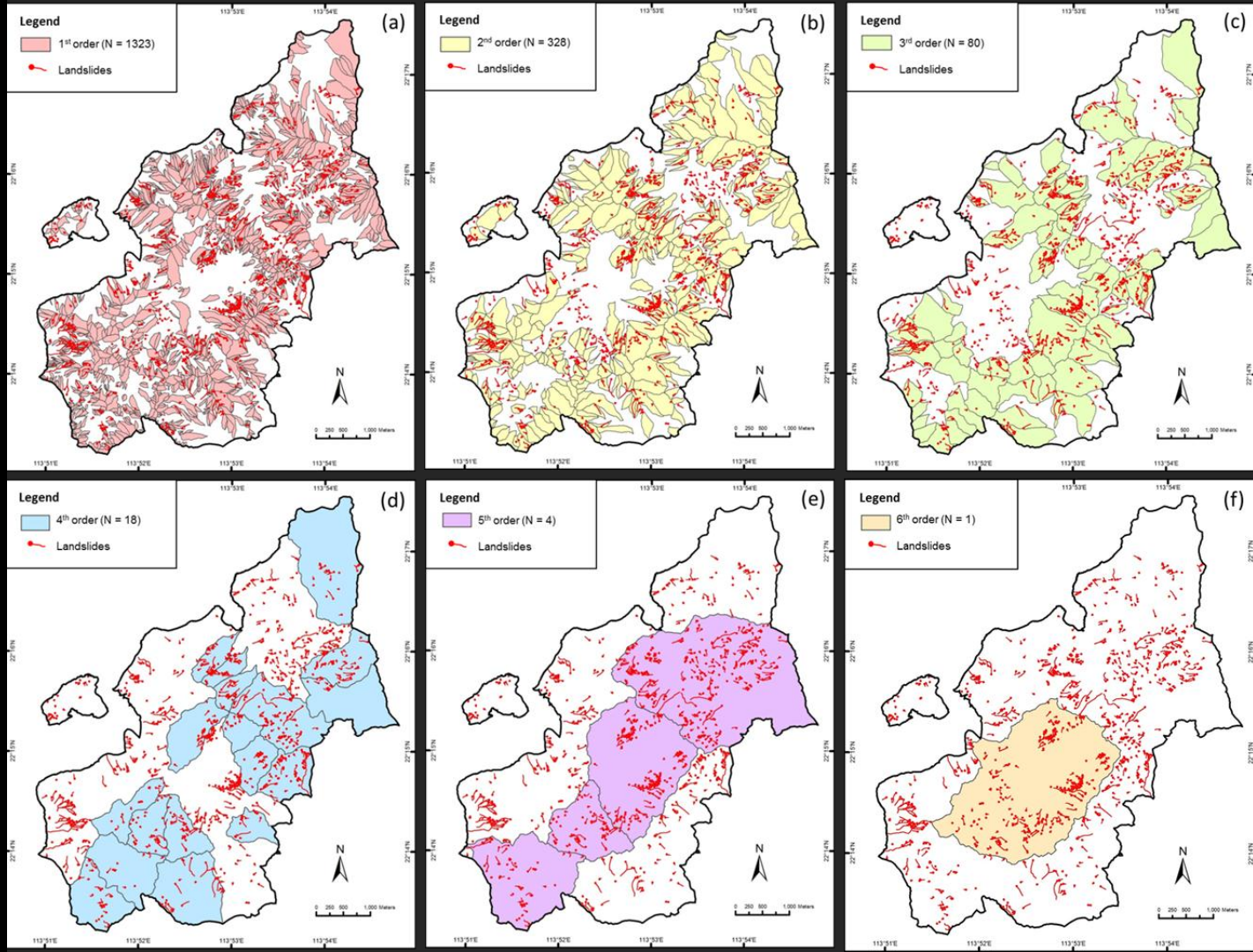


Drainage network system in
Strahler's order



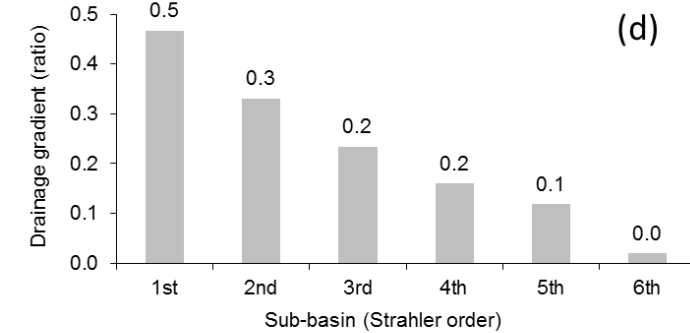
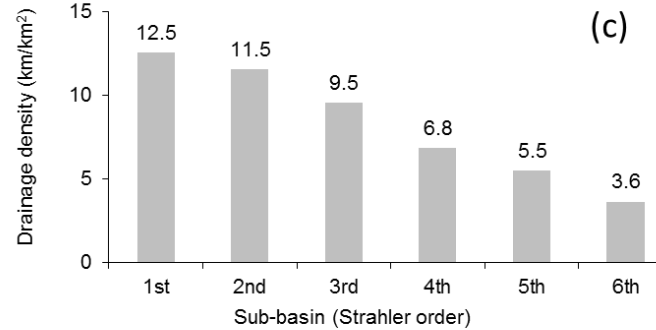
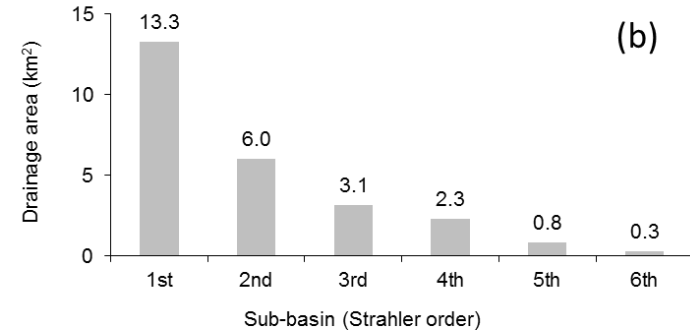
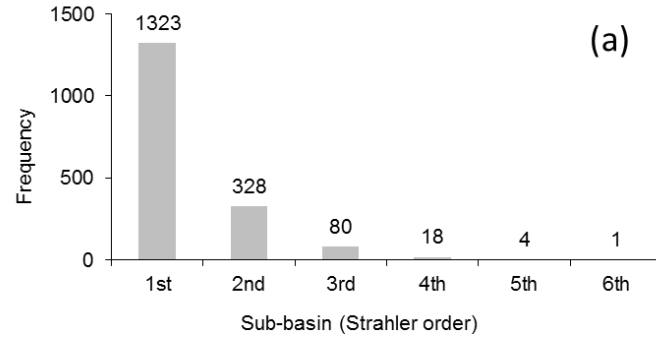
The geomorphic position of
landslides within sub-basins

Key Findings – The Geomorphic Position of Landslides



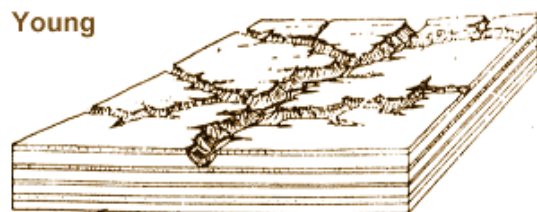
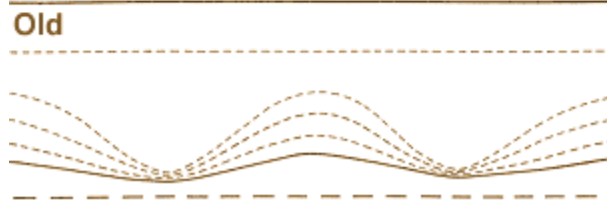
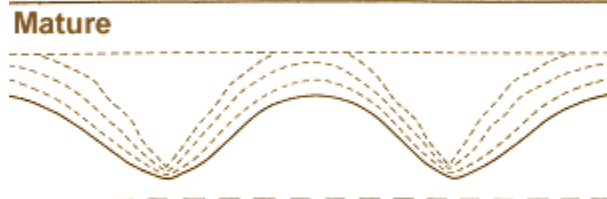
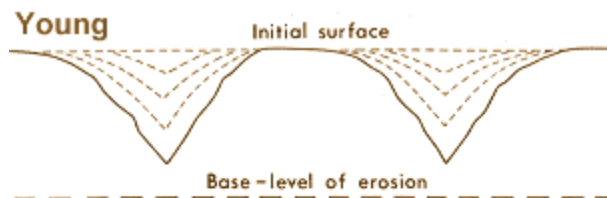
Key Findings —

Drainage Basin Morphometry



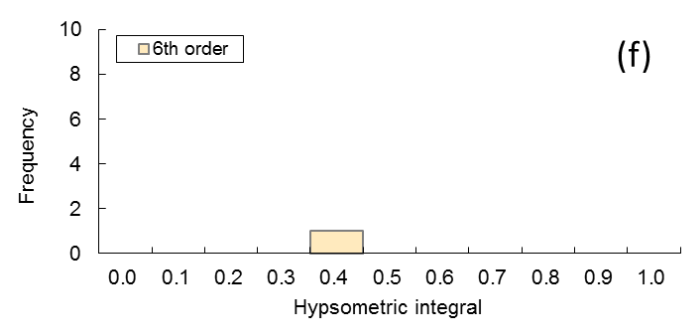
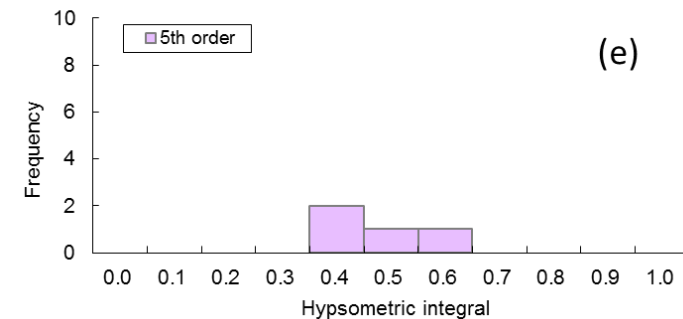
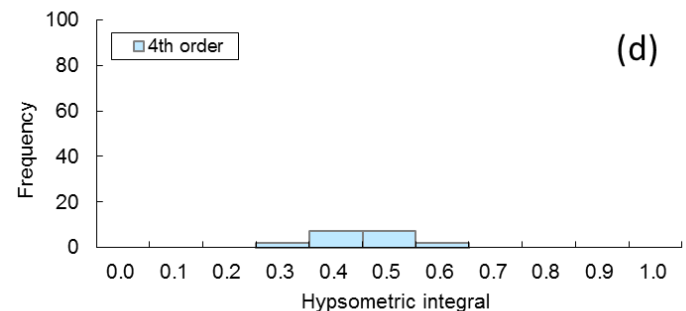
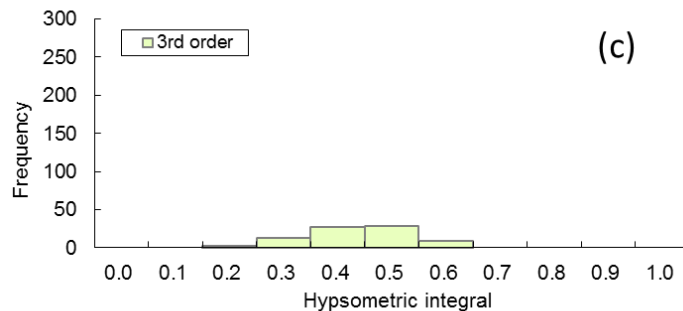
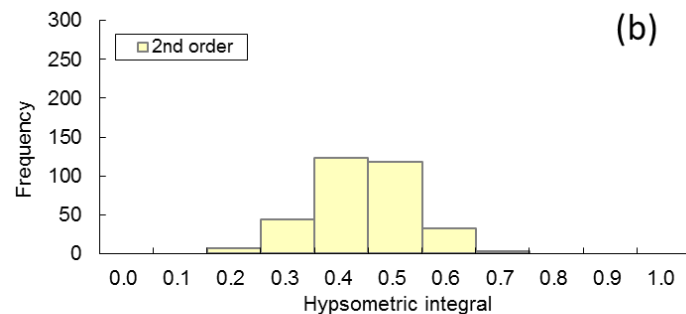
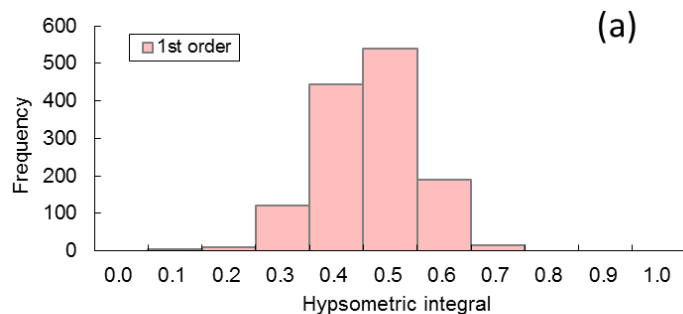
Systematic Distribution of Morphometric Parameters in Strahler's order

Which Stage of Landform Evolution?

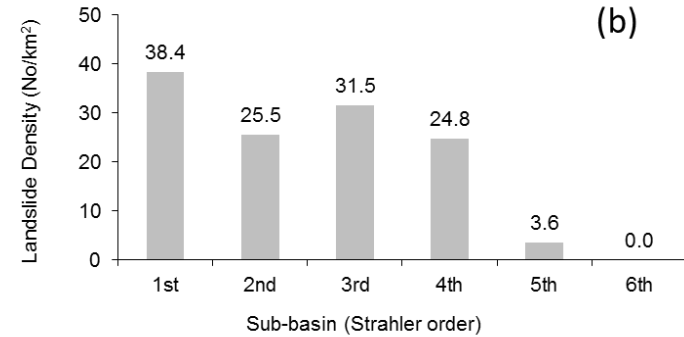
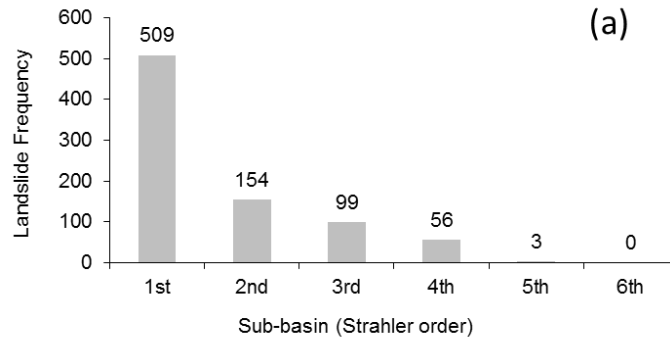


Key Findings –

Frequency Distribution of Hypsometric Integral



Key Findings – Landslide Distribution in Strahler's Order





Discussions

What are the implications for landslide hazard assessment?



Landslides and Drainage Network Development

Academic Perspective

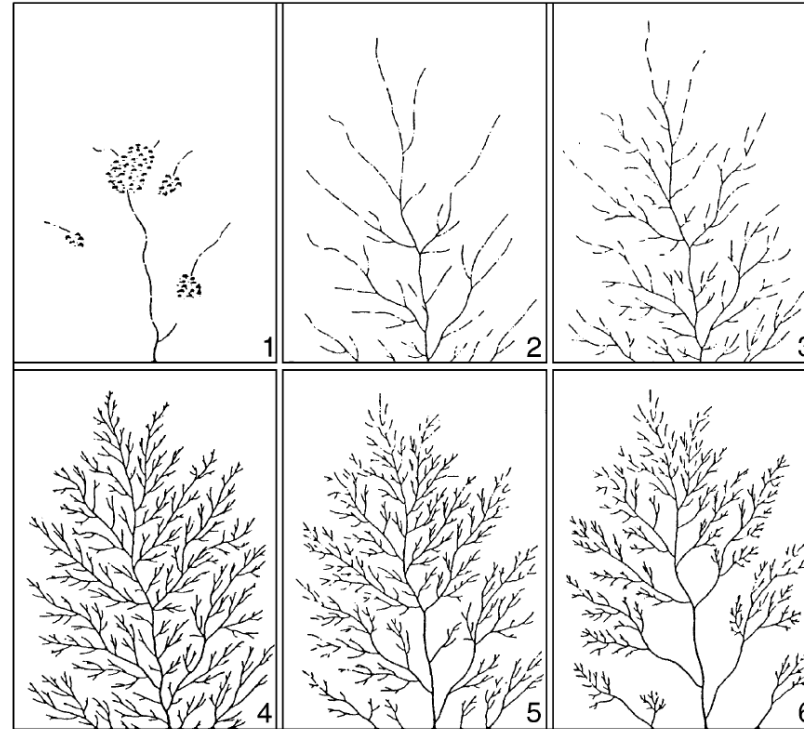
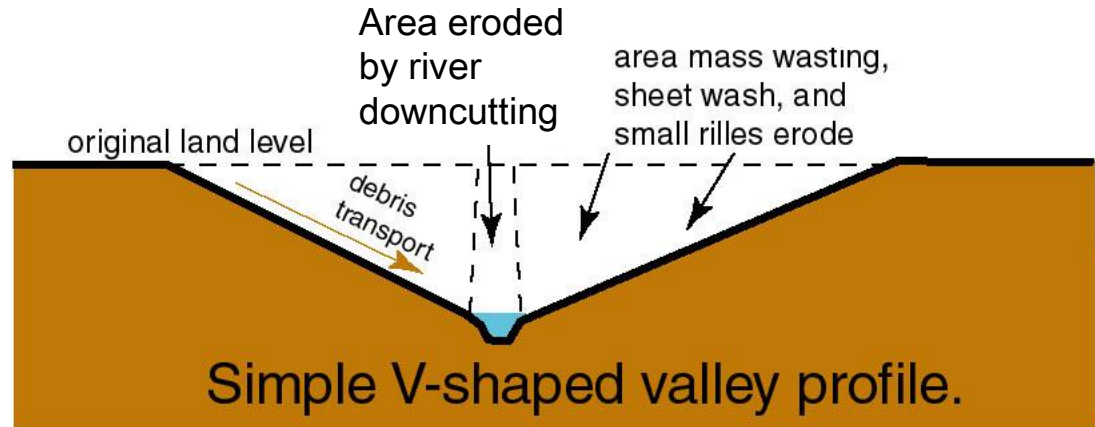
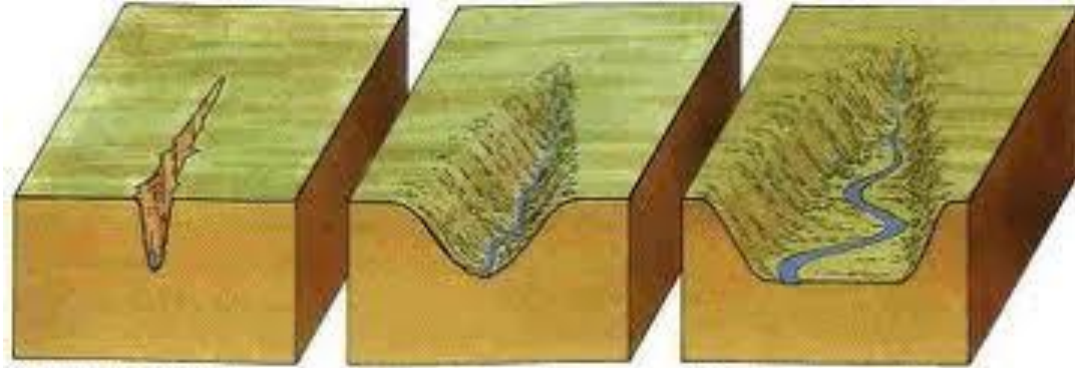


Fig. 1. Drainage network development showing (1) initiation, (2) elongation, (3) elaboration, (4) maximum extension and (5 and 6) integration by abstraction and absorption. (1–4) Drainage network extension and (5–6) drainage network integration (after [Glock, 1931](#)).

Ng, (2006) Landslides Locations and drainage network development. *Geomorphology*, 76, 229-239.

Interactions of Slope and Fluvial Processes

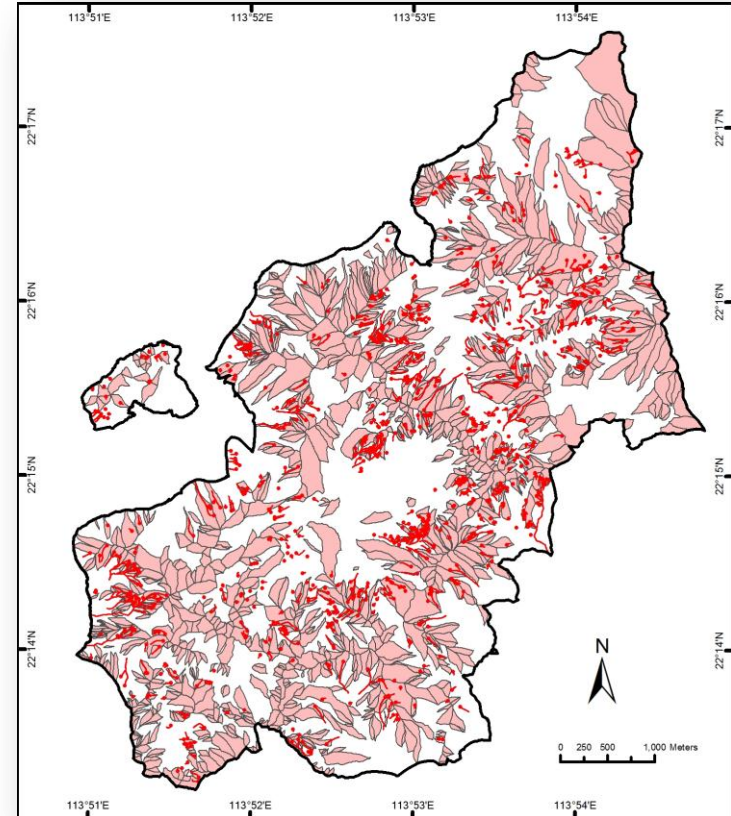
Academic
Perspective



Potential Hazard Zoning at Regional Scale

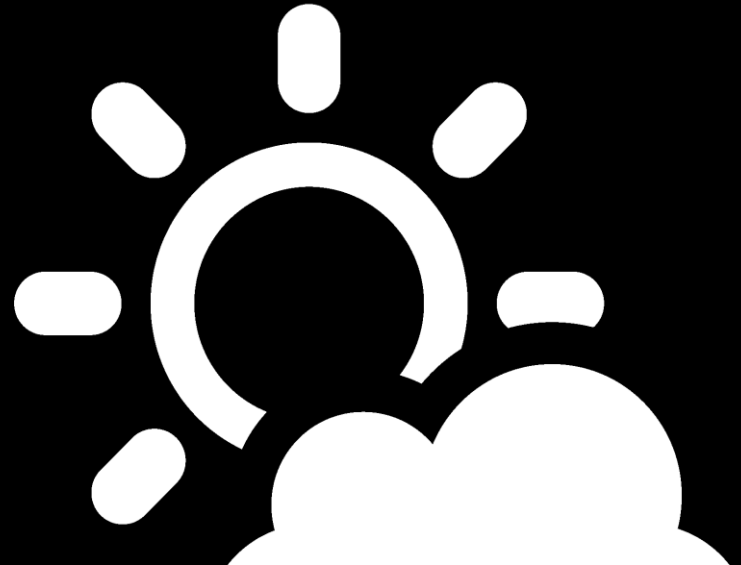
Practical Implications

- Overview of landslide distribution in a geomorphological context
- GIS facilitates the quantification of various morphological parameters for the analyses



Significance

- Reveal systematic relationship between fluvial morphometric parameters and landslide distribution
- Rapid quantitative geomorphological analyses on 'where' landslides occur at a regional catchment scale
- The relative simplicity of Strahler's ordering system makes this approach readily followed and understood by non-specialists



But still there is a gap....



Little is known on **when** and **where** landslide will occur despite advances in research and practice



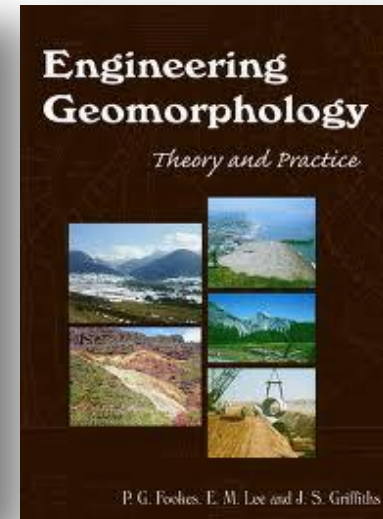
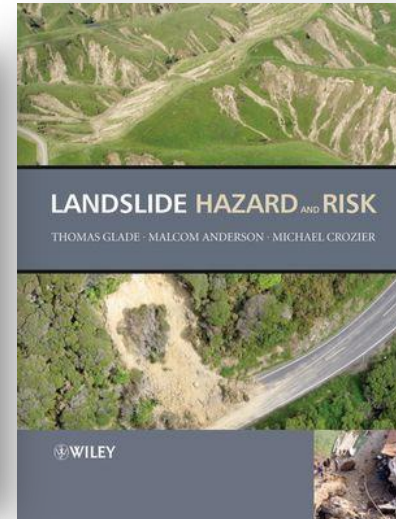
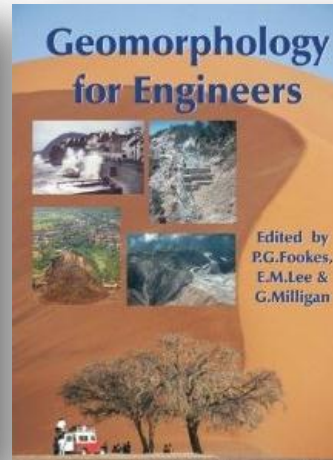
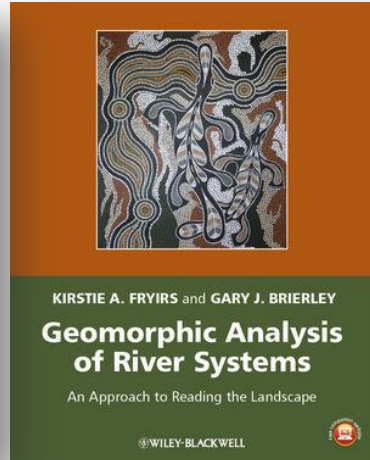
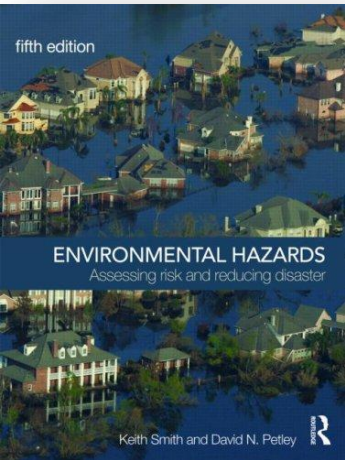


Future Prospects

Applied geomorphology in assessing hazard and risk



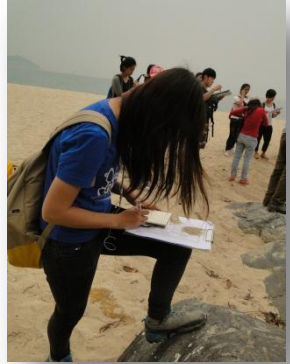
Hazard & Risk Assessment – Applied Geomorphology



- Appreciation of the understanding and practical application of the knowledge

University Education

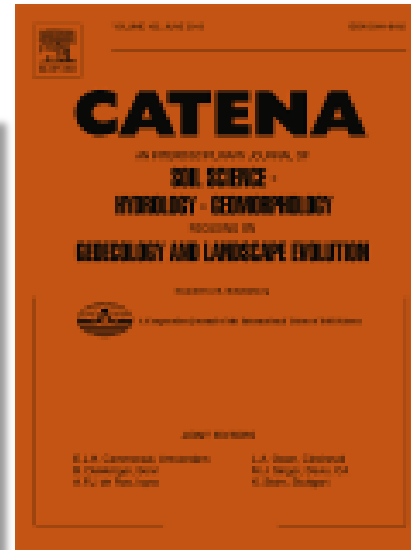
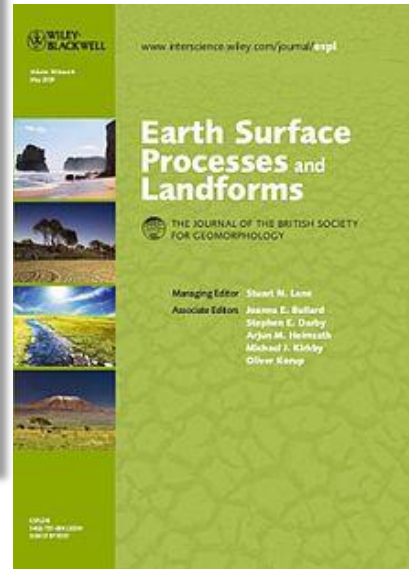
- Geomorphology Courses at HKU, CUHK, HKBU



Course Field Trip, 2013

and Research....

- Advance knowledge
- Publish research papers in high impact journals



Zeitschrift für Geomorphologie

Annals of Geomorphology Annales de Géomorphologie

A journal recognized by the International Association of Geomorphologists (IAG)

Neue Folge
Volume **57** Number **1** March 2013

Editors: A. Asrat, Addis Ababa; V.R. Baker, Tucson; R.J. Battaglia, Lleida; M. Becht, Eichstätt; H.-R. Bork, Kiel; H. Brückner, Köln; R. Dikau, Bonn; E. Eitel, Heidelberg; C. Embleton-Hamann, Wien; A. Gupta, Wollongong; W. Haebler, Zürich; A. Huguette, Dunkerque; A. Kranjc, Ljubljana; Y. Lagat, Brest; D. Lóczy, Pécs; R. Mausbacher, Jena; J. Runge, Frankfurt; O. Slaybacker, Vancouver; T. Scholten, Tübingen; P.A. Warke, Belfast; P.W. Williams, Auckland

Editor-in-Chief: Karl-Heinz Pfeffer, Tübingen

Editorial Board: D. Barsch, Heidelberg; A. Godard, Maudon; H. Hagedorn, Würzburg; J. Hoyer, Göttingen; A. Pissart, Liège

Now online
www.borntraeger-cramer.de/jzg



Borntraeger-Cramer • Stuttgart

On-the-Job Training and CPD



Chartered Geographer

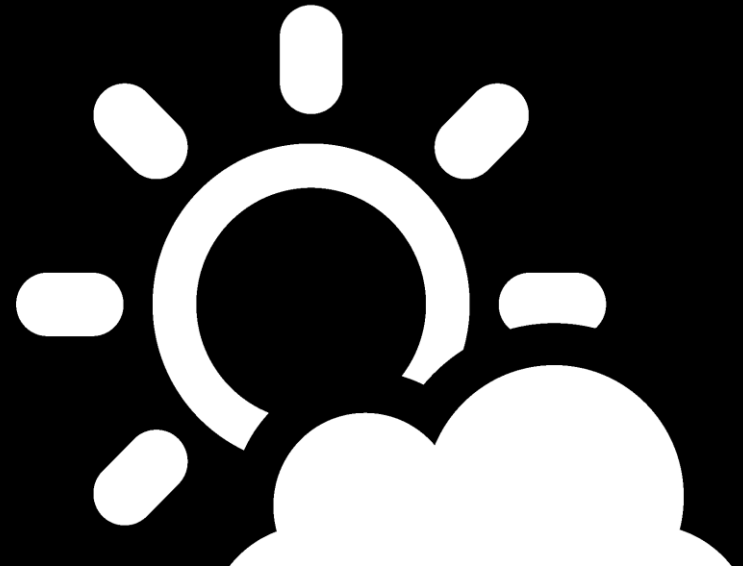
**Royal
Geographical
Society**
with IBG
Advancing geography
and geographical learning

- A **professional accreditation** awarded to geographers who demonstrate their **geographical skills and knowledge**
- Administered by the Royal Geographical Society (with IBG)
- Privy Council status awarded in 2002
- Four CGeog post nominals: GIS, Economic, **Geomorphology**, Teacher
- >400 CGeogs worldwide
- About 13% abroad
- Collaborate with the AGI on CGeog (GIS)





Conclusions



An Application of Quantitative Geomorphology on Regional Scale Landslide Hazard Assessment in HK

Thank you



June 2008 landslides, Sham Wat