COURSE: GEO-INFORMATICS IN EARTH SCIENCE, TECTONIC HAZARD AND INFRASTRUCTURE MANAGEMENT

LECTURE 7 – Science of Landslide

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What is Landslide

Early morning on Jan. 24, 2012 in the remote Southern Highlands of Papua New Guinea, a massive landslide destroyed communities living below a quarry used by the country's largest liquefied natural gas (LNG) project.

Source: Wilson, C, 2012, online; https://www.ipsnews.net/2012/03/papua-new-guinean-landslide-survivors-wait-in-vain-for-justice/

What is Landslide

- The Donghekou landslide, caused by the May 2008 Wenchuan Earthquake in Sichuan County, China.
- This extremely large landslide buried hundreds of people and caused a landslide dam to form in the Dong He River.

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Photograph by Lynn Highland, U.S. Geological Survey

What is Landslide

- Earthquake-induced landslides, Sichuan Province, China, May 12, 2008.
- Photograph courtesy of Dr. Yin Yueping,China Geological Survey, Ministry of Land and Resources, China.

Source: Highland, L.M., and Bobrowsky, Peter, 2008

What is Landslide

- Landslide is a general term used to describe the downslope movement of soil, rock, and organic materials under the effects of gravity
- Picture shows an example of one type of landslide.
- This landslide occurred at La Conchita, California, USA, in 2005.

In order for landslide to occur:

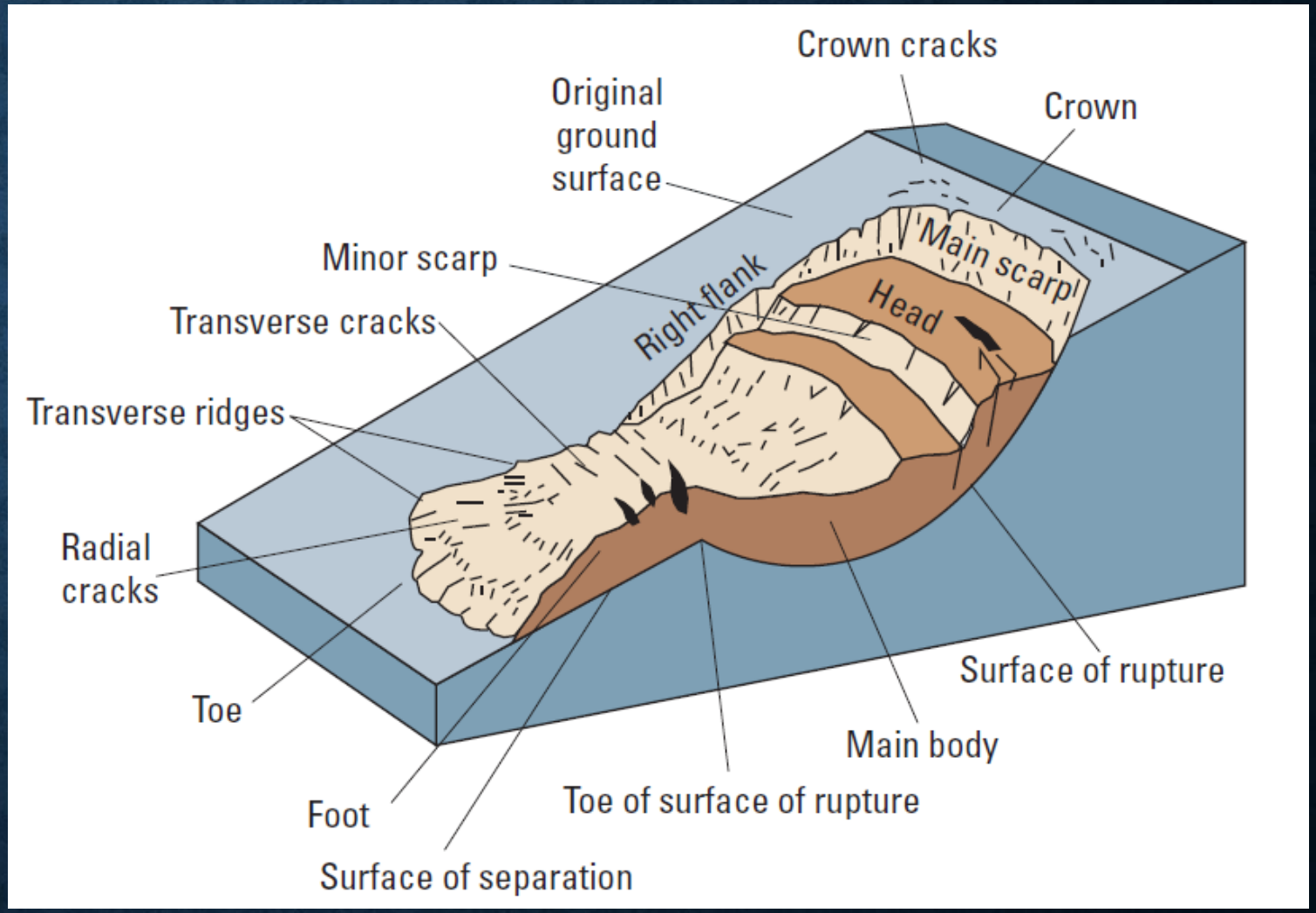
· An increase of shear stress

· A decrease of material strength

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Photograph by Mark Reid, U.S. Geological Survey.

What is Landslide

- The position and the most common terms used to describe the unique parts of a landslide.
- A simple illustration of a rotational landslide that has evolved into an earthflow.
- Image illustrates commonly used labels for the parts of a landslide



Source: Varnes, D.J., 1978 .

Source: Highland, L.M., and Bobrowsky, Peter, 2008.

Basic Landslide Types

- Landslides can be classified into different types on the basis of the type of movement and the type of material involved .

- The type of movement describes the actual internal mechanics of how the landslide mass is displaced:

- *fall*,
- *topple,*
- *slide,*
- *spread,*
- *flow.*

- Thus, landslides are described using two terms that refer respectively to material and movement.

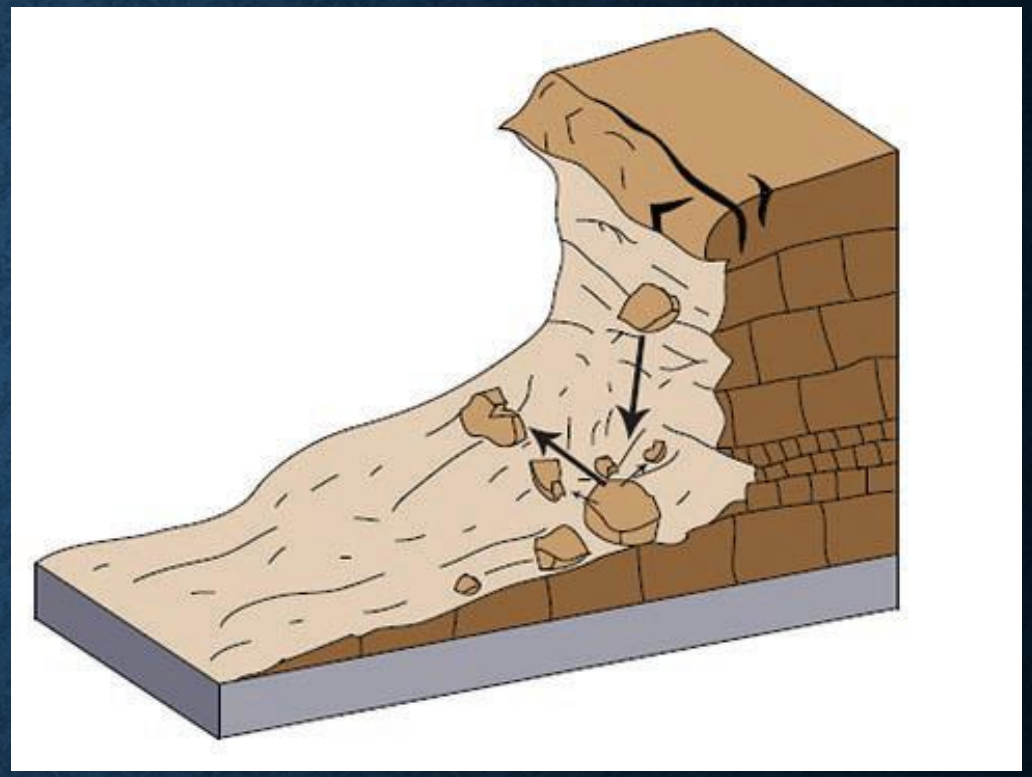
- rockfall,
- debris flow, and
- so forth).

Source: Highland, L.M., and Bobrowsky, Peter, 2008.

Basic Landslide Types

Fall:

- A fall begins with the detachment of soil or rock, or both, from a steep slope along a surface on which little or no shear displacement has occurred.
- The material subsequently descends mainly by falling, bouncing, or rolling.



Schematic of a rockfall.

A rockfall/slide that occurred in Clear Creek Canyon, Colorado, USA, in 2005, closing the canyon to traffic for a number of weeks.

Photograph by Colorado Geological Survey.

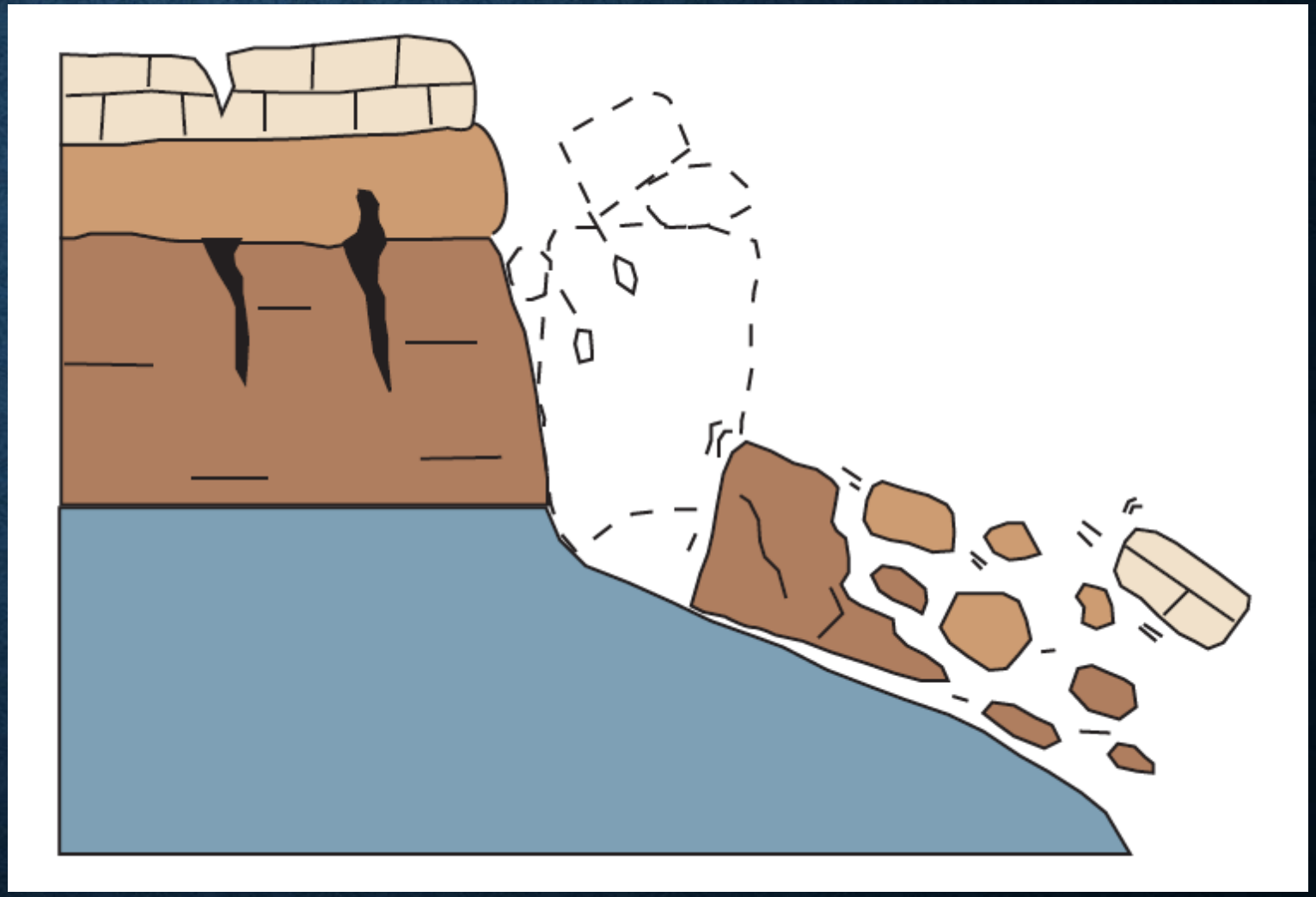
Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Topple:

A topple is recognized as the forward rotation out of a slope of a mass of soil or rock around a point or axis below the center of gravity of the displaced mass.

Toppling is sometimes driven by gravity exerted by the weight of material upslope from the displaced mass.



Schematic of a topple

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Topple:

Photograph of block toppling at Fort St. John, British Columbia, Canada.

(Photograph by G. Bianchi Fasani.)

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Slides:

A slide is a downslope movement of a soil or rock mass occurring on surfaces of rupture or on relatively thin zones of intense shear strain.

Movement does not initially occur simultaneously over the whole of what eventually becomes the surface of rupture; the volume of displacing material enlarges from an area of local failure.

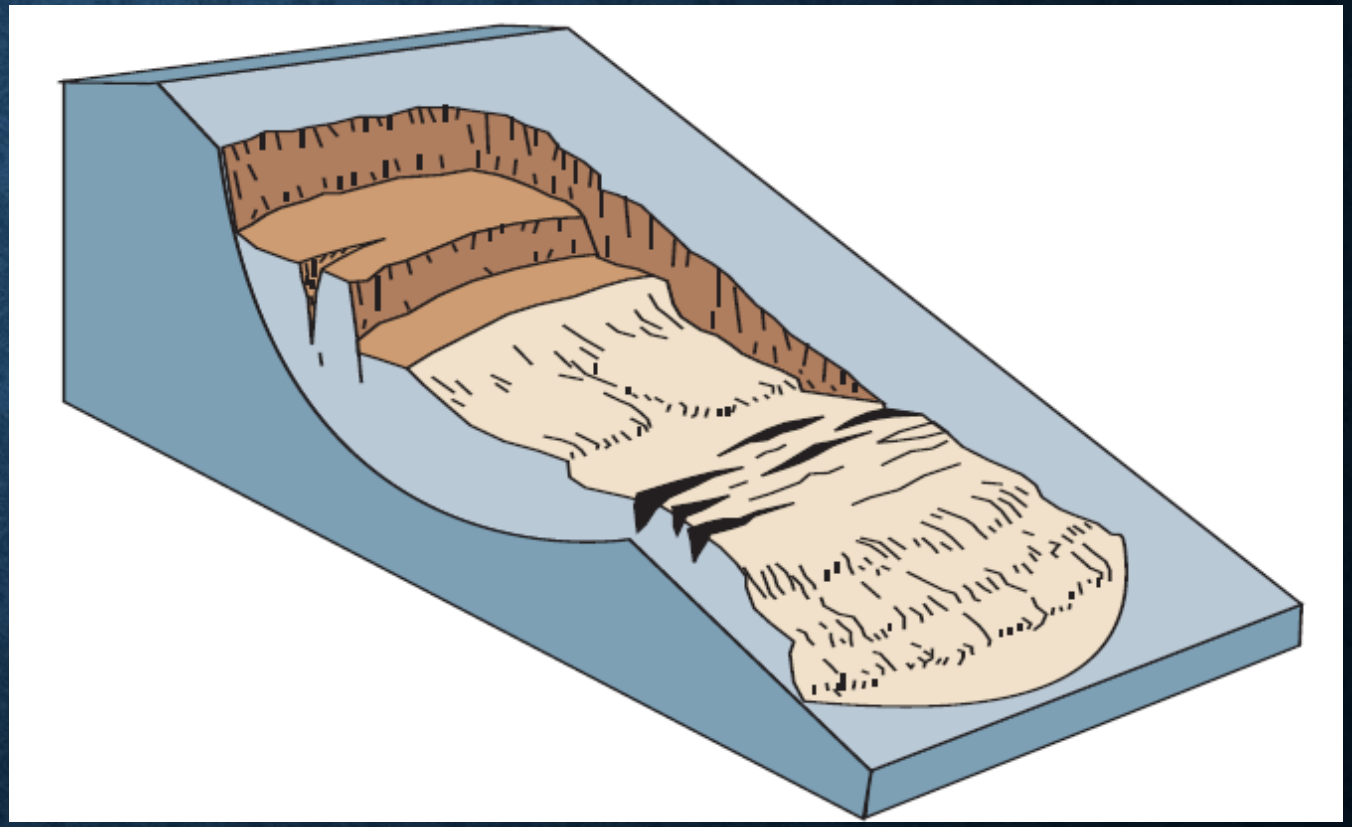
Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Rotational Landslides:

- A landslide on which the surface of rupture is curved upward (spoon-shaped) and the slide movement is more or less rotational about an axis that is parallel to the contour of the slope.

- Historical slides can be reactivated; cracks at tops (heads) of slopes are good indicators of the initiation of failure



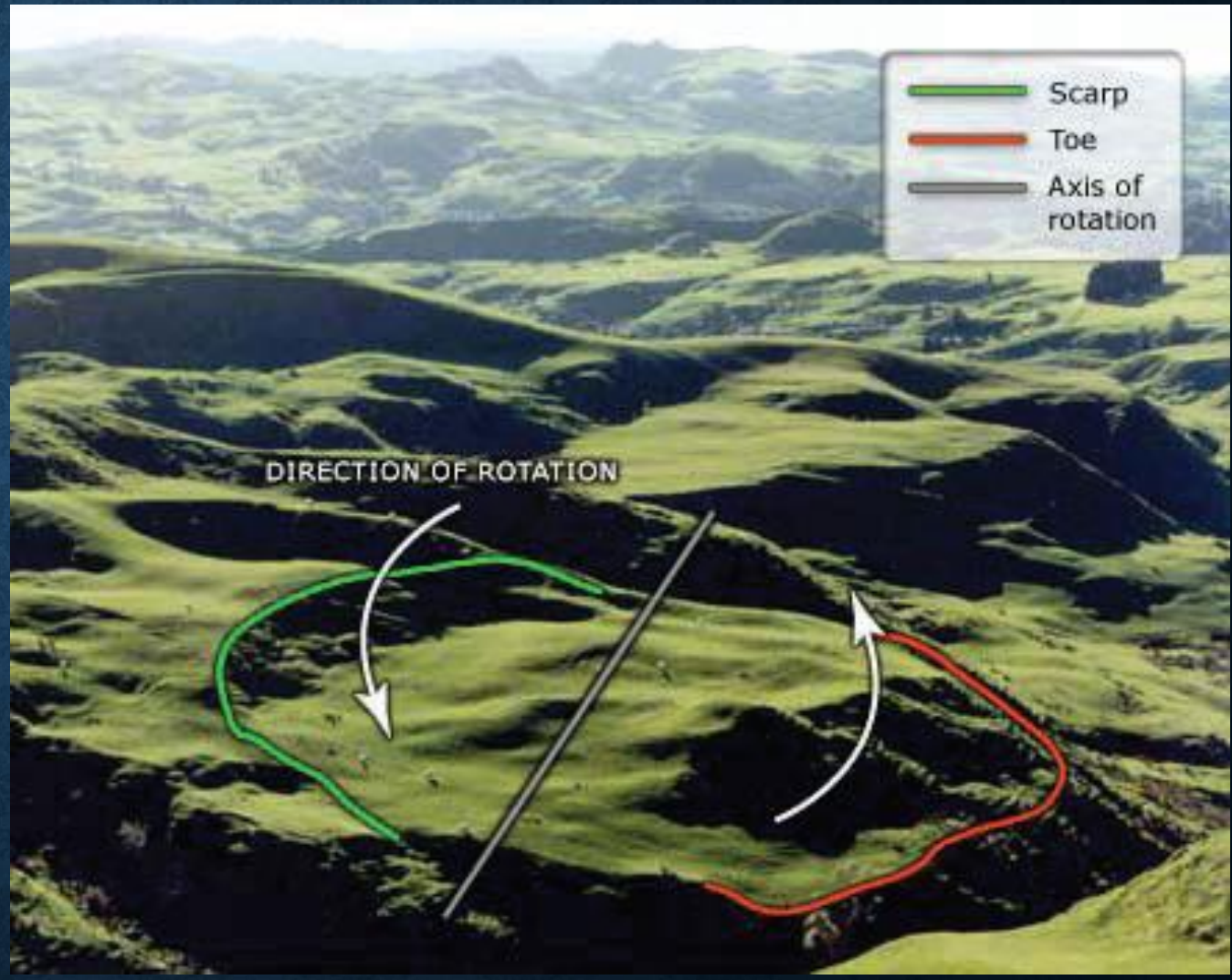
Schematic of a rotational landslide

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Rotational Landslides:

- Photograph of a rotational landslide which occurred in New Zealand.
- The green curve at center left is the scarp (the area where the ground has failed).
- The hummocky ground at bottom right (in shadow) is the toe of the landslide (red line).
- This is called a rotational landslide as the earth has moved from left to right on a curved sliding surface.



Photograph by Michael J. Crozier, Encyclopedia of New Zealand, updated September 21, 2007

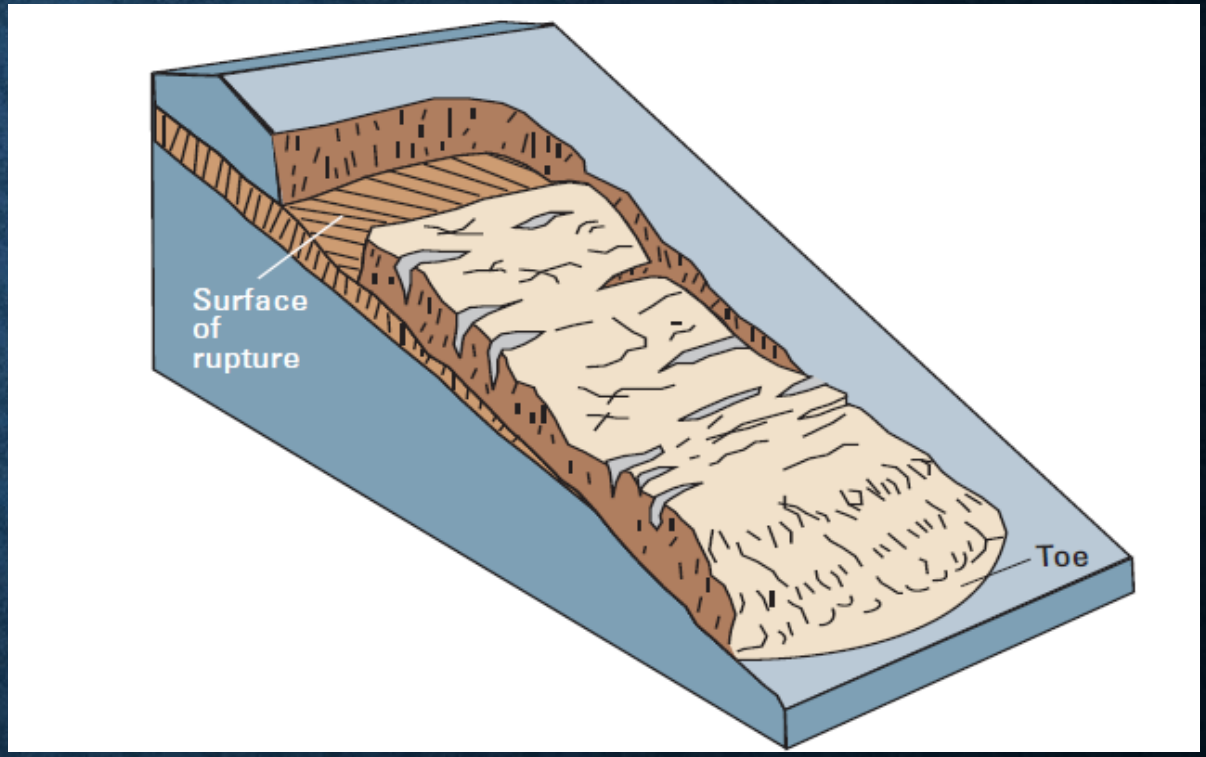
Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Translational Landslides:

- The mass in a translational landslide moves out, or down and outward, along a relatively planar surface with little rotational movement or backward tilting.

- This type of slide may progress over considerable distances if the surface of rupture is sufficiently inclined, in contrast to rotational slides,



Schematic of a translational landslide

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Translational Landslides:

A translational landslide that occurred in 2001 in the Beatton River Valley, British Columbia, Canada.

(Photograph by Réjean Couture, Canada Geological Survey.)

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Spreads:

- An extension of a cohesive soil or rock mass combined with the general subsidence of the fractured mass of cohesive material into softer underlying material.

- Spreads may result from liquefaction or flow (and extrusion) of the softer underlying material.

- Types of spreads include;

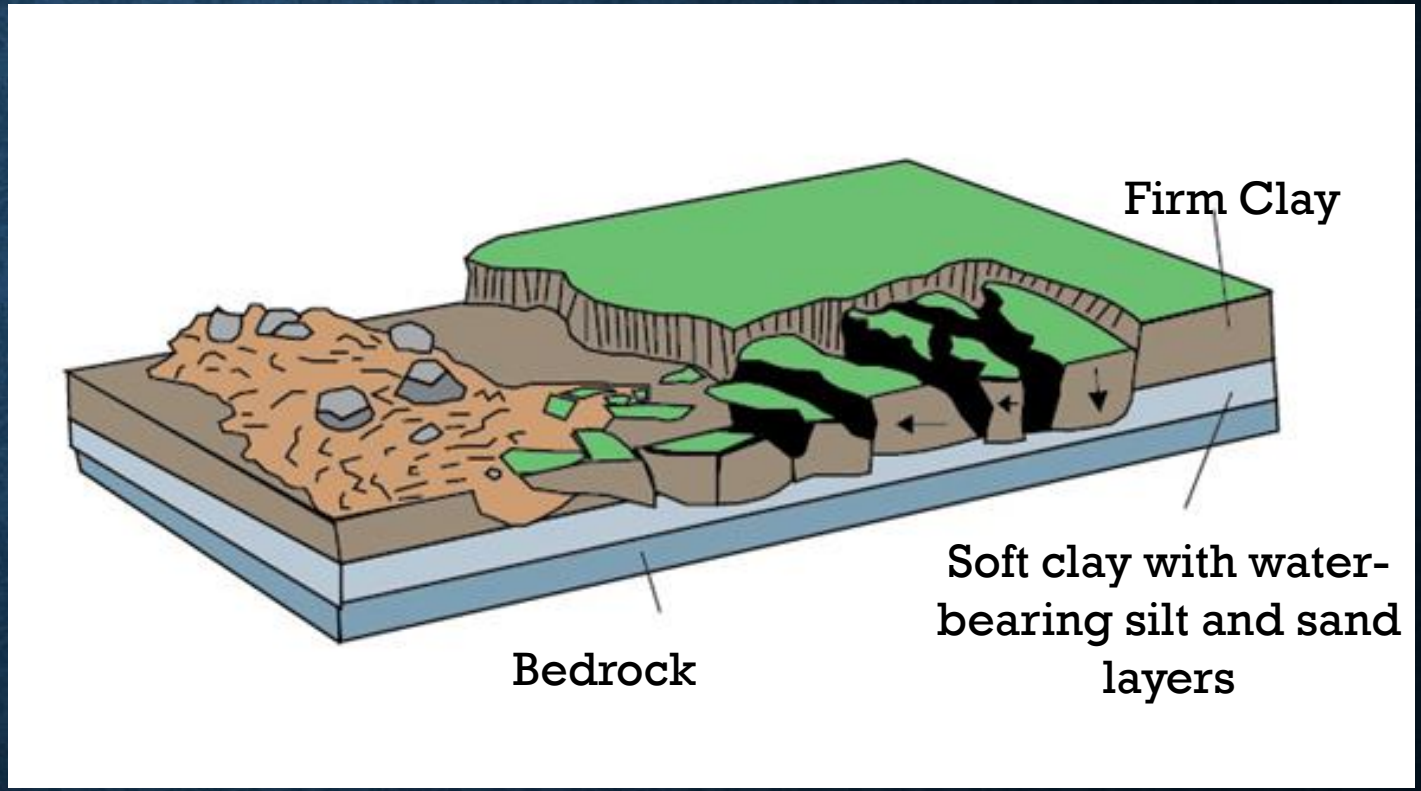
- block spreads,
- liquefaction spreads, and
- lateral spreads.

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Lateral Spreads:

- Lateral spreads usually occur on very gentle slopes or essentially flat terrain, especially where a stronger upper layer of rock or soil undergoes extension and moves above an underlying softer, weaker layer



- Schematic of a lateral spread. A liquefiable layer underlies the surface layer.

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Lateral Spreads:

- Photograph of lateral spread damage to a roadway as a result of the 1989 Loma Prieta, California, USA, earthquake.

(Photograph by Steve Ellen, U.S. Geological Survey.)

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

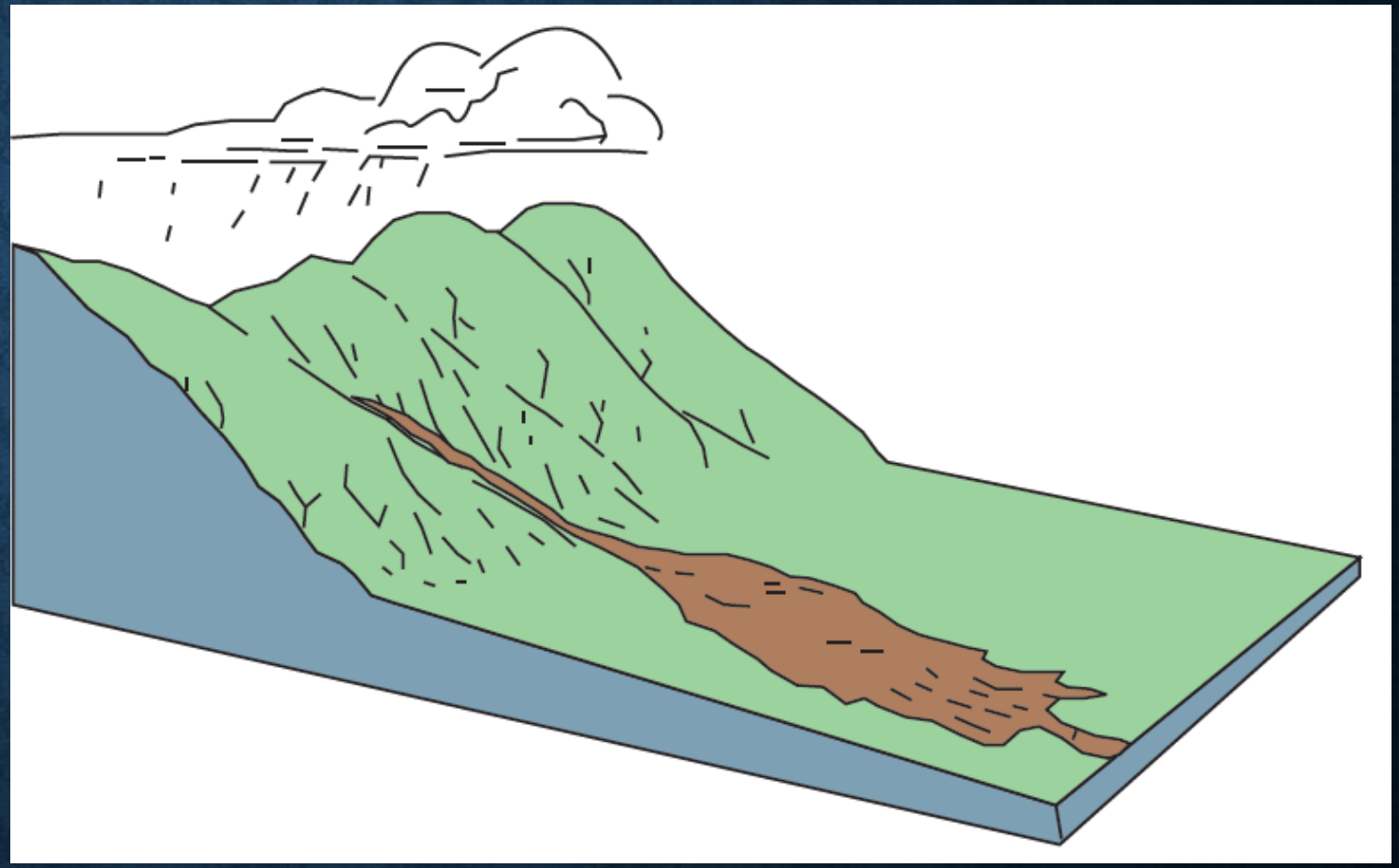
Basic Landslide Types

Flows:

- A flow is a spatially continuous movement in which the surfaces of shear are short-lived, closely spaced, and usually not preserved.

Debris Flow

- A form of rapid mass movement in which loose soil, rock and sometimes organic matter combine with water to form a slurry that flows downslope. They have been informally and inappropriately called "mudslides" due to the large quantity of fine material that may be present in the flow



Schematic of a debris flow

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Basic Landslide Types

Flows:

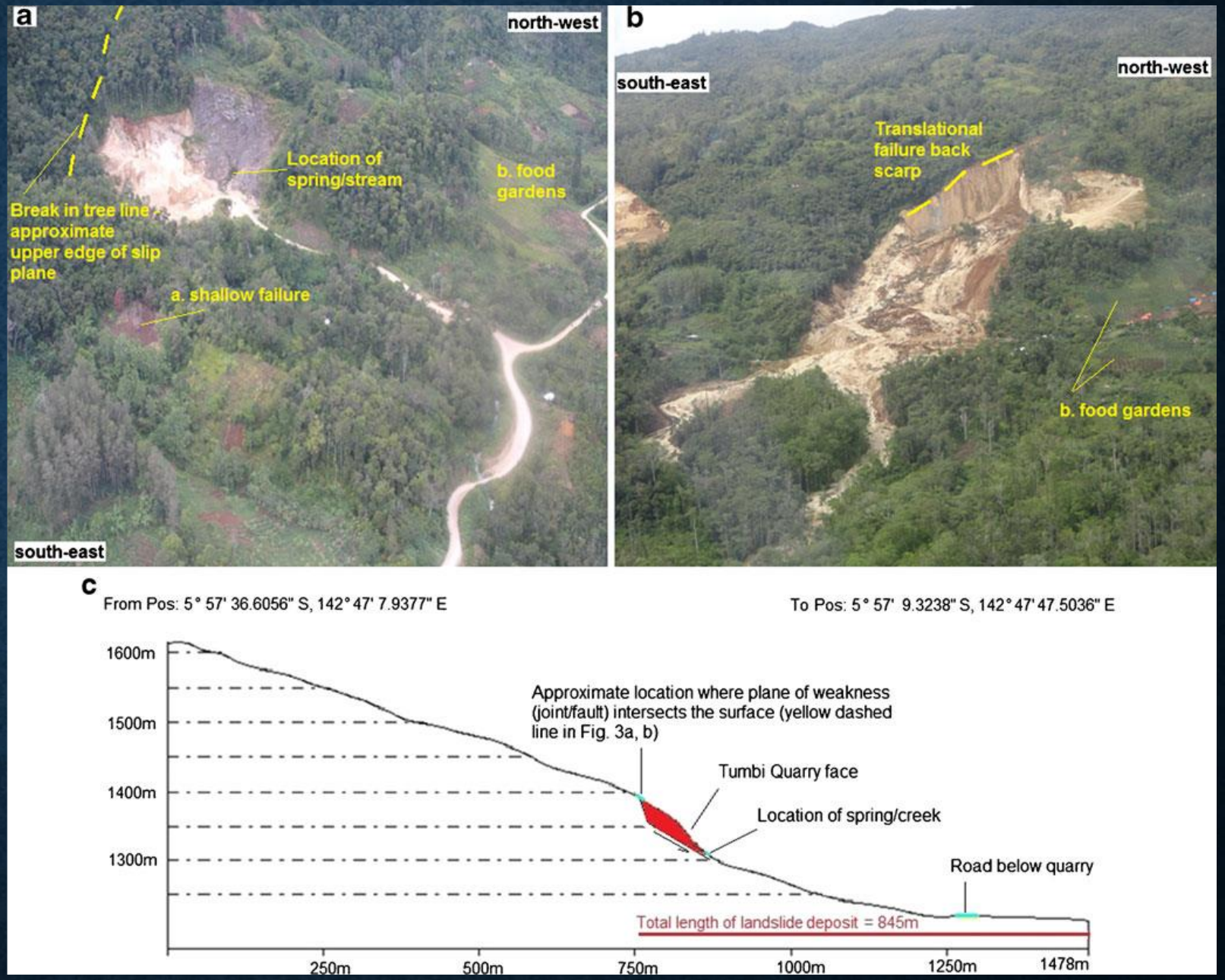
- Debris-flow damage to the city of Caraballeda, located at the base of the Cordillera de la Costan, on the north coast of Venezuela. In December 1999, this area was hit by Venezuela's worst natural disaster of the 20th century; several days of torrential rain triggered flows of mud, boulders, water, and trees that killed as many as 30,000 people.

- Photograph by L.M. Smith, Waterways Experiment Station, U.S. Army Corps of Engineers.)

Source: Highland, L.M., and Bobrowsky, Peter, 2008., Cruden, D.M, and Varnes, D.J., 1996

Landslide Assessment

- An aerial photograph showing Tumbi Quarry 2 years prior (27 January 2010) to the landslide on 24 January 2012.
- second aerial photograph showing the Tumbi Landslide shortly after failure on 24 January 2012.
- A pre-failure slope profile of the landslide site derived from a 5-m DTM



Source: Robbins, J.C., Petterson, M.G., Mylne, K. et al. Tumbi Landslide, Papua New Guinea: rainfall induced?. Landslides 10, 673–684 (2013). https://doi.org/10.1007/s10346-013-0422-4

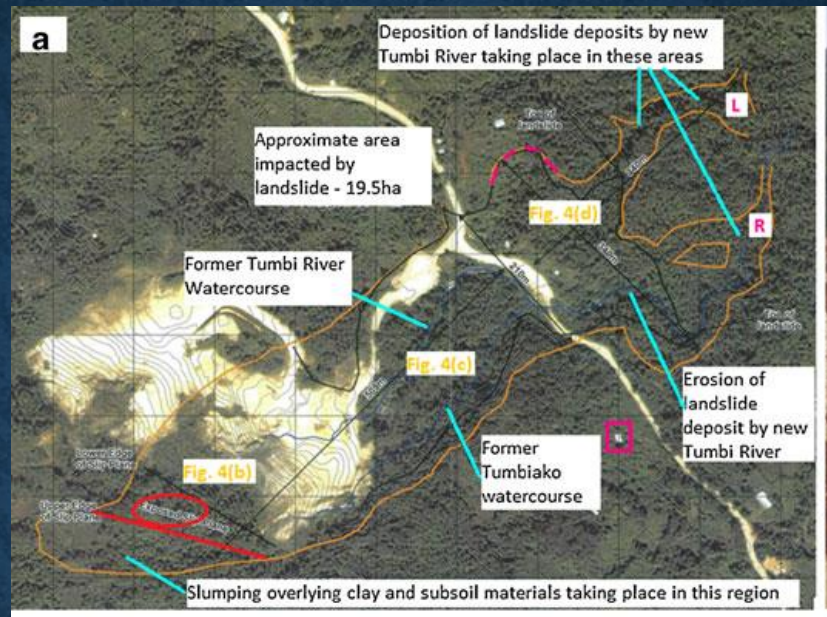
Landslide Assessment

- Annotated IKONOS satellite image showing the outline of the Tumbi Landslide deposit and aerial photographs of;

b .the upper region,

c. the medial region and

d. distal region of the landslide deposit.

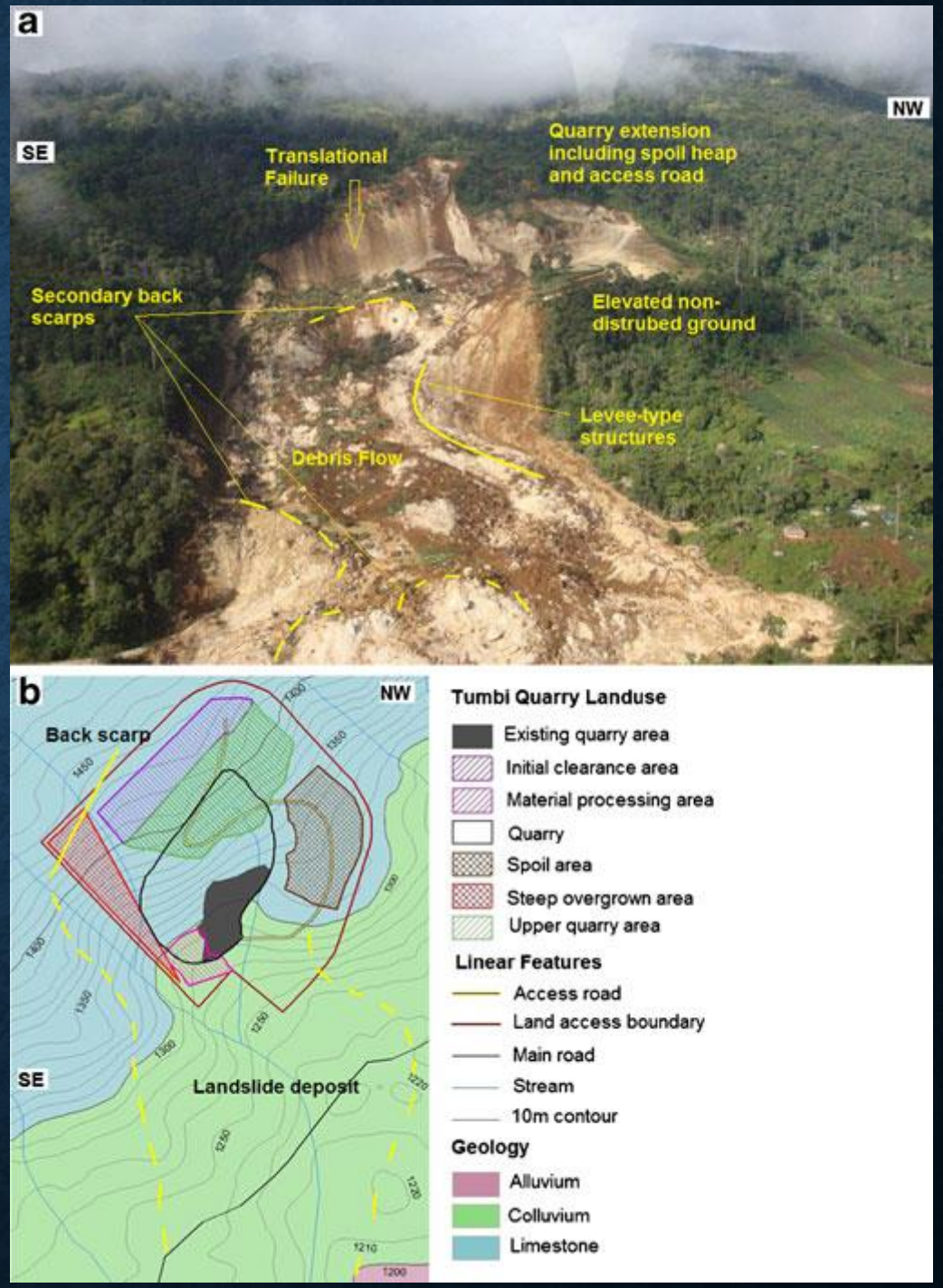


Source: courtesy of the Geohazards Management Division in Papua New Guinea

Source: Robbins, J.C., Petterson, M.G., Mylne, K. et al. Tumbi Landslide, Papua New Guinea: rainfall induced?. Landslides 10, 673–684 (2013). https://doi.org/10.1007/s10346-013-0422-4

Landslide Assessment

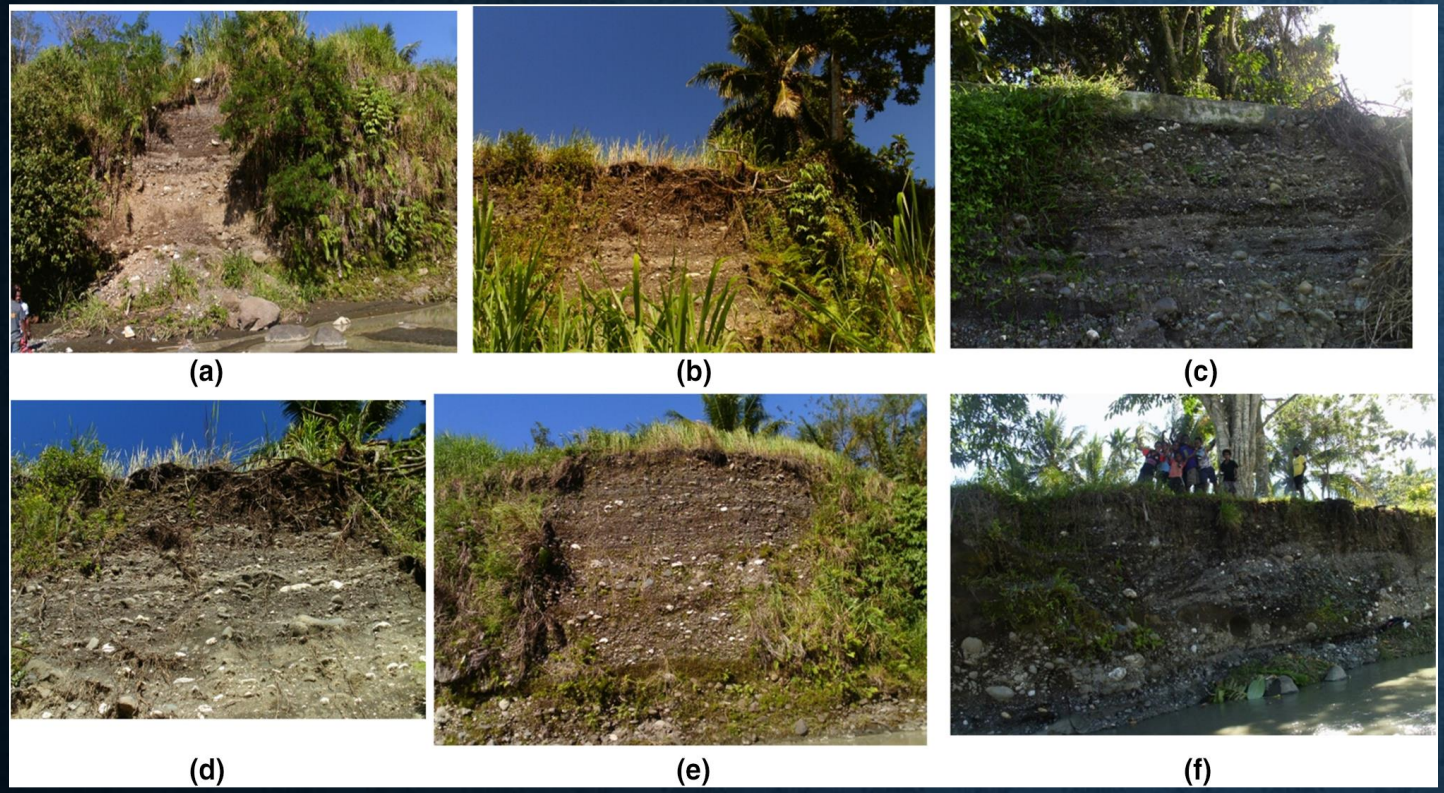
- Annotated aerial photograph of the upper and medial regions of the Tumbi landslide, contextualised with a schematic diagram of the land-use within the quarry's land access boundary.



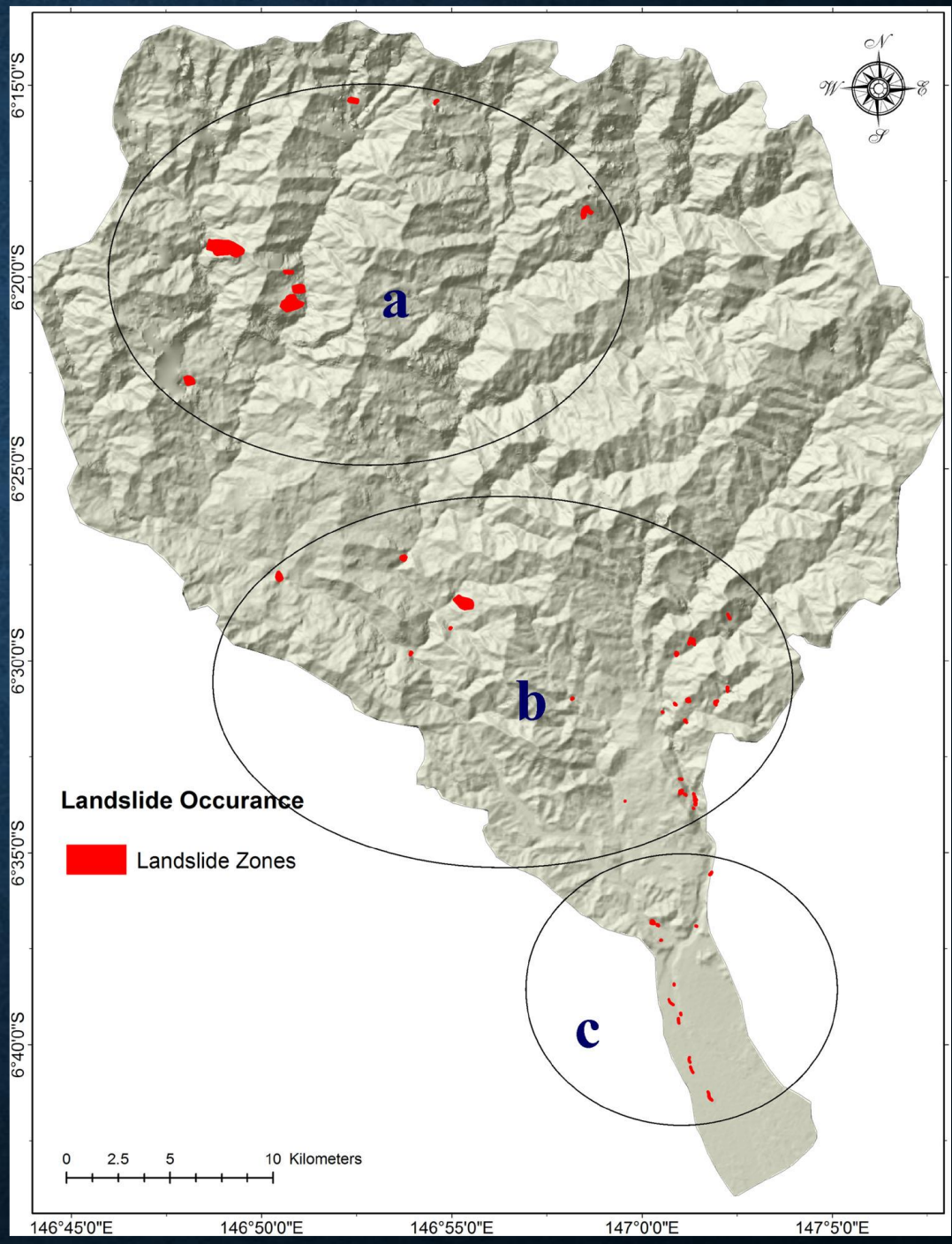
Source: Robbins, J.C., Petterson, M.G., Mylne, K. et al. (2013).

Landslide Assessment

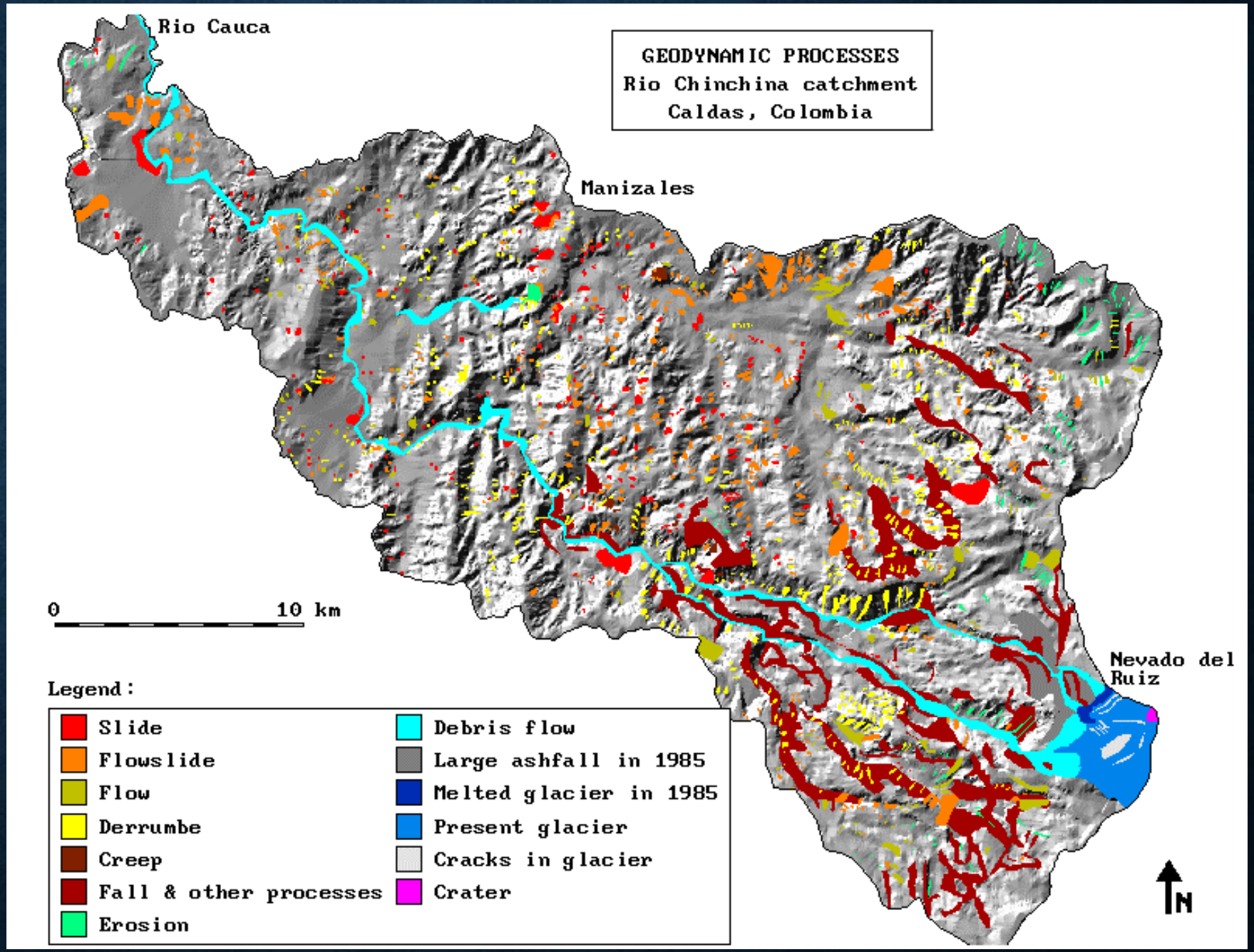
Busu River Catchment Landslide Investigation, in PNG



Locality map of landslide occurrence; (a) rock fall, (b) mud, surface and debris flow, (c) riverside landslide, bank erosion and bank cut



Landslide Assessment

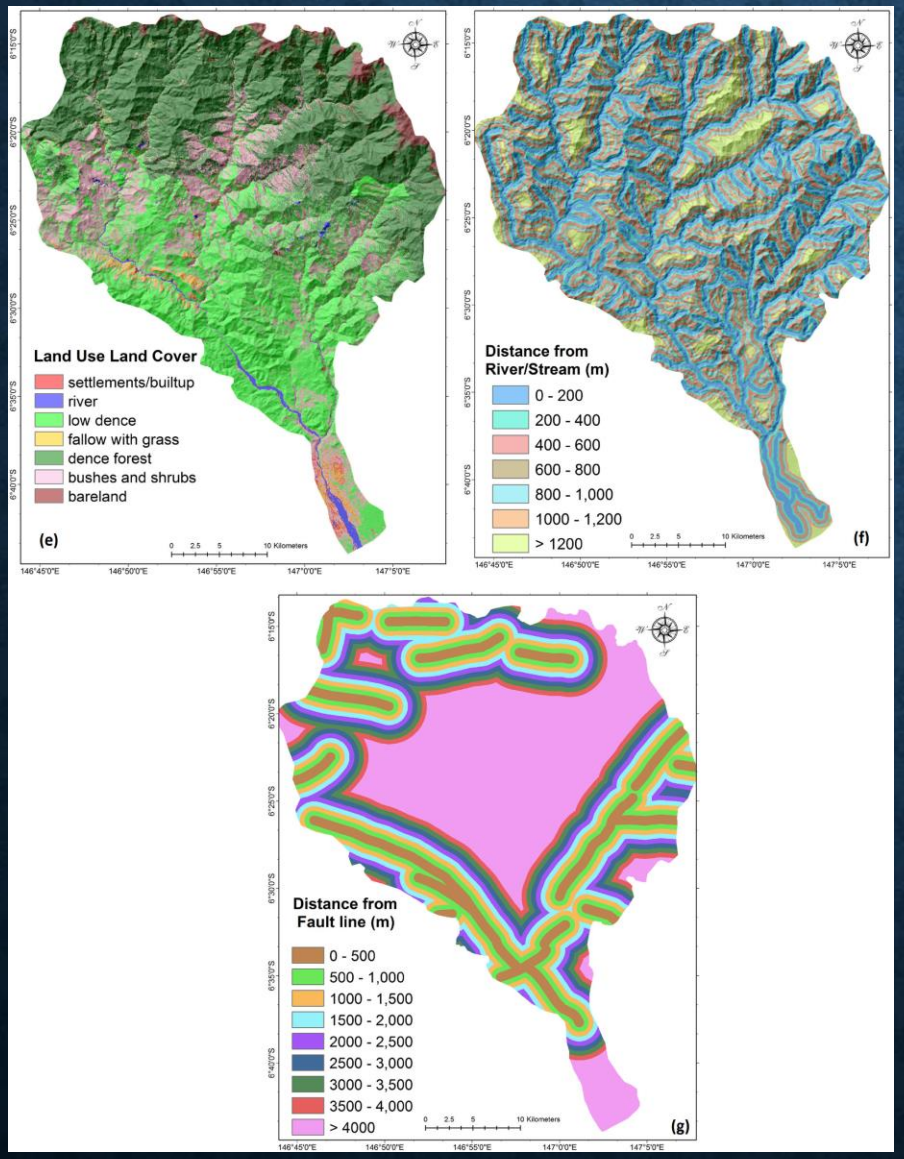


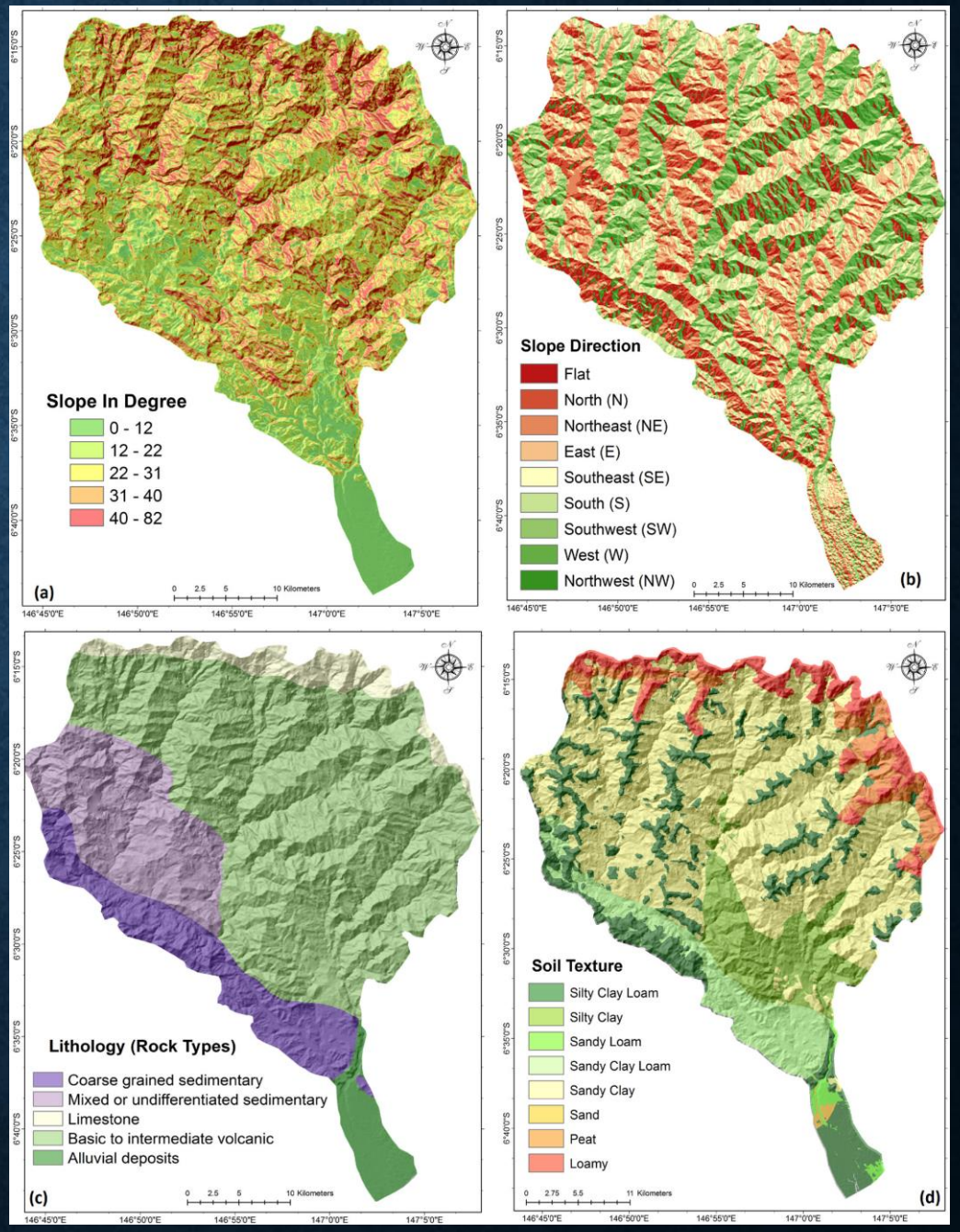
Source: Cees van Westen, International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands

Landslide Assessment

Landslide Investigation at Busu River Catchment , PNG

Various thematic layers prepared for Landslide susceptibility zonation

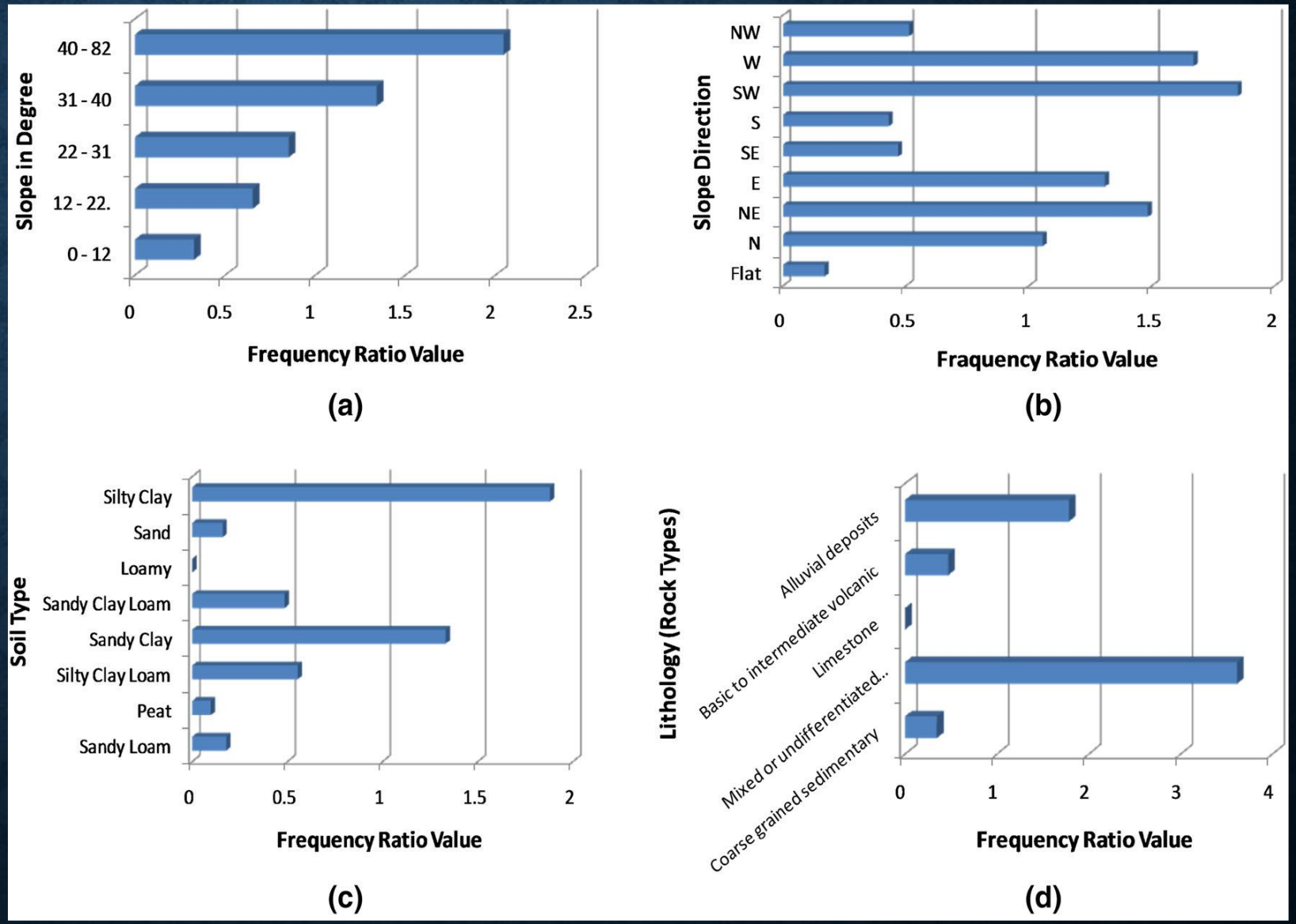




Landslide Assessment

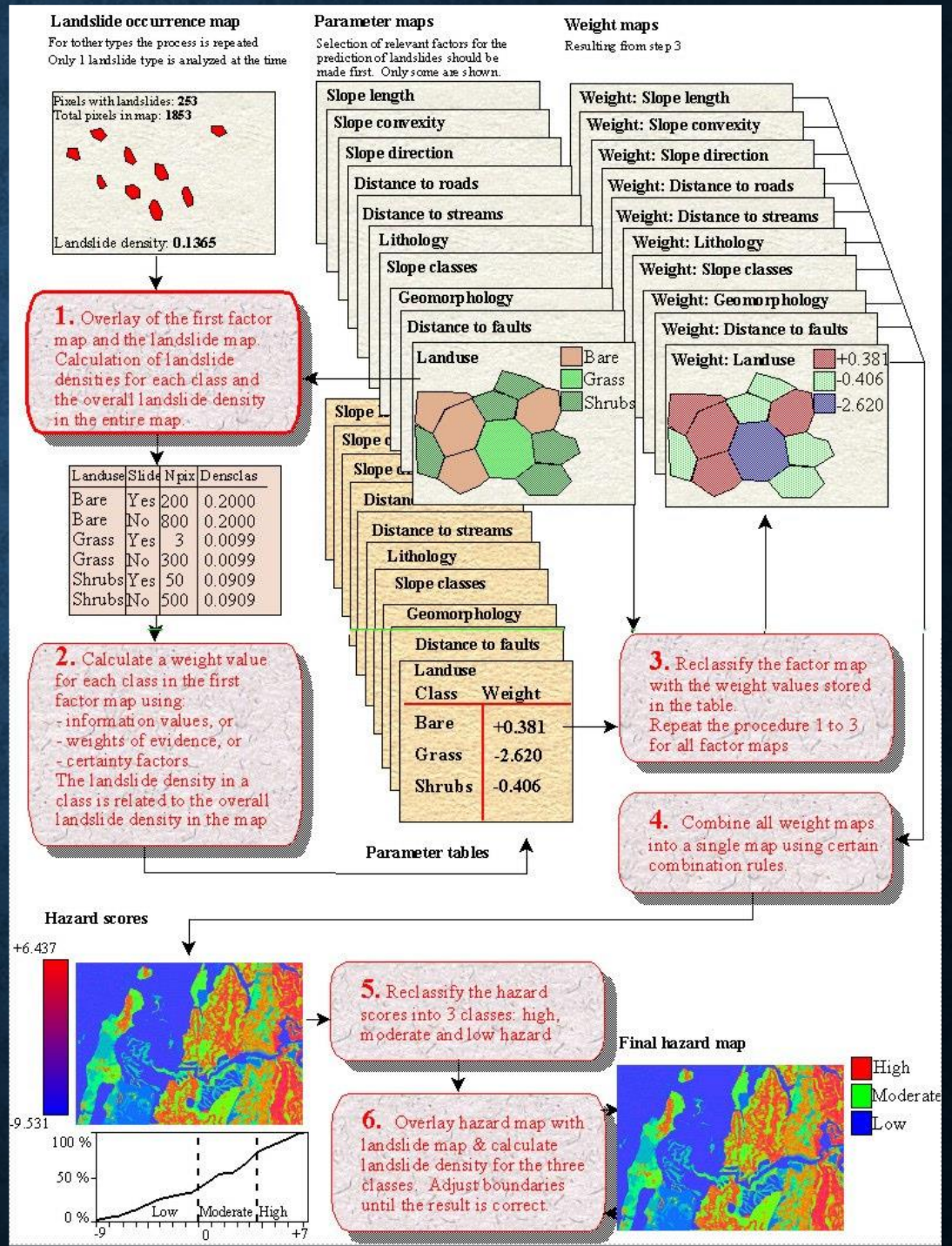
Landslide Investigation at Busu River Catchment , PNG

Assessing of Landslide occurrence at each factors classes layers.



Landslide Assessment

Bivariate Landslide Statistical Analysis

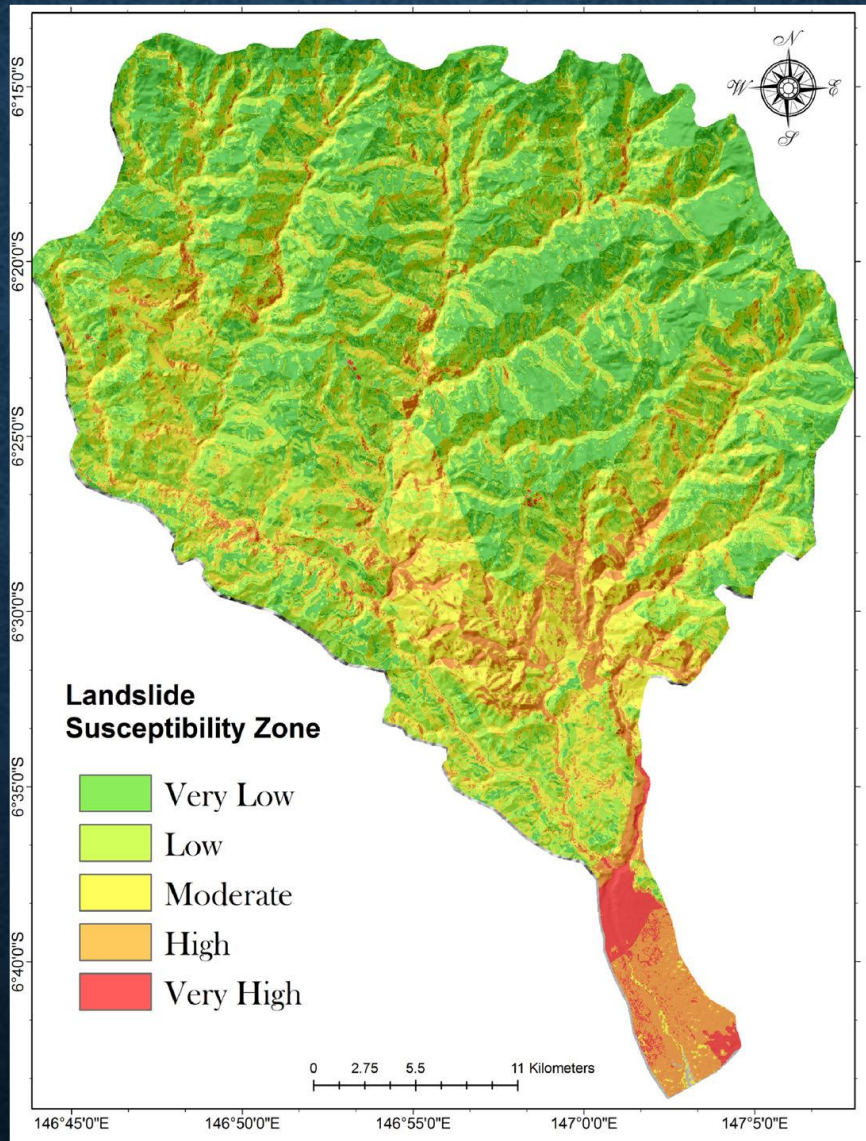


Source: Cees van Westen, International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands

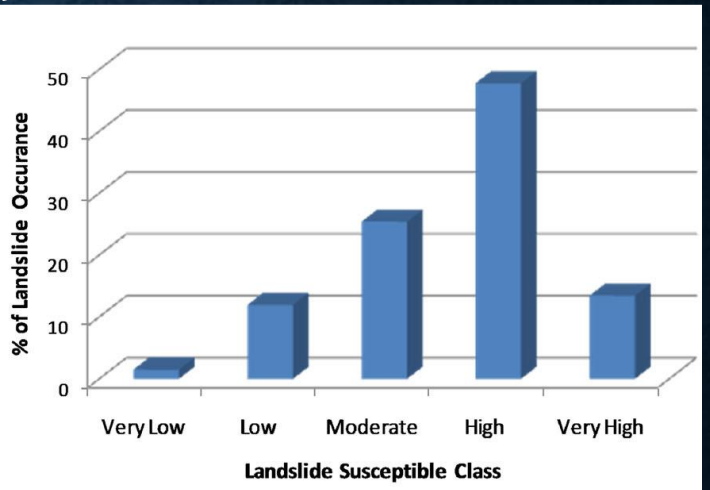
Landslide Assessment

Landslide Investigation at Busu River Catchment , PNG

Landslide Susceptibility Mapping



(a)

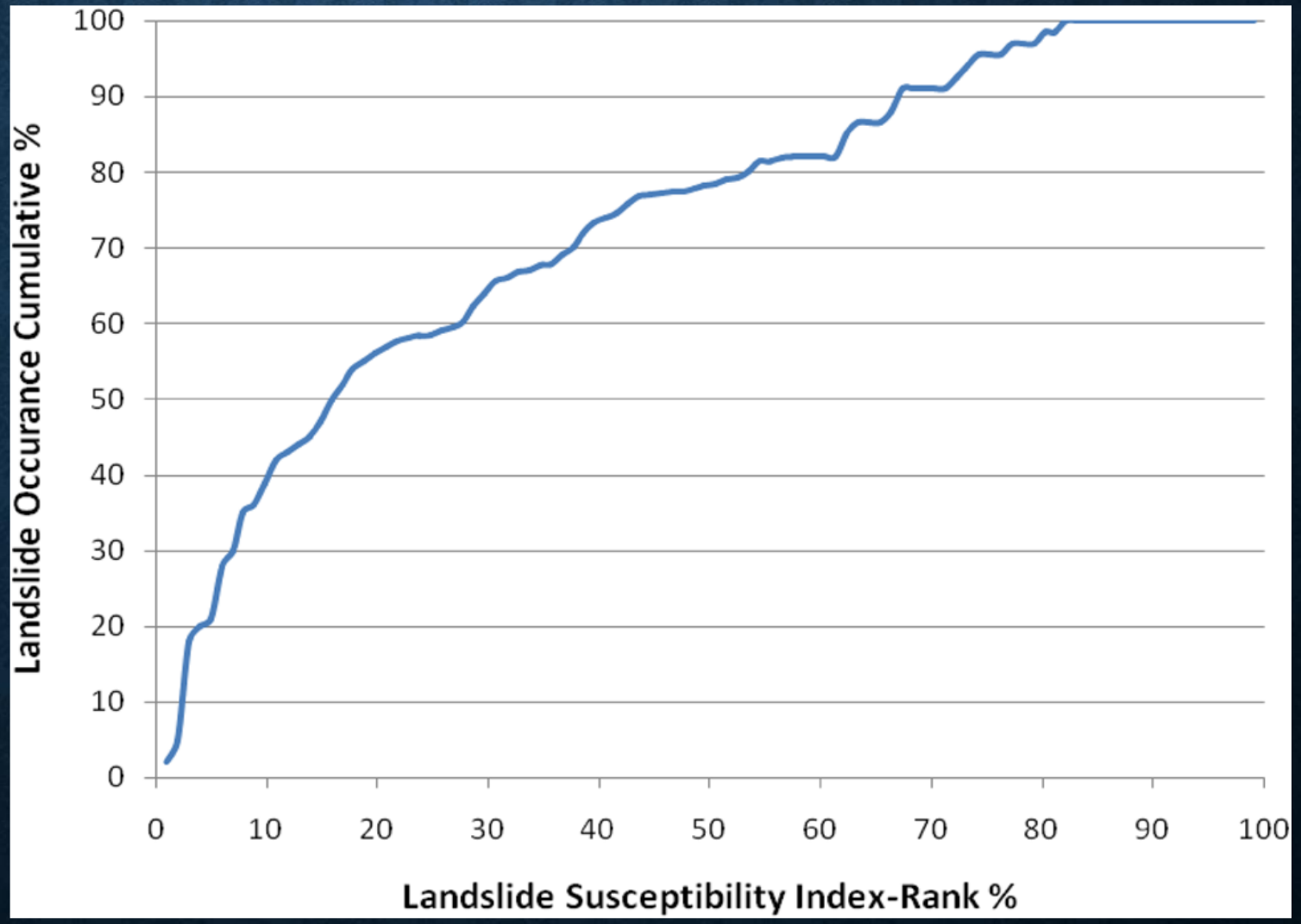


(b)

Landslide Assessment

Landslide Investigation at Busu River Catchment , PNG

Landslide Susceptibility Mapping validation curve



References:

Highland, L.M., and Bobrowsky, Peter, 2008, The landslide handbook—A guide to understanding landslides: Reston, Virginia, U.S. Geological Survey Circular 1325, 129 p.

Varnes, D.J., 1978, Slope movement 43. types and processes, *in* Schuster, R.L., and Krizek, R.J., eds., Landslides—Analysis and control: Transportation Research Board Special Report 176, National Research Council, Washington, D.C., p. 11–23.

Robbins, J.C., Petterson, M.G., Mylne, K. et al. Tumbi Landslide, Papua New Guinea: rainfall induced?. Landslides 10, 673–684 (2013). https://doi.org/10.1007/s10346-013-0422-4

Cruden, D.M, and Varnes, D.J., 1996, Landslide types and processes, *in* Turner, A. Keith, and Schuster, Robert L. eds. Landslides—Investigation and mitigation: Transportation Research Board, Special report no. 247, National Research Council, National Academy Press, Washington, D.C., p. 36–75.