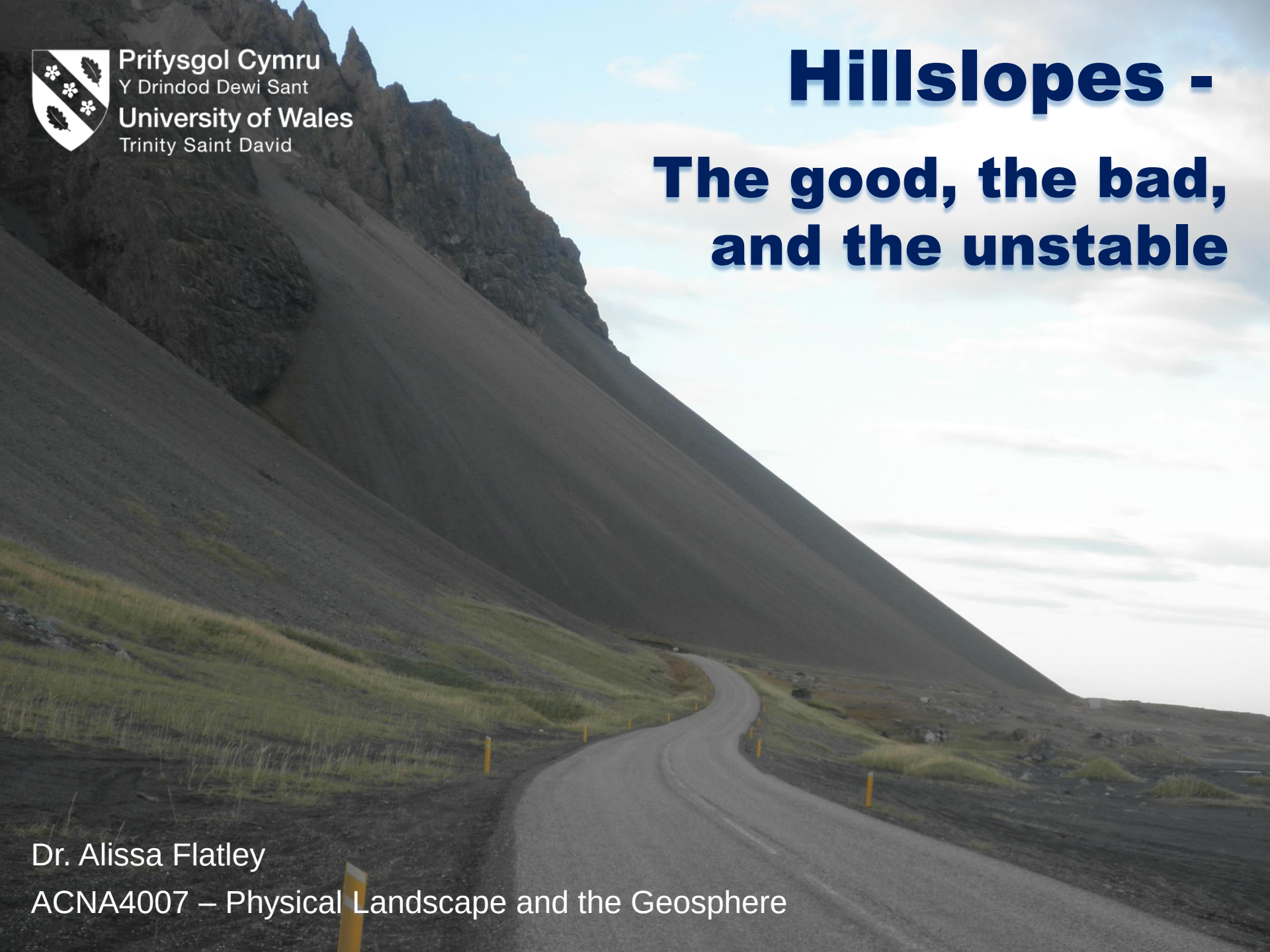


Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Hillslopes -

The good, the bad, and the unstable

Dr. Alissa Flatley

ACNA4007 – Physical Landscape and the Geosphere

Landscapes…

- How does topography and relief (i.e. landforms) evolve?
- How does material move around the landscape - the next stage of the journey from source to sink

- Weathering and downslope transport - to river channels

Hillslopes = critical transition zone between non-channelized and channelized transport… (channel initiation)

Allen 2005

What is a hillslope?

- The sides of valleys + the margins of eroding uplands
- Material is loosened by weathering and then transported downslope, often to a river channel, via exogenic processes (and gravity)
- > 90% of Earth's surface is comprised of hillslopes (Huggett, 2002)
- Varying degrees of slope angles and shapes…

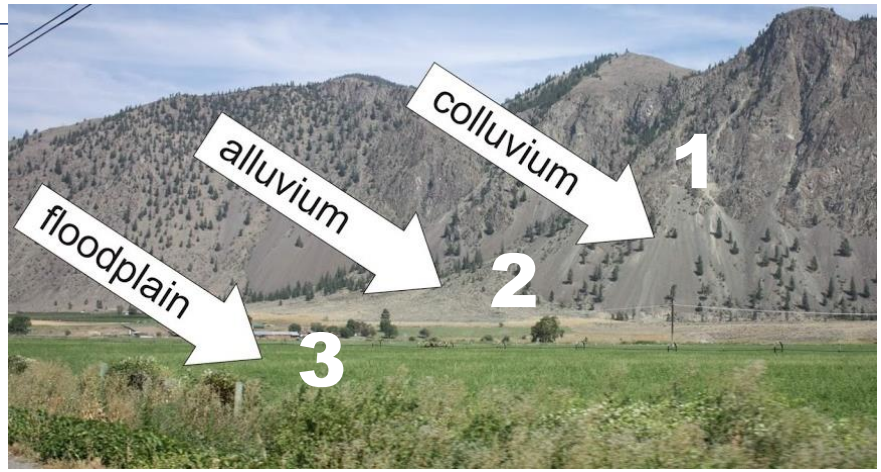
Why do we care?

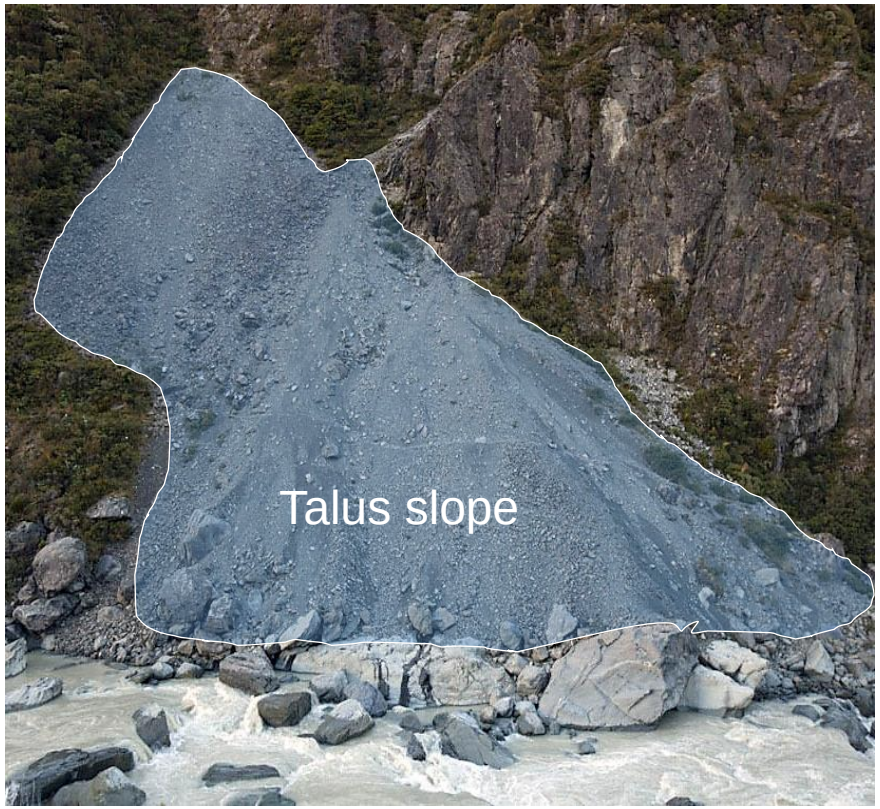
- **A hazard:** Direct and indirect influences on people and property (i.e. if material is deposited in the ‘wrong’ place…)

- Interaction with floodplains – (i) hazard, (ii) **source of material** for depositional landforms (deliver water and sediment to streams)

Colluvial vs alluvial…

- **Colluvial** = mobile sediment moved by gravity and not by channelized flow
- **Alluvial** = sediment moved by running water

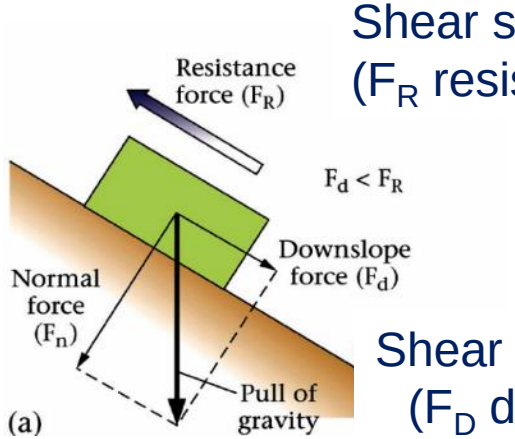




Colluvium = poorly sorted (i.e. made up of different sizes), angular, and unconsolidated material. Deposited at the base of a hillslope…

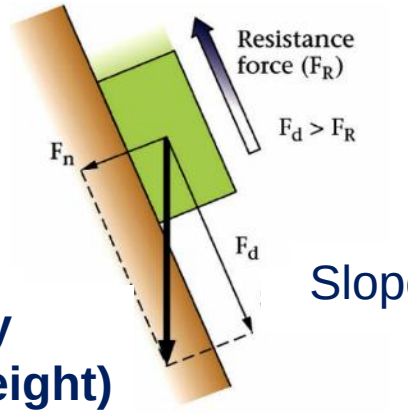
Slope stability

- What determines slope stability... ?



Shear strength (F_R resistance)

Shear stress (F_D driver)



Slope angle

Gravity (i.e. weight)

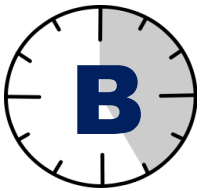
A

- Factor of Safety (FS) F_D / F_R > 1 leads to movement / event...

- Gradual change over time („disposition“) = de-stabilization (e.g. weathering)

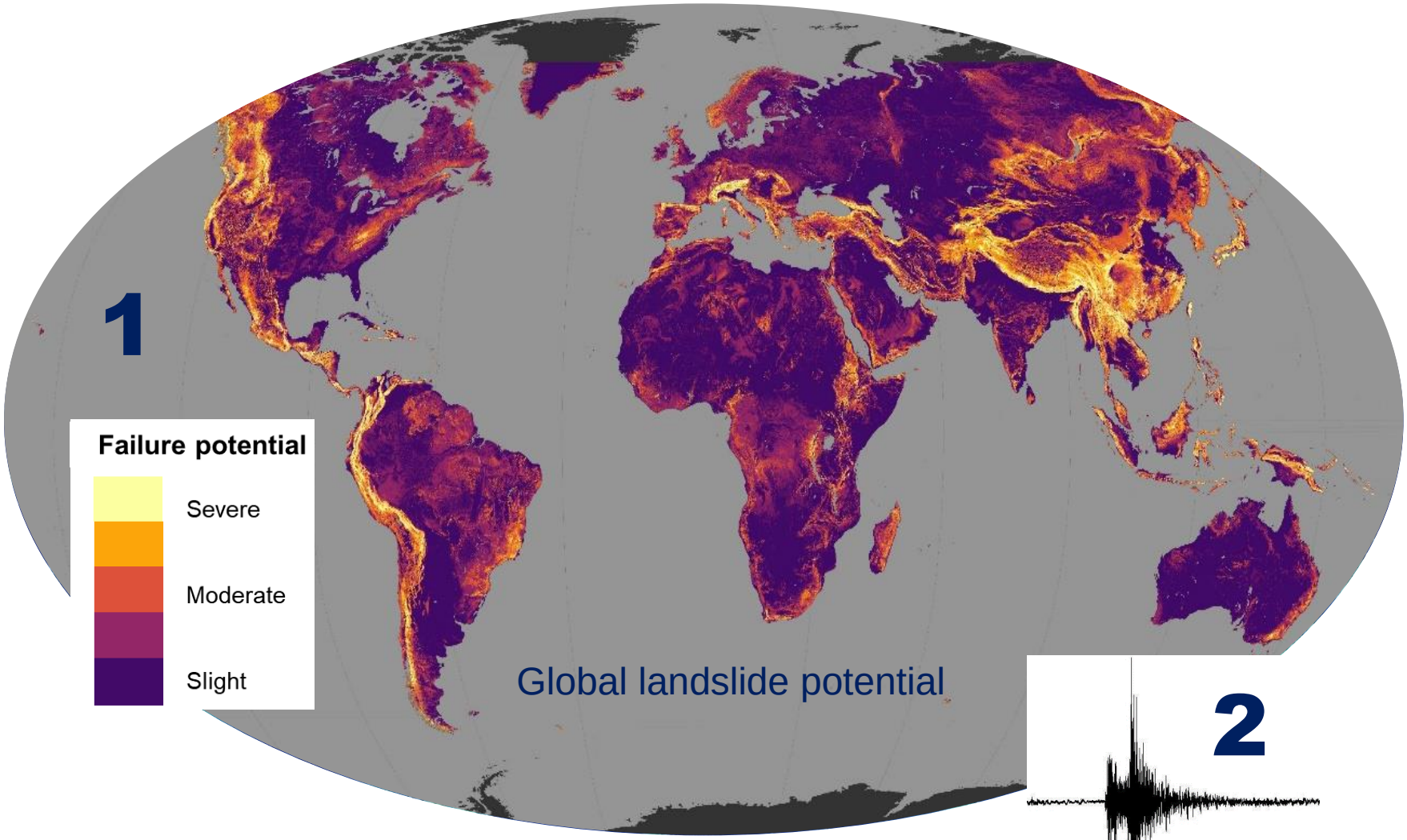
- Abrupt, event-based change („trigger“), e.g. earthquake, strong rainfall

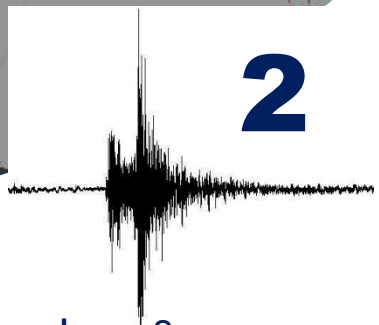
Change over time



High mountain areas potentially most affected...

Slopes and topographic relief





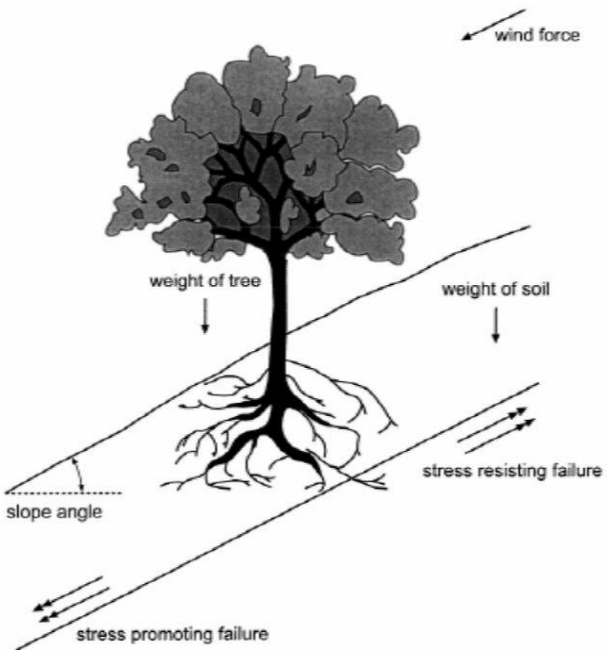
- Higher relief (≠ elevation) – steep slope more likely to fail
- Earthquakes & Seismic shaking

NOAA (2000), NASA (2019)

Slope stability vs vegetation

- **The good:** roots stabilise soil - hold hillslopes in place; and vegetation intercepts rain drop erosion (rain splash)

- **The bad:** excess weight of soil and trees; and added wind force

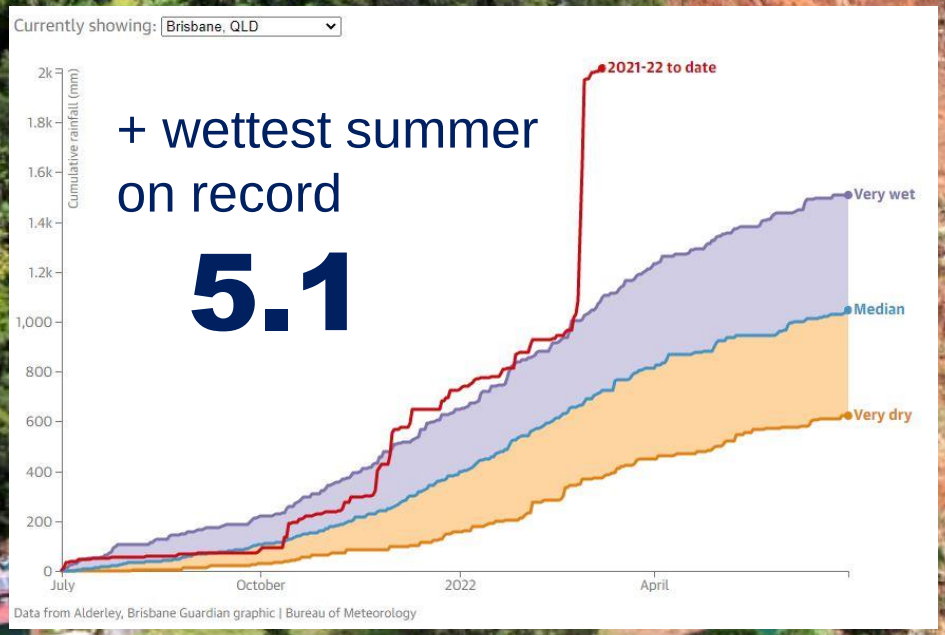


Phillips (1999)

Slope stability vs water content

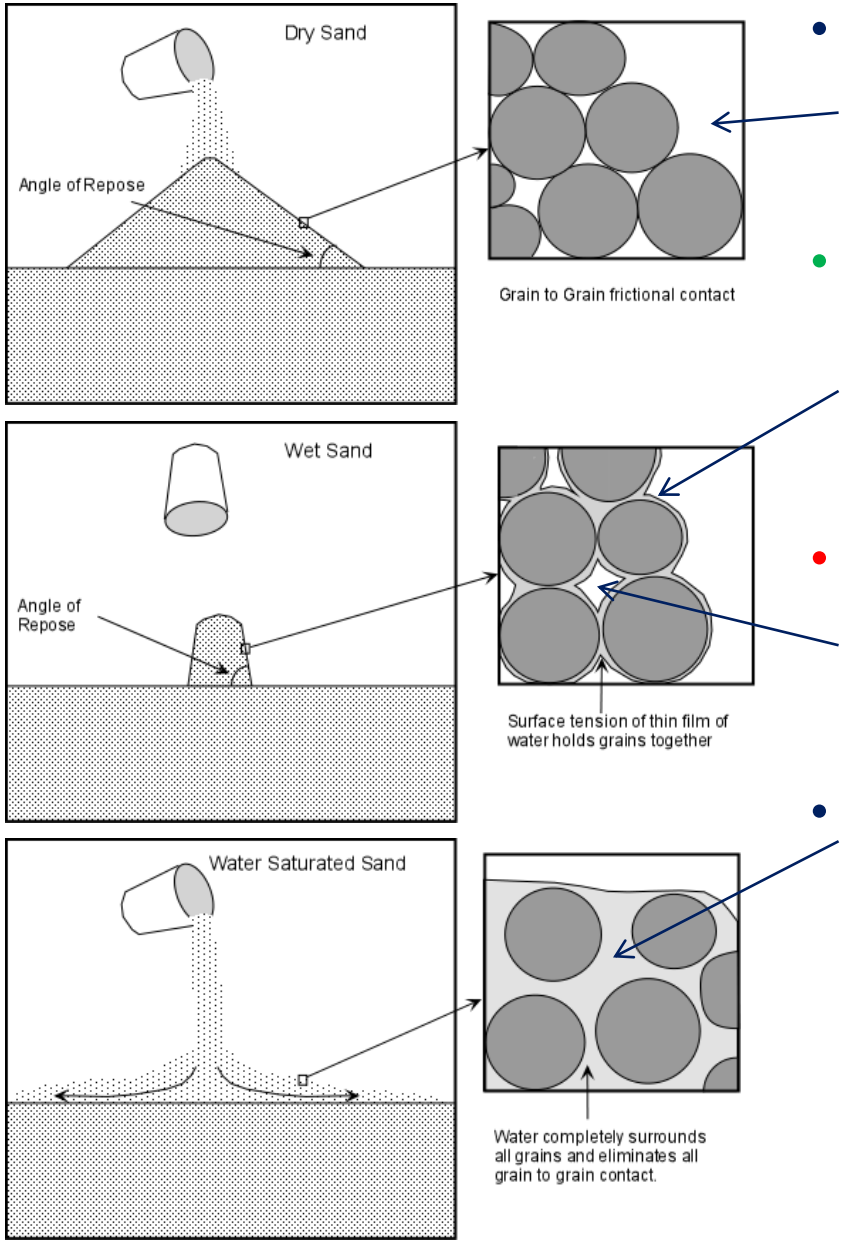
Deeply weathered regolith

4



Main Arm, NSW

Slope stability vs water content

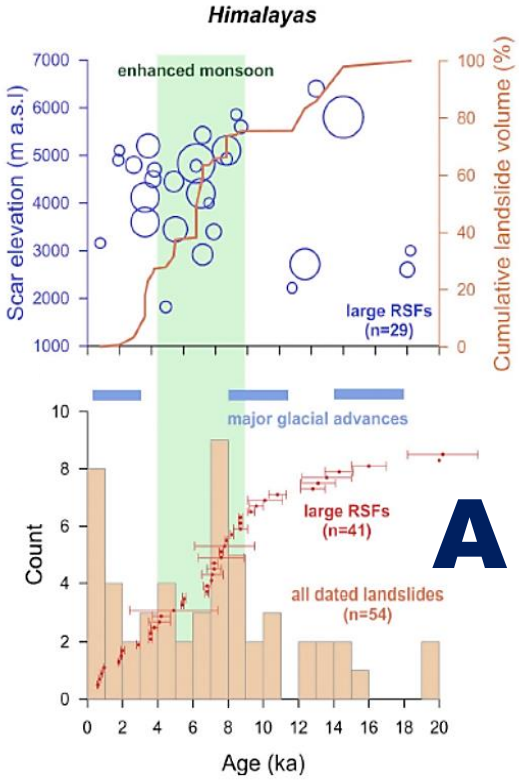


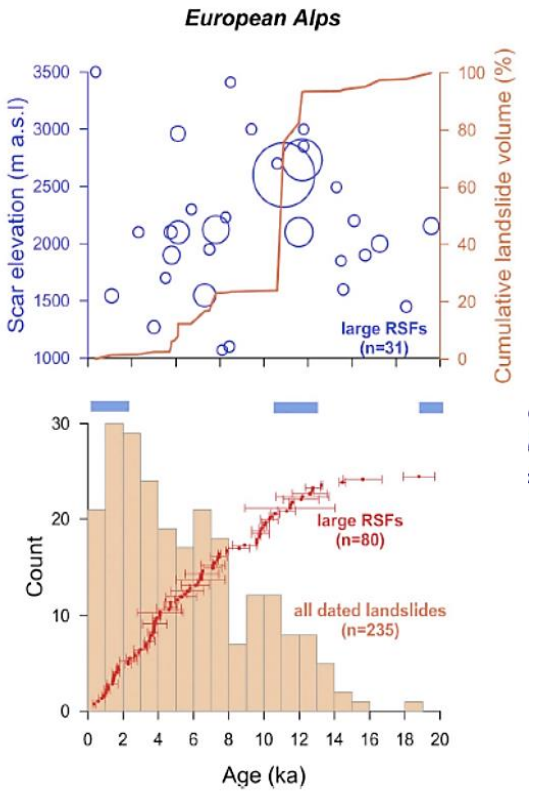
- **Dry unconsolidated grains** form a pile with the slope angle determined by the angle of repose [no cohesion]
- **The good:** Moisture increases the cohesion of soil grains via surface tension (e.g. a wet sandcastle can be more stable than a dry one)
- **The bad:** wet (saturated) sand flows like a fluid; water seeps into soil pores vs air (adds weight)
- **The ugly:** full saturation eliminates the grain-to-grain frictional contact, leading to very low angle of repose commonly triggering slope failure

High intensity rainfall events commonly trigger slope failure

Landslides and climate change

- View into the past
- Wet climate phases affect stability (e.g. Himalaya) – variability in total rainfall and intensities...





Strong increase (volumen) at transition Pleistocene – Holocene (temperature?)

Many small events (volume)

Few large events dominate

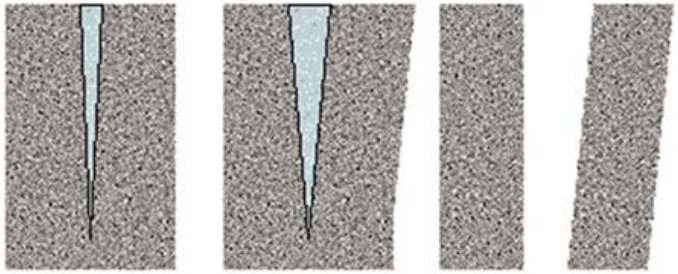
frequency = strong monsoon ?

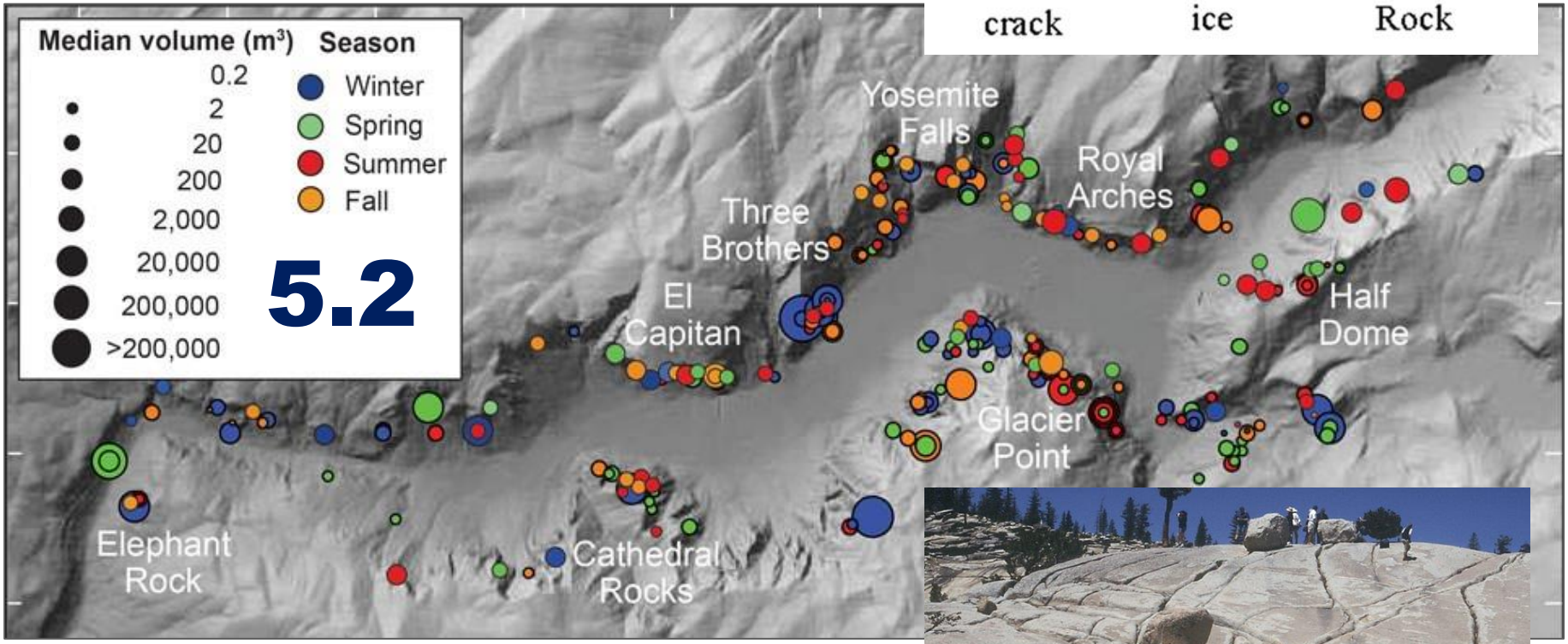
- Disappearence of glaciers (due to climate warming) as important factor?

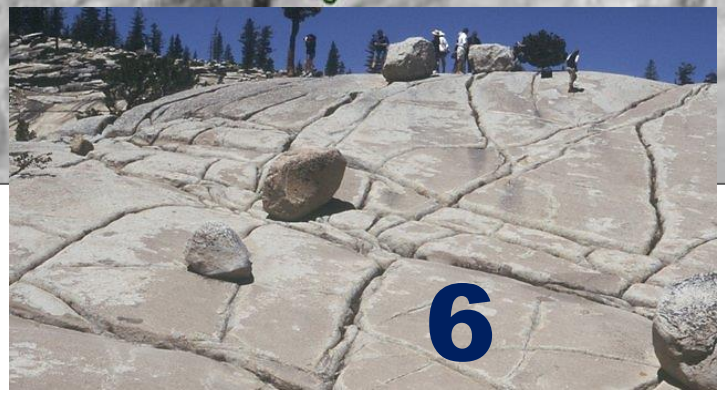
Panek 2019

Slope stability vs climate

- Larger rock falls outside summer months = wet + cold (moisture and temperature as combined climatic control)







- Rock type and structure play key role

Wieczorek et al., 2008

3 minutes...

Mass movements…

- **Definition:** *movement of rock or soil down slope under the force of gravity (without the help of other agencies, e.g. water, wind, ice)*

- Large spectrum of processes over many spatial and temporal scales

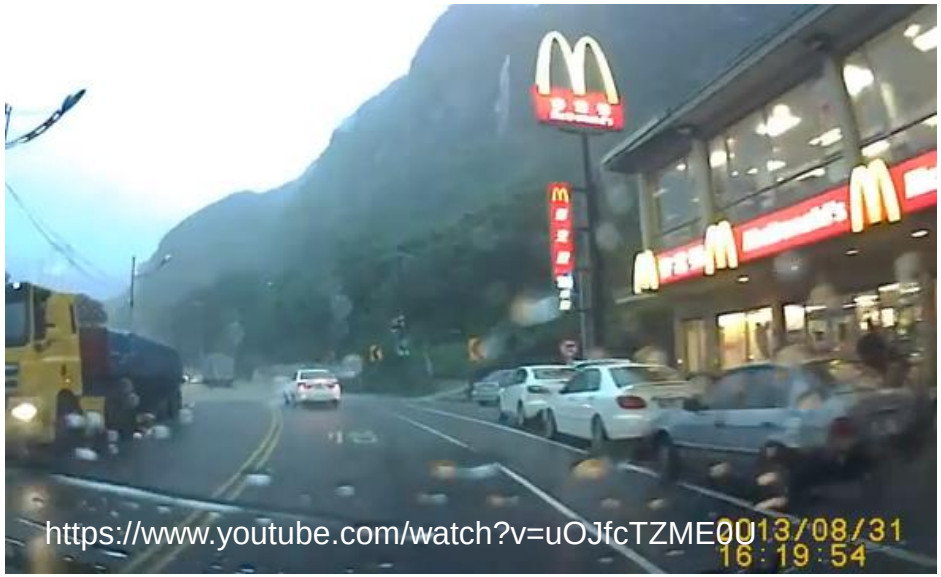
Mass movements…

- **Definition:** *movement of rock or soil down slopes under the force of gravity (without the help of other agencies, e.g. water, wind, ice)*

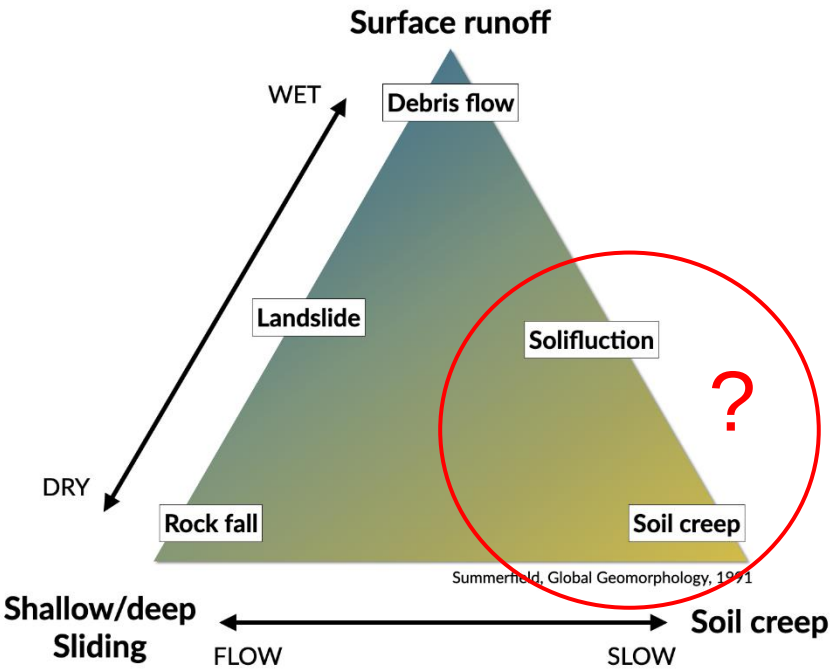
- Large spectrum of processes over many spatial and temporal scales

- ... And large range of resulting forms and deposits with differing risk potential

Mass movements (cont.)…



- Defined by…



- … type of movement and the material moved

Mass movements – slow…

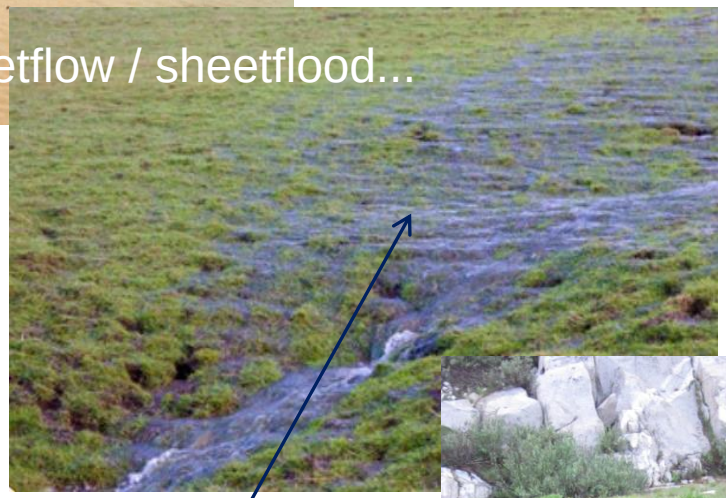
- Creep - slow downward progression of material on low grade slopes
- Rates: 1-3 mm/year (temperate)

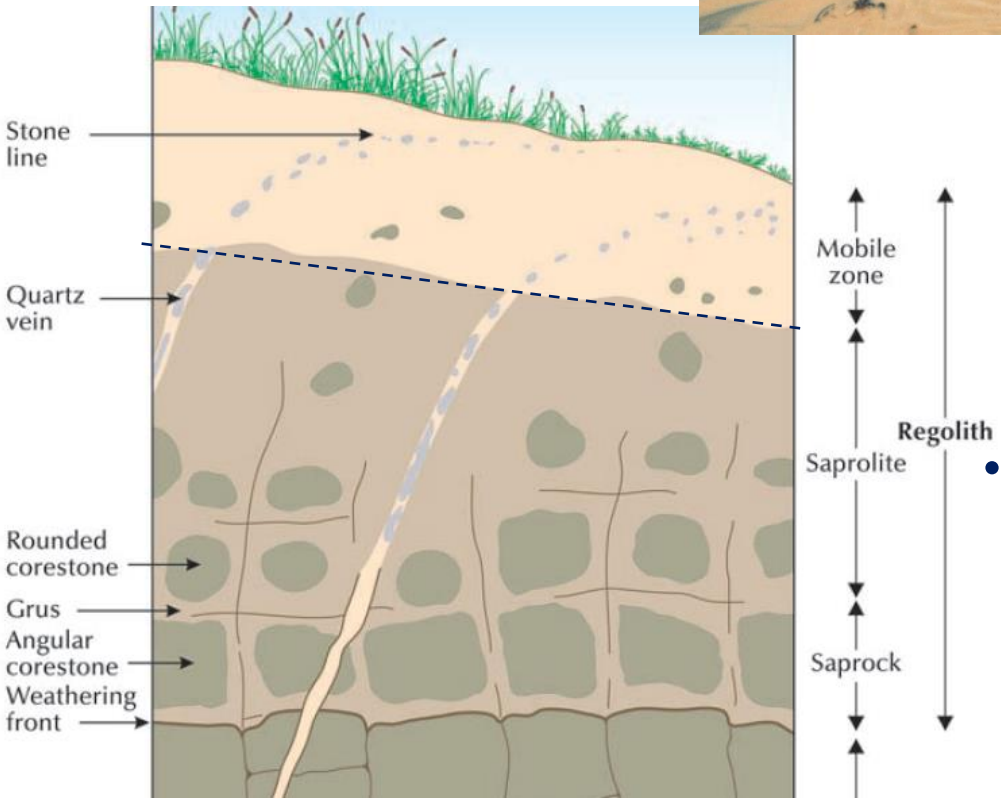
Terracettes – expansion and contraction from wetting and drying

Slopes and drainage networks

- Creep = (sub-)surface movement through
  - Roots
  - Soil Fauna
  - Wetting / Drying
  - Freezing / Thawing

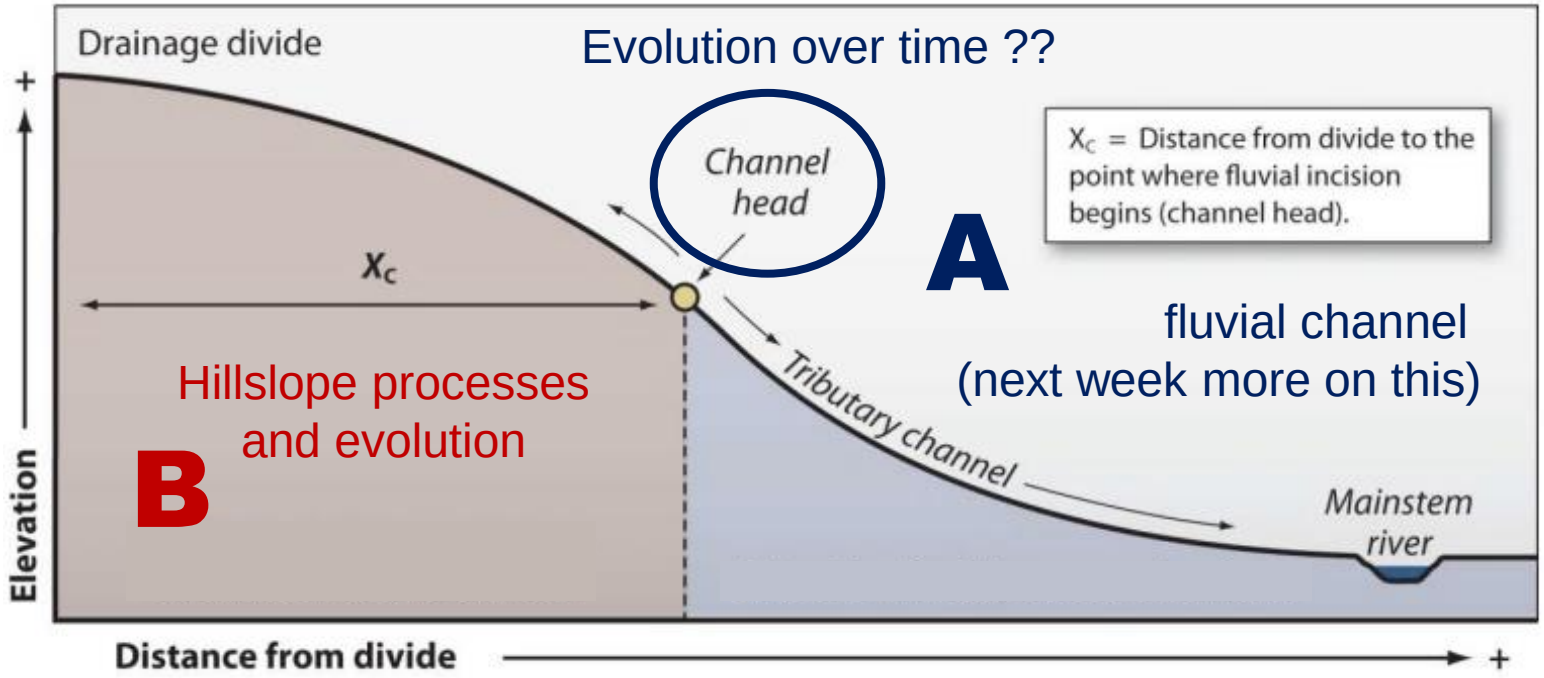
• sheetflow / sheetflood...





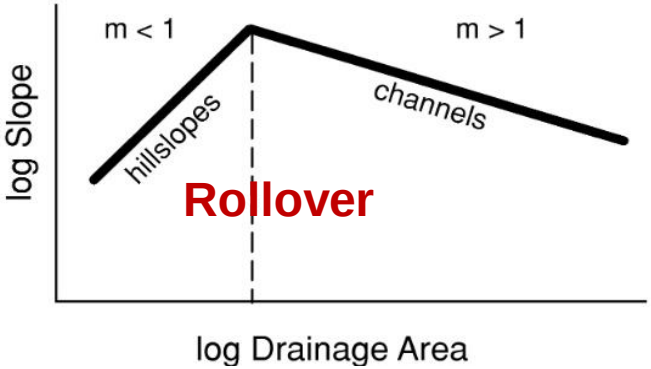
- Non-channelized vs channelized sediment transport through water

Slopes and drainage networks



What determines position of the **channel head** (start of fluvial channel)?

- The **rollover** marks hillslope to channel transition = transition between the positive and negative change in slope of the curve



Slopes and gullies

Gullies = concentration of flow into channels and rapid headward migration of channel head = incision (the ugly..?)

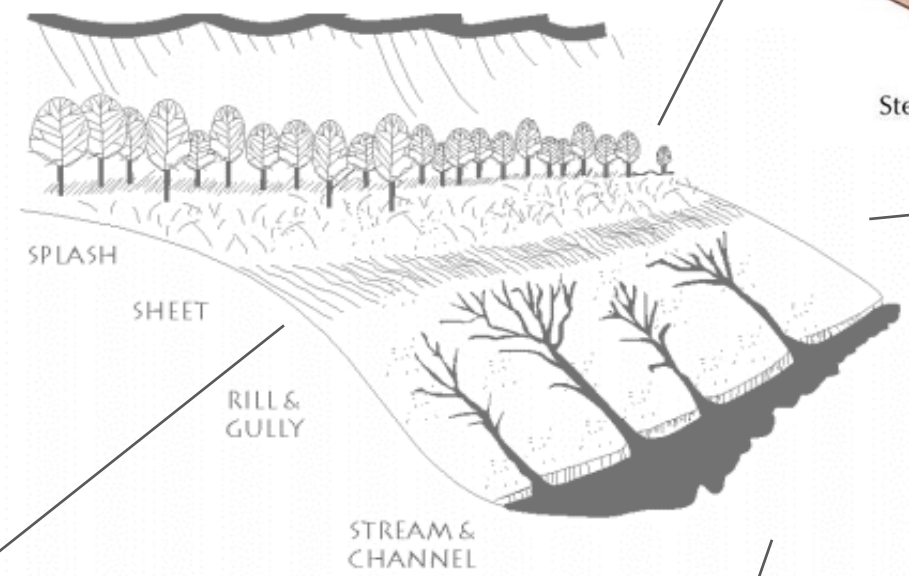
A

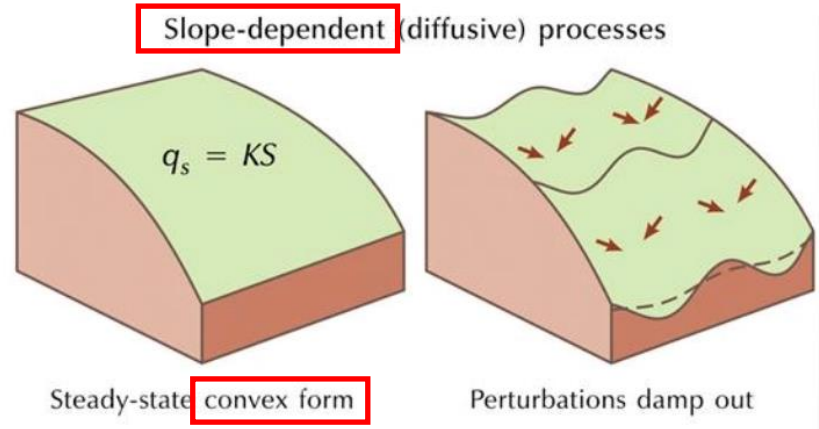
… but part of a **natural transition point between hillslopes, and channels** - so are they really the bad guy?

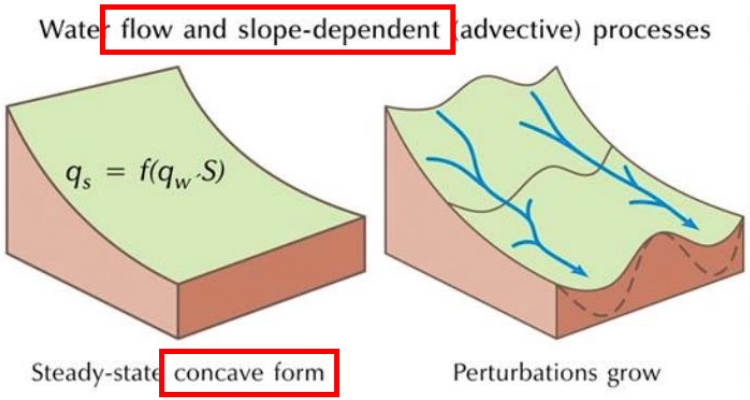
Slope morphology

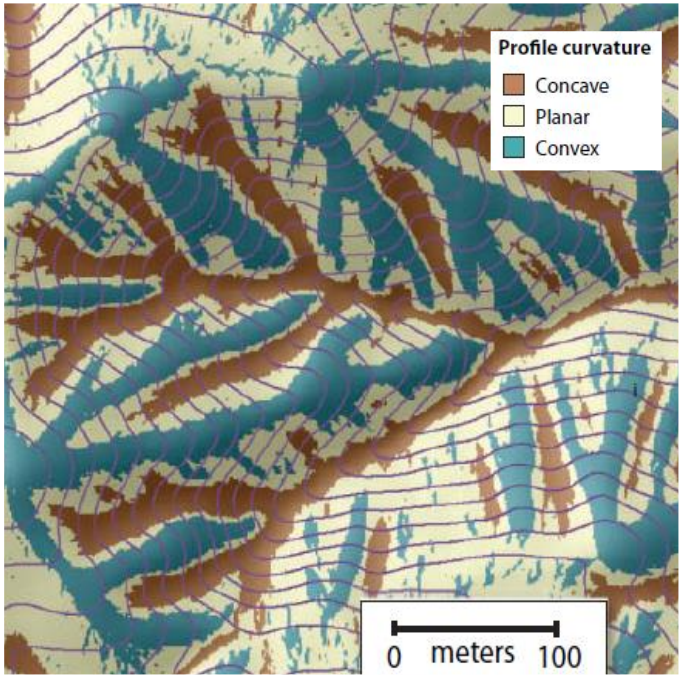
- Diffusive vs advective processes

B







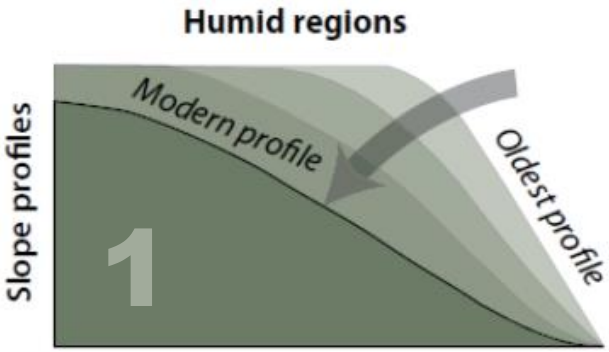


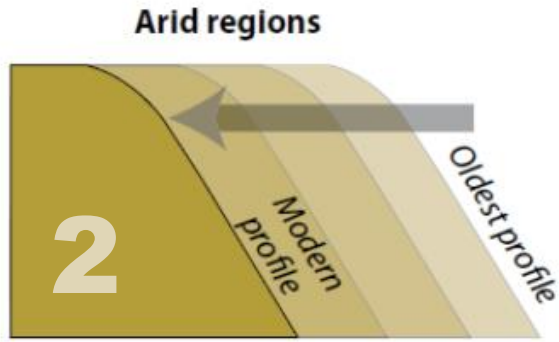
Hillslope evolution and landforms…

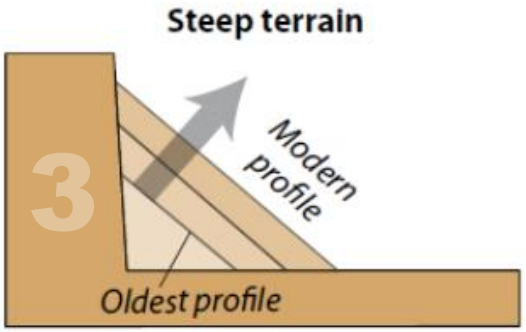
Humid regions = soil mantled, erosion via slope-dependent diffusive processes

Arid regions = weathering-limited bedrock slopes (rock strength!)

Steep terrain – high accumulation of debris cannot be removed







Progressive rounding, lowering of profiles (and gradients decline)

Erosion via progressive backwearing – parallel slope retreat

Cliff replaced by talus slope

Slope decline (Davis)
Upper slope weathers and erodes at a fast rate – progressive decline of slope angle over time

Parallel retreat (Penck)
Slope angle/length remain uniform as slope retreats parallel to itself – hillslopes essentially free of sediment

Replacement (King)
upper slope retreats parallel to itself while replacement of the lower slope forms pediment

Hillslope landscapes…

Sediment transport (mass removal) < regolith production (weathering)

Sediment transport (mass removal) > regolith production (weathering)

Hillslopes - Summary

- Slope stability driven by shear stress vs strength
- Mass movement can be fast or slow
- Classification by material and movement
- Controls on stability: water content, vegetation etc.
- Drainage networks form along hillslopes
- Channel initiation - link into fluvial system (maximum efficiency of flow and transport)
- Different hillslope evolution models

https://blogs.agu.org/landslideblog/