



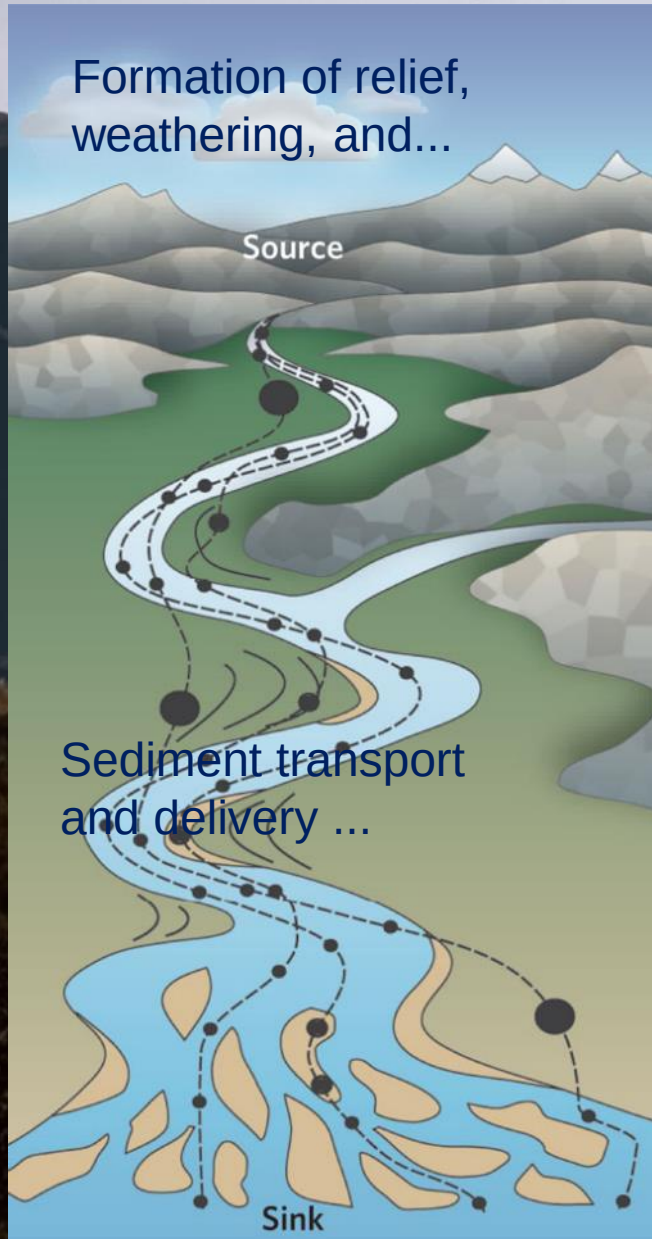
Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

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)

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?

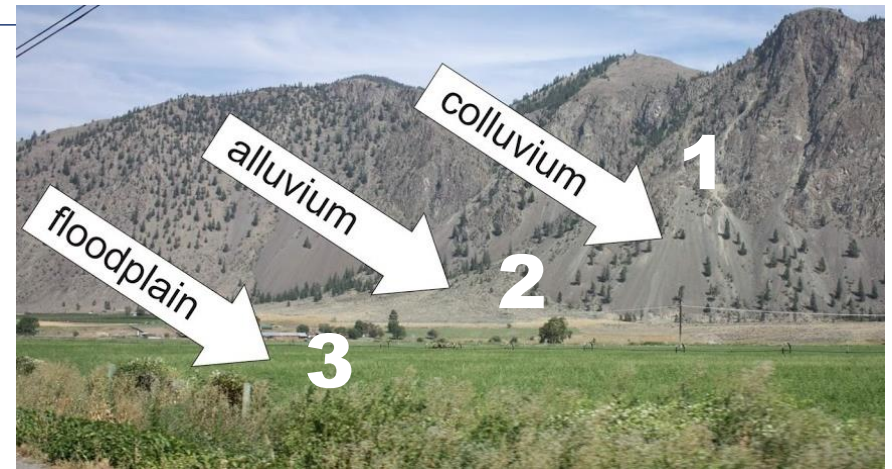
- **A hazard:** Direct and indirect influences on people and property (i.e. if material is deposited in the 'wrong' place...)



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

Colluvial vs alluvial...

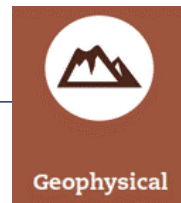
- **Colluvial** = mobile sediment **moved by gravity** and not by channelized flow
- **Alluvial** = sediment moved by running water



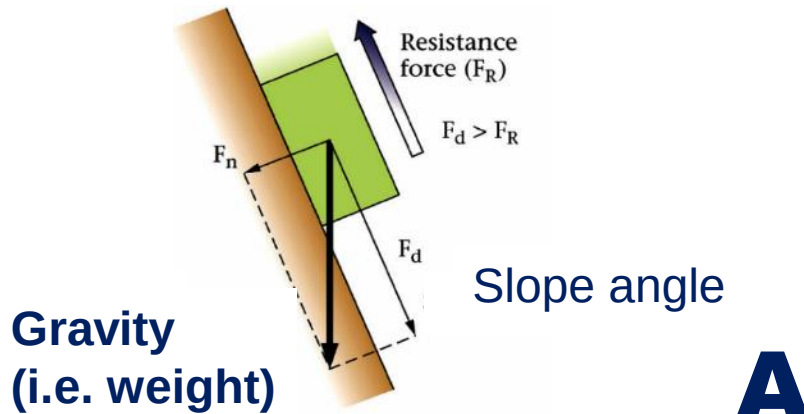
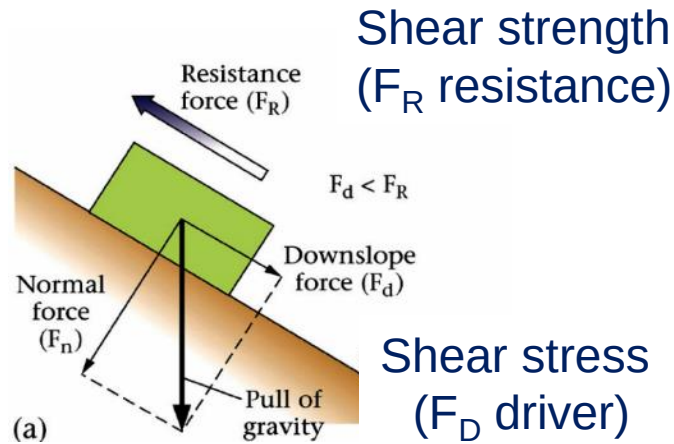
Colluvium = poorly sorted (i.e. made up of different sizes), angular, and unconsolidated material. Deposited at the base of a hillslope...



Slope stability



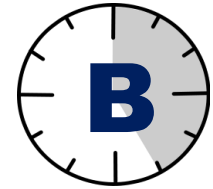
- What determines slope stability... ?



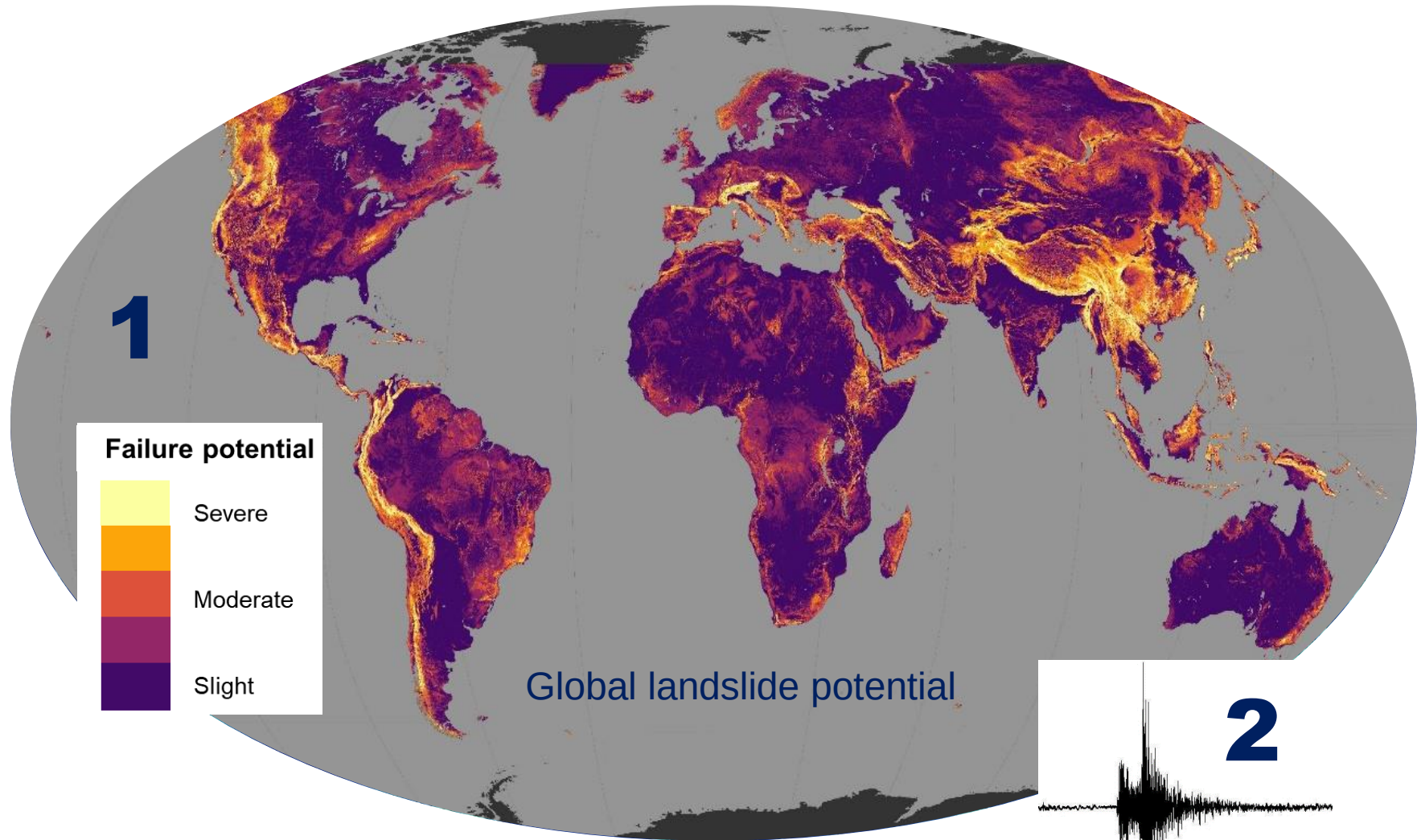
- Factor of Safety (FS) $F_D / F_R > 1$ leads to movement / event...

- Gradual change over time („disposition“) = de-stabilization (e.g. weathering)
- Abrupt, event-based change („trigger“), e.g. earthquake, strong rainfall

Change over time



Slopes and topographic relief

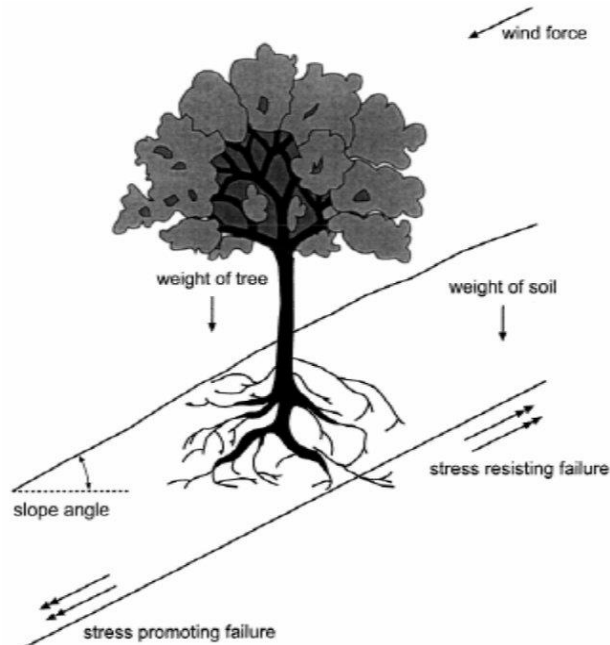


- Higher relief ($\neq$ elevation) – steep slope more likely to fail

- Earthquakes & Seismic shaking

Slope stability vs vegetation

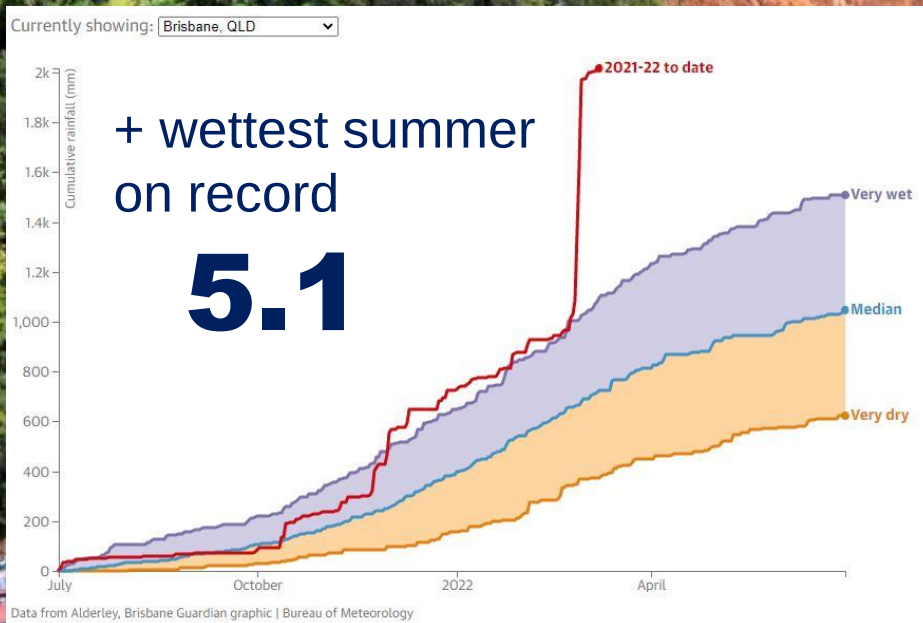
- **The good:** roots stabilise soil - hold hillslopes in place; and vegetation intercepts rain drop erosion (rain splash)
- **The bad:** excess weight of soil and trees; and added wind force



Slope stability vs water content

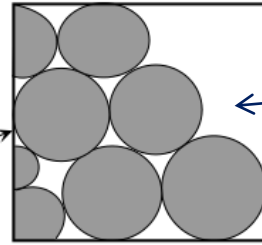
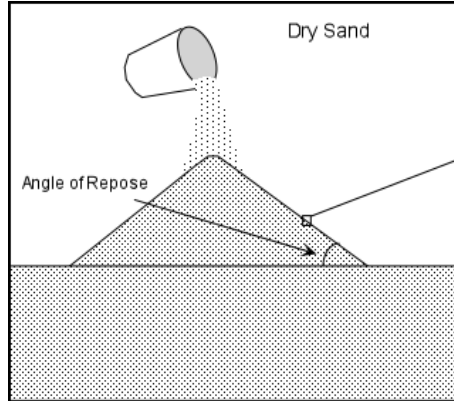
Deeply weathered regolith

4

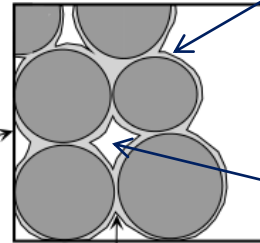
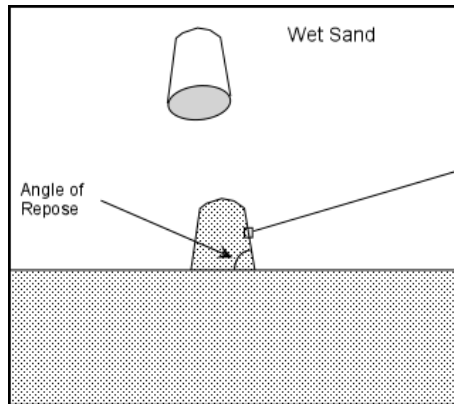


Main Arm, NSW

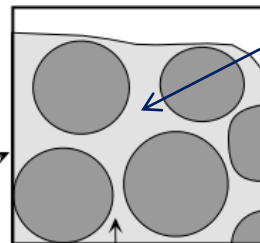
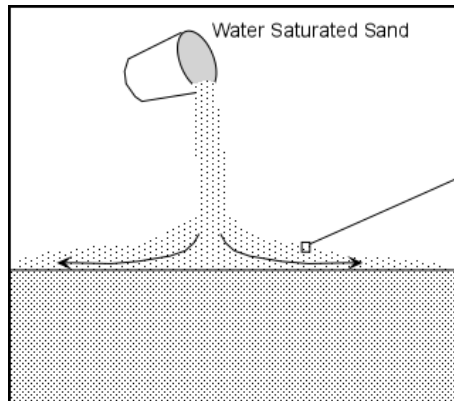
Slope stability vs water content



Grain to Grain frictional contact



Surface tension of thin film of water holds grains together



Water completely surrounds all grains and eliminates all grain to grain contact.

- **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

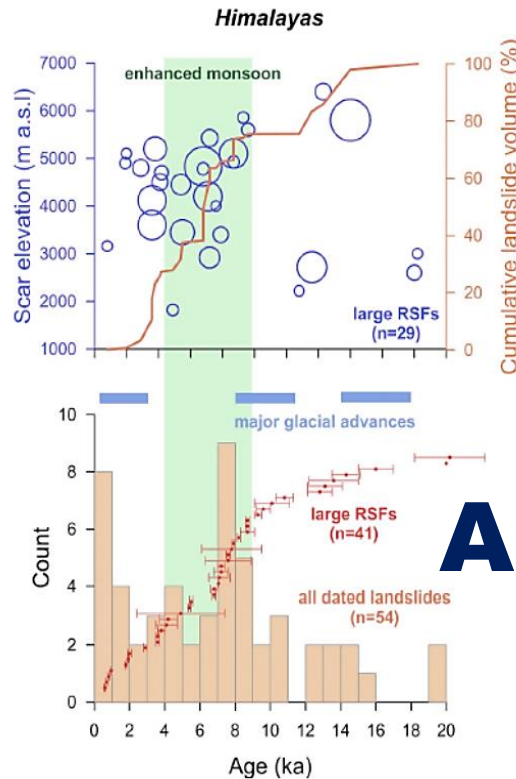
High intensity rainfall events commonly trigger slope failure

Landslides and climate change

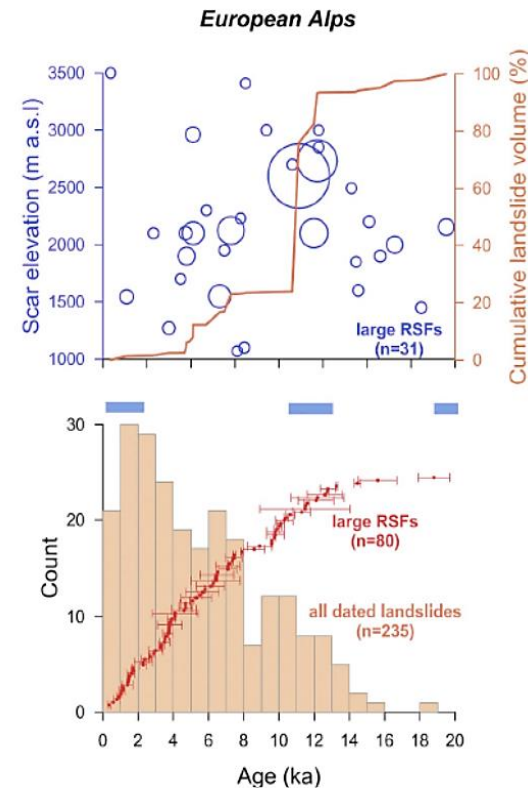
- View into the past
- Wet climate phases affect stability (e.g. Himalaya) – variability in total rainfall and intensities...

Many small events
(volume)

frequency =
strong monsoon
?



A



B

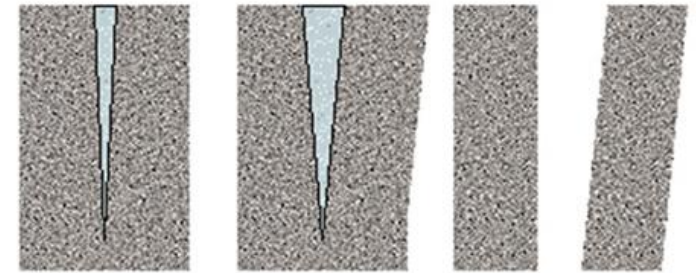
Strong increase
(volumen) at transition
Pleistocene –
Holocene
(temperature?)

Few large
events
dominate

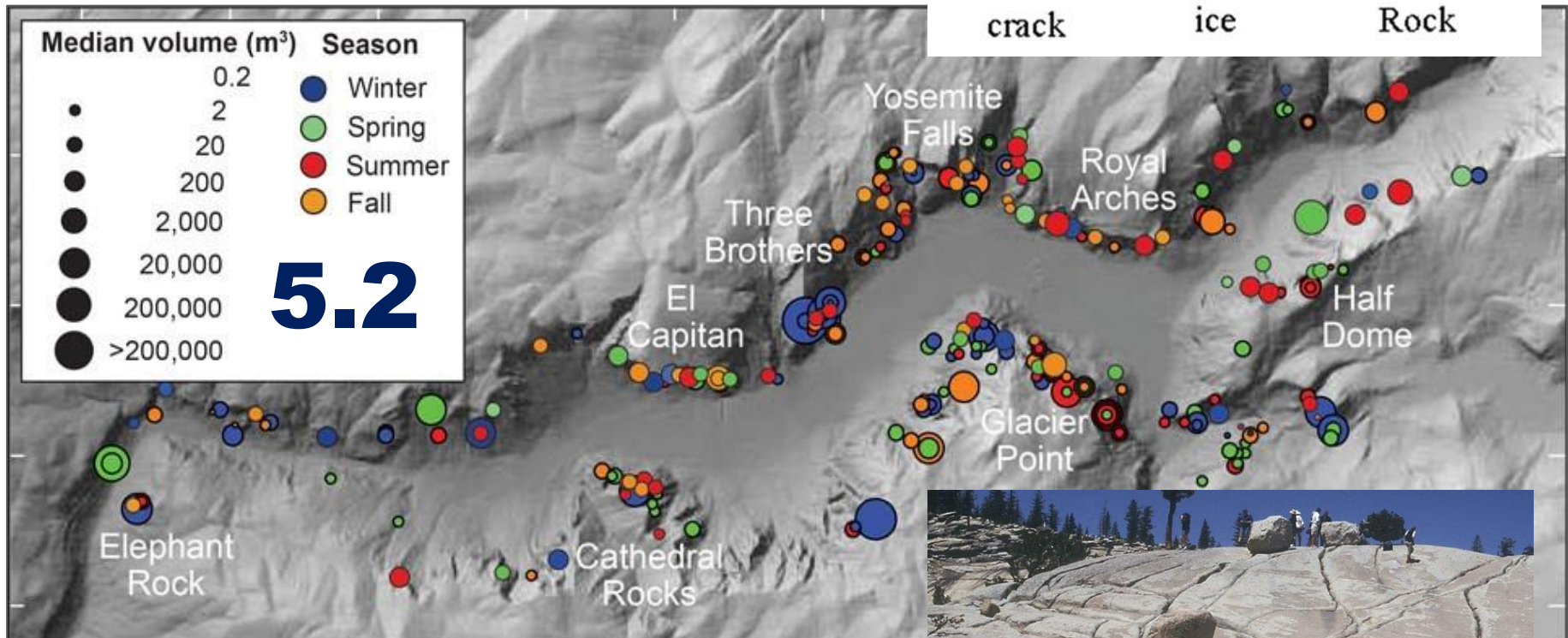
- Disappearance of glaciers (due to climate warming) as important factor?

Slope stability vs climate

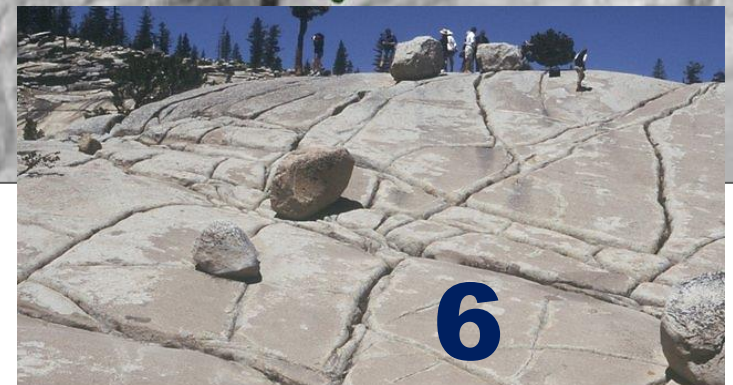
- Larger rock falls outside summer months = wet + cold (moisture and temperature as combined climatic control)



Water-filled crack Freezes to ice Breaks Rock



- Rock type and structure play key role



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

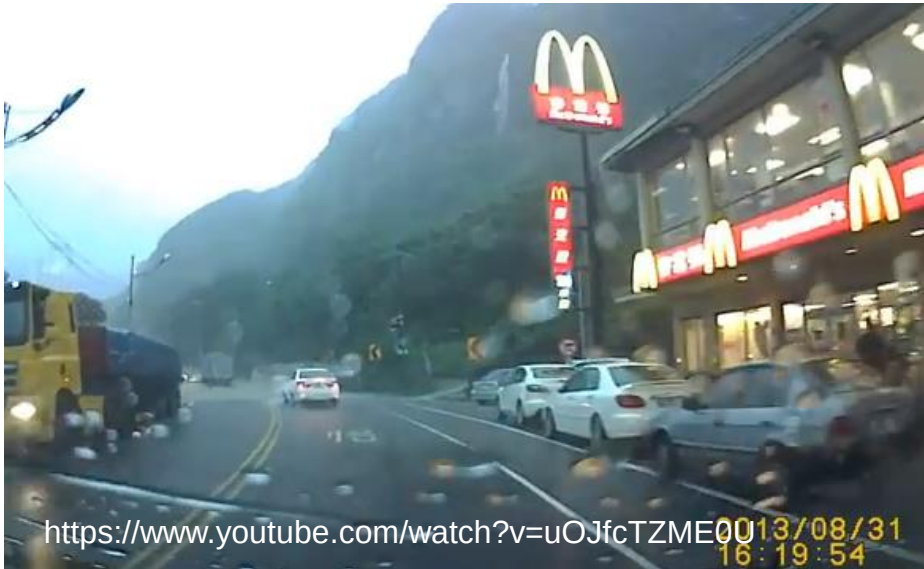
Mass movements...

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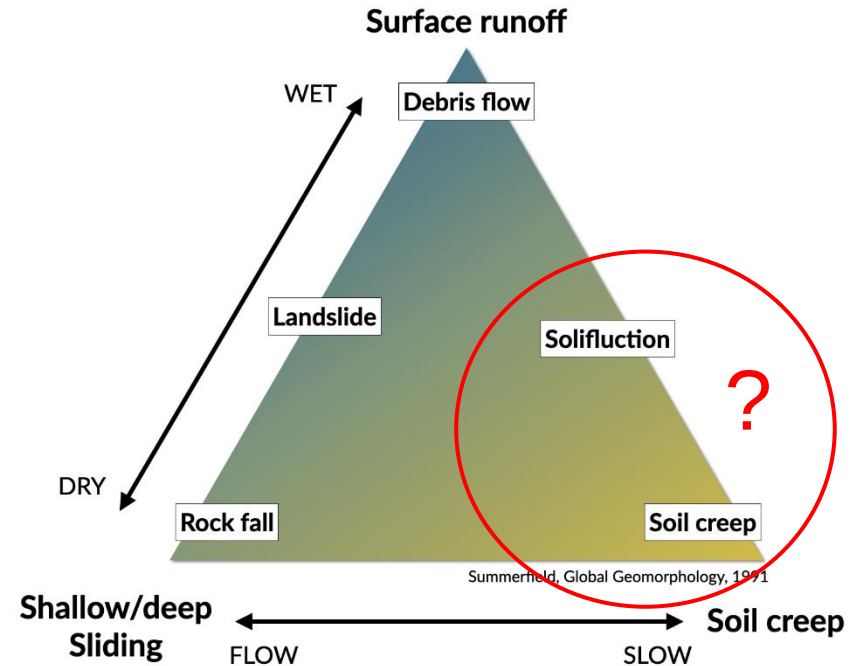


- ... And large range of resulting forms and deposits with differing risk potential

Mass movements (cont.)...



- Defined by...



- ... type of movement and the material moved

Mass movements – slow...

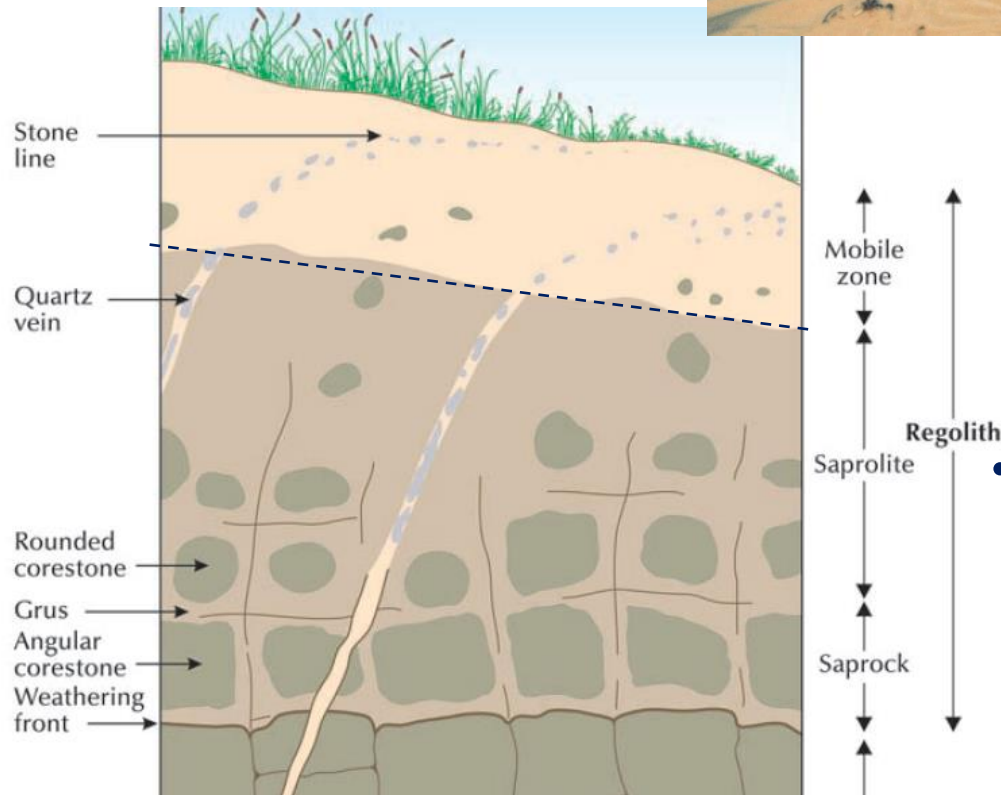
- Creep - slow downward progression of material on low grade slopes
- Rates: 1-3 mm/year (temperate)

Terracettes – expansion and contraction from wetting and drying

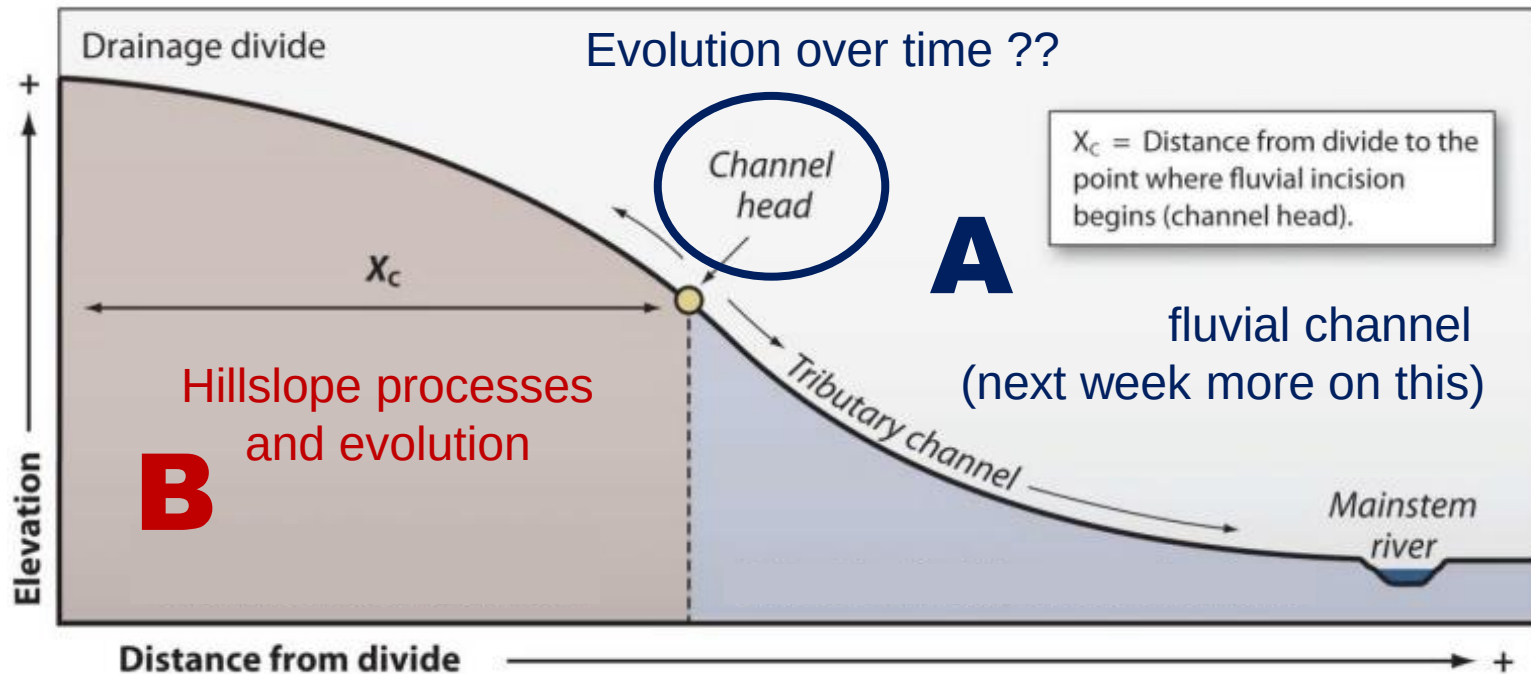


Slopes and drainage networks

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

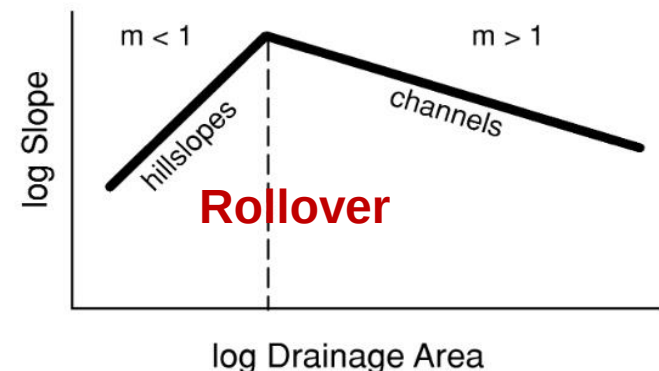


Slopes and drainage networks



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

Bowen River catchment gullies (QLD)



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

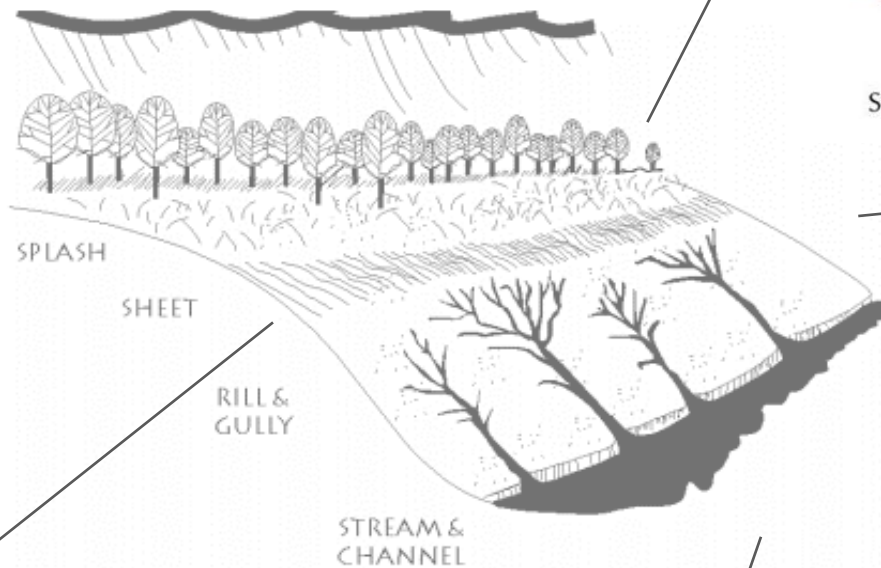
A

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

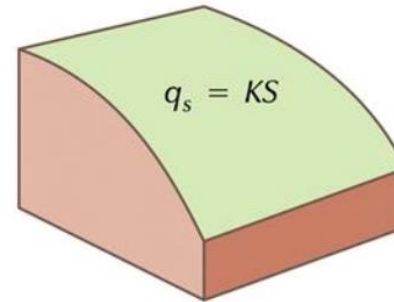
Slope morphology

- Diffusive vs advective processes

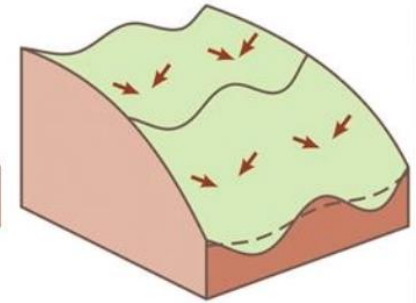
B



Slope-dependent (diffusive) processes

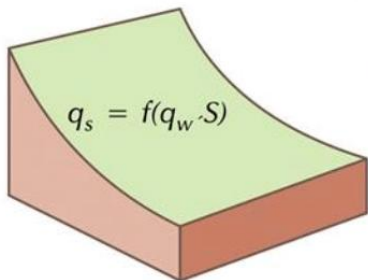


Steady-state convex form

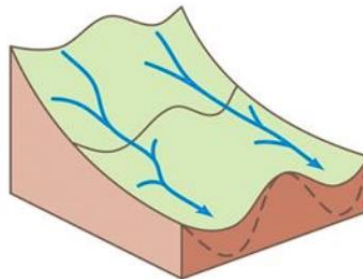


Perturbations damp out

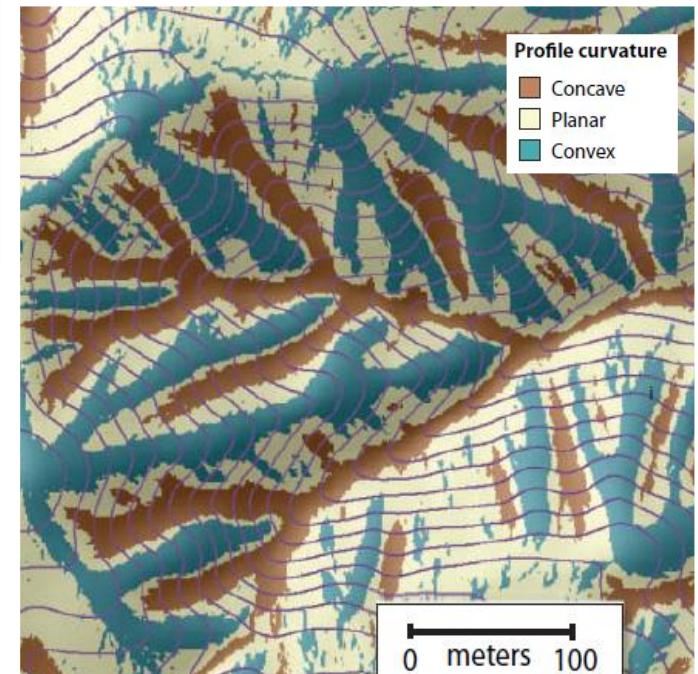
Water flow and slope-dependent (advective) processes



Steady-state concave form

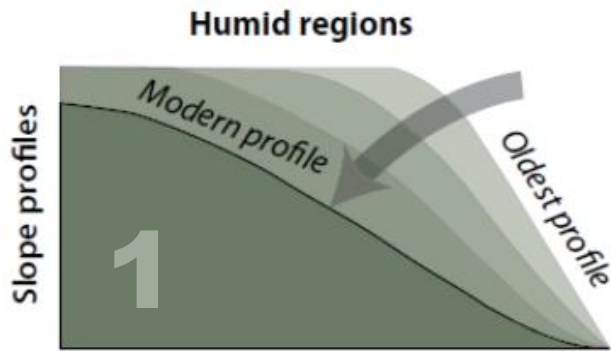


Perturbations grow



Hillslope evolution and landforms...

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



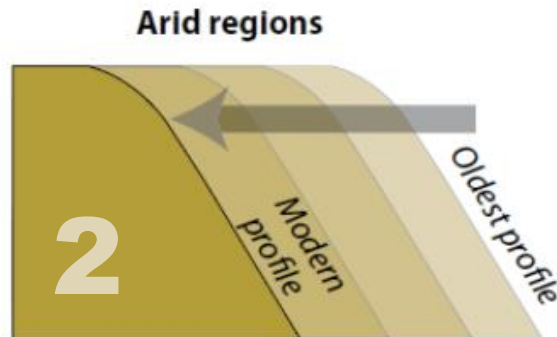
Progressive rounding, lowering of profiles (and gradients decline)



Slope decline (Davis)

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

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



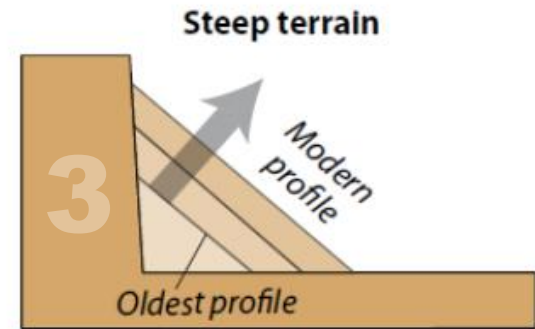
Erosion via progressive backwearing – parallel slope retreat



Parallel retreat (Penck)

Slope angle/length remain uniform as slope retreats parallel to itself – hillslopes essentially free of sediment

Steep terrain – high accumulation of debris cannot be removed



Cliff replaced by talus slope



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/>

Activity

- Find an example of a slope issue in S. Wales
- This could be a landslide (for example)
- **Answer the following:**
- What is the main issue? Are there any habitat implications?
- Does the surrounding landscape make this worse (and how?)
- What is being done to minimise the risk?
- If you complete this; have a go at labelling the slope process diagram: [Label the slope process diagram. \(uwtسد.ac.uk\)](http://uwtسد.ac.uk)

Suggested Reading

- [Hillslope processes — EarthSurface 0.0.1 documentation](#)
- [Slope Stability \(tulane.edu\)](#)
- [Introduction to Hillslopes and Hillslope Processes: Creep, Mass Wasting, and Diversity of Forms – GeomorphOnline](#)
- **Gervais (2019) Weathering and Mass Movement pp478-499.**