Landslides 2

No. Seriously. Your house was here a minute ago.

Goals for Today

1) **Define** Angle of repose
2) **Assess** the balance between the shear strength and shear stress of a slope (Factor of Safety)
3) **Compare** and **contrast** landslide causes and landslide triggers
4) **List** and **describe** several external causes of landslides

Angle of Repose

Loose materials rest at a natural **angle of repose**, the steepest angle at which the material can accumulate without sliding

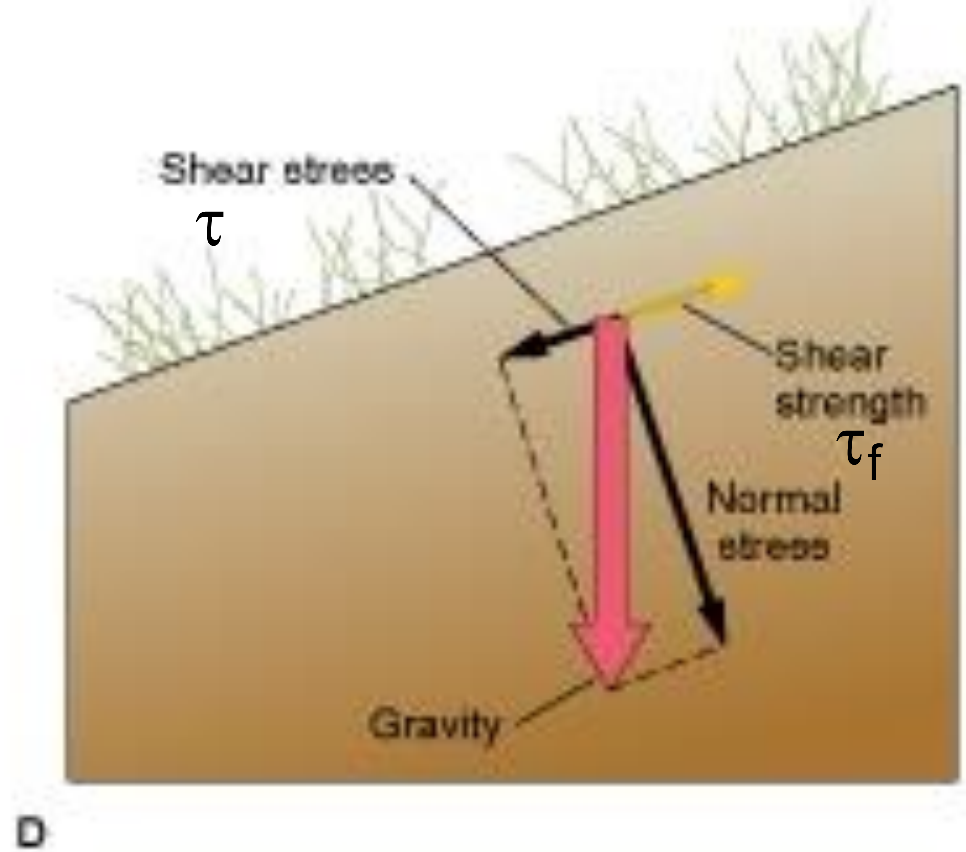
Depends on:
- The material (clay silt, sand, etc.)
- Particle size and shape
- Moisture level

Stability of Slopes

Forces involved:

Driving Force

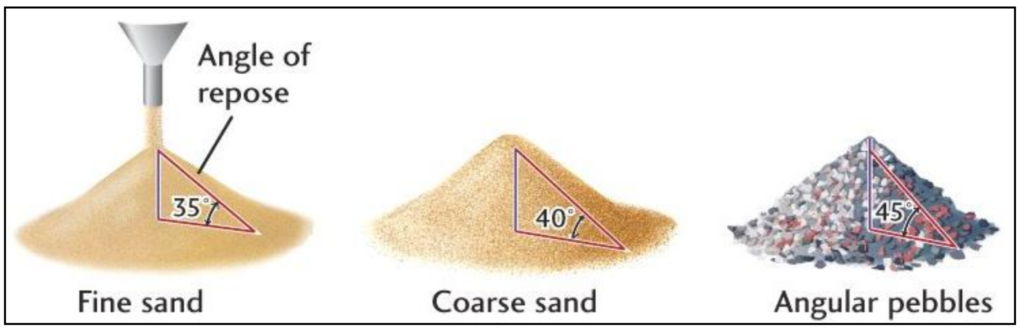
- Gravity
- Manifests as Shear stress (τ)
  - "Shearing" is motion from side to side
  - Component of the force of gravity parallel to the slope



Stability of slopes

Resisting forces prevent slopes from failing

Frictional Strength



Friction – Resistance to sliding (proportional to normal force/stress)

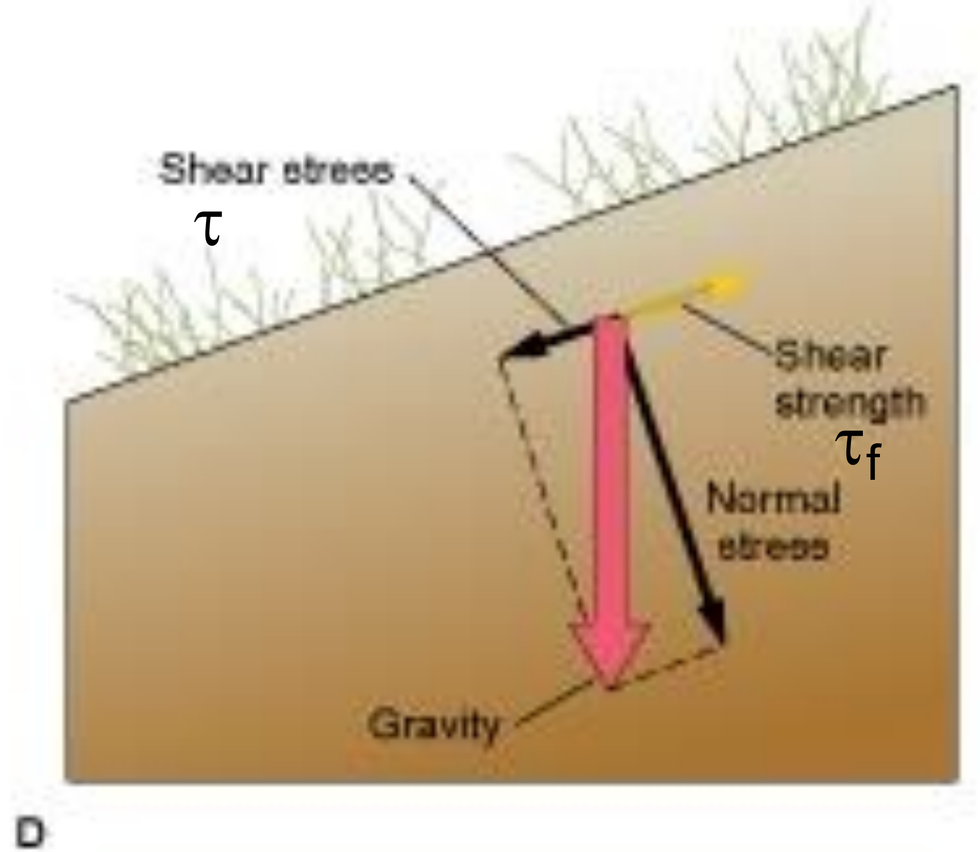
Cohesive Strength

Cohesion – How the material holds together

Stability of Slopes

Resisting forces

- Friction and Cohesion
- Together they are Shear strength (τ_f)
  - Shear strength is the slope's ability to resist shearing motion



Average Material Strength

Material	Friction	Cohesion	Shear Strength
Most Crystalline Rock (Igneous or Metamorphic) 	Moderate	Very High	High (if cohesive)
Most Sedimentary rock 	Moderate	High to Moderate	Moderate
Most Sediment (clay silt, sand, gravel) 	Low to moderate	Low	Low

Stability of Slopes

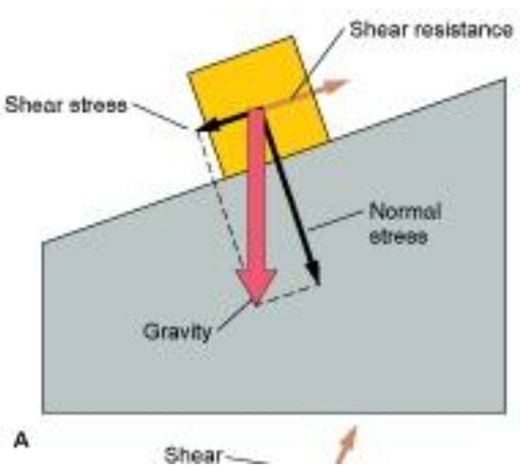
We can model the stability of any slope by comparing

Resisting forces (Shear Strength-τ_f)

and Driving forces (Shear Stress-τ)

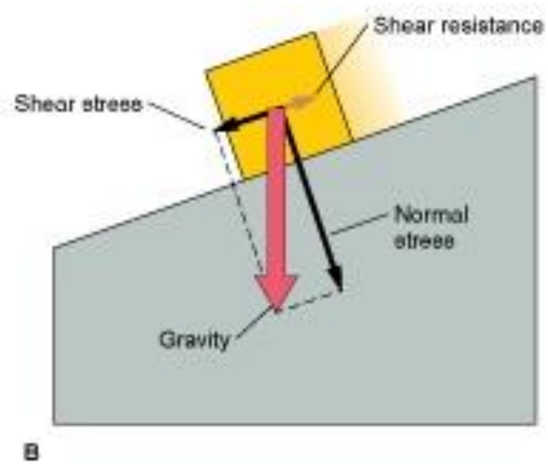
If $\tau < \tau_f$

Slope is stable



If $\tau > \tau_f$

Slope fails



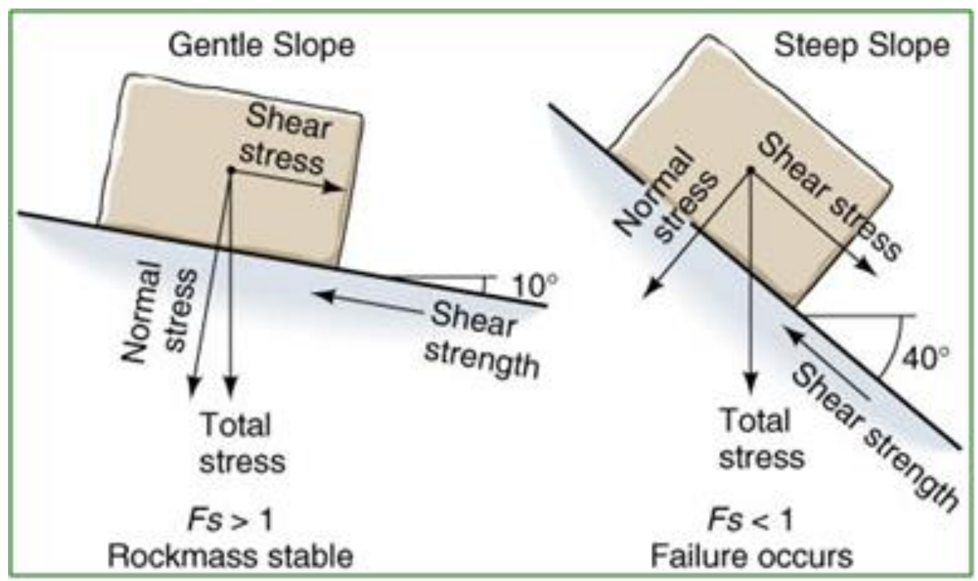
Stability of Slopes

Factor of Safety (F_s)

- ratio of Shear strength (τ_f resisting forces)

  To Shear stress (τ driving forces)

$$F_s = \frac{\tau_f}{\tau}$$



F_s >> 1.0 stable slope

F_s < 1.0 Fail!

Shear strength slightly greater than shear stress

$F_s \sim 1.0$

Shear strength less than shear stress

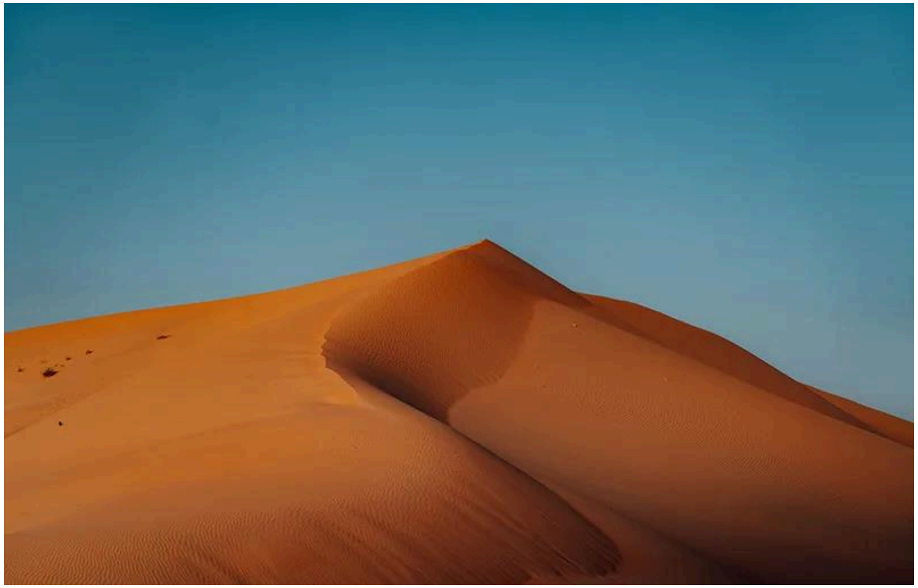
Source: simplytex

$F_s < 1.0$

Stability of Slopes

At the angle of repose shear stress is exactly balanced by shear strength

– F_S is equal or just above 1.0

Mass Movements

Cause vs. Trigger

Causes are factors (often long term) leading to instability of a given slope

They reduce the shear strength or increase shear stress of a slope

But do not initiate movement

Mass Movements

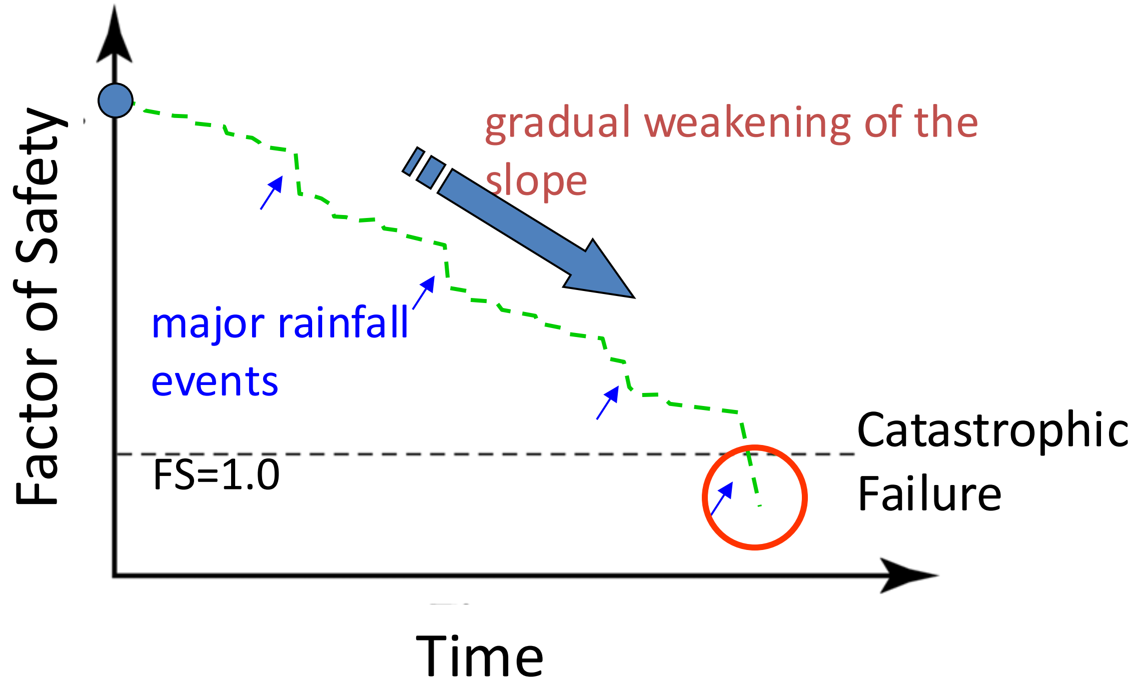
Triggers are factors (usually short events) that translate instability into motion

There can be many causes, but there is only ever one trigger

(its possible we won’t know what it is though)

Landslide Processes

<u>Cause</u>: makes slope susceptible to movement without actually initiating failure.



<u>Trigger</u>:
initiates failure.

Mass Movements

Causes of Mass Movement

1) External Causes
   – Factors outside of the slope that affect stability
2) Internal Causes
   – Factors inside the slope that affect stability

1) External Causes

a) Slope Angle

You must have a slope to have mass movement

Steeper slopes = more movement

1) External Causes

b) Undercutting

The lower part of the slope is removed by roads, rivers, buildings, etc. which removes support

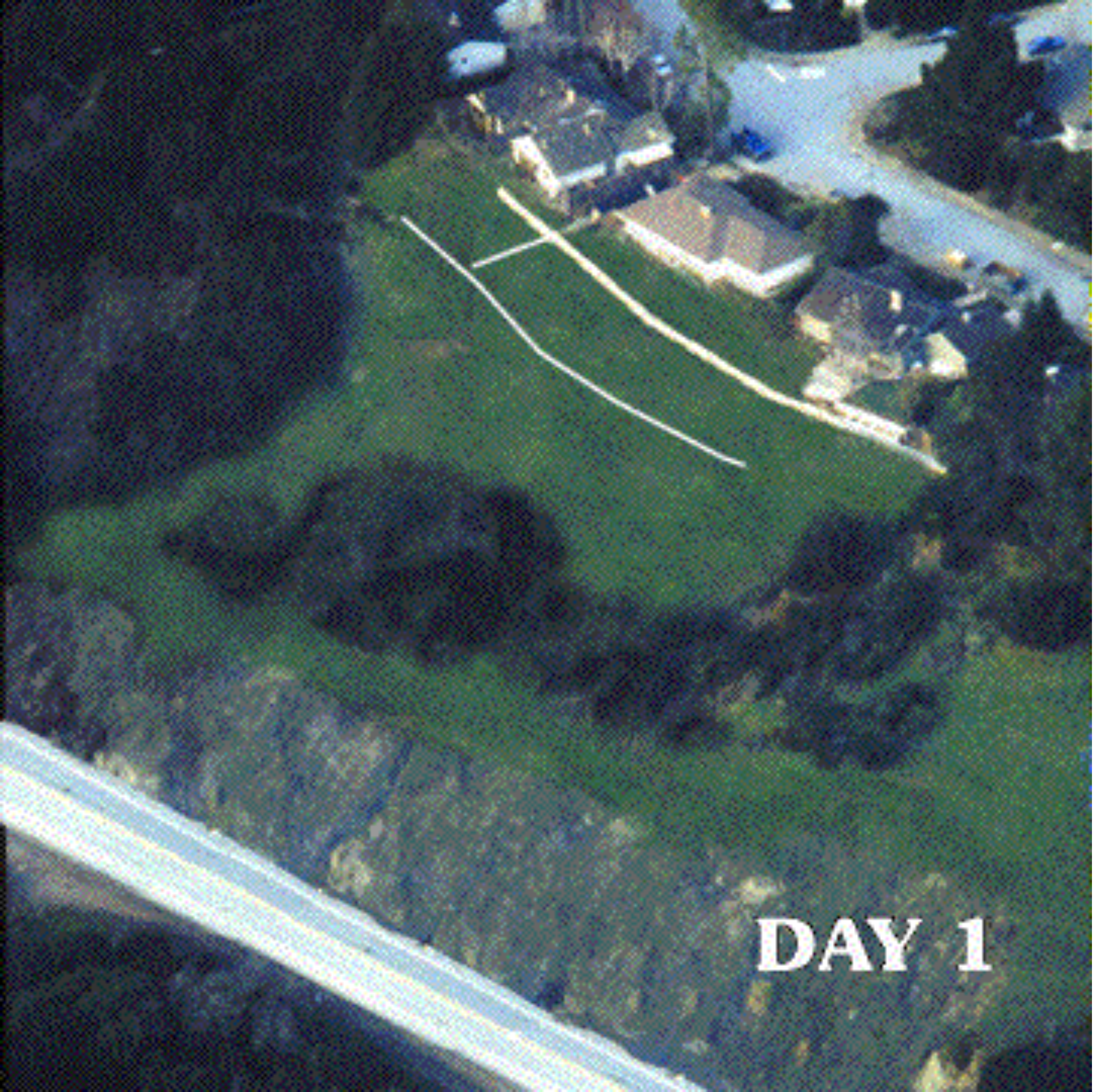


Photo USGS

1) External Causes

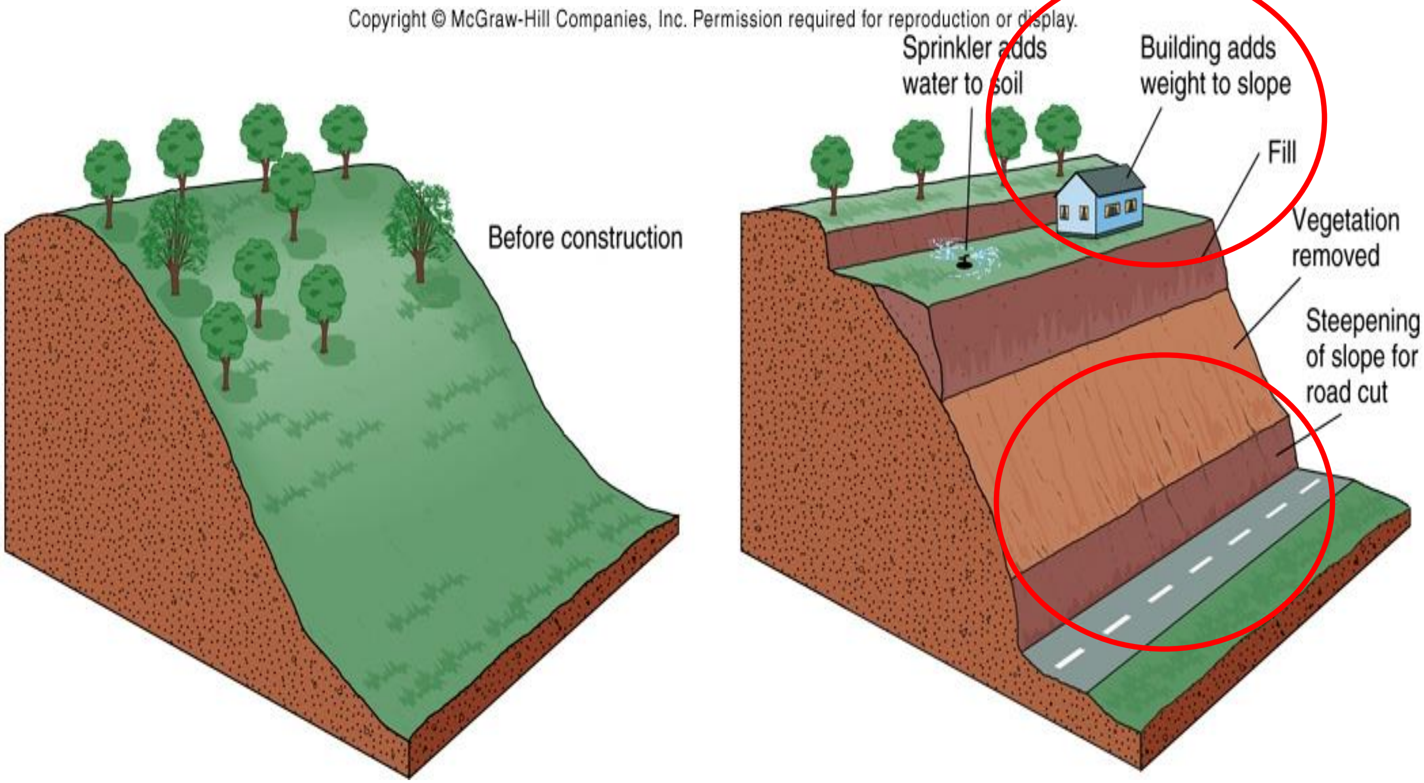
c) Overloading

Adding weight

Caused by buildings, roads, landslides, trees, me, etc.

b) and c)

Overloading and Undercutting together



1) External Causes

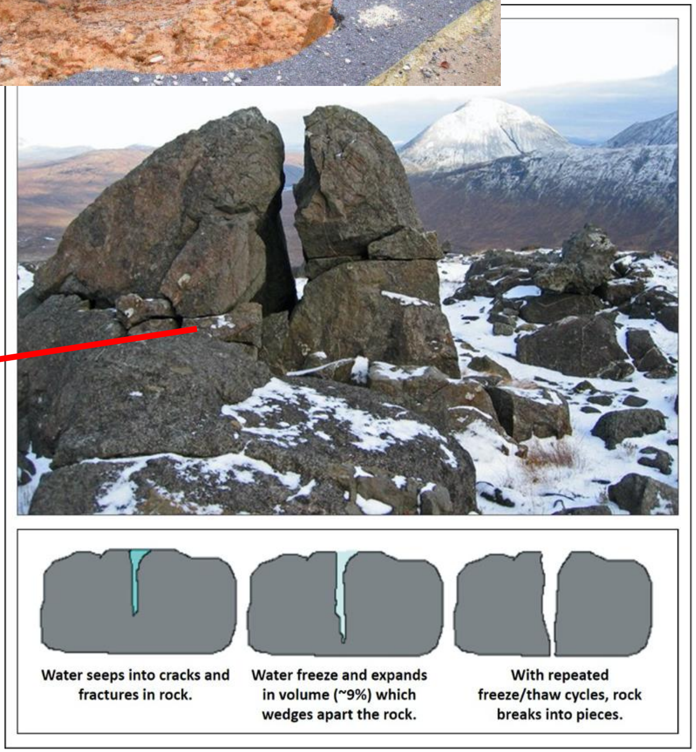
d) Vegetation

- Roots bind loose material
- Trees remove water for transpiration
- Mostly adds to slope stability

1) External Causes

e) Climate

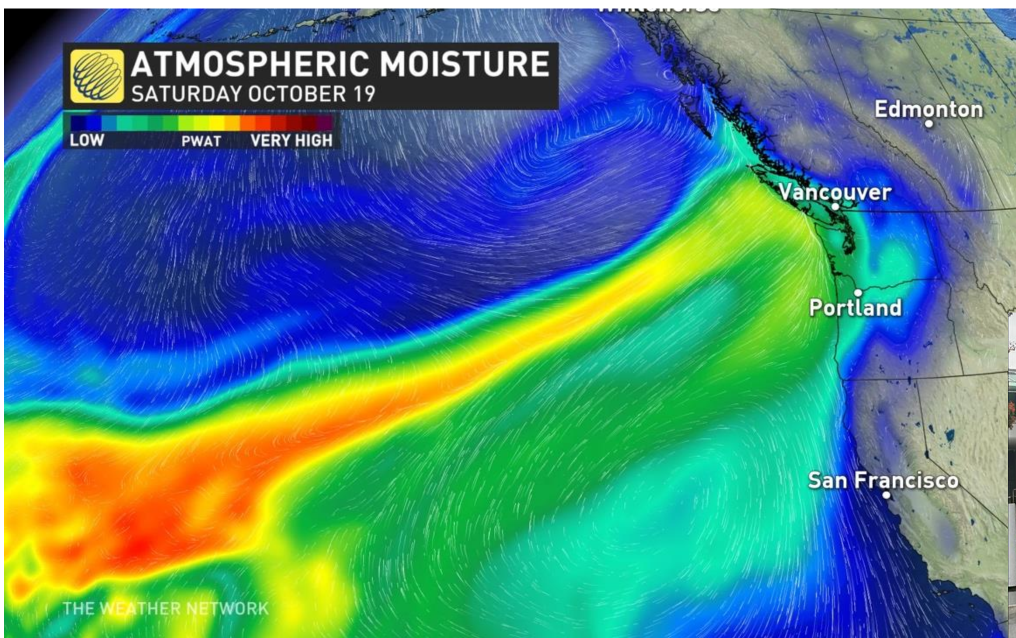
- **<u>If</u>** average temperature and rainfall is high
    - More water
    - Increased weathering of rocks
        - More fractures
        - More soil
        - Etc.
- If average temperature is around 0° … Freeze/thaw see internal causes

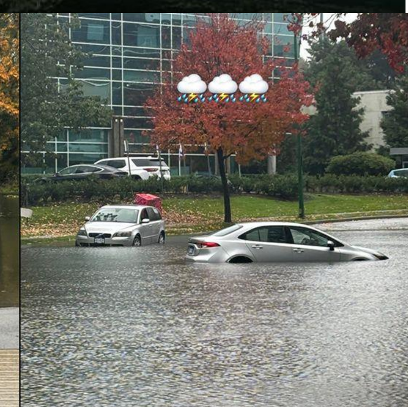


1) External Causes

e) Climate

How about atmospheric rivers?





External Causes Summary

a) Slope
b) Undercutting
c) Overloading
d) Vegetation
e) Climate