

An aerial photograph showing a significant landslide in a residential neighborhood. A large, light-colored mass of earth and debris has slid down a hillside, partially burying several houses. One house in the center is tilted at a sharp angle. Other houses are visible on the left and right, some with debris scattered around them. The scene is dark and somber, with the landslide area appearing as a stark, light-colored scar on the hillside.

Landslides 3

I should have bought landslide insurance...

Today's Goals

- 1) **List** and **describe** 4 internal causes of landslides
- 2) **List** several landslide triggers
- 3) **Compare** and **contrast** key triggers and causes of landslides and how they affect the force balance equation (i.e. Factor of Safety)
- 4) **Explain** how liquefaction landslides develop in sensitive marine clays (Quick Clay Slides)
- 5) **List** and **describe** the site conditions (Causes and Trigger) that lead to the development of the Oso Landslide in Washington State

2) Internal Causes

a) Water Content

In all slopes water, especially sediment:

Adds weight (overloading)

Decreases normal force/normal stress,
which **decreases friction and thus τ_f**

Increases weathering

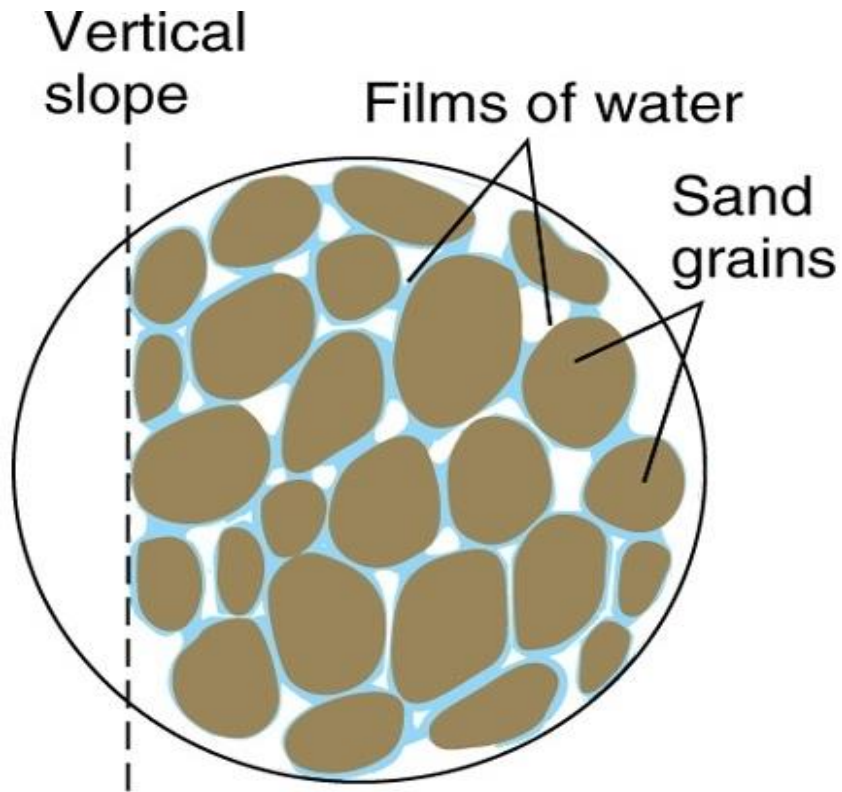
Acts as a medium for flows

2) Internal Causes

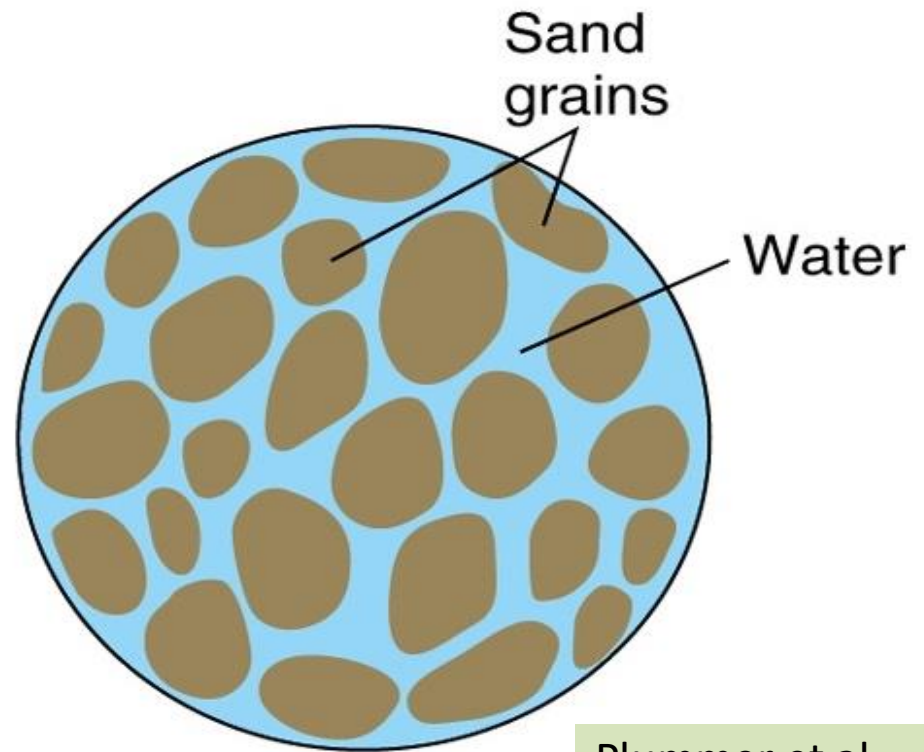
Unsaturated soil or debris vs. saturated soil or debris

Surface tension is an important force

Grains are forced apart and the material flows



A



B

Plummer et al.,
(2012) Figure 9.3



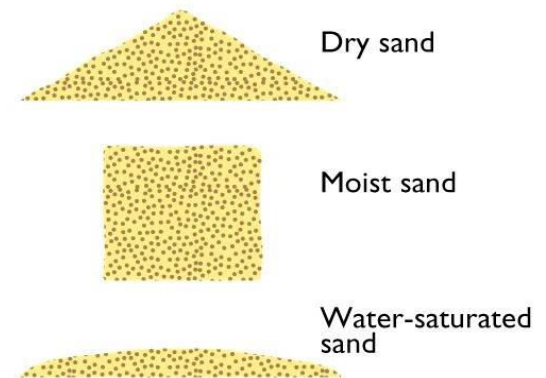
For unconsolidated materials instability is the result of too little or too much water occupying pore space

Effect on angle of repose

No water - low angle of repose

Some water - high angle

Too much water - very low angle



Mass Wasting

a) Water Content

In solid rock:

Water reduces shear strength along planes of weakness (fractures)



Water infiltrates fractures,
decreases friction,
making material more likely to
slide

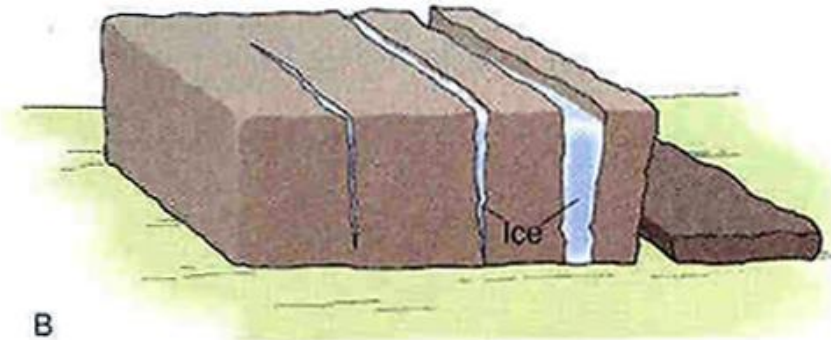
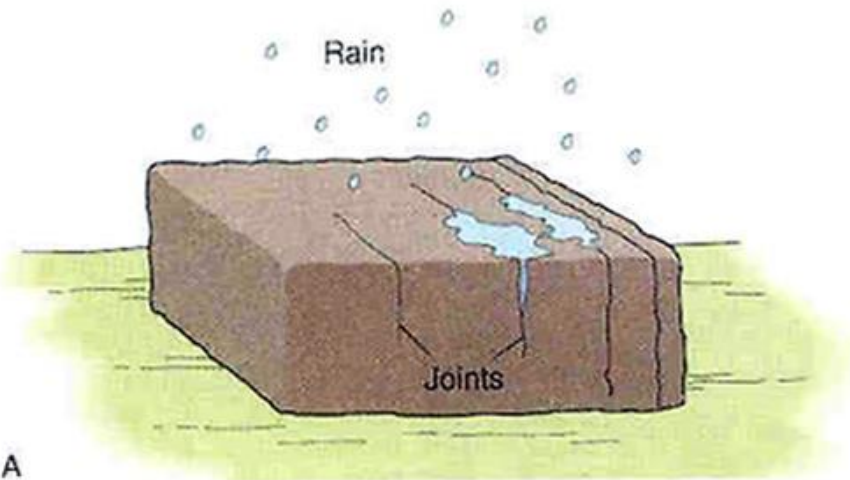
2) Internal Causes

b) Frost wedging/Freeze thaw

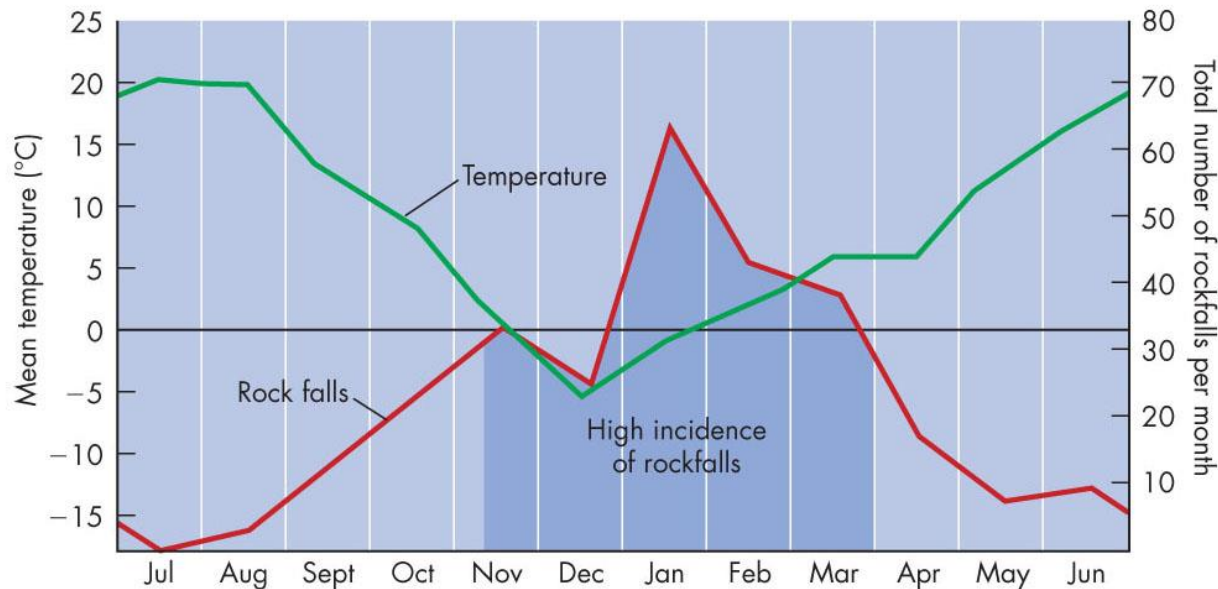
In colder climates

Water gets into cracks and fractures (joints)

If it freezes it expands - forcing the fractures apart



In alpine settings
temperature and
rock falls are
inversely correlated



2) Internal Causes

c) Inherently Weak Materials

Some materials are very weak

Fail at relatively and/or very low angles of repose

Two examples of many:

volcanic rock

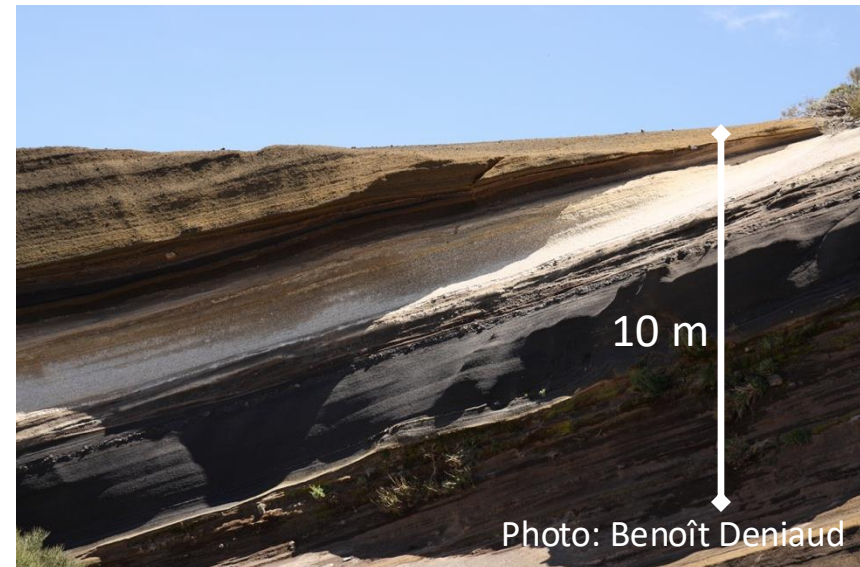
“quick clay”

2) Internal Causes

c) Inherently Weak Materials

Volcanic layers?




Why would these layers be weak?



2) Internal Causes

c) Inherently Weak Materials

–Clay is especially odd

256 mm and up	BOULDERS	GRAVEL
64-256 mm	COBBLES	
2-64 mm	PEBBLES	
0.0625-2 mm	SAND	
0.002-0.0625 mm	SILT	
0.002 mm and smaller	CLAY	

The term 'clay' can refer to either a mineral type or a particle size



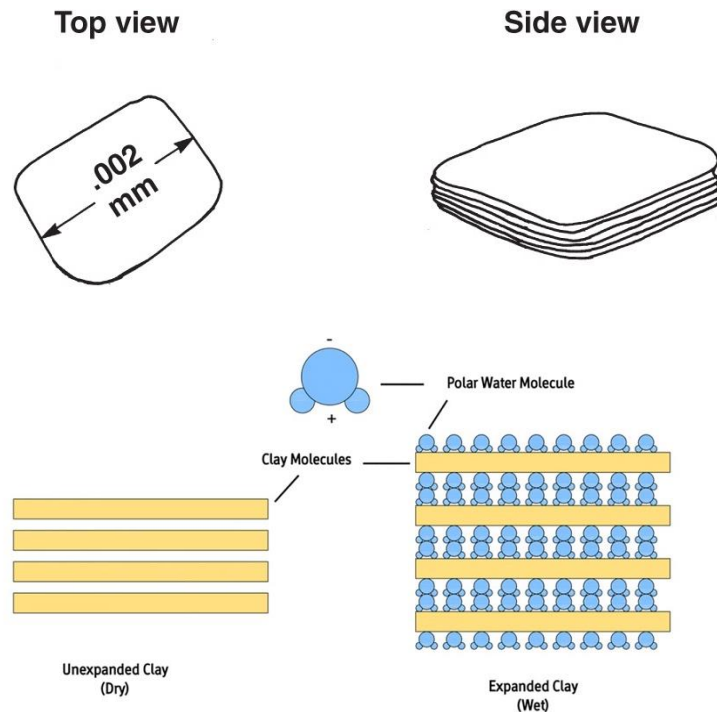
Mineral: kaolinite

2) Internal Causes

c) Inherently Weak Materials

So small that Van Der Waals force has an effect
(Electrostatic effects)

When in salt water clay is attracted to other clay particles



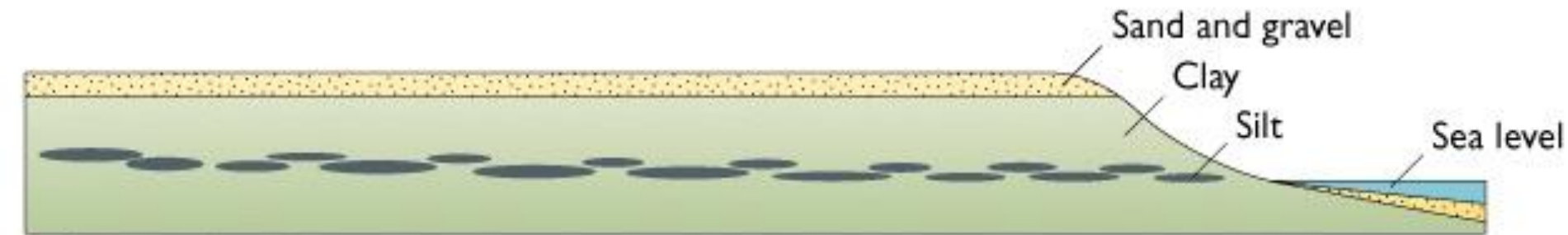
Clay minerals are often layered silicates in which layers are bound together

Clay can swell in the presence of water as water is trapped between layers

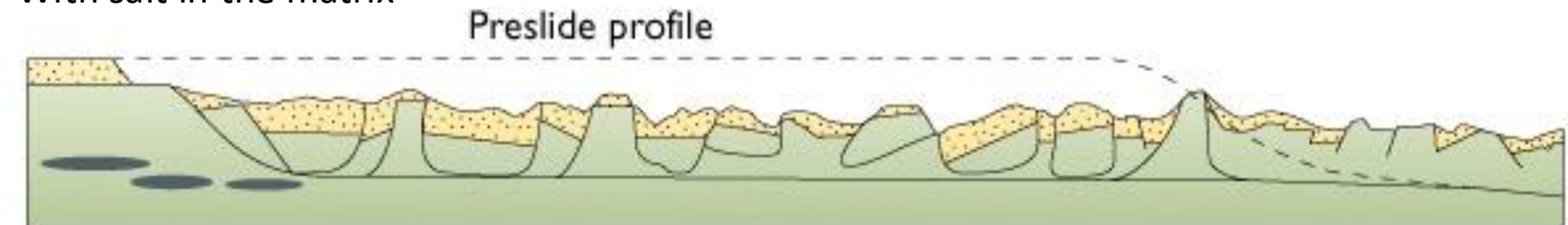
Quick Clay Slide

Quick clay is a type of clay that was originally deposited below sea level and has salt in the matrix

Over time the salt is washed out which makes the clay very unstable



With salt in the matrix



Without salt in the matrix and after a trigger



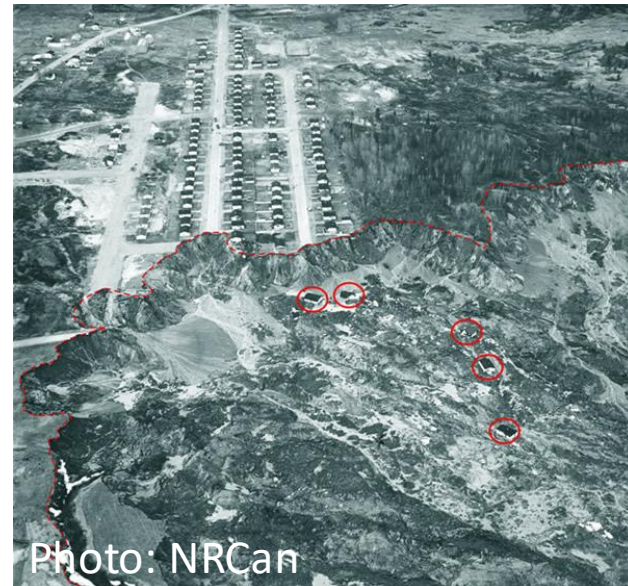
Photo: NRCan

2) Internal Causes

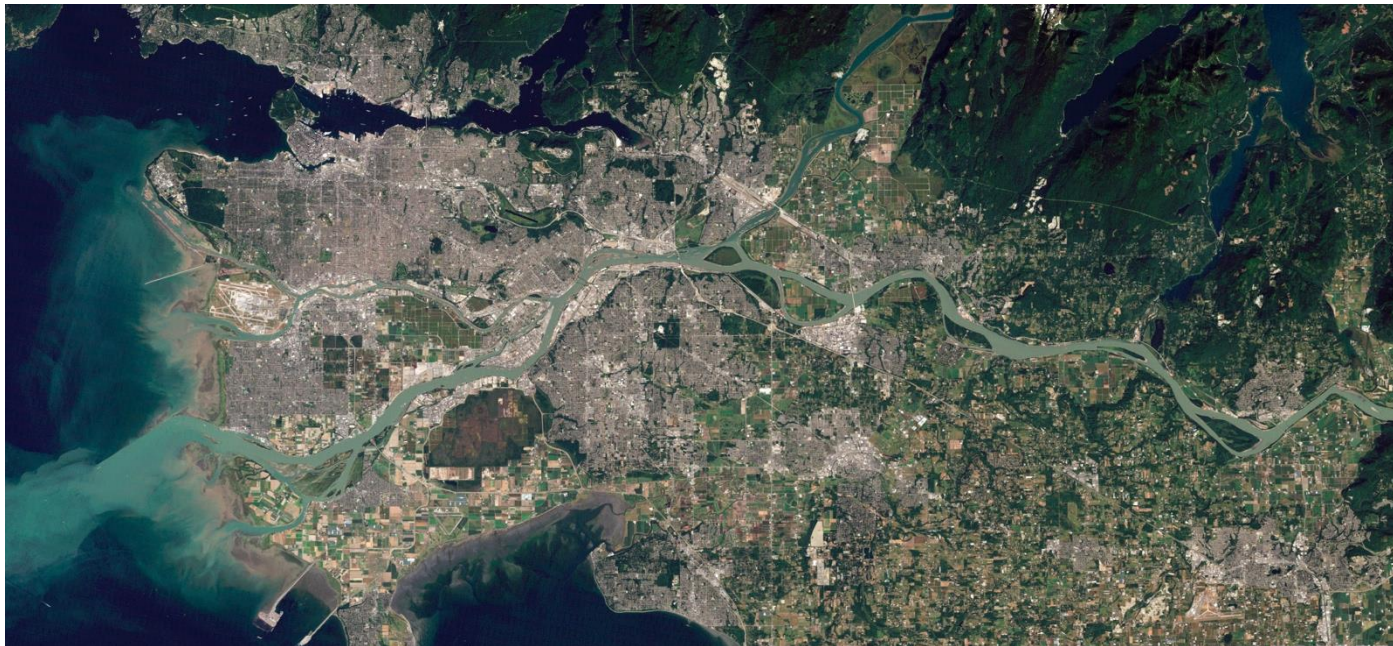
c) Inherently Weak Materials

Quick clay slides not common, but very cool (and scary)

Quick clays are moderate to fast landslides



Quick Clay Slides in Metro Van?



2) Internal Causes

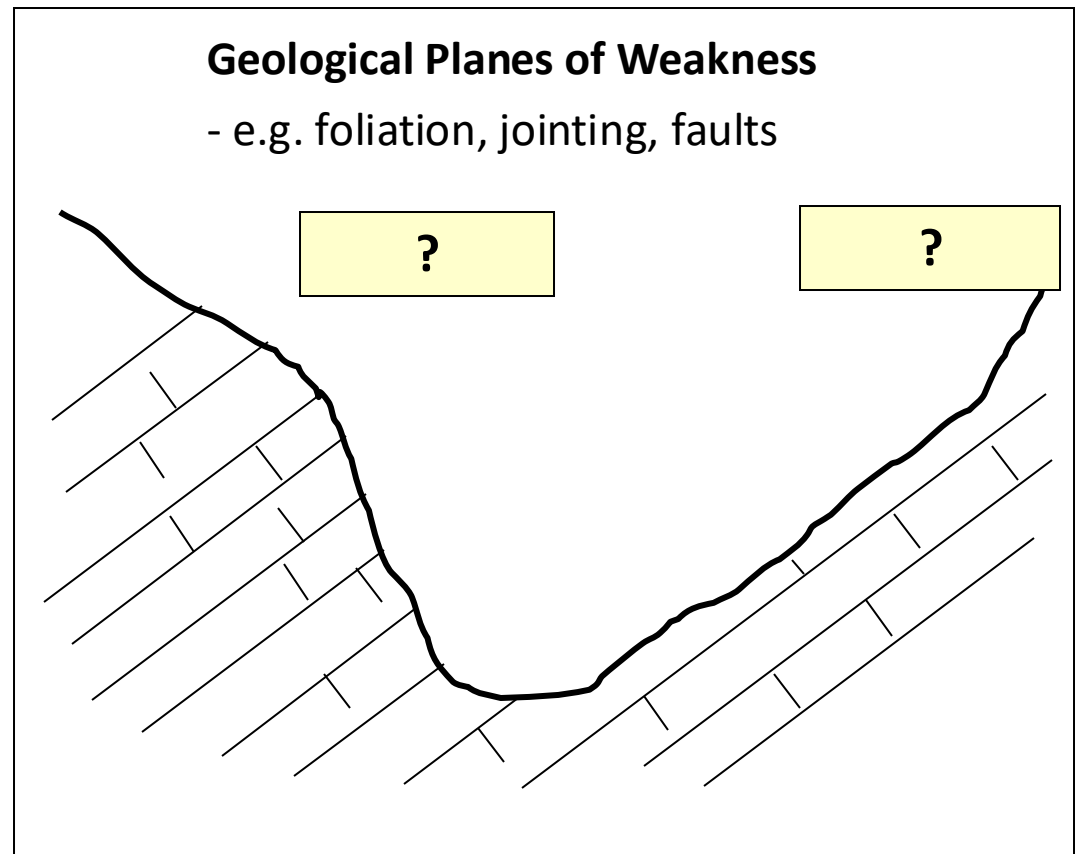
- d) Adverse (bad)
Geologic Structures
Unfortunate bedding
or fracture
orientation
Weaknesses or
structures within
slope at an unstable
angle/orientation



iClicker

Question

What types of
Landslide motion
will occur on
the sides?



A) Slide, Slide

B) Fall, Slide

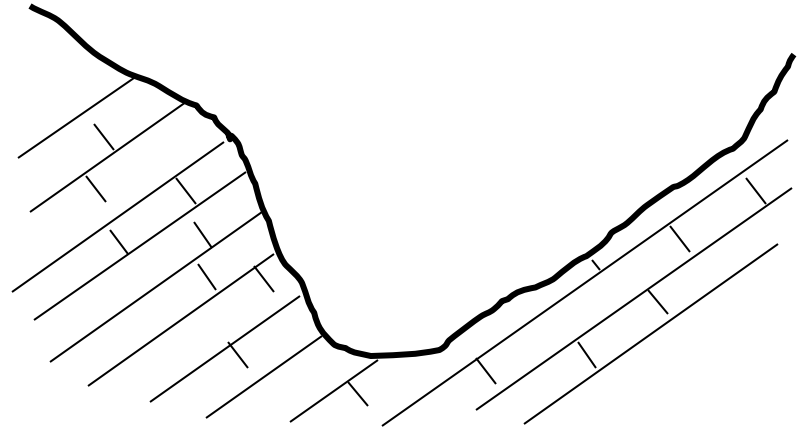
C) Slide, Fall

D) Fall, Fall

E) Not enough info

Geological Planes of Weakness

- e.g. foliation, jointing, faults



Natural Resources
Canada

Ressources naturelles
Canada

Triggers

Trigger - A force or event that disrupts the equilibrium of a slope and initiates mass movement

A few triggers

- Earthquakes
- Snow melt
- Heavy Rainfall
- Rain on Snow
- Loud Noises
- Vehicles
- Volcanic Eruptions
- Excavation
- Skiing
- Jumping up and down

Case Study: Oso Landslide

Washington State 2014



Oso Event

March 22, 2014 10:37 AM

45 days of heavy rain

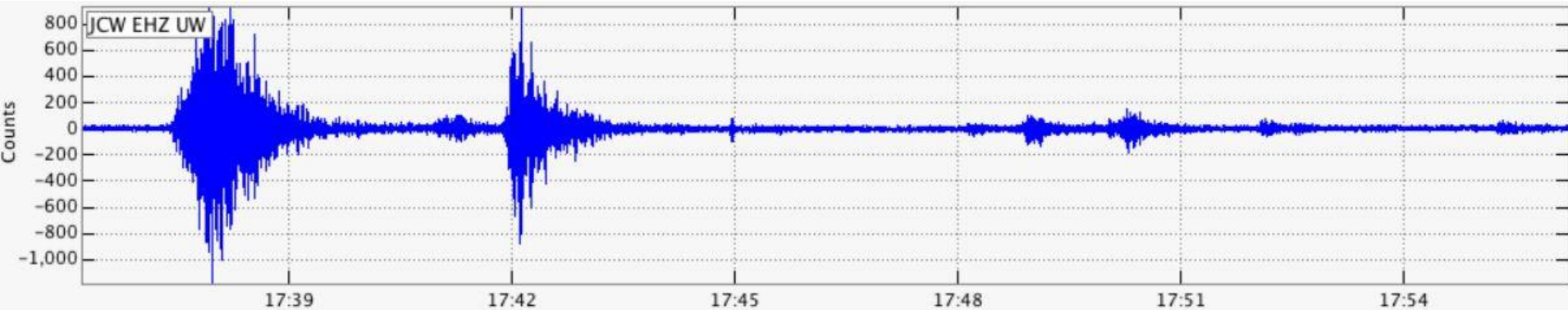
Collapse of layers of glacial sediment

“Fast moving wall of mud”

Hit river, caused Tsunami

43 fatalities (original reports of 200
missing)

Seismic Trace



Event sent seismic waves detectable over 200 km away

The seismic data shows multiple collapses, but 2 major ones approx. 3 minutes apart

Director of Emergency Management

"This was a completely unforeseen slide. This came out of nowhere."

Public Works Director

"A slide of this magnitude is very difficult to predict. There was no indication, no indication at all."

Slide History

1937: aerial photographs show active landslides

1949: A large landslide (1000 feet long and 2600 feet wide) affected the river bank

1951: Another large failure of the slope; the river was partially blocked

1967: Slump and accompanying mud flows push the river channel south. Area referred to as “Slide Hill”

1988: Erosion of the toe leads to another slide. River pushed South again

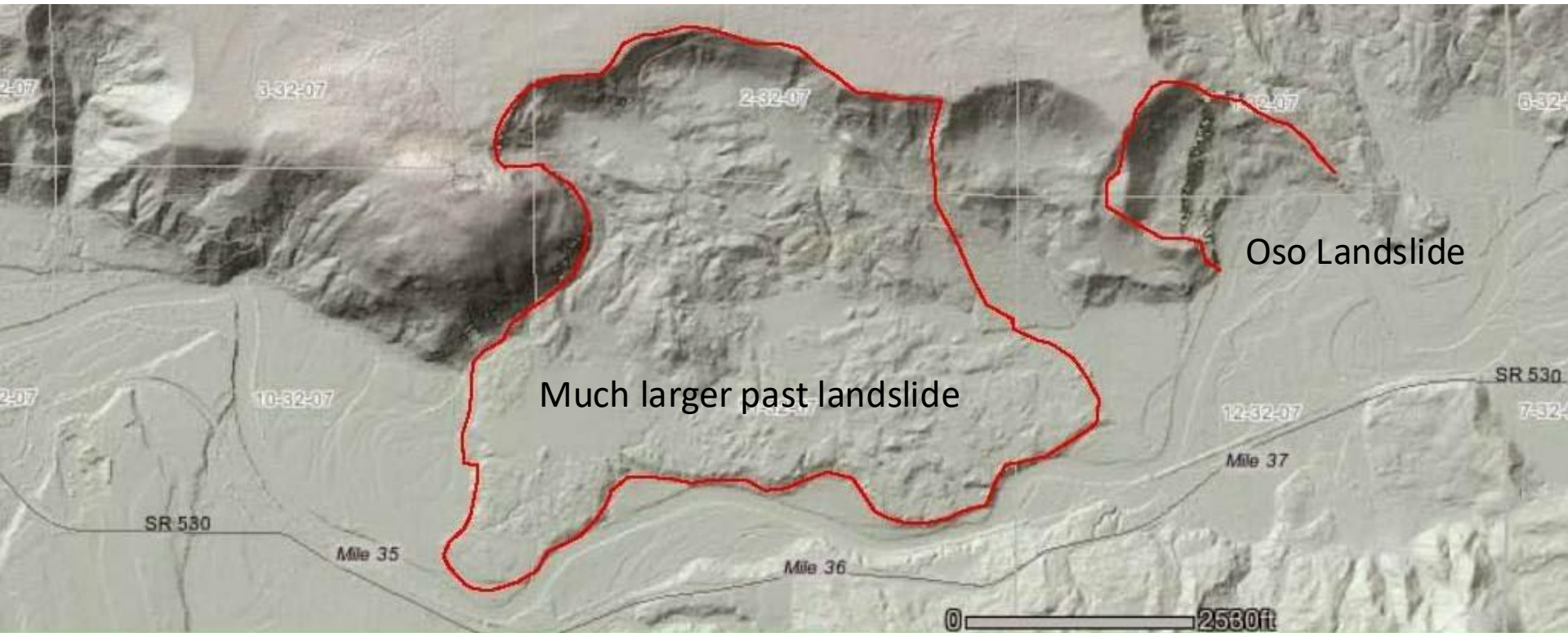
1999: US Army Corps of Engineers report Miller that warns of “the potential for a large catastrophic failure”

2004: County rejects owner buyout plan. Puts up wall.

2006: Large movement blocks river

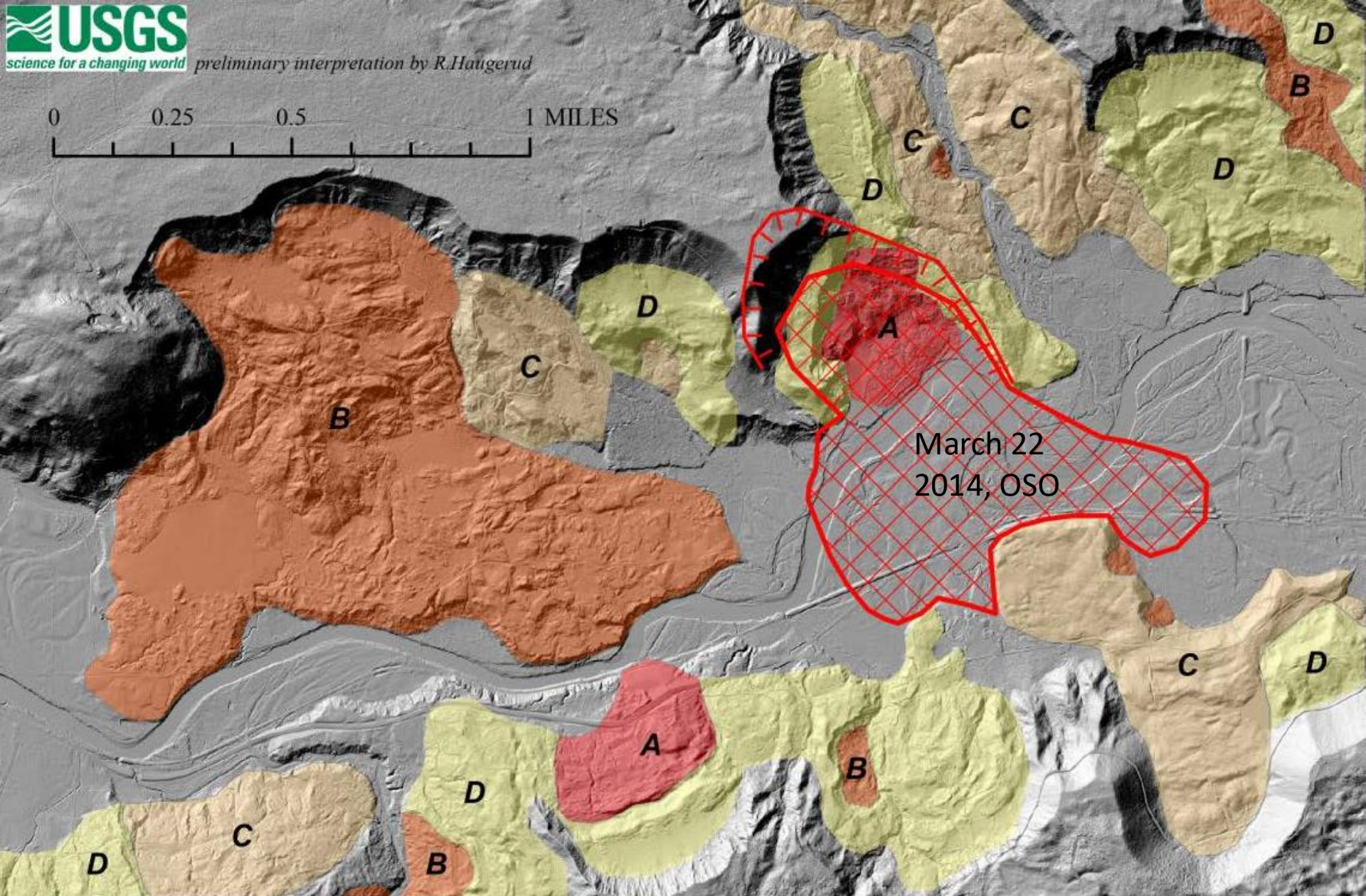
2010: Study commissioned by the county, warns hillside above Steelhead Drive is one of the most dangerous in the county

Could it be foreseen?



LiDAR imagery is a technique used in geology to scan the surface topography of the Earth
The technique 'sees through' trees

[Dan McShane](#)



Yellow = past, oldest landslides

Orange = past landslides

Red = past, recent landslides

Groups of 4 ish

List what you think might be the causes of this landslide

Then, speculate on possible triggers

What type of slide is this?

Finally, how would you protect people?

Mass Movements

Next class: Mitigation!

Fine.

So landslides are important.

What can we do about them?