# ANNOUNCEMENTS

- The exam is next Tuesday (details to follow on Avenue about the where)
- Takes place during class time
- Covers everything up until Permafrost
- Chapters 1-5, 7 and 8 in the textbook
- Remember the exam is about lecture material

https://www.youtube.com/watch?v=HLHvV-GflkA

# For video (this is ‘homework’)

- Think of the following things:
  - Why did the event occur?
  - What are the processes that trigger this event?
  - What precautions were taken afterwards to help mitigate?

  - https://www.youtube.com/watch?v=3q-qfNlEP4A


Landslides

# Learning Objectives

- Understand slope processes and the different types of landslides
- Know the forces that act on slopes and how they affect slope stability
- Know which geographic regions in North America are at risk from landslides
- Know the effects of landslides and their links with other hazardous natural processes

# Learning Objectives

- Understand how people can affect the landslide hazard

- Be familiar with adjustments people can make to avoid death and damage caused by landslides

# Introduction

- **Landslide** and **mass wasting**
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- Types of landslides are determined by:
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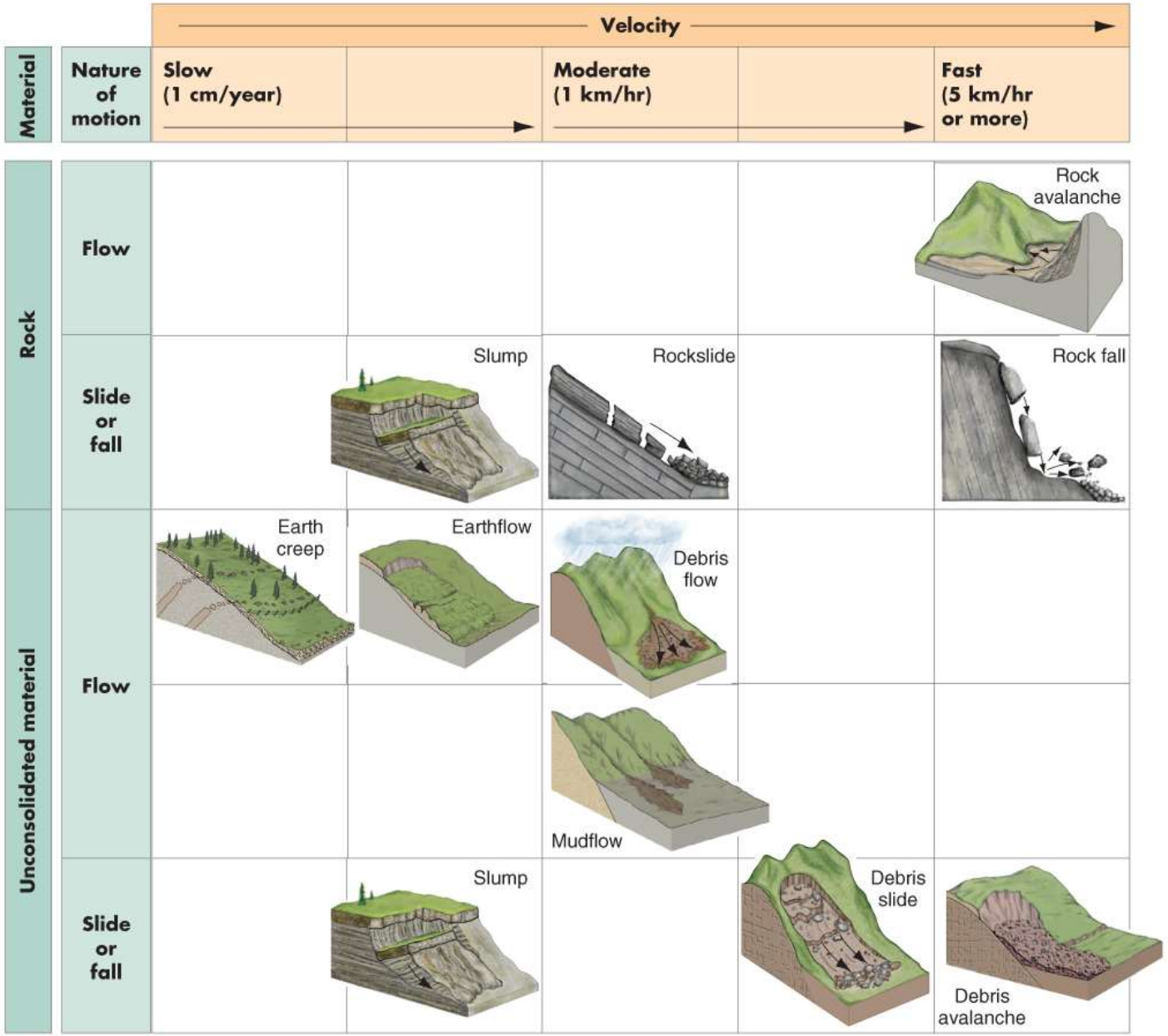



▲ **FIGURE 6.2 TYPES OF LANDSLIDES** Landslides are classified according to (1) type of movement (fall, slide, topple, flow), (2) type of material that fails (i.e., rock or unconsolidated sediment), (3) amount of water or air involved in the movement, and (4) velocity.

# 1971 - Saguenay River, Quebec

- 27 hectare landslide
- 26 homes lost
- 31 killed

# 1903 – Frank Slide, Alberta

- buried town of Frank
- killed 70 people
- lasted ≈ 90 seconds

# St. Jude, Quebec (May 10, 2010)

- Landslide claimed lives of a family of 4

http://gsc.nrcan.gc.ca/landslides/stjude_e.php

# 1969 - Aberfan, Wales

– coal spoil heap failed
– killed 144, predominantly school children

Landslides kill thousands each year – often related to heavy rains

**“ZHOUQU: State medium say the death toll in Sunday's landslides in northwestern China has risen to 1,117.”**

**“Landslides add to Pakistan deaths”**

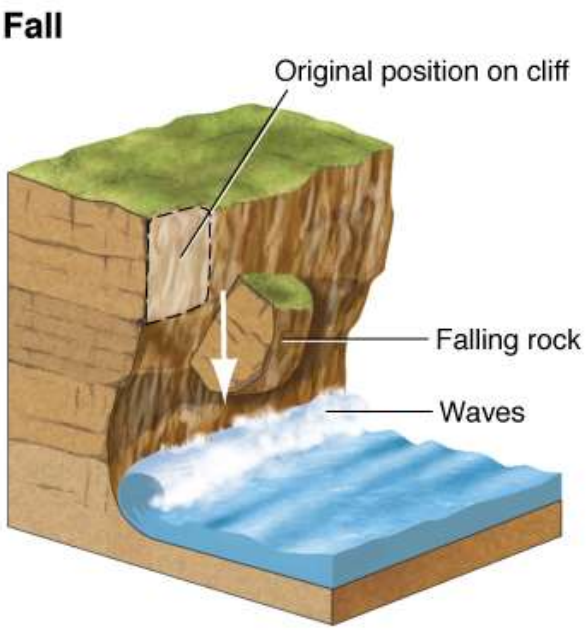
**“20 dead in landslide in Costa Rica”**

# Types of Landslides

- Bounding of rock or blocks of sediment fron the face of a cliff

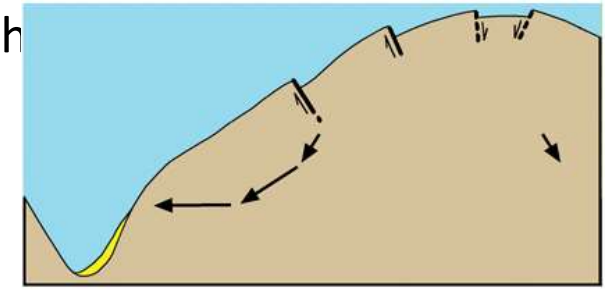
- Downslope movement of a coherent block rock or sediment along a discrete failure plane

- Failure plane is curved upward



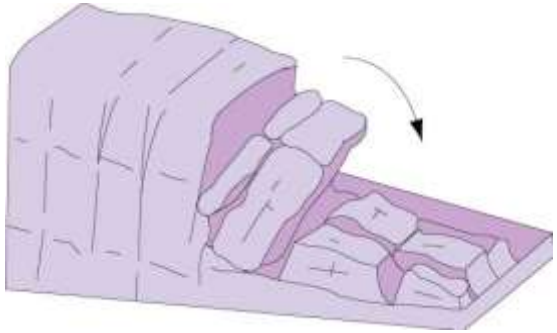
# Types of Landslides

- Downslope movement of sediment in which particles move semi-independently of one anoth often with the aid of water



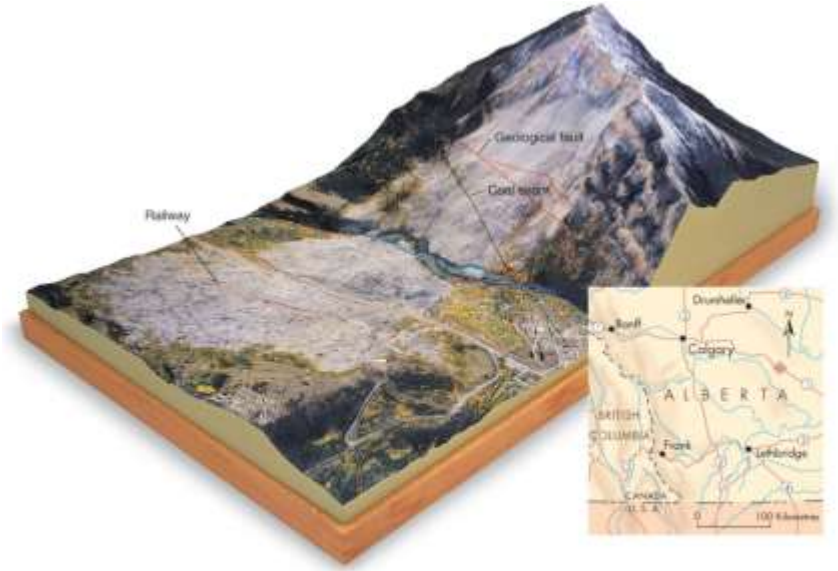
- Typically move rapidly; mixtures of mud, debris and water

- Very slow flow of rock or sediment
- **Sackung** - slow movement of large masses of rock
- **Topple** – a rock mass pivots about a point



▲ **FIGURE 6.3** **ROCK FALL** Rock fall on the Trans-Canada Highway near Yale, British Columbia. A rock fall is a fast-moving mass of fragmented rock that bounds down a steep slope. *(Duncan Wyllie)*






▲ **FIGURE 6.1** **FRANK SLIDE** The 1903 Frank slide is Canada's best-known landslide and a classic example of a rock avalanche. It travelled more than 3 km in 100 seconds (average velocity of about 30 m/s) and buried part of the town of Frank, Alberta, killing at least 76 people. Coal mining at the base of the mountain likely triggered the landslide. *(By Steven Fick and Mary Vincent, March/April 2003. Reprinted with permission. Photo by David Bachour/GeoSolutions Consulting Inc.)*



◀ **FIGURE 6.5** **SLUMP** Slumps are landslides with curved failure surfaces. In this example near Quesnel, British Columbia, a large coherent block of silt rotated backward as it slid downward and outward. *(John J. Clague)*

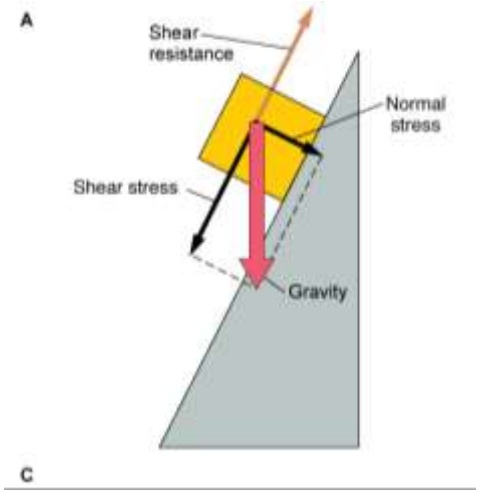
◄ **FIGURE 6.6 EARTHFLOW** This landslide near the community of Pavilion, British Columbia, is a slow-moving earthflow involving weathered sedimentary rocks. The hummocky surface and natural levees at the margins of the landslide are indicative of highly viscous, flow-like motion. *(John J. Clague)*



◄ **FIGURE 6.7 ROCK AVALANCHE** A photo-draped digital elevation model (DEM) of a rock avalanche on the flank of Mount Munday in the Coast Mountains of British Columbia. The landslide began as a rockslide but rapidly evolved into a high-velocity flow that streamed across the glacier in the foreground. The distance from the top to the bottom of the photo is 4 km. *(Evans, S. G. 2006. "Single-event landslides resulting from massive rock slope failure, characterizing their frequency and impact on society." In S. G. Evans, G. Scarascia-Mugnozza, A. L. Strom, and R. L. Hermanns (eds.), Landslides from Massive Rock Slope Failure, pp. 53–73. NATO Science Series IV, Vol. 49, Springer, Dordrecht)*

# Forces on Slopes

- **Driving forces** move rock or sediment down a slope
  - The weight of slope material is the largest driving force
    - Can include fill material and buildings




- **Resisting forces** oppose downslope movement.
  - Shear strength of the material
    - Resistance of material to sliding or flowing along slip planes

- _____is the ratio of the resisting forces to the driving forces.
  - Stable when greater than 1; unstable when less than 1

# Forces on Slopes

- Driving and resisting forces are not static
  - As local conditions change, these forces may change
    - Factor of safety may increase or decrease

- Forces on slopes are determined by:
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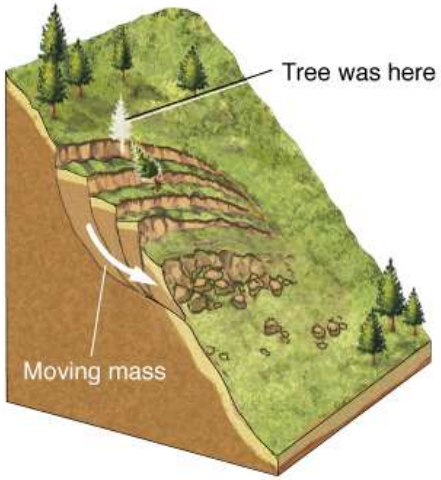
# The Role of Material Type

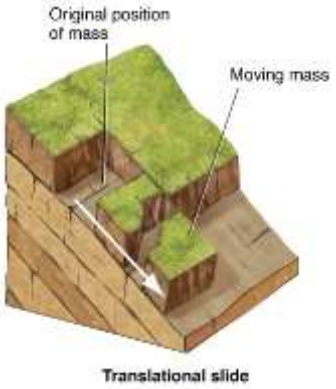
- Planes of weakness
  - Occur in bedding planes, foliation planes in metamorphic rocks, joints, or zones along which Earth has moved before
- Degree of consolidation
  - Slumps  are common in unconsolidated materials
- Shape of slip surface
  - **Rotational** slides or slumps are curved
  - **Translational** slides are planar



Rotational slide (slump)

# The Role of Slope and Topography

- **Slope** steepness
  - Steeper the slope, the greater the driving force
  - Steep slopes are associated with falls
  - Moderate slopes are associated with flows
  - Gentle slopes are associated with creep

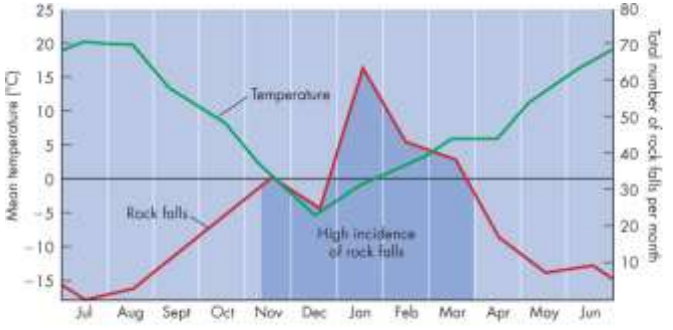



- Topographic **relief**
  - Refers to the height of a hill or mountain above the land below
    - Landslides occur more frequently in areas of high relief

# The Role of Climate

- **Climate** is the characteristic weather typical of a place or region over years or decades

- Influences the amount and timing of water that infiltrates or erodes a slope
  - Arid regions are prone to rock falls, debris flows, and soil slips; free-face and **talus** slopes are common
  - Humid and sub-humid regions are prone to complex landslides, creep, slides, slumps, and debris flows



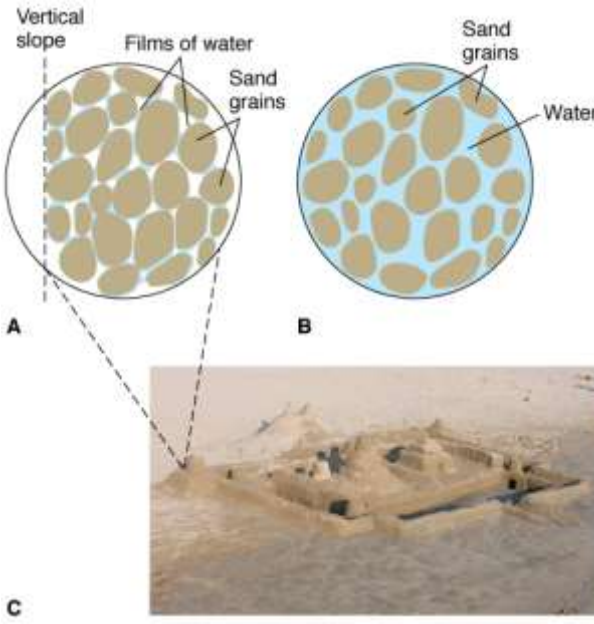

◄ **FIGURE 6.17 EFFECTS OF WEATHER ON ROCK-FALL ACTIVITY** A plot of rock-fall frequency and weather in the Fraser Canyon, southwest British Columbia, 1933–1970. Rock fall is most frequent at times when temperatures fluctuate above and below freezing. *(Based on Peckover, F. L., and J. W. G. Kerr. 1977. "Treatment and maintenance of rock slopes on transportation routes." Canadian Geotechnical Journal 14:487–507)*

# The Role of Vegetation

- Vegetation provides a protective cover that reduces the impact of falling rain
- Plant roots add strength and cohesion to slope materials
- Vegetation adds weight to slopes
  - Increases the likelihood that the slope will fail

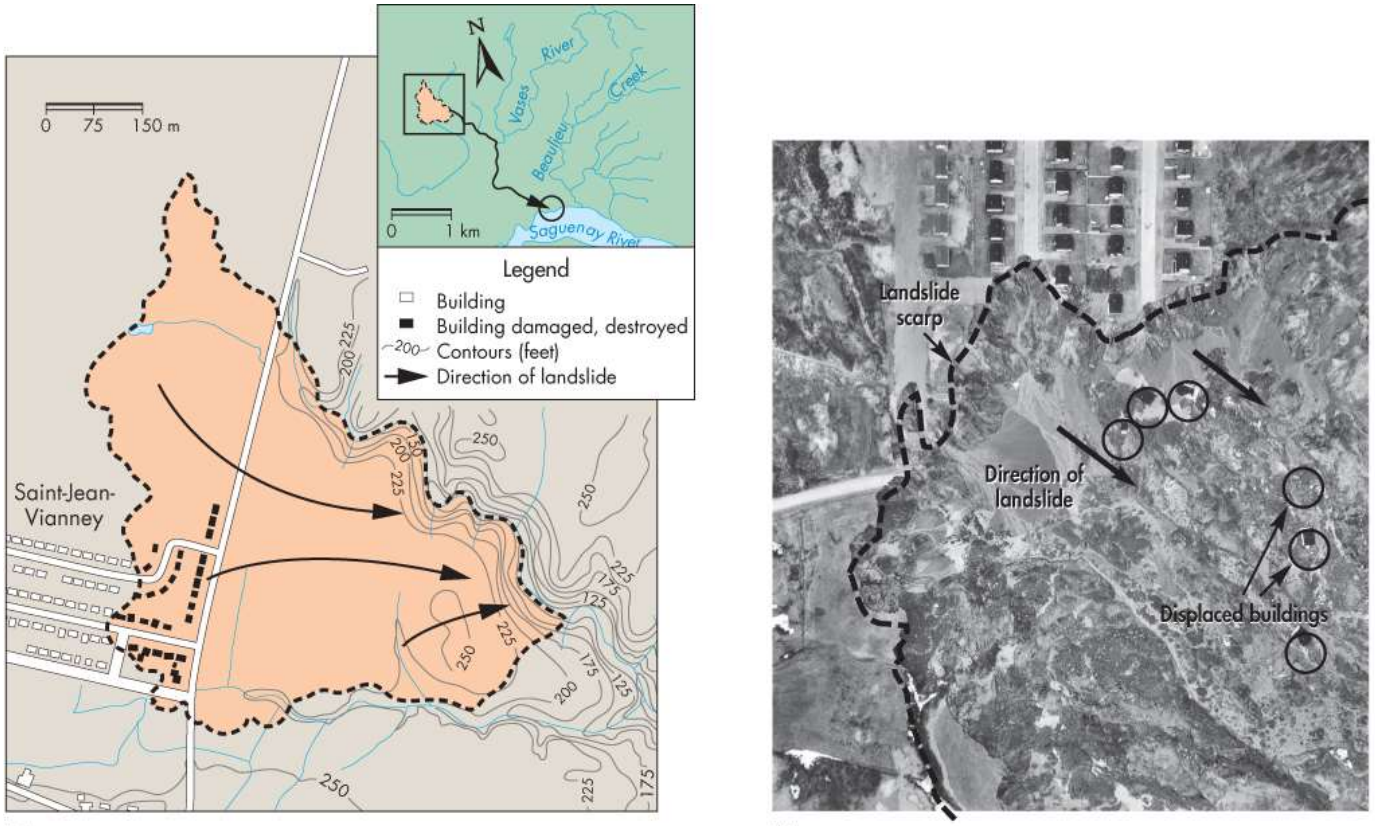
# The Role of Water

- Water saturates soil, causing soil slips and debris flows
- Slumps develop months or even years following deep infiltration of water into a slope
- Water erodes bases of slopes which decreases stability
- Water can cause spontaneous _____ or quick clay failure
  - Fine-grained material that loses strength when disturbed and flows like a liquid



# The Role of Time

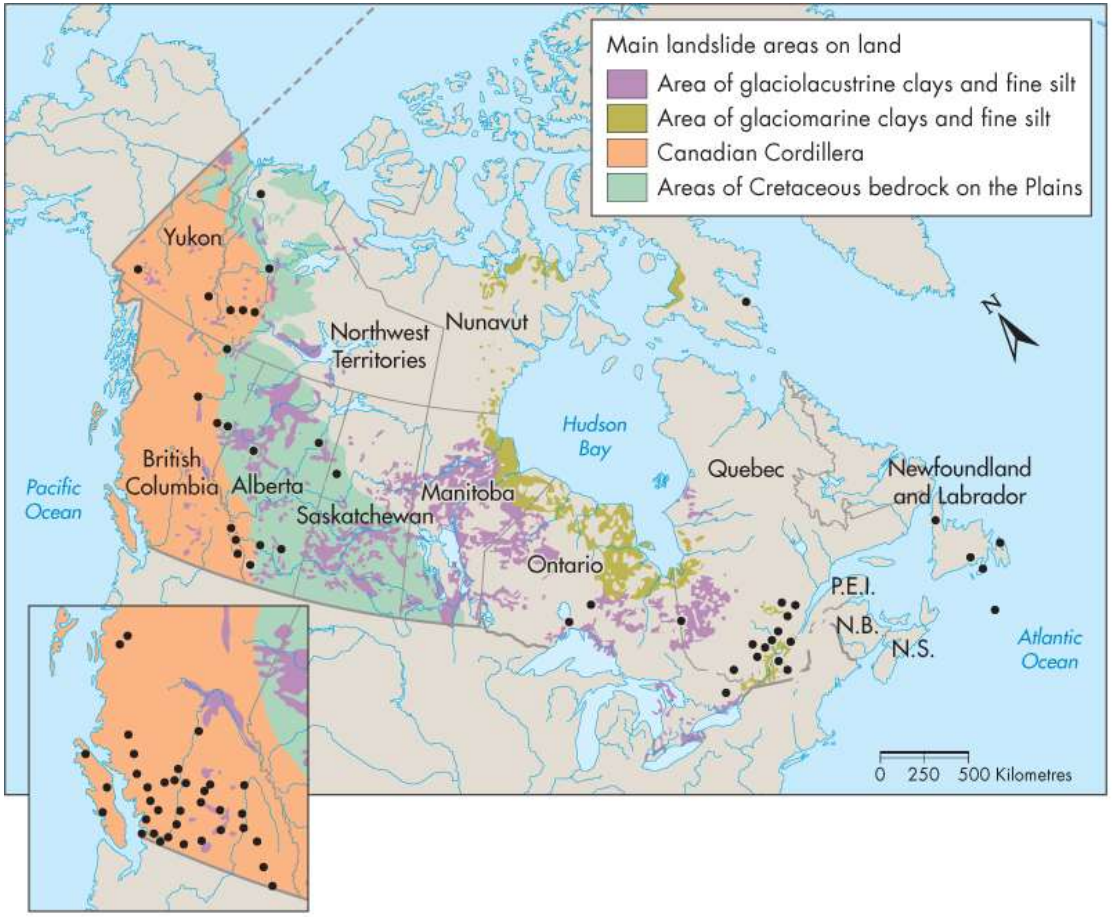
- Forces acting on slopes change with time
- Driving and resisting forces change seasonally as the water table fluctuates
- Chemical weathering of rocks occurs slowly over time




▲ **FIGURE 6.15 QUICK CLAY FAILURE** (a) A map and (b) oblique aerial view of the Saint-Jean-Vianney landslide, which happened in southern Quebec on May 4, 1971. Approximately 40 houses were engulfed by the landslide and 31 lives were lost. Some displaced houses can be seen in the debris below the scarp. *((a) Reproduced or adapted with the permission of Natural Resources Canada 2013, courtesy of the Geological Survey of Canada (Bulletin 548); (b) © Gouvernement du Québec)*

# Geographic Regions at Risk from Landslides

- Landslides occur wherever there are significant slopes
- In Canada, landslides are most common in:
  - Western Cordillera region of B.C., Alberta, and Yukon
  - Appalachian Mountains of Quebec and New Brunswick
- Factors expected to increase landslide incidence:
  - Urbanization and development of landslide-prone areas
  - Tree cutting in landslide-prone areas
  - Changing global climate patterns resulting in increased precipitation




◄ **FIGURE 6.19 LANDSLIDES IN CANADA** This map shows locations of large historic landslides and the distribution of landslide-prone materials in Canada. Landslides are most common in mountainous areas, the St. Lawrence Lowland, and river valleys on the western Interior Plains. Materials particularly prone to landsliding include lacustrine and marine silts and clays and Cretaceous shales. *(Reproduced or adapted with the permission of Natural Resources Canada 2013, courtesy of the Geological Survey of Canada (Bulletin 548))*

# Effects of Landslides

- 30 people are killed each year on average in North America; damage exceeds $1 billion USD per year

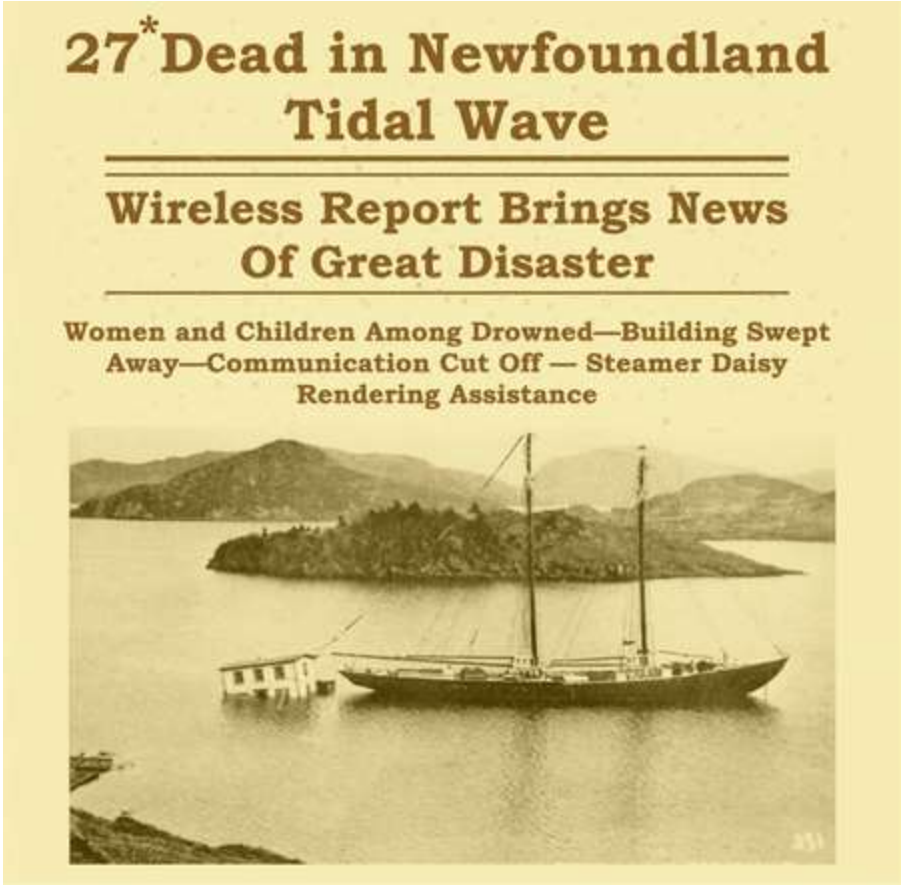
- Slides may damage homes, roads, and utilities constructed at the top, base, or side of a hill

- Slides may block roads and railways impeding travel, or may block streams causing flooding

# Linkages with Other Natural Hazards

- Earthquakes, volcanoes, storms, and fires may cause landslides

- Landslides may cause flooding or tsunamis
  - Ex: Grand Banks, 1929



27* Dead in Newfoundland Tidal Wave

Wireless Report Brings News Of Great Disaster

Women and Children Among Drowned—Building Swept Away—Communication Cut Off — Steamer Daisy Rendering Assistance

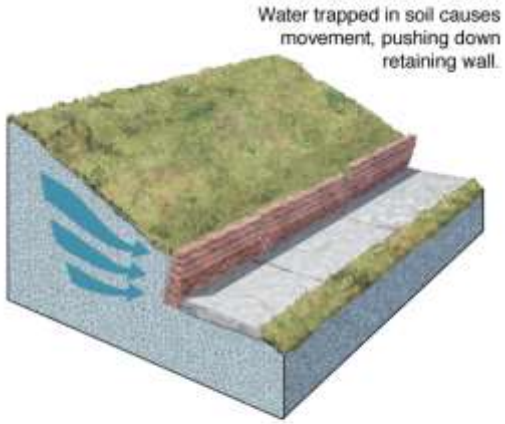
# Natural Service Functions of Landslides

- Produce deposits that become mineral resources
  - Weathering frees mineral grains from rocks, and landslides transport these materials downslope
  - Gold and diamonds have been mined from landslide deposits

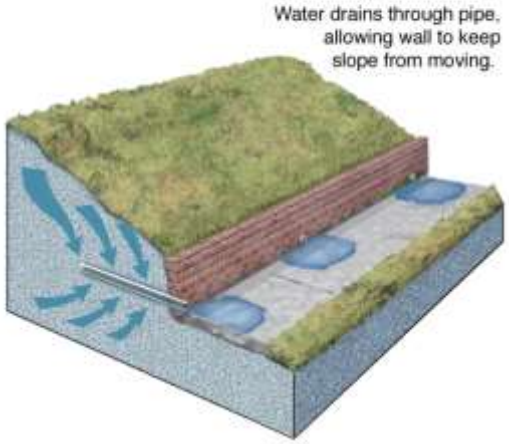
- Creation of new habitats in forests and aquatic ecosystems
  - Increases plant and animal diversity

# Human Interaction with Landslides

- Expansion of urban areas and transportation networks, and exploitation of natural resources have increased landslide incidence.

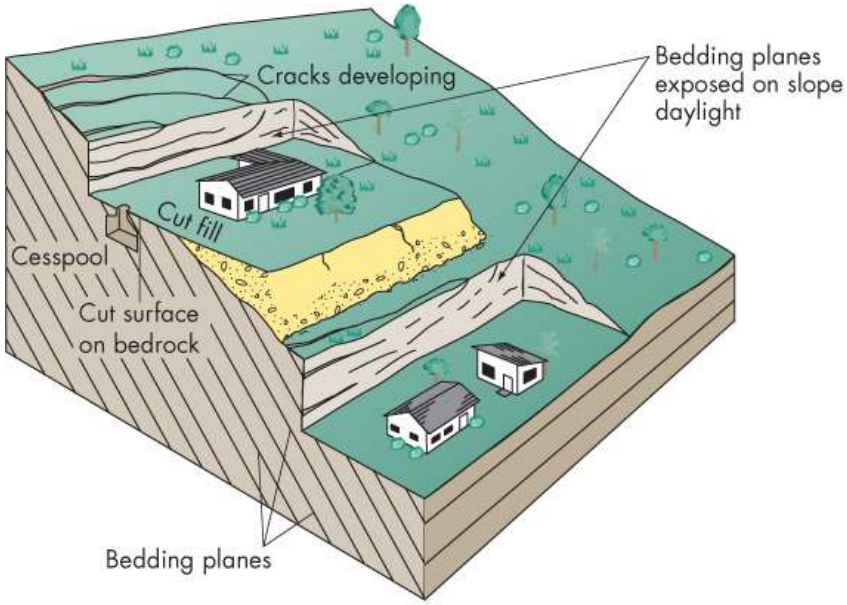



- Grading of land surfaces for housing developments can initiate landslides on previously stable slopes.



# Human Interaction with Landslides

- Timber Harvesting
  - Clear-cutting and logging road construction
    - Increases landslide-related erosion on unstable slopes
    - Interrupts surface drainage, alters subsurface movement of water, and can change the distribution of materials on a slope
- Urbanization (ask!)
  - Removal of anchoring vegetation
  - Construction of roads and buildings
  - Installing septic systems, watering lawns and gardens
  - Cutting the base of slopes
  - Placing fill materials on slopes






◀ **FIGURE 6.25 URBANIZATION AND LANDSLIDE POTENTIAL** This diagram shows how building on slopes can increase the chance of landslides. The diagonal lines at the left side of the block diagram are bedding planes in sedimentary rock. Excavation into the hillside behind the houses has removed support. Fill (yellow) used to extend the flat pad for building adds weight to the slope. Cracks shown in the upper part of the diagram are an early sign that a landslide is likely to occur. Wastewater from septic fields adds water to the hillslope. *(Reprinted, with permission, from Leighton, F. B. 1966. "Landslides and urban development." In* Engineering Geology in Southern California. *Los Angeles Section of the Association of Engineering Geologists)*

# Minimizing Landslide Hazard and Risk

- Identification of Potential Landslides (will post after)
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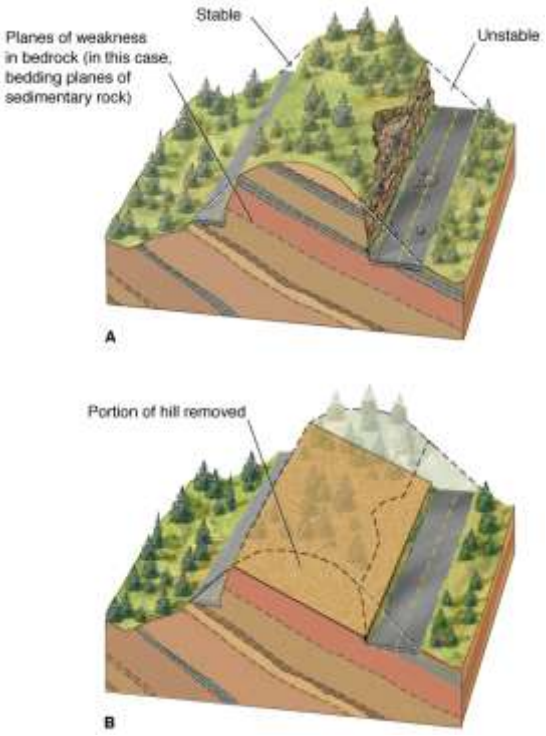
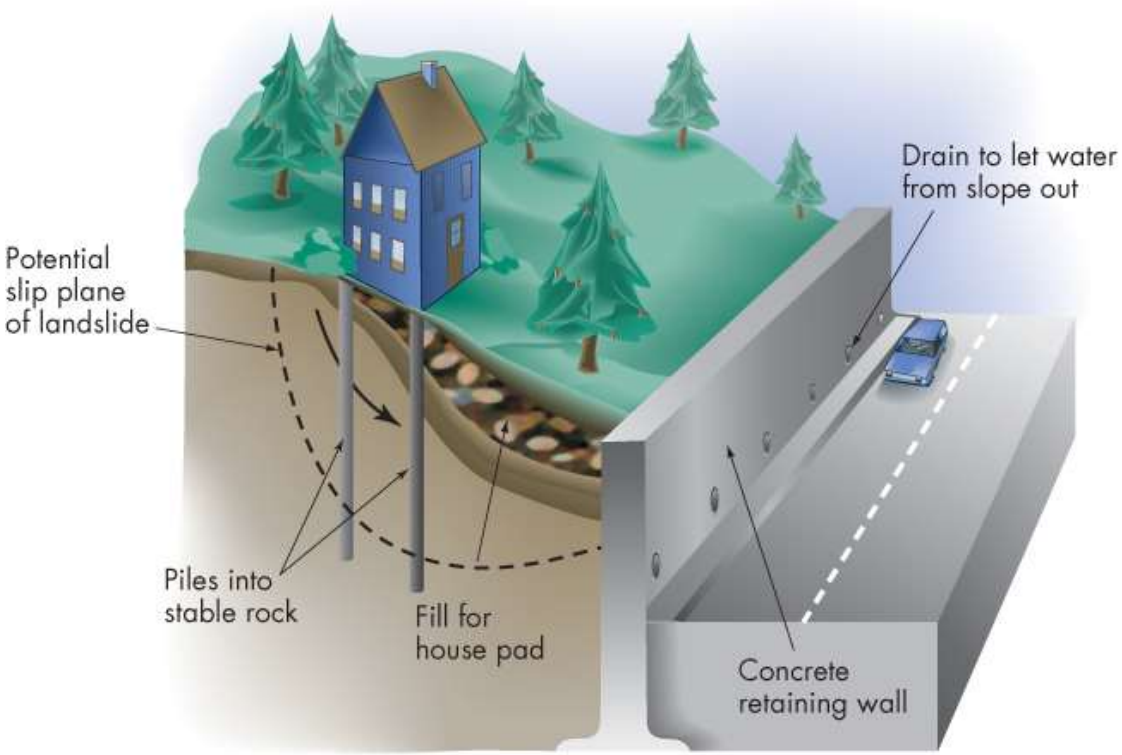
# Prevention of Landslides

- Drainage control
  - Objective is to keep water from infiltrating a slope
  - Drains can intercept and divert water
- Grading can improve slope stability
  - Material from the upper slope can be moved to the base
- Slope supports
  - Retaining walls constructed of concrete or brick






◀ **FIGURE 6.29 HOW TO SUPPORT A SLOPE** The types of slope support shown in this illustration include a deeply anchored concrete retaining wall along a road, concrete piles sunk into stable rock, and subsurface drains that reduce water pressure in the slope.

# Landslide Warning Systems

- Provide time for people to evacuate
- Human monitoring for surface changes and small rockfalls
- Electrical systems, tiltmeters, and geophones
- Railways have rock fences linked to signal systems
- Wells can indicate dangerous amounts of water

# Perception of and Adjustment to Landslide Hazards

- Perception of Landslide Hazards
  - Landslide hazard maps do not prevent people from moving into hazardous areas

- Adjustments to the Landslide Hazard
  - Siting of critical facilities
    - Hospitals, schools, police stations
  - Remedial Corrective Measures
    - Effective drainage systems to reduce water pressure

# Personal Adjustments

- Seek an evaluation of the property by a geologist
- Avoid homes at the mouth of a valley or canyon
- Consult local agencies and engineering departments
- Monitor small landslides on the property
- Look for cracks in house walls, leaning retaining walls, doors or windows that stick, or uneven floors

# Personal Adjustments, cont.

- Be wary of leaks in swimming pools or septic tanks, trees or fences that tilt, or sagging or taut utility wires
- Avoid slopes with small springs
- Look for linear or curved cracks that might indicate instability
- Do not purchase property that is in an area prone to landslides