

Mass Wasting



Mass wasting

MSc.1st Semester Geomorphology

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Introduction: What is Mass Wasting?

- ▶ Mass wasting is the downslope movement of regolith and masses of rock under the pull of gravity.
- ▶ Mass wasting is a basic part of the rock cycle.
 - Weathering, mass-wasting, and other aspects of erosion constitute a continuum of interacting processes.

Introduction: What is Mass Wasting?

- ▶ Under most conditions, a slope evolves toward an angle that allows the quantity of regolith reaching any point from upslope to be balanced by the quantity that is moving downslope: a **steady-state** condition.

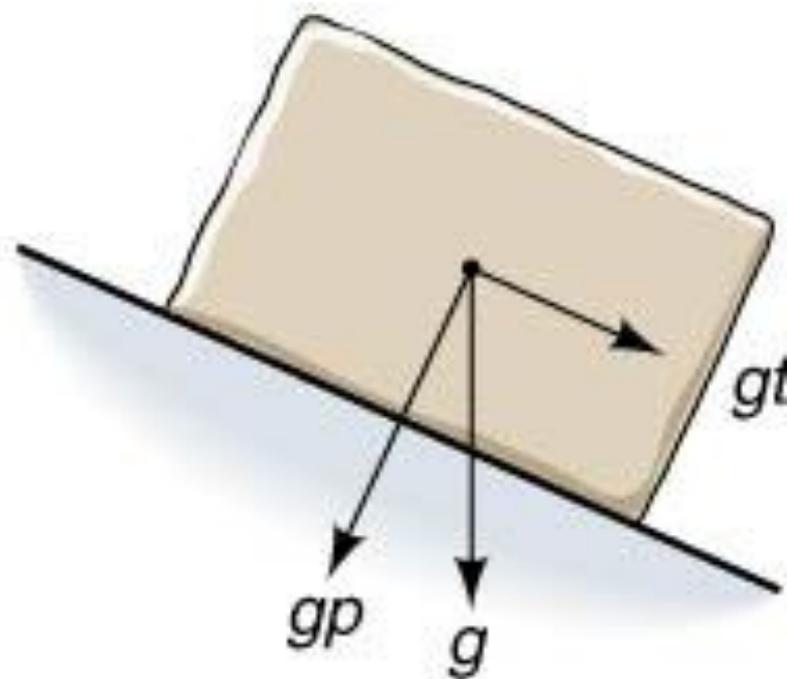
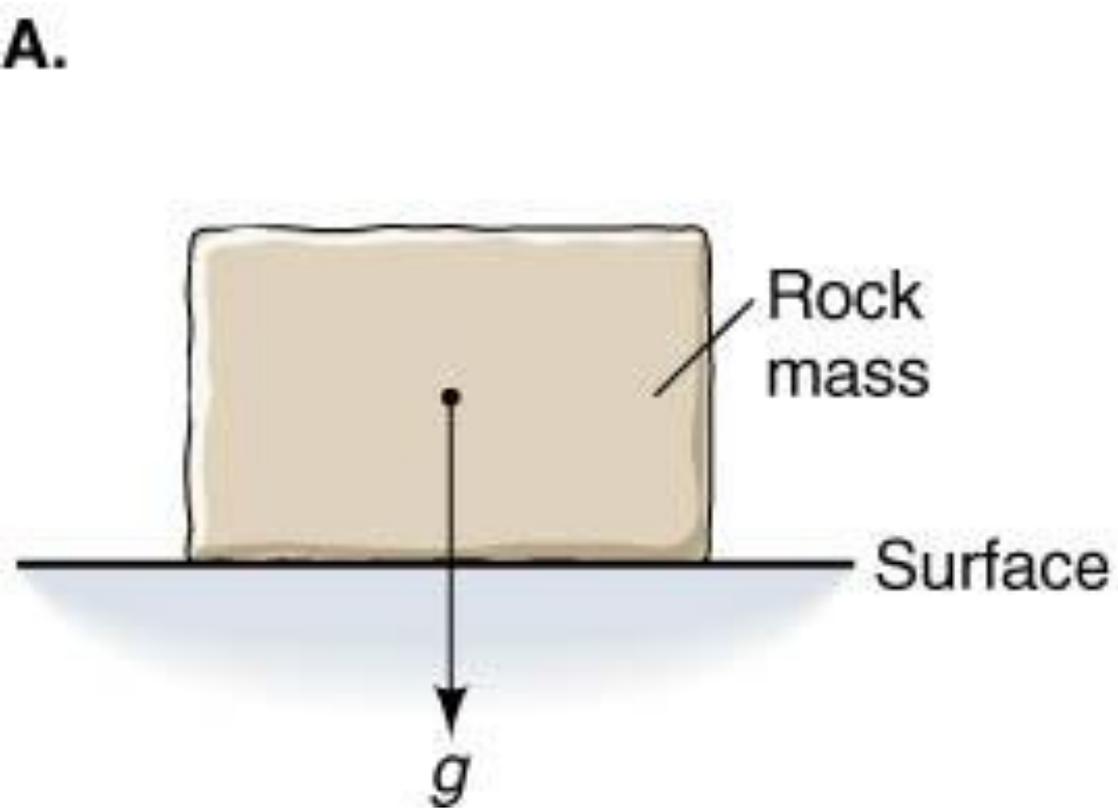
Role of Gravity and Slope Angle

- ▶ Gravitational force acts to hold objects in place by pulling on them in a direction perpendicular to the surface.
- ▶ The tangential component of gravity acts down a slope: it causes objects to move downhill.

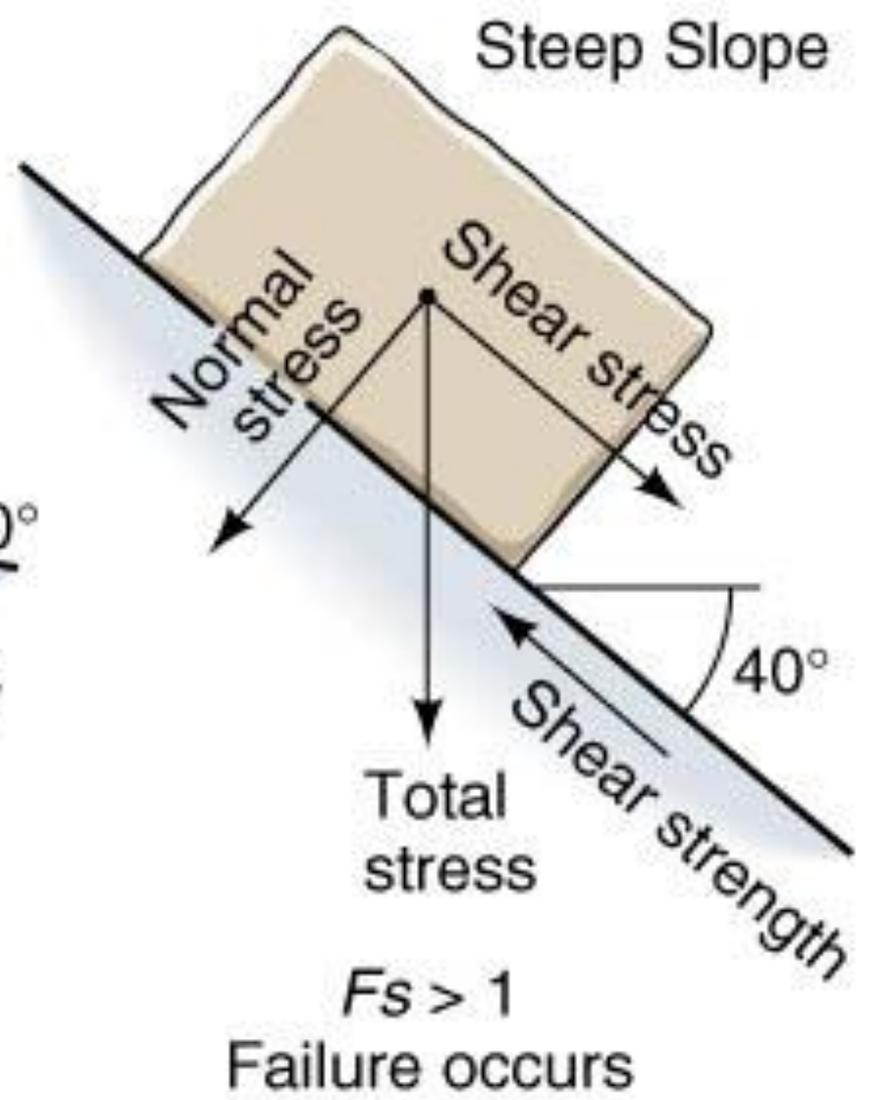
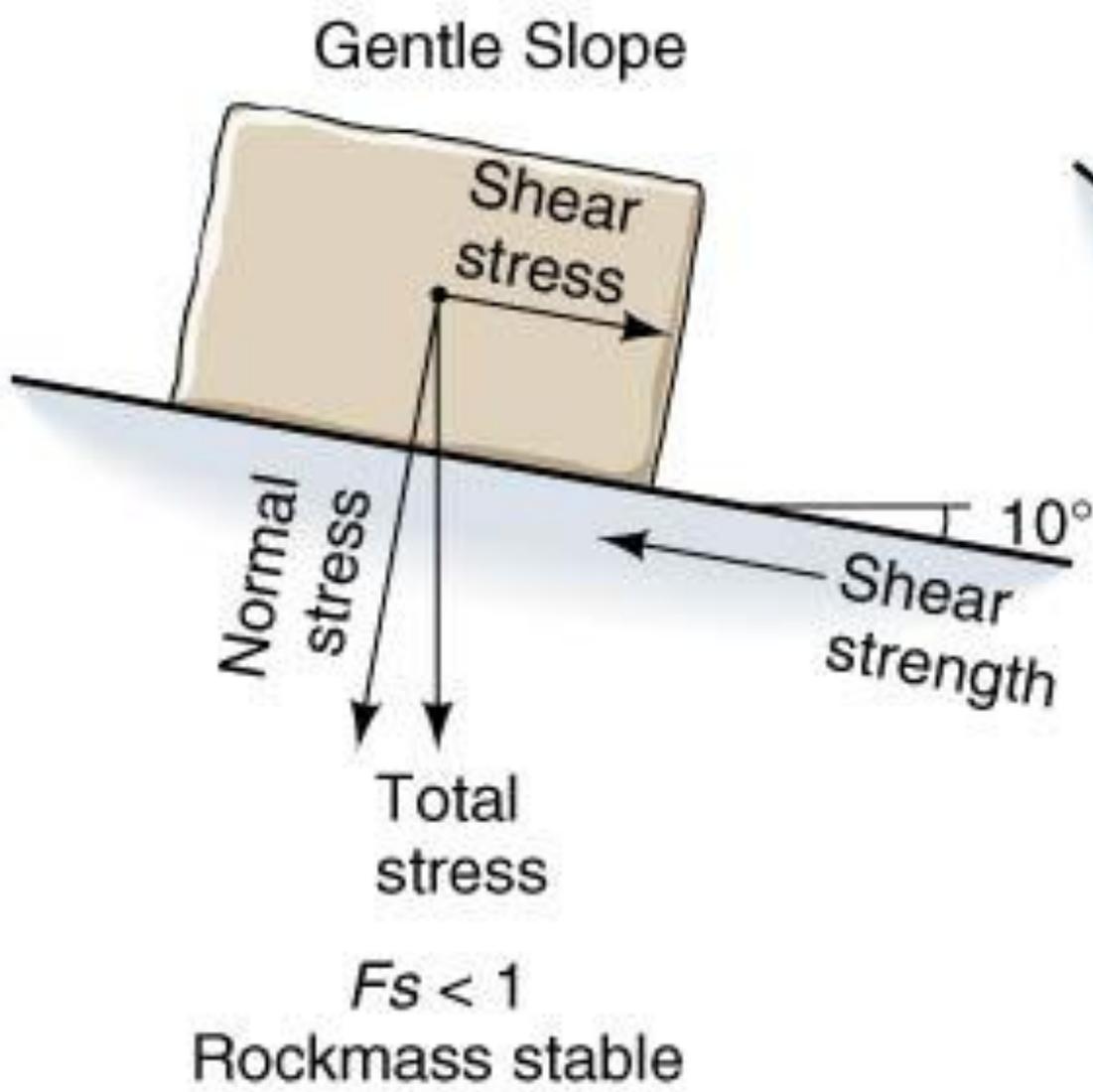
Role of Gravity and Slope Angle

- ▶ **Shear stress** is the downslope component of the total stress involved.
 - Steepening a slope by erosion, jolting it by earthquake, or shaking it by blasting, can cause an increase in shear stress.
 - ▶ **Normal stress** is the perpendicular component.
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The Role of Water

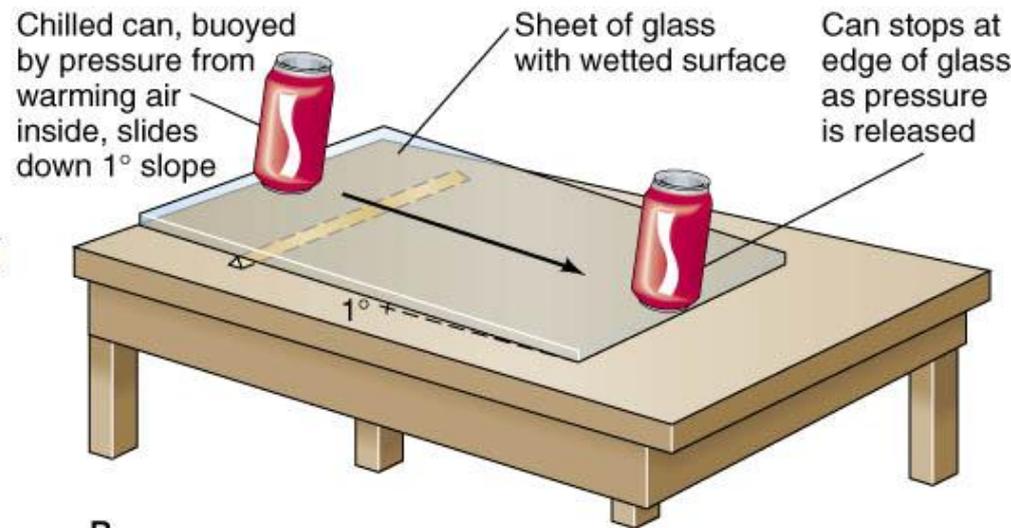
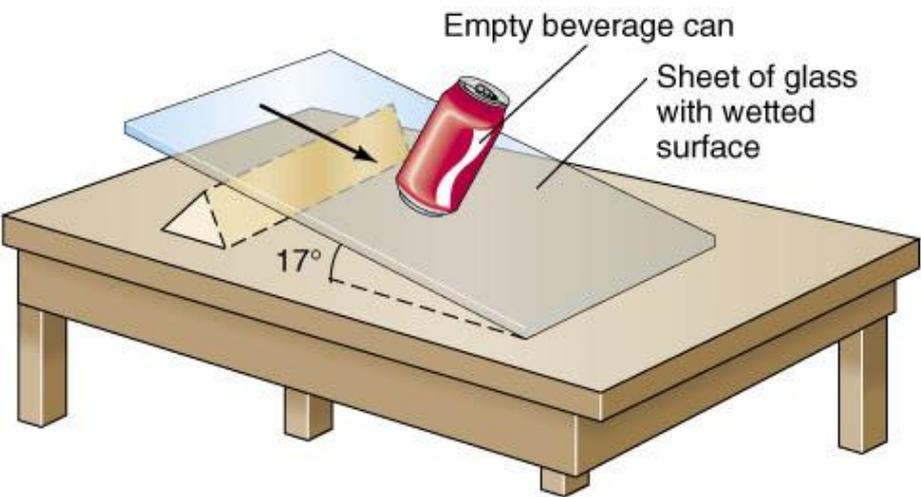
- ▶ Water is almost always present within rock and regolith near the Earth's surface.
- ▶ Unconsolidated sediments behave in different ways depending on whether they are dry or wet.
- ▶ Capillary attraction is the attraction that results from surface tension.
 - This force tends to hold the wet sand together as a cohesive mass.

The Role of Water

- ▶ If sand, silt, or clay becomes saturated with water, and the fluid pressure of this water rises above a critical limit, the fine-grained sediment will lose strength and begin to flow.
 - ▶ If the voids along a contact between two rock masses of low permeability are filled with water, the water pressure bears part of the weight of the overlying rock mass, thereby reducing friction along the contact.
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The Role of Water

- ▶ **Failure** is the collapse of a rock mass due to reduced friction.
 - An analogous situation is hydroplaning, in which a vehicle driven on extremely wet pavements loses control.



A

B

Mass–Wasting Processes

- ▶ All mass–wasting processes share one characteristic: they take place on slopes.
- ▶ There are two broad categories of mass wasting:
 - The sudden failure of a slope that results in the downslope transfer of relatively coherent masses of rock or rock debris by:
 - Slumping.
 - Falling.
 - Sliding.

Mass–Wasting Processes

- The downslope flow of mixtures of solid material, water, and air which are distinguished on the basis of :
 - **Velocity.**
 - **The concentration of particles in the flowing mixture.**

Slope Failures

- ▶ **Slope failure** is the collapse of rock or sediment mass.
- ▶ 3 major types of slope failure:
 - Slumps.
 - Falls.
 - Slides.

Slumps

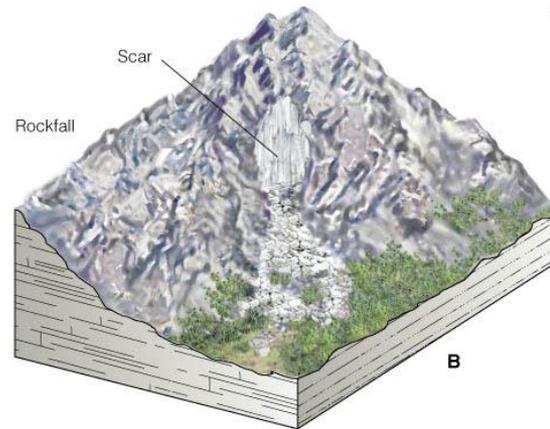
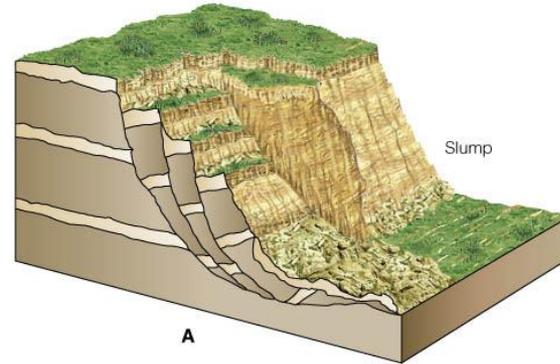
- ▶ A **slump** is a type of slope failure in which a downward and outward rotational movement of rock or regolith occurs along a curved concave-up surface.
 - Often the result of artificial modification of the landscape.
 - Associated with heavy rains or sudden shocks, such as earthquakes.
- ▶ The top of the displaced block usually is tilted backward, producing a reversed slope.



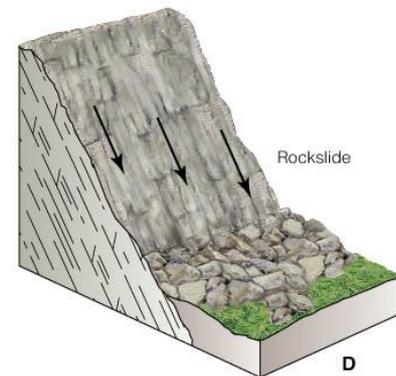
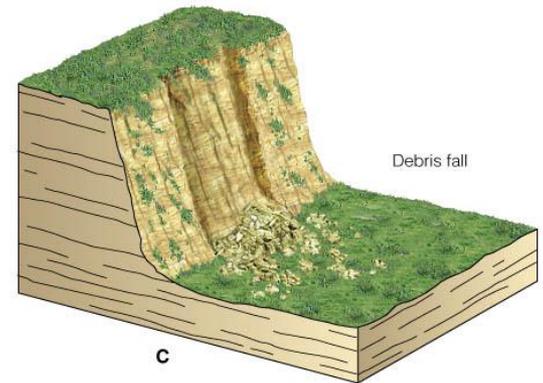
Rockfalls and Debris Falls

- ▶ Rockfall is the free falling of detached bodies of rock.
- ▶ It is common in precipitous mountainous terrain, where debris forms conspicuous deposits at the base of steep slopes.
- ▶ As a rock falls, its speed increases.
 - $V = 2 gh$, where:
 - g = the acceleration due to gravity.
 - h = the distance of fall.
 - v = the velocity.

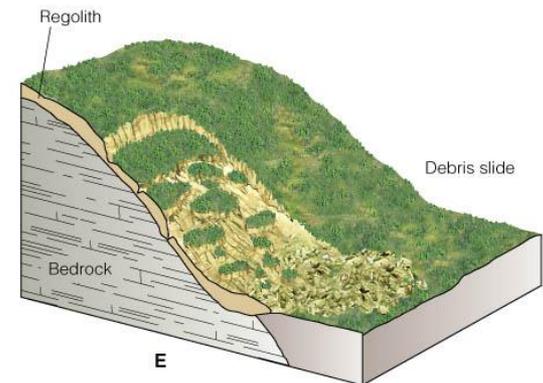
Slope Failures



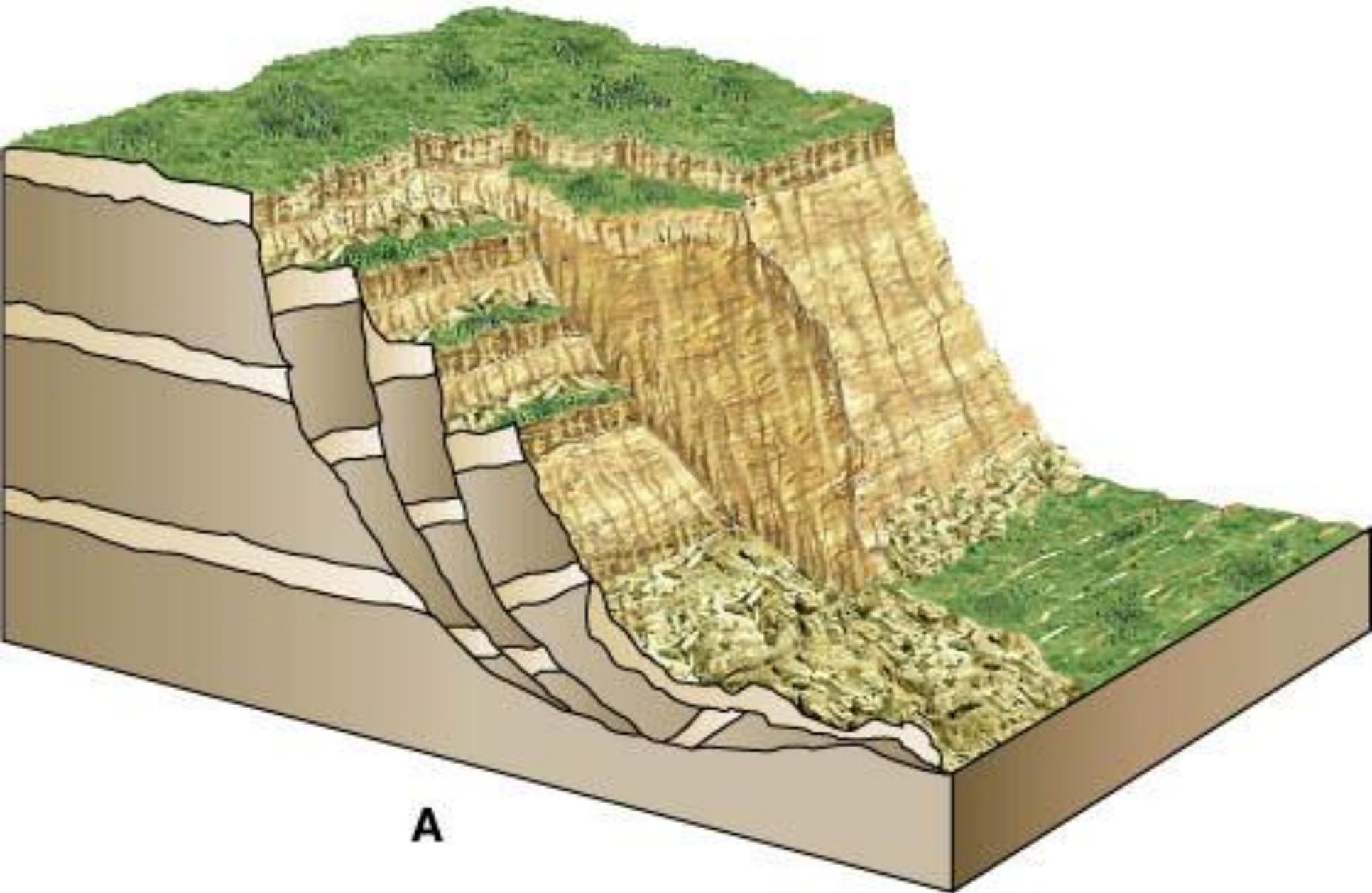
FALLS



SLIDES



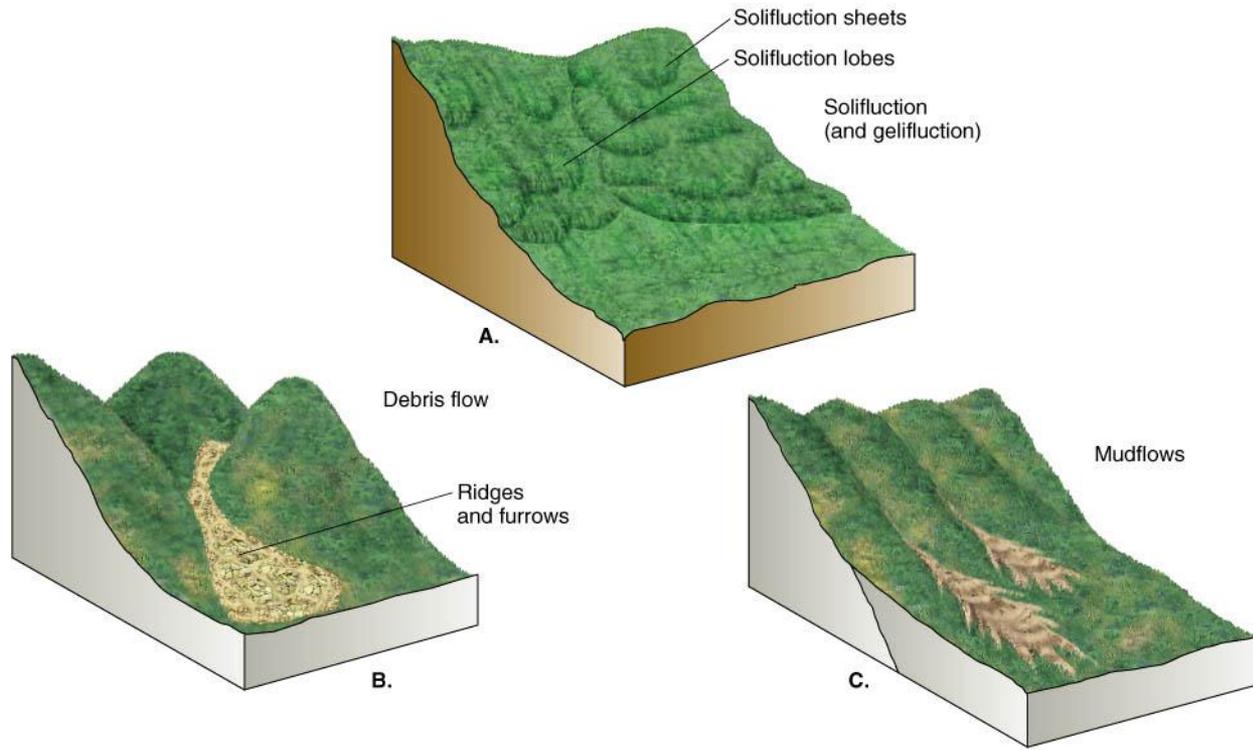
SLUMP



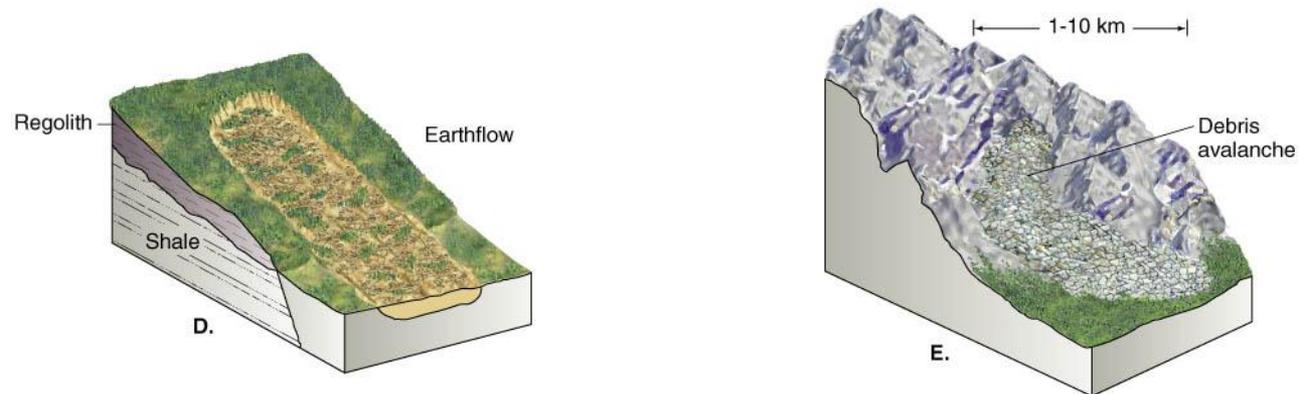
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Sediment Flows

SLURRY (WET) FLOWS



GRANULAR (DRY) FLOWS

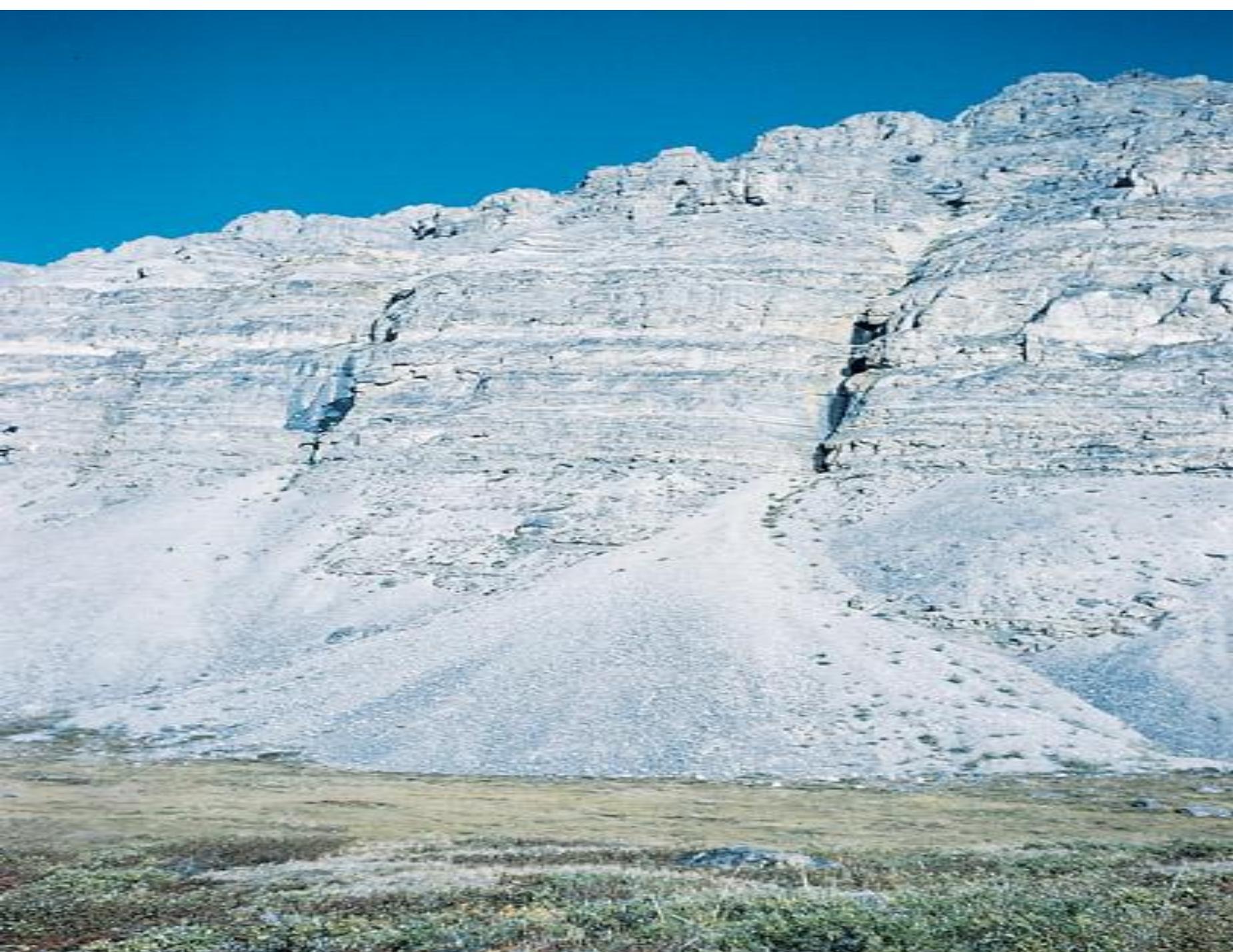


Rockfalls and Debris Falls

- ▶ When a mountain slope collapses, not only rock but overlying regolith and plants are generally involved. The resulting **debris fall** is similar to a rockfall, but it consists of a mixture of rock and weathered regolith, as well as vegetation.

Rockfalls and Debris Falls

- ▶ **Rockslides:**
 - Involve the rapid displacement of masses of rock or sediment along an inclined surface, such as a bedding plane.
 - Are common in high mountains where steep slopes abound.
 - Typically range in size from sand grains to large boulders.
 - Forms talus, a body of debris sloping outward from the cliff.
- ▶ **The angle of repose** (the angle at which the debris remains stable) typically lies between 30° and 37° .





Sediment Flows

- ▶ **Sediment flows** are mass-wasting processes in which solid particles move in a flowing motion.
- ▶ Factors controlling flow:
 - The relative proportion of solids, water, and air.
 - The physical and chemical properties of the sediment.
- ▶ Water helps promote flow, but the pull of gravity on the solid particles remains the primary reason for their movement.

Sediment Flows

- ▶ There are two classes of sediment flows, based on sediment concentration:
 - A **slurry flow** is a moving mass of water-saturated sediment.
 - A **granular flow** is a mixture of sediment, air, and water (not saturated with water).

Creep

- ▶ **Creep** is a very slow type of granular flow.
- ▶ It is measured in millimeters or centimeters per year.
- ▶ Rates tend to be higher on steep slopes than on gentle slopes.
- ▶ Rates tend to increase as soil moisture increases.
 - However, in wet climates vegetation density also increases and the roots of plants tend to inhibit creep.

Creep

- ▶ Loose, incoherent deposits on slopes that are moving mainly by creep are called **colluvium**.
 - Particles are angular and lack obvious sorting.
- ▶ **Alluvium** tends to consist of rounded particles, sorted and deposited in layers.

Slurry Flows

- ▶ The nonsorted or poorly sorted sediment mixture in **slurry flows** is often so dense that large boulders can be suspended in it.
- ▶ There are several key types of **slurry flows**.
 - **Solifluction:**
 - The very slow downslope movement of saturated soil and regolith.
 - Rates of movement are less than about 30 cm/yr.
 - Creates distinctive surface features:
 - Lobes.
 - Sheets of debris.
 - Occurs on hill slopes in temperate and tropical latitudes,
 - Regolith remains saturated with water for long intervals.



Slurry Flows

- Debris flows:
 - The downslope movement of unconsolidated regolith, the greater part being coarser than sand.
 - Rates of movement range from only about 1 m/yr to as much as 100 km/h.
 - Debris flow deposits commonly have a tongue-like front.
 - They are frequently associated with intervals of extremely heavy rainfall that lead to saturation of the ground.

Slurry Flows

- Mudflows:
 - Rapidly moving debris flow with a water content sufficient to make it highly fluid.
 - Most mudflows are highly mobile.
 - After heavy rain in a mountain canyon, a mudflow can start as a muddy stream that becomes a moving dam of mud and rubble.
 - Mudflows produce sediments fans at the base of mountain slopes.
 - A particularly large mudflow originating on the slopes Mount Rainier about 5700 years ago traveled at least 72 km.
 - Mount St Helens has produced mudflows throughout much of its history.

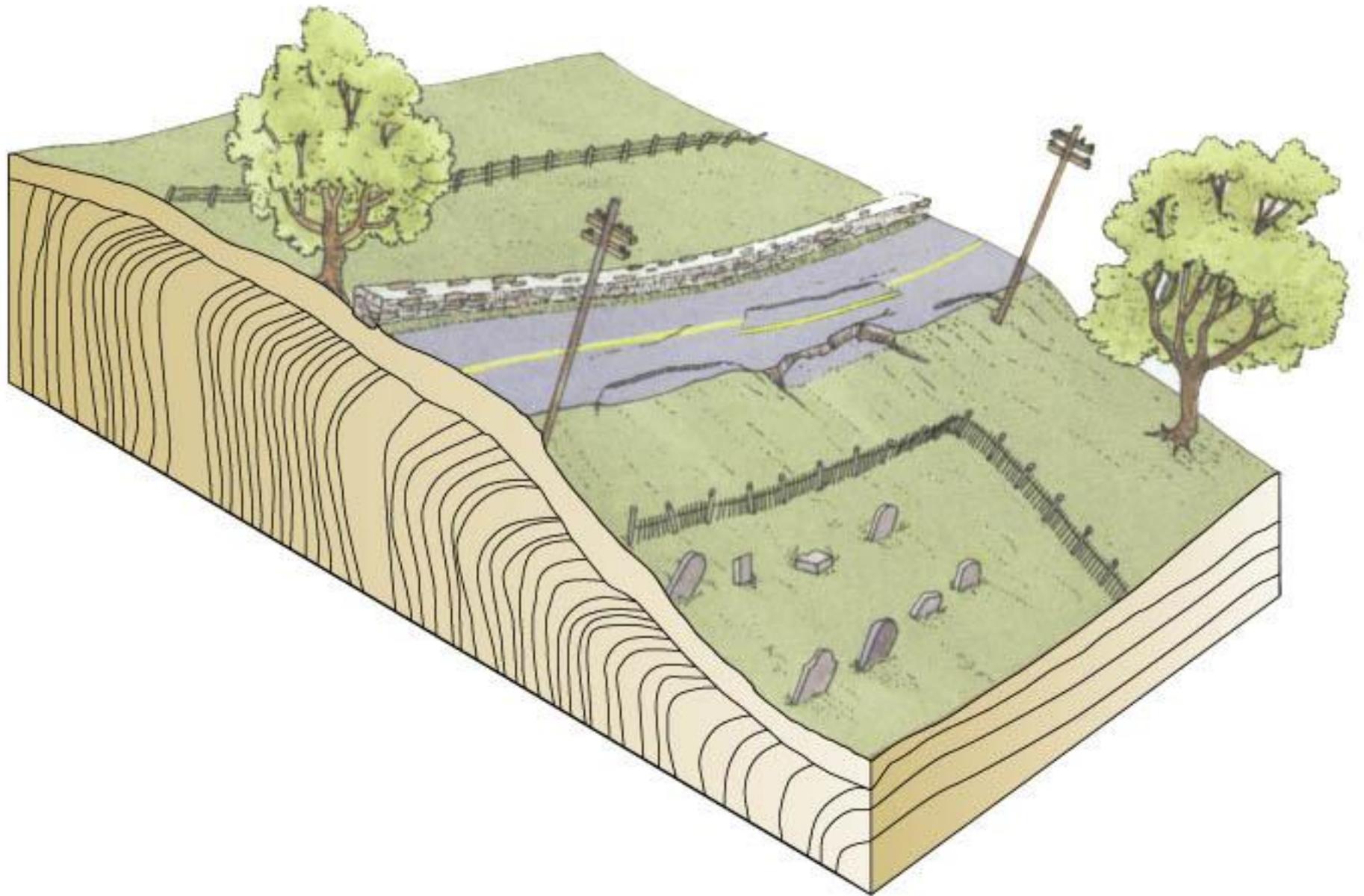






Granular Flows

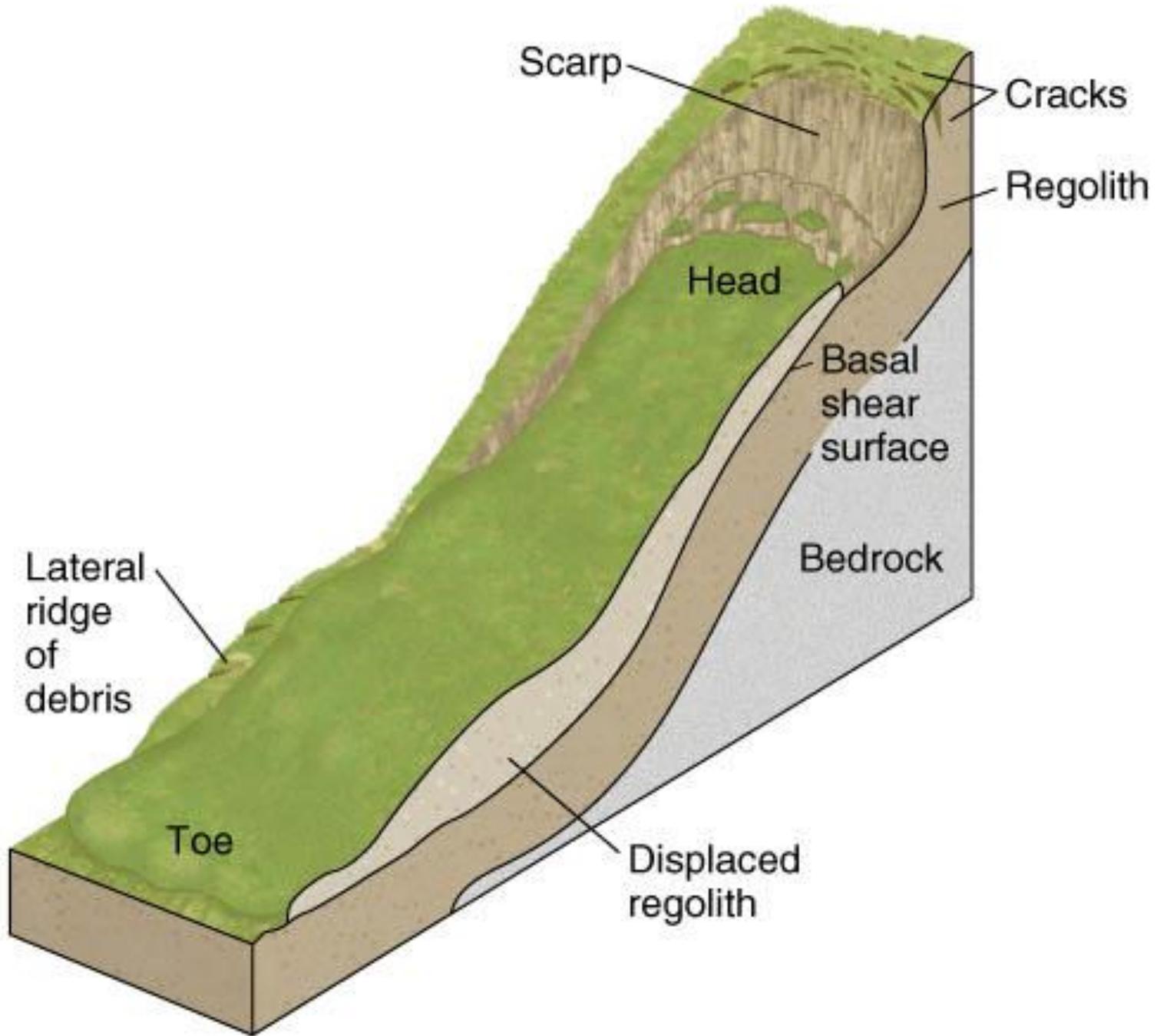
- ▶ The sediment of **granular flows** is largely dry.
- ▶ Granular flows have a velocity in the range of about 1 cm/day to several hundred m/h.
- ▶ They are often made up of weak regolith.
 - Predominantly silt and clay-sized particles.
- ▶ They occur on gentle to moderately steep slopes (2° to 35°).





Earthflows

- ▶ **Earthflows** are the most common mass-wasting process.
 - ▶ At the top of a typical earthflow is a steep scarp.
 - ▶ In a longitudinal profile from head (top) to toe (leading edge), an earthflow is concave upward near the head and convex upward near the toe.
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Earthflows

- ▶ A special type of earthflow called **liquefaction** occurs in wet, highly porous sediment consisting of clay to sand-size particles weakened by an earthquake.
 - An abrupt shock increases shear stress and may cause a momentary buildup of water pressure in pore spaces which decreases the shear strength.
 - A rapid fluidization of the sediment causes abrupt failure.

Grain Flows

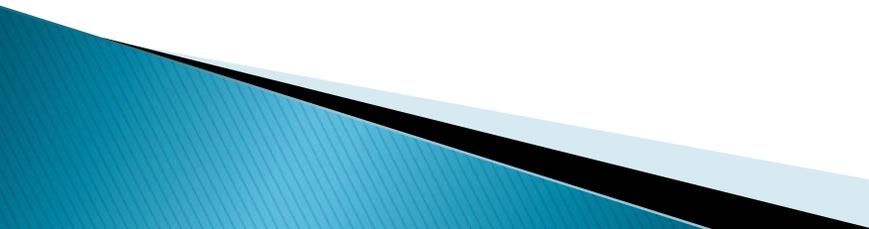
- ▶ **Grain flows** are the movement of a dry or nearly dry granular sediment with air filling the pore spaces.
 - Sand flowing down the dune face.
- ▶ Velocities of the moving sediments typically range between 0.1 and 35m/s.

Debris Avalanches

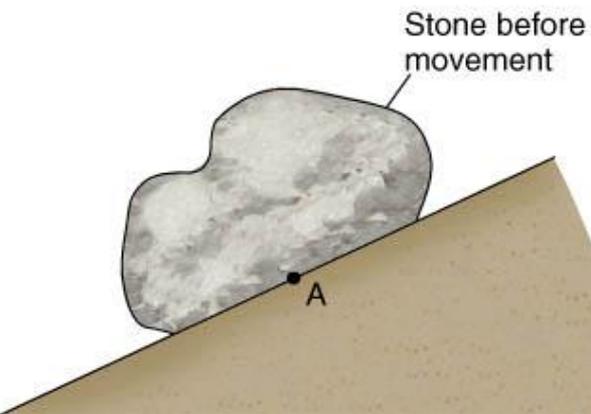
- ▶ A **debris avalanche** is a huge mass of falling rock and debris that breaks up, pulverizes on impact, and then continues to travel down slope.
- ▶ The flanks of steep strato volcanoes are especially susceptible to collapse that can lead to the production of debris avalanches.
 - Such a collapse occurred about 300,000 years ago at Mount Shasta.
 - The volume of the landslide on Mount St. Helens was about ten times smaller than that of the Mount Shasta event.



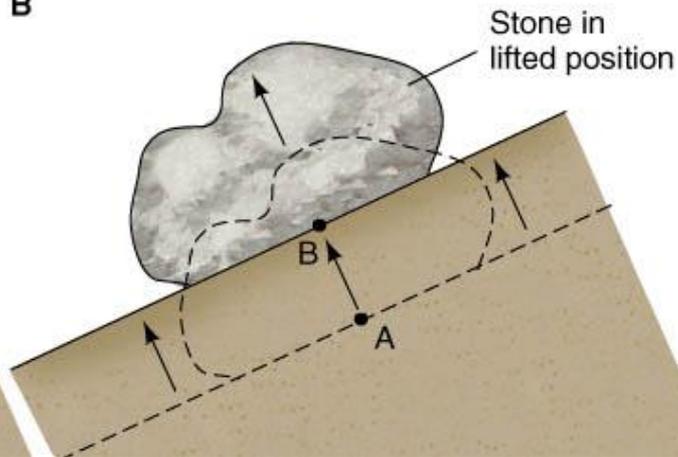
Mass Wasting In Cold Climates

- ▶ When water freezes, it increases in volume.
 - ▶ Frost heaving is the lifting of regolith by the freezing of contained water.
 - It strongly influences downslope creep of regolith in cold climates.
 - As the ground thaws, the regolith returns to a more natural state.
 - Some horizontal movement takes place.
 - Repeated episodes of freezing and thawing produces progressive downslope creep.
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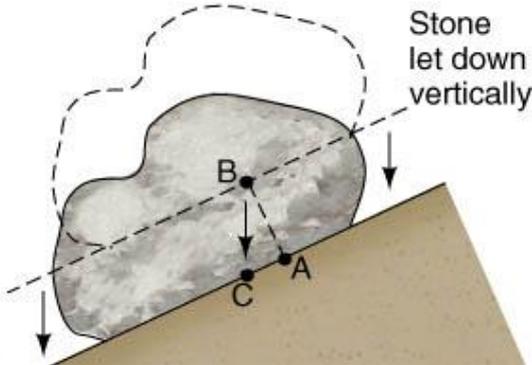
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Gelifluction

- ▶ In cold regions underlain year-round by frozen ground, a thin surface layer thaws in summer and then refreezes in winter.
 - ▶ During the summer, this thawed layer becomes saturated with meltwater and is very unstable, especially on hillsides.
 - ▶ As gravity pulls the thawed sediment slowly downslope, distinctive lobes and sheets of debris are produced.
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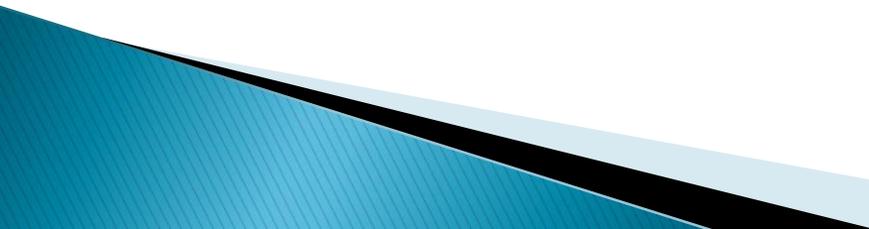
Gelifluction

- ▶ This process, known as **gelifluction**, is similar to solifluction in temperate and tropical climates;
- ▶ Rates of movement are low, generally less than 10 cm/yr.

Rock Glaciers

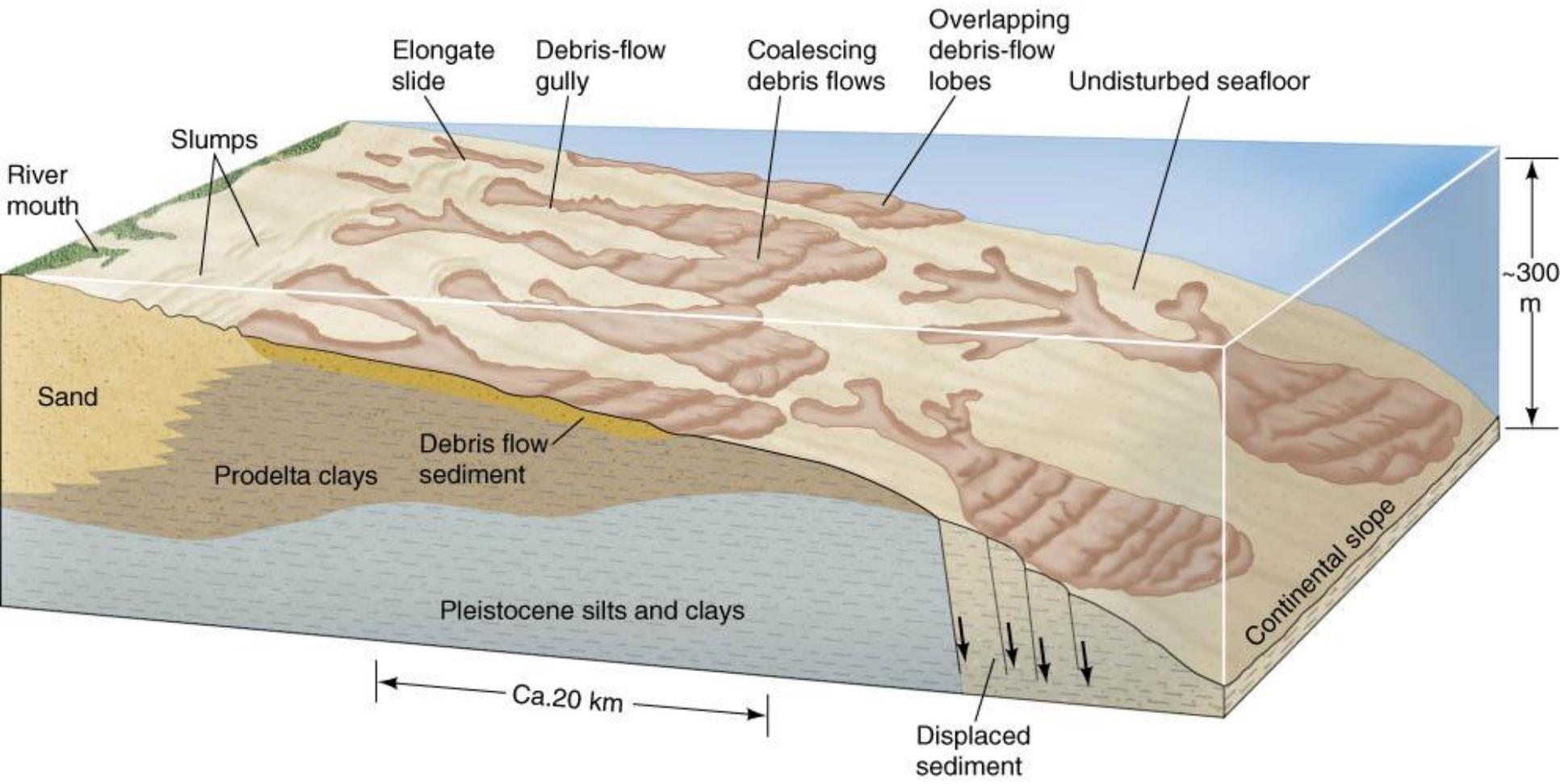
- ▶ Characteristic feature of many cold, relatively dry mountain regions, is a tongue or lobe of ice-cemented rock debris that moves slowly downslope in a manner similar to glaciers.
 - ▶ Active rock glaciers may reach a thickness of 50 m or more and advance at rates of up to about 5 m/yr.
 - ▶ Especially common in high interior mountain ranges like the Swiss Alps, the Argentine Andes, and the Rocky Mountains.
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Mass Wasting Under Water

- ▶ Mass wasting under water is an extremely common and widespread means of sediment transport on the seafloor and in lakes.
 - ▶ Is a gravity–induced movement of rock and sediment.
 - ▶ Slides and sediment flows are extremely active on the Mississippi delta front.
 - ▶ Vast areas of the seafloor are disrupted by submarine slumps, slides, and flows in the Western North Atlantic.
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Mass Wasting Under Water

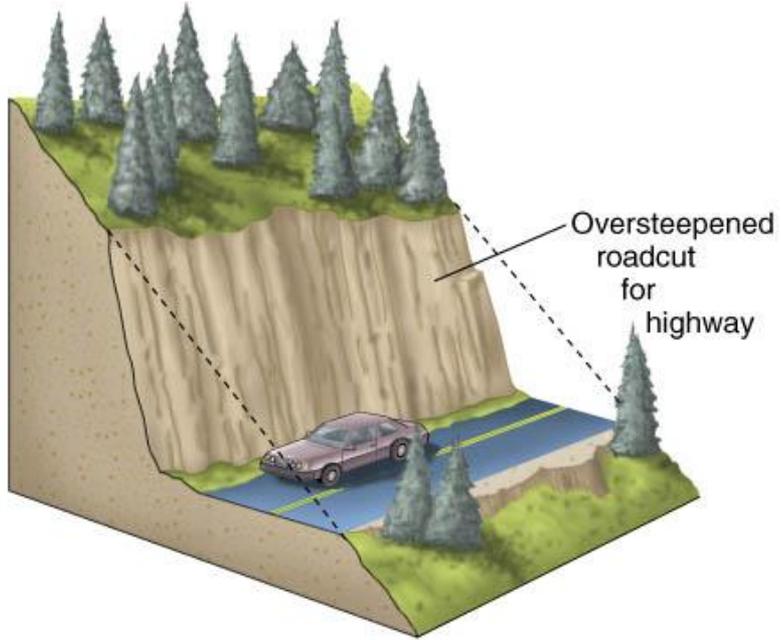
- ▶ In Hawaii, coral-bearing gravels found up to altitudes of 326 m on Lanai and nearby islands have been attributed to a giant wave that deposited the coral fragments high above sea level.
 - ▶ The wave is believed to have resulted from a huge submarine landslide off the western coast of the island of Hawaii.
 - ▶ Based on dating of the corals on Lanai, the landslide occurred about 105,000 years ago.
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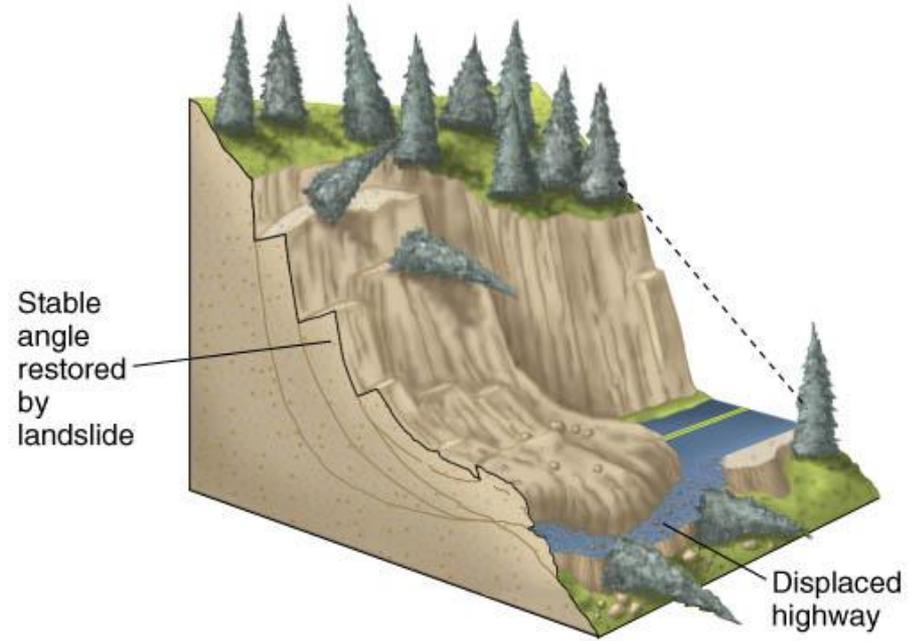
What triggers Mass–Wasting Events?

- ▶ Shocks, such as an earthquake, may release so much energy that slope failures of many types and sizes are triggered simultaneously.
 - ▶ Slope modification by human activities, such as occurs in road cuts, creates artificially steep slopes that are much less stable than the more gentle original slopes.
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A



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What triggers Mass-Wasting Events?

- ▶ Undercutting action of a stream along its bank or surf action along a coast can trigger landslides.
- ▶ Exceptional precipitation coupled with melting snow is an ideal trigger for slope failure.
 - The Gros Ventre River basin of western Wyoming.



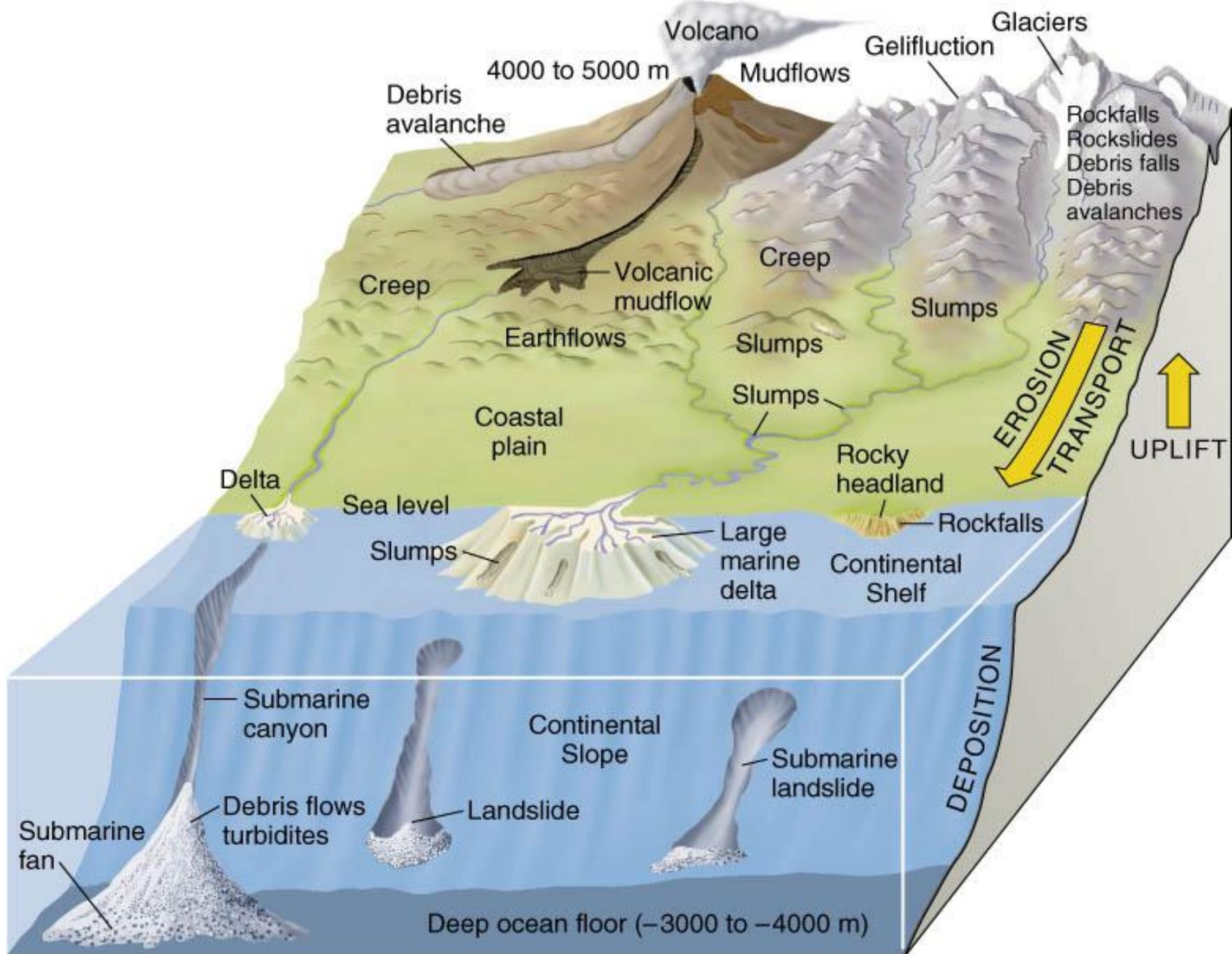
What triggers Mass–Wasting Events?

- ▶ Volcanic eruptions may produce large volumes of water, released when summit glaciers and snowfields melt during eruption of hot lavas or pyroclastic debris.
 - Mudflows or debris flows can be produced that move rapidly downslope and often continue for many kilometers down valley.
- ▶ Submarine slope failures on continental slopes and delta fronts can promote the formation of large submarine landslides.

Hazards To Life And Property

- ▶ In the United States alone, landslides in a typical year cause more than \$1 billion in economic losses and 25 to 50 deaths.
 - ▶ Careful planning can often reduce or even eliminate the impact of mass-wasting processes on human environment.
 - ▶ Slopes subject to creep can be stabilized by draining or pumping water from saturated sediment.
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Landslides and Plate Tectonics

- ▶ The world's major historic and prehistoric landslides tend to cluster along belts that lie close to the boundaries between converging lithospheric plates.
- ▶ They do so for two main reasons:
 - First, the world's highest mountain chains lie at or near plate boundaries.
 - Second, it is along the boundaries between plates, where plate margins slide past or over one another, that most large earthquakes occur.