

# UGRC 144

## Science and Technology in Our Lives/Geohazards

### Session 9 – Slope Stability and Mass Movement

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# UNIVERSITY OF GHANA

College of Education

**School of Continuing and Distance Education**

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# Session Overview

- In this session, we shall look at Mass Movement, understand the mechanisms involved and the preventive measures available to reduce their impact on humans.
- Mass-wasting processes are occurring continuously on all slopes; some act very slowly, others occur very suddenly, often with disastrous results.
- The earth materials involved in mass movement include loose uncemented mixture of soil and rock particles

# Session Outline

The key topics to be covered in the session are as follows:

- Topic One – Forces Involved in Mass Movement
- Topic Two – Natural Factors Influencing Slope Stability and Mass Movement
- Topic Three – Human Activities Influencing Slope Stability and Mass Movement
- Topic Four – Classification of Mass Movement

# Reading List

- Chapter 8 of Environmental Geology 4<sup>th</sup> Edition, Wm. C. Brown Publishers – by Carla W Montgomery (1995)
- Chapter 19 of Physical Geology. 3<sup>rd</sup> Edition. Wm. C. Brown Publishers – by Carla W Montgomery. (1993).
- Chapter 7 of Geology and the Environment. 3<sup>rd</sup> Edition. Brooks/Cole Thomson Learning – by Pipkin, B. W. and Trent, D. D. (2001)
- Unit 2, Sections 5 of UGRC 140 II Geohazards – Institute of Continuing and Distance Education.

Topic One

# **FORCES INVOLVED IN MASS MOVEMENT**



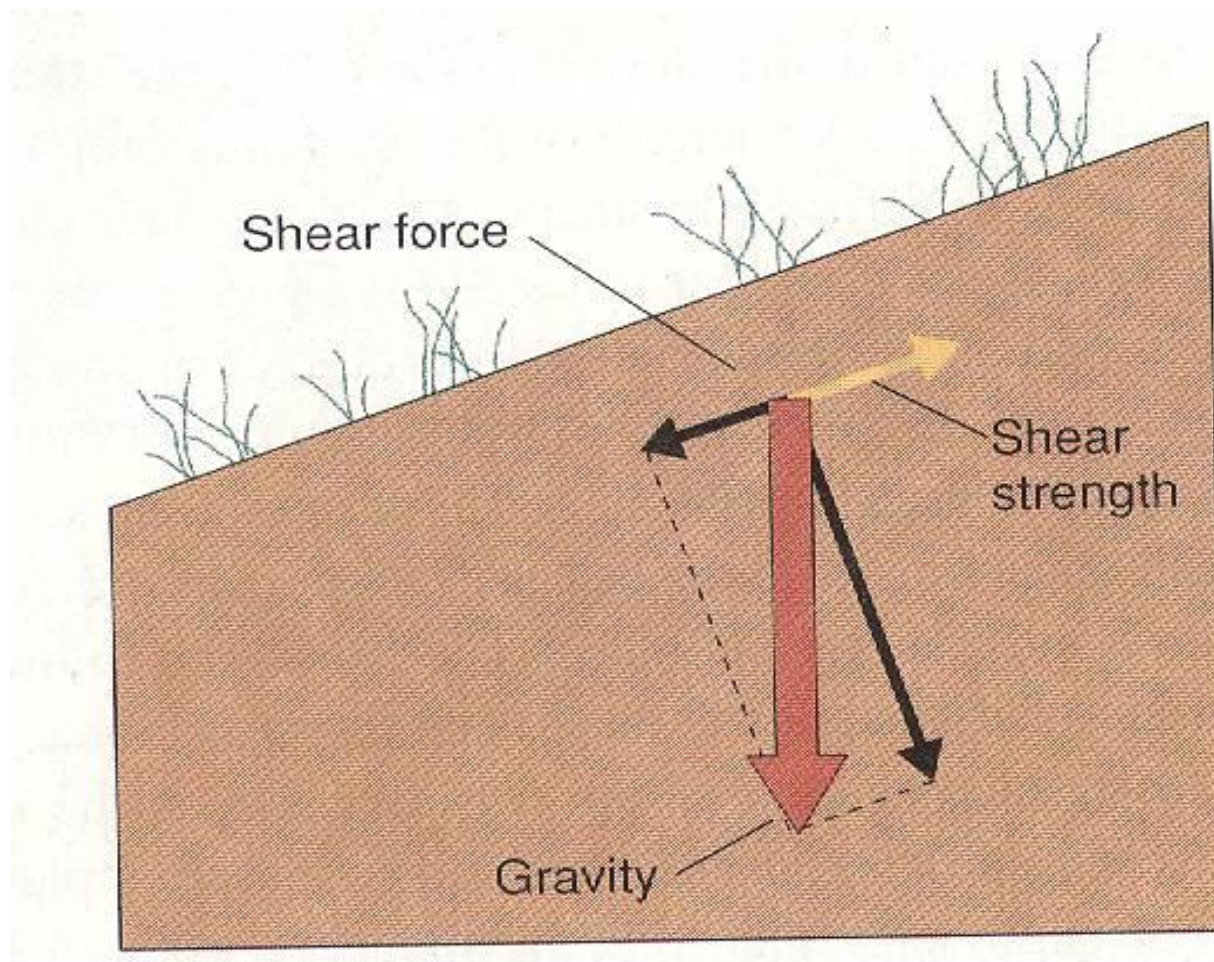
# Forces Involved in Mass Movement

- **Mass Movement (also known as Mass Wasting)** is the down-slope movement of loose uncemented mixture of soil, regolith and rock particles under the direct influence of **gravity** (without material being transported by other transporting media, e.g., running water).
- The earth materials behave as solids or viscous masses, and may be consolidated (compacted and cemented) or unconsolidated (loose and uncemented).
- Movement occurs when the force of gravity exceeds the resisting force.

# Forces Involved in Mass Movement

- **Gravity**, a vertical force that can be split into vectors parallel to (tangential) and perpendicular to a surface(normal)
- **Shearing Stress** is the downward pull that tends to cause mass movement, and depends on the mass of material and angle of slope.
- Countering the shearing stress is **friction**, or in the case of a cohesive solid, **Shear Strength**.

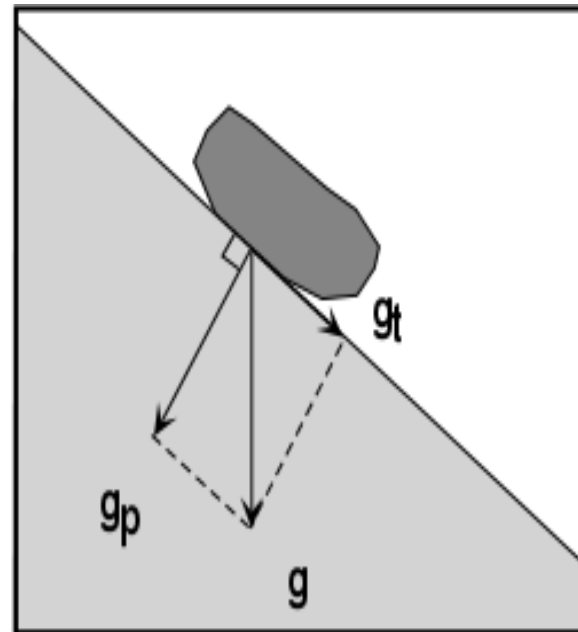
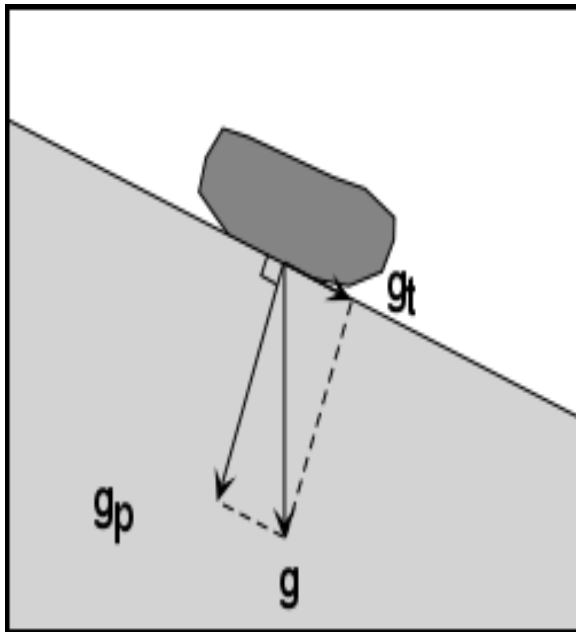
# Forces Involved in Mass Movement





# Forces Involved in Mass Movement

- On a slope, the force of gravity can be resolved into two components:
  - a component acting perpendicular to the slope ( $g_p$ ), and
  - a component acting tangential to the slope -Shear force ( $g_t$ )



# Forces Involved in Mass Movement

## Gravity

- The perpendicular component of gravity,  $g_p$ , helps to hold the object in place on the slope.
- The tangential component of gravity,  $g_t$ , causes a shear stress parallel to the slope that pulls the object in the down-slope direction parallel to the slope.
- On a steeper slope, the shear stress or tangential component of gravity,  $g_t$ , increases, and the perpendicular component of gravity,  $g_p$ , decreases.

Topic Two

# **NATURAL FACTORS INFLUENCING SLOPE STABILITY & MASS MOVEMENT**



# Natural Factors Influencing Slope Stability & Mass Movement

## Water/Fluid Content

- Water can seep along bedding planes of sedimentary rocks, reducing friction and increasing shearing stress, making sliding more likely.
- Water in saturated soil may add extra weight, enough additional downward pull, to set off a landslide on a slope that was stable when dry.

# Natural Factors Influencing Slope Stability & Mass Movement

## Vegetation

- Plants roots provide an interlocking network which hold unconsolidated materials together providing stability of the materials.
- The roots of plants take up water from the soil thus reducing the overall water content and loss of shear strength.
- Therefore, the absence of vegetation increases the risk of mass movement.

# Natural Factors Influencing Slope Stability & Mass Movement

## Slope Gradient

- Steepness of slope contributes to the occurrence of mass movements. The steeper the slope, the greater the shearing stress, and consequently the occurrence of landslide

## Earthquake

- The shaking of the ground triggers the movement of soils and rocks, reducing friction which holds the materials together in place and increasing shear stress.

Topic Three

# **HUMAN ACTIVITIES INFLUENCING SLOPE STABILITY & MASS MOVEMENT**



# Human Activities Influencing Slope Stability and Mass Movement

- The following Human activities can also trigger the movement of earth materials;
  - Construction in most cases clear away stabilizing vegetation which exposes sloping soils and rocks.
  - Removal of materials from dipping rock layers.
  - Construction of houses on dipping materials.
  - In ground swimming pool from which water can seep out slowly into surrounding materials.
  - Irrigation and the use of septic tanks, which increase the amount of water flushed through the soils and sediments.



# Human Activities Influencing Slope Stability and Mass Movement

- **Overloading** - This is almost always the result of human activity and typically results from dumping, filling, or piling up of material
- Naturally, a material's load is carried by its grain-to-grain contacts, and a slope is thus maintained by the friction between grains
- The additional weight created by overloading increases the water pressure within the material, which in turn decreases its shear strength, thereby weakening the slope material

Topic Four

# **CLASSIFICATION OF MASS MOVEMENT**



# Classification of Mass Movement

- Mass movements are classified by their dominant behavior according to:
  - the type of movement
  - the rate of movement, and
  - the type of material involved

# Classification of Mass Movement

- There are two broad classifications, namely;
  - **Slope Failures** - a sudden failure of the slope resulting in transport of debris downhill by sliding, rolling, falling, or slumping.
  - **Sediment Flows** - debris flows downhill mixed with water or air.

# Classification of Mass Movement - Slope Failures

- **Falls** - Falls are usually the free-fall of pieces of rock from a mountain or cliff face. The size of the piece(s) can range from tiny grains to blocks weighing a ton or more.
  - **Rock falls** occur when a piece of rock on a steep slope becomes dislodged and falls down the slope.
  - **Debris falls** are similar, except that they involve a mixture of soil, regolith, vegetation, and rocks

# Classification of Mass Movement - Slope Failures

- Because this process involves the free fall of material, falls commonly occur where there are steep cliffs.
- At the base of most cliffs is an accumulation of fallen material termed **talus**. This talus protects the base of the mountain from erosion.



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Rock Fall

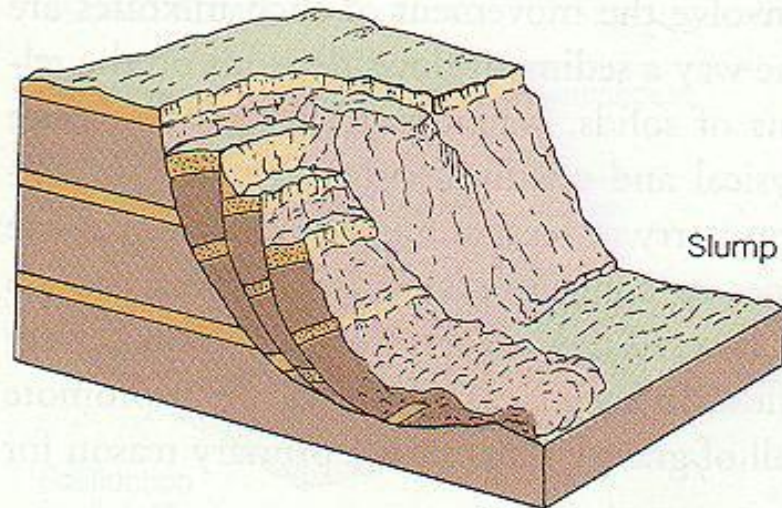
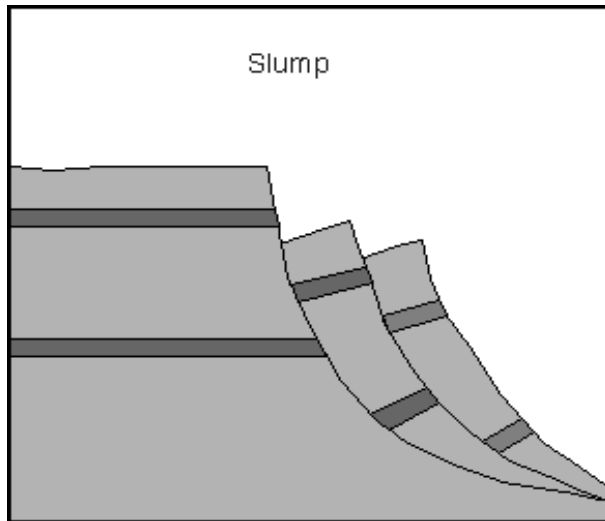


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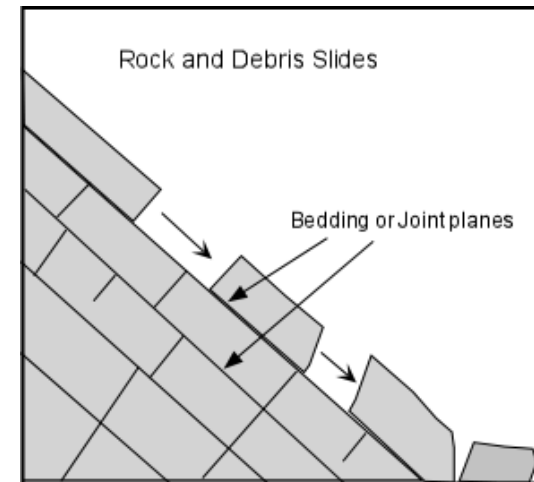
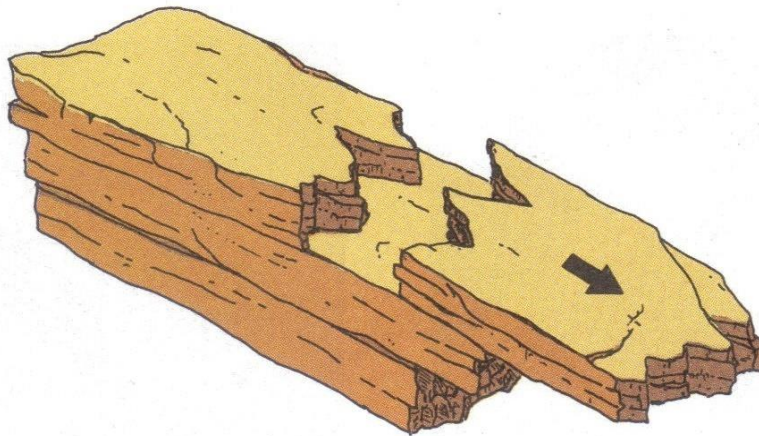
# Classification of Mass Movement - Slope Failures

- **Slump** – Slump occurs when there is downward rotation movement of rock, soil or regolith along a curved surface.
- The upper surface of each slump block remains relatively undisturbed, as do the individual blocks. Slumps leave arcuate scars or depressions on the hill slope.
- Heavy rains and earthquakes can also cause slumps.



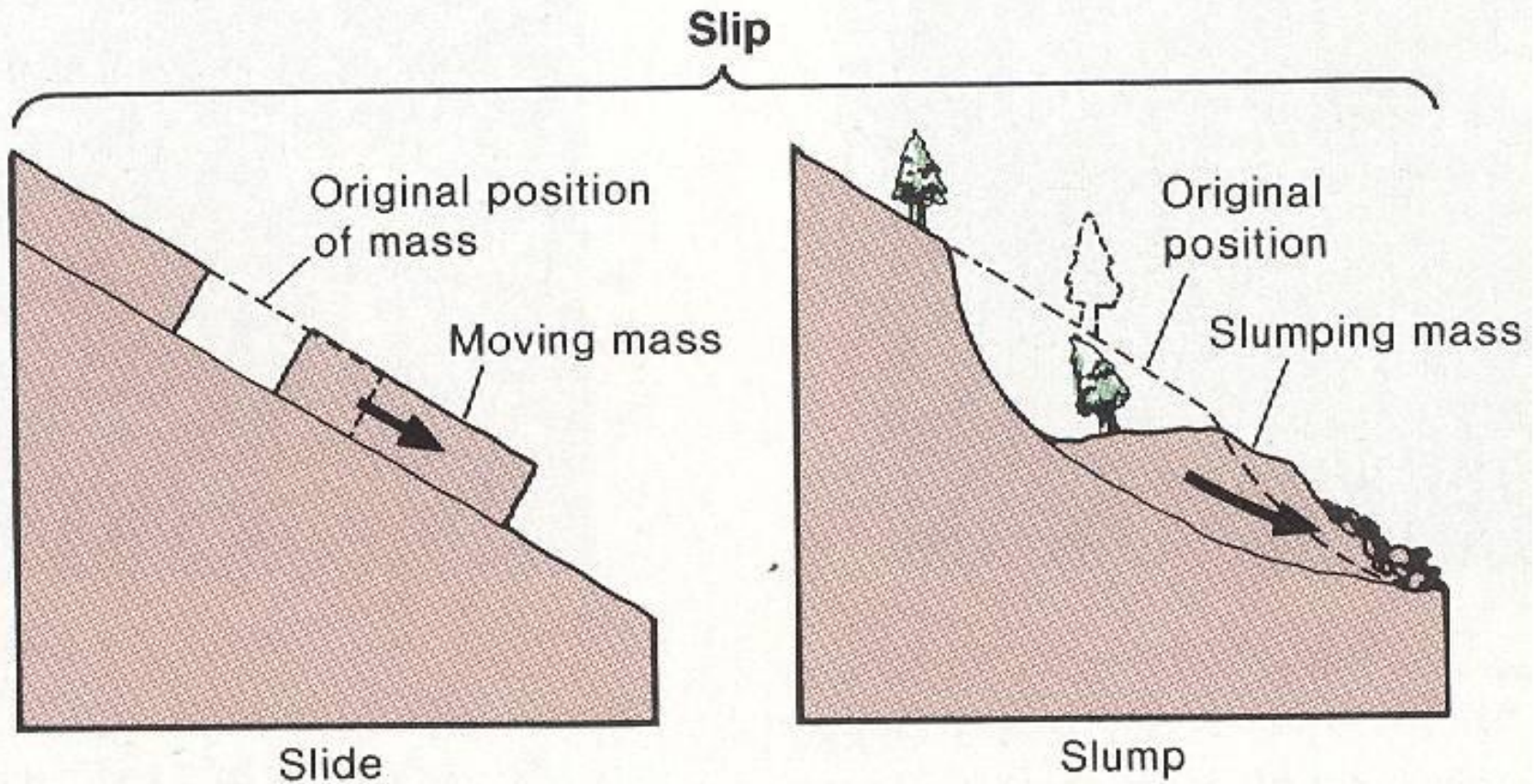
# Classification of Mass Movement - Slope Failures

- **Slides** - Rock slides and debris slides result when rocks or debris slide down a pre-existing surface, such as a bedding plane, foliation surface, or joint surface
- Piles of talus are common at the base of a rock slide or debris slide.
- Slides differ from slumps in that there is no rotation of the sliding rock mass along a curved surface.





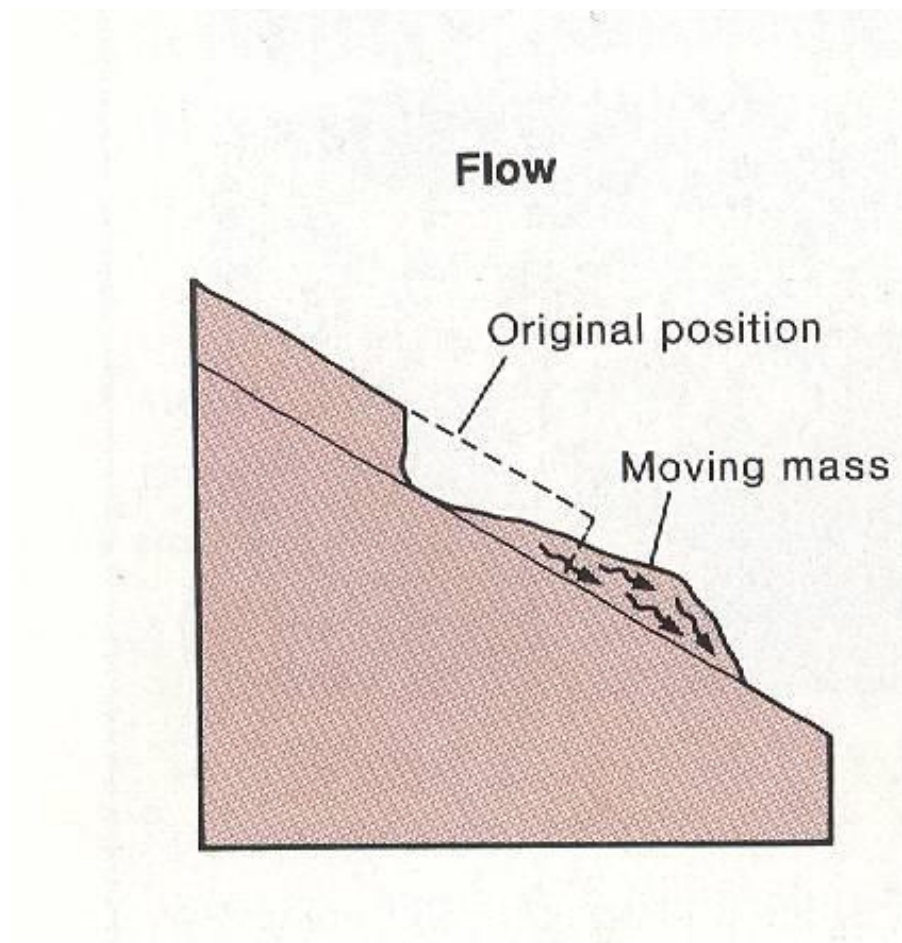
# Classification of Mass Movement - Slope Failures



# Classification of Mass Movement – Sediment Flows

- Sediment flows occur when sufficient force is applied to rocks and regolith such that they begin to flow down slope.
- A sediment flow is a mixture of rock, and/or regolith with some water or air.
- They can be divided into two types depending on the amount of water present;
  - **granular flow** (sediment flow contains between 0 and 20% water)
  - **slurry flow** (sediment flow contains between 20 and 40% water).

# Classification of Mass Movement – Sediment Flows

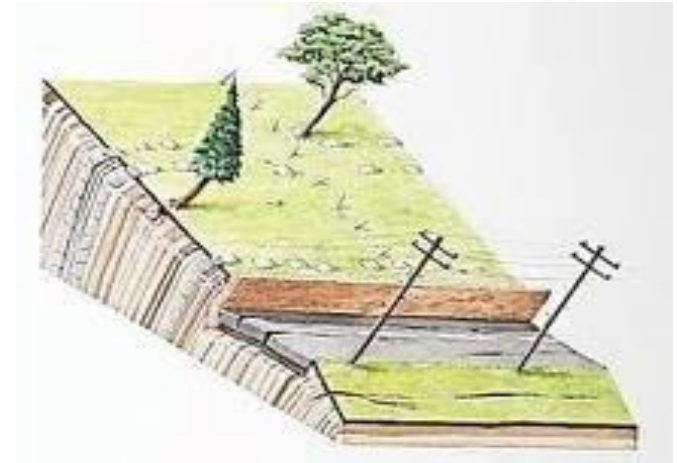
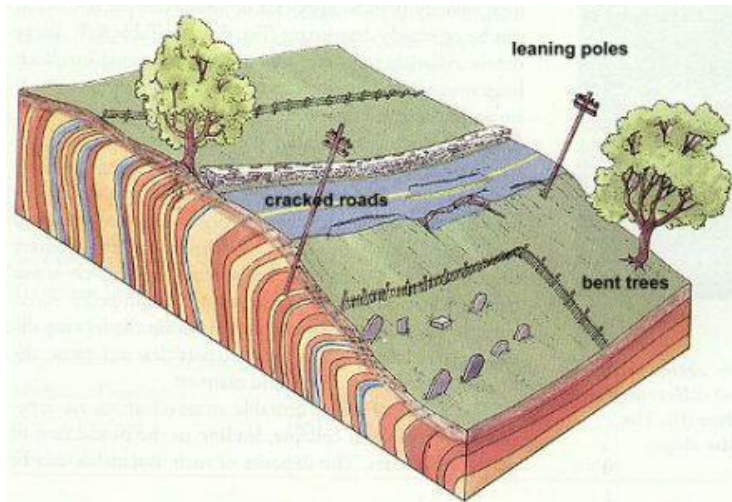


# Classification of Mass Movement – Sediment Flows

## Creep

- This is a very slow, usually continuous movement of soil and rock down slope.
- Soil Creep is an extremely slow form of mass wasting resulting from the slow adjustment of soil and rocks such that it is so hard to notice.
- Soil creep is gradual and always occurs without notice until properties are damaged.
- Evidence for creep is often seen in fence posts shifted out of alignment, bent trees, offsets in buildings, roads, and railways, and inclined utility poles tipping downslope, especially when it rains.

# Classification of Mass Movement – Sediment Flows



## Creep



# Classification of Mass Movement – Sediment Flows

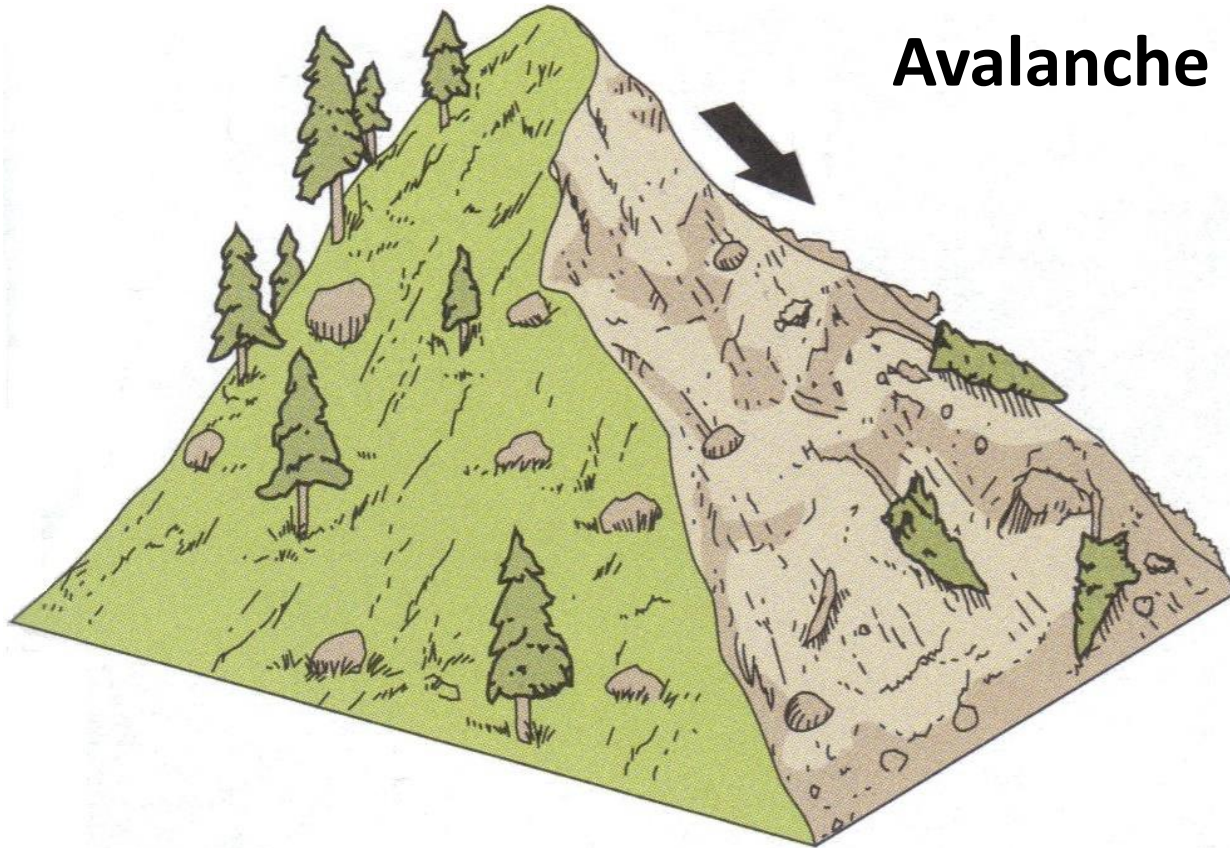
- **Earthflows** - These are usually associated with heavy rains and move at velocities between several cm/yr and 100s of m/day.
- **Grainflows** - They usually form in relatively dry material, such as a sand dune, on a steep slope.
  - A small disturbance sends the dry unconsolidated grains moving rapidly down slope.

# Classification of Mass Movement – Sediment Flows

- **Debris Avalanche** is a very high velocity flow of large volume mixtures of rocks, soil and plants that result from complete collapse of a mountainous slope.
- They move down slope and can travel for considerable distances along relatively gentle slopes.
- They are often triggered by earthquakes and volcanic eruptions.

# Classification of Mass Movement – Sediment Flows

## Debris Avalanche





# Classification of Mass Movement – Sediment Flows

- **Solifluction** is a special type of creep that occurs in areas of permafrost. Permafrost refers to the layer of groundwater that fills in the pore spaces of soil and rock that is permanently frozen.
- The permafrost layer can be anywhere from a meter to several hundred meters thick.
- These occur in areas where the soil remains saturated with water for long periods of time.

# Classification of Mass Movement – Sediment Flows

## **Solifluction**

- In times of warm weather, the ground will begin to thaw from the surface downward. All of the freshly melted water cannot absorb into or move through the permafrost layer.
- This causes the upper layer of soil and regolith to become saturated and flow down the slightest of slopes as it slips over the frozen ground underneath.

# Classification of Mass Movement – Sediment Flows

- **Debris Flows** - these occur at higher velocities than solifluction, with velocities between 1 metre/yr and 100 meters/hr
- They often result from heavy rains causing saturation of the soil and regolith with water.

# Classification of Mass Movement – Sediment Flows

- **Mudflow** – this is highly fluid, high velocity mixture of sediment and water that has a characteristic ranging between soup-like and wet concrete.
- They move at velocities greater than 1 km/hr and tend to travel along valley floors.
- These usually result from heavy rains in areas where there is an abundance of unconsolidated sediment that can be picked up by streams.

# Summary

- The movement of earth materials downslope is influenced by several factors, including nature of materials.
- Earth materials saturated with fluid reduce friction which can destabilize a slope due to additional weight of the added fluid, thereby, increasing downslope pull.
- Human activities such as irrigation and the use of septic tanks increase the amount of water flushed through the soils and sediments.
- Depending on the material involved, the moisture content and the velocity of movement, mass movements are grouped into different types, including falls, slides, slumps, granular flows, creep, debris avalanche, debris flow, mudflow, etc.

# END

